## Kadrmas, Bethany R.

**From:** David Friedman <DFriedman@afpm.org>
**Sent:** Wednesday, October 01, 2014 2:15 PM
**To:** Hogan, Hope L.
**Cc:** Kadrmas, Bethany R.
**Subject:** American Fuel & Petrochemical Manufacturers Comments for September 23, 2014 Oil Conditioning Hearing
**Attachments:** AFPM CBR Comments 9-30-14 FINAL.PDF; Stabilization White Paper September 23.pdf

The American Fuel & Petrochemical Manufacturers (AFPM) submits the following documents to be included in the September 23, 2014 Oil Conditioning hearing docket. AFPM is a national trade association of more than 400 petroleum refiners and petrochemical manufacturers throughout the United States. AFPM members operate 120 U.S. refineries comprising more than 95 percent of U.S. refining capacity. AFPM requests that the attached comments filed on the Pipeline and Hazardous Materials Safety Administration's (PHMSA's) Notice of Proposed Rulemaking for Hazardous Materials: Enhanced Car Standards and Operational Controls for High-Hazard Flammable Trains be included as part of the hearing docket. Related to the Oil Conditioning hearing, AFPM's comments on crude stabilization may be found on pages 49-53. Also attached for the docket is a paper titled "The Need for Bakken Crude Stabilization Prior to Rail Transportation" which provides the basis for the AFPM comments on crude stabilization included in the PHMSA Notice of Proposed Rulemaking. Please contact me should you have any questions on this matter and thank you for allowing AFPM to provide these comments.

**David N. Friedman**
Vice President
Regulatory Affairs

**American**
**Fuel & Petrochemical**
**Manufacturers**
1667 K Street NW
Suite 700
Washington, DC 20006
202.457.0480 office
202.552.8461 direct
202.457.0486 fax

dfriedman@afpm.org

# The Need for Bakken Crude Oil Stabilization Prior to Rail Transport

## American Fuel & Petrochemical Manufacturers

**Prepared by**

**Dangerous Goods Transport Consulting, Inc.**

September 23, 2014

## ISSUE

The Department of Transportation, Pipeline and Hazardous Materials Administration (PHMSA) requested that the American Fuel & Petrochemical Manufacturers (AFPM) comment on whether Bakken crude oil should be stabilized to reduce volatility prior to transport. In response, AFPM agreed to give consideration to the potential safety benefit(s). This document evaluates the consequences of Bakken crude oil stabilization and concludes that crude oil stabilization[1] would not reduce the overall transportation risk of transporting Bakken crude oil. Therefore, AFPM has not adopted a policy favoring stabilization.

## BACKGROUND/CONSIDERATIONS

### Gas Stabilization of Bakken Crude Oil

*Current Gas Removal Practice for Bakken Crude Oil:* Generally, produced Bakken crude oil is passed through liquid/gas separation equipment[2] where water and oil are separated from entrained gases and pumped to a storage tank near the wellhead to be stored while awaiting pick up by tank truck or pipeline. Stored crude oil is subsequently transported to a rail head where it is loaded into a rail tank car or stored again prior to loading into a rail tank car. Separated gases are frequently flared.

*Products of Stabilization:* The products of stabilization may vary depending on the specific stabilization system but the stabilization process typically results in a treated crude oil stream, a stream containing petroleum gases, and a stream referred to as condensate which is predominately made up of the more volatile liquids found in unprocessed crude oil (e.g., pentanes, hexanes).

*Gas Processing Facilities:* Gases derived from stabilization are commonly routed to processing facilities where the methane is separated and piped through natural gas transmission lines. Other separated petroleum gases may be condensed (e.g., liquefied petroleum gases, propane and butane) and may be transported by pipeline, highway or rail.

*Current Impediments to Stabilizing Bakken Crude Oil:* Although further stabilization is not recommended, the following are some of the practical considerations contributing to low utilization of stabilization processes for Bakken crude oil. These would need to be addressed if widespread stabilization were implemented:

- A lack of collection piping systems from well heads to gas processing facilities for dealing with gases (e.g., LPG, propane and butane) and liquids (e.g., natural gas liquids, casing head gasoline,

[1] Crude oil stabilization is the industry recognized term for the process of removing methane, ethane and propane from crude oil while retaining butane and pentane isomers. Stabilization also removes hydrogen sulfide from crude oil that is processed. See Chapter 9, Oilfield Processing of Petroleum: Crude oil, by Francis S. Manning, Richard E. Thompson (Ph.D.)

[2] See examples of systems at: https://www.google.com/search?q=crude+oil+heater+treater+diagram&biw=1440&bih=775&tbm=isch&imgil=Clj8p0SfSMf7pM%253A%253BVXIaT0OTmKuVBM%253Bhttp%25253A%25252F%25252Fwww.des-co.com%25252Fportfolioentry%25252Fheater-treaters%25252F&source=iu&fir=Clj8p0SfSMf7pM%253A%252CVXIaT0OTmKuVBM%252C_&usg=__PAcxoxY3pQwZSZ51JSOWSN18-as%3D&sa=X&ei=fYEIVLiAFdafyAST2oGABQ&ved=0CCAQ9QEwAA#imgdii=_

condensate) produced by stabilization and lack of subsequent infrastructure for further distribution;
- Need for additional tankage and equipment to store and handle condensate and liquefied gases; and
- Low demand for light crude oil fractions in condensate, introducing distribution complexities for Bakken producers.

*Gas Capture from Bakken Wells:* Wells producing Bakken crude oil are reported to be flaring more than 30 percent of the gases (e.g., natural gas including methane and ethane) produced due to a lack of collection pipelines. In comparison, in Texas, due to the State's long oil extraction history and with an extensive refining capability in close proximity, less than 1% of produced gas is flared. The production industry in North Dakota aims to reduce flared gas to less than 15 percent by 2016 and 10 percent by 2020. [3] A recent North Dakota Department of Mineral Resources (DMR) order dated 1 July 2014 limits flaring from wells to not more than 40%. The DMR has adopted a flaring-reduction plan that seeks to reduce flaring to 5% of gas production by 2020. Considering the high flared percentages in current practice and long term goals to reduce flaring due to the current lack of pipelines available for transferring gas from wellhead locations to gas processing facilities, widespread stabilization of crude oils in the Bakken region is impracticable in the immediate future.

*Most Practical Approach to Stabilizing Bakken Crude Oil Prior to Transportation by Rail, if Required:* Considering the lack of pipeline infrastructure at wellheads, the most practical way of stabilizing Bakken crude oil may be to stabilize it at the rail head prior to loading into rail tank cars. Gas derived from stabilization could be piped to a gas processing facility where natural gases could be further separated and piped into natural gas transmission lines for domestic or commercial use. Condensate and stabilized crude oil would then be transported by rail tank cars. Liquefied gases from gas processing facilities would most probably also need to be transported by rail. The rail tank cars used for condensates would be the same types authorized for crude oil and other liquid fractions. The rail cars used for LPG would be pressure tank cars.

The total amount of crude oil liquids and gases transported would not be changed appreciably. The volatility of Bakken crude oil transported by rail would be reduced but this stabilized crude oil would continue to meet the criteria for a flammable liquid and would continue to pose similar risks as unstabilized crude oil, in the event of a derailment. A considerable amount of condensate, other volatile liquids and LPG (a compressed flammable gas) would need to be transported by rail. Thus, stabilization would likely result in concentrating the more volatile components in fewer cars. There would be little or no difference in the total number of cars utilized. There would continue to be a risk of tank car rupture in the event of a rail accident such as derailment. Thus, stabilization would result in minimal overall reduction of risk posed by rail transportation.

**Bakken Crude Oil Vapor Pressures/Operational Considerations**

*Data:* AFPM survey results showed that Bakken crude oil had a mean Reid vapor pressure (RVP) of approximately 8 psia in the summer and 12.5 psia in the winter. The North Dakota Petroleum Council (NDPC) data showed an annual mean RVP of 11.7 psia with similar seasonal variations.

[3] http://newsok.com/north-dakota-starts-natural-gas-capturing-plans/article/feed/694409

*True Vapor Pressure (TVP) as it Pertains to Bakken Crude Oil Operations:* While RVP is widely used and more readily available, the vapor pressure of the crude oil at the temperature it is being handled (i.e., as more accurately represented by TVP) is more relevant (*e.g.*, in pumping or storage in floating roof tanks) for operational purposes. A TVP of 10 psia is generally suitable for operational purposes.

*Comparison of RVP and TVP:* Correlations between RVP at 100°F and TVP at actual temperatures are not available. Lower ambient temperatures in the winter when RVP values of Bakken crude oil are at their highest will tend to result in TVP values below operational thresholds of concern. The RVP of Bakken crude oil in the summer is not an issue. <u>Bakken crude oil vapor pressures appear to be within operational limits required for transport in pipelines (facility piping and transmission lines) and for purposes of storage in floating roof tanks; thus operational vapor pressure limits do not necessitate stabilization in advance of rail transportation.</u>

*Shortcoming of RVP in so far as Demonstrating Flammable Gas Content:* While RVP is indicative of light hydrocarbon content, RVP values do not directly correlate with a percent flammable gas content. Higher RVPs could be the result of volatile liquids or gases. Pentane, a flammable liquid and a light end hydrocarbon, has an RVP of 15.5 psia as a pure liquid (i.e., with no flammable gas present). A relatively low concentration of methane, a flammable gas, results in a higher RVP than the same concentration of butane. Based on varying contributions to RVP from different components, RVP should not be relied on as a predictor of flammable gas content.

**Crude oil commercial considerations**

*Light End Content:* Light end content is normally taken to mean the percentage of the crude oil made up of ethane, propane, butanes and pentanes (C2 to C5). AFPM's survey of Bakken crude samples showed an average light end content of up to 7.2%.[4] Similarly, a study by the North Dakota Petroleum Council indicated concentrations of light ends (methane, ethane, propane and butane) were most commonly around 5% in the case of Bakken crude oil.[5]

*Current Demand for Light Ends:* Production of Bakken crude oil is resulting in a surplus of light ends among those engaged in refining Bakken crude oil.[6]

*Note: While stabilization of Bakken crude oil prior to transportation would result in reducing the potential light ends surplus produced by refiners, this is a commercial consideration that is not considered further in this analysis.*

**Transportation Regulatory Considerations**

Reports by AFPM and others show that Bakken crude oil is authorized for transportation as a flammable liquid by rail in DOT specification 111 rail tank cars. There is currently no regulatory impediment to transporting unstabilized Bakken crude oil by rail.

---

[4] AFPM Survey

[5] The North Dakota Petroleum Council Study on Bakken Crude Properties, by Turner Mason and Company, dated August 4, 2014.

[6] http://www.api.org/~/media/Files/Policy/LNG-Exports/LNG-primer/API-Crude-Exports-Study-by-ICF-3-31-2014.pdf

**DISCUSSION**

Rail incidents involving Bakken crude and the ensuing fires have led PHMSA to consider whether stabilizing Bakken crude oil prior to transportation by rail should be required. As an organization representing companies that ship Bakken crude oil, AFPM has been asked for its policy regarding stabilization of Bakken crude oil. As noted above, additional stabilization is not required for operational purposes. Vapor pressures of Bakken crude oil currently transported are within operating limits. Additionally, from an emergency response perspective, crude oils, whether stabilized or not, pose similar risks in the event of an accident or incident. This is evidenced by the North American Emergency Response Guidebook published by DOT which assigns the same emergency response procedures to crude oils independent of Packing Group, as well as, to other common flammable liquids such as Diesel Fuel and Jet Fuels assigned to Packing Group III. Likewise, environmental protection as related to overall release of gas to the environment is not affected by a decision to stabilize crude oil at the rail head. Since stabilization is not necessary to ensure compliance with environmental regulations, environmental protection or compatibility with refinery and petrochemical processes, the question for AFPM becomes whether stabilization at the rail head enhances transportation safety.

With pressures realized in rail tank cars containing Bakken crude oil well below the design pressures of authorized DOT specification 111 rail tank cars, volatility of Bakken crude oil as currently transported poses no additional risk in intact rail tank cars. AFPM's Survey on Bakken Crude Oil reported maximum rail tank car pressures measured in rail cars carrying Bakken crude oil at the delivery point was 11.3 psig with a mean measured value of 8.5 psig. All pressure values were substantially below design pressures for DOT 111 rail tank cars. As such, the safety impact of volatility is limited to accident situations where crude oil is spilled.

Under accident conditions, volatility *could* influence the size of any flammable vapor plume created upon spillage. However, even here further analysis using vapor dispersion modeling is needed to demonstrate whether plumes produced in spills of Bakken crude oil differ significantly from those produced in spilling other flammable liquids (e.g., pure liquids such as diethyl ether, iso-pentane, 1-pentene). Plume size could affect the probability of plume ignition and subsequent ignition and burning of spilled crude oil. But other factors present in a derailment overshadow the significance of vapor plume size in influencing the likelihood of crude oil ignition in a crude oil tank car derailment. These include the volume of flammable liquid spilled during a multiple car derailment, the violence of rail tank car accidents creating multiple ignition sources (e.g., sparks from metal to metal contact, hot metal surfaces produced by bending metals, friction from hard braking or dragging of rail tank cars over tracks, and grass fires ignited by sparks or hot metals) in close proximity to breached rail tank cars.

Stabilized Bakken crude oil would continue to be classified as a flammable liquid. Once ignited, the volatility of the crude oil becomes immaterial. The burning intensity of unstabilized and stabilized crude oil would not be substantially different because the energy densities of unstabilized and stabilized crude oil are comparable.

In addition, while stabilization would reduce the number of rail tank cars transporting products with a volatility comparable to that of Bakken crude oil currently transported, substantial amounts of more volatile condensate and liquefied gases would still require transportation by rail or an even larger number of trucks so that overall impact on transportation risk is likely to be minimal.

**CONCLUSION**

AFPMs decision whether to support requiring crude oil stabilization should depend on whether transportation safety is enhanced to a meaningful extent by doing so. Based on the data produced to date, there is no reason to conclude that Bakken crude oil poses a substantially different risk than other flammable liquids when transported by rail in bulk rail tank cars. At this time, the safety basis for justifying a requirement to further stabilize Bakken crude oil prior to rail transport has not been established.

The safety effect of volatility as it pertains to Bakken crude oil is limited to accident situations. The extent to which volatility affects the likelihood of intense fire conditions after a rail accident has not been established, particularly in view of the high probability of ignition sources being present in close proximity to spilled crude oil.

Requiring stabilization at the rail head would lead to significant capital investments and higher operating costs for rail head loading facilities. It would also transfer the significant responsibility of marketing and distributing condensate and liquefied gases to the rail head loading facilities. From a regulatory perspective, the benefits of stabilization at the rail head would need to be justified based on the safety benefits. Such a justification has not been established. Since these safety benefits appear to be marginal at best, AFPM has not adopted a policy supporting crude oil stabilization at rail head loading facilities.

**American**
**Fuel & Petrochemical**
**Manufacturers**

1667 K Street, NW
Suite 700
Washington, DC
20006

202.457.0480 office
202.457.0486 fax
afpm.org

# COMMENTS OF THE AMERICAN FUEL & PETROCHEMICAL MANUFACTURERS ON THE PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION'S ("PHMSA'S") NOTICE OF PROPOSED RULEMAKING FOR HAZARDOUS MATERIALS: ENHANCED CAR STANDARDS AND OPERATIONAL CONTROLS FOR HIGH-HAZARD FLAMMABLE TRAINS, DOCKET NO. PHMSA-2012-0082 (HM-251), 79 FED. REG. 45,015 (AUG. 1, 2014)

September 30, 2014

David Friedman
American Fuel & Petrochemical
Manufacturers
1667 K Street, NW, Suite 700
Washington DC 20006
United States of America
(202) 457-0486

## TABLE OF CONTENTS

PAGE

## INDEX OF EXHIBITS

**Exhibit 14**: D.Y. Jeong, Volpe National Transportation Systems Center, U.S. Department of Transportation, "Probabilistic Approach to Conditional Probability of Release of Hazardous Materials from Railroad Tank Cars During Accidents," ASME 2009 International Mechanical Engineering Congress and Exposition, Paper No. IMECE2009-10872

**Exhibit 15**: FRA, Full-Scale Shell Impact Test of a DOT-111 Tank Car, at 4 (Aug. 2014)

**Exhibit 16**: RSI, CTC Comments, at 8 (Sept. 1, 2014)

**Exhibit 17**: National Academies of Science, National Research Council, Committee to Review the Department of Homeland Security's Approach to Risk Analysis, "Review of the Department of Homeland Security's Approach to Risk Analysis" (2010) (excerpts)

**Exhibit 18**: Bob Tita, "Railcar Shortage in U.S. Pushes Up Lease Rates," Wall Street Journal (May 14, 2014)

**Exhibit 19**: AFPM, "A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transport" (May 14, 2014)

**Exhibit 20**: AFPM, "The Need for Bakken Crude Oil Stabilization Prior to Rail Transport," (Sept. 2014)

**Exhibit 21**: Written Statement of Timothy P. Butters, Deputy Administrator, U.S. Department of Transport, Pipeline and Hazardous Materials Safety Administration, Before the Subcommittee on Energy and Oversight, Committee on Science, Space, and Technology, U.S. House of Representatives, Bakken Petroleum: The Substance of Energy Independence, at 12 (Sept. 9, 2014)

**Exhibit 22**: Written Testimony of John R. Auers – Turner, Mason & Company, Subcommittee on Energy and Oversight, Joint Hearing, Bakken Petroleum: The Substance of Energy Independence (Sept. 9, 2014)

**Exhibit 23**: PHMSA & Transport Canada, Emergency Response Guidebook (2012) (excerpts)

## I. INTRODUCTION

The American Fuel & Petrochemical Manufacturers ("AFPM") appreciate the opportunity to provide comments on the U.S. Department of Transportation ("DOT"), Pipeline and Hazardous Materials Safety Administration's ("PHMSA's") Notice of Proposed Rulemaking for Hazardous Materials: Enhanced Car Standards and Operational Controls for High-Hazard Flammable Trains ("Proposal" or "NPRM"). [1] AFPM members share a deep commitment to safety and strive for opportunities to proactively integrate safety into their operations and management culture. With that strong commitment to safety in mind, AFPM is concerned that the Proposal largely ignores measures that could prevent derailments of crude and ethanol shipments, focusing instead on mitigating the impact of derailments. While AFPM supports appropriate and effective mitigation, several of PHMSA's proposed measures fail to take meaningful steps toward preventing derailments, risk significantly reducing crude rail capacity, and cost billions of dollars. We respectfully submit these comments to promote further dialogue on how to fashion a final rule that is preventative as well as protective, data-driven, and effective.

### A. AFPM's Interest in the Proposal

AFPM is a national trade association of more than 400 petroleum refiners and petrochemical manufacturers throughout the United States. AFPM members operate 120 U.S. refineries comprising more than 95 percent of U.S. refining capacity.

AFPM members depend upon a plentiful, affordable supply of crude oil as a feedstock for the transportation fuels and petrochemicals that they manufacture. As manufacturers, AFPM members acquire crude oils from multiple sources, with a growing proportion coming from domestic sources, including oil produced from the Bakken formation. Ethanol is also a critical commodity for refiners because the Renewable Fuel Standard ("RFS") of the Clean Air Act requires ethanol to be blended into gasoline.

Safe, reliable, and economic transportation of crude oil and ethanol from source to refinery plays a vital role in ensuring the efficient, economical, and continuous operation of our refining and petrochemical operations. Approximately 11 percent of the crude oil processed by AFPM members arrives by rail. Rail shipments are of particular importance for the Bakken formation, which lacks a pipeline infrastructure. As a result of the RFS mandate, AFPM members are also impacted by the transportation of ethanol from plant to terminal, since most ethanol is transported to market by rail.

In order to ship crude and ethanol, AFPM members lease and own tens of thousands of rail tank cars. About 40% of the tank cars used by AFPM members are owned, with the remaining cars leased.[2] Most rail shipments of crude and ethanol are carried in unit trains. The average size of such unit trains is 94 cars, according to an AFPM membership survey. [3]

---

[1] Docket No. PHMSA-2012-0082 (HM-251), 79 Fed. Reg. 45,015 (Aug. 1, 2014).

[2] *See* AFPM Member Tank Car Retrofit Survey, at 5 (Sept. 14, 2014) ("AFPM Retrofit Survey") (**Exhibit 1**).

[3] Fifteen AFPM members, who collectively own or lease about 29,000 tank cars, responded to the survey.

### B. AFPM's Unwavering Commitment to Safety

The refining and petrochemical manufacturing industries are committed to protecting the health and safety of our workers, our contractors, our neighbors, our customers, and the communities through which crude oil and ethanol are shipped. AFPM supports a holistic, preventative approach to improving the safe transportation of crude oil by rail and other modes, and is committed to working with PHMSA on this issue. AFPM and its members work diligently to maintain a safe working environment in our refineries, with a goal of zero incidents. This commitment applies to the safe transportation of crude oil and other feedstocks to refineries, and of refined products to our members' customers.

As part of a longstanding commitment to safety, AFPM members have been proponents of AAR Tank Car Committee's proposed Petition P-1577 recommendations, which were introduced in 2011 as CPC-1232 standard tank cars. AFPM members made an enormous capital investment, now estimated at more than $3 billion, in tank cars meeting the updated standard because of their good-faith expectation that the standard would soon be adopted as law by the U.S. government. This expectation was supported by the fact that the U.S. DOT and Canadian Transport Ministry were both active participants in the AAR Tank Car Committee. Approximately 25% of the DOT-111 tank cars currently in crude and ethanol service are compliant with the CPC-1232 standard. [4] This number is expected to increase to more than 50,000 cars by the end of 2015. Despite the lack of regulatory certainty, the shipper sector has continued its good-faith, high-cost efforts to meet the CPC-1232 standard.

[4] *See* Alltranstek, LLC, "Economic Impact on the North American Tank Car Fleet and Supply with the Implementation of the Anticipated New Tank Car Regulations" (Sept. 30, 2014) ("Alltranstek Technical Analysis") (**Exhibit 2**).

## II. EXECUTIVE SUMMARY OF AFPM'S COMMENTS

Domestic oil and gas production has grown dramatically in recent years, with crude oil projected to soon reach levels last seen in 1970. Rail has played a critical role in facilitating the growth of domestic energy production and manufacturing, spurring the creation of tens of thousands of new jobs. Recent increases in crude oil output are transported mainly by rail. For example, producers in the Bakken formation use rail to ship 70% of crude oil to refineries and midstream companies. Similarly, 70% of ethanol reaches refineries by rail.

Although transportation by rail is very safe – with 99.997% of all hazardous materials moving by rail reaching its destination without incident – our industry is committed to a culture of continuous improvements and focused on zero incidents as the goal. AFPM respectfully submits that any effort to enhance rail safety must begin with addressing the primary root causes of derailments and other accidents: (1) track integrity and (2) human factors. Eighty-eight percent of derailments occur due to track defects. Human error is the predominant cause of other train accidents (*e.g.*, collisions with other trains). Investment in accident prevention would result in the greatest reduction in the risk of rail incidents.

In particular, DOT should consider recommendations made by the National Transportation Safety Board ("NTSB") to improve track safety standards and reduce human error. Those recommendations include requiring railroads to regularly report track service failure data, so that the Federal Railroad Administration ("FRA") may review high-stress, at risk areas of track. FRA rejected NTSB's safety recommendation, deferring to the railroads' claim that they could not obtain sufficient equipment and personnel to test high-stress areas of track. The Proposal continues the pattern of ignoring accident prevention: Nothing in this rulemaking would require railroads to buy one more piece of track inspection equipment, hire one more qualified inspector or inspect one more mile of track. The Proposal would instead mandate that shippers spend billions of dollars on tens of thousands of new and retrofitted tank cars to mitigate the impacts of accidents.

AFPM supports the "Option 3" specification for new and retrofitted rail tank cars shipping crude and ethanol in unit trains of 75 cars or more. The Option 3 specification tank car is an enhanced CPC 1232 tank car with a 7/16" shell and other enhanced safety features. The Option 1 and 2 tank cars with a 9/16" shell provide only negligible safety benefits at a substantial incremental cost. For example, an independent DOT study in 2009 concluded that shell thickness played a "relatively weak" role in determining whether an accident would result in a tank car puncture and loss of lading.

By comparison, PHMSA's cost-benefit analysis of the tank car options appears to be results-oriented, unreliable and based on data that PHMSA declined to place in the administrative record. PHMSA did not follow basic Office of Management and Budget procedures, such as preparing a "Statement of Energy Effects" analyzing how the rule may affect the supply of crude, its price, and the ability to meet demand with domestic crude. Indeed, the Proposal would create a significant risk of disrupting gasoline supplies. The numerous procedural and substantive flaws of PHMSA's cost-benefit analysis make it clear that Options 1 and 2 would cost far more and provide little in the way of additional safety improvements.

PHMSA's proposed three-year schedule for retrofits of existing tank cars is infeasible and would damage the economy. The Proposed Rule represents the largest tank car retrofit in history, affecting more than 67,000 tank cars. AFPM requested that Alltranstek, LLC, a leading rail consulting company, assess the capacity of retrofit shops to perform the retrofits required under the Proposal. Based on that analysis, AFPM concludes that a ten-year retrofit schedule would be achievable. Insisting upon a more aggressive schedule would risk tank car shortages, a significant loss in crude and ethanol rail capacity, higher prices for consumers of petroleum products, and steep opportunity costs for refiners who would no longer be able to maintain current business levels.

Equally infeasible is PHMSA's proposal that the new tank car standards, the retrofit standards, speed restrictions and other requirements of the rule apply to "high-hazard flammable trains" ("HHFT"), *i.e.*, a single train carrying 20 or more carloads of a Class 3 flammable liquid. While the purpose of the Proposed Rule is to regulate crude and ethanol rail shipments, the HHFT definition would have the practical effect of requiring that *all* flammable liquids transported in HHFTs comply with the tank car standards and other obligations of the rule. Shippers sending a manifest train of only a few cars of flammable liquids cannot reasonably predict whether a railroad might gather additional cars down the line, triggering the 20 car threshold for HHFT. Regulating all flammable liquids would require a separate risk assessment and cost-benefit analysis, procedural steps that PHMSA failed to take.

In place of the unworkable HHFT definition, AFPM proposes that PHMSA tie the tank car standards and other requirements of the rule to a definition of "unit train," meaning a train of 75 or more cars in crude or ethanol service. This definition more accurately addresses the purpose of the rule: mitigating risks of release from large, multi-car derailments. An AFPM member survey showed that the smallest unit train in crude and ethanol service was 86 cars. Thus, setting a 75-car threshold for the definition of a unit train should capture all crude and ethanol in unit train service.

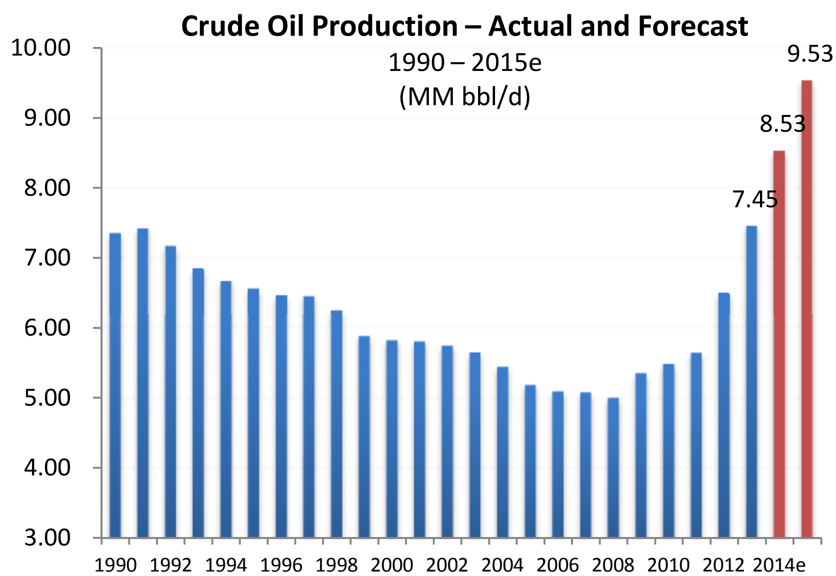
AFPM supports the Option 3 rail speed limit. That option will impose a 40 mph speed limit in high-threat urban areas ("HTUAs") for HHFTs unless all shipments meet the proposed tank car standards. AFPM agrees with the railroads that this is an appropriate speed limit, but suggests that it be tied to AFPM's proposed unit train definition, rather than HHFTs. The other speed limit options under consideration in the Proposal would unduly restrict rail capacity and risk supply disruptions of crude oil and other commodities throughout the rail system.

PHMSA's proposed classification and testing program for crude oil is unnecessary, unduly prescriptive, and burdensome. The properties of crude oil, including Bakken crude, are well understood. However, if PHMSA does decide to go forward with the proposed classification and testing program, these comments provide several suggestions to appropriately tailor the program. Finally, stabilization of Bakken crude is unnecessary and inappropriate because the properties of Bakken fall within the normal range for several other light crudes and stabilization would not reduce the risk of transporting this flammable liquid.

## III. THE IMPORTANCE OF RAIL TO DOMESTIC ENERGY INDEPENDENCE

Domestic oil and gas production has grown significantly in recent years, providing tens of thousands of jobs.[5] U.S. crude oil production is forecasted to increase from an estimated 7.45 million barrels per day ("MM bbl/d") in 2013 to 8.53 MM bbl/d in 2014 and 9.53 MM bbl/d in 2015, the highest annual average crude oil production since 1970. The amount of domestic crude oil supplied to East Coast refineries and petrochemical facilities has increased with rising domestic production in the Bakken area and expansion of crude-by-rail infrastructure. Hydrocarbon gas liquids (HGL) production at natural gas liquids plants is projected to increase from 2.6 MM bbl/d in 2013 to 3.1 MM bbl/d in 2015—most of this growth is expected to come from additional ethane and propane production. The growth in U.S. petroleum and other liquids production is shown in Figures 1 and 2 below. For the first time since 1995, domestic crude production exceeds imports, reducing our dependence on crude from the Middle East, Africa, and Latin America.[6]

Figure 1



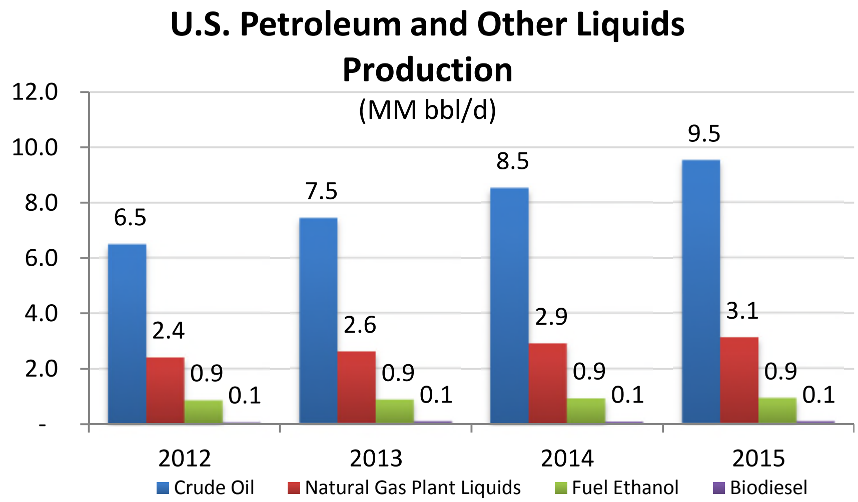

*Source*: Alltranstek Technical Analysis, at 9.

---

[5]Unless otherwise noted, this section of the comments is drawn from the Alltranstek Technical Analysis (Exhibit 2).

[6]Congressional Research Service, "U.S. Rail Transportation of Crude Oil: Background and Issues for Congress" at 1-2 (Feb. 16, 2014) (Excerpts at **Exhibit 3**) ("CRS Report"), *available at* https://www.fas.org/sgp/crs/misc/R43390.pdf

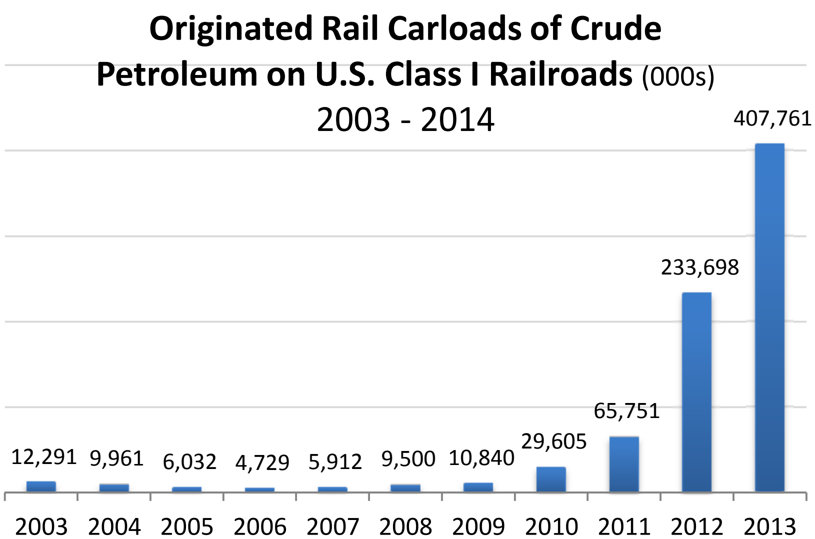
Figure 2




*Source*: Alltranstek Technical Analysis, at 9.

Rail has played a key role in facilitating the growth of domestic energy production. Historically, crude oil was moved from production area to refinery by pipeline. However, recent increases in crude oil output are transported mainly by rail—producers in the Bakken field in North Dakota, in particular, have used rail to ship 70% of crude oil to refineries and midstream companies at newly built unloading terminals on the East and West Coasts.[7] Rail carloads of crude oil have increased 4,000% between 2008 and 2013, as Figure 3 shows.

Figure 3

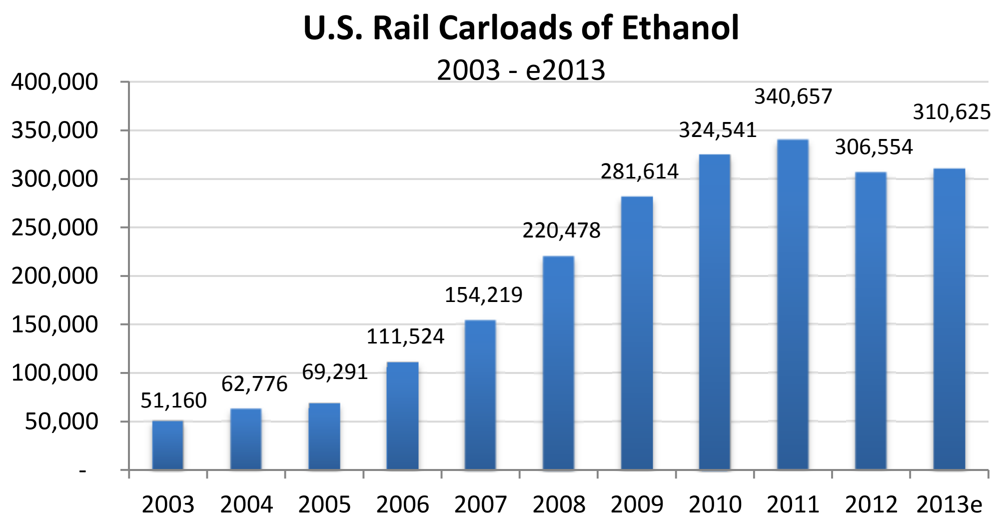



[7] *See, e.g.*, Justin J. Kringstad, North Dakota Pipeline Authority, Energy Development and Transmission Committee, at 6 (July 8, 2014) (**Exhibit 4**).

*Source*: Alltranstek Technical Analysis, at 11.

Due to the RFS, ethanol production has increased sharply as well. In 2013, U.S. ethanol production was approximately 13.3 billion gallons — a 291% increase over the 3.4 billion gallons produced in 2004. An estimated 70% of ethanol production ships via rail. The growth in ethanol rail production is illustrated in Figure 4.

Figure 4




*Source*: Alltranstek Technical Analysis, at 13.

## IV. PREVENTING DERAILMENTS AND OTHER TRAIN ACCIDENTS

Although transportation by rail is very safe – with 99.997% of all hazardous materials moving by rail reaching its destination without incident [8] – our industry is committed to a culture of continuous improvements and focused on zero incidents as the goal. PHMSA asserts that the "hazardous material regulatory system" is also "prevention-oriented." 79 Fed. Reg. at 45,023. However, the NPRM largely ignores accident prevention. As PHMSA admits, the "focus of this NPRM is on mitigating the damages of train accidents . . . ." *Id.*at 45,026.

[8]*See, e.g.*, Federal Railroad Administrator Joseph C. Szabo, Prepared Remarks, 50th Meeting of the Railroad Safety Advisory Committee, at 1 (Oct. 31, 2013) (**Exhibit 5**) ("Our rail system is extremely safe. As I have said repeatedly, 2012 – by virtually all measures – was the safest year in railroading history, with train accidents down a remarkable 43 percent in 10 years. And among the millions of annual shipments of hazardous materials by rail, less than a fraction of one percent of these has resulted in any type of release."); Federal Railroad Administration, Safety Fact Sheet, at 1 (Feb. 2014) (**Exhibit 6**) ("Rail has never been safer."); American Association of Railroads ("AAR"), Railroad Safety and Security" (last visited Sept. 26, 2014) (**Exhibit 7**), *available a*t https://www.aar.org/Safety/Pages/default.aspx ("99.997 percent of the approximately 1.7 million carloads of hazmat successfully reaching their final destination without a release caused by an accident.").

AFPM respectfully disagrees with PHMSA. Any effort to enhance rail safety must begin with addressing the primary root causes of derailments and other train accidents: [9] (1) track integrity and (2) human factors. Investment in prevention would result in the greatest reduction in the risk of rail incidents and their consequences. AFPM acknowledges that railroads have made tremendous strides in enhancing safety and have voluntarily taken steps to go "beyond compliance" to protect against accidents. While those steps should be applauded, this rulemaking fails altogether to analyze whether additional regulatory measures are necessary to improve track integrity and reduce human error. Rather than a comprehensive risk assessment of the rail system, this rulemaking represents yet another example of piecemeal regulatory burdens falling unevenly on the businesses and economies that must depend on the railroads' ability to safely deliver their freight without any systemic analysis of where the greatest safety improvements may lie. Furthermore, the imperative to enhance rail safety by both *preventing* and mitigating risks requires that DOT comprehensively analyze whether railroads should take action beyond these voluntary initiatives.

### A. The Importance of Track Integrity to Preventing Derailments

Improving track integrity and inspections are the most effective ways to prevent derailments. As the NPRM found, "[b]roken rails or welds [and] track geometry . . . are [among the] leading causes of derailments." 79 Fed. Reg. at 45,026. PHMSA reached this conclusion based, in part, on the multiple derailments over the last decade that were caused by rail defects. *Id.* at 45,021 (Table 3), 45,026.

A 2012 study showed that "broken rails or welds were the leading derailment cause on main, yard, and siding tracks." Xiang Liu, M. Rapik Saat, & Christopher P. L. Barkan, "Analysis of Causes of Major Train Derailment and Their Effect on Accident Rates," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2289, Transportation Research Board of the National Academies, Washington, D.C., 2012, at 154 ("Liu et al. 2012") (**Exhibit 8**). [10] Broken rails or welds resulted in 88% of derailments, causing approximately 670 derailments between 2001 and 2010, which far exceeds the average of 89 derailments for all other causes. In part because of the prevalence of these causes, the study determined that, "only if 50% of broken rails or welds could be prevented, the prevention would result in a larger percentage reduction in train and car derailment rates than would any of the other accident prevention strategies at 100% effectiveness." *Id.* at 162. In light of this finding, the proposed rule's focus "on mitigating the damages of train accidents," rather than preventing them, is misplaced and arbitrary. 79 Fed. Reg. at 45,026.

---

[9] FRA requires railroads to file monthly reports on "train accidents" causing damage above a certain threshold, including derailments, collisions with highway vehicles and train collisions. *See* 49 C.F.R. § 225.5 (defining "train accident" for purposes of FRA reporting as "any collision, derailment, fire, explosion, act of God, or other event involving operation of railroad on-track equipment (standing or moving) that results in damages greater than the current reporting threshold to railroad on-track equipment, signals, track, track structures, and roadbed."); FRA, Office of Safety Analysis, "9-12 Definitions," *available at* http://safetydata.fra.dot.gov/officeofsafety/publicsite/definitions.aspx (explaining FRA reporting of train accidents).

[10] The study is available at http://railtec.illinois.edu/CEE/pdf/Journal%20Papers/2012/Liu%20et%20al%202012.pdf

Rail defects cause the most severe derailments. Broken rails or welds derailed the highest number and percentage of rail cars, resulting in accidents that were "likely to be more damaging and more costly, have a greater likelihood of involving a hazardous materials car if any are in the consist, and if derailed, they are more likely to suffer a release." Liu et al. at 156-57 (Table 2). In other words, rail defects cause "high-frequency, high-severity" derailments, *see id.* at 158 (Figure 1), and must be addressed as part of any effort to mitigate the consequences of such accidents.

DOT has taken minimal efforts to regulate track safety, most notably the FRA issued a final rule that is effective on March 25, 2014. Track Safety Standards; Improving Rail Integrity, 79 Fed Reg. 4,234 (Jan. 24, 2014) ("Track Safety Standard Rule" or "Track Rule"). The intent of that rule was to require the use of performance-based inspections. Specifically, the Track Safety Standard Rule established "minimum qualification requirements for rail flaw detection equipment operators, as well as revising requirements for effective rail inspection frequencies, rail flaw remedial actions, and rail inspection records." *Id.*

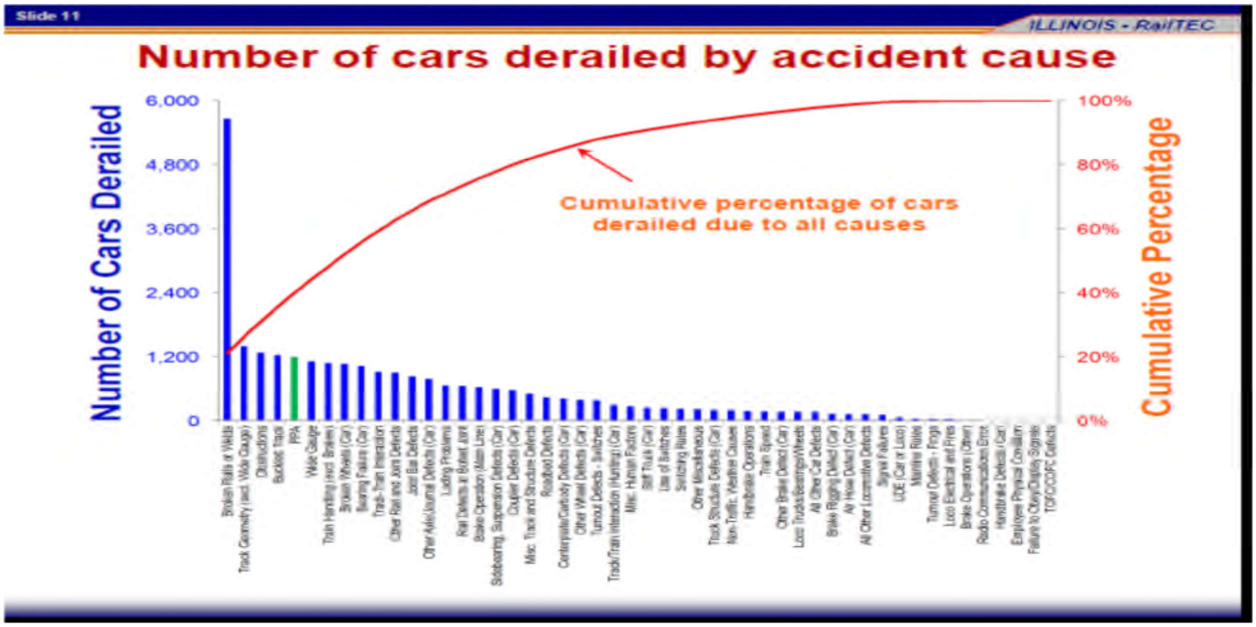
As DOT acknowledges, however, these measures largely reflect the status quo. PHSMA has observed that "[t]he bulk of [the January 2014] regulation codified the [railroad] industry's current good practices." 79 Fed. Reg. at 45,027. DOT fails to explain why codifying existing track maintenance practices is appropriate when track integrity causes more derailments than all other causes combined. Indeed, Dr. Christopher Barkan's [11] recently provided analysis to NTSB concludes that the most frequent and severe derailments are caused by rail defects. *See* Presentation of Christopher Barkan to the NTSB, *Rail Safety Forum: Transportation of Crude Oil and Ethanol* (April 23, 2014) (**Exhibit 9**) ("Barken 2014). [12] Figure 5 is a reproduction of a graph from Dr. Barkan's NTSB presentation. It illustrates that track integrity is the primary root cause of derailments, with broken rails and welds causing eighty-eight percent of them.

---

[11] Dr. Barkan is the Executive Director of the Rail Transportation and Engineering Center and a Professor and George Krambles Faculty Fellow at the University of Illinois's Department of Civil and Environmental Engineering.

[12] http://www.ntsb.gov/news/events/2014/railsafetyforum/presentations/Panel%202_E_Chistopher%20Barkan.pdf.

Figure 5: Number of cars derailed by accident cause.




*Source*: Barkan 2014, at 11.

DOT's embrace of the status quo for track integrity is arbitrary. DOT has proposed tank car standards and other measures that would cost shippers billions of dollars to build new tank cars to carry crude and ethanol over old tracks. That approach to risk is backwards: it is far more effective to prevent a derailment than mitigate impacts from it. Risk prioritization and common sense suggest that DOT should focus on heightened track integrity before mandating the largest rail car retrofit program in history. [13]

The Proposal fails to meaningfully explain why track inspections and maintenance were not considered. *See* 79 Fed. Reg. 45,026 ("This NPRM does not directly address regulations governing the inspection and maintenance of track."). Instead, DOT declines to analyze track safety after noting that "existing regulations and on-going rulemaking efforts—together with this NPRM's proposals for speed, braking, and routing—sufficiently address safety issues involving rail defects and human factors." *Id.* at 45,026–27 (Table 3). Given the importance of these issues, this brief explanation is inadequate. At the very least, DOT should describe why and how focusing on mitigation is appropriate when the studies show that track integrity has the greatest effect on derailments.

[13] PHMSA's proposed retrofit standards make the refusal to consider track integrity measures all the more arbitrary. The Proposal would result in at least 66,000 tank cars being retrofitted with heavier shells and other equipment. PHMSA admits that all of that additional weight will increase wear on the rail system, requiring more track maintenance. RIA, at 81 ("*Costs resulting from increased weight* [of proposed DOT-117s]*:* the heavier tank cars will lead to . . . more track maintenance."). Yet the NPRM has no analysis of whether track inspections, track maintenance or other track integrity measures are needed to address the added stress of heavier tank cars on the rail system.

### B. The Role of Human Error in Train Accidents

AFPM also supports additional regulations addressing the various human factors that cause train accidents. The Federal Railroad Administration estimates that, "since 2009, *human factors have been the most common cause of reportable train accidents* . . . ." 79 Fed. Reg. 53,361 (emphasis added). Based on FRA's "accident reporting data for the period from 2009 through 2012, 35.7 percent of train accidents were human factor-caused." Emergency Order Establishing Additional Requirements for Attendance and Securement of Certain Freight Trains and Vehicles on Mainline Track or Mainline Siding Outside of a Yard or Terminal, 78 Fed. Reg. 48,218-02, 48,221). From May 2009 through May 2014, "approximately 3,030 accidents/incidents were caused by human factors, and 906 involved equipment that was placarded as containing hazardous materials." 79 Fed. Reg. at 53,361 n.13.

For example, the tragic Lac-Mégantic accident that occurred just last year involved human error. Before leaving the train unattended, an engineer failed to set an adequate number of hand brakes to prevent the train from moving. In response to this event, FRA issued an Emergency Order 28 on securement, which, among other things, prohibits railroads from leaving trains or vehicles transporting certain hazardous materials unattended unless the railroad adopts and complies with a plan that provides sufficient justification. *See* 78 Fed. Reg. at 48,222. At the same time, DOT circulated a voluntary Safety Advisory recommending that "railroads review their crew staffing practices for over-the-road train movements of trains" transporting certain hazardous materials. Lac-Mégantic Railroad Accident Discussion and DOT Safety Recommendations, 78 Fed. Reg. 48,224-01, 48,228.

However, DOT apparently views these steps to prevent human error as temporary measures. On September 9, 2014, FRA proposed a rule on securement that would repeal certain requirements of Emergency Order 28. *See* Federal Rail Administration, Securement of Unattended Equipment, 79 Fed. Reg. 53,356 (Sept. 9, 2014). As an example, FRA proposes to abolish the requirement from the order that railroads maintain records "verifying proper securement." *Id.* at 53,366-67. FRA also proposes to end the mandatory duty of railroads to review and adjust their securement procedures. *Id.* at 53,364. Instead, railroads would be expected to voluntarily follow their "existing . . . processes and procedures" *Id.* Contrary to the emergency order, railroads would be allowed to leave unattended trains on mainline track "adjacent to the yard" without having to prepare a "plan that identifies the specific locations and circumstances for which it is safe and suitable for leaving such trains or vehicles unattended." *Id.*

AFPM continues to review the merits of this securement proposal and will decide whether to comment upon it in due course. Nevertheless, the securement proposal is a classic example of the disjointed and ad-hoc *process* for addressing rail safety. DOT is simultaneously proposing two rules: one that would partially repeal an order intended to prevent human errors and this proposal to mitigate the consequences of those errors. DOT has no metrics, criteria or governing principles to prioritize between prevention and mitigation. [14] Nor will such a comprehensive risk approach be possible when DOT continues to break rail safety into different procedural silos that deprive the government and the regulated community of the opportunity to holistically discuss the merits of accident prevention and mitigation polices. [15]

### C. NTSB's Recommendations on Track Safety Standards

Rather than focusing solely on the mitigation of the impacts from train accidents, including derailments, DOT should prevent accidents by promoting track integrity and reducing human error. To that end, AFPM recommends that DOT revisit the Track Safety Standard Rule. *See* Track Safety Standards; Improving Rail Integrity, 79 Fed Reg. 4,234 (Jan. 24, 2014) ("Track Safety Standard Rule" or "Track Rule"). As described above, the Track Rule codified existing railroad industry practices on track maintenance and "internal" rail inspections. Internal rail flaws are cracks, fissures and splits in a rail. The development of these internal flaws is the "predominant factor that determines the risk of rail failure …" 79 Fed. Reg. at 4,237. The primary method for internal inspections is ultrasonic testing where sound waves are directed at the rails. The reflected signal is interpreted by a qualified operator to detect internal flaws. *Id.* at 4,237, 4,250. [16]

Rather than enhancing safety, the Track Rule focused on reducing the railroads' operating costs. The rule imposed no obligation on railroads to purchase additional ultrasonic testing equipment, hire more qualified inspectors, or make other investments in detecting track defects. The government admitted as much, stating that the rule did not impose "any material costs" on railroads. 79 Fed. Reg. 4,235. [17] The benefits of the rule did not include reducing derailments or other accidents. Instead, FRA touted the "main benefit" of the Track Rule as

---

[14] While this Proposal to impose multi-billion dollar mitigation measures moves forward, DOT continues to consider whether to implement NTSB recommendations regarding minimum train crew staffing binding on railroad carriers. Presentation of Rich Connor to the NTSB, *Rail Safety Forum: Transportation of Crude Oil and Ethanol* (April 22, 2014) (**Exhibit 10**), *available at* http://www.ntsb.gov/news/events/2014/railsafetyforum/presentations/Panel%202_A_Rich%20Connor.pdf. While it may be sound policy to reject crew staffing requirements, the NPRM fails to comprehensively analyze and consider whether such measures would reduce accident impacts. That is unreasonable and arbitrary.

[15] In the Proposal, PHMSA suggests that human factors are being addressed because of FRA's 2010 advanced notice of proposed rulemaking ("ANPR") on "Risk Reduction Programs" (2130-AC11). *See* 79 Fed. Reg. at 45,027. On the contrary, this risk reduction rulemaking confirms DOT's failure to take seriously the role of human error in derailments. After nearly four years, FRA has yet to even issue a proposed rulemaking on risk reduction programs, much less finalize the rule. Moreover, these risk management programs are simply another variant of safety management systems that the Transportation Safety Board of Canada ("TSB") found inadequate in preventing the Lac-Mégantic incident, in the absence of sustained regulatory oversight and accountability from Transport Canada over the MM&A Railway. *See* TSB, Railway Investigative Report R13D0054, at 70-92, 120-28, 154-160 (2014) (**Exhibit 11**) ("TSB Lac-Mégantic Report").

[16] Induction testing is another form of internal rain inspection. Induction testing passes a direct current into the top of the rail, creating a magnetic field through which an induction sensor is passed to detect distortions in the field created by internal rail flaws. 79 Fed. Reg. at 4,237.

[17] *See also id.* at 4,251 (describing the costs of the rule as "minimal").

saving railroads about $8,400 per day because they would be granted additional time to verify internal rail defects. [18]

NTSB asked FRA to do more. In comments filed on the proposed Track Rule, NTSB pointed out that the rulemaking was intended to implement Section 403 of the Rail Safety Improvement Act ("RSIA") of 2008, Pub. L. 110-432, Div. A. The RSIA required DOT to conduct a safety study on tracks and issue a rule based on the study. *See id.* DOT conducted the safety study; [19] however, NTSB's comments demonstrate that the proposed rule failed to implement the study and thus the intent of the RISA. *See* Comments from Deborah A.P. Hersman, Chairman, NTSB, to Docket FRA-2011-0058 (RIN 2130-AC28) (Dec. 18, 2012) ("NTSB Comments") (**Exhibit 12**). Most of NTSB's safety concerns about the rule were dismissed by FRA in the final Track Safety Standard Rule. [20]

Without necessarily taking a position on the merits of NTSB's comments on the Track Rule, AFPM believes that they warrant further consideration as part of a broader rule on rail safety. We highlight below a few of NTSB's safety comments on the Track Rule and provide a copy of the comments for DOT's consideration in this docket.

NTSB expressed significant concern with FRA's new standards for track inspection. The Track Rule abolished internal track inspection intervals based strictly on the passage of time and the amount of million gross tons ("mgt") traveled over the track. 79 Fed. Reg. at 4,234–35. FRA replaced those "time and tonnage" inspection intervals with "self-adaptive performance goals" for inspections. *Id.* at 4,240. The performance goals authorize railroads to have a certain amount of track failures [21] per mile across a segment of track, referred to as "service failure rates."

[18] 79 Fed. Reg. at 4,235 ("The *main benefit* associated with this final rule is derived from granting track owners a four-hour window to verify certain defects found in a rail inspection. Without the additional time to verify these defects, track owners must stop their inspections anytime a suspected defect is identified to avoid civil penalty liability, and then resume their inspections after the defect is verified. The defects subject to deferred verification allowances are usually considered less likely to cause immediate rail failure, and require less restrictive remedial action. The additional time permits track owners to avoid the cost of paying their internal inspection crews or renting a rail flaw detector car an additional half day, *saving the industry $8,400 per day*.") (emphasis added).

[19] DOT, Track Inspection Time Study (2011), *available at* http://permanent.access.gpo.gov/gpo26599/TrackInspectionTimeStudyFR62911.pdf

[20] 79 Fed. Reg. at 4,241 (stating that FRA will study NTSB's comment that the rule fails to address the problems raised by having inspectors visually inspect two train tracks at the same time); *id.* (rejecting NTSB's call for greater automated track inspections because "the current level of automated inspections is satisfactory at this time"); *id.* at 4,246 (rejecting NTSB's comment that railroads should not be allowed to define the length of the segment used to determine compliance with the performance standards for track inspections); *id.* at 4,248 (rejecting NTSB's recommendations on inspection-intervals for plug rails); *id.* at 4,249 (denying NTSB's request that FRA amend the rule to require reporting of service failure data so that FRA can assess the performance of high stress segments of rail).

[21] FRA defines "service failures" as "a broken rail occurrence, the cause of which is determined to be a compound fissure, transverse fissure, detail fracture, or vertical split head." 40 C.F.R. § 213.237(j)(3). *See also* 79 Fed. Reg. at 4,245 ("The final rule … require[s] track owners to maintain service failure rates of no more than 0.1 service failure per year per mile of track for all Class 4 and 5 track; no more than 0.09 service failure per year per mile of track for all Class 3, 4, and 5 track that carriers regularly scheduled passenger trains or is a hazardous material route; and no more than 0.08 service failure per year per mile of track for all Class 3, 4, and 5 track that carriers regularly scheduled passenger trains and is a hazardous materials route."). For purposes of the Traffic Safety Standards in 49

*Id.* at 4,245, 4,258. The proposed Track Rule allowed the railroads to define the length of the segment used to determine compliance with the service failure rate. *Id.* at 4,246. NTSB expressed concern that this proposal would allow railroads to "collect[] service failure rates that were averages over excessively large segments of track . . . [and] would [therefore] fail to identify discrete areas of weakness with chronically high concentrations of service failures." 79 Fed. Reg. at 4,246. *See also* NTSB Comments, at 8. FRA rejected NTSB's safety concern and allowed selection of any segment length because railroads have "research[ed] their own internal rail testing requirements." 79 Fed. Reg. at 4,246. This might not be an issue but for the fact that rail integrity is the root cause of the derailments that are the predicate for this rulemaking.

NTSB also objected to FRA's method of determining compliance with the service failure rates. Those failure rates are not set on a daily, monthly, or even an annual basis. Instead, railroads only violate the failure service rates when they do not comply over *two consecutive years* for a particular segment of track. *Id.* at 4,249, 4,258.[22] NTSB objected to this prolonged self-assessment because "there is no reporting requirement for presenting [service failure] data …, and there is no systemic approach to how the FRA would use these data to assure acceptable performance." NTSB Comments, at 9. NTSB recommended regular reporting of track service failures and oversight by FRA to ensure that "areas of high stress are being identified and risk of failure is being mitigated by the track owners in a timely manner." *Id.* at 8.

FRA rejected NTSB's recommendation that railroads regularly report service failure data and identify high risk areas of track. FRA asserted that NTSB's recommendation for regular oversight might require too many internal rail inspections and force railroads to purchase additional inspection vehicles to perform ultrasonic testing and hire more qualified test operators. Rather than mandating the commitment of more railroad resources, FRA deferred to the railroads:

> [D]uring RITF [Rail Integrity Task Force] meetings there was much discussion that the practice of increased test frequency on localized areas would lead to unmanageable amounts of test frequencies. The *AAR noted that there is a limited supply of inspection vehicle resources and test operators, and that a greatly increased amount of test frequencies would not be achievable by the railroads. FRA agrees ….*

79 Fed. Reg. at 4,249 (emphasis added).[23]

---

C.F.R. Part 213, Class 1-2 track can carry freight up to 10 miles per hour, while Class 3-5 track can carry freight 40-80 mph. 49 C.F.R. § 213.9(a).

[22]The consequence of two years of non-compliance is that the violating segment must be internally inspected every 10 million gross tons or reduced to Class 2 service. *Id.* at 4,249.

[23]FRA also paid lip service to reviewing service failure data and following up "as necessary," *id.*, but, as NTSB pointed out, the Track Safety Standard Rule does not require railroads to report service failure rate data to FRA. NTSB Comments, at 9. Without any system of reporting and review, it is difficult to imagine how FRA will conduct comprehensive, regular reviews of railroad data to identify high-stress areas in local segments of track.

DOT has turned rail safety on its head. Without any analysis, DOT declines to require that railroads purchase *one more inspection vehicle* or hire *one more inspector*. Yet shippers such as AFPM members must purchase tens of thousands of new and retrofitted tank cars. The billions committed by shippers for new and retrofitted tank cars will do little good unless DOT ensures a commensurate investment in track infrastructure and inspectors. Accordingly, AFPM encourages DOT to consider NTSB's recommendations for improving the Track Safety Standard Rule.

## V. PROPER HARMONIZATION WITH CANADA'S STANDARDS IS CRITICAL

AFPM supports appropriate harmonization between this rule and Transport Canada's proposed tank car and rail operations rules. Both governments share a common interest in enhancing rail safety in a cost-effective manner. Common business interests demand an efficient and consistent infrastructure, including rails and rail cars, since rail routes will frequently cross borders from origination to destination. Equipment cannot be changed in the middle of a delivery route without introducing significant inefficiencies and potentially raising safety concerns. Separate standards in each country would unnecessarily complicate and impede compliance and enforcement. To ensure proper harmonization, AFPM respectfully requests that PHMSA issue a final rule consistent with these comments, and that PHMSA coordinate with Canada to ensure that it follows common requirements that protect the safe, efficient and economical flow of rail shipments across the border.

## VI. NEW TANK CAR STANDARDS

In the NPRM, PHMSA proposes a standard for new tank cars, the DOT Specification 117 ("DOT 117"). This DOT 117 standard would apply to tank cars manufactured after October 1, 2015 for use in an HHFT. PHMSA proposes three options for the DOT 117, referred to as Options 1, 2, and 3. These options would all require the following on each tank car:

(1) bottom outlet valve handle removed or designed to prevent unintended actuation during a train accident ("BV");
(2) full height 1/2 of an inch thick head shield ("FHHS");
(3) reclosing pressure relief device ("PRV");
(4) minimum 11-gauge jacket constructed from A1011 steel or equivalent, which must be weather-tight;
(5) TC-128 Grade B, normalized steel; and
(6) thermal protection system pursuant to 49 CFR 179.18 ("thermal protection").

*See* 79 Fed. Reg. 45,018-19; RIA, at 76.

However, the proposed options would differ in three respects. First, Options 1 and 2 would require a wall thickness after forming the tank shell and heads of 9/16 of an inch, while Option 3 would require a 7/16 of an inch shell thickness. Moreover, Option 1 would require electronically controlled pneumatic ("ECP") brakes, while Options 2 and 3 would require transport in trains with distributed power ("DP") or two-way End-of-Train ("EOT") braking systems. *See* 79 Fed. Reg. 45,018-19; RIA, at 76. Finally, Option 1 would require a toxic-by-inhalation ("TIH") top fittings protection system and nozzle capable of sustaining, without failure, a rollover accident at a speed of 9 mph, while Options 2 and 3 would require top fittings protection equipped pursuant to AAR Specifications Tank Cars, appendix E, paragraph 10.2.1.

Based on the differences in these proposed specifications, AFPM supports Option 3 as the authorized tank car specification for crude and ethanol shipments in unit train service. [24] Option 3 is essentially an enhanced jacketed CPC-1232 tank car standard. Compared to a CPC-1232 tank car, Option 3 – as well as Options 1 and 2 – would enhance the bottom outlet handle and pressure relief valve, as described above. Option 3 would further modify the CPC-1232 by removing the legal options to build cars with a thicker shell but no jacket. As PHMSA notes, Option 3 "is a substantial safety improvement over the current DOT Specification 111 . . . . ." 79 Fed. Reg. 45,052.

AFPM's rationale for supporting Option 3 is provided below. Our analysis focuses on the benefits and costs of the three key differences between the options: shell thickness, top fittings and braking systems. We also discuss the flaws in the PHMSA's cost-estimates for new tank cars. In addition to supporting Option 3 as the specification for DOT 117s, AFPM also supports the performance standard alternative for that option.

## A. Shell Thickness

### 1. The 9/16" Shell Provides Only a Marginal Safety Benefit, at Best

In deciding between the benefits of a 7/16" and 9/16" shell, PHMSA relied on "effectiveness rate" estimates. *See* 79 Fed. Reg. at 45,033. In the NPRM, PHMSA promised to place into the docket for the rulemaking a "technical supplement that describes the model input and assumptions that were used to develop the effectiveness rates." *Id.* That happened about half-way into the public comment period, when PHMSA placed in the docket an eleven-page "Effectiveness Rate Memo." *See* PHMSA, Calculating the Effectiveness Rates of Tank Car Options, at 1 n.1 (docketed Aug. 25, 2014). In the Effectiveness Rate Memo, PHMSA defined the effectiveness rate as "a calculated value comparing the predicted volume of lading lost in a derailment between an alternative tank car design and a baseline deign [*sic*] (in this case a non-jacketed DOT 111 tank car)." For example, PHMSA calculated that Option 1 was 54% more effective than a DOT 111, while Option 3 was 41.3% more effective. *Id.* at 11.

PHMSA's effectiveness rate "methodology" is suspect. To AFPM's knowledge, it has not been formally peer reviewed or appeared in peer reviewed literature. Nor is it generally accepted or widely used in the fields of rail safety and rail transportation. The only "technical paper" using effectiveness rates appears to be the Effectiveness Rate Memo itself. Furthermore, none of the underlying calculations used to derive the effectiveness rates have been placed in the docket, making it impossible for the regulated community to replicate PHMSA's work.

In the Effectiveness Rate Memo, PHMSA used 11 historical derailments to calculate effectiveness rates, but made no attempt to show that those derailments are representative. To

[24] Under the HMR, the DOT 117 would be authorized package for all Class 3 materials in all packing groups and other hazard classes.

the contrary, PHMSA's selection of these 11 derailments appears to be cherry picking the data. PHMSA relied on 13 derailments in the NPRM, but relied on only 11 in the Effectiveness Rate Memo. PHMSA removed the three derailments in its original list of 13 that had the lowest volumes of crude or ethanol lost: LaSalle Colorado (5,000 gallons); Lynchburg, Virginia (30,000 gallons); and Vandergrift, Pennsylvania (10,000 gallons). PHMSA then added a derailment with the most volume loss of any it considered, Lac-Mégantic (1,580,000 gallons). *See* 79 Fed. Reg. at 45,020, Table 3; Effectiveness Rate Memo, at 4, Table 2.

No reasonable person would believe it a coincidence that PHMSA removed the three lowest volume spills and added a high volume spill; it appears that PHMSA sought to influence the results of the effectiveness rate calculations. PHMSA has no plausible alternative explanation. The agency claims it removed the LaSalle and Vandergrift derailments because "there were no breached cars as such there is not [*sic*] point including these incidents." Effectiveness Memo, at 3 n.5. However, the number of breached cars for LaSalle and Vandergrift is listed in the NPRM, found in FRA's data and reported in the media. PHMSA has no explanation for removing the Lynchburg derailment and adding Lac-Mégantic. How much of a difference these changes made in the results is impossible to determine because none of the agency's underlying work papers and calculations were put in the docket. In the interest of fair notice and transparency, all of PHMSA's effectiveness rate calculations should be placed on the docket, so that the effect of these last minute data changes can be examined.

The effectiveness rate estimates are also flawed because PHMSA failed to analyze the uncertainty of the estimates. As the Rail Transportation and Engineering Center has explained, "[r]isk analysis of railroad hazmat transportation is subject to uncertainty due to statistical inference based on sample data." [25] Because uncertainties "affect the reliability of risk estimate[s] and corresponding decision making," "standard error and confidence interval should also be quantified and incorporated into" rail safety risk estimates. *Id.* It is particularly important to examine standard error and confidence intervals when analyzing a small sample size of 11 past incidents. PHMSA failed to do so, making its estimates uncertain and unreliable.

PHMSA's effectiveness rate estimates are expressed in percentages that appear to show significant differences between the tank car options. But a closer examination of the accident data upon which the rates are calculated reveals that the shell thickness has only a marginal impact during a derailment. Looking behind those effectiveness rates, they are based on 11 historical derailments of crude and ethanol. PHMSA used those 11 historical incidents to predict the number of Option 1, 2, and 3 cars that would be punctured during derailments at different speeds. Reproduced below is Table 3 from PHMSA's Effectiveness Rate Memo, which provides the predicted number of punctured cars for various tank car options. As PHMSA's table shows, Options 1 and 2 only result in *1.4 to 2.7 fewer punctured cars per derailment* than Option 3, depending on the speed of the derailment. With an average of 22 cars derailed in these historical incidents, [26] the predicted reduction in punctured cars is insufficient to justify moving beyond

[25] Liu et al., Rail Transportation and Engineering Center, University of Illinois at Urbana-Champaign, "Railroad Hazardous Materials Transportation Risk Analysis Under Uncertainty," at 21, (Oct. 15, 2012) (**Exhibit 13**) ("Liu 2012").

[26] *See* Effectiveness Rate Memo, at 4, Table 2.

Option 3. Nothing in the record demonstrates that small reductions in punctured cars would have any material effect on safety and environmental risks during a derailment, much less an impact that would justify spending billions more on a 9/16" shell.

Table 3: Predicted number of punctured tank cars (interpolated values)

| Tank Car | Predicted # of cars punctured at 30 mph derailment speed | Predicted # of cars punctured at 40 mph derailment speed | **Interpolated number at specific derailment speed (Arcadia – 46 mph)** | Predicted # of cars punctured at 50 mph derailment speed |
|---|---|---|---|---|
| 111 | 7.7 | 10.9 | **14.02** | 16.1 |
| Option 1 | 4.3 | 6.6 | **8.46** | 9.7 |
| Option 2 | 4.3 | 6.6 | **8.46** | 9.7 |
| Option 3 | 5.7 | 8.3 | **10.76** | 12.4 |

*Source*: PHMSA, Effectiveness Rate Memo, at 5.[27]

Consistent with AFPM's analysis, an independent DOT study found that shell thickness had a "***relatively weak effect***" on preventing releases during derailments. In a 2009, a DOT engineer, D.Y. Jeong, published a paper for the American Society of Mechanical Engineering on the conditional probability of release of hazardous materials from railroad tank cars during an accident. [28] The conditional probability of release "is the probability that release of hazardous materials from a railroad tank car will occur given that an accident … has already occurred." *Id.* at 1. DOT examined the Tank Car Accident Damage Database, which contains over 40,000 records of damaged tank cars from accidents. *Id.* Based on a regression analysis of that data, DOT developed a probabilistic model and ran 100,000 Monte Carlo simulations[29] of rail car accidents to determine which factors contributed to the conditional probability of release. The schematic for this model is reproduced below. Jeong 2009, at 2.

[27]PHMSA separately analyzed the effectiveness rates of the different braking systems under consideration in the NPRM, an issue discussed below. *See* PHMSA, Calculating Effectiveness Rates for Emergency Brake Signal Propagation Systems at 2 n.3 (docketed Aug. 25, 2014) ("Braking Memo").

[28]D.Y. Jeong, Volpe National Transportation Systems Center, U.S. Department of Transportation, " Probabilistic Approach to Conditional Probability of Release of Hazardous Materials from Railroad Tank Cars During Accidents," ASME 2009 International Mechanical Engineering Congress and Exposition, Paper No. IMECE2009-10872 ("Jeong 2009") (**Exhibit 14**), *available at* http://www.fra.dot.gov/eLib/Details/L02883.

[29]A Monte Carlo simulation "arrives at an approximation of a probability by running many, many trials." MIT, OpenCourseWare, "Sampling and Monte Carlo Simulation," *available at* http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-00sc-introduction-to-computer-science-and-programming-spring-2011/unit-2/lecture-14-sampling-and-monte-carlo-simulation/ (last visited Sept. 25, 2014).

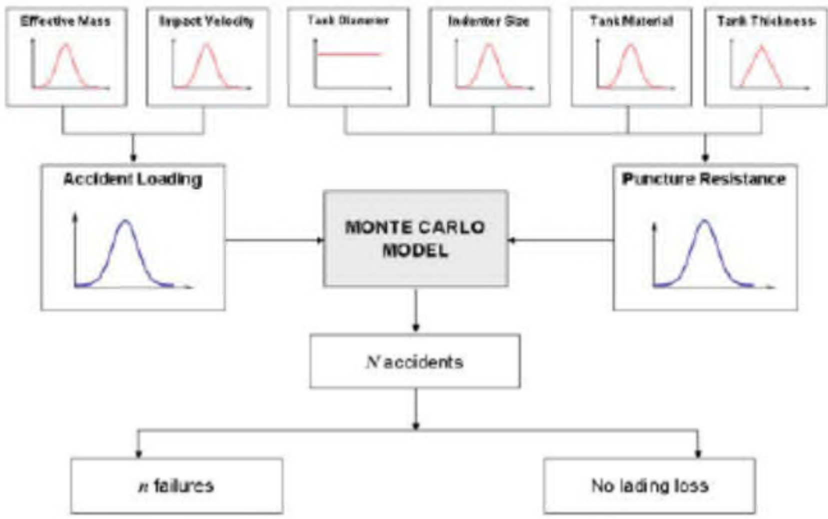



**Figure 2. Schematic of Simulation Model**

*Source*: Jeong 2009.

Based on the 100,000 simulated train accidents, DOT found a "relatively weak effect of thickness" on the conditional probability of release. *Id.* at 6. The study concluded that "the most significant factors affecting conditional probability of release are impact velocity, effective collision mass, and indenter size." *Id.* at 5. Because the study showed that shell thickness played such a weak role in preventing releases, DOT actually changed the probability functions in the modeling to see if it would affect the results, but it did not do so: impact velocity, mass and indenter size remained the key variables. *Id.* These study results are shown graphically in Figure 8 from the paper, which is reproduced below. [30]

[30] "Triangular" and "uniform" in Figure 8 refers to the differing distribution functions that Jeong used to test whether the probability distribution was resulting in the weak effect of shell thickness on the conditional probability of release. Jeong 2009, at 5.

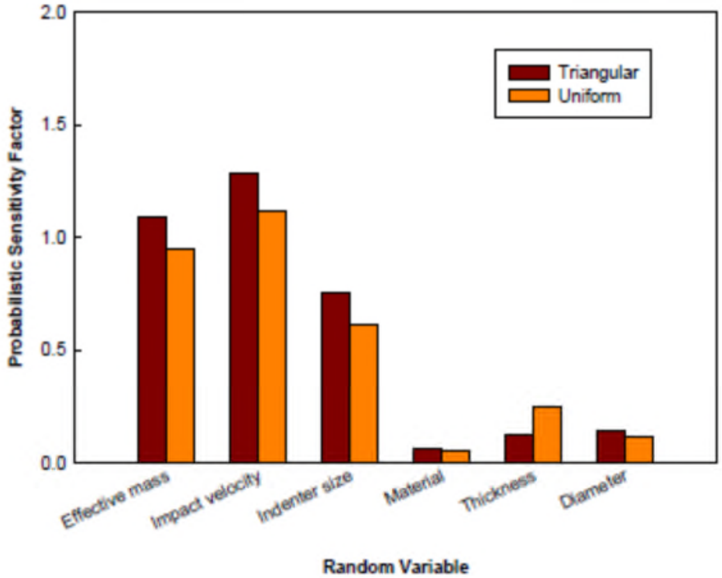



**Figure 8. Probabilistic Sensitivity with Respect to Changes in Standard Deviation**

*Source*: Jeong 2009 [31]

PHMSA also used the wrong inputs in performing its effectiveness rate calculations. Specifically, PHMSA assumed the wrong shell puncture velocity for the 7/16" shell proposed in Option 3. Shell puncture velocity is a critical input to PHMSA's analysis; it is used to calculate the number of cars punctured in a derailment. According to PHMSA's computer models and simulations, the Option 3 7/16" shell had a puncture velocity of 9.6 mph, while Options 1 and 2 had a puncture velocity of 12.3 mph. *See* 79 Fed. Reg. at 45,054. But a recent FRA full-scale shell impact test showed that a 7/16" shell on a jacketed DOT 111 had a puncture velocity of 12.1 mph, nearly indistinguishable from the 12.3 mph puncture velocities for Options 1 and 2. *See* FRA, Full-Scale Shell Impact Test of a DOT-111 Tank Car, at 4 (Aug. 2014) (**Exhibit 15**).

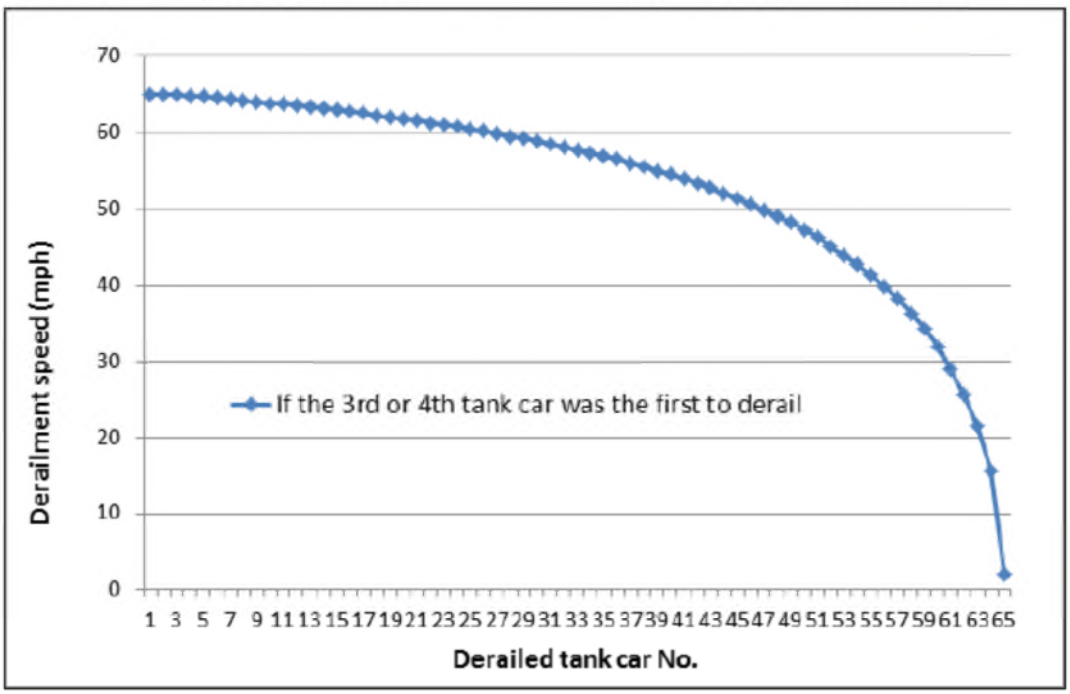
Even if PHMSA's effectiveness rate calculations were perfect, they show that none of the tank car options under consideration could have prevented a release of product in the event of the derailment. As noted, PHMSA based its calculations on 11 historical derailments, which varied in speed from 19 to 65 mph. Effectiveness Rate Memo, at 4. The most stringent new tank car standard option, Option 1, has a shell puncture velocity of 12.3 mph and a head puncture velocity

[31] PHMSA asserted that the results of the effectiveness rate calculations were "validated" by a conditional probability release calculation. *See* Effectiveness Rate Memo, at 10-11. But PHMSA appears to have just repeated its effectiveness rate calculations using the puncture resistance assumptions from a conditional probability of release paper, Treichel et al. 2006. PHMSA's calculations, data and assumptions are not in the docket. Nor did PHMSA place the paper in the docket, even though it is not published (or publicly available). The results of PHMSA's conditional probability of release calculation differ from the results achieved with the effectiveness rate calculations, but the agency provides no explanation for the difference. PHMSA provides no uncertainty or probably analysis, a key step in the analysis, *see* Liu 2012, which was addressed with Monte Carlo simulations in Jeong 2009.

of 18.4 mph, indicating that even Option 1 would have punctured in all 11 representative derailments. *See* 79 Fed. Reg. at 45,054.

PHMSA acknowledges that the derailment speeds analyzed in the NPRM "exceed the puncture velocity of the DOT Specification 111 tank car and the Options proposed in this rule." 79 Fed. Reg. 45,060. PHMSA asserts, however, that "during a derailment the speeds of impact will vary considerably between cars," so the "impacts that could result in a puncture would decline with the higher puncture velocity of the DOT Specification 117 tank car Options proposed in this NPRM." *Id.* Yet PHMSA performed no analysis of accident data to substantiate its claim that the tank car options would have prevented punctures in light of the differing speeds of cars during a derailment. To further illustrate that the proposed tank cars would fail to prevent punctures, below is a reproduction of Figure 5 from the TSB Lac-Mégantic Report. As this graph illustrates, the first rail car at Lac-Mégantic derailed at approximately 65 mph. All but one of the subsequent cars to derail were traveling above 20 mph.

Figure 5. Estimated speed at which each car derailed if the third or fourth car was the first to derail[32]




2. <u>PHMSA Significantly Understates the Costs of the New Tank Car Options</u>

PMHSA's calculations of the costs of the tank car shell options are also problematic. First and foremost, PHMSA assigns a zero cost to the 7/16" shell required by Option 3. The agency assumes as a "base case" that all newly constructed cars in the absence of the rulemaking would be enhanced jacketed, CPC 1232 tank cars, identical to the tank cars required by Option

3. [32] However, that assumption is mistaken. Some CPC 1232s being built are "slick cars" (no jacket and no insulation) and have a half height head shield instead of a full height head shield. The difference in new car cost between a bare CPC-1232 and a jacketed CPC-1232 is about $10,000 (from $139,000 to $149,000). To meet Option 3, enhanced BOV and PRV would also be required at $2,700. Accordingly, the Option 3 car has a $12,700 incremental cost that needs to be considered in the analysis. *See* Alltrantek Analysis, at 27.

PHMSA's cost-benefit analysis is also skewed because it uses different base cases for costs and benefits. As noted, PHMSA compares the tank car options to a base case of the enhanced CPC 1232, which has the effect of lowering the costs. The agency then switches tack and calculates benefits by comparing the tank car options to the puncture resistance of a legacy DOT 111 car, which inflates the benefits. *See* Draft RIA, 80, 82, 90, 94, 120-26. Cost-benefit analysis requires an apples-to-apples comparison, assuming either DOT 111s or CPC 1232 as the base case.

PHMSA assumed a 10 percent reduction in the costs of new tank car standards because of economies of scale, *i.e.*, the average (per unit) costs declines due to higher rates of production.[33] Nothing in the record justifies this speculative assumption. PHMSA has conducted no study of the relationship, if any, between economies of scale and pricing in the rail car market. Economies of scale may mean that the manufacturers' costs to produce tank cars might decline because so many are being produced. However, tank car manufacturers are under no legal obligation to pass along those costs savings in the form of reduced prices to shippers. Indeed, tank car manufacturers have been operating at capacity for several years, but prices have risen, not fallen. The only impact from economies of scale may be that manufacturers receive a higher profit on selling and leasing tank cars because it costs less to make them. In terms of the prices facing shippers such as AFPM members, demand will be driven up significantly due to the rulemaking, the largest rail tank car mandate in history. Further, demand is already at an all-time high, with an 18 to 24 month backlog of tank car orders. Unsurprisingly, prices are escalating steeply. In 2011, a large tank car used to ship crude or ethanol cost about $94,000, while today the same car costs between $139,000 and $149,000. That represents a price increase of 33% to 37% in the last three years. *See* Alltranstek Analysis, at 29.

In calculating the costs of the new tank car standard options, PHMSA also ignored the potential payload penalty due to heavier tank cars. AFPM members may have to offset the increased weight of the tank cars by shipping cars containing less crude or ethanol product. The net effect will be more tank cars on the rails, creating additional opportunities for exposure, human error and wear and tear on tracks. Shipping additional cars will also result in greater transportation costs, a factor that the cost-benefit analysis alludes to, but fails to analyze. *See* Draft RIA, at 81. PHMSA dismisses the impacts from significantly heavier tank cars because the agency "expects" its tank performance standard "to spur innovation in tank car design and construction." 79 Fed. Reg. 45,056; Draft RIA, at 86-87. In particular, PHMSA claims that

---

[32] *See* PHMSA, Draft Regulatory Impact Analysis, Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains; Notice of Proposed Rulemaking, at 77-80 (July 2014) ("Draft RIA").

[33] Draft RIA, at 110.

"[i]ndustry is currently evaluating new, tougher steels as well as composite materials and crash energy management systems intended to improve energy absorption with little or no weight penalty." 79 Fed. Reg. 45,056; Draft RIA, at 86-87.

Shippers in the rail transportation economy are aware of no such evaluation of new steel or composite materials. We are not aware of the AAR Tank Car Committee evaluating new steel or other materials that would ameliorate the significant weight penalty from the proposed tank car standards. Nor has RSI indicated that it is evaluating a new breakthrough material. Even if new steel or other composites were under consideration, the lead time for evaluating and approving the use of such materials in tank car construction would be several years. With an October 15, 2015 deadline for new tank car standards, PHMSA's aspirational hope for novel tank building materials appears to be unfounded. Accordingly, the agency needs to evaluate the costs of the payload penalty from heavier cars and include it in the cost-benefit analysis.

PHMSA also fails to consider that having more tank cars in use will affect the risk of a derailment. According to PHMSA, "the number of trains and derailment rate is relevant," and if more tank cars are on the rails, "DOT believes that railroads will optimize the unit train length which *may result in longer trains*." 79 Fed. Reg. at 45,036 (emphasis added). [34] This does not address whether PHMSA should have quantified the increased risk of derailments from transporting additional cars and the increased costs from a payload penalty. In any case, on the very next page of the Proposed Rule, PHMSA directly contradicts its own analysis and conclusions, stating: "[W]e *do not expect* more or *longer trains* being offered into transportation as a result of any tank car requirement options in the proposal." *Id.* at 45,057 (emphasis added).

Finally, PHMSA "believe[s] that the additional weight of the safety features will be accommodated by the increase in allowable GRL [gross rail load] and will not decrease the load limit (or innage) . . . . " 79 Fed. Reg. 45,057. However, increasing the allowable GRL is not a viable option for CPC-1232 cars. They are already at the maximum 286,000 pound GRL. Adding more safety features constructed of steel increases the tare weight of the tank car, resulting in a decrease in the volume of commodity that can be shipped. As previously mentioned, the current base tank car is the unjacketed CPC-1232 tank car. The capacity of the unjacketed version with 1/2" thick TC-128-B tank shell and half height head shields is 31,800 gallons. The capacity of the jacketed version with 7/16" thick TC-128-B tank shell and full height head shields is 29,000 gallons. Both of these tank cars are designed to run at 286,000 GRL. In other words, adding an additional 1/8" thickness to the tank shell of the jacketed version can only reduce the load limit of the tank car. For example, if we assume a crude oil tank car has a surface area of 1750 square feet, then the increased weight of the tank shell when going from 7/16" to 9/16" thick is just below 9,000 lbs. With crude oil at a density of 7lb/gallon, this equates to a payload decrease of 1275 gallons per tank car.

[34] PHMSA's statement about the possibility of longer trains ignores that there are train length limitations due to factors such as terrain, power required, and siding length.

### B. Top Fittings

AFPM supports top fittings protections in Option 3 for new tank cars, *i.e.*, top fittings that meet AAR Specifications for Tank Cars, appendix E, paragraph 10.2.1. PHMSA has not demonstrated the feasibility or cost-effectiveness of the proposal in Option 1 for a TIH-style fitting that would sustain a 9 mph rollover. As PHMSA acknowledged, TIH-rollover protection has *not* been tested on a 9/16" shell required for Option 1. *See* Railway Supply Institute Q&A – HM 251 NPRM (docketed Sept. 8, 2014). In its comments on the recent Transport Canada consultation on tank cars, RSI raised serious questions about the feasibility of TIH-rollover protection on 7/16" or 9/16" inch cars:

> It should also be noted that TIH rollover protection has only been applied to tanks having a thickness of at least 0.89 inches and is largely undeveloped and unproven in non-pressure tanks. These cars have thicker shells than non-pressure tanks and are clearly capable of supporting the additional weight of rollover protection. The application of this heavy rollover protection structure to 7/16 inch and 9/16 inch non-pressure tank cars will not only result in a loss of carrying capacity, but also will alter and could increase the stresses in other areas of the tank, potentially leading to unanticipated tank failure modes in both derailment and normal operational scenarios. Here too, research performed for FRA by Sharma and Associates indicates '[t]he structural connection of any add-on structure to the tank shell is a major limiting factor in the design of any system of protection.'

RSI, CTC Comments, at 8 (Sept. 1, 2014) (**Exhibit 16**). [35]

PHMSA ignores the costs of the top fitting required by Option 1. In the Draft RIA, PHMSA appears to assume no cost to this TIH-style top fitting in a new tank car, assigning no dollar value to it. *See* Draft RIA, at 82. According to RSI, however, this top fitting may increase the cost of a tank car by $4,500, nearly doubling PHMSA's estimated cost of $5,000 for an Option 1 car. *See* RSI, TC Comments, at 8 n.10.

### C. Braking Systems

AFPM supports the brake signal systems reflected in Option 3, distributed power ("DP") or two-way end-of-train ("EOT") brakes, rather than the electronically controlled pneumatic ("ECP") brake system required under Option 1. ECP brake systems simultaneously transmit a braking command to all cars in a train, which can result in the pneumatic brakes becoming engaged more quickly than conventional brakes. DP brake systems allow control of a number of locomotives dispersed throughout a train from a controlling locomotive in the lead position. The system provides control of the rearward locomotives by command signals originating at the lead locomotive and transmitted to the remote (rearward) locomotives. The two-way EOT device

---

[35] RSI's TC Comments quoted U.S. DOT, Federal Railroad Administration, "Survivability of Railroad Tank Car Top Fittings in Rollover Scenario Derailments," DOT/FRA/ORD-06/11 at 41 (Dec. 14, 2005) (analysis performed by Sharma & Associates, Inc.).

includes two pieces of equipment linked by radio that initiate an emergency brake application command from the front unit located in the controlling locomotive, which then activates the emergency air valve at the rear of the train within one second. As PHMSA acknowledges, "[a] two way EOT device is more effective than conventional brakes because the rear cars receive the brake command more quickly." 79 Fed. Reg. at 45,048.

Beginning in April 2014, railroads agreed to use either DP or EOT on trains with twenty or more loaded cars of crude oil on a main track. In contrast, prior ECP use has been limited, with only about 15 trains using the technology. *See* John Rimer, CSX Corporation, on behalf of the American Association of Railroads, "Braking Systems and Distributed Power," at 2, 4 (June 10, 2014), presented to the White House Office of Management and Budget [hereinafter "AAR Braking Presentation"].[36] RSI estimates that it will take several years to prove that ECP brakes are operationally effective, as FRA's prior tests of ECP proved inconclusive.

PHMSA proposed ECP for Option 1 based on computer modeling of derailments using the TEDS program, developed by Sharma & Associates. The simulations assessed whether the ECP and DP braking systems reduced the kinetic energy that leads to punctures of individual railcars during a derailment. Compared to conventional braking systems, the computer simulations showed that ECP reduced punctures by 36% and DCP reduced punctures by 18%. *See* 79 Fed. Reg. at 45,048–45,051.

These computer simulations are technically and procedurally flawed. None of the simulations examined Option 3, the 7/16" shell. In a memorandum explaining the simulations, PHMSA wrote that: "[D]ue to time constraints and the significant computing capacity and time for each simulation, only scenarios involving tank car construction with a 9/16" tank shell derailing at 40 mph were completed." PHMSA, Calculating Effectiveness Rates for Emergency Brake Signal Propagation Systems at 2 n.3 (docketed Aug. 25, 2014) ("Braking Memo"). The Braking Memo also states that "[a]dditional simulation [*sic*] will be performed in advance of the rule," but the regulated community will have no notice and opportunity to comment upon those simulations. Similarly, PHMSA never performed modeling simulations of EOT braking devices, a braking system authorized for Options 2 and 3. 79 Fed. Reg. at 45,048 ("Derailments involving trains equipped with two way EOT devices were not specifically simulated."). These circumstances suggest that PHMSA arbitrarily prejudged and selected Option 1, the 9/16" shell with ECP and channeled its analysis to that predetermined outcome.

Furthermore, PHMSA should have put in the docket at the time of the proposal all of the EOT braking simulations. It never did so. Instead, PHMSA placed the technical paper on the simulations in the docket on August 25, about halfway through the comment period. Without the simulations, the regulated community cannot replicate PHMSA's conclusions, perform sensitivity analyses of the modeling, and evaluate the performance and accuracy of the model. PHMSA's failure to provide the computer simulations and technical paper on a timely basis denies AFPM members notice and a fair opportunity to comment.

---

[36] The AAR Braking Presentation is available as "Handout 2" at http://www.reginfo.gov/public/do/viewEO12866Meeting?viewRule=false&rin=2137-AE91&meetingId=212&acronym=2137-DOT/PHMSA

In any case, the comparative safety benefit of ECP is minimal. ECP only mitigates incidents where the engineer has an advance opportunity to react. None of the derailments relied upon by PHMSA to justify the NPRM would have been prevented by ECP. *See* AAR Braking Presentation, at 2. After reviewing derailment simulations, the AAR T87.6 task force concluded that ECP provided only "marginal benefits" when compared to conventional braking systems. T86.7 Task Force Report, at 14.

Despite these marginal benefits, the costs of ECP are substantial. Unlike DP and EOT, ECP requires retrofitting *all* of the railcars and locomotives on a train. ECP costs $8,000 to $15,000 per car, and $20,000 to $25,000 per locomotive. Moreover, any car with ECP brakes would also need to have air brakes so it could operate in a manifest train that has other cars only equipped with air brakes. The ECP brakes provide no value for Class 3 flammable cars moving in manifest service. If PHMSA finalized the rule as proposed, ECP would cost $12 to $21 billion for the entire current U.S. fleet. *See* AAR Braking Presentation, at 2, 4.

### D. PHMSA's Cost Estimates

At AFPM's request, Alltranstek analyzed PHMSA's incremental cost estimates for the new tank car options. In the Draft RIA, PHMSA assumed that Options 1 and 2 would respectively cost $5,000 and $2,000 more than Option 3. *See id.* at 80, 103. PHMSA's pricing data and methodology does not appear in the docket, at least in a way that could be rigorously analyzed and replicated.

Alltranstek analyzed market conditions and builder quotes to formulate more reasonable estimates of the incremental costs of the new tank car options. Alltranstek took account of the fact that there are five builders of new tank cars, with backlogged orders stretching out 18 to 24 months. Some of these tank car manufacturers insist upon steel escalation clauses. Reflecting these market conditions, the price of tank cars used to ship crude or ethanol has gone up 33% to 37% since 2011. Based upon all of these factors, Alltranstek estimates that the typical cost difference between Option 1 and 3 is $19,000 while Option 2 costs about $9,000 more than Option 3. *See* Alltranstek Analysis, at 29. These cost estimates are reflected in the following Table from the Alltranstek Analysis.

| PHMSA NPRM Option # | Typical | Low | High | Description |
|---|---|---|---|---|
| Option 1 (same as TC 140) | $177,000 | $174,000 | $182,000 | • Top fittings – 9 mph rollover protection<br>• ECP brakes<br>• Plus Option 2 features |
| Option 2 | $167,000 | $165,000 | $172,000 | • 9/16” tank shell thickness<br>• Plus Option 3 features |
| Option 3 | $158,000 | $157,000 | $162,000 | • 7/16” tank shell thickness<br>• TC-128 Gr B normalized steel<br>• Thermal protection & 1/8" jacket<br>• Full height head shield & 286k Grl<br>• Top fittings protection<br>• Hi-flow pressure release valve PRV<br>• Modified BOV |

### E. Performance Standards as a Compliance Alternative

AFPM supports the “DOT 117P,” PHMSA’s proposed performance standard alternative for new tank cars manufactured after October 1, 2015. Under the proposal, a tank car meeting certain performance criteria would qualify as a DOT 117P, and therefore provide a compliance alternative for shipping crude and ethanol in an HHFT. These performance criteria consist of puncture resistance, thermal protection, and top fitting protection.

In general, performance standards, when used as a compliance alternative, may provide advantages over prescriptive standards. New tank car standards are difficult to promulgate. Future advances in manufacturing techniques and materials are difficult to predict. Performance standards allow manufacturers to capture future improvements in safety and productivity. It also conserves government resources because technological advancements are more easily translated into approved measures, enhancing safety and decreasing costs.

While AFPM generally supports performance standards in the NPRM, the performance criteria for Options 1 and 2 are more stringent than Option 3. For example, Options 1 and 2 tank cars must have a puncture resistance at a side impact speed up to 12 mph, while Option 3 requires puncture resistance for the same test up to 9 mph. *Compare* 79 Fed. Reg. at 45,077–08 (proposed Options 1 and 2, Sections 179.202-11 and 179.203-11), *with* 79 Fed. Reg. at 45,079 (proposed Option 3, Section 179.204-11). Consistent with its support of the Option 3 prescriptive DOT 117 standard, AFPM supports the Option 3 performance standard as a compliance alternative.

To be clear, AFPM supports a performance standard for new tank cars only as an alternative way to comply with the rule. PHMSA has not provided sufficient data, testing, and design information to require performance standards as the exclusive means of complying with tank car standards. Imposing a performance standard without sufficient technical justification would create substantial uncertainty and delay compliance.

## VII. RETROFITS OF EXISTING TANK CARS

PHMSA proposes to mandate the largest rail tank car retrofit in history. In conducting these retrofits, PHMSA should begin with tank cars that ship crude and ethanol in unit trains, the commodity shipments that prompted the rule. Risk prioritization requires policy decisions that reflect solid data and a hard look at safety benefits and costs before expanding retrofit requirements. AFPM's comments on this issue are intended to suggest ways that PHMSA could achieve the shared objective of promoting safety, while avoiding negative impacts such as tank car shortages and restrictions on rail capacity.

### A. The HHFT Proposal

The NPRM would require retrofitting existing tank cars that are used in HHFTs, *i.e.*, a single train carrying 20 or more carloads of a Class 3 flammable liquid by PHMSA's proposed definition. In the preamble to the Proposal, PHMSA presumed that "only crude oil and ethanol shipments would be affected by the limitations of this rule as they are the only known Class 3 (flammable liquid) materials transported in trains consisting of 20 cars or more." 79 Fed. Reg. 45,040.

PHMSA's fundamental assumption is mistaken. A practical result of the definition is that the HHFT would apply to most flammable liquids, not just crude oil and ethanol. Railroads are common carriers. A train of flammable liquids that may start out below the 20-car threshold for an HHFT could be gathered with other cars, triggering the HHFT threshold. This gathering of cars over the 20-car threshold happens frequently in the experience of AFPM's members who ship other class 3 materials. A variety of factors contribute to this circumstance. Railroads may hand off tank car shipments to one another. Even when a single railroad is involved, most facilities do not receive seven-day-a-week service. Pick-up service at facilities may only be Monday through Friday, creating a backlog of tank cars after the weekend. The same backlog can occur when main trains do not run seven days a week.

Shippers such as AFPM members cannot reasonably predict the other Class 3 flammable liquid freight that will be on the train when it arrives or that may be added further down the line. Making uninformed guesses is not a viable compliance option. As a result, the Proposal would compel many shippers to package all Class 3 flammable liquid materials for train transportation into new or modified cars meeting the HHFT standard or face severe operating restrictions (e.g., stringent speed limits). Thus, PHMSA would sweep into the rule all rail shipments of all Class 3 flammable liquids. Crude and ethanol cars in unit train service should be the focus of this rule, as PHMSA intended.

The administrative record does not support the incidental regulation of other flammable liquids. Crude and ethanol comprise approximately 65% of the rail shipments of flammable liquids. Draft RIA, at 13. Other flammable liquids do not typically move in unit trains at the same volumes.[37] In light of these circumstances, PHMSA's analysis of the costs and benefits of the rulemaking focused only on crude oil and ethanol.[38] To calculate the benefits of the tank car standards, PHMSA looked only at crude and ethanol derailments and the degree to which new and retrofitted cars would mitigate those incidents. *See, e.g.*, Effectiveness Rate Memo, at 4; Draft RIA, at 20-54. Similarly, PHMSA's calculations of the costs of the rulemaking assume that the new tank car standards and retrofit requirements will apply only to the crude and ethanol portions of the national flammable liquid fleet. *See, e.g*., Draft RIA, at 90. PHMSA omitted from its calculation the economic impact to about one-third of flammable liquid rail transportation.

Regulation of other flammable liquids would require a subsequent rulemaking to assess any risks associated with shipping flammable liquids via rail, and whether those risks justify the extreme measure of requiring retrofits. Mandating retrofits fosters uncertainty, and it deprives tank owners of their property rights and expected return on investment of a previously purchased, government approved asset.

As part of AFPM's members' commitment to safety, they respectfully suggest moving forward in addressing crude and ethanol in unit train service, while PHMSA undertakes a separate analysis focused on the benefits and costs of addressing other flammable liquids in a separate rulemaking proceeding, as necessary and appropriate. This bifurcation of the regulation would afford PHMSA an opportunity to assess the risks of the other flammable tank cars, and would not delay the retrofit of those cars, if justified, as retrofitting the subset of ethanol and crude tank cars will take at least 10 years, more than enough time for PHMSA to analyze the costs and benefits of an expanded retrofit requirement.

In addition to clarifying that the scope of the rulemaking applies only to crude oil and ethanol rail shipments, AFPM recommends replacing the HHFT definition with a "unit train" definition. Our proposed definition of unit train would tie retrofits to rail tank cars used in a single train with 75 or more cars shipping crude and/or ethanol. To implement our definition of unit train, AFPM recommends amending proposed § 171.8 as follows: ~~*High-hazard flammable train*~~ *Unit train* means a single train carrying ~~20~~ *75* or more carloads of *crude oil or ethanol.*~~a Class 3 flammable liquid.~~

---

[37] *See, e.g.*, Draft RIA at 2. ("The risk of flammability is compounded in the context of rail transportation because petroleum crude oil and ethanol are commonly shipped in large unit trains.").

[38] In response to PHMSA's request for comment on whether crude oil and ethanol pose differing risks when traveling in HHFTs, 79 Fed. Reg. 45,040, AFPM respectfully submits that nothing in the record distinguishes crude and ethanol unit train derailments from a safety perspective. On the contrary, FRA recently found that "denatured alcohol poses a similar, if not greater risk as (Bakken) crude oil when released from a tank car failing catastrophically and resulting in a large fireball type of fire with or without explosion." Karl Alexy, Office of Safety, FRA, Comparative Analysis of Documented Damage to Tank Cars Containing Denatured Alcohol or Crude Oil Exposed to Pool Fire Conditions: A White Paper, at 1 (Docketed Sept. 9, 2014) ("FRA Ethanol/Crude Analysis"). . Excluding ethanol from the final rule would therefore be arbitrary and capricious.

AFPM's definition of unit train would focus on those tank cars where PHMSA identifies the greatest risk to safety. The risk of a multi-car release increases in unit trains. Unit trains also have the highest turn rate, traveling far more miles than manifest trains. Moreover, AFPM's proposed definition is supported by a survey of its membership's use of unit trains to ship crude oil and ethanol. The survey showed that the smallest unit train in crude and ethanol service was 86 cars. [39] The 75-car threshold for qualification as a unit train should therefore capture all crude and ethanol in unit train service.

### B. Analysis of Retrofit Options

In the NPRM, PHMSA generally proposes the same requirements for new cars and existing cars, except that it is not requiring top fittings protection for retrofits. 79 Fed. Reg. at 45,059. Thus, PHMSA refers to the options for both new and existing DOT 117 cars as Options 1, 2, and 3. *Id.* at 45,060. AFPM supports Option 3 as the retrofit standard for unit trains of ethanol and crude, subject to certain clarifications and amendments.

#### 1. <u>AFPM Supports PHMA's Rejection of Top Fittings for Retrofits</u>

The proposed text of the Option 1 retrofit rule still contains the top fitting standard, namely the ability to withstand a 9 mph rollover, but AFPM assumes that was an oversight because of PHMSA's firm rejection of top fittings in the preamble to the NPRM and the Draft RIA. *See, e.g.*, 79 Fed. Reg. at 45,078 (proposed 49 C.F.R. § 179.202-11(f)). As PHMSA explained, "the costliness of such retrofit is not supported with a corresponding appropriate safety benefit." 79 Fed. Reg. at 45,058. PHMSA found that the top fitting retrofit cost $24,500, and the comparable effectiveness rates "are low." Id. At 45,058 n.63. [40]

Since the enactment of the Hazardous Materials Transportation Act ("HazMat Act" or "Act") in 1975, DOT has consistently interpreted its statutory authority under the Act as requiring it to weigh safety benefits and costs. For example, DOT conducted a cost-benefit analysis of pressure car standards in 1976, concluding that "the requirements set forth in this rule represent a cost-effective solution to the safety problems . . . ." 42 Fed. Reg. 46,306, 46,312 (1976).[41] "While not conclusive, it surely tends to show that . . . [DOT's] current practice is a reasonable and hence legitimate exercise of its discretion to weigh benefits against costs that the agency has been proceeding in essentially this fashion for over 30 years." *Entergy Corp. v. Riverkeeper*, 556 U.S. 208, 224 (2009). Another factor supporting DOT's consideration

---

[39] *See* AFPM Retrofit Survey, at 12. The average unit train crude and ethanol service was 94 cars and the largest was 102 cars. *See id.* The AFPM Survey is based on responses from 15 member companies. *Id.* at 3.

[40] Furthermore, as discussed above, the top fitting protection in Option 1 is not technically feasible and should be rejected on that ground as well.

[41] *See, also, e.g.*, 57 Fed. Reg. 17,141 (1992) ("This rulemaking solicits comments on the costs and safety benefits that would be derived should the Hazardous Materials Regulations be amended to improve the level of safety of tank cars..."); 58 Fed. Reg. 50,224, 50227 (1993) ("As stated in the NPRM, RSPA believes the overall costs associated with requiring placards for Class 9 materials outweigh the benefits of such requirements."); 68 Fed. Reg. 61,906 (2003) ("This final rule excludes consignee unloading of rail cars from regulation under the HMR, thereby reducing the costs of compliance with the HMR for rail tank car unloading facilities . . .").

of costs is that Congress amended the Act in 1990 and 1994, but declined to disturb the DOT's longstanding practice of considering cost. *United States v. Bergh*, 352 U.S. 40, 46-47 (1956) ("This contemporaneous interpretation of the 1938 Resolution by the agency charged with its supervision—an interpretation followed by all agencies of the Government—together with acquiescence of the Congress, must be given great weight.").

2. Performance Standard for Retrofits as a Compliance Option

Option 3 for retrofits should be structured to provide the choice of complying with *either* a DOT 117 specification standard or the DOT 117P performance standard. The new tank car standards clearly provide that option. The retrofit standard, however, is ambiguous on whether shippers must comply exclusively with either a performance or specification standard. [42] Relying solely on a performance standard for retrofits would create substantial uncertainty and delay retrofits. Performance standards require testing and modeling of the proposed design, typically performed by third-party engineering firms. In addition to AAR's role, FRA must then approve the design after reviewing the testing and modeling.[43] The cost and lag time for that process could exacerbate tank car shortages. These factors do not appear to have been considered in the rulemaking. To avoid these unintended consequences, the final rule should make clear that companies may comply with the specification standard *or* the performance standard.

3. Scope of the Option 3 Retrofit

Option 3 for retrofits is the same "enhanced CPC-1232" required for new cars, but with important differences. In addition to rejecting top fittings for retrofits, PHMSA made clear that retrofitted tank cars "may continue to rely on the equipment installed at the time of manufacture." 79 Fed. Reg. at 45,058. For example, PHMSA confirmed with RSI during the rulemaking that TC-128 normalized steel would not be required as part of the Option 3 retrofit, a position that AFPM supports. *See* Railway Supply Institute Q&A – HM251 NPRM (docketed Sept. 3, 2014) ("Q21. Will non-normalized steel be allowed on existing cars? A21. Yes.").

As applied to retrofits, AFPM understands that Option 3 would require 7/16" shell tank cars achieved with a jacket retrofit, plus BV, PRV, head shields, and a thermal protection system. *See, e.g.*, RIA, at 97. AFPM's position is that the thermal protection system need not necessarily be a thermal blanket as long as the existing and/or retrofitted equipment (*e.g.*, valves, insulation, *etc.*) allows the car to survive a 100-minute pool fire. As a practical matter, Jacketed CPC-1232s will only require enhanced BOVs and PRVs to comply with Option 3 (when those BOVs

---

[42] *Compare* 79 Fed. Reg. at 45,058 ("PHMSA proposes to also require existing cars to meet the same DOT Specification 117P performance standard as these new cars, except the requirement to include top fittings protection") (emphasis added), *with id.* at 45,061 ("As proposed in this NPRM, DOT Specification 111 tank cars may be retrofitted to DOT Specification 117, retired, repurposed, or operated under speed restrictions.") (emphasis added). PHMSA's cost-benefit analysis examined only the specification standard for Option 1 through 3; it did not analyze DOT 117Ps for existing cars. *See* Draft RIA, at 91, 97, 103. To the extent that PHMA wishes to force companies to comply solely with a performance standard, it would need to perform a new cost-benefit analysis.

[43] *See* Proposed 49 C.F.R. §§ 179.202-11, 179.203-11, 179.204.-11, at 79 Fed. Reg. at 45,077-79.

and PRVs are market ready). [44] Unjacketed CPC 1232s with 8/16" shell should not require any retrofitting, other than enhanced BOVs and PRVs. Adding jackets to those 1232s would make little sense in light of their existing shells.

In reviewing the retrofit options, it is important to keep in mind that these comments set forth realistic retrofit cost calculations that differ from those provided in PHMSA's cost-benefit analysis, as discussed below in Section VII.D and the Alltranstek Analysis. AFPM believes that each of the Option 3 retrofit requirements requires more careful consideration than provided in the NPRM, Draft RIA and other information that PHMSA provided in the docket.

### 4. PHMSA's Analysis Supports the Option 3 Retrofit

Option 3 provides the most reasonable and cost-effective improvement in tank car standards among the three options proposed for public comment. As AFPM has argued throughout these comments, PHMSA's cost benefit analysis is deeply flawed and should be re-considered. Yet even PHMSA's analysis showed that Option 3 provided a significant increase in effectiveness rate, while costing substantially less.

As discussed earlier, PHMSA defines effectiveness rate as the volume of lading lost in a derailment. *See* Effectiveness Rate Memo, at 1 n.1. For new tank car standards, PHMSA calculated the effectiveness rate by comparing the standards to unjacketed DOT 111s. The retrofit effectiveness calculations also compared the tank car standards to jacketed DOT-111s, unjacketed CPC-1232s and jacketed CPC-1232s. *See* Draft RIA, at 116-17. Even the agency's skewed analysis showed that Option 3 provided a 40% to 18% improvement in the effectiveness rate compared to unjacketed DOT-111s and unjacketed CPC-1232s, respectively. *See* Draft RIA, at 120, 126-27. PHMSA estimates that Option 3 would cost $2.04 billion, $1 billion less than Option 1 and about $500 million less than Option 2. *See* Draft RIA, at 95, 102, 109. AFPM believes that PHMSA significantly understates the costs of the options, making it likely that the cost spread between the options is even greater.

While PHMSA's own analysis, despite its flaws, indicates that Option 3 provides a more cost-effective option, AFPM questions whether the cost-benefit analysis supporting the NPRM provides an adequate understanding of the benefits of improved effectiveness given a more accurate calculation of the costs of retrofit. AFPM hired Alltranstech to provide technical comments on the NPRM. *See* Alltranstek Analysis at 28. One of the tasks Alltranstek performed was a more detailed confirmation of retrofit costs to existing tank cars based upon data obtained from prior retrofit and repair activities as well as tank maintenance shop surveys. *See id.* While PHMSA's NPRM estimated the cost of Option 3 retrofits to be about $27,000, Alltranstek's estimates range from $42,700 to $86,900 per car depending on the tank car category. *See id.* Comparing PHMSA's calculations of the value of the retrofits to the prevention of projected high consequence and catastrophic events to these more accurate retrofit

[44] PHMSA assumes that an unjacketed DOT 111 would require a full jacket retrofit with half height head shields, while an unjacketed CPC 1232 would require a full jacket, as it already has a half-height head shield. *See id.*

cost estimates prepared by Alltranstek, requires PHMSA to reassess the cost-`benefit calculation of each of the Option 3 retrofit modifications to demonstrate their individual and combined benefits. Only with this careful reexamination can the most effective use of resources be put to the task of truly providing the improved safety benefit that both AFPM and PHMSA wish to achieve.

### C. The Retrofit Schedule

PHMSA proposes a schedule to retrofit tank cars used in HHFTs based on the packing group of the commodity transported, with cars transporting Packing Group I ("PG") cars retrofitted by October 2017, PGII cars by October 2019 and PGIII cars by October 2020. *See* 79 Fed. Reg. 45,076. PHMSA proposes to apply the same tank car standards to new and retrofitted cars. Therefore, the agency requests comment on the same Option 1, 2 and 3 alternatives for tank car specifications, except that the agency will not require additional top fitting protection for retrofits due to the costs exceeding the benefits. *Id.* at 79 Fed. Reg. 45,059.

#### 1. Prioritize Retrofits Based on Crude and Ethanol Unit Train Service

AFPM recommends initially focusing on retrofits used in crude and ethanol service in unit trains. It would allow PHMSA to begin with the crude and ethanol fleets that the rule is intended to address.

In contrast, prioritizing retrofits based on PG is inappropriate and disconnected from the purpose of this rulemaking. While PG distinctions may make sense in prioritizing risks from non-bulk shipping containers, taking that approach is illogical when dealing with bulk transport via rail. Regardless of the PG, the risk associated with a train derailment of crude or ethanol risks loss of a large volume of flammable liquid, a fire, and other consequences. Whether a product is PGI, PGII or PGIII makes little difference to the risks posed by the consequences of a breach during a crude oil or ethanol derailment. That common-sense observation was recently confirmed by an FRA study of the consequences of ethanol and crude oil derailments. *See* FRA Ethanol/Crude Analysis. After noting that "[d]enatured alcohol is a packing group II material … and [c]rude oil from the Bakken shale play is typically a packing group I material," FRA's study concluded:

> There is little evidence supporting the position that crude oil (especially the extracted crude from the Bakken region) poses a heightened risk of a high energy or explosive event when tank cars containing the material are exposed to pool fire conditions. In fact, the failure rate (due to thermal damage) of tank cars containing denatured alcohol is 1.5x greater than that of a tank car transporting crude oil.

*Id.* at 8.

PHMSA should initially focus the retrofit schedule on crude and ethanol cars in unit train service. It would allow the improved prioritization of limited retrofit shop capacity. As this rulemaking illustrates, retrofits also disrupt the tank shop industry, creating long delays and the inability to meet customer needs for ongoing maintenance of rail car fleets as they reach requalification deadlines.

### 2. PHMSA Should Set a 10-Year Retrofit Schedule

PHMSA assumes the size of the fleet to be retrofitted is 66,185 cars, broken down between 43,805 unjacketed DOT-111s and 22,380 unjacketed CPC-1232s. PHMSA further assumes that these tank cars can be retrofitted in three years. That would work out to an average of 22,062 tank retrofitted per year. *See* Draft RIA, at 89, 98-99, 105-06.

PHMSA's retrofit schedule is infeasible. The agency claims that its schedule is based on discussions with tank car manufacturers. But RSI, which represents 70% of the tank car market, recently increased its estimate of annual shop capacity to 6,400 tank cars per year, a number that is less than thirty percent of PHMSA's estimated shop capacity necessary to meet its proposed three-year retrofit schedule. Significantly, the RSI estimate of 6,400 cars per year requires a ramp up period. Current capacity is only 2,430 tank cars per year, suggesting that it will take several years to grow to RSI's projected capacity. See Alltranstek Analysis, at 19–20.

PHMSA's retrofit schedule ignores a number of real world factors that impact shop capacity. The industry's capacity to repair rail cars today is relatively the same as it was ten years ago when the fleet was 20% smaller and the regulatory environment less volatile. Shop capacity is extremely tight. In fact, many tank car repair shops have become "booked-out" for the next 2-3 years. Furthermore, a heavy requalification wave will start in 2015 as a result of the large number of tank cars built for ethanol service in 2005-2007, exacerbating the tank car repair shop shortage considerably over the next several years. Tank car cleaning and coating/lining capacity is currently constrained and is a critical pressure point in the tank car repair supply chain. See Alltranstek Analysis, at 16.

At AFPM's request, Alltranstek prepared an estimate of the size of the potential fleet of existing crude and ethanol tank cars subject to the proposed retrofit options. As of May 1, 2014, Alltranstek estimated that there are about 94,000 crude and ethanol tank cars. *See* Alltranstek Analysis, at 21. The breakdown of this fleet is provided below in Table 1. In analyzing retrofit issues, RSI estimated that approximately 28% of the existing fleet would be scrapped under the Proposal. This scrappage estimate is based on the age of the existing fleet and the feasibility of retrofitting these tank cars to meet the Option 3 retrofit specifications. Applying that 28% scrappage rate to 94,000 cars yields 68,000 crude and ethanol tank cars to be retrofitted, a slightly higher number than PHMSA's estimate of about 66,000 tank cars.

Table 1: Existing Fleet

| | Tank car category | Option 3 | Option 2 | Inventory 5/1/2014 | % of Total | Assumptions |
|---|---|---|---|---|---|---|
| 1 | CPC-1232 Bare tank car - 286k GRL | $45,900 | $56,900 | 16,106 | 17% | |
| 2 | CPC-1232 jacketed tank car | $2,700 | $35,700 | 7,696 | 8% | Assume that car can exist with current insulation - 286k GRL |
| 3 | DOT pre-CPC-1232 bare tank car | $68,400 | $79,400 | 55,485 | 59% | Assume that PHMSA will accept A-516-70 tank material - 263k GRL |
| 4 | DOT pre-CPC-1232 jacketed tank car | $42,700 | $75,700 | 3,355 | 4% | Assume that PHMSA will accept A-516-70 tank and insulation - 263k GRL |
| 5 | DOT pre-1996 bare tank car | $86,900 | $97,900 | 11,617 | 12% | Assume that PHMSA will accept A-516-70 tank material - 263k GRL |
| 6 | DOT pre-1996 jacketed tank car | $61,200 | $94,200 | | | Assume that PHMSA will accept A-516-70 tank and insulation - 263k GRL |
| | Total | | | 94,259 | 100% | |

*Source*: Alltranstek Analysis at 28

Alltranstek also prepared an analysis of annual shop capacity to perform retrofits. Alltranstek conducted a survey of about 74% of the tank car repair market. Based on the survey, Alltranstek concluded that 54 shops can perform the types of major retrofits required by the NPRM (*e.g.*, jackets, head shields, *etc.*). *See* Alltranstek Analysis, at 15, 17-18. Alltranstek then looked at two retrofit capacity scenarios, a "base case" and an "investment case." Both scenarios account for "on the ground" facts such as capacity currently under contract through 2015, upcoming requalification demand and average retrofit turn-around times. The principle difference between the two scenarios is that the investment case assumes 30% growth in the number of shops entering the retrofit market over the first four years of the retrofit schedule. *See id.* at 19-20.

The results of Alltranstek's analysis of shop capacity show that a three-year schedule would impose severe capacity restrictions on crude and ethanol rail service. Annual retrofit capacity for both the base case and investment case are shown below in Figures 6 and 7. *See* Alltranstek Analysis, at 19-20. Alltranstek estimated that about 10,000 cars could be retrofitted by year three in the investment case, while the base case could result in retrofitting about 8,500 cars. These numbers are nowhere near the 68,000 cars that AFPM estimates would have to be retrofitted within the same time period. As a result, over 50,000 tank cars would be forced off the rails.

Figure 6: Alltranstek Base Case Results for Retrofit Shop Capacity.

| **Estimated shop capacity for next four years** ***Base Case*** | Year 1 | Year 2 | Year 3 | Year 4 | Total |
|---|---|---|---|---|---|
| Number of retrofit capable shops | 54 | 56 | 58 | 60 | |
| (x) Avg annual retrofit production per shop | 45 | 45 | 47 | 49 | |
| (=) Estimated number of annual retrofits | 2,430 | 2,520 | 2,726 | 2,940 | |
| (+) Respondent currently planned capacity | 0 | 363 | 363 | 363 | |
| (=) Total number of potential annual retrofits | 2,430 | 2,883 | 3,089 | 3,303 | **11,705** |
| | | | | | |
| Growth in shops providing service | | 2 | 2 | 2 | |
| *Growth in production efficiency* | | *0.0%* | *5.0%* | *5.0%* | |

Figure 7: Alltranstek Investment Case for Retrofit Shop Capacity

| **Estimated shop capacity for next five years** **Investment Case** | Year 1 | Year 2 | Year 3 | Year 4 | Total |
|---|---|---|---|---|---|
| Number of retrofit capable shops | 54 | 59 | 69 | 79 | |
| (x) average annual retrofit production per shop | 45 | 50 | 58 | 70 | |
| (=) estimated number of annual retrofits | 2,430 | 2,950 | 4,002 | 5,530 | |
| (+) Respondent currently planned capacity | 0 | 363 | 363 | 363 | |
| (=) Total number of potential annual retrofits | 2,430 | 3,313 | 4,365 | 5,893 | **16,001** |
| | | | | | |
| Growth in shops providing service | | 5 | 10 | 10 | |
| *Growth in production efficiency* | | *10.0%* | *15.0%* | *20.0%* | |

Adopting PHMSA's three-year phase-in would restrict crude and ethanol rail capacity and damage the economy. RSI has estimated that withdrawing 31,000 tank cars from service would be equivalent to reducing the capacity of the crude and ethanol fleet by 20% to 25%, a huge loss at a time of growing domestic crude production in our nation. *See* RSI TC Comments, at 11. Indeed, AFPM Members face the possibility of paying damages on contracts that involve "take or pay" commitments, another cost PHMSA ignored in the rulemaking.[45] PHMSA's schedule would also impact domestic energy production. Shortages of tank cars could result in disrupting the gasoline supply if insufficient supplies of ethanol are available for blending operations. Crude deliveries to refiners could also be constricted as 70% of Bakken crude is shipped by rail.

Setting a tight three-year retrofit period poses particular risks because the retrofit data provided by tank car manufacturers has been changing frequently. For example, the RSI estimates of the retrofit fleet have changed substantially over the last eight months by as much as 20,000 cars. The enhanced PRVs and BOVs are still going through testing and trials, with the Tank Car Committee considering the flow rates for the PRVs. Imposing a 36 month retrofit period heightens the uncertainty and risk created by highly dynamic data.

Instead of a three-year retrofit schedule, AFPM recommends a ten-year schedule. Using the more optimistic "investment case," Alltranstek estimates that about 16,000 tank cars will have been retrofitted by year four of the schedule. That would leave approximately 52,000 tank cars to retrofit. The investment case projects that, by year four, tank car shops will have built up a capacity to perform about 5,900 retrofits per year. Similarly, RSI estimates that, after a period of ramp up, annual shop capacity will reach 6,400 retrofits per year. At 6,400 retrofits a year, the retrofit schedule would extend another eight years, making it 12 years total. However, AFPM believes that additional efficiencies and shop capacity may build up over time to allow the investment necessary to complete retrofits within 10 years. That schedule also accords with the ten year requalification period that tank cars must all undergo.

A ten-year retrofit schedule would be consistent with past precedent. In 1995, the Research and Special Programs Administration ("RSPA"), the predecessor agency to PHMSA, issued a rule requiring the retrofit of tank cars used to ship certain high hazardous materials, including those that are poisonous-by-inhalation, such as chlorine. 60 Fed. 49,048 (1995). In the rule, RSPA determined that a ten year schedule for the retrofit of the existing fleet was appropriate. *Id.* at 49,058, 49,073-74.

In setting a ten-year schedule, it is important that PHMSA prioritize retrofits to further the objectives of the rule. Otherwise, retrofitting will be done purely on a commercial basis without regard to the issues PHMSA seeks to address. Accordingly, AFPM proposes the following retrofit schedule to be accomplished within ten years:

- DOT-111 unjacketed cars December 2020.
- CPC-1232 unjacketed cars by March 2024.

DOT-111 jacketed cars by March 2025.

---

[45] In general, a "take or pay" commitment is a contractual obligation to pay for a certain amount of crude oil, regardless of whether the buyer can ship the oil.

Once PHMSA sets a realistic retrofit schedule, PHMSA should commit to have an independent reassessment of the schedule at the mid-point of implementation.[46] The NPRM envisions an unparalleled retrofit mandate, one that is likely infeasible in light of retrofit capacity at tank car shops. To avoid disruptions in rail service of crude, ethanol, and potentially other commodities, the Department of Energy—or another agency independent of DOT—should evaluate the implementation of the retrofit schedule at its midway point to ensure that shippers will still have access to the fleet necessary to move commodities. [47] This midway check can be accomplished by reviewing the Umler database or R-1 filings with AAR to see whether retrofits appear to be on a path toward achieving the schedule.

### D. PHMSA'S Draft Cost-Benefit Analysis

AFPM requests that PHMSA issue a notice of data availability ("NODA") with a new, supplemental cost-benefit analysis that addresses the numerous deficiencies in the agency's current analysis. [48] PHMSA's draft cost-benefit analysis of the tank car retrofit options is riddled with errors. It omits key calculations and assumptions, leaving the regulated community to guess at how the agency arrived at certain values used to justify this multi-billion dollar retrofit mandate. What PHMSA does include in the cost-benefit analysis appears to be inaccurate, unreliable and little more than guess-work, with inadequate studies, testing, and real-world data. The cumulative effect of PHMSA's errors is to substantially understate the costs of the Proposal. Indeed, the flaws in the cost-benefit analysis all appear to lower the costs of Option 1, suggesting that PHMSA arbitrarily selected that option before going through the rulemaking process.

AFPM's ability to meaningfully participate in the rulemaking process is substantially prejudiced by the agency's failure to prepare a complete analysis. Even if the agency fully accepted AFPM's comments, the resulting cost-benefit analysis would be so fundamentally different that we would have no opportunity to comment fairly and effectively on the agency's "re-do." Accordingly, we respectfully request that PHMSA issue a NODA that provides notice and an opportunity to comment upon the revised cost-benefit analysis before the rule becomes final. To the extent that PHMSA declines this opportunity to provide sufficient notice, its final rule would be unreasonable and arbitrary.

---

[46] Even before the mid-point of a reasonable retrofit schedule, PHMSA may need to adjust the schedule for particular equipment that remains unproven. In particular, the timeline for the enhanced pressure relief valve and bottom outlet handle continues to slip. As of the writing of these comments, tank car manufacturers continue to work on the flow rate for the pressure relief valves. The design and proving of the bottom outlet handles is ongoing. The retrofitting of tank cars should only begin when the equipment is market ready, including retrofitting jacketed CPC-1232s with the enhanced pressure relief valves and bottom outlet handles. To the extent that these retrofits are not fully designed, tested and proven by the retrofit deadline, PHMSA should adjust the deadline to the next tank car qualification or other major shop event to allow the technology to mature before retrofit.

[47] AFPM opposes having an AAR or RSI committee or working group oversee or determine any adjustment to the retrofit schedule. Railroads and tank car manufacturers work cooperatively with shippers on several issues, but it is still the case that AAR and RSI speak for their own members and interests. Shippers deserve an independent assessment, not one overseen by their commercial counterparties.

[48] While the bulk of our criticisms of PHMSA's cost benefit analysis appear in this section on retrofits, the criticisms apply more broadly to the entire rule and should not be construed as merely critiquing the retrofit obligations.

1. Lack of Effectiveness Rate Data and Calculations for Retrofit Options

The benefits of the tank car options all flow from the relative effectiveness rates of the options compared to various existing tank cars. For new tank car standards, the effectiveness rate is a comparison of the options to an unjacketed DOT-111. *See* Effectiveness Rate Memo. While the Draft RIA does not provide the effectiveness rate calculations for retrofit tank standards, it describes those calculations as comparing the retrofit options to unjacketed DOT-111s, as well as jacketed DOT-111s and jacketed and unjacketed CPC-1232s. *See* Draft RIA, at 116-17. According to PHMSA's description of the calculation, the effectiveness rate analyzes, on a percentage basis, how much better each of the tank car options performs than existing tank cars in a derailment situation. The relative improvement in effectiveness rate is measured by how much lading will be lost or retained in derailments at various speeds. To calculate that effectiveness rate number, PHMSA uses variables such as the puncture rate velocity of tank cars, the predicted number of cars punctured in derailments, and other factors.

None of the calculations used to derive the effectiveness rates for the retrofit tank car options appear in the administrative record, denying AFPM members notice and a fair opportunity to comment. In the August 1 NPRM, PHMSA wrote in the section on new tank car standards that it "will place into the docket for this rulemaking a more detailed technical supplement that describes the baseline accidents, model inputs, and assumptions that were used to develop the effectiveness rates for each tank car option." 79 Fed. Reg. at 45,053. As to existing tank car retrofit options, PHMSA described its effectiveness rate methodology as "[s]imilar to the methodology for estimating the effectiveness of new tank cars …" *Id.* at 45,060. About halfway into the public comment period, on August 25, PHMSA placed into the docket a short memo entitled "Calculating Effectiveness Rates of Tank Car Options," (the "Effectiveness Rate Memo") which calculated the effectiveness rate for only one of the new tank car options, Option 1. [49]

Providing only the effectiveness rate calculation for Option 1, new tank car standards fail to inform the regulated community of the basis for the effectiveness rate calculations for retrofits. New tank car standard effectiveness rates are a comparison to one tank car, unjacketed DOTs-111s. The retrofit effectiveness rates are calculated differently, according to PHMSA's descriptions of them. As noted, the Draft RIA retrofit rates compare Options 1-3 to four different tank car configurations, jacketed and unjacketed DOT-111s and CPC-1232s. Draft RIA, at 116-17. In other words, there are twelve separate calculations needed to compute retrofit effectiveness rates. All PHMSA provided, however, was a table of the results of the twelve calculations in the RIA, with no supporting documentation. *See* Draft RIA, at 116-17, 120, 126-27. None of the underlying values and assumptions were disclosed for these twelve calculations.

[49] The untimely and incomplete provision of PHMSA's effectiveness rate calculations denies AFPM members fair notice and an opportunity to comment on the calculations. The calculations should have been provided with the NPRM, not slipped into the record halfway through the comment period. Nor is it proper for PHMSA to only show its work for the effectiveness rate calculations for Option 1 new tank car standards. The entire set of calculations, assumptions and methodology for *all* effectiveness rate calculations for all new and retrofit options should have been disclosed, particularly in a rulemaking that imposes billions of dollars in costs.

Fair notice and transparency require the disclosure of the data, calculations, methodology and assumptions underlying this multi-billion dollar rule.

2. PHMSA's Risk Analysis is Inaccurate and Unreliable

PHMSA quantified the benefit of the Proposal by applying the effectiveness rates of tank car standards and other measures to the economic impacts of future derailments. To predict future derailments, PHMSA prepared a risk analysis of derailments from 2015 to 2034. *See* Draft RIA, at 20-54, 178-93.

At the outset, the risk analysis ignores whether preventing derailments and other accidents would produce greater benefits than mitigation. Excluding these prevention alternatives *a priori* violates the central teaching of the Rand Corporation paper ("Rand Paper") upon which PHMSA bases its risk assessment, namely that agencies should engage in a thorough "assessment of the cost effectiveness of *alternative risk-reduction opportunities*."[50]

PHMSA's risk assessment breaks from standard risk assessment practices. In preparing its assessment, PHMSA borrows from the Rand Paper and the Department of Homeland Security ("DHS") a formula used to assess terrorism risks: Risk (R) = Threat (T) x Vulnerability (V) x Consequence (C). *See* Draft RIA at 20. In 2010, the National Academies of Science conducted a review of that risk formula, concluding that: "While the basic structure of the R = f(T,V,C) framework is sound . . . [the] variables, indicators, and measures employed in calculating T, V, and C can be *crude, simplistic, and misleading*" due to the uncertainties of predicting future risks. [51] As a result, the National Academies recommended that a risk assessment undergo a quantitative assessment of uncertainty, external peer review and other standard reliability checks, all of which PHMSA ignored here.[52] Instead, PHMSA simply projected a linear increase in the rate of derailments, even though the actual rate of derailments declined by 40% from 2004 to 2012. *See* Draft RIA, at 23, Figure B.2.

PHMSA's linear projection of an increase in the crude and ethanol derailment rate is illusory. It is built on a series of inconsistent and illogical assumptions, which can only be explained as cherry picking data to reach the desired result. In calculating the effectiveness rates of tank car standards, PHMSA relied only on crude and ethanol derailments. *See* Effectiveness Rate Memo, at 4, Table 2 (listing 11 crude and ethanol derailments). PHMSA was also able to identify 40 crude and ethanol derailments that it reviewed to determine the amount of lading lost per derailment. *See* Draft RIA at 40-41. Yet, in predicting whether the derailment rate would increase for purposes of the risk assessment, PHMSA used derailments resulting in the release of "any quantity of hazardous material," Draft RIA, at 22, concluding that "it is impossible to isolate the derailment rate of only crude oil and ethanol trains." *Id.* at 21. PHMSA's derailment

---

[50] Henry H. Willis et al., Rand Corporation, "Estimating Terrorism Risk" (Kindle Location 77) ("Rand Paper") (Kindle Edition) (cited in Draft RIA, at 20) (emphasis added).

[51] National Academies of Science, National Research Council, Committee to Review the Department of Homeland Security's Approach to Risk Analysis, "Review of the Department of Homeland Security's Approach to Risk Analysis" at 96 (2010) ("NAS Risk Report") (emphasis added) (excerpts at **Exhibit 17**).

[52] See NAS Risk Report, at 48, 56, 96-97, 112.

also includes all mainline *and yard derailments* of hazardous materials *Id.* at 22-23. PHMSA admitted that it included yard derailments because using only mainline derailments would show a declining rate of derailments, reaching near zero in 2026. *Id.* at 26. Mixing together mainline and yard derailments to inflate the derailment rate ignores mainline and yard track "are used for different operational functions and consequently have different associated accident types, causes, and consequences." Liu et al. 2012, at 155. Most important, none of the derailments relied upon by PHMSA to justify this rule occurred in rail yards, where typically trains are stationary or moving more slowly during loading/unloading, sorting and other operations off the mainline tracks. *See* Effectiveness Rate Memo at 4, Table 2 (listing derailments relied upon in the rule). While PHMSA used rail yard derailments to calculate the derailment rate, it then turned around and excluded rail yard incidents when calculating the amount of product lost per derailment because "derailments that occurred in rail yards … are not the focus of the NPRM." *See* Draft RIA, at 25.

### 3. Assumed Transfer to Alberta Oil Sands Service

In calculating the cost of the Proposal, PHMSA makes the "key assumption" that a significant portion of the national crude oil fleet—23,237 tank cars—would be "transferred" to Canada to ship Alberta "tar sands," *i.e.*, oil sands. According to PHMSA, the 23,237 "re-purposed" tank cars would consist of 7,787 unjacketed DOT-111s, 5,600 jacketed DOT-111s, and 9,850 CPC 1232s built before 2015. *See* Draft RIA, at 81-2.

PHMSA's pejorative reference to "tar sands" raises questions about its neutrality and the purpose of this rulemaking. The Congressional Research Service has found that most executive branch agencies use the term "oil sands." "Tar sands," on the other hand, is a loaded phrase used by activists opposed to crude production. *See* CRS Report, at 1 n.1.

Perhaps reflecting its lack of objectivity, PHMSA's assumption about the transfer of tank cars to oil sands service is pure conjecture. PHMSA provides no analysis indicating demand in the Canadian oil sands market for the 23,237 tank cars. Nor is AFPM aware of any study or survey of the Canadian oil sands market indicating that this "re-purposed" fleet would be needed in the next two to three years.

PHMSA also fails to define "tar sands," leaving the regulated community in the dark about whether the agency is referring to bitumen, synthetic bitumen ("synbit"), diluted bitumen ("dilbit"), or another Canadian crude or blend of crude and lights. Second, we do not understand the basis for PHMSA's categorical statement that oil sands "has a high flashpoint and is generally classified as a combustible liquid …" Draft RIA, at 81. To be sure, Canadian crude may qualify as a combustible liquid, but it is also possible that a Canadian crude could be classified as a flammable liquid. Dangerous goods regulations require offerors to have a reasonable basis for classification. It is doubtful that PHMSA's musings in a proposal on how oil sands might be classified in Canada would provide sufficient certainty to allow shippers to simply assume (without analysis) that shipments of Canadian crude qualify as combustible, rather than flammable, liquids. Without any binding commitment from Canada on classification of oil sands, PHMSA's speculation on the issue is meaningless.

PHMSA admits that repurposing cars to oil sands service would require retrofits with jackets and thermal insulation. Draft RIA, at 81. However, PHMSA ignores that oil sands may also require retrofitting with coils and insulation due to the need for heating during unloading. That would further add to the costs of the rule and consume shop capacity, factors that PHMSA did not consider in fashioning its infeasible retrofit schedule. According to an analysis from Alltranstek, retrofitting with coils and heaters would cost about $18,000. If a jacket was also required, the total cost to "re-purpose" an unjacketed car would be about $40,000 per car.[53]

PHMSA's speculation about "re-purposing" 23,237 tank cars appears intended to exclude the cost of scrapping these cars. While the precise cost of scrapping these cars would depend on their age, AFPM estimates that the cost could range from $975 million to $1.3 billion. *See* Alltranstek Analysis at 21. Because PHMSA has no reasonable basis for concluding that the 23,237 cars would be deployed in Canada, the agency needs to include the costs of those cars in the rule.

4. <u>Significant Underestimates of Costs</u>

In evaluating retrofit options, PHMSA substantially underestimated the retrofit costs. See Draft RIA, at 84-85, 97, 103-04. AFPM requested that Alltranstek evaluate retrofit costs based on market information and other data. The table below compares the PHMSA and Alltranstek price estimates. As the table below shows, Alltranstek's cost estimates are significantly higher, and in some cases more than double what PHMSA estimated. See Alltranstek Analysis, at 28.

Table 2: Comparison of PHMSA and Alltranstek Retrofit Cost Options

| **Base Car** | **Option 1** | **Option 2** | **Option 3** |
|---|---|---|---|
| PHMSA: Unjacketed DOT 111 | $33,390 | $28,890 | $26,730 |
| Alltranstek: Unjacketed DOT 111 | $87,400 | $79,400 | $68,400 |
| PHMSA: Unjacketed CPC 1232 | $32,850 | $28,350 | $26,190 |
| Alltranstek: Unjacketed CPC 1232 | $64,900 | $56,900 | $45,900 |

[53] Thermal protection is different than insulation; a car suitable to operate in Canadian heavy oil sands crude service may require both. Thermal protection protects the tank and the lading from heat from a fire. Insulation is used to keep a lading warm to allow it to be unloaded easily. Canadian oil sands requires heater coils and insulation to allow the lading to be heated so it can be unloaded. These cars would require heater coils to be added, plus insulation and a jacket. Heater coils and insulation would be about $18,000 and RSI's cost for a jacket is $22,000. So the total cost to "repurpose" a car (i.e. a non-coiled, non-insulated and un-jacketed car) for oil sands would be about $40,000. This does not include thermal protection, head shields, and valve modifications, which would not be required for tank cars in oil sands service, providing the oil sands could be properly shipped in both Canada and the U.S. as a combustible liquid.

### 5. Opportunity Costs of Retrofits

PHMSA substantially underestimates the opportunity costs of the retrofits. The agency assumes that retrofitting DOT-111s and CPC-1232s would take 12 weeks and eight weeks respectively. Draft RIA, at 85. This assumption is unrealistic. PHMSA ignored the time needed to travel back and forth to the shop, which extends the retrofit time to 16 weeks, rather than the 8-12 weeks that PHMSA assumed. Additionally, PHMSA failed to consider the number of ethanol cars scheduled for requalification. Many of these cars were built between 2006 and 2007 to support the "boom period" of ethanol plant growth. The ten-year requalification requirement for these cars would fall between 2016 and 2017, during PHMSA's proposed retrofit schedule. Because ethanol cars are consumers of the same shop space, their requalification must be considered in shop time estimates.

Similarly, PHMSA skews downward the monthly value of lost service for tank cars undergoing retrofits. It estimates a $344 monthly value of lost service for unjacketed DOT-111s, and a $472 monthly value of lost service for unjacketed CPC-1232s. Draft RIA, at 86-87. But lease rates for crude rail cars can range three to four times higher, with reported rates at $1,500 to $2,000 per month. *See, e.g.*, Bob Tita, "Railcar Shortage in U.S. Pushes Up Lease Rates," Wall Street Journal (May 14, 2014) (**Exhibit 18**).

PHMSA also needs to analyze the potential opportunity costs of tank car shortages due to the mandates of the NPRM. AFPM members will likely face opportunity costs associated with their inability to ship raw materials and products while their tank cars are in the shop. It is extremely unlikely that sufficient tank cars will be available during the retrofit schedule to maintain current business activity given the current high utilization rate of the cars.

### 6. Other Flaws in PHMSA's Cost Estimates

PHMSA makes several other errors in its cost estimates that were also present in its estimates of the costs of new tank car standards. These errors include (i) assuming a 10% across-the-board reduction in all costs due to tank car manufacturers' efficiencies of scale, (ii) assuming that Option 3 enhanced CPC-1232 cars would be built absent the rulemaking, and (iii) ignoring the payload penalty because of unsupported assumptions about the development of "new steel" and other factors that would purportedly offset the increased weight of the retrofitted cars. Draft RIA, at 86-87. Rather than repeating those comments, they are incorporated by reference here.

## VIII. COMPLIANCE WITH EXECUTIVE ORDER 13211 GOVERNING RULES THAT IMPACT ENERGY SUPPLY, DISTRIBUTION AND USE

The Proposed Rule violates Executive Order 13221, which requires agencies "to appropriately weigh and consider the effects of the Federal Government's regulations on the supply, distribution and use of energy." 66 Fed. Reg. 28,355 (May 22, 2001). As the Executive Order notes, federal regulations "can significantly affect the supply, distribution and use of energy." Despite that impact, "there is too often little information regarding the effects of governmental regulatory action [] on energy." *Id.* § 1.

To "improve the quality of agency decision-making," Executive Order 13221 requires agencies to "prepare a Statement of Energy Effects" for "significant energy actions," defined to include "significant regulatory actions under Executive Order 12866." *Id.* §§ 1, 4(a). The "Statement of Energy Impacts" must include "(i) any adverse effects on energy supply, distribution or use (including a shortfall in supply, price increases, and increased use of foreign supplies), and (ii) reasonable alternatives to the action … and the expected effects of such alternatives …." *Id.* § 3.

The Proposed Rule triggered Executive Order 13221 as a "significant energy action," but PHMSA failed to include a Statement of Energy Effects. The NPRM is a "significant energy action" because it qualifies as a "significant regulatory action" under Executive Order 12866. *Id.* §§ 1, 4(a); 79 Fed. Reg. at 45,063 ("The NPRM is considered a significant regulatory action under … Executive Order 12866"). Significant energy actions require a Statement of Energy Effects, including an analysis of impacts on supply and price, as well as consideration of reasonable regulatory alternatives. Executive Order 13221, § 3.

This is precisely the type of rule that the Executive Order is intended to address. The Proposal risks disrupting the nation's gasoline supply if insufficient quantities of ethanol are available for use in blending operations at the product distribution terminals. The NPRM also risks severe reductions in the capacity of rail shipments of crude oil, which may impact the supply and price of crude. Disrupting the gasoline supply and constricting the domestic production of crude are issues of vital national interest that require deliberate and careful consideration. Reasonable alternatives to the rule are apparent: PHMSA could analyze accident prevention including improving track integrity and reducing human error. Reflecting the importance of crude shipments, DOT has previously analyzed whether Executive Order 13221 applies to rail operations' rules that might only have an indirect effect on crude supplies. 79 Fed. Reg. at 53,382 (analyzing whether the executive order applies to the proposed rule on securing crude oil trains).

## IX. CLASSIFICATION AND CHARACTERIZATION OF "MINED LIQUIDS AND GASES"

Our industry partners who ship, consign, and offer flammable liquids by rail are fully committed to both operational excellence and regulatory compliance in all aspects of dangerous goods transportation. It is their goal to achieve and maintain world class performance in safety, environmental stewardship, regulatory compliance, reliability, and efficiency.

Industry members are committed to compliance with all international, federal, state and local regulations during each phase required in the transport of dangerous goods. This requires training and management programs for employees who have responsibility for Hazardous Materials Regulations ("HMR"), including identification, classification, selection of authorized packagings, marking, label-placarding, and documentation (*e.g.*, Electronic Data Interface-EDI, Shipping Papers, etc.).

AFPM members understand that the HMR are designed to ensure hazardous materials are packaged and handled safely and securely during transportation; provide effective communication to transportation workers and emergency responders during incidents; and minimize the consequences of an incident should one occur. The HMR are considered a guiding standard of incident prevention. AFPM appreciates PHMSA's commitment to reduce the probability and severity of hazardous material releases while providing critical information to emergency first responders.

Compliance with the HMR includes (but is not limited to) the following processes:

- IDENTIFICATION of relevant physical & chemical properties (characteristics)
- CLASSIFICATION: Typically as Hazard Class 3 Flammable Liquids including the assignment of packing group (per 49 CFR 173.120 - 121. See Table 2)
- SELECTION of authorized packagings ( *e.g.*, DOT 111 rail tank cars for HazClass 3, PG I, PGII, PGIII, SP B1 and Combustible Liquids rated ladings) for safe transport in accordance with 49 CFR HMR 173.243 (a)
- MARKING/LABEL-PLACARDING of authorized packagings
- DOCUMENTATION to provide Shipping Papers (EDI) in accord with Subpart C - 49 CFR 172.200 – 172.205. Shippers must to certify all Dangerous Goods (DG)/HazMat are offered for transportation in accord with all provisions of 49 CFR HMR.

While AFPM members share PHMSA's goal of promoting safe transport of crude and ethanol, we are concerned that PHMSA's proposed "sampling and testing program" for "mined gas and liquid" is unnecessary, unduly burdensome, and confusing.

### A. Lack of Safety Benefit

The proposed sampling and test program would have no safety benefit. The existing HMRs require the offeror to properly classify hazardous materials and to certify that the classification is correct. 49 C.F.R. § 173.22. Improper transport classifications played *no role* in any of the recent crude oil and ethanol train accidents cited by PHMSA. The involved rail tank cars were all authorized, either meeting or exceeding the applicable packaging requirements. [54] Emergency response communications were correct at these derailments. All involved tank cars were properly marked, label-placarded, and documented to lead first responders to the 2012 Emergency Response Guidebook (ERG2012) number 128. The guidance provided by the ERG assists first-responders by describing the risk of vapor ignition, formation of explosive mixtures, and the potential of explosion of containers if heated. Notably, the ERG does not take Packing Group into account when advising emergency responders on immediate first response measures.

Consider the tragedy at Lac Mégantic. The investigations confirmed that testing, sampling, and any change in documentation concerning the characteristics of the Bakken crude oil involved would not have made a difference. Authorized rail tank cars (DOT 111s) were used. All marks, label-placards, and all hazards communications were correct. All transport hazards and emergency response communications were proper. The shipping papers (EDI) did have a

[54] *See* Table 3, Major Crude Oil/Ethanol Train Accidents in the U.S., 79 Fed. Reg. at 45,020; PHMSA, "Calculating Effectiveness Rates of Tank Car Options," Table 2, Major Crude Oil/Ethanol Train Accidents involving Crude oil and Ethanol Involving a Breach of a Tank Car (docketed Aug. 25, 2014).

miss-assigned Packing Group, indicating a PG III (lower degree of Flammable Liquid, Hazard Class 3) when the lading was actually PG II (moderate degree of risk); however, this was an immaterial error. Packaging (rail tank car) authorizations for PG II and PG III are exactly the same. The hazard communications are precisely the same. Regardless of the error in the shipping papers, the selected rail tank cars were DOT 111 (PG I), a more robust package than required by regulation.

Despite an extensive and ongoing enforcement effort over the last year, PHMSA has identified few examples of incorrect PG assignment. The agency has found zero instances of misclassification of the hazard class of crude oil. It would be difficult to imagine such a misclassification, as it is well understood that petroleum crude oil meets the HMR criteria for a Class 3 flammable liquid.

Rather than misclassifying the hazard class, the Bakken Blitz found a few missed assignments of packing groups on truck shipping papers, even though the trucks themselves were authorized for the lading. Specifically, a few shipping papers had selected the lower degree of risk (PG III) on shipping forms, rather than the moderate Class 3 risk (PG II). The tank trucks were otherwise properly authorized, marked, label-placarded, and documented in good order. Such mis-assignments are immaterial for bulk flammable liquids where the packing authorizations for PG II and PG III are the same. There was no impact on package selection, placarding, hazards communications, or emergency response. Correction of such dispatch/shipping paper errors requires training, as offerors/consignors/dispatchers should select the correct proper shipping description and/or product code. Such back-office errors, however, do not mandate a wholesale revision to the HMR.

### B. Confusing Terminology

PHMSA proposes an elaborate sampling and testing program for “mined gases and liquids,” but that term is not used by the petroleum industry and would only cause confusion in the regulated community. While some highly asphaltic bitumen may be “mined” from open pits and oil sands, most petroleum crude oils and associated liquefied petroleum gases are produced from wells, not mines. By-products associated with the production of petroleum may need different transportation infrastructure than petroleum crude oils. To promote certainty and compliance, the scope of the rulemaking should be limited to petroleum crude oil and ethanol transported in unit trains (defined as 75 cars or more).

Equally puzzling is the NPRM’s use of the term “characterization,” an undefined term in the Proposed Rule and HMR. AFPM recommends that PHMSA rely on the standard DG/HMR term “classification,” not “characterization.” Introducing characterization into the regulation would create confusion because the oil and gas industry already “characterizes” petroleum in several different contexts, including:

- in the workplace in association with the Globally Harmonized System (“GHS”) Purple Book and material safety data sheets (“MSDS”); [55]

[55] MSDS can be relied upon in DG/HMR classifications.

- during the commercial characterization of crude oil, including crude assays and certifications of analysis, which are a slate of tests that establish economic/operational/product oriented information;
- during transport (DG/HMR);
- for functional/operational (process and stock control) information needed by manufacturing (refining) sector; and
- general crude type characterizations such as ultra-light, light, medium, heavy.

### C. Scope of Crude "Characterization" Testing

As PHMSA notes, classification for flammable liquids requires testing crude oil (and other substances) for flash point and initial boiling point. 79 Fed. Reg. at 45,043 (citing 49 CFR § 173.120). But PHMSA also suggests that "characterization" of crude oil may be affected by "corrosivity, vapor pressure, specific gravity at loading and reference temperatures, and the presence and concentration of specific compounds such as sulfur." *Id.* AFPM supports PHMSA's continued use of flash point [56] and initial boiling point [57] to determine whether a commodity should be classified as a flammable liquid, but opposes PHMSA's suggestion that "characterization" testing is necessary for crude oil. As discussed below, crude oil is well-characterized and understood. AFPM, PHMSA, and others have commissioned studies of Bakken crude oil, all of which found Bakken crude to be consistent with other light oils.

### D. Method of Testing and Recordkeeping

Should PHMSA decide to ignore the costs and benefits underlying its proposal to create a sampling and testing program for crude oil. AFPM suggests the following changes to the program:

#### 1. <u>Exemption for Shipments in DOT 117s Tank Cars</u>

PHMSA requested comment on how the agency could "provide flexibility and relax the sampling and testing requirements for offerors who voluntarily use the safest packaging and equipment replacement standards." 79 Fed. Reg. at 45,045. AFPM respectfully suggests that shipments in DOT 117s require no elaborate classification and characterization program. As PHMSA notes in the Proposed Rule, the classification of a commodity determines the authorized packaging. 79 Fed. Reg. at 45,043. Once crude oil is shipped in a DOT 117, it would already be in the safest packaging under the HMR. PHMSA has failed to articulate any additional benefit that would result from requiring testing and classification of that oil. [58]

---

[56] Flash Point (closed cup) determination is a requirement per 173.120. Several alternative ASTMs are provided in the HMR.

[57] (Initial) Boiling Point ("IBP") is typically required to assign PG I or PG II. Testing can be problematic when the IBP is near the regulatory threshold of 95 deg F/ 35 deg C. IBP has a high degree of uncertainty, making tests difficult to reproduce.. Variances of 12 to 15 deg F on the same samples have been noted.

[58] To ensure that tank cars are used for the proper service, AFPM is committed to working with PHMSA to develop appropriate ways of identifying DOT 117 or 117P tank cars such as stenciling.

2. Less Prescriptive Mandates for Sampling and Testing

PHMSA requested comment on whether "more or less specificity regarding the components of a sampling and testing program" would aid offerors in complying with the HMRs. 79 Fed. Reg. at 45,045. AFPM strongly supports less prescriptive requirements for the sampling and testing program. There is no need for a detailed, onerous, and highly burdensome testing regime of crude oil shipments. Several industry and PHMSA studies have confirmed that the characteristics of Bakken crude oil are consistent with those of other light oils.

- *Frequency*: The Proposal requires a "frequency of sampling and testing that accounts for appreciable variability of the material, including the time, temperature, method of extraction (including chemical use) and location of extraction." 79 Fed. Reg. 45,075. Crude oil is well understood and characterized. A federally mandated and enforced sampling and testing program could become extraordinarily problematic. While there have been no improper classifications of petroleum crude oil or ethanol in the recent train wrecks, PHMSA has, nonetheless, fined industry members tens of thousands of dollars for immaterial PG mis-assignments on crude truck shipping documents. PHMSA's Safety Alert on January 2, 2014, warned of potential crude oil variability and emphasized proper and sufficient testing to ensure accurate characterization and classification. PHMSA's initial concern that unprocessed crude oil presents additional hazards in transport (e.g., corrosivity, sulfur content, dissolved gas content, low levels of H2S) has been proven to be unwarranted. *See* Section X.A. below (discussing the characteristics of Bakken crude oil).

- *Points of Sampling*: The Proposal asks for sampling "along the supply chain." 79 Fed. Reg. at 45,044, 45,075. Sampling and testing along the supply chain, in locations not directly associated with the loading of the packages being offered for transport, is unnecessary to ensure proper classification of consignment-specific packages (rail tank cars). PHMSA's jurisdiction is the transport of DG/HazMat packages in commerce and does not reach to manufacturing and production processing. The physical and chemical properties of petroleum crude oils do not change during transit. The goal of taking a sample for transport is to obtain a representative sample of the lading in the package. These procedures and methodologies do not need to be mandated by federal regulation.

- *Representative Sampling*: The Proposal requests sampling methods that ensure "a representative sample of the entire mixture." 79 Fed. Reg. at 45,044, 45,075. Shippers should be able to rely on existing data from oil taken from a field to ensure compliance with the HMR. Existing studies confirm the characteristics of Bakken crude, and oil and gas companies already characterize crude for a variety of commercial and compliance purposes. Those existing studies and data provide sufficient information for HMR compliance.

- *Complete Analysis*: The Proposal requires testing methods that "enable complete analysis, classification and characterization." PHMSA fails to define what a "complete analysis" would entail. As discussed earlier, shippers are only required to conduct analysis of flash point and initial boiling point in order to properly classify a commodity as a flammable liquid.

- *Statistical Justification*: The Proposal mandates "statistical justification for sample frequencies." As used in the NPRM, the term "statistical justification" is undefined. What are the rules of justification? Statistics are typically numerical and could be applied to variation/uncertainty in data/test results. Justification could mean the qualitative assessment associated with converting numbers into information. But this term is very unclear. It gives no information on how a sampling/testing/classification program should be implemented. It is possible, as mentioned above, that technical knowledge of process quality control of operational parameters (observed temperatures, pressures, gravity/API density, BS&W, physical state of visual stability, etc.) could be used by trained technicians to verify steady state conditions that correlate to a given transport classification.

- *Duplicate Samples*: The Proposal calls for "duplicate samples for quality assurance purposes." Duplicate samples are not typically taken in the industry, for quality assurance or any other reason. Nothing in the record indicates a need for duplicate samples. It will simply add unnecessarily to the cost and burden of testing and sampling. Additionally, this mandate is also vague, as PHMSA fails to specify the type of quality assurance that it seeks.

- *Criteria for Modification.* The Proposal mandates "criteria for modifying the sampling and testing program." What this requirement seeks to address is vague. Any testing and sampling program will necessarily change; samples cannot be taken by the same people at the same place at the same time. This appears to be another unnecessary paperwork requirement with no corresponding benefit.

### 3. Document Retention and Review

The Proposal requires documentation for the testing and sampling program to be retained while the program remains in effect, but the preamble is ambiguous about whether testing records need to be retained. In one sentence, the preamble states that PHMSA does "not require a specified retention requirement for the actual testing records," but the next sentence states that PHMSA "acknowledges testing results will be supplemental materials to support the requirements of the sampling and testing program." 79 Fed. Reg. 45,044. If PHMSA concludes that the benefits outweigh the costs and includes a testing program, then AFPM suggests that testing records be retained for two years.

## X. CRUDE STABILIZATION

PHMSA's broad questions in the NPRM suggest that it might be considering further stabilization or pretreatment of Bakken crude oil before shipment by rail as a compliance option.[59] The data demonstrates that Bakken crude falls within the normal range of hazard classification of light crude oil. As such, AFPM opposes stabilization of Bakken crude as unnecessary and unwarranted. Bakken crude characterization and stabilization are discussed at length in two white papers prepared by Dangerous Goods Transport Consulting on behalf of AFPM, "A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transport" (May 14, 2014) (["AFPM Survey") (**Exhibit 19**) and "The Need for Bakken Crude Oil Stabilization Prior to Rail Transport," (Sept. 2014) ("AFPM Stabilization Report") (**Exhibit 20**). The technical analysis from these white papers is summarized below.

### A. Bakken Crude Characteristics

At the request of PHMSA, AFPM conducted a survey of its members on data regarding the characteristics of Bakken crude. The AFPM survey collected data stemming from analysis of approximately 1,400 samples of Bakken crude. The survey data showed that the characteristics of Bakken crude oil are consistent with the hazard characteristics of other light crudes, making stabilization unnecessary. Bakken crudes (40-42 API gravity) are not classified for transport any differently that other light crude oils such as Eagle Ford (API 48), Eagle Ford Light (API 58), Arabian Super Light (API 51), DJ (Colorado) Basin (API 45), Saharan Blend (API 43), or West Texas Intermediate (API 38-40+). Bakken crudes pose no higher flammability or ignitability risk in transport than do other similar light crude oils. While Bakken crude (and other light crudes) may contain higher amounts of dissolved flammable gases as compared to some heavy crudes, the percentage of dissolved gases would not cause Bakken crude to be transported under a DOT hazard class other than Class 3 Flammable liquid. *See* AFPM Survey, at 3-4, 21-24.

In evaluating the flammable gas content of Bakken crude, vapor pressure provides a key parameter, as it correlates with flammable gas content. AFPM's survey collected data on vapor pressure of Bakken in transportation, [60] with the data showing a maximum vapor pressure at 50$^{o}$C of 16.72 pounds per square inch absolute ("psia"). That maximum vapor pressure falls 61% below the vapor pressure threshold limit of 43 psia for liquids under the HMR. *See* AFPM Survey, at 4-5, 18-20.

[59] In the NPRM, PHMSA's questions relating to characterization and stabilization include:

- "Is the current exception for combustible liquids sufficient to incentivize producers to reduce the volatility of crude oil for confined use of existing tank cars?"
- "Would an exception for all PG III flammable liquids further incentivize producers to reduce the volatility of crude oil prior to transportation?"
- "What are the impacts and costs and safety benefits of degasifying to these levels?"
- "What characteristics of a released flammable liquid significantly affect the likelihood of fire or explosion upon release?"

79 Fed. Reg. at 45,062.

[60] All but two of AFPM's samples used to analyze vapor pressure were taken at the rail loading point in North Dakota. *See* AFPM Survey, at 18-19.

AFPM's Survey also analyzed the corrosivity of Bakken Crude, finding no examples of corrosive Bakken crude. Nor have AFPM members observed tank car corrosion due to crude oil. As the owners and lessees of thousands of tank cars, AFPM members have every incentive to routinely and carefully monitor their fleet in order to promote safety and protect their investments. AFPM is not aware of any rail incidents (including the 11 derailments that PHMSA uses to justify the rulemaking) resulting from corrosion of crude oil tank cars. *See* Effectiveness Rate Memo, at 4, Table 2 (listing crude oil and ethanol derailments). While PHMSA notes reports of damage to tank cars in service in the form of corrosion of the bottom internal surface of the tank, manway covers, and valves and fittings, that type of damage is typical to equipment in hostile service environments.

In addition to collecting data on Bakken characteristics in transportation, the AFPM Survey collected data on rail tank car pressure measurements for Bakken upon arrival at the refinery. The highest value reported was 11.3 pound-force per square inch ("psig"), a value that is less than half of the 35 psig minimum relief valve setting for older DOT 111 tank cars and their required 240 psig minimum design burst pressure. *See* AFPM Survey, at 21. Measured tank car pressures show that even older DOT 111's authorized to transport Bakken crude oil are built with a wide margin of safety relative to the pressures that may be experienced when transporting Bakken crude. [61]

In a recent statement to Congress, PHMSA's Deputy Administrator, Tim Butters, confirmed that AFPM's Survey accurately characterized Bakken crude as falling within the norm for light crude oils. Mr. Butters stated:

> AFPM's 'Survey of Bakken Crude Oil Characteristics' concludes Bakken crude oil, when compared with other light crude oils, is determined to be within the norm in the case of light hydrocarbon content, including dissolved flammable gases. PHMSA does not dispute this conclusion. [62]

Mr. Butters further explained that PHMSA independently reached the same conclusion as AFPM's Survey based on the data that the agency collected in Operation Safe Classification. *Id.* ("The PHMSA data show that Bakken crude oil's gas content, flash point, boiling point, and vapor pressure are not outside the norm for light crude oils."). [63]

---

[61] Section 179.201-1 provides summary specifications for DOT-111 rail tank cars. Earlier DOT-111s were designed to 240 psig burst pressure while later designs are built to a minimum burst pressure of 500 psig. Based on § 179.15(b)(2)(ii), the minimum pressure relief value settings for tank cars with a minimum burst pressure of 240 psig is 35 psig and for 500 psig designs the minimum setting is 75 psig. *See* AFPM Survey, at 5 n.4.

[62] Written Statement of Timothy P. Butters, Deputy Administrator, U.S. Department of Transport, Pipeline and Hazardous Materials Safety Administration, Before the Subcommittee on Energy and Oversight, Committee on Science, Space, and Technology, U.S. House of Representatives, Bakken Petroleum: The Substance of Energy Independence, at 12 (Sept. 9, 2014) (**Exhibit 21**).

[63] The North Dakota Petroleum Council commissioned a study that reached the same fundamental conclusion as AFPM and PHMSA: Bakken crude is a light crude "similar to many other light sweet crudes produced and transported in the United States." Written Testimony of John R. Auers – Turner, Mason & Company, Subcommittee on Energy and Oversight, Joint Hearing, Bakken Petroleum: The Substance of Energy Independence (Sept. 9, 2014) (**Exhibit 22**).

AFPM's Survey and other studies confirm that Bakken Crude oils are correctly classified. Identification of flammable liquids by geographic, regional, or even a particular country of origin serves no known purpose except to impose unnecessary paperwork requirements. [64] The Hazard Class 3 appropriately communicates the risks of transport and leads first responders to the appropriate guidance in the NA Emergency Guide Book (Guide number 128).

**B. Stabilization**

Before assessing the merits of stabilization of Bakken crude, it is important to understand current gas removal practices for such crude and the existing impediments to stabilization, as explained in AFPM's Stabilization Report.

Generally, produced Bakken crude oil is passed through a liquid/gas separator where water and oil are separated from entrained gases and pumped to a storage tank at the wellhead where it is stored awaiting pick up by tank truck. Stored crude oil is subsequently transported to a rail head where it is stored until it is loaded into a rail tank car. Separated gases are frequently flared. *See* AFPM Stabilization Report, at 1.

Stabilization of crude oil commonly involves heating crude oil coming from a liquid/gas separator to between $200^{o}$F to $250^{o}$F, letting the heated crude oil splash down a tower to evaporate off the lighter components, separating the resulting liquid and vapors and cooling the vapors so that substances that are liquids at ambient temperatures are recondensed. The products of stabilization are "dead" crude oil, liquid condensate (containing ethane, propane, butanes, pentanes, hexanes, etc.), and petroleum gases (methane, ethane, propane and butane). Gases derived from stabilization are commonly routed to processing facilities where the methane is separated and piped through gas transmission lines. Other separated gases may be condensed and may be transported by highway or rail. *See* AFPM Stabilization Report, at 1.

Several factors contribute to low utilization of stabilization processes for Bakken crude oil including the following:

- a lack of infrastructure for transporting gas produced by stabilization, namely collection piping systems from well heads to gas processing facilities;
- the capital and operating costs of stabilization equipment;
- the need for additional tankage/equipment to store and handle condensate and liquefied gases; and
- the demand for light crude oil fractions in condensate is frequently lower, introducing distribution complexities for Bakken producers.

---

[64] It would be inappropriate and unnecessary to classify crude oil based on rail carrier codes such as STCC codes. These codes are used primarily for freight type billing purposes. The STCC codes are included on rail EDI/shipping papers, but are not necessarily created by authorized HazMat employees for emergency guidance. The STCC code serves no purpose to first responders who rely on placards and shipping papers for shipping names and/or hazard class. And there is no need to create or utilize STCC code to identify crude oils by geographic source. STCC codes are not used to differentiate Packing Groups. Nor are they used for selection of packagings.

The combination of these operational realities and Bakken's characteristics make stabilization inappropriate and unwarranted for several reasons. First, stabilization would not necessarily reduce the number of rail cars with volatile commodities. While stabilization would reduce the volatility of Bakken crude, the stabilization process would result in volatile light ends that would have to be shipped out of the Bakken by rail. Second, it is unlikely that refining processes would result in Bakken crude's reclassification as a combustible liquid. Reclassification would require refining Bakken crude to a 100$^{o}$F flash point range. Achieving that characteristic would entail a refining process with full distillation equipment, rather than just simple heater treaters. In other words, there would need to be a topping refinery operation, which does not exist in the Bakken. Third, the relative volatility of Bakken crude would not make any material difference in the context of a multiple car breach of a crude oil shipment during a derailment, the scenario that the Proposal is intended to address. Derailments result in multiple ignition sources such as sparks from metal-to-metal contact, creating a risk of a fire regardless of whether the crude oil has been stabilized. Once ignited, the burning intensity of unstabilized and stabilized crude would not substantially differ. *See* AFPM Stabilization Report, at 4.

## XI. SPEED RESTRICTIONS

In the NPRM, PHMSA proposes to establish a maximum 50 mph speed restriction on HHFTs. AFPM's position is that the railroads should determine the appropriate maximum speed for crude and ethanol shipments.

PHMSA also requests comment on three options to further reduce speed: (1) Option 1 will impose a 40 mph speed limit in all areas unless the tank cars meet the DOT 117 standards; (2) Option 2 will establish a 40 mph speed limit in areas with more than 100,000 people unless the tank cars meet the DOT 117 standards; and (3) Option 3 will establish a 40 mph speed limit in high-threat urban areas ("HTUAs") unless the tank cars meet the DOT 117 standards. *See* 79 Fed. Reg. at 45,047.

AFPM supports the Option 3 speed limit in HTUAs, provided that it is tied to unit train service of crude oil and ethanol. This option is appropriately limited to HTUAs, which represent the 2% of tracks that have been deemed to be in high-threat areas. The AAR already reached a voluntary agreement in February 2014 to abide by the 40 mph speed limit in HTUAs, indicating that the railroads believe that Option 3 will not significantly impact and disrupt other traffic.

AFPM has substantial concerns that the other proposed speed options would unduly restrict all rail traffic without any commensurate improvement in safety. Approximately "83% of [the] U.S. rail network is single track with passing tracks spaced every 5 to 50 miles." AAR, Speed Restriction Impacts to Train Performance & Railroad Capacity, at 3 (June 10, 2014) ("AAR Speed Restrictions Presentation"). These tracks are shared by passenger, premium, manifest, and unit/bulk trains. *Id.* at 2. As a result, the blanket speed restrictions in Options 1 and 2, if imposed on HHFTs or unit trains, would significantly restrict rail capacity and speeds for all of these major traffic groups. AAR, for example, estimated that a 30 mph speed limit would restrict capacity by 10 percent. *See* AAR Speed Restrictions Presentation; BNSF, Calculating Railroad Capacity and Performance Impacts that Result from Changing the Maximum Permitted Speed of Specific Train Types (2014).

PHMSA should carefully analyze whether significant speed restrictions may actually increase the risk of derailments. As a practical matter, speed restrictions require shippers to use more tank cars to move the same volume of commodities. For example, a tank car slowed by speed restrictions might have its turns per month lowered from four to two, necessitating using an additional tank car to make up for that lost volume. Boosting the volume of tank cars due to speed restrictions may have the unintended consequence of creating a greater risk of derailments. PHMSA should conduct an analysis of this issue to ensure that speed restrictions provide a net safety benefit.

## XII. REVOCATION OF PRIOR EMERGENCY ORDERS GOVERNING CRUDE SHIPMENTS

AFPM respectfully requests that DOT clarify the status and effect of prior emergency orders that regulate the same subject matter as the Proposal. Specifically, DOT should confirm that these prior emergency orders will be superseded once the NPRM becomes final. Otherwise, offerors, such as AFPM members, will be subject to different, and possibly conflicting, requirements. For example, the DOT issued an emergency order on February 25, 2014, which was revised and amended on March 6, 2014, requiring that all rail shipments of crude oil that are properly classed as flammable liquids as PG III material be treated as PG I or II material. *See* Docket No. DOT-OST-2014-0025. PHMSA is now proposing to modify classification standards again to require a sampling and testing program for mined gas and liquid, such as crude oil. 79 Fed. Reg. at 45,021. To avoid confusion and potential inconsistency, PHMSA should rescind superseded emergency orders in the final rule.

By doing so, DOT would be reinforcing the purpose of emergency orders as a stop-gap measure to address imminent dangers. DOT is authorized to issue emergency orders "without notice or an opportunity for a hearing, but only to the extent necessary to abate the imminent hazard." 49 U.S.C. § 5121(d); *see also* 49 C.F.R. § 109.17(a). The lack of any procedural safeguards before issuance of an emergency order raises serious due process concerns, which are only ameliorated when orders are narrowly tailored to address imminent dangers for a limited time period. Using emergency orders as a long-term method of regulation would allow PHMSA to dodge the procedural protections afforded by the rulemaking process. Emergency orders, therefore, should expire upon promulgation of a final rule after notice and comment. *See* Docket No. DOT-OST-2014-0025 ("This Amended Order remains in effect until . . . Federal regulation occurs that supersedes the requirements of the Amended Order").[65] PHMSA should affirm that emergency orders are of limited duration by explicitly rescinding those prior orders that regulate the same subject matter as the final rule.

## XIII. SERC NOTIFICATIONS

[65] Although some emergency orders also provide that in the event they are superseded "the Secretary will issue a Rescission Order," *see e.g., id.,* regulated entities should not be forced to wait for individual rescission orders while remaining uncertain about what exactly the final rule supersedes.

In the Proposal, PHMSA requested comment on continuing the requirement that railroads notify state emergency response commissions ("SERCs") of Bakken crude oil shipments of one million gallons or more. The agency issued an emergency order to require these SERC notifications on May 7, 2014. The NPRM seeks comment on codification and clarification of SERC notifications in the HMR. *See* 79 Fed. Reg. at 45,040–42.

AFPM does not support SERC notification. Unlike track integrity and human factors, SERC notifications provide little to no safety benefit. The notifications do nothing to prevent accidents. Nor do the notifications put first responders in a better position to react to an emergency. On the contrary, the fact that certain states have publicly released SERC notifications showing the routes for Bakken crude oil shipments heightens security risks, as that information could be used by terrorists, protesters, [66] or others to target shipments. Moreover, there is no basis for tying SERC notifications to shipments of Bakken crude. The accident record shows no increased risks from Bakken crude compared to other light crudes or flammable liquids.

AFPM respectfully submits that the Emergency Response Guidebook ("ERG") [67] properly promotes safety in responding to crude oil derailments. DOT, Mexico, and Canada jointly publish the ERG, which is intended for use by emergency responders first arriving on the scene of an accident or incident. First responders include law enforcement personnel and fire department personnel—both professionals and volunteers. DOT distributes the ERG widely throughout the United States, with the objective of making it available to every potential first responder. The frequency of hazardous materials rail accidents and incidents is so rare that an average first responder is expected to encounter fewer than one incident in their career. As such, information must be basic and understandable to those who have a low probability of encountering a hazardous materials accident or incident.

The ERG serves this purpose. Through the UN number or proper shipping name of a substance, a first responder is able to access instructions on what steps to take upon arrival at the scene of an accident or incident. For crude oil assigned to UN 1267 Petroleum crude oil, irrespective of Packing Group, or crude oil meeting combustible liquid criteria and transported under NA 1993 Combustible liquid, NOS, guide page 128 of the ERG provides a first responder with the appropriate information (see Appendix 5). In this respect, it is important to note that the range of crude oils subject to the HMR (i.e., crude oils of Packing Groups I, II and III and combustible liquid crude oils) are addressed by one set of instructions made available to first responders. The same guide page is applicable to many other flammable liquids independent of the degree of hazard.

To the extent that PHMSA maintains SERC notifications in the final rule, AFPM suggests modifying the notifications. Rather than being triggered by shipments of one million

---

[66] *See, e.g.*, Mike Aldax, "Protesters Chain Themselves to Kinder Morgan Fence to Oppose Crude-byRail," Richmond Standard (Sept. 4, 2014), ***available at***, http://richmondstandard.com/2014/09/protesters-chain-kinder-morgan-fence-oppose-crude-rail/

[67] The relevant excerpts from the ERG are available at **Exhibit 23**.

gallons, SERC notifications should be tied to shipments of crude oil or ethanol in "unit trains," meaning trains that have 75 cars or more shipping crude oil or ethanol.

Furthermore, PHMSA should clarify that SERC notifications are sensitive security information exempt from state Freedom of Information Acts and sunshine laws. The purpose of notifying states about shipments is served by providing the routing information to the state director of public safety. Broader dissemination raises significant security concerns in light of the possible targeting of rail by terrorist groups and others. States have taken widely-varying approaches to releasing SERC notifications, resulting in some states publicly distributing Bakken crude oil routes. Rather than this patchwork response that creates significant security concerns and uncertainty, the final rule should further the HazMat Act's significant interest in national uniformity and clarify that SERC notifications remain sensitive security information exempt from public release.

## XIV. CONCLUSION

AFPM thanks PHMSA for the opportunity to comment upon the Proposal. AFPM shares PHMSA's goal of promoting rail safety, but has significant concerns about whether the Proposal achieves that goal in an effective and reasonable fashion. We would be happy to meet with you to discuss the comments. Please contact AFPM's Vice President of Regulatory Affairs, David Friedman, if you wish to discuss these issues further. He may be reached at 202-457-0480.

This letter was not received in accordance with NDAC § 43-02-03-90.2. Therefore, it is not part of the evidentiary record of this case.

**Kadrmas, Bethany R.**

**From:** Roberson, Evie A.
**Sent:** Wednesday, October 01, 2014 3:24 PM
**To:** Kadrmas, Bethany R.
**Subject:** FW: recent hearing on Bakken oil transport

**From:** Thomas F Duckwall [mailto:tomfduckwall@cs.com]
**Sent:** Tuesday, September 30, 2014 7:59 PM
**To:** Roberson, Evie A.
**Subject:** recent hearing on Bakken oil transport

Evie - Sorry if you're the wrong person for this--if so please fwd as needed.

I just wanted to say that I, as a consumer in a distant state (NC), would most appreciate your Commission's implementation of stabilization requirements with the use of appropriate equipment, as is done in Texas with Eagle Ford shale. Any additional cost would be insignificant compared to that of an accident like the one in Canada, and even though that was certainly avoidable (had railroad safety rules been followed) we cannot rely on a single safety mechanism when many lives are at stake and an excellent backup system is available. In other words, railroad safety procedures would probably prevent a derailment, but if not it would be best to limit the damage to the spill and a containable fire, and prevent the explosion. I would think that just the thought of the potential liability would be enough for all parties to take every possible precaution.

Thank you for giving this your consideration --- Tom Duckwall, Greensboro, NC

| | |
|---|---|
| **From:** | Scott Skokos |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Addendum to DRC testimony |
| **Date:** | Wednesday, September 24, 2014 3:47:38 PM |
| **Attachments:** | r13d0054 (Canada).pdf<br>07_23_14_Operation_Safe_Delivery_Report_final_clean.pdf |

Hi,

At the hearing yesterday Lynn Helms requested that we send two studies as an addendum to our testimony and comments. I have attached the studies requested by Lynn Helms. The two studies are as follows:

-PHMSA/FRA study relating to Bakken Crude composition/volatility

-Canadian TSB investigation of the Lac Megantic trail derailment.

All the best,

Scott

--
Scott Skokos
Senior Field Organizer
scott@drcinfo.com

Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

# RAILWAY INVESTIGATION REPORT R13D0054

## RUNAWAY AND MAIN-TRACK DERAILMENT

## MONTREAL, MAINE & ATLANTIC RAILWAY FREIGHT TRAIN MMA-002 MILE 0.23, SHERBROOKE SUBDIVISION LAC-MÉGANTIC, QUEBEC 06 JULY 2013

Canada

Transportation Safety Board of Canada
Place du Centre
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741
1-800-387-3557
www.tsb.gc.ca
communications@bst-tsb.gc.ca


Cat. No. TU3-6/13-0054E
ISBN 978-1-100-24860-8

# Railway Investigation Report R13D0054

# Runaway and main-track derailment

## Montreal, Maine & Atlantic Railway
## Freight train MMA-002
## Mile 0.23, Sherbrooke Subdivision
## Lac-Mégantic, Quebec
## 06 July 2013

## *Summary*

On 06 July 2013, shortly before 0100 Eastern Daylight Time, eastward Montreal, Maine & Atlantic Railway freight train MMA-002, which was parked unattended for the night at Nantes, Quebec, started to roll. The train travelled approximately 7.2 miles, reaching a speed of 65 mph. At around 0115, when MMA-002 approached the centre of the town of Lac-Mégantic, Quebec, 63 tank cars carrying petroleum crude oil (UN 1267) and 2 box cars derailed. About 6 million litres of petroleum crude oil spilled. There were fires and explosions, which destroyed 40 buildings, 53 vehicles, and the railway tracks at the west end of Megantic Yard. Forty-seven people were fatally injured. There was environmental contamination of the downtown area and of the adjacent river and lake.

*Ce rapport est également disponible en français.*

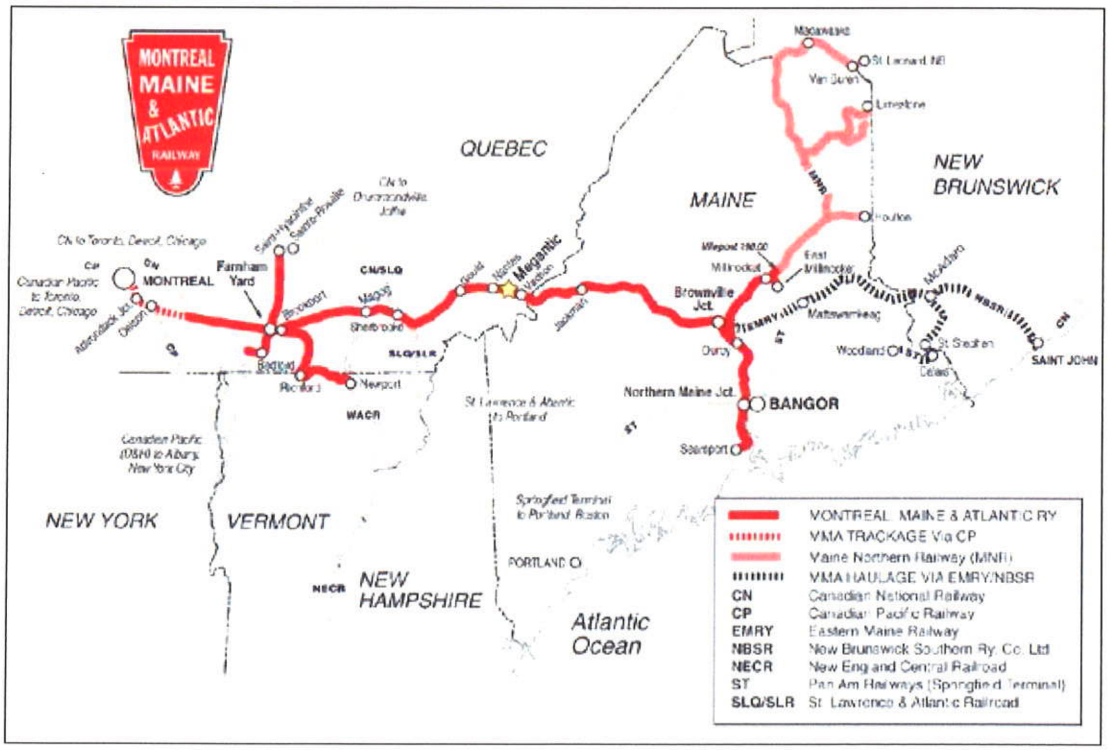
# Table of contents

# 1.0 *Factual information*

## 1.1 *The accident*

On 05 July 2013, at about 1355,[1] eastward Montreal, Maine & Atlantic Railway (MMA)[2] freight train MMA-002 (the train) departed Farnham (near Brookport, Mile 125.60 of the Sherbrooke Subdivision), Quebec, destined for Nantes (Mile 7.40 of the Sherbrooke Subdivision), Quebec, where it was to be re-crewed and was to continue on to Brownville Junction, Maine. The train's final destination was Saint John, New Brunswick (Figure 1). The train consisted of 72 tank cars loaded with approximately 7.7 million litres of petroleum crude oil (UN 1267), 1 box car (buffer car[3]), and the locomotive consist (5 head-end locomotives and 1 VB car[4]). The train was controlled by a locomotive engineer (LE) who was operating alone and was positioned in the lead locomotive, MMA 5017. During the trip, the LE reported mechanical difficulties with the lead locomotive, which affected the train's ability to maintain speed.

**Figure 1. Montreal, Maine & Atlantic Railway (MMA) map (source: MMA, with TSB annotations)**




At around 2250, the train arrived at Nantes, was brought to a stop using the automatic brakes, and was parked for the night on a descending grade on the main track. The LE

---

1 All times are Eastern Daylight Time.

2 See Appendix L for abbreviations and acronyms.

3 A non-placarded car of any type used to separate the locomotive consist from dangerous goods cars in order to enhance the safety of the crew members in the locomotive consist.

4 A special-purpose caboose equipped to remotely control the locomotives.

applied the independent brakes to the locomotive consist. He then began to apply the hand brakes on the locomotive consist and the buffer car (7 cars in total), and shut down the 4 trailing locomotives. Subsequently, the LE released the automatic brakes and conducted a hand brake effectiveness test without releasing the locomotive independent brakes. The LE then contacted the rail traffic controller (RTC) responsible for train movements between Farnham and Megantic Station (Megantic), who was located in MMA's yard office in Farnham, to indicate that the train was secured.

The LE then contacted the RTC in Bangor, Maine, who controlled movements of United States crews east of Megantic. During this conversation, the LE indicated that the lead locomotive had continued to experience mechanical difficulties throughout the trip and that excessive black and white smoke was now coming from its smoke stack. The LE expected that the condition would settle on its own. It was mutually agreed to leave the train as it was and that performance issues would be dealt with in the morning.

A taxi was called to transport the LE to a local hotel. When the taxi arrived to pick up the LE at about 2330, the taxi driver noted the smoke and mentioned that oil droplets from the locomotive were landing on the taxi's windshield. The driver questioned whether the locomotive should be left in this condition. The LE indicated that he had informed MMA about the locomotive's condition, and it had been agreed upon to leave it that way. The LE was then taken to the hotel in Lac-Mégantic and reported off-duty.

At 2340, a call was made to a 911 operator to report a fire on a train at Nantes. The Nantes Fire Department responded to the call and arrived on site, and the Sûreté du Quebec (SQ) called the Farnham RTC to inform the company of the fire. After MMA unsuccessfully attempted to contact an employee with LE and mechanical experience, an MMA track foreman was sent to meet with the fire department at Nantes. When the track foreman arrived on site, the firefighters indicated that the emergency fuel cut-off switch had been used to shut down the lead locomotive. This shutdown put out the fire by removing the fuel source. Firefighters also moved the electrical breakers inside the locomotive cab to the off position to eliminate a potential ignition source. These actions were in keeping with railway instructions.

Both the firefighters and the track foreman were in discussion with the Farnham RTC to report on the condition of the train. Subsequently, the fire department and the MMA track foreman left the scene.

With no locomotive running, the air in the train's brake system slowly began to be depleted, resulting in a reduction in the retarding force holding the train. At about 0100 (July 06), the train started to roll downhill toward Lac-Mégantic, 7.2 miles away. At about 0115, the train derailed near the centre of town, releasing about 6 million litres of petroleum crude oil, which resulted in a large fire and multiple explosions.

The locomotive consist did not derail; rather, it separated from the rest of the train and then further separated into 2 sections. Data downloaded from the de la Gare Street crossing (located by Megantic Station) showed that the 2 sections were separated by 104 feet. Both continued travelling eastward onto the Moosehead Subdivision, coming to rest on an ascending grade in the eastern part of town and stopping approximately 475 feet apart. During the course of this entire sequence, the train passed through 13 level crossings.

After approximately 1.5 hours, while emergency and evacuation efforts were under way, the leading section of the locomotive consist rolled backwards toward downtown and contacted the trailing section; both sections travelled backwards an additional 106 feet. At approximately 0330, MMA officials secured the locomotive consist on the grade by re-tightening the hand brakes.

See Appendix A for more detailed information about the sequence of events.

Photo 1. The Lac-Mégantic derailment site following the accident

## 1.2 *Aftermath*

As a result of the derailment and the ensuing fires and explosions, 47 people died, and about 2000 people were evacuated. Forty buildings and 53 vehicles were destroyed (Photo 1).

The derailed tank cars contained about 6.7 million litres of petroleum crude oil, about 6 million litres of which were released, contaminating approximately 31 hectares of land. Crude oil migrated into the town's sanitary and storm sewer systems by way of manholes. An estimated 100 000 litres of crude oil ended up in Mégantic Lake and the Chaudière River by way of surface flow, underground infiltration, and sewer systems. About 740 000 litres were recovered from the derailed tank cars.

The hydrocarbon recovery and cleanup operation began as soon as the fire was extinguished and the site was stabilized, approximately 2 days after the derailment. The assessment and remediation of the environment were performed using a combination of monitoring wells and exploratory trenches serviced by vacuum trucks under the guidance of a specialized engineering firm.

## 1.3 Weather

At 2300 on 05 July 2013, the temperature at the weather station in Sherbrooke, Quebec, approximately 95 km west of Lac-Mégantic, was 21.7 °C. The dew point was 20.5 °C, and wind speed was 5 km/h from the south. At 0100 on 06 July 2013, the temperature was 21.2 °C, with a dew point of 20.4 °C and wind speed of 0 km/h.

## 1.4 Subdivision information

The Sherbrooke and Moosehead Subdivisions were owned and operated by MMA. These subdivisions were previously owned by Quebec Southern Railway (QSR) and, prior to that, by Canadian Pacific Railway (CPR).

### 1.4.1 Sherbrooke Subdivision

The MMA Sherbrooke Subdivision was a single main track extending west from Megantic (Mile 0.00) to Brookport (Mile 125.60), Quebec, where it connected with the Adirondack and Newport Subdivisions, near Farnham. Train movements were controlled by the Occupancy Control System (OCS), as authorized by the *Canadian Rail Operating Rules* (CROR), and supervised by an RTC located in Farnham. Traffic on the Sherbrooke Subdivision consisted of 2 freight trains per day, for an annual tonnage of 4.5 million gross tons. The track was classified as Class 3[5] according to the Transport Canada–approved *Track Safety Rules* (TSR). The maximum allowable speed for freight trains was 40 mph. However, due to track conditions, the speed on the entire subdivision had been reduced with temporary slow orders, including:

- 25 mph between Mile 0.82 and Mile 93 (with 11 locations further reduced to 10 mph),
- 10 mph between Mile 93 and Mile 103.87, and
- 25 mph between Mile 103.87 and Mile 125.60 (with 2 locations further reduced to 10 mph).

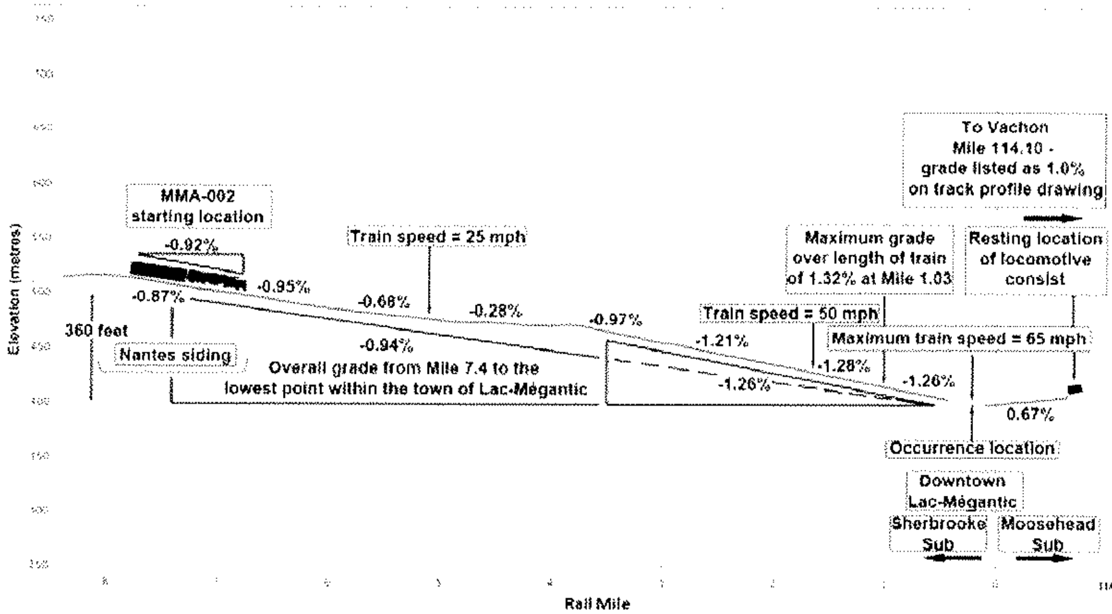
The subdivision was equipped with 6 hot box detectors, the last one located at Mile 13.30. MMA-002 did not receive any alarms from these detectors.

Between Nantes and Megantic (Mile 7.40 to the lowest point near Mile 0.00), the average descending grade was 0.94%, and the steepest grade over the length of the train was 1.32% at Mile 1.03 (Figure 2). The elevation dropped approximately 360 feet between Nantes and Megantic. For the last 2 miles before the point of derailment, the track descended at a grade of approximately 1.30%. The maximum horizontal curvature of the track was 4.25°, which was at the derailment location (Engineering Laboratory Report LP167/2013).

---

5 The *Track Safety Rules* (TSR) define 5 classes of track. The maintenance requirements, as well as the maximum speed for both freight and passenger trains, are dictated for each class.

Figure 2. Grade and elevation between Nantes and Megantic




Cautionary limits[6] were in effect between Mile 0.82 and Mile 0.00, due to the presence of the yard at Megantic. Movements were to be made in accordance with CROR 94 and 105(c).[7] There was a permanent speed restriction of 10 mph over Frontenac Street (Mile 0.28) until the crossing was fully occupied.

### 1.4.2 *Moosehead Subdivision*

The Moosehead Subdivision was a single main track that extended east from Megantic (Mile 117.14) to Brownville Junction (Mile 0.00), where it connected with the Millinocket Subdivision. The track was classified as Class 3 according to the TSR. Movements departing Megantic and heading eastward on this subdivision encountered an ascending grade of approximately 1%. Further east at Vachon (Mile 114.10), Quebec, the closest siding to Lac-Mégantic, there was a 6470-foot passing track.

## 1.5 *Rail traffic control*

MMA had 2 RTCs on duty at all times (1 in Bangor and the other in Farnham), with duty periods of 12 hours, starting at 0600 and 1800. The Farnham RTC controlled movements west of Megantic, and the Bangor RTC controlled movements east of Megantic. The Farnham RTC on duty at the time of the accident was a qualified LE with previous experience securing trains at Nantes.

---

6 Cautionary limits, as defined in the *Canadian Rail Operating Rules* (CROR), are essentially an extension of the main track through yards and terminals where there is need for caution due to the likelihood of encountering other equipment or unlined switches.

7 This rule requires a movement to operate at a speed that will allow it to stop within ½ of the range of vision of equipment or a track unit.

## 1.6 *Personnel information*

From Farnham to Nantes, MMA-002 was operated by 1 LE positioned in the lead locomotive as per single-person train operations (SPTO) special instructions. The LE was rules-qualified and met fitness and work/rest regulatory requirements. The LE's 2 previous shifts were:

- MMA-002 (eastbound from Farnham to Megantic) on 02 July 2013 from 1230 to 0030, and
- MMA-001 (westbound from Megantic to Farnham) on 03 July 2013 from 0830 to 2030.

Both trips had been performed with a conductor.

On 05 July 2013, the LE awoke at approximately 0530 and reported for duty at 1330 for MMA-002. When the LE was at home in Farnham, he normally slept about 8 hours per night. When the LE laid over, he usually slept between 5 and 6 hours per night.

The LE was hired by CPR in January 1980, and qualified as an LE in 1986. In September 1996, he transferred to QSR when that company acquired the trackage from CPR. In January 2003, the LE transferred to MMA when QSR was purchased by Rail World, Inc. (RWI), MMA's parent company. During this time, he completed hundreds of trips between Farnham and Lac-Mégantic and was familiar with the territory.

In the 12 months before the accident, the LE completed about 60 eastbound trips on MMA-002. About 20 of these trips were completed as a single-person train operator.

## 1.7 *Train information*

The tank cars originated in New Town, North Dakota, where they were picked up by CPR. At origin, the train consisted of 1 box car (the buffer) and 78 tank cars loaded with petroleum crude oil (UN 1267), a Class 3 flammable liquid. On 30 June 2013, when the train was in Harvey, North Dakota, 1 tank car was removed for a mechanical defect after the train received a safety inspection and a Class I air brake test.[8] This air brake test verifies the integrity and continuity of the brake pipe, as well as the brake rigging, the application, and the release of air brakes on each car.

The petroleum crude oil had been purchased by Irving Oil Commercial G.P. from World Fuel Services, Inc. (WFSI). The shipping documents indicated that the shipper was Western Petroleum Company (a subsidiary of WFSI) and the consignee was Irving Oil Ltd. (Irving).

The cars operated through Minneapolis, Minnesota, Milwaukee, Wisconsin, Chicago, Illinois, and Detroit, Michigan, and arrived in Canada through Windsor, Ontario. The cars travelled to Toronto, Ontario, and underwent a No. 1 air brake test by a certified car inspector on 04 July 2013. The cars departed Toronto as part of a mixed freight train, consisting of 2 locomotives and 120 cars, destined for Montréal. When the train arrived in Montréal, it underwent a routine safety and mechanical inspection in Saint-Luc Yard on

---

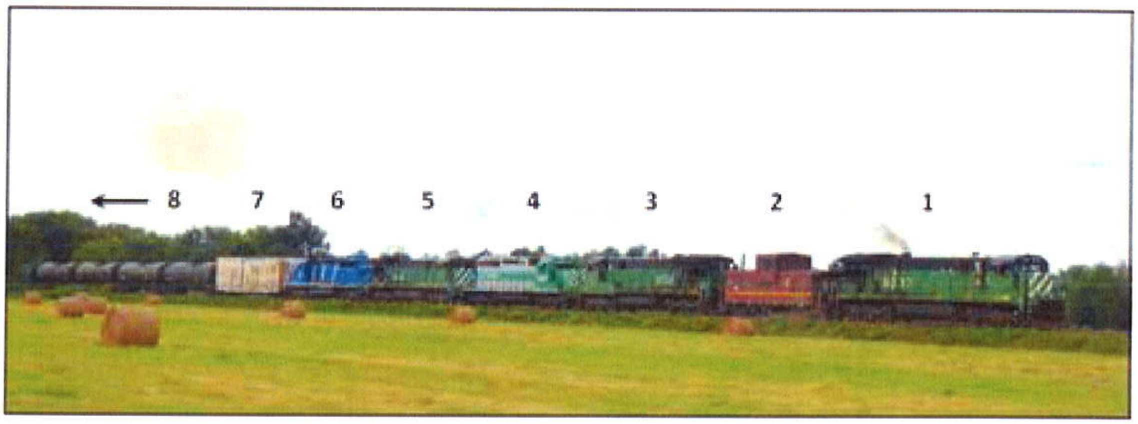
8 In Canada, this type of test is called a No. 1 air brake test.

05 July 2013. Mechanical defects were identified on 5 tank cars, which were removed from the train. The remaining tank cars were then interchanged to MMA.

On the morning of 05 July 2013, the cars were taken to Farnham, where they received a brake continuity test and a mechanical inspection by Transport Canada (TC). Minor defects were noted on 2 cars, and these were corrected. Departing Farnham, the train was approximately 4700 feet long, weighed about 10 290 tons (Appendix B) and consisted of the following (Photo 2):

1. lead locomotive MMA 5017, General Electric Company (GE) C30-7;
2. special-purpose caboose (VB car) VB 1;
3. locomotive MMA 5026, GE C30-7;
4. locomotive CITX 3053, General Motors (GM) SD-40;
5. locomotive MMA 5023, GE C30-7;
6. locomotive CEFX 3166, GM SD-40;
7. buffer car CIBX 172032; and
8. 72 tank cars.

Photo 2. MMA-002 at Brookport on 05 July 2013 (photo: Richard Deuso, with TSB annotations)

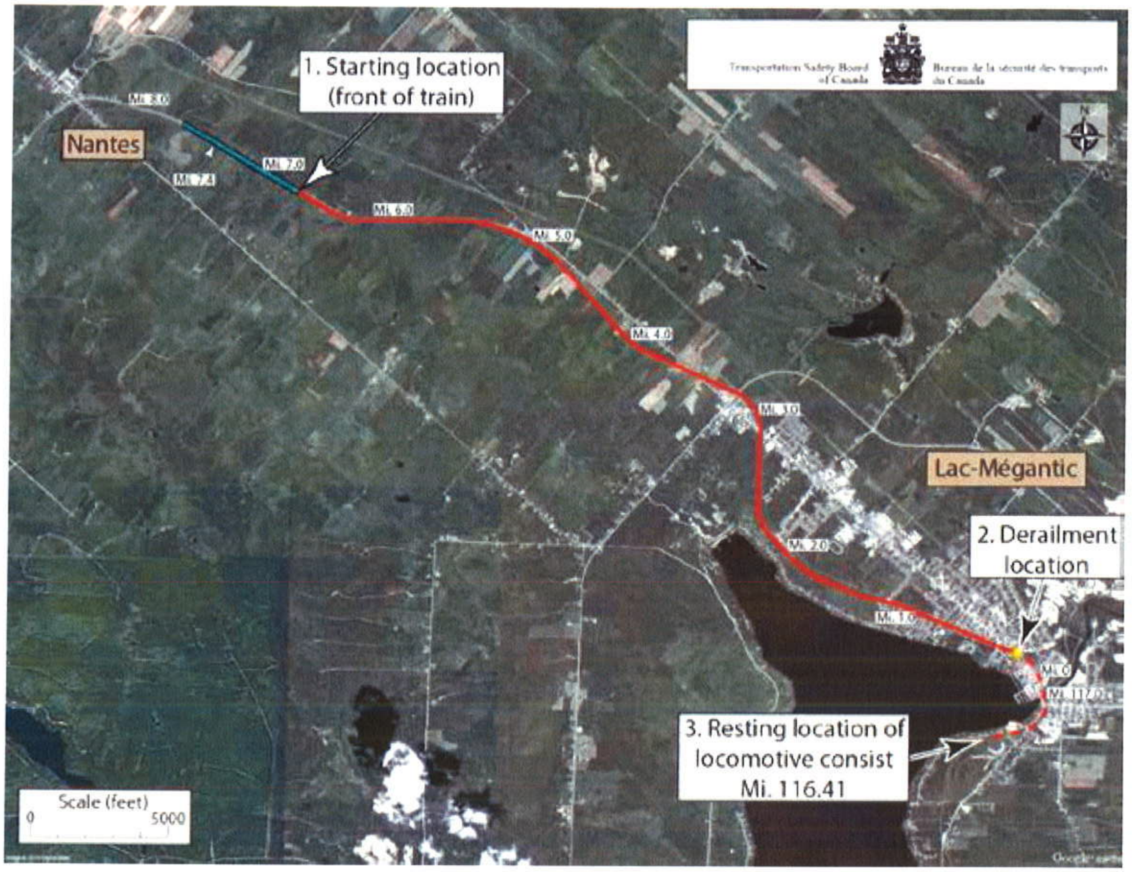



## 1.8 *Accident site information*

The investigation focused on 3 locations (Figure 3):

- Nantes, where the train was parked;
- downtown Lac-Mégantic, where the train derailed; and
- the ascending grade, east of Megantic, where the locomotive consist came to its final stop (Mile 116.41 of the Moosehead Subdivision).

Figure 3. The 3 locations that were the focal points of the investigation: Nantes, downtown Lac-Mégantic, and the location where the locomotives came to a stop (Mile 116.41 of the Moosehead Subdivision) (source: Google Earth, with TSB annotations).




### 1.8.1 *Nantes*

Railway lines at Nantes are located in a rural area where the main track and a siding run parallel and immediately adjacent to public highway 161. The average descending grade on the main track where the train was parked is 0.92%.[9] During site examination, a black oily residue was found on the surrounding vegetation and on the rails where the lead locomotive was parked (Photo 3).

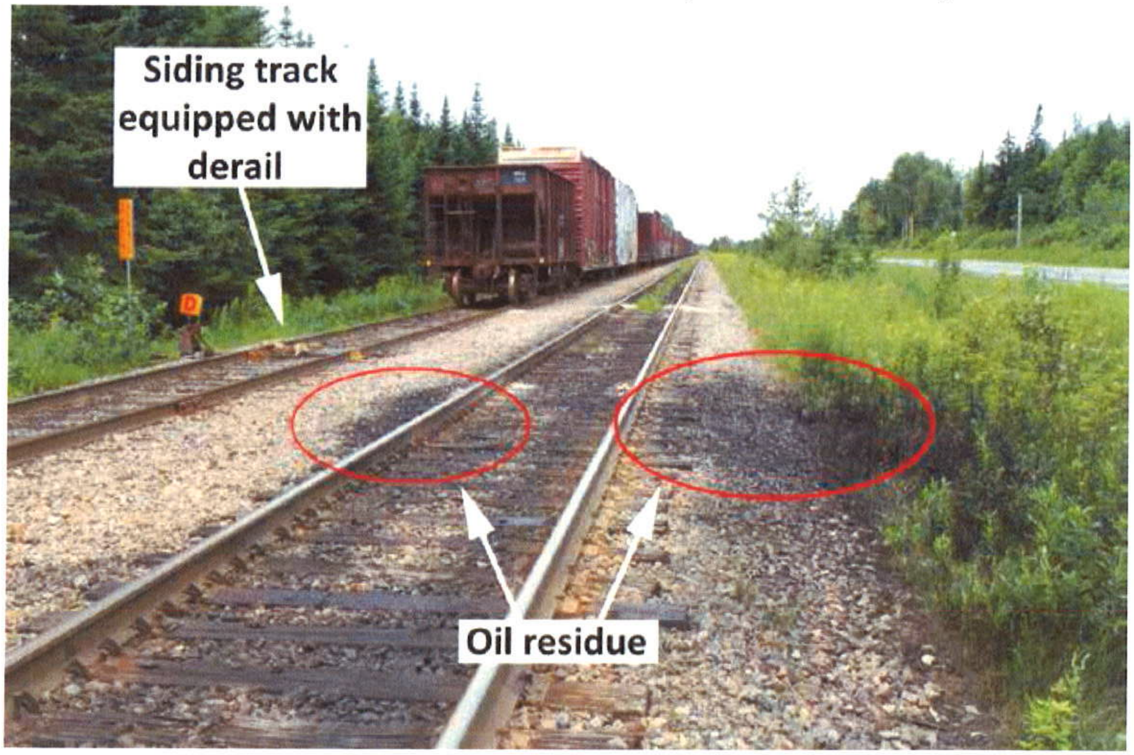
The east siding switch was located at Mile 6.67, and the siding was 7160 feet long. At the time of the accident, several rail cars were being stored there. The siding was equipped with a special derail,[10] located approximately 230 feet west of the switch (Photo 3). A derail is a mechanical safety device that sits on top of the rail and is used to derail runaway equipment. This derail was locked in the derailing position to protect the main track from unintended movements out of the siding.

---

9 Grades of approximately 1.00% are considered steep for railway purposes (see section 1.12.4 for more information).

10 A special derail is a derail that may be left in non-derailing position when equipment is not present. (Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* [CROR] 104.5: Derails.)

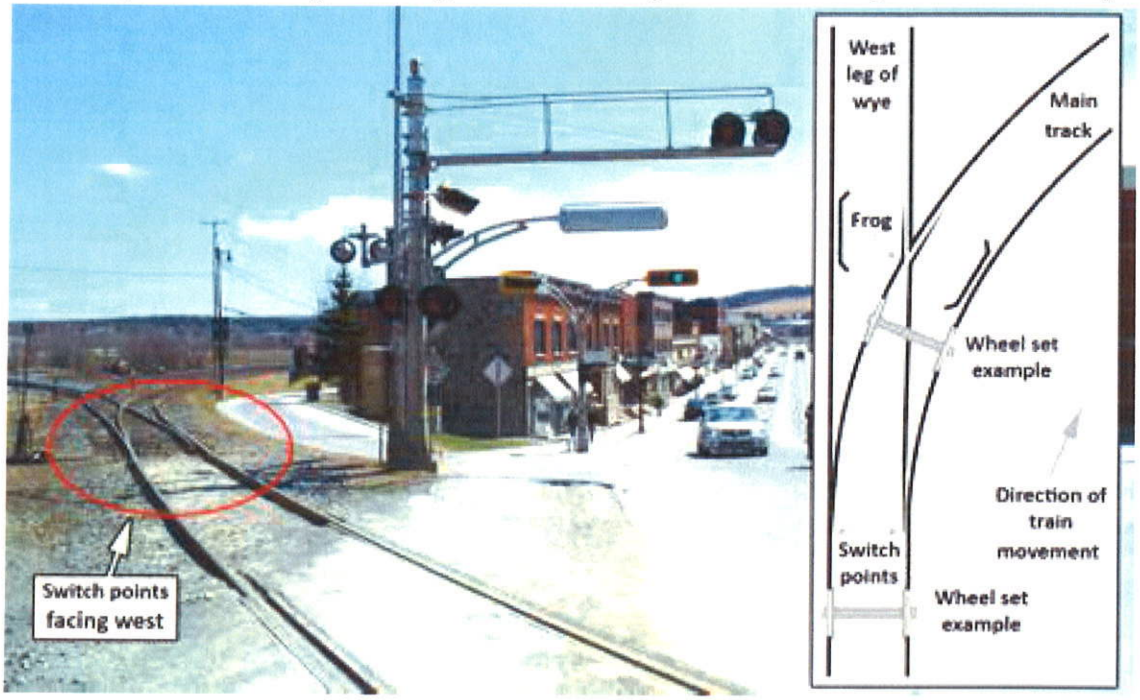
Photo 3. Oil residue on the ground and vegetation at Nantes. Note derail on adjacent siding track on left (view westward from the location where the lead locomotive was parked on the main track).




### *1.8.2 Lac-Mégantic derailment site*

The MMA Megantic Station was located in a commercial district of Lac-Mégantic, where the Sherbrooke and Moosehead Subdivisions met. Frontenac Street, a main thoroughfare, ran through the centre of the town. The main track intersected with Frontenac Street just west of the Megantic West turnout and was maintained for a maximum speed of 15 mph. The turnout was located at Mile 0.23, with the switch points facing west (Photo 4).

Photo 4. Frontenac Street public grade crossing, looking eastward. The circled area denotes the location of the switch points and the frog for the Megantic West turnout (photo: Pierre Blondin, with TSB annotations).




The derailed equipment covered the main track, 3 adjacent yard tracks, and the west leg of the wye, which is a triangular arrangement of tracks that can be used for turning rail equipment (Photo 5).[11] At the time of the accident, there were box cars parked in yard tracks 1 and 2.

11 At Lac-Mégantic, the wye track also served as an access location to an industry serviced by MMA.

Photo 5. Eastward view of the location of the tracks in relation to the first derailed cars: main track (A), yard track 1 (B), yard track 2 (C), yard track 3 (D), and the west and east legs of the wye tracks (E and F)


The track and crossing infrastructure was damaged as follows:

- The damage to the main track started approximately 20 feet east of Frontenac Street.
- The main-track turnout, approximately 400 feet of main track, and an additional 2000 feet of yard and wye tracks, including 3 turnouts, were destroyed.
- Approximately 500 feet from the crossing, the main track was shifted about 4 feet to the north.
- Yard tracks 1 and 2 were demolished from the west-end turnout for about 600 and 500 feet, respectively.
- Rails were curled and twisted, unsettled from tie plates, and moved randomly. Due to the severity of the fire, most track components were badly damaged.
- The Frontenac Street southeast public-crossing cantilever mast and the control box were shattered. Road traffic lights, electrical wires, lighting posts, and other appliances were also damaged.

The derailed equipment at the Lac-Mégantic site consisted of 2 box cars and 63 loaded tank cars.

The derailed equipment came to rest as follows:

- The buffer box car, which had a broken knuckle from a torsional overstress on the leading end (Engineering Laboratory Report LP184/2013), and the first 3 derailed tank cars were on their sides, jackknifed, and partially coupled. They came to rest close to each other and came in contact with the 7 box cars in yard track 2, derailing 1 of the standing box cars.

- The fourth and fifth derailed tank cars were also on their sides, jackknifed, and resting between yard tracks 2 and 3, about 50 feet north of the main track. They were separated by 125 feet from the preceding cars and had struck a pile of rails stored in the yard.
- The sixth and seventh derailed tank cars, still coupled together, came to rest near yard track 3, about 150 feet north of the main track.
- The eighth derailed tank car was uncoupled and came to rest in a wooded area between yard track 3 and the west leg of the wye.
- All of the remaining derailed tank cars came to rest in a large pileup toward the west leg of the wye, with the last derailed car coming to rest on the Frontenac Street crossing. The ninth and tenth cars stayed coupled and aligned with the roadbed. The next 53 cars came off their trucks, jackknifed, and were severely damaged. The debris from the derailed equipment was confined to the derailment site. Most of the wheel sets and trucks were found on the south side of the pileup, within approximately 400 feet from the Frontenac Street crossing. There were no reports of any pieces of tank cars being projected away from the downtown area.

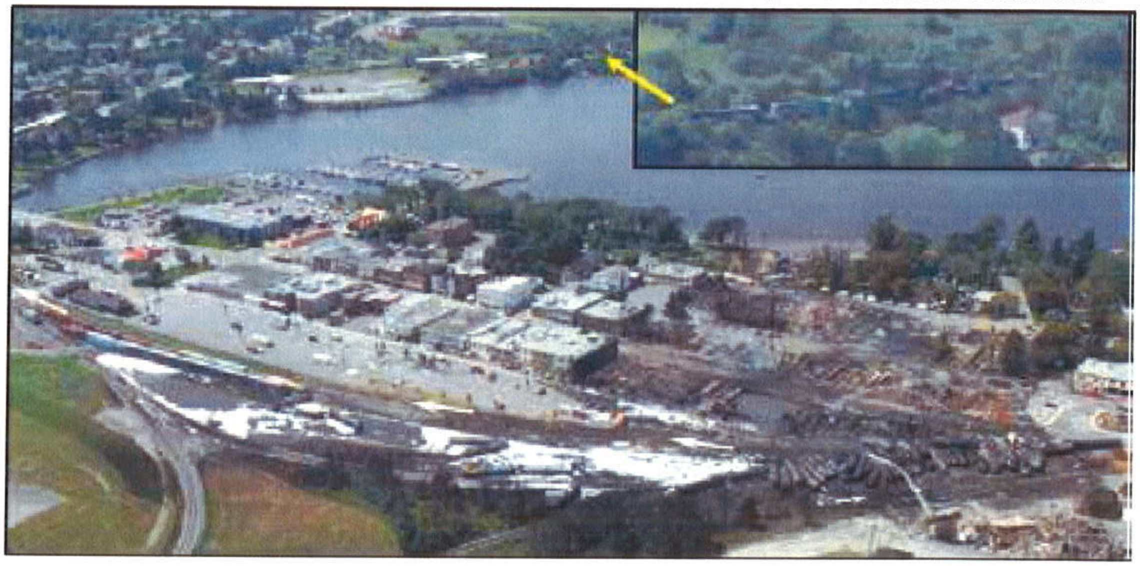
The last 9 tank cars on the train were still coupled to the last derailed car, but did not derail.

Examination of the derailed equipment determined that a hand brake had been applied on the buffer car. No hand brakes were found to have been applied on any of the tank cars.

### 1.8.3 *Location of the locomotive consist*

The locomotive consist came to rest approximately 4400 feet east of the Lac-Mégantic derailment site, at Mile 116.41 of the Moosehead Subdivision (Photo 6).

Photo 6. Location of the locomotive consist (Mile 116.41 of the Moosehead Subdivision) in relation to the derailment site. The white arrows denote the route of the locomotive consist, which followed the main track.



At this location, the track ran parallel to d'Orsennens Street. During site examination, the following was noted:

- There was no damage to the track between the derailment site and the location of the locomotives.
- There was a black oily residue, similar to the residue observed at Nantes, on the ground adjacent to the lead locomotive (MMA 5017), as well as about 600 feet east of where the locomotives came to rest.
- Hand brakes were applied on all 5 locomotives and the VB car.
- There was severe wear on some of the brake shoes and various degrees of blueing[12] on most of the wheels.
- One of the knuckles connecting the second locomotive (MMA 5026) and the third locomotive (CITX 3053) was broken, and a locomotive connector cable had been pinched between the knuckles (Photo 7), indicating that a separation had occurred and the consist had rejoined.
- A broken piece of the knuckle was found under the second locomotive, approximately 15 feet from the coupling (Photo 8). The locomotive knuckle and pin failed in tensile overstress mode, initiating at pre-existing fatigue cracks (Engineering Laboratory Report LP184/2013).

---

12 Blueing is a blue discolouration of steel surfaces that is indicative of exposure to heat. On railway wheels, tread blueing is caused by the frictional heat generated during a heavy or extended brake application.

Photo 7. Pinched connector cable between couplers of second and third locomotives (occurring after the accident)

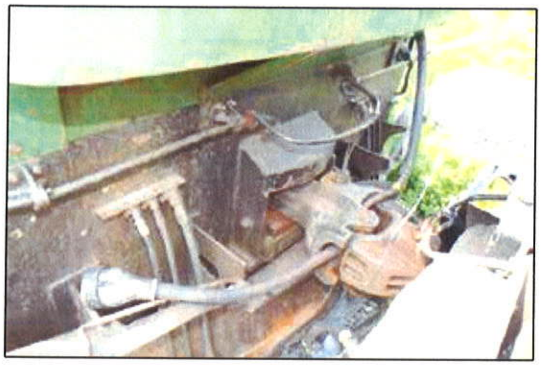


Photo 8. Broken locomotive knuckle segment found under the second locomotive

## *1.9 Train air brakes*

Trains are equipped with 2 air brake systems: automatic and independent. The automatic brake system applies the brakes to each car and locomotive on the train, and is normally used during train operations to slow and stop the train. Each locomotive is equipped with an independent brake system, which only applies brakes on the locomotives. Independent brakes are not normally used during train operations, but are primarily used as a parking brake.

### *1.9.1 Automatic brakes*

A train's automatic braking system is supplied with air from compressors located on each operating locomotive. The air is stored in the locomotive's main reservoir. This reservoir supplies approximately 90 pounds per square inch (psi) of air to a brake pipe that runs along the length of the entire train, connecting to each locomotive and individual car. Air pressure changes within this brake pipe activate the brakes on the entire train.

When an automatic brake application is required, the LE moves the automatic brake handle to the desired position. This action removes air from the brake pipe. As each car's air brake valve senses a sufficient difference in pressure, air flows from a reservoir located on each car into that car's brake cylinder, applying the brake shoes to the wheels.

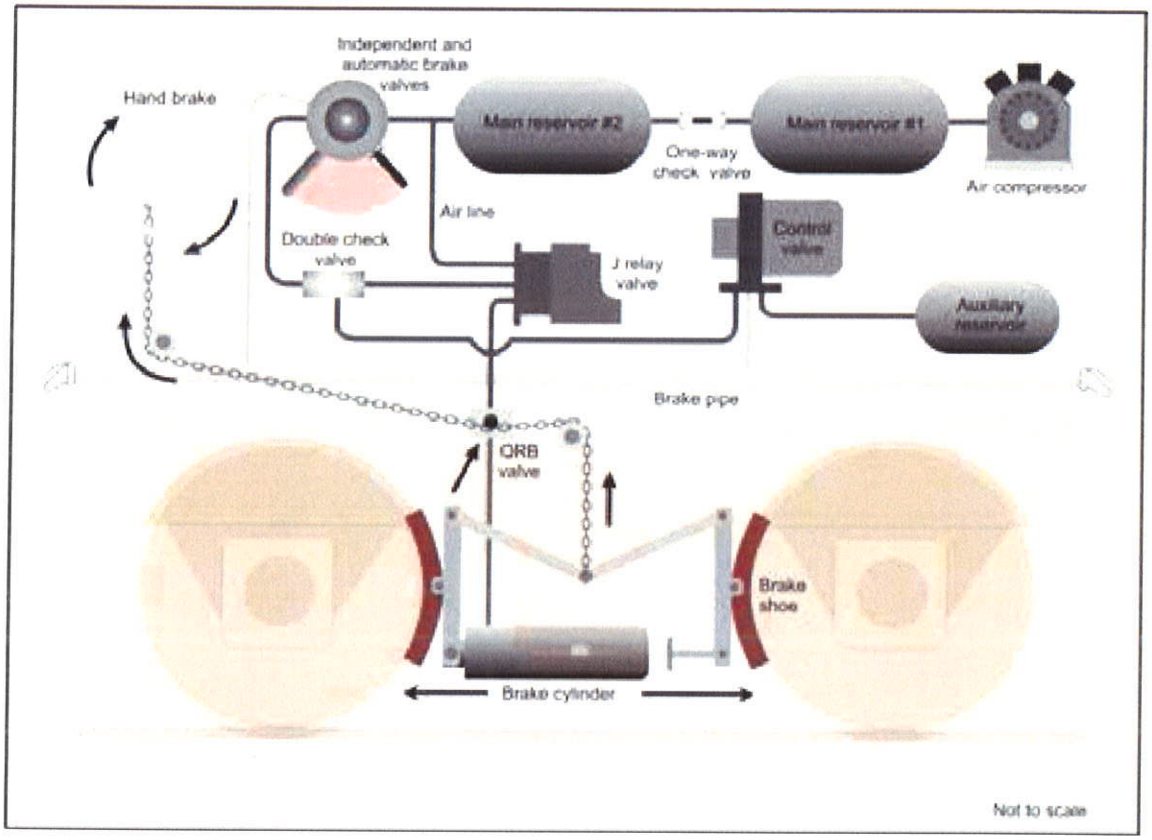
In order to release the brakes, the LE moves the automatic brake handle to the release position. This action causes air to flow from the main reservoir on the locomotive into the brake pipe, restoring pressure to 90 psi. Sensing this, each car's brake valve allows air to be released from its brake cylinder, and the shoes are removed from the wheels.

### *1.9.2 Independent brakes*

The independent brakes are also supplied with air from the main reservoir. When an independent brake application is required, the LE moves the independent brake handle, which in turn injects up to 75 psi of air pressure directly from the main reservoir into the brake cylinders of the locomotive. This causes the brake shoes to apply to the wheels (Figure 4).

To release the independent brakes, the LE moves the independent brake handle to the release position. This causes air to be released from the locomotive's brake cylinders, and the shoes are removed from the wheels.

Figure 4. Schematic of the locomotive air brake and hand brake




## 1.9.3 *Penalty brake application*

A penalty brake application is similar to a full automatic brake application. However, this type of braking further reduces the brake pipe pressure to zero, requiring a moving train to stop and recharge the brake pipe. This type of braking occurs as a result of a "penalty" applied by the system, such as when the reset safety control (RSC) is not reset. This application occurs at a rate that does not deplete all of the air in each car's reservoir.

## 1.9.4 *Emergency brake application*

An emergency brake application is the maximum application of a train's air brakes, during which the brake pipe pressure is rapidly reduced to zero, either from a separation of the brake pipe or operator-initiated action. Following an emergency brake application, a train's entire air system is depleted.

Brake pipe pressure below 40 psi cannot be relied upon to initiate an emergency brake application.

### 1.9.5 Leakage

When locomotives are shut down, the air compressors are also shut down and no longer supply air to the train. Given that the system has many connections, which are prone to air leaks, the main reservoir pressure will slowly begin to drop soon afterward.

Because the main reservoir supplies air to the entire system, when its pressure falls to the level of that in the brake pipe, the pressure in both components will thereafter diminish at the same rate. This sequence also occurs when the main reservoir and brake pipe reach the same pressure as that in the brake cylinder, at which point all 3 will lose pressure at the same rate.

As the air in the brake cylinder decreases, the amount of force being applied to the locomotive wheels by the independent brakes is reduced. If the system is not recharged with air, the brakes on the locomotives will eventually become completely ineffective.

## 1.10 Train hand brakes

In addition to a train's air brake system, all locomotives and rail cars are equipped with at least 1 hand brake, which is a mechanical device that applies brake shoes to the wheels to prevent them from moving or to retard their motion (Photo 9). Typically, hand brakes consist of a hand brake assembly, which designates the B-end of each car. When the wheel on the hand brake assembly is tightened, the brakes are applied.

The effectiveness of hand brakes depends on several factors, including hand brake gearing system lubrication and lever adjustment. Also critical is the force exerted by the person applying the hand brake, which can vary widely from one person to another. For example, railway standards are based on an application of 125 pounds of force on the outside rim of the hand brake wheel. However, previous TSB investigations have noted that, on average, employees apply 80 to 100 foot-pounds of force.

Photo 9. Hand brake assembly and wheel at the B-end of a tank car


## *1.10.1 Hand brake requirements*

### *1.10.1.1 Locomotives*

There are no requirements for a locomotive to hold any other equipment when the hand brake is applied. On many locomotives, including the ones in this accident, when the hand brake is applied, only 2 of as many as 12 brake shoes are applied to the locomotive wheels.

For locomotives placed in service after 04 January 2004, the Federal Railroad Administration (FRA) in the United States requires that the hand brake(s) alone be capable of holding a locomotive on a 3% grade. This equates to a net braking ratio[13] of approximately 10%. Although there were no such requirements prior to 2004, locomotive manufacturers generally designed locomotive hand brakes to meet the 3% holding capacity.

---

13 The brake ratio reflects the amount of brake shoe force being applied on a rail car or locomotive relative to its gross loaded weight. For example, a total of 26 000 pounds of brake shoe force applied to the wheels of a rail car weighing 260 000 pounds equates to a braking ratio of 10%.

#### 1.10.1.2 Cars

According to Standard S-401 (Brake Design Requirements) of the Association of American Railroads' (AAR) *Manual of Standards and Recommended Practices* (MSRP), the force applied to the wheels by the brake shoes must be equal to about 10% of the car's gross load weight, with 125 pounds of force applied to the outside rim of the hand brake wheel.

Unlike hand brakes on many locomotives, hand brakes on cars normally apply all brake shoes (typically 8) to the wheels.

## 1.11 Hand brake effectiveness test

In order to verify that the hand brakes applied are sufficient to secure the train, crews were required to perform a hand brake effectiveness test, in accordance with CROR 112 (b), to ensure that the equipment will not move. After applying the hand brakes, the test is performed by releasing all of the air brakes and allowing the slack to adjust under gravity, or by attempting to move the equipment slightly with reasonable locomotive force.

If the hand brakes prevent the equipment from moving, then they are determined to be sufficient. If not, additional hand brakes must be applied and the process repeated until a successful effectiveness test has been completed.

Special instructions of some Canadian railway companies, including MMA, permitted the hand brakes on the locomotive consist to be included in the minimum required number of hand brakes. For example, if a company's special instructions required at least 10 hand brakes to be applied, and the train were operating with 4 locomotives, then only 6 hand brakes were required to be applied on the cars in addition to those on the locomotives. During an effectiveness test performed with hand brakes applied on the locomotive consist, the LE has to overcome the braking force on the locomotives before moving the rest of the train.

## 1.12 Rules and instructions on securing equipment

### 1.12.1 Rule 112 of the Canadian Rail Operating Rules

The CROR are the rules by which Canadian railways under federal jurisdiction operate, which include MMA's Canadian operations. At the time of the accident, CROR 112 stated the following, in part:

> (a) When equipment is left at any point a sufficient number of hand brakes must be applied to prevent it from moving. Special instructions will indicate the minimum hand brake requirements for all locations where equipment is left. If equipment is left on a siding, it must be coupled to other equipment if any on such track unless it is necessary to provide separation at a public crossing at grade or elsewhere.[14]

---

[14] Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR), 112: Securing Equipment, (a).

To ensure that there was sufficient retarding force to prevent a train or cars from moving unintentionally, CROR 112 required the effectiveness to be tested when hand brakes were used to secure the equipment. The rule stated:

> (b) Before relying on the retarding force of the hand brake(s), whether leaving equipment or riding equipment to rest, the effectiveness of the hand brake(s) must be tested by fully applying the hand brake(s) and moving the cut of cars slightly to ensure sufficient retarding force is present to prevent the equipment from moving [. . .][15]

In addition to CROR 112, MMA employees were governed by the special instructions in MMA's *General Special Instructions* (GSIs) and *Safety Rules*.

Since MMA operated in former CPR territory, it adopted CPR's General Operating Instructions (GOIs).[16]

### 1.12.2 *Montreal, Maine & Atlantic Railway's General Special Instructions on Rule 112*

Section 112-1 (Hand Brakes) in MMA's GSIs provided instructions on the minimum number of hand brakes required, and stated in part:

> Crew members are responsible for securing standing equipment with hand brakes to prevent undesired movement. The air brake system must not be depended upon to prevent an undesired movement.
>
> [...]

| **Cars** | **Handbrakes** | **Cars** | **Handbrakes** |
|---|---|---|---|
| 1 - 2 | 1 Hand Brake | 50 - 59 | 7 Hand Brakes |
| 3 - 9 | 2 Hand Brakes | 60 - 69 | 8 Hand Brakes |
| 10 - 19 | 3 Hand Brakes | 70 - 79 | 9 Hand Brakes |
| 20 - 29 | 4 Hand Brakes | 80 - 89 | 10 Hand Brakes |
| 30 - 39 | 5 Hand Brakes | 90 - 99 | 11 Hand Brakes |
| 40 - 49 | 6 Hand Brakes | 100 - 109 | 12 Hand Brakes |

> Note: [...] If conditions require, additional hand brakes must be applied to prevent undesirable movement.[17]

The numbers in the table are commonly referred to by MMA employees as the "10% + 2" instruction.

Section 112-2 (Hand Brakes: Reduced Minimum Number, Designated Specific Locations) provided specific locations where the minimum number of hand brakes had been reduced.

---

15 Ibid., 112(b).

16 Montreal, Maine & Atlantic Railway (MMA) decided to use Canadian Pacific Railway's (CPR) General Operating Instructions (GOIs), and decided how to apply and interpret any instruction.

17 Montreal, Maine & Atlantic Railway (MMA), *General Special Instructions* (First Edition, 01 March 2012), Section 112-1: Hand Brakes.

For example, at Sherbrooke, between cautionary limit signs, including the main track and sidings, and at Farnham, the minimum number of hand brakes equated to approximately 10%. For Megantic Yard, the required number was less than 10%.

### 1.12.3 *Montreal, Maine & Atlantic Railway's Safety Rules on Rule 112*

MMA's Safety Rule 9200 (Sufficient Number – Operating Hand Brakes) stated in part:

> Employees must:
>
> a. Know how to operate the types of hand brakes with which various types of cars are equipped.
>
> [...]
>
> c. Before attempting to operate handbrake, make visual inspection of brake wheel, lever, ratchet and chain.
>
> [...]
>
> f. **Be aware of and work within the limits of your physical capabilities and do not use excessive force to accomplish tasks. Past practices that do not conform to the rules are unacceptable.**[18]

MMA's Safety Rule 9210 stated in part:

> h. All hand brakes shall be fully applied on all locomotives in the lead consist of an unattended train.
>
> i. When leaving railway equipment, the minimum number of hand brakes must be applied as indicated in the following chart.[19] Additional hand brakes may be required; factors which must be considered are:
>
> Total Number of Cars
>
> Empties or Loads
>
> Weather Conditions
>
> Grade of Track
>
> [...]
>
> k. In reference to the minimum number of hand brakes in the preceding chart,[19] it is acceptable to include the hand brakes applied on locomotives.

---

[18] Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Sufficient Number – Operating Hand Brakes, 9200. (Bold text in original.)

[19] The chart was not included in the *Safety Rules*.

[...]

m. There may be situations where all hand brakes should be applied.

[...]

o. To ensure an adequate number of hand brakes are applied, release all air brakes and allow or cause the slack to adjust. It must be apparent when slack runs in or out, that the hand brakes are sufficient to prevent that cut of cars from moving. This must be done before uncoupling or before leaving equipment unattended.[20]

### 1.12.4 *Instructions of Class 1 railways regarding Rule 112 of the Canadian Rail Operating Rules*

#### 1.12.4.1 *Canadian Pacific Railway*

Prior to early 2013, CPR's instructions for determining the minimum number of hand brakes were to divide the number of cars to be left unattended by 10, and then add 2. The instructions also included the requirement to secure each locomotive left unattended with its hand brake. When a train was to be left unattended with the locomotive(s) attached, it was acceptable to include the locomotive hand brakes as part of the minimum required number of hand brakes.

Prior to the accident, CPR modified its hand brake instructions, no longer specifying the minimum number of hand brakes. Crews were responsible for evaluating their train and other operating conditions to determine the sufficient number of hand brakes and for testing their effectiveness before the equipment was left unattended.

In addition, section 2.0 of CPR's GOIs still stated that on light, heavy, and mountain grades,[21] a specific number of hand brakes (higher than the minimum) was required when a hand brake effectiveness test could not be performed. For example, on grades between 1.0% and 1.29%, hand brakes were required on 25% of the train. Additionally, in some territories, an increased number of hand brakes had to be applied when a movement was stopped on a grade.

#### 1.12.4.2 *Canadian National*

At Canadian National (CN), the hand brake instructions in effect at the time of the accident for rail cars left unattended were:

- Divide the number of cars on the train by 10 and add 1 additional hand brake, up to a maximum of 5 hand brakes.
- If the hand brake effectiveness test is not successful, more hand brakes are required to ensure that the movement remains immobilized.

---

[20] Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Sufficient Number - Operating Hand Brakes, 9210.

[21] Light grades are below 1.0%, heavy grades are between 1.0% and 1.8%, and mountain grades are above 1.8%.

- Certain locations outlined in CN's timetable required double (up to a maximum of 10) the number of hand brakes, depending on the track characteristics.
- Trains with locomotives attached with at least 1 locomotive running can be left on the main track with only 1 locomotive hand brake applied, provided that there is brake continuity throughout the train, the automatic air brakes are fully applied and the independent brakes are applied.[22]

In addition to the above instructions, CN special instructions for leaving trains or transfers unattended on mountain grade territory were as follows:

- Every effort must be made, including RTC pre-planning, to avoid leaving trains or transfers in steep grades in excess of 0.75%.
- When absolutely necessary, a sufficient number of hand brakes must be applied to prevent any unintended movement caused from possible brake cylinder leak-off.
- The automatic air brakes must not be solely relied upon to secure equipment against undesired movement.
- Stop with the least amount of air brake application possible.
- Leave locomotives attached with brake pipe continuity throughout the train, and do not bleed off cars before applying hand brakes.
- Apply 25% of the train hand brakes on grades between 0.75% and 0.9%, and apply 40% of the train hand brakes on grades up to 1.4%.[23]

Crew members were required to communicate and confirm that they had left the train in accordance with these instructions, and the RTC was to be advised of the number of hand brakes applied.

## *1.13 Recorded information*

### *1.13.1 Locomotive event recorder*

A train's locomotive event recorder (LER) is analogous to a "black box" on an aircraft. The LER monitors and records a number of parameters, including throttle position, time, speed, and distance, as well as pressure within the brake pipe and locomotive brake cylinder. Changes in the brake pipe pressure cause each car to apply (or release) its air brake. In this accident, because the train was unattended, the LER was instrumental in providing key pieces of data.

Table 1 summarizes some important information obtained from the download of the LER on the lead locomotive. Brake pipe pressure is at its maximum at 95 psi (brakes fully released), and locomotive brake cylinder pressure is maximized at 70 psi (full independent brake application). Any drop in brake cylinder pressure indicates a reduction in retarding force.

---

[22] Canadian National (CN), General Operating Instruction (GOI) 7.12.

[23] Canadian National (CN), Regional Special Instructions: Time Table 20, Rule 112 – Leaving Trains or Transfers Unattended, Mountain Grade Territory (effective 01 August 2012).

Table 1. Locomotive event recorder information

| Time | mph | Brake pipe pressure (psi) | Locomotive brake cylinder pressure (psi) | Event |
|---|---|---|---|---|
| 05 July 2013 2249:37 | 0 | 82 | 69 | MMA-002 was stopped at Nantes using a 13-psi automatic brake application, and the independent brakes were fully applied. |
| 2303:48 | 0 | 94 | 69 | The automatic brakes were released. The locomotive independent brakes remained fully applied. |
| 2358:42 | 0 | 95 | 69 | Lead locomotive MMA 5017 was shut down. |
| 06 July 2013 0005:55 | 0 | 94 | 70 | Brake pipe pressure began to decrease, and continued to decrease at an average rate of 1 psi per minute. |
| 0013:55 | 0 | 79 | 69 | Independent brake cylinder pressure began to decrease at the same rate as the brake pipe pressure. |
| 0058:21 | 1 | 32 | 27 | MMA-002 began to run away. |
| 0115:30 | 65 | 16 | 14 | The highest recorded speed of 65 mph was attained. |
| 0115:31 | 65 | 0 | 14 | Brake pipe pressure dropped to 0 psi as the cars began to derail. The locomotive consist separated into 2 sections. |
| 0117:12 | 0 | 0 | 6 | The first section stopped 5016 feet east of the point of derailment, at Mile 116.30 of the Moosehead Subdivision, on a 1% ascending grade. |
| 0245:06 | 1 | 0 | 0 | The first section of the locomotive consist began to move backwards (west) down the grade toward downtown Lac-Mégantic. |
| 0246:23 | 8 | 0 | 0 | The first section of the locomotive consist travelled 475 feet west and struck the stationary second section of the consist. |
| 0246:42 | 0 | 0 | 0 | The 2 sections rejoined and moved an additional 106 feet west before coming to a final stop. |

### *1.13.2 Sense and braking unit*

The sense and braking unit (SBU) is a device placed on the rear of the train and is connected to the train brake pipe. The SBU senses train movement, monitors brake pipe pressure, and sends the information to the locomotive, where it is displayed in the cab. The SBU can also be used to initiate an emergency brake application from the end of the train.

The SBU data from MMA-002 were downloaded (Engineering Laboratory Report LP132/2013). The SBU data and crossing download data were used to corroborate the LER data. An analysis of the SBU data determined that when the SBU first recorded movement (start-to-move) at Nantes, brake pipe pressure at the rear of the train was 29 psi.

Approximately 16 minutes and 40 seconds after the train began to move, the brake pipe pressure at the rear of the train had diminished to 0 psi.

## *1.14 Brake testing conducted by the Transportation Safety Board*

### *1.14.1 Air brake and hand brake tests using similar locomotives and tank cars*

A train similar to MMA-002 was assembled to test braking system performance. The train consisted of 5 locomotives (2 GE C30-7s, 2 GE C39-8s, and 1 GM SD-40), 1 VB car, and 80 Class 111 tank cars. The first test was conducted to determine the time required to manually shut down the 4 trailing locomotives and apply hand brakes. The test results are summarized in Table 2.

Table 2. Time required to shut down the 4 trailing locomotives and apply hand brakes

| Number of locomotives shut down | Number of hand brakes applied | Time |
|---|---|---|
| 4 | 7 | 9 minutes and 20 seconds |
| 4 | 9 | 10 minutes and 55 seconds |
| 4 | 18 | 17 minutes and 20 seconds |

With the locomotives shut down, the brake pipe fully charged with air, the automatic brakes released, and the independent brakes applied, a second test was conducted to understand the effects of a normal loss of air on the brake system. The train brake pipe pressure as well as the locomotive brake cylinder pressure were monitored at different locations on the train. The test results were as follows:

- After 30 minutes, the brake pipe pressure began to drop, and continued to drop at an average rate of approximately 1 psi per minute.
- After 50 minutes, the locomotive brake cylinder pressure began to decrease at the same rate as the brake pipe pressure.
- After 1 hour and 35 minutes, the brake cylinder pressure dropped to 27 psi, the point at which MMA-002 first began to roll.
- Due to the slow decrease in brake pipe pressure, no automatic brake application occurred.

Also, when the electrical breakers were put in the off position, no penalty brake application occurred.

### *1.14.2 Air brake and hand brake tests on the occurrence locomotives*

The locomotives from MMA-002 were moved to the siding at Vachon for examination and testing of the air brakes and hand brakes. This testing included a brake leakage test of the entire consist, a full brake system evaluation for each locomotive, and brake shoe force testing.

The first test determined that, starting from a fully charged brake system, the brake cylinder pressure dropped to 27 psi in 1 hour and 6 minutes due to air leakage.

The second test evaluated the braking performance of each locomotive and its components. Appendix C identifies the sources of measurable air leakage for each locomotive.

Locomotives are expected to leak air from their systems once they are shut down, yet the amount of time it takes for the independent brakes to leak off is highly variable. While leakage was noted, and was sometimes excessive on several components, it did not exceed the pressure-maintaining capabilities of the locomotives, and the combined leakage was within industry norms. Nevertheless, as a result of the above tests, 5 valves, including the quick release brake (QRB) valve, were removed for further analysis. The majority of the defects with the valves were related to the age and condition of their internal components (rubber seals, O-rings, return springs, etc.). See Engineering Laboratory Report LP185/2013 for complete details on the condition of the valves.

#### 1.14.2.1 *Quick release brake valve*

On GE C30-7 locomotives, the brake cylinder for the brake shoes applied by the hand brake is equipped with a QRB valve. The QRB valve is normally tripped during the application of the hand brake by the brake chain. When tripped, the QRB valve removes air from the brake cylinder so that an effective hand brake can be applied (Photo 10 and Photo 11).

Photo 10. QRB valve used to exhaust brake cylinder air during hand brake application

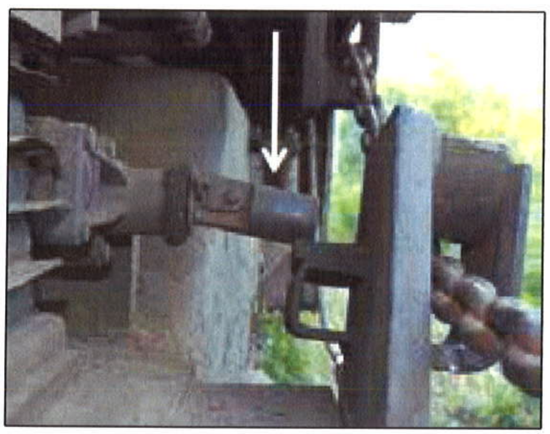


Photo 11. As the hand brake is tightened, the upward movement is intended to activate the release mechanism on the QRB valve.

The QRB valve on the second locomotive (MMA 5026) did not trip to exhaust brake cylinder air when tested. An examination of the valve showed wear and damage to the QRB valve's lifter and inside surface of the retaining disc. In addition, the examination showed that non-standard repairs had been applied to the valve's release mechanism in an attempt to keep the valve working.

If the QRB valve does not trip, the hand brakes will not provide any braking effort. To ensure that the hand brakes remain operational on these locomotives, MMA issued *Summary Operating Bulletin* 2-276, which stated in part:

> The hand brake will not tighten if the air from the R#2 brake cylinder is not exhausted. The handbrake chain will tighten and it may appear that the handbrake is set however if the R#2 brake cylinder is in the "out" position, the handbrake is not applied. On C-30-7 locomotives if an air exhaust is not heard while tightening the handbrake the QRB valve may be malfunctioning or out of adjustment.
>
> It is possible to manually operate the valve from the ground on the right side of the locomotive. The QRB valve and handle is located directly adjacent to the handbrake chain, mounted on the top of the front truck between axles 2 and 3. A crew member can manually trip the valve by use of the lever located on the valve. After tripping the QRB valve the handbrake must immediately be re-tightened.[24]

The LE was not aware of this instruction.

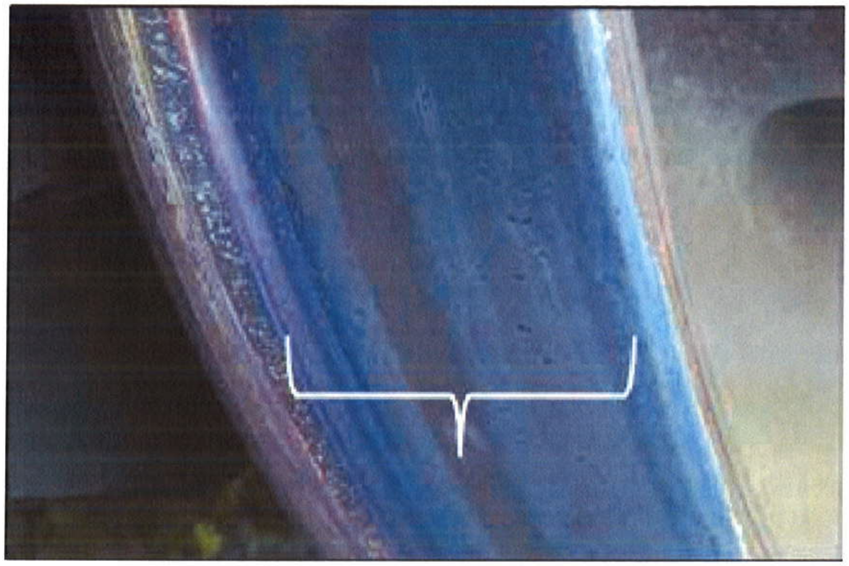
#### 1.14.2.2 *Examination of the wheels and brake shoes on the locomotive consist*

The wheels and brake shoes on the locomotives were examined. The brake shoes were measured to analyze the wear that had occurred during the runaway and to determine the amount of braking force that was being applied (Engineering Laboratory Report LP182/2013). The following was determined:

- Some of the brake shoes had worn through the lining to the backing plate.
- The pattern of wheel blueing (Photo 12) and brake shoe lining wear indicated that the independent brakes had been providing most of the retarding brake force for the train.
- Not all of the wheels subjected to hand brake force (2 per locomotive) showed full tread blueing or excessive brake shoe lining wear. This pattern indicated that these hand brakes had not been, or could not be, applied securely.

[24] Montreal, Maine & Atlantic Railway (MMA), Summary Operating Bulletin No. 2-276 (Effective 01 July 2013), (U) Six Axle C-30-7.

Photo 12. Blueing of locomotive wheel due to heat



### 1.14.2.3 *Brake shoe force testing on the locomotive consist*

An examination of the brake shoe force generated by the locomotive consist was performed with both air brakes and hand brakes (Engineering Laboratory Report 187/2013). Using a coefficient of friction of 0.38 and 100 foot-pounds of torque,[25] the following was determined:

- The total retarding brake force required to hold the train on the grade where it was parked at Nantes was calculated to be approximately 146 700 pounds.
- Before applying the hand brakes, the total retarding brake force generated by the independent brakes was approximately 249 760 pounds.
- After applying the hand brakes (and activating the QRB valves on those locomotives so equipped), the total retarding brake force generated by the independent brakes was approximately 215 500 pounds.
- The total retarding brake force generated by the 7 hand brakes on the train (taking into consideration that the QRB valve did not trip on MMA 5026) was approximately 48 600 pounds. Had the QRB valve been operative, the total retarding brake force would have increased by 4830 pounds.
- At a brake cylinder pressure of 27 psi, when the train first began to move, the retarding brake force of the independent brakes was reduced to approximately 97 400 pounds.
- The average brake ratio of the locomotive hand brakes was approximately 3.8% (range of 3.0% to 4.7%). The average retarding brake force generated by the locomotive hand brakes was approximately 5590 pounds per locomotive. (When 80

---

25 Previous investigations have determined that hand brakes are typically applied with approximately 65 foot-pounds to 80 foot-pounds of torque. During field testing, it was determined that, with reasonable force, hand brakes on these locomotives could be applied with approximately 100 foot-pounds of torque.

foot-pounds of torque were applied, the average retarding brake force was 4360 pounds per locomotive.)

- The brake ratio of the VB car was 19.2%.

### *1.14.3 Hand brake and air brake testing on tank cars*

The air brakes and hand brakes of the 9 tank cars that did not derail were tested and met AAR requirements. The average retarding brake force generated by the hand brakes at 80 foot-pounds of torque was approximately 6920 pounds per car. At 100 foot-pounds of torque, the brake force was approximately 8650 pounds per car.

### *1.14.4 Testing of the sense and braking unit*

Testing was conducted on a rail car to evaluate how the rate of brake pipe leakage affected the car's air brake system. Following simulated brake pipe leakage, the car's brake pipe pressure dropped 5 psi (to 85 psi) in 7 minutes. The car's air brakes did not engage. The car was then recharged to 90 psi, and the test was repeated. In this test, the brake pipe was reduced by 80 psi (to 10 psi) in 75 minutes. The car's air brakes again did not engage.

A turbine-equipped SBU,[26] similar to the one used on MMA-002, was then tested to determine what effect the brake pipe air lost through the SBU would have on the car's air brake system. The venting of air through the SBU caused the air brakes on a single car to engage almost immediately.

Testing was then conducted with a turbine-equipped SBU on a train with 2 locomotives and 71 cars. The test showed that a similar rate of brake pipe air loss through the SBU would initiate a brake application on a train that was 5 cars or fewer, but not on a train longer than 5 cars. Similar to the single-car test, this test demonstrated that brake pipe air pressure on an entire train can be reduced to 0 psi at a slow rate and result in no brake application on the cars.

### *1.14.5 Additional hand brake testing on tank cars*

Railways require that air brakes be fully released on cars prior to the application of hand brakes. However, in some instances, such as when a train is stopped on a grade, it is not possible to release the air brakes before applying the hand brakes. Testing was conducted on a cut of tank cars to determine the effect on the hand brakes from the 13-psi automatic brake application on MMA-002 at Nantes. It was determined that when the hand brakes were applied after an air brake application, more brake force was applied to the wheels. The extent of the additional force was relative to the extent of the brake application. Through this testing, it was also determined that an air brake application of 13 psi would result in hand brake forces approximately 40% higher than the same application without air brakes applied.

---

[26] A turbine-equipped sense and braking unit (SBU) uses brake pipe air to drive a small electrical generator to power the SBU. The air that is used is vented to the atmosphere, and brake pipe air is replaced by the pressure-maintaining feature of the locomotives.

### 1.14.6 *Previous brake testing for other occurrences*

The TSB investigated other runaway train occurrences where extensive hand brake tests were conducted (TSB Rail Investigations R95C0282, R96C0172, and R11Q0056). It was determined that an average of 65 foot-pounds to 80 foot-pounds of torque had been applied on the hand brakes. In one occurrence, the air brakes leaked off and released after approximately 7 hours due to weather conditions. In another occurrence, the majority of the brake cylinders of the cars leaked off after approximately 1 hour following an emergency brake application due to their poor condition. See Appendix D for more information on previous brake testing for other occurrences.

### 1.14.7 *Wiring of the locomotive reset safety control*

New locomotives manufactured since 1986 must be equipped with a reset safety control (RSC). The RSC is a vigilance system that activates alarms and then applies a penalty brake application if it is not reset by the LE, or the controls are not being manipulated within a predetermined time interval. There are no standards for the installation of RSCs. Usually, when the electrical breaker on an RSC is opened or the main electrical power is shut off on a locomotive, a penalty brake application will result. However, when the electrical power was shut off on MMA 5017 at Nantes, the RSC did not create a penalty brake application.

The 3 GE locomotives on MMA-002 were built before 1986 and were retrofitted with an RSC by a previous owner. The locomotives were examined by the TSB (Engineering Laboratory Report LP233/2013), and the following was determined:

- The wiring modifications on the 3 locomotives were not consistent, and the penalty brake performance for all 3 locomotives was different.
- Locomotive MMA 5017 did not produce a penalty brake application under any of the power loss conditions tested. The RSC had been connected directly to the battery. Therefore, the RSC would remain powered even when the main electrical cut-off switch was opened.

Testing of 5 other GE locomotives owned by MMA showed similar variations. In total, no penalty brake application occurred when the electrical breakers were opened on 5 of the 8 locomotives tested. Since there is no requirement for the RSC to initiate a penalty brake application in the event that the power to the device is cut, there is no requirement for this function to be verified during shop inspections.

## 1.15 *Lead locomotive MMA 5017*

Lead locomotive MMA 5017 was a GE model C30-7 that had been placed in service in 1979. It was equipped with a 16-cylinder, turbocharged 4-stroke diesel engine, and generated 3000 horsepower. The locomotive had 2 three-axle trucks and a 26 L-type air brake system. The overall weight of MMA 5017 was approximately 195 tons.

### 1.15.1 *Engine repair and fire on locomotive MMA 5017*

On 07 October 2012, MMA 5017 entered the shop in Derby, Maine, after an engine failure. It was determined that several power assemblies as well as cam segments had been damaged as a result of an articulated rod failure on one of its power assemblies. The engine block had also been damaged at the same cam bearing. On 15 March 2013, the locomotive was returned to the shop, where an oil leak was found at the same cam bearing bore. To repair the leak, the cam bearing mounting bolt at the cam bearing bore was tightened.

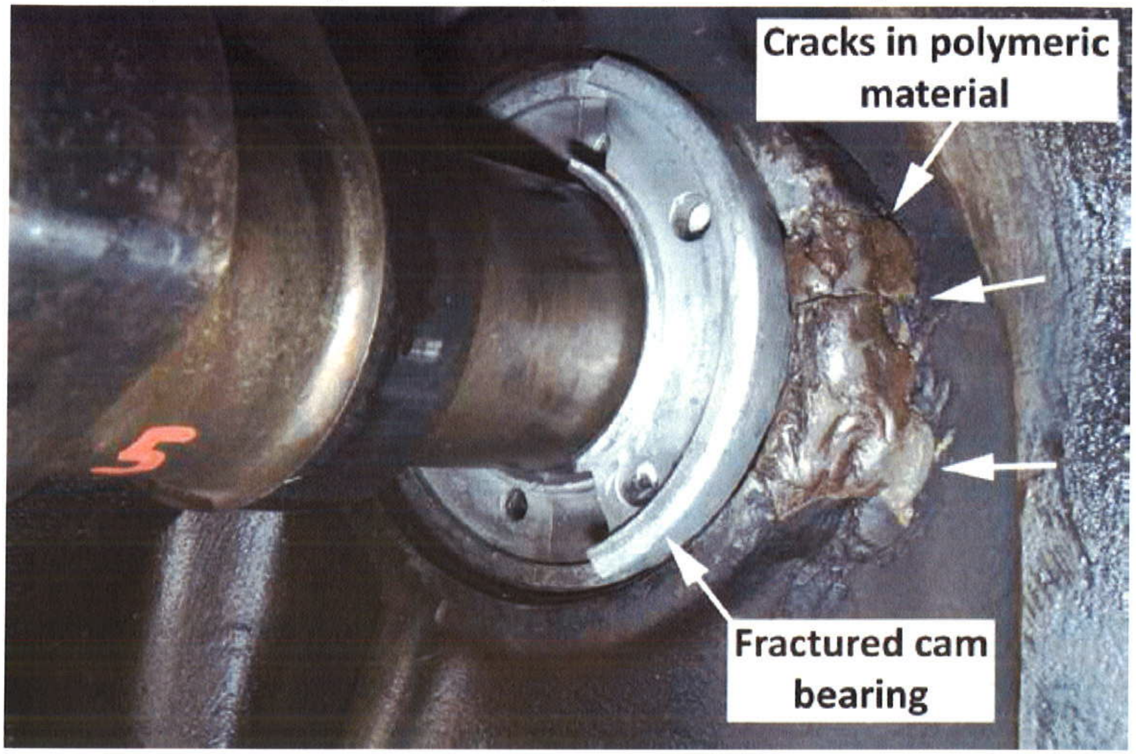
On 04 July 2013, MMA 5017 was in the lead position of MMA-001, being operated by another LE. On the trip from Nantes to Farnham, MMA 5017 was having engine problems. The engine was surging, which was reported by fax to the shop in Derby that day, and verbally to Farnham management the next morning. No action was taken, and MMA 5017 remained in service.

On 05 July 2013, with MMA 5017 in the lead position of MMA-002, the LE reported to the RTC upon departure that there were problems with the engine surging when the throttle was at full. During the trip to Nantes, the engine continued to surge, affecting the LE's ability to maintain a consistent speed. Upon arrival, heavy black and white smoke, as well as oil droplets, were observed coming from the lead locomotive. At 2340, shortly after the LE's departure, a fire ignited in the locomotive smoke stack (Photo 13).

Photo 13. Locomotive fire at Nantes (photo: Nancy Cameron)

Following the accident, the locomotive consist was moved from Lac-Mégantic to a maintenance facility in Saint John for examination. A partial engine teardown of MMA 5017 was conducted (see Engineering Laboratory Report LP181/2013 for complete details). It was determined that the cam bearing had fractured when the mounting bolt was over-tightened after the cam bearing had been installed as part of a non-standard repair to the engine block. This temporary repair had been performed using a polymeric material, which did not have the strength and durability required for this use (Photo 14). Failure of the cam bearing reduced the engine oil supply to the valve train at the top of the associated power assembly. The decreased lubrication led to valve damage and eventually to a punctured piston crown. The damaged valves and piston crown allowed engine oil to flow into the cylinder and the intake and exhaust manifolds. Some of the engine oil collected in the body of the turbocharger. The engine fire later occurred in the exhaust stack due to the build-up and ignition of engine oil in the body of the turbocharger.

Photo 14. Polymeric material applied to cam bearing bore and fractured cam bearing




### 1.15.2 *Abnormal engine conditions*

MMA's Safety Rule 9126 stated:

> When there is an abnormal condition such as noise, smoke or odor coming from engine, the engine should be shut down. Employees must immediately leave the engine room and shut down the engine by emergency "shut down" button at the control stand, control panel or fueling location on either side of the locomotive.[27]

## 1.16 *Defences to prevent runaway trains*

Runaways can best be avoided by selecting a location that would limit the distance travelled by an uncontrolled movement (bowl-shaped tracks for switching) or by ensuring that trains are not left unattended by performance of crew-to-crew exchanges. Due to many factors, such as mechanical breakdowns and severe weather conditions, railways have developed rules regarding the safe securement of equipment. In addition, there are physical defences that provide additional levels of safety, such as:

- Derails—These are usually placed on secondary tracks, and in some cases in sidings, and set in the derailing position to protect the main track from cars that may be rolling uncontrolled. In locations such as the main track, where there are no permanent derails, portable derails weighing about 40 pounds can be carried in a

---

27 Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Working with Locomotives, 9126.

locomotive cab. They can be easily applied by an LE and can provide a physical defence to prevent uncontrolled movements. Portable derails are not commonly used when securing trains on the main track.

- Chocking devices—These portable devices weigh as little as 20 pounds, and can be applied to the rail, directly against the leading wheels of a train. They provide temporary blocking of that equipment. Chocking devices are more commonly used when securing trains on other than main track.
- Mechanical emergency device—This device activates the braking system of a stopped train in the case of an undesired movement. It consists of a clamp that attaches to the rail and to the lead locomotive air brake hose. If the train begins to move, the hose detaches from the locomotive, the brake pipe air is vented, and the emergency brakes are activated.
- Electronically controlled pneumatic (ECP) brakes—This braking system is an alternative to conventional air brakes. The system sends electrical signals to the cars, instantaneously applying the brakes (quick response braking); it does not rely on the flow of air from the locomotive to each car to activate the brakes. Information is also exchanged between the locomotives and each car. When the system senses that the brake pipe pressure has dropped below 50 psi, a "low brake pressure condition" message is initiated. This message results in all of the ECP-equipped cars and the ECP-equipped locomotives automatically applying their brakes in emergency.

Auto-start systems (also known as hot starts) can be installed on locomotives to automatically shut down and restart locomotives for fuel conservation and to protect critical systems. Locomotives equipped with auto-start will automatically shut down when they are idling for a set time and will automatically restart when certain parameters are met, such as when locomotive brake cylinder pressure falls below a prescribed level and when main reservoir pressure falls below 100 psi. However, the auto-start feature would be nullified if the locomotive is set to isolate, or if it has been shut down manually.

Some of the locomotives used by MMA were equipped with an auto-start system, including locomotives CITX 3053 and CEFX 3166. MMA's Summary Operating Bulletin 2-276 states:

> (L) Hot Starts/Locomotive Shut Down: Unless equipped with a working Hot Start, when temperature is above 45 degrees, Engineers must shut down locomotives that will be idling for periods in excess of 15 minutes [....][28]

When MMA crews were leaving trains at Nantes, most would leave the lead locomotive running and shut down all others, including those equipped with the auto-start system. On the night of the accident, the LE manually shut down locomotives CITX 3053 and CEFX 3166.

Operating instructions adopted by MMA on locomotive auto-start systems highlight the importance of ensuring that trains are properly secured and tested, as it is expected that main reservoir, brake pipe, and brake cylinder pressures will eventually leak off.

[28] Montreal, Maine & Atlantic Railway (MMA), Summary Operating Bulletin No. 2-276 (effective 01 July 2013), (L) Hot Starts/Locomotive Shut Down.

The RSC can be upgraded to include a built-in runaway protection feature that initiates an alarm as soon as it detects a movement of 0.5 mph. If the RSC is not reset, a penalty brake application is initiated.

As the SBU, along with the input and display unit (IDU) in the locomotive, serves as a monitor for the air pressure, manufacturers indicated that, with a software update, SBUs could be set up to apply a penalty or emergency brake application before the brake pressure becomes too low to provide effective braking.

## 1.17 *Track information*

### 1.17.1 *Particulars of the track*

In the vicinity of the derailment, the track was continuous welded rail (CWR). The rail was secured with 2 spikes per tie plate in tangent track, and 3 spikes per tie plate in the curves. Most of the rail was Algoma Steel 115-pound RE rolled between 1966 and 1971, except in some curves, where the high rail was rolled and installed in 2003. The rail was laid on 14-inch double-shouldered tie plates. There were approximately 3200 hardwood ties per mile. Every second tie was box-anchored. The ballast consisted mainly of crushed rock and was generally in good condition. There was insufficient ballast, or ballast fouling, noted at 10 locations over a 10-mile distance.

### 1.17.2 *In-train forces, vehicle dynamics, and derailment speed*

MMA-002 ran away eastward and, when approaching Megantic Station, encountered a reverse curve configuration beginning with a 1.5°, left-hand, 670-foot curve with a maximum superelevation[29] of 1 inch, followed by a 60-foot tangent section of track, then a 4.25° right-hand, 1200-foot curve. This curve had a 230-foot-long entry spiral, starting approximately 100 feet west of the Frontenac Street public grade crossing. After the crossing, the turnout at Megantic West provided access to Megantic Yard and its wye tracks. The turnout was a No. 11, 115-pound, left-hand-operated turnout[30] at the end of the entry spiral.

For the right-hand curve section in the vicinity of the derailment, the superelevation (1 inch to 1 ½ inches) corresponded to a balanced speed[31] of between 18 mph and 22 mph. An analysis of the derailment speeds estimated that 10 cars derailed below 40 mph, 5 of which derailed below 30 mph (Engineering Laboratory Report LP039/2014) (Figure 5). Recorded data showed that the derailment took approximately 1 minute (Engineering Laboratory Report LP136/2013).

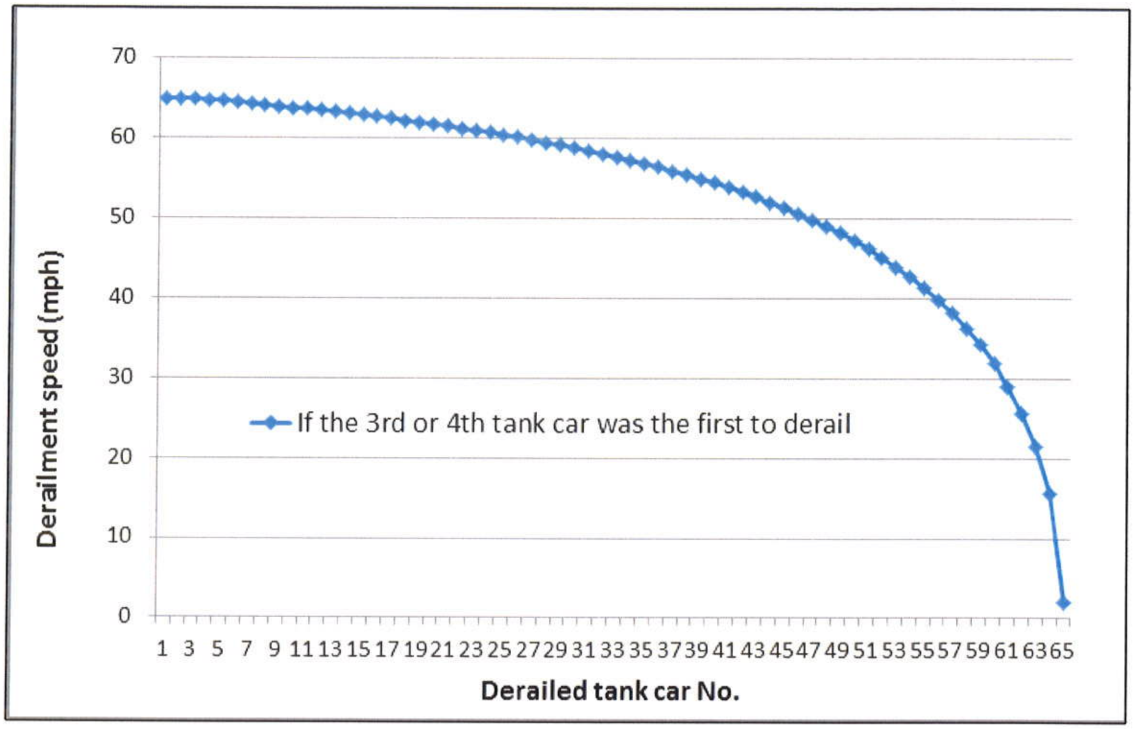
---

29 Superelevation is the difference in elevation (height) between the 2 rails. For the right-hand curve, most of the superelevation varied between 1 inch and 1 ½ inches, except for a 60-foot section where the superelevation reached 3 5/8 inches.

30 A No. 11 turnout turns with a 5°40'44" of curvature.

31 Balanced speed is defined as the speed at which the combination of curvature and superelevation exactly balance the centrifugal acceleration.

Figure 5. Estimated speed at which each car derailed if the third or fourth car was the first to derail[32]




At the time of the derailment, the train was near the Megantic West turnout. The train was analyzed to assess the in-train forces as it transitioned from the downhill grade of 1.26% to the relatively flat terrain of 0.2% at Megantic. A vehicle dynamics simulation of a Class 111 tank car negotiating the curve at Megantic Station was also conducted (see Engineering Laboratory Report LP188/2013 for complete details). It was determined that a combination of the centrifugal force and the dynamic forces generated by the track geometry conditions at a speed of 65 mph was sufficient to cause the derailment. With extremely high lateral forces on the high rail, gauge widening could occur. Furthermore, with complete unloading on the low rail, wheel lift could occur. Either of these conditions or a combination could cause track damage and a derailment.

### *1.17.3 Track inspections by Montreal, Maine & Atlantic Railway*

The main track was regularly inspected as per the TSR. Prior to the accident, MMA performed these track inspections:

- Visual inspection by a track maintenance employee in a hi-rail vehicle was performed on 05 July 2013. During this inspection, no exceptions were noted in the vicinity of the derailment.
- Monthly turnout inspections were performed as required. The most recent turnout inspection was performed on 21 June 2013, and no defects were noted.

32 The derailment speeds of both scenarios are nearly identical. For the last 5 derailed tank cars, there is less than 4% difference in derailment speeds if the third car was the first to derail, versus if the fourth car was the first to derail.

- The track was tested annually for internal rail defects using an automated rail flaw detection system. The most recent rail flaw testing was on 19 September 2012, and no defects were noted in the vicinity of the derailment.
- The track geometry was last tested by a track geometry car on 21 August 2012 (Appendix E).

In the immediate area of the rail joints located between the Frontenac Street public grade crossing and the Megantic West turnout, the track geometry readings for surface, cross-level, gauge, and alignment were measured.

The track geometry readings met the maximum allowable limits for 15 mph. According to the TSR, to operate as Class 2 track, the track had to be improved to meet the 25-mph criteria (within 72 hours after the passage of the track geometry car). Consequently, following the August 2012 track geometry test, the rail joints were lifted to correct the geometry irregularities and restore the track to Class 2 criteria. The fouled ballast was not replaced, and was not compacted with heavy machinery.

### *1.17.4 Post-accident track examination*

The TSB examined sections of track over approximately 30 miles on each side of the town of Lac-Mégantic (that is, between Mile 106.00 of the Moosehead Subdivision and Mile 18.00 of the Sherbrooke Subdivision). The following was observed:

- The rail surface had microcracks, corrugation, and multiple signs of wheel slippage and crushed rail head.
- The rail head on the low rail (that is, inside of the curve) of many curves was flattened and worn.
- The vertical rail wear exceeded the acceptable wear limits at Miles 106.60, 107.50, 110.40, 115.56, and 116.25 of the Moosehead Subdivision, and at Miles 3.00, 16.15, 17.50, and 17.60 of the Sherbrooke Subdivision. The vertical wear was as much as 25 mm (1 inch) in some areas.
- Lateral rail wear could not be accurately measured because of crushed rail head and loss of rail profile condition. At Mile 110.55 of the Moosehead Subdivision, the lateral part of the rail head on the field side was completely worn.
- In the curve at Mile 17.60 of the Sherbrooke Subdivision, the rail showed signs of track buckling (for example, the rail undulated laterally, and the ties had shifted sideways).
- At rail joints with significant vertical rail wear, there was damage to the joint bars due to wheel load impacts (that is, contact with wheel flanges). Wheel flange contacts were observed in the area of the derailment (Photo 15).

**Photo 15. Damaged rail joint bar due to contact with wheel flanges**

## *1.17.5 Rail wear standards at Montreal, Maine & Atlantic Railway*

MMA's track standards were based on standards previously developed by the Bangor & Aroostook Railroad[33] (that is, System Track Standards, Part I, for track maintenance limits, and Part II for construction and maintenance practices).

For rail wear, System Track Standards, Part I, Section 113.5 (b), specifies in part:

> (1) VERTICAL HEAD WEAR
> 115 RE ¾"– Then limit track speed to 25 mph
>
> [...]
>
> (2) GAGE WEAR (is measured five-eighths of an inch below the top of the rail head)
> 115 RE ¾"– Then limit track speed to 25 mph[34]

At MMA, when the vertical rail wear exceeded the limits set out in its Rail Wear Standard, a temporary slow order of 25 mph was placed on the track. This track section would also be identified for its rail replacement program. MMA did not have a vertical head wear limit specific to jointed rail.

In comparison, the rail wear standards for Canadian Class 1 railways are:

- CN's track standards are summarized in Engineering Track Standard (ETS) TS 1.0 – General 13 and 14, June 2011 edition. Based on these standards, the vertical wear

---

33 In 1995, Iron Road Railways acquired Bangor & Aroostook Railroad. In 2003, its lines were sold to RWI, who initially incorporated them into MMA. In 2010, the tracks from Millinocket north to the Canadian border were sold to the State of Maine to be operated by Irving's Maine Northern Railway.

34 Montreal, Maine & Atlantic Railway (MMA), Montreal, Maine & Atlantic Rail Wear Standard, Section 113.5 (b).

limit for 115-pound rail is 16 mm (5/8 inch) for CWR, and 8 mm for jointed rails. For jointed track, high-clearance joint bars must be used to avoid any contact between the wheel flange and joint bar. Rail wear standards do not require replacement of the rail, as long as the wear limit has not been reached. However, the sum of the vertical and flange wear shall not exceed 21 mm (13/16 inch). A speed restriction may be placed and additional inspection frequency specified if rail is worn beyond the limits and is to be left in the track. The condition of rail (for example, shells, spalls, corrugation) must also be taken into consideration if the rail is left in the track.[35]

- CPR's track standards are summarized in the *Red Book of Track Requirements*. These standards specify that the vertical wear limit of 115-pound RE rail is 17 mm (11/16 inch). A varying amount of combined vertical and flange wear is allowed, up to a maximum of 23 mm (7/8 inch). Where rail wear has resulted in joint bars being heavily affected by wheel flanges, the joint must be welded, or a high-clearance bar or compatible worn bar must be applied. Train speed must be restricted to a speed as near as possible to equilibrium speed until the joint is welded or a high-clearance bar is applied.[36]

### *1.17.6 Laboratory examination of track components*

A No. 11 rail-bound manganese frog and other track components were recovered and sent to the TSB Laboratory for examination (Engineering Laboratory Report LP151/2013). It was determined that the wing rails and other components were damaged due to overstress fractures. It was also determined that the vertical rail wear was within allowable limits, and that there were no pre-existing defects or fatigue cracks on the fracture surfaces.

## *1.18 Class 111 tank cars*

In 2013, there were approximately 228 000 Class 111 tank cars in service in North America, of which over 141 000 were being used to transport dangerous goods (DGs). Of those, 98 000 were used to carry Class 3 DGs (flammable liquids). The majority of these tank cars were general-service cars (Figure 6). The specifications applicable to these cars are listed in TC safety standard CAN/CGSB-43.147[37] and the U.S. *Code of Federal Regulations* Title 49 (49 CFR), paragraph 179.200,[38] for Canada and the United States, respectively.

---

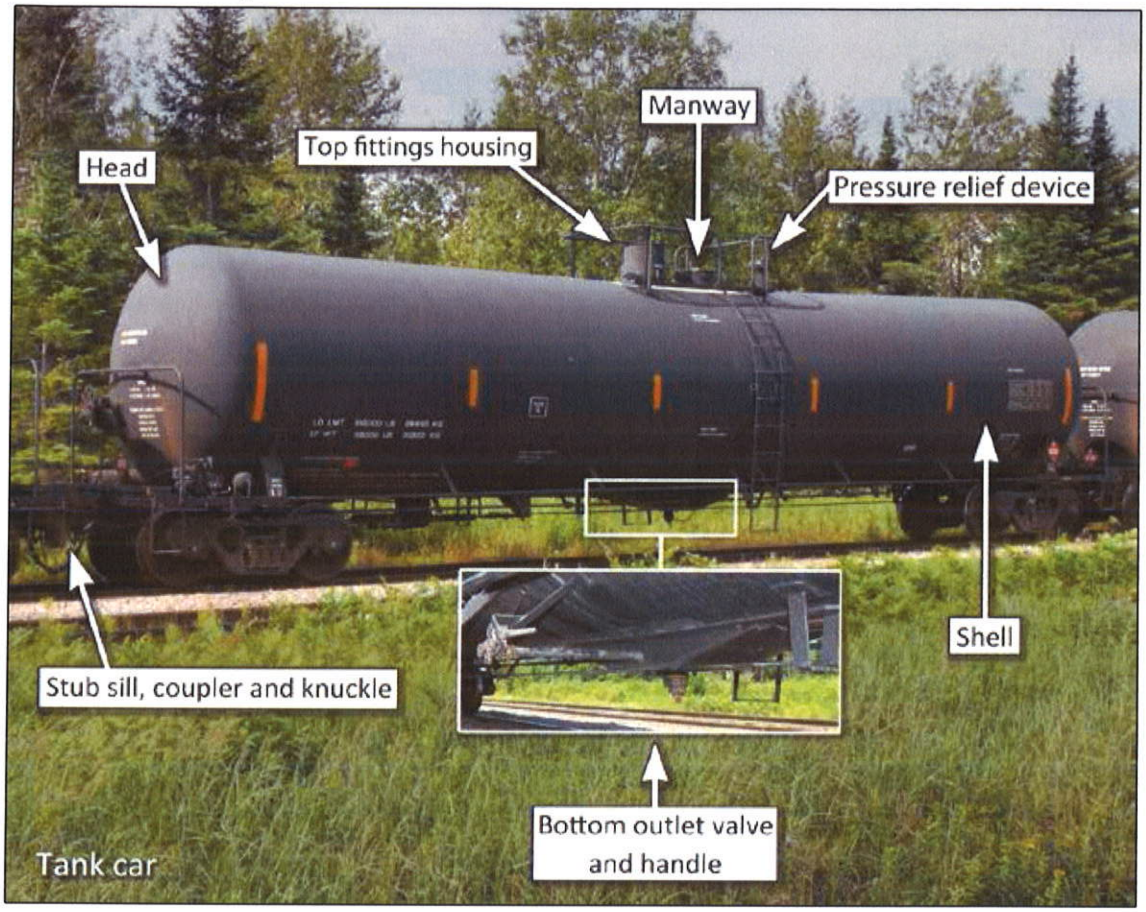
35 Canadian National Railway (CN), Engineering Track Standard (ETS) (June 2011 edition), TS 1.0 – General 13 and 14.

36 Canadian Pacific Railway (CPR), *Red Book of Track Requirements* (2012), sections 6.1.3 and 17, Appendix 6.

37 Section 5.14 of the *Transportation of Dangerous Goods (TDG) Regulations* specifies that a means of containment manufactured, selected, and used in accordance with safety standard CAN/CGSB-43.147, last amended July 2008, is a permitted means of containment for the transportation of Class 3, 4, 5, 6.1, 8, or 9 DGs by rail or by ship.

38 United States *Code of Federal Regulations*, Title 49, Part 179, Specifications for Tank Cars.

Figure 6. Tank car components




### *1.18.1 Examination of the derailed tank cars*

The 63 derailed tank cars were examined in the field (Engineering Laboratory Report LP149/2013), and the following was determined:

- All tank cars were manufactured to United States Department of Transportation (DOT) specification 111A100W1 between 1980 and 2012, and 78% were built in the 5 years prior to the accident.
- All tank cars had been ordered before 01 October 2011.
- None of the tank cars were equipped with head shields, jackets, or thermal protection.
- The shells of 52 tank cars and the heads of 44 tank cars were made of non-normalized steel.[39]
- The shells of 11 tank cars and the heads of 19 tank cars were made of normalized steel.

---

39 Normalization is a type of process used to improve ductility and toughness properties. The steel is heated slightly above its upper critical temperature and then is air cooled. This results in a fine pearlitic structure, and a more uniform structure.

All 63 derailed tank cars were in compliance with the specification requirement that was in effect at the time of their approval and construction.

The stencilling or stamped markings on some of the tank cars was not legible due to fire and impact damage. Furthermore, some tank car identification plates had been affixed with low-melting-point fasteners and had separated from the tank during the post-derailment fire.

### 1.18.2 *Tank car damage assessment*

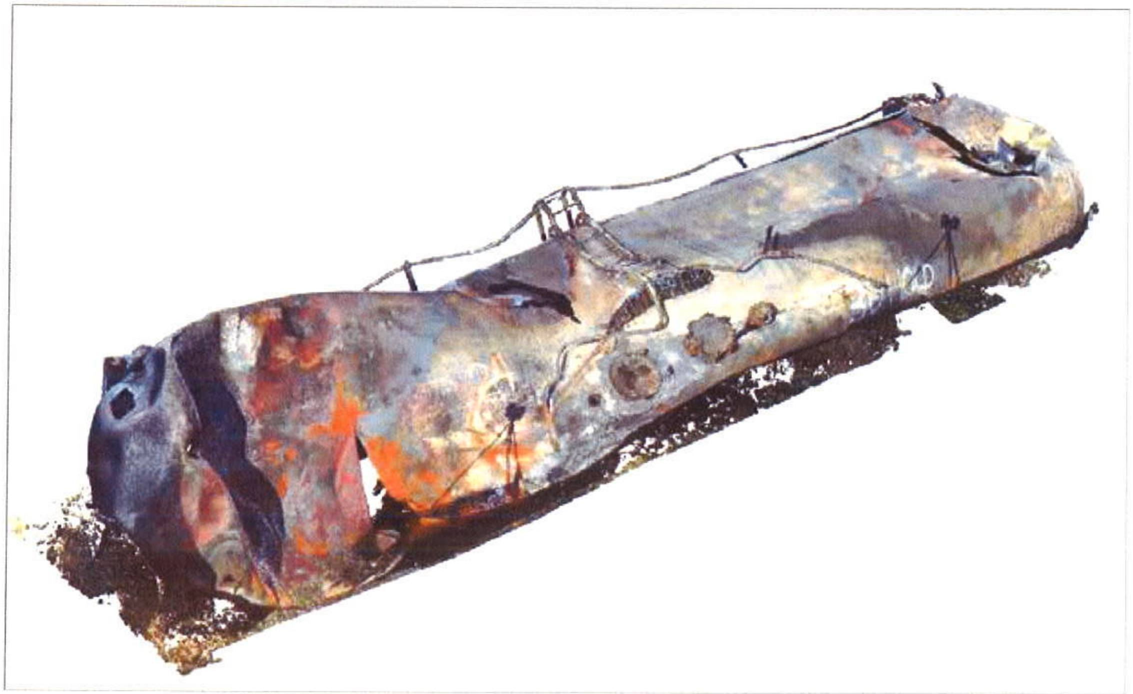
An assessment of the damage sustained by the 63 derailed tank cars revealed that 59 (94%) were breached and released crude oil due to tank damage. The location and extent of the damage varied, depending on the orientation and speed of the cars during the derailment. Many cars sustained damage in multiple locations (Table 3).

**Table 3. Distribution of damage on derailed tank cars**

| | |
|---|---|
| Tank car shells | 37 cars |
| Tank car heads | 31 cars |
| Top fittings and protective housings | 20 cars |
| Pressure relief devices | 12 cars |
| Bottom outlet valves | 7 cars |
| Thermal tears | 4 cars |
| Manway covers | 2 cars |

Three-dimensional (3D) laser scanning was performed on selected derailed tank cars (Engineering Laboratory Report LP165/2013). Analysis of the data revealed that the shells of the tank cars exhibited impact damage ranging from localized buckles to large-scale buckling, and sustained significant reductions in volume (for example, close to 40% reduction in volume was sustained by the most deformed tank) (Photo 16).

Photo 16. 3D laser scan of badly deformed tank



### 1.18.2.1 *Damage to stub sills and couplers*

Stub sills are located at each end of a tank. For cars so equipped, the tank not only carries the product, but is also used as the primary structural member to carry in-train forces. The stub sills contain draft gear components that help absorb in-train dynamic buff (push) and draft (pull) forces, as well as coupler vertical forces (Photo 17).

The field examination showed the following:

- Five tank cars had no impact damage to either the stub sill or coupler.
- Fifty-eight tank cars exhibited at least 1 damaged stub sill or coupler.
- Forty-six tank cars were damaged at both ends of the car, including damage to the stub sill or coupler.
- The last 2 derailed cars exhibited significant impact damage to their stub sills and couplers.
- Nine tank cars exhibited separations at the stub sill attachments (Photo 18).

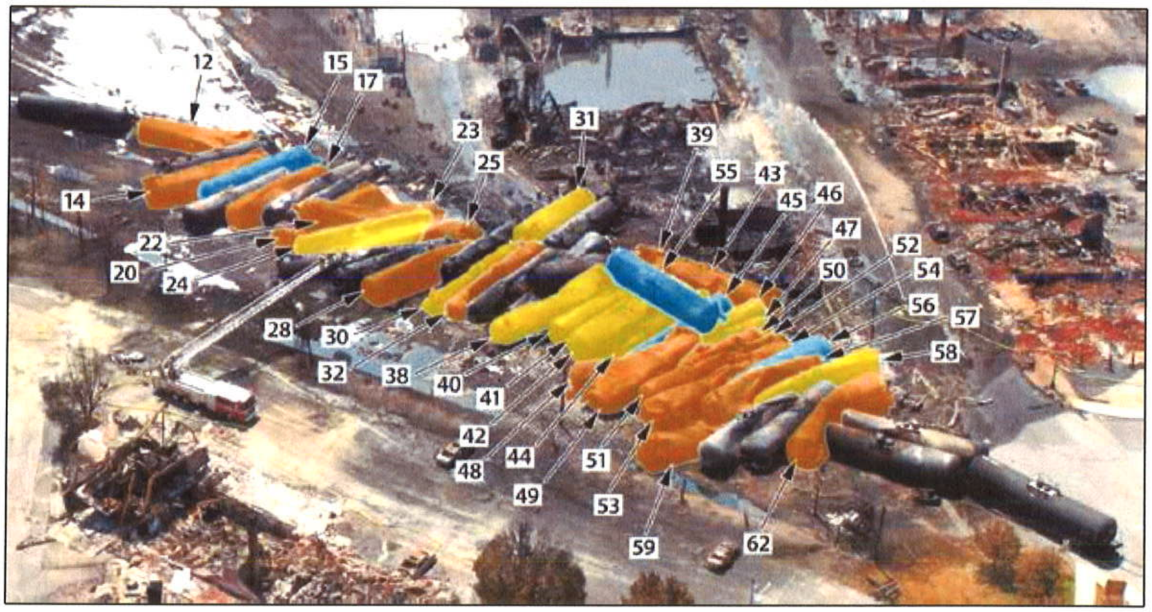
Photo 17. Complete stub sill

Photo 18. Damaged stub sill

### 1.18.2.2 *Damage to tank car shells*

More than half of the tank cars (37 cars) released product due to impact damage to their shells (Photo 19). Other tank car shell damage included deformed/dented shells with no breach, as well as breaches due to thermal tears.

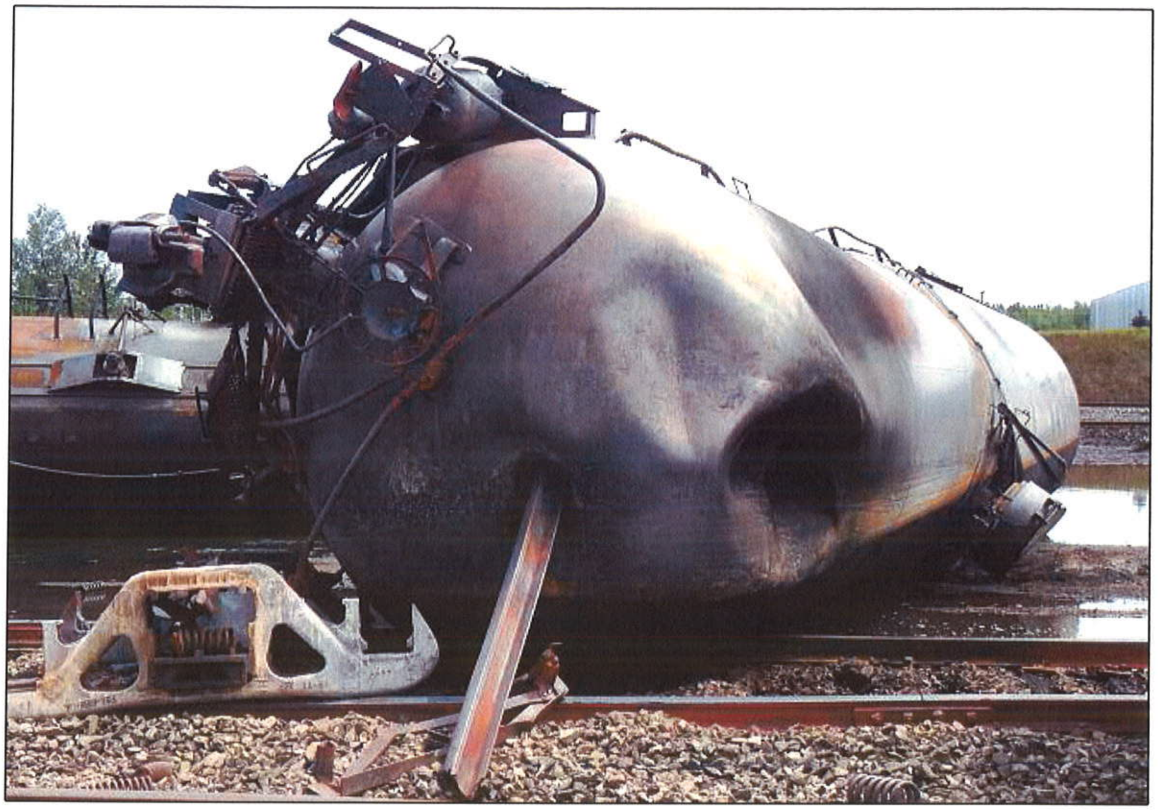
Photo 19. Tank cars with breaches to their shells (colour indicates relative size of breach: orange = large, yellow = medium, blue = small). The relative size of the breaches is also identified in Appendix B.




### 1.18.2.3 *Damage to tank car heads*

All but 4 of the 63 derailed cars exhibited some form of impact damage (for example, denting or breach) in the top portion of at least one head (Photo 20). About half of the tank cars (31) released product due to damage to the tank car head.

Photo 20. Head puncture due to rail impact



*1.18.2.4 Damage to top fittings and housings*

The majority of the tank cars with damaged top fittings came to rest on their sides or upside down, allowing the product to flow from the damaged top fittings and feed the pool fire.

The top fittings of 32 of the 63 tank cars were housed in a ¾-inch-thick steel circular protective housing designed to provide top discontinuity protection in accordance with applicable AAR requirements[40] (Photo 21).

The top fittings of the remaining 31 tank cars were located in a hinged housing that did not have to meet any of the top discontinuity protection requirements (Photo 22).

40 Association of American Railroads (AAR), *Manual of Standards and Recommended Practices* (2007), Specification M-1002, Chapter 2.6: Top Fittings Protection Requirements for Nonpressure Cars.

Photo 21. Protective housing providing top discontinuity protection for tank car fittings (removed cover)

Photo 22. Hinged housing for tank car fittings

The field examination determined the following:

- The top fittings were breached on 4 of the 27 cars (15%) that were equipped with top discontinuity protection housings and that sustained impact damage.
- The top fittings were breached on 16 of the 26 cars (62%) that were equipped with a hinged housing and that sustained impact damage.

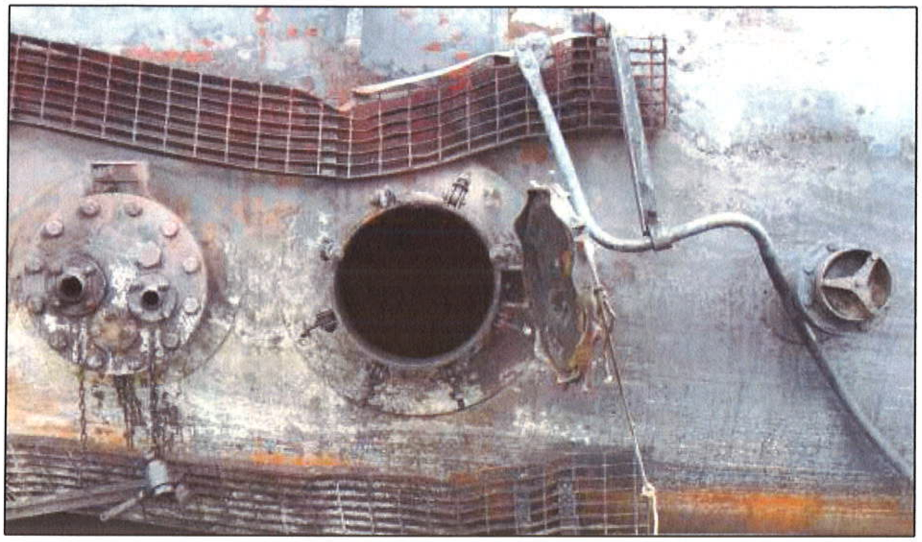
#### 1.18.2.5 *Damage to manway covers*

A manway cover is used to seal the large opening at the top of the tank (Photo 23). This opening is used by personnel to gain entry into the tank for inspection and maintenance activities and, in Class 111 tank cars, may also be used to load product into the tank car. The manway cover is secured to the manway nozzle using a hinge and typically 6 to 8 bolts. It is sealed by tightening the bolts onto a manway cover gasket.

The field examination determined the following:

- The manway gaskets on most of the derailed tank cars were damaged by extended exposure to the post-derailment fire.
- The manway cover of 2 cars had separated as a result of impact damage.
- The manway cover hinges, bolts, or lugs of 22 tank cars exhibited impact damage that may have compromised their seals.

Photo 23. Manway cover and opening



### 1.18.2.6 *Damage to pressure relief devices*

All 63 derailed tank cars were equipped with at least 1 reclosing pressure relief device (PRD),[41] as per the federal regulations.[42] The start-to-discharge (STD) pressure[43] of these PRDs was either 75 psi (on 48 tank cars) or 165 psi (on 15 tank cars). In addition to different STD pressures, PRDs are designed with different flow capacities.[44] A PRD that can discharge product at greater than 27 000 cubic feet per minute (CFM) is considered to have high flow capacity. In this accident, 13 of the 15 PRDs with STD pressure of 165 psi had flow capacities of about 38 900 CFM.

The field examination determined the following:

- Most of the cars with damaged PRDs came to rest on their sides or upside down, putting the PRD in contact with the liquid space inside the tank; product flowed from the damaged PRD and fed the pool fire.
- On 32 cars, the PRD was fastened to the top unloading nozzle assembly within the top discontinuity protection housing. The PRD of 3 of these 32 cars, or 9%, were breached.
- On the 31 other cars, the PRD was fastened to a safety valve nozzle attached to the top of the tank (Photo 24). The PRDs of 9 of these, or 29%, were breached.

---

41 A reclosing pressure relief device (PRD) uses positive pressure from a return spring to keep the PRD valve in a closed position during normal operation. Some cars had 2 PRDs (that is, a PRD located on either side of the top fitting housing and manway).

42 In order to ensure that PRDs are capable of relieving pressure build-up in the tank in prescribed fire conditions, a combination of various parameters and performance standards, such as minimum and maximum start-to-discharge (STD) pressures and minimum flow capacities, are specified.

43 This is the pressure at which the PRD will activate to relieve pressure within the tank.

44 The STD pressure and the flow capacity of a PRD together determine how efficiently the pressure in a tank car tank can be relieved in fire conditions.

Photo 24. Pressure relief device

### 1.18.2.7 *Damage to bottom outlet valves*

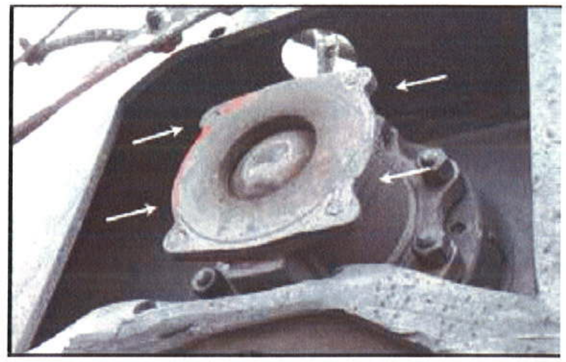
Federal regulations require that tank cars equipped with bottom outlet valves (BOVs) be built to prevent damage to the valve and the subsequent loss of product during a derailment. Design features include various combinations of breakaway designs and skid protection structures around the valve, as well as a locking arrangement to ensure that the BOV stays closed during transit (Photo 25). The AAR *Manual of Standards and Recommended Practices* (MSRP) specification M-1002, Appendix E, section 10.1.2.8, specifies that BOV handles, unless stowed separately, must either be designed to bend or break free on impact or be positioned so that the handles, in the closed position, are above the bottom surface of the skid protection.

The field examination determined the following:

- There were 36 tank cars with sheared-off BOV nozzles (Photo 26).
- Seven of these tank cars had damaged or missing BOV handles, resulting in the ball valve being open or partially open, which led to a release of product.
- Six tank cars were equipped with internal plug-type BOVs. None of these BOVs were breached.
- The BOV handle assemblies of 43 tank cars were deformed, impact-damaged, or missing.

Photo 25. Bottom outlet valve

Photo 26. Bottom outlet valve with sheared-off nozzle



### 1.18.2.8 *Damage due to thermal tears*

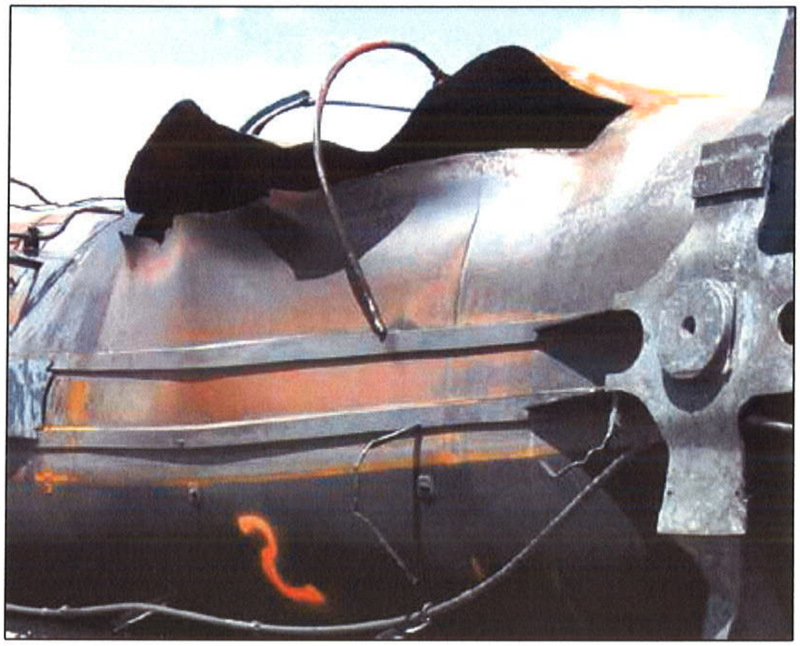
A thermal tear occurs when a tank car is exposed to elevated temperatures such as that from a post-derailment fire. As the temperature inside the tank rises, the product vapourizes, causing an increase in both its internal pressure and the stresses in the tank wall. If the pressure is not relieved, the tank ruptures. Ruptures involving the sudden release of built-up pressure can result in large explosions and fire.

Thermal protection helps delay the rate at which the internal tank temperature rises. It typically consists of an insulating material applied to the exterior of the tank and covered by a steel jacket. Federal regulations specify when thermal protection is required, as well as the performance standard it has to meet (for example, prevention of tank failure for at least 100 minutes in a pool fire and at least 30 minutes in a torch fire). Most general-service Class 111 tank cars are not required to have thermal protection.

Examination of the 63 derailed tank cars showed the following:

- None of the cars were equipped with thermal protection.
- Four cars that had sustained only minor impact damage due to the derailment experienced thermal tears, resulting in an energetic release.
- The length of the thermal tears ranged from 1.6 m to 4.4 m. No fragments of tank material were separated as a result of the thermal tears.
- All of the thermal tears were situated in the vapour space, and the PRDs were located in the liquid space.
- The car with the largest thermal tear (4.4 m) (Photo 27) was equipped with a PRD with an STD pressure of 75 psi, whereas the car with the smallest thermal tear (1.6 m) had a 165-psi PRD.
- Two tank cars experienced a thermal tear within approximately 20 minutes after the fire began.

Photo 27. Thermal tear



### *1.18.2.9 Damage due to burn-through*

Thirteen tank cars had localized loss of tank material in the form of a burn-through[45] as a result of extreme fire damage (Photo 28). In the regions around these perforations, there were jagged edges and the tank material exhibited reduced wall thickness, and in some cases, contained brittle cracks.

Photo 28. Burn-through

45 A burn-through is a perforation of the tank shell caused by fire damage.

### *1.18.2.10 Metallurgical examination of tank cars*

Selected samples were taken from tank cars involved in the derailment and sent for metallurgical analysis (Engineering Laboratory Report LP168/2013). At least 1 tank car from each car builder was selected.

It was determined that the tank car material generally met all applicable specifications at the time of manufacture. The sample examination did not find any material deficiency that would have affected the performance of the tank cars during the derailment.

### *1.18.3 Regulatory activities related to Class 111 tank cars*

Following a TSB investigation[46] into an accident in August 2004 involving a petroleum product unit train near Lévis, Quebec, the Board recommended that:

> The Department of Transport extend the safety provisions of the construction standards applicable to 286 000-pound cars to all new non-pressurized tank cars carrying dangerous goods.
>
> **TSB Recommendation R07-04 (issued 2007)**

Subsequently, an AAR task force examined improvements to tank car safety, and the AAR tank car standards were amended (Casualty Prevention Circular No. CPC-1232)[47] to incorporate a number of enhancements to all Class 111 tank cars built after 01 October 2011 for the transportation of crude oil and ethanol in PG I or PG II. These enhancements include construction of the tank cars to 286 000-pound standards, protection of the service equipment on the top shell, use of reclosing PRDs, use of normalized steel for tank shells and heads, increased minimum thickness for all tank cars not jacketed and insulated, and at least ½-inch half-head shields. As all of the tank cars had been built before October 2011, none were subject to the requirements of AAR Circular No. CPC-1232.

In 2011, the AAR petitioned Canadian and U.S. regulators to adopt these changes in regulations.

In 2012, following the Cherry Valley, Illinois, investigation,[48] the NTSB recommended that the Pipeline and Hazardous Materials Safety Administration (PHMSA):

---

46 TSB Rail Investigation Report R04Q0040

47 Association of American Railroads (AAR), Casualty Prevention Circular No. CPC-1232 (issued 31 August 2011) pertains to cars built for the transportation of PG I and PG II materials with the proper shipping names "Petroleum Crude Oil", "Alcohols, n.o.s." (denatured ethanol), and "Ethanol/Gasoline Mixture" in packing groups (PGs) I and II.

48 United States National Transportation Safety Board (NTSB), Accident Report NTSB/RAR-12-01, *Derailment of CN Freight Train U70691-18 With Subsequent Hazardous Materials Release and Fire*, Cherry Valley, Illinois, June 19, 2009 (Washington, DC, 14 February 2012).

> Require that all newly manufactured and existing general service cars authorized for the transportation of denatured fuel ethanol and crude oil in Packing Groups I and II have enhanced tank head and shell puncture resistance systems and top fittings protection that exceeds existing design requirements for DOT-111 tank cars.
>
> NTSB Recommendation R-12-5

In the same investigation, the NTSB recommended that the AAR:

> Review the design requirements in the Association of American Railroads Manual of Standards and Recommended Practices C-III, "Specifications for Tank Cars for Attaching Center Sills or Draft Sills," and revise those requirements as needed to ensure that appropriate distances between the welds attaching the draft sill to the reinforcement pads and the welds attaching the reinforcement pads to the tank are maintained in all directions in accidents, including the longitudinal direction.
>
> NTSB Recommendation R-12-9

In September 2013, PHMSA announced its intent to propose a regulation[49] adopting new tank car requirements in the *Hazardous Materials Regulations* (49 CFR). PHMSA requested comments from stakeholders on the AAR's 2011 Class 111 tank car improvements.

In November 2013, both the AAR and the American Short Line and Regional Railroad Association (ASLRRA) expressed support for even more stringent tank car standards. They called for additional improvements to tank cars transporting flammable liquids (including PG III flammable liquids), retrofitting of existing tank cars in flammable liquid service, and aggressive phase-out of tank cars that cannot meet retrofit requirements. The tank car improvements include modifications such as:

- tank car jackets, for added puncture resistance;
- full-height head shields;
- thermal protection blanket or coatings in conjunction with jackets;
- high-capacity PRDs;
- reconfiguration of the BOV handles; and
- possible designation of a new tank car class.

In January 2014, TC proposed[50] adopting AAR's 2011 Class 111 tank car improvements in the *Transportation of Dangerous Goods Regulations* (*TDG Regulations*).

In January 2014, TSB Recommendation R14-01 called for enhanced protection standards for tank cars used to transport flammable liquids. See section 4.1.2.1 for further details.

---

49 Pipeline and Hazardous Materials Safety Administration, PHMSA-2012-0082 (HM-251): Hazardous Materials: Rail Petitions and Recommendations to Improve the Safety of Railroad Tank Car Transportation (06 September 2013).

50 Government of Canada, *Canada Gazette*, Part I, Vol. 148, No. 2 (11 January 2014), Regulations Amending the Transportation of Dangerous Goods Regulations (Safety Standard TP14877: Containers for Transport of Dangerous Goods by Rail).

## 1.19 Dangerous goods

The transportation of dangerous goods[51] (DGs) is governed in Canada[52] and the United States[53] by federal regulations, which are based on the *United Nations Recommendations on the Transport of Dangerous Goods.*

### 1.19.1 Class 3 – Flammable liquids

Flammable liquids in Class 3 are DGs whose vapours form an ignitable mixture with air at or below a temperature of 60 °C. Flammable liquids can pose serious hazards due to their volatility and flammability, which are determined respectively by the initial boiling point[54] and by flashpoint.[55]

Given that volatility and flammability of flammable liquids vary widely, they are grouped together based on these characteristics so that different requirements, including packaging, storage, handling, and transportation, can be established. According to the *TDG Regulations*, Class 3s are divided into 3 packing groups (PGs), ranging from PG I (highest hazard) to PG III (lowest hazard):

- PG I, if the flammable liquid has an initial boiling point of 35 °C or less at an absolute pressure of 101.3 kPa and any flashpoint.
- PG II, if the flammable liquid has an initial boiling point greater than 35 °C at an absolute pressure of 101.3 kPa and a flashpoint less than 23 °C.
- PG III, if the criteria for inclusion in PG I or PG II are not met.

The PG is established by determining a flammable liquid's flashpoint and boiling point.

### 1.19.2 Petroleum crude oil

Petroleum crude oil is a Class 3 flammable liquid with a wide range of flammability and volatility characteristics, and is therefore assigned to one of the 3 PGs. It is most prominently qualified in terms of its sulphur content (sweet to sour) and density (light to heavy).

---

51 Dangerous goods are also referred to as "hazardous materials" in the United States. In this report, the term "dangerous goods" is used, except when referring to United States regulations or standards.

52 *Transportation of Dangerous Goods Act* and *Transportation of Dangerous Goods (TDG) Regulations.*

53 United States *Code of Federal Regulations*, Title 49 (49 CFR), *Hazardous Materials Regulations.*

54 The initial boiling point of a liquid mixture is the temperature value when the first bubble of vapour is formed from the liquid mixture, at a given pressure. The initial boiling point is a function of pressure and composition of the liquid mixture.

55 The flashpoint of a liquid is the minimum temperature at which the liquid gives off vapour in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. A lower flashpoint represents a greater flammability hazard under laboratory conditions.

The density of petroleum crude oil is described in terms of its American Petroleum Institute (API) gravity[56] (expressed in degrees), whereby a higher number indicates lower density. The thresholds defining "light," "medium," and "heavy" crude oil vary by the product's region of origin and by the organization making the determination.[57]

#### 1.19.2.1 *Testing of crude oil samples*

Crude oil samples were collected from 9 tank cars on MMA-002 that did not derail. Samples were also taken from 2 tank cars in Farnham that were part of another MMA unit train (MMA-874). This train was transporting petroleum crude oil from the same origin.

All crude oil samples were collected at atmospheric pressure and tested for characteristics relevant to the classification of the petroleum crude oil and to its behaviour and effects during the post-accident spill and fire. The level of hazard posed by the petroleum crude on MMA-002 had not been accurately documented, as the samples that were tested had the properties of a flammable liquid of Class 3, PG II. It was concluded that the large quantities of spilled crude oil, the rapid rate of release, and the oil's high volatility and low viscosity were the major contributors to the large post-derailment fireballs and pool fire. There was no indication that the crude oil's properties had been affected by contamination from fracturing process fluid additives. No detectable levels of hydrogen sulphide gas were found at the derailment site. See Appendix F for a summary of the test results of the crude oil samples, and Engineering Laboratory Report LP148/2013 for further details.

### 1.19.3 *Regulatory requirements for classification and packaging*

The federal regulations[58] require DGs to be properly classified and packaged[59] before they are offered for transport. For flammable liquids, the classification consists of determining the primary class, subsidiary class, UN number, proper shipping name, and PG. Once a DG is properly classified, an authorized container must be selected.

For DGs imported into Canada, the *Transportation of Dangerous Goods Regulations*[60] (*TDG Regulations*) require the importer (consignor)[61] to ensure that the DGs have the correct classification before they are transported in Canada. For flammable liquids, the *TDG Regulations* also permit[62] a consignor to use a classification that was determined by a previous consignor or the manufacturer.

---

56 The American Petroleum Institute (API) gravity is a measure of a crude oil's relative density in degrees API, as defined by the American Petroleum Institute.

57 Petroleum crude oil with an API gravity range above 32° to 37° is generally referred to as a "light" crude oil. Petroleum crude oil with an API gravity range below 20° to 26° is considered a "heavy" crude oil.

58 *Transportation of Dangerous Goods (TDG) Regulations*, Section 2.2; United States: *Hazardous Materials Regulations*, Section 171.1.

59 Packaging refers to the means of containment for the dangerous goods. In this accident, the containers were the tank cars.

60 *Transportation of Dangerous Goods (TDG) Regulations* (23 November 2012), subsection 2.2(2).

61 Ibid., Section 1.4.

62 Ibid., paragraphs 2.2(3)(c) and (d).

The *TDG Regulations* allow dangerous goods to be included in PG I if the packing group is unknown, and in PG II if it is known (or reasonably believed) to be PG II or III.[63] They also contain provisions in case of detected or suspected classification errors.

### 1.19.4 Safety data sheets

A safety data sheet (SDS)[64] is produced by chemical manufacturers, distributors or suppliers pursuant to federal hazardous products legislation and standards.[65] The primary purpose of the SDS is to communicate the dangers of the hazardous chemical product. It contains detailed information about the nature of the hazardous product, including physical and chemical properties, and health, safety, fire and environmental hazards. Although not required by federal law, an SDS may also include other information, such as DG classification and transportation information.

Some products, such as petroleum crude oil, contain many ingredients whose concentrations can vary depending on the product's origin and vintage. Common industry practice, as permitted by federal hazardous products legislation, is to prepare and provide generic, representative SDSs that apply to products having similar characteristics.

The petroleum crude oil transported by MMA-002 originated from oil wells belonging to 11 different producers in the Bakken shale formation in North Dakota. WFSI provided 10 different SDSs representing the petroleum crude oil in the train (Appendix G). The classification of the petroleum crude oil for the purpose of transportation was not based on SDS information.

There was no specific practice or procedure to either verify that each SDS accurately reflected the properties of the product or family of products it represented, or that the products were properly classified for transport. Further, where there were multiple SDSs for products having similar characteristics, there was no review to compare and reconcile the provided information for consistency.

### 1.19.5 Transportation of petroleum crude oil from North Dakota toward New Brunswick

#### 1.19.5.1 Transportation of petroleum crude oil by road

The petroleum crude oil was loaded in DOT-407[66] cargo tank trucks operated by Prairie Field Services at each product supplier facility, and transported by road to the rail loading facility at New Town, North Dakota, operated by Strobel Starostka Transfer, LLC (SST).

The shipping documents indicated that the shipper was the product's supplier and that the consignee was WFSI. The product was described on the majority of the shipping documents

---

[63] Ibid., subsection 2.19(2).

[64] A safety data sheet (SDS) is the term used by the Globally Harmonized System of Classification and Labelling of Chemicals, and will be the term used in this report. In Canada, it was previously known as a material safety data sheet.

[65] Canada: *Hazardous Products Act*; United States: *Occupational Safety and Health Standards*.

[66] DOT-407 cargo tank trucks are authorized by federal regulations to transport petroleum crude oil, UN 1267, Class 3, PGs I, II, and III by road.

as UN 1267, petroleum crude oil, Class 3, PG II.[67] The majority of producers in the Bakken region considered crude oil from the region as PG II product, and had cargo tank truck shipping documents preprinted to reflect this designation.

There was no practice, procedure, or activity to verify, confirm, or validate the classification of the product transported by cargo tank trucks from the suppliers' facilities to the rail loading facility. The product was not being tested for the purpose of classification for transportation by road.

SST's standard operating procedures were to collect and test (on a monthly basis) composite samples representing the product being shipped from New Town. The tests primarily determined sulphur content, API gravity, boiling point, and the presence of light-end gases. The testing was performed primarily for quality assurance and control purposes and to establish the product's market value. The product's flashpoint was not being determined.

#### *1.19.5.2 Transportation of petroleum crude oil by rail*

At the New Town rail loading facility, the product was transloaded directly from the cargo tank trucks into Class 111[68] rail tank cars, with about 3 truckloads filling 1 tank car. The tank cars were leased by the Western Petroleum Company. The product was loaded, offered for transport, and being transported from New Town to Saint John pursuant to the applicable provisions of the United States *Code of Federal Regulations*, Title 49 (49 CFR).[69]

The shipping documents for the tank cars identified the shipper as Western Petroleum Company and the consignee as Irving Oil Ltd. The product was identified as UN 1267, petroleum crude oil, Class 3, PG III.

The tank car shipping documents were generated by CPR based on the shipper's instructions. These instructions were provided by SST on behalf of the shipper, using CPR's web-based bill-of-lading instruction system. The shipper had no procedure to verify, validate, or confirm the classification of the DGs being offered for transport, or to reconcile the shipping document information of the tank cars being offered for transport with those of the inbound product transloaded into those tank cars prior to releasing the tank cars to CPR.

The characteristics of the product for the purpose of classification for transportation by rail were not tested prior to being offered for transport. At destination, Irving sampled petroleum crude oil based on the volume of product being unloaded. Tests at an on-site laboratory determined density (which is used to calculate the API gravity), Reid vapour pressure, and whether bottom sediment or water were present.

This testing was performed for quality assurance and control purposes, and the product's flashpoint and initial boiling point were not determined. Irving relied on its suppliers to

---

[67] A few shipping documents indicated the product to be a PG III.

[68] Class 111 rail tank cars are authorized by federal regulations to transport petroleum crude oil, UN 1267, Class 3, PGs I, II and III by rail.

[69] Dangerous goods (hazardous materials) shipments by rail originating in the United States are allowed under the *TDG Regulations* (subsection 10.1) to be transported from the United States to Canada pursuant to the applicable provisions of 49 CFR, under certain conditions.

determine the classification of imported petroleum crude oil, as permitted by the *TDG Regulations*.[70]

## 1.20 Route planning and analysis for trains carrying dangerous goods

The frequency and consequences of derailments are dependent on several operational factors, such as train speed, rail integrity, braking systems, and emergency response.

Train speed is a factor because the energy dissipated during a derailment depends on the kinetic energy of the train in movement, and thus on its speed and mass. TSB data on main-track derailments from 2003 to 2012 indicate that higher derailment speeds are significantly associated with a higher number of derailed cars; the number of derailed cars is an indicator of accident severity. Speed reduction has the potential to reduce the severity and consequences of derailments, but would not necessarily result in a reduction in the number of derailments. This is because track maintenance standards are less stringent for lower classes of track.

In January 1990, the AAR issued Circular OT-55, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials*. Circular OT-55 gave the rail industry guidance on railroad operating practices for the transport of selected dangerous goods, including poisonous-by-inhalation (PIH) or toxic-by-inhalation (TIH) products and radioactive materials. It also identified technical and handling requirements for "key trains" and "key routes." Key trains were restricted to 50 mph, and main tracks on key routes had to be inspected by rail defect detection cars and track geometry inspection cars (or be subject to an equivalent level of inspection) at least twice per year, and all sidings at least once per year. Following the Lac-Mégantic accident, the definition of a "key train" was expanded in Circular OT-55-N.[71]

Route planning and analysis involves a comprehensive, system-wide review of all operations, infrastructure, traffic, and other factors affecting the safety of train movements. Factors to be considered in selecting the route that presents the fewest overall safety risks include hazards related to the nature of the product, the volume being transported, the handling of the product, railway infrastructure characteristics (for example, signalling, track class, crossings, wayside systems, traffic density), passenger traffic (that is, shared track), geography, environmentally sensitive areas, population density, and emergency response capability along the route. Route planning and analysis, as well as periodic assessments of the safety risks along the selected route, are critical to enhancing rail transportation safety because they allow the identified vulnerabilities to be proactively addressed (Figure 7).

---

70 *Transportation of Dangerous Goods (TDG) Regulations* (23 November 2012), paragraphs 2.2(3)(c) and (d).

71 Association of American Railroads (AAR), Circular OT-55-N, Recommended Railroad Operating Practices for Transportation of Hazardous Materials (effective 05 August 2013), available at http://www.boe.aar.com/CPC-1258%20OT-55-N%208-5-13.pdf (last accessed on 15 July 2014). OT-55-N was expanded by reducing from 5 to 1 the required number of car loads of poisonous or toxic-inhalation hazard and anhydrous ammonia and ammonia solutions. Also, the circular was expanded to include any combination of hazardous materials when transported as a car load or intermodal portable tank load.

Figure 7. Approximate route of the tank cars on MMA-002, which travelled through Toronto and Montréal en route to Lac-Mégantic


In January 2014, TSB Recommendation R14-02 called for route planning and analysis, as well as periodic risk assessments, for trains carrying dangerous goods. See section 4.1.2.2 for further details.

## 1.21 Emergency response

The Lac-Mégantic Fire Department was notified by 911 calls immediately after the accident. Given the size of the fire, the city's emergency response plan was put into effect. The first general alarm was sounded at 0119 on 06 July 2013. The first fire rescue vehicle and the SQ arrived at the accident site at about 0122 on 06 July 2013.

The Lac-Mégantic Fire Department and the Nantes and Saint-Augustin-de-Woburn fire departments have intermunicipal mutual aid agreements to allow joint action in case of major disasters. More than 1000 firefighters from 80 different municipalities in Quebec, and from 6 counties in the state of Maine, participated in the response, which was reported to be the largest fire response in recent Quebec history. At any given time, approximately 150 firefighters were on site. Initial firefighting efforts focused on evacuating people and preventing further spread of the fire to nearby buildings and structures. Approximately 2000 people were evacuated.

Following confirmation that the DGs involved in the fire consisted of a Class 3 flammable liquid hydrocarbon, the emergency responders assessed the situation and estimated that approximately 33 000 litres of foam concentrate would be required to allow a continuous, uninterrupted production of foam to be applied to the fire. As that quantity of supply was not available locally, the Lac-Mégantic Fire Department arranged to transport the foam concentrate from a refinery in Lévis, about 180 km away.

The foam concentrate arrived on site at approximately 1800 on 06 July 2013. Application of the foam started at approximately 2200 and continued uninterrupted for about 8 hours, until the fire was under control at 0600 on 07 July 2013. The fire was extinguished at approximately 1100 on 07 July 2013, with minor occasional flare-ups afterward.

Class 3 flammable liquid hydrocarbons present a risk of fire and explosion if exposed to heat, sparks, or flames. All firefighters in Quebec are trained in accordance with provincial requirements. The training, which includes a DG component, is not specific to rail transportation.

Support from numerous organizations arrived at various intervals, including personnel from MMA, CN, the Railway Association of Canada (RAC), the federal and provincial governments, WFSI, the importer (Irving Oil Commercial G.P.), the petroleum industry, and environmental remediation companies.

Throughout the emergency response, regular coordination meetings were held with all involved. During these meetings, priorities were established, and participants discussed what action should be taken and possible response methods, as well as the impact on the progress of the overall operations. For several hours, all work at the site stopped due to concerns about the ability of the railway to cover all emergency response costs. The stoppage affected the progress of the emergency response and environmental remediation, resulting in oil migrating back to zones that had earlier been declared safe.

### *1.21.1 Emergency response assistance plans*

The risks posed by specific DGs are determined based on the properties, characteristics, and quantities of the DGs being transported. An emergency response assistance plan (ERAP) is required by the *TDG Regulations* for certain DGs[72] that pose a higher than average risk when transported in certain quantities. Persons who offer such DGs for transport or import must have an ERAP approved by TC.

When there is an accident, the handling of these DGs requires special expertise, resources, supplies, and equipment. An approved ERAP describes the specialized response capabilities, equipment and procedures that are available to local emergency responders to assist with addressing the consequences of the accident.

In 2013, the *TDG Regulations* did not require an approved ERAP for petroleum crude oil (UN 1267). However, meetings were held between MMA and a number of stakeholders in April 2013 to discuss mutual assistance plans in the event of a petroleum crude oil spill.

#### *1.21.1.1 Previous recommendation*

Following the TSB investigation into the 1999 derailment, collision, and fire involving a unit train carrying flammable liquid hydrocarbons near Mont-Saint-Hilaire, Quebec (TSB report R99H0010), the Board determined that a comprehensive emergency response plan, for which roles, resources, and priorities for emergency response are defined ahead of time, would enhance the emergency response and alleviate post-accident risks. The Board recommended that:

> Transport Canada review the provisions of Schedule I and the requirements for emergency response plans to ensure that the transportation of liquid hydrocarbons is consistent with the risks posed to the public.

**TSB Recommendation R02-03 (issued June 2002)**

---

72 Dangerous goods such as explosives, flammable gases, certain acids, and toxic substances.

At that time, liquid hydrocarbons were not routinely transported in unit trains of tank cars. The *TDG Regulations* were amended to require an approved ERAP for diesel fuel, gasoline, and aviation fuel when offered for transport or imported in a configuration of 17 or more interconnected rail tank cars that are each at least 70% full.

In assessing the response to TSB Recommendation R02-03, the Board found that the updated ERAP application criteria, as implemented by TC, mitigated the risks to the public posed by the transportation of large volumes of liquid hydrocarbons that were regularly transported between Québec and Montréal in interconnected tank cars. The Board therefore assessed the response to TSB Recommendation R02-03 as Fully Satisfactory in August 2008.

In January 2014, TSB Recommendation R14-03 called for emergency response assistance plans for the transportation of large volumes of liquid hydrocarbons. See section 4.1.2.3 for further details.

## 1.22 Montreal, Maine & Atlantic Railway

MMA was formed in January 2003, when RWI acquired the Bangor & Aroostook assets, including the former QSR, from Iron Road Railways. RWI is a railway management, consulting and investment corporation specializing in privatizations and restructurings.

MMA owned 510 miles of track in Maine, Vermont, and Quebec, and employed approximately 170 people. Its head office was in Bangor, Maine, and there was a Canadian office in Farnham, where about 25 LEs and train conductors were based. At the time of the accident, MMA operated about 15 trains daily, with a fleet of 52 locomotives, 38 of which were available for service. Main-track operations were conducted regularly between Millinocket, Maine, and Searsport, Maine, and from Brownville Junction, Maine, to Montréal, Quebec. Service was also provided between Newport, Vermont, and Farnham to connect the northeastern United States westbound trains to Montréal for CPR destinations in the United States and Western Canada.

MMA connected with 7 railways (Class 1, short line, and local) and provided the shortest, most direct rail link through Maine, between Saint John and Montréal.

### 1.22.1 Montreal, Maine & Atlantic Railway's operations for MMA-001 and MMA-002

Prior to June 2012, westbound MMA-001 from Brownville Junction, and eastbound MMA-002 from Saint-Luc Yard through Farnham, were operating 3 times per week. These trains carried mixed freight, which included some DGs. Upon arrival at Megantic, MMA-002 would be immediately taken over by a Brownville Junction crew for the continuation of its journey. At the beginning of each week, an extra Brownville Junction crew would travel by road to Megantic to ensure the uninterrupted journey of MMA-002. On occasion, when these crews were not immediately available, MMA-002 was left unattended at Nantes on the main track or in the siding. After arrival, a Farnham crew would lay over for rest, and the next day would take MMA-001, which would have been tied up for the night at Vachon, westward to Farnham.

Starting in June 2012, the addition of unit trains to transport crude oil resulted in an increase in MMA's train traffic. Eastward weekly train traffic consisted of about 2 unit fuel trains and 5 mixed freight (that is, 1 train per day). Westward train traffic was also about 1 train per day. All crew changes were performed near Lac-Mégantic. As a result of this increase in traffic, both the Brownville Junction crew and the Farnham crew would lay over and, once they met the work/rest requirements, they would take control of the opposing train for their return trip. The next day, the LE for MMA-002 would be called earlier than the LE for MMA-001. The trains would meet at Vachon; MMA-001 would be in the siding while MMA-002 would pass on the main track.

This crew-change practice usually resulted in MMA-002 being left unattended on the main track at Nantes and MMA-001 being left unattended at Vachon, often for 6 or more hours. As per normal MMA operating practice, these trains were left with the reverser[73] removed from the control stand and placed with the train's paperwork on the console or on the LE seat. The doors on all locomotives were left unlocked.

Travel time for an MMA train between Farnham and Nantes typically was between 10 to 12 hours. Trains were normally left at Nantes instead of Vachon so that the crew would not exceed the maximum of 12 hours on duty. On some occasions, the trip to Nantes took longer than expected, resulting in the crew members exceeding their allowable duty time or leaving the train at Gould, Quebec, at Mile 31.00 of the Sherbrooke Subdivision.

### *1.22.2 Mandatory off-duty times for operating employees*

The maximum continuous on-duty time for operating employees on a single tour of duty is 12 hours. The *Work/Rest Rules for Railway Operating Employees*[74] specify that operating employees who are off duty after being on duty in excess of 10 hours at other than the home terminal must have at least 6 continuous hours off duty, with the mandatory off-duty time commencing upon arrival at the accommodations provided by the railway company. In case of an emergency, off-duty employees can be recalled. If a crew's rest is interrupted, the rest time is reset.

The continuous duty time of the LE for MMA-002 was 10 hours and 15 minutes. The LE for MMA-001 was under the same mandatory off-duty time and was lodging at the same accommodations in Lac-Mégantic as the LE for MMA-002.

### *1.22.3 Securement of trains (MMA-002) at Nantes*

With the new train schedule, trains were left at Nantes and at Vachon (the location where the 2 trains could meet, some 10 miles away). By leaving MMA-002 at Nantes, the train could be parked in a location where no crossing would be blocked, where access would be easy for pick-up and drop-off of crews, and where rail access to the siding would be allowed where cars were normally stored. There were no regulations precluding trains, including those carrying DGs, from being left unattended on a main track. When trains were secured at Nantes, they would be left on the main track with at least 1 locomotive running, the automatic brakes released, the independent brakes applied, and a number of hand brakes applied.

---

73 The reverser is a directional control handle that must be inserted into the controls of a locomotive before it can be operated, thereby acting as a key for the locomotive.

74 Transport Canada, TC O 0-140, *Work/Rest Rules for Railway Operating Employees* (February 2011), available at http://www.tc.gc.ca/eng/railsafety/rules-tco140-364.htm (last accessed on 15 July 2014).

For 2-person crews, train securement was the responsibility of both crew members. Securement consisted of applying a number of hand brakes and then testing their effectiveness. The conductor would determine the number of hand brakes to be applied and would apply them once the train was brought to a stop. On occasion, LEs would assist in the application of the hand brakes.

With a single-person train operator, the responsibility rested with the LE for both the application and the effectiveness testing of the hand brakes. To ensure that the train would not roll away while the LE was applying the hand brakes, the automatic brakes were applied.

TSB conducted a survey of LEs and conductors to determine train securement practices at Nantes, and it showed that the number of hand brakes applied to trains varied. Two-person crews would consistently apply at least the minimum number of hand brakes specified in MMA's GSIs. Some single-person train operators reported applying less than the minimum number of hand brakes.

To perform a hand brake effectiveness test, some LEs would release the automatic and independent brakes and attempt to move the train, while others would not release the independent brakes and would not attempt to move the train. When a proper hand brake effectiveness test was performed, additional hand brakes would be applied, if required.

For fuel conservation purposes, MMA instructions were to shut down all idling locomotives not equipped with an auto-start. To comply with U.S. regulations (requiring brake testing by qualified employees if a train is off air for more than 4 hours), the MMA practice was to leave at least 1 locomotive running on U.S.-bound trains. Some crews left all of the locomotives running in all weather.

### *1.22.4 Securement of trains (MMA-001) at Vachon*

Shortly before the accident, MMA-001 was parked in the siding at Vachon by a Brownville Junction single-person train operator who was to be assigned to MMA-002 the following morning. MMA-001, consisting of 5 locomotives and 98 residue tank cars, had been secured with 5 hand brakes, and the independent brakes were applied. The locomotive cab door was not locked, and the train's paperwork along with the reverser were sitting on the locomotive console. The minimum hand brake requirement for a train of this length, as per MMA's instructions, was 11 hand brakes.

### *1.22.5 Recent runaway train history at Montreal, Maine & Atlantic Railway and previous TSB investigations*

According to TSB's Rail Occurrence Database System (RODS), there were 5 occurrences involving runaway MMA equipment between 20 September 2004 and the date of the accident. All 5 involved yard-switching movements, 1 of which involved cars rolling onto the main track.

The TSB has investigated 9 runaway train occurrences since 2005; in addition to this accident, 5 others involved short line railway operations. In all of these occurrences, the investigation into the operations of these railways identified safety deficiencies in training, oversight, and operational practices (Appendix H).

### 1.22.6 *Training and requalification of Montreal, Maine & Atlantic Railway crews in Farnham*

Section 10 of the *Railway Employee Qualification Standards Regulations* (SOR/87-150) states that "a railway company shall, at intervals of not more than three years, have each employee in an occupational category re-examined on the required subjects."[75] CROR General Rule A requires every employee in any service connected with movements to:

> [...]
> (vi) be conversant with and governed by every safety rule and instruction of the company pertaining to their occupation;
> (vii) pass the required examination at prescribed intervals, not to exceed three years, and carry while on duty, a valid certificate of rules qualification;[76]
> [...]

Railways design and administer training and requalification programs according to their needs. The programs usually take place in a classroom setting, where the exam topics are reviewed with an instructor and discussions take place to ensure that the rules are properly understood and applied. Exams vary from knowledge-based to scenario-based, with short-answer questions requiring written responses or with multiple-choice questions. Knowledge-based exams contain questions that test specific rules or instructions and are typically closed-book. Scenario-based exams require the interpretation and application of CRORs, as well as of special instructions, to frequent scenarios. These exams are usually open-book and promote the development of problem-solving skills while using the company-provided manuals. Instructor feedback is a component of a requalification program. TC has the authority to review companies' training and requalification programs.

MMA delivered training to RTCs, locomotive engineers, conductors, and engineering employees. A review of MMA's training and requalification program determined the following:

- MMA's requalification exams tested employees on most CRORs and several MMA special instructions. They were knowledge-based, with short answers and multiple-choice questions.
- Requalification typically consisted of 1 day to complete the exam, and did not always involve classroom training. On many occasions, employees would take the exam home for completion.
- MMA employees did not have the opportunity to review their requalification exam after it was corrected, and received no feedback on their mistakes.
- A comparison between multiple requalification exams revealed that, over the years, they had essentially remained the same. However, there was increased use of multiple-choice questions.

---

[75] Canadian Transport Commission, SOR/87-150, *Railway Employee Qualification Standards Regulations* (12 March 1987), General, 10 (1).

[76] Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR) (2008), General Rules, A (vi) and (vii).

- The exams repeated the same question on the minimum number of hand brakes for leaving unattended equipment. They did not have questions on the hand brake effectiveness test, the conditions requiring application of more than the minimum number of hand brakes, nor the stipulation that air brakes cannot be relied upon to prevent an undesired movement.
- Inconsistencies in the correction and grading of exams were noted. On some multiple-choice questions, more than one answer was accepted as correct, and some short-answer questions were answered by writing the applicable CROR number rather than writing the procedure to be followed.
- MMA did not consistently comply with the 3-year interval for requalification. For several employees, the deadlines were exceeded by several months, with temporary certificates being issued.

### *1.22.7 Training and requalification of the locomotive engineer*

The accident LE had completed a requalification exam in September 2006. The next requalification was completed in December 2009, which was 3 months beyond the mandatory deadline. The LE received a new certificate of rules qualifications in March 2013, again 3 months after the expiration of his certificate. In April 2013, the LE completed the requalification exam at home, after having received the new certificate. The LE did not receive feedback on the results of that exam.

The LE's requalification exams in 2006 and 2009 included the same question on the number of hand brakes for a cut of cars left in a siding. In both exams, the LE's answers complied with MMA's hand brake requirements as per the instructions. In 2012, the LE's requalification exam contained 2 multiple-choice questions on the minimum number of hand brakes required for a cut of cars left unattended. Again, the LE's answers complied with MMA's hand brake instructions.

CROR General Rule A requires every employee in any service connected with movements to:

> (ii) have a copy of this rule book, the general operating instructions, current time table and any supplements, and other documents specified by the company accessible while on duty.[77]

At MMA, the other required documents under CROR General Rule A included its GSIs and *Safety Rules*. At the time of the accident, the LE was not in possession of all of the mandatory documents, including the GSIs and *Safety Rules*.

### *1.22.8 Operational tests and inspections at Montreal, Maine & Atlantic Railway*

MMA developed the Operational Tests and Inspections (OTIS) Program for its supervisors to monitor employees' adherence to railway safety rules and instructions. The OTIS program at MMA involved field supervisors observing employees as they performed their work. These observations were to be conducted unannounced. The employee evaluations

---

77 Ibid., (ii).

were based on compliance with GSIs, operating bulletins (OBs), *Safety Rules*, timetables, GOIs, and CROR.

Non-compliance with rules and instructions would be noted, and corrective action could result. Depending on the severity of the infraction, the non-compliance could result in a verbal correction, a letter of reprimand, or a suspension. All observations were entered into the OTIS system with either a "pass" or "failure" evaluation. Employees were notified of the result only if they failed the test.

MMA developed an OTIS manual to aid supervisors in the implementation of the program. The manual outlined the program's objectives, provided guidance on the methods and frequency of test administration, and provided general field instructions on implementing the program. Each supervisor was required to conduct a minimum of 15 OTIS tests per month (that is, 180 per year). Additional guidance provided to the supervisors included:

- instruction in ensuring that observations are conducted at various times and locations so that employees perceive that they may be tested at any time;
- direction in identifying those employees who need remedial rules training or appropriate discipline;
- guidance in periodically advising employees who consistently comply with all operating instructions that they were found to be in compliance with a recent test;
- development of a list of "Core Rules". The 2013 list, on which supervisors were to focus, included CROR 112(a) and (b), and OB 2-133, which covered the application and testing of hand brakes;
- identification of several rules in which a minimum number of tests per month were to be conducted. For example, CROR 112 was to be tested at least 2 times per month per supervisor.

Supervisors were provided with periodic reports (at least quarterly) on their progress in completing the required number of tests and were reminded of which rules to focus on. Table 4 summarizes the number of OTIS observations completed by each supervisor.

**Table 4. Operational Tests and Inspections (OTIS) observations completed per supervisor**

| | Supervisor 1 | Supervisor 2 | Supervisor 3 | Supervisor 4 | Supervisor 5 |
|---|---|---|---|---|---|
| 2012 | 197 | 58 | 116 | 89 | N/A |
| 2011 | 208 | 84 | 137 | 216 | 154 |
| 2010 | 232 | 181 | 216 | 224 | 260 |
| 2009 | 233 | 140 | 199 | 177 | 230 |

Note:
Supervisor 5 was no longer employed at MMA after July 2011.

For the 4-year period from 2009 to 2012, the OTIS results were as follows:

- Of the 3789 tests conducted, 128 of the observations were entered into the system as "Failure".
- Testing on CROR 112 and GSI 112 had been conducted 31 times. There were 2 failures.

- Testing on OB 2-133 had been conducted 35 times. There were 5 failures.

During a test for compliance with hand brakes, supervisors checked the number of hand brakes applied to ensure that the number met the minimum requirement. However, they seldom checked to ensure that a proper hand brake effectiveness test was conducted. To test for a proper hand brake effectiveness test, supervisors had to be at the site, unannounced, when the train arrived. Failing that, supervisors had to review the LER download after the trip. MMA reviewed downloads only after accidents. Since 2009, no employee had been tested on CROR 112(b), which targeted the hand brake effectiveness test. In 2012, U.S. employees had been tested twice on that rule; both tests had resulted in a "Failure".

Since 01 January 2009, the LE had been tested 97 times, and had failed 3 of these tests. Eight of the tests had been conducted outside of the hours of 0800 to 1800. Of the 97 tests, 70 were conducted within 27 miles of Farnham, and the remaining 27 were conducted in Sherbrooke. Seven of the 97 tests were on CROR 112 or OB 2-133, and the LE had successfully passed. None of the tests targeted the hand brake effectiveness test, and none were performed at Nantes.

## *1.23 Single-person train operations*

### *1.23.1 Implementation of single-person train operations*

At the time of the accident, there were no rules or regulations preventing railways from implementing SPTO (single-person train operations). In Canada, there are only 2 federally regulated railways to have operated using SPTO: MMA, and Quebec North Shore and Labrador Railway (QNS&L).

QNS&L implemented SPTO in 1996, without seeking a Minister's exemption to certain CROR provisions.[78] A collision occurred on the second day of operation.[79] TSB's investigation determined that, without a comprehensive analysis and the implementation of effective compensatory safety measures by the railway, SPTO operation was a contributory factor. As a result, a working group was formed involving TC, QNS&L management and employees, and representatives from industry and labour. Recommencement of SPTO was conditional on arriving at a consensus on minimum operating conditions to ensure a level of safety equivalent to that of 2-person operating crews.

In September 1996, rather than requiring railways to obtain exemptions, TC suggested to the RAC that rules be developed for SPTO.

In 1997, SPTO was re-implemented at QNS&L with 69 new conditions. Some of the key conditions were to:

- provide LEs and RTCs with 120 to 130 hours of training, including in SPTO emergency procedures, with the training program to be monitored by TC;

---

78 This was Canada's first experience with single-person train operations (SPTO) in freight service. QNS&L is a closed-loop railway based in Sept-Îles, Quebec, that primarily services the iron ore mines and operates mostly in rural areas.

79 TSB Rail Investigation Report R96Q0050: An SPTO-operated train collided with the tail end of a stationary train at Mile 131.68 of the Wacouna Subdivision near Mai, Quebec.

- provide increased supervision of LEs; and
- install proximity detection devices (PDDs) on all lead locomotives, track units, and on-track vehicles operating on the main track.

In June 1997, TC acknowledged that the RAC had been developing an SPTO circular for its members, while repeating the expectation that the RAC develop SPTO rules for inclusion in the CROR.

In 1998, the RAC first proposed rule changes to the CROR under Section 20 of the RSA relating to SPTO. TC rejected these proposed changes, as they did not establish rules for SPTO that would ensure a level of safety equivalent to that of existing crew requirements.

In 2000, the RAC produced SPTO guidelines based on industry review and consultation[80] and made them available to its members.[81] The guidelines were based on the principles of risk assessment, mitigation, and monitoring. They were not approved by TC, nor were they required to be. The guidelines specified the following:

> Railway companies must advise Transport Canada in writing at least 60 days prior to implementing One Person train operations.
>
> [...]
>
> Prior to implementation of One Person operations, the railway company shall identify safety issues and concerns associated with One Person Train Operations, evaluate the risk involved with such an operation, and take appropriate measures to mitigate the risk.
>
> [...]
>
> Each railway company shall develop and institute an appropriate monitoring program for One Person operations that measures the safety performance of the operation.
>
> This program shall be described to Transport Canada and may be subject to follow-up regulatory review.[82]

A copy of the guidelines was provided to MMA.

---

80 W. Hanafi, Beauchemin Beaton Lapointe Inc., *Study of One-person Train Operations* (Transportation Development Centre: Montreal, May 1997). Information gathered for the report was through telephone interviews with railway officials of companies experienced in one-person operation.

81 Not all railways in Canada are members of the RAC.

82 Railway Association of Canada (RAC), Circular No. 8, R35-8, *Guidelines for One Person Train Operations* (21 February 2000), 3. Notification to Transport Canada, 4. Requirements, and 6. Monitoring Process.

### 1.23.2 *Canadian Railway Operating Rules (CROR)*

TC can order the development of a rule or the amendment of an existing rule. The RAC, in consultation with its member railways, would then draft the rule. Once completed, it must be circulated to employee associations for comment before it is submitted to the Minister for approval. If there are objections to the proposed changes, the RAC can respond to the employee association's objections, and then their comments, along with the RAC response, are provided to the Minister's representatives for consideration. The rules must be approved by the Minister before coming into force. Rules may also be formulated by individual railways on their own, which also requires union consultation and submission to the Minister for approval.

In 2008, a major revision of the CROR by the RAC, approved by TC, introduced General Rule M, which provided in part, "Where only one crew member is employed, operating rules and instructions requiring joint compliance may be carried out by either the locomotive engineer or conductor…"[83] The union consultation period for the rules was 90 days, and a 2-day meeting was held. These rule changes allowed railways to implement SPTO without the need for exemptions from TC to specific CROR rules, such as were required by QNS&L in 1997.[84]

### 1.23.3 *Single-person train operations at Montreal, Maine & Atlantic Railway*

In 2003, MMA discussed the implementation of SPTO in Canada with TC. TC advised that MMA should consider QNS&L's SPTO implementation and operation as a Canadian "best practices" model. Between 2004 and 2008, MMA did not pursue SPTO in Canada, as it considered the 69 conditions that had been implemented at QNS&L to be unattainable.

In April 2009, after being informed of MMA's intention to begin SPTO, TC initiated a research project[85] to develop internal guidelines to review SPTO applications. The targeted completion date was October 2009. The research was completed in March 2012 (see section 1.23.5).

In June 2009, MMA submitted its SPTO risk assessment and proposal to TC. MMA advised of its intent to pursue a phased approach to implementing SPTO, using the 23-mile segment between the Maine-Quebec border and Lac-Mégantic as a "test-bed" for further expansion, pending approval by TC. In its risk assessment, MMA stated that a single-person crew member is more attentive when working alone, and cited its previous success on its U.S. network.

In July 2009, TC expressed a number of concerns that centred on deficiencies in MMA operations, including lack of consultation with employees in doing risk assessments, problems managing equipment, problems with remote-control operations, issues with rules compliance, issues with fatigue management, and a lack of investment in infrastructure

---

[83] Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR) (2008), General Rules, M (i).

[84] Canadian Rail Operating Rules (CROR) 3(b), 34(c), 81(b), 82(c), 82.1(b), 84, 102(a)(ii), 110(a), 135, 137.1, 143, 143.1, 146(b), 147(b), 147(c), 564.1(b), 567(a), 567.1(b), and 569(b).

[85] The research was conducted by the National Research Council (NRC) and the report, titled *Identification and Evaluation of Risk Mitigating Countermeasures for Single-Person Train Operation (TP151176E)* was released in March 2012.

maintenance. TC reiterated its recommendation that MMA look at the QNS&L consensus-based process as a model in crafting operational conditions.

In May 2010, MMA began its test operation running SPTO. TC was told that MMA's SPTO crews were coming across the border[86] as far as Nantes. However, on a number of occasions, TC became aware that MMA had operated SPTO trains with U.S. crews beyond these limits when there had been weather issues or other operational demands, such as equipment failures. There were no performance indicators identified for tracking, nor was a formal monitoring program established. TC Quebec Region reiterated its concern about MMA's suitability as an SPTO candidate.

In the same month, TC Headquarters and the FRA conducted an informal review of MMA's U.S. operations, including SPTO. As a result of that review, TC and the FRA identified 4 areas for subsequent action, including the absence of a written emergency response plan and concerns over employee fatigue, efficacy of company oversight, and rules compliance.

In December 2011, MMA informed TC that, as of 09 January 2012, it was extending SPTO westward to Farnham. TC indicated that it viewed this expansion as a significant change to operations, reiterating that it required a new risk assessment. MMA submitted a revised risk assessment for its SPTO that identified 16 risks. Several mitigation measures were proposed, and where necessary, added to the company's SPTO special instructions, such as informing local authorities, establishing procedures for a single operator when taking control of an unattended train, allowing an SPTO engineer to stop the train for 20-minute naps, and requiring formal communications between the engineer and the RTC at least every 30 minutes. This risk assessment did not identify or address the specific risks of a single-person train operator performing tasks previously performed by 2 persons, such as securing a train and leaving it unattended at the end of a shift.

In February 2012, TC met with MMA and the RAC. TC advised MMA that TC did not approve SPTO. MMA only needed to comply with all applicable rules and regulations. TC Quebec Region remained concerned about the safety of SPTO on MMA.

In April 2012, the collective agreement was renegotiated to allow for SPTO. Later in April, TC Quebec Region acknowledged that MMA was going ahead with the expanded use of SPTO to Farnham once the employee consultations were completed and the crews were trained. MMA committed to informing the regulator in advance of the date when SPTO would commence.

The SPTO training plan for LEs (which scheduled training for approximately 4 hours) was intended to address the new SPTO special instructions.

The actual SPTO training for several LEs, including the accident LE, consisted of a short briefing in a manager's office on the need to report to the RTC every 30 minutes, on the allowance for power naps, and on the need to bring the train to a stop to write clearances. In some cases, training consisted of a briefing within the hour preceding the operator's first SPTO train departure. The training did not cover fatigue management or a review of tasks normally performed by conductors, such as determining the minimum number of hand

---

[86] Brownville Junction crews were crossing the border and operating trains a short distance into Canada, near Lac-Mégantic, without TC being informed.

brakes. A review of RTC recordings determined that the instruction to communicate to the RTC at least every 30 minutes was not consistently followed.

In July 2012, MMA began operating SPTO between Lac-Mégantic and Farnham. However, no job task analysis with the employees in the territory specific to SPTO was performed, nor were all of the potential hazards associated with those tasks identified. MMA had no plan for further monitoring and evaluating SPTO. MMA did take specific measures, such as:

- extending train radio range to eliminate "dead spots";
- supplying SPTO crews with equipment so that they could operate the locomotive remotely;
- meeting with every community along the track;
- installing mirrors on the left-hand side of its locomotives;
- identifying locations along the track where a helicopter could safely land to evacuate employees; and
- making arrangements with emergency service companies to be on call if an evacuation was needed.

On 29 August 2012, TC became aware that MMA had extended SPTO operations to Farnham. TC did not verify that the mitigation measures identified in MMA's risk assessment were implemented and effective.

In March 2013, TC published an internal guideline to assist in evaluating SPTO applications. The purpose of the guideline was to provide TC regional staff with a guide to review and address SPTO risk assessments provided by railway companies.

### 1.23.4 *Review of the Montreal, Maine & Atlantic Railway submission and its relation to the requirements of Standard CSA Q850*

In December 2011, 2 guidance documents published by TC for filing rule submissions recommended the use of Standard CSA-Q-850-97, *Risk Management Guidelines of Decision-Makers* (October 1997). A comparison was made between MMA's risk assessment on SPTO introduction and the requirements of standard CSA-Q-850-97. There were significant gaps identified in MMA's process. For example, MMA did not quantify safety data to indicate safety trends and to identify some of the possible hazards when major operational changes were being planned.

### 1.23.5 *Research into single-person train operations*

MMA's 2009 request prompted TC to renew research into SPTO. TC recognized that it lacked the tools to review an SPTO risk assessment.

TC contracted the National Research Council (NRC) to conduct the research. The report was issued in 2012 and indicated that the safety impact of SPTO is unique to each individual task, and that risk-mitigating countermeasures should be designed accordingly. It stated that "reducing the train crew to one person without appropriate operational changes and technological intervention diminishes safety." The report recommended:[87]

- consolidating human factors knowledge into a best practices resource;
- identifying which technologies are required to fully support SPTO, depending on operational complexity;
- developing an SPTO guide with recommended training and refresher programs for operating personnel;
- developing communication protocols;
- developing a procedures guide to be used to determine if an operation is suitable for SPTO;
- conducting a workshop involving TC, NRC, and railways to review SPTO knowledge and identify one or two specific routes that could be used for a pilot test program; and
- running a pilot test program, complete with detailed monitoring and evaluation, over a 2-year period.

In the United States, the FRA conducted a series of cognitive task analyses pertaining to railway operating crews.[88] With respect to the role of the conductor, they found the following:

- Conductors and LEs not only work together to monitor the operating environment outside the locomotive cab, they also work together to plan activities, to solve problems, and to plan and implement risk mitigation strategies.
- Operating in mountain grade territory can significantly alter the complexity of a conductor's duties, introducing additional cognitive demands.
- When the conductor must handle unexpected situations, "these unanticipated situations impose cognitive as well as physical demands on the conductor."[89]
- New technologies, such as positive train control (PTC), will not account for all of the cognitive support that the conductor provides.

SPTO has been implemented in other parts of the world, including the U.S., Europe, Australia and New Zealand. In many countries, technological advancements were used to mitigate the risks of operating with one less crew member (Appendix I).

---

87 National Research Council of Canada (NRC), TP 15176E, *Identification and Evaluation of Risk Mitigating Countermeasures for Single-Person Train Operation*, prepared for Transport Canada (March 2012).

88 H. Rosenhand, E. Roth and J. Multer, DOT/FRA/ORD-12/13, *Cognitive and Collaborative Demands of Freight Conductors Activities: Results and Implications of a Cognitive Task Analysis* (Cambridge, MA: United States Department of Transportation, July 2012), available at http://ntl.bts.gov/lib/46000/46100/46162/TR_Cognitive_Collaborative_Demands_Freight_Conductor_Activities_edited_FINAL_10_9_12.pdf (last accessed on 16 July 2014).

89 Ibid., p. 5 and 43.

## 1.24 *Safety culture*

All members of an organization, and the decisions made at all levels, have an impact on safety. A recognized definition of an organization's "safety culture" is:

> shared values (what is important) and beliefs (how things work) that interact with an organization's structures and control systems to produce behavioural norms (the way we do things around here).[90]

TC's *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* states:

> An effective safety culture in a railway company can reduce public and employee fatalities and injuries, property damage resulting from railway accidents, and the impact of accidents on the environment.
>
> In simple terms, an organization's safety culture is demonstrated by the way people do their jobs—their decisions, actions and behaviours define the culture of an organization.
>
> *The safety culture of an organization is the result of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organization's health and safety management system.*
>
> *Organizations with a positive safety culture are characterized by communications from various stakeholders founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.*[91]

The Guide also states:

> Experience has shown that a railway company will be markedly more successful in developing a safety culture if employees and their representatives, where applicable, are involved in the development and implementation of the safety management system.[92]

The relationship between safety culture and safety management is reflected in part by the attitudes and behaviour of a company's management.

An effective safety culture includes proactive actions to identify and manage operational risk. It is characterized by an informed culture where people understand the hazards and risks involved in their own operation and work continuously to identify and overcome

---

[90] B. Uttal, The Corporate Culture Vultures, *Fortune* (17 October 1983), pp. 66–72, as cited by J. Reason in *Managing the Risks of Organizational Accidents* (Ashgate Publishing, 1997), p. 192.

[91] Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), section 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014). (Italics in original.)

[92] Ibid., section 3.1(c).

threats to safety. It is a just culture, where the workforce knows and agrees on what is acceptable and unacceptable. It is a reporting culture, where safety concerns are reported and analyzed and where appropriate action is taken. And it is a learning culture, where safety is enhanced from lessons learned.[93]

A company's policies determine how safety objectives will be met by clearly defining responsibilities; by developing processes, structures and objectives to incorporate safety into all aspects of the operation; and by developing the skills and knowledge of personnel. Procedures are directives for employees and set management's instructions. Practices are what really happens on the job, which can differ from procedures and, in some cases, increase threats to safety.

The report on the review of the RSA states, "The cornerstone of a truly functioning SMS is an effective safety culture," and notes that "[a]n effective safety culture is one where past experience is not taken as a guarantee of future success and organizations are designed to be resilient in the face of unplanned events."[94] The RSA review recommended that the TC Rail Safety Directorate and the railway industry "take specific measures to attain an effective safety culture."[95] TC's SMS guide contains a section on achieving an effective safety culture, and TC has published a safety culture checklist for companies to perform a self-assessment on their safety culture.[96]

## 1.25 *Regulatory oversight*

### 1.25.1 *Transport Canada*

#### 1.25.1.1 *Background information*

TC promotes safe and secure transportation systems in the air, marine, rail, and road modes, as well as the safe transportation of dangerous goods. To do so, TC develops safety regulations and standards, or in the case of railways, it facilitates the development of rules by the rail industry. TC is then responsible for enforcement. It tests and promotes safety technologies and has also introduced safety management system (SMS) regulations requiring railways to manage their safety risks. Rail safety is governed by the *Railway Safety Act* (RSA). The transportation of dangerous goods is governed by the *Transportation of Dangerous Goods Act* (*TDG Act*).

---

93 Adapted from: Transport Canada, TP 13739, *Introduction to Safety Management Systems* (April 2001).

94 Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), available at http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

95 Ibid.

96 Transport Canada, TP 15062, *Rail Safety Oversight and Expertise: Safety Culture Checklist* (November 2010), available at http://www.tc.gc.ca/media/documents/railsafety/sms_checklist.pdf (last accessed on 16 July 2014).

The objectives of the RSA are:

> *(a)* to promote and provide for the safety and security of the public and personnel, and the protection of property and the environment, in railway operations;
> *(b)* to encourage the collaboration and participation of interested parties in improving railway safety and security;
> *(c)* to recognize the responsibility of companies to demonstrate, by using safety management systems and other means at their disposal, that they continuously manage risks related to safety matters; and
> *(d)* to facilitate a modern, flexible and efficient regulatory scheme that will ensure the continuing enhancement of railway safety and security.[97]

To carry out the objectives of the RSA, TC's Rail Safety Directorate, based at TC Headquarters in Ottawa, sets the direction for railway safety oversight through the development of policy and programs. TC's Surface Group, based out of regional offices, is responsible for implementing the policies and programs. Regional railway safety inspectors (RSIs) monitor and promote regulatory compliance regarding railway operations, equipment, infrastructure, and railway-roadway grade crossings. RSIs also promote education and awareness, as well as conducting SMS audits and enforcement activities.

The tools and strategies available to TC to promote safety and further the objectives of the RSA are outlined in *Rail Safety: Compliance and Enforcement Policy (September 2007)*. The tools and strategies for compliance and safety fall into 3 categories of activity: promoting, monitoring, and enforcing.

Promoting refers to the means by which TC ensures that regulations are workable and understood by the railways. It includes regulatory development, consisting of clear and enforceable requirements, as well as consultation. It also includes implementation, consisting of *Railway Safety Management System Regulations* (*SMS Regulations*) and providing information, education/awareness, and counselling. SMS is specifically mentioned due to the requirement in the *SMS Regulations* for companies to put processes in place to ensure awareness of the applicable regulations and to demonstrate compliance.

Monitoring refers to the types of activities undertaken to monitor the level of safety and compliance within the industry. Key monitoring tools include:

- inspections to verify compliance with rail safety regulatory requirements, to collect data, and to identify threats to rail safety that require corrective action;
- safety audits to verify compliance with regulatory requirements and to assess safety performance;
- SMS audits (audits) to examine the company's SMS, or a portion of it, to determine "whether the company's actual operations conform to the procedures they developed to demonstrate compliance with applicable regulatory requirements";[98] and
- accident and incident investigations.

---

97 *Railway Safety Act* (1985, c. 32 [4th Supp.]), Section 3.

98 Transport Canada, *Rail Safety: Compliance and Enforcement Policy* (September 2007), p. 8.

Inspections and audits are complementary processes. While inspections look at conditions (that is, what is wrong), audits look at systems and processes (that is, to identify why the conditions exist). Inspections should be used to help target future audits and to help monitor the corrective action taken following previous audits.

Enforcing refers to the tools available to TC where a non-compliant condition or a safety concern is identified. TC's enforcement tools include the following:

- Letter of non-compliance, which is issued by the RSI to promote regulatory compliance and to address non-compliance;
- Letter of concern, which is issued by the RSI to identify and inform railways of safety concerns;
- Notice, or notice and order, which is issued by the RSI to respond to threats (notice) or immediate threats (notice and order) to safe railway operations;
- Ministerial order, which is issued by the minister to address a rail safety problem;
- Emergency directive, which is issued by the minister to mitigate an immediate threat to safe railway operations by requiring companies to cease a particular unsafe action or to take a specific action;
- Order of the court, whereby a notice and order, ministerial order, or emergency directive can be made into an order of the court and enforced as such;
- Prosecution, which can be pursued at the discretion of the Attorney General of Canada. This enforcement tool may be considered when there is serious, willful, uncorrected and/or continued non-compliance, or if the company disobeys orders issued by RSIs or the Minister of Transport.

In May 2013, the RSA was amended to enable improvements to the *SMS Regulations* and the implementation of regulations pertaining to administrative monetary penalties and railway operating certificates.

### 1.25.1.2 *Rail Safety organization*

#### 1.25.1.2.1 *Headquarters*

The Rail Safety Directorate is under the direction of the Assistant Deputy Minister (ADM) for the Safety and Security Group, which reports to the Deputy Minister. The ADM is responsible for the development and enforcement of regulations and national standards, as well as for the implementation of monitoring, testing, and inspection programs in the aviation, marine, rail, and road modes of transportation.

The Director General of the Rail Safety Directorate reports to the ADM and is responsible for implementing the rail safety program. The Rail Safety Directorate consists of 4 branches: Regulatory Affairs, Operations Management, Program Management and the Rail Safety Secretariat. The Director of Operations Management is responsible for developing and managing the oversight programs, monitoring national trends, monitoring and supporting SMS auditing activities, and monitoring the level of completion of the inspection program.

At the time of the accident, the Director of Operations Management was responsible for a number of functional areas, including operations, engineering, equipment, and the SMS program. All were based at TC Headquarters, but provided program support to their regional counterparts.

The Audit, Enforcement and Risk Evaluation Group, created in 2011, provides oversight of the SMS program. It develops policies and procedures, reviews railway's initial and annual SMS submissions, audits national railways, provides auditor training, and oversees SMS activities conducted in TC's Regions. Regional oversight activities include supplying auditing expertise and assisting in audit planning activities.

In 2013, enforcement programs for the *SMS Regulations* had not yet been developed, and there was no procedure for the follow-up of audit findings.

#### *1.25.1.2.2 Transport Canada Quebec Region*

Each TC Region is headed by a regional director general, who is responsible for the delivery of transportation programs and services. The regional director general reports to the Deputy Minister.

The regional office is responsible for assessing the railways within its region, allocating regional inspection and auditing resources, and conducting any follow-up activities to ensure that the railways are in compliance with the rules and regulations and are operating safely.

When auditing regional railways,[99] the TC Regions identify the target of audits through a risk-based business planning process. The audit scope is also determined in the TC Regions by the audit team and approved by the convening authority, who is typically the regional director. The Rail Safety staff and TDG staff for TC Quebec Region report to the Surface Regional Director through the functional managers of Equipment and Operations, of Engineering, of Safety Systems Overview, and of Transportation of Dangerous Goods.

The role of the Manager, Safety Systems Overview, had evolved over time and initially included the responsibility for implementing SMS audits. In the 2006–2007 operating year, the responsibility for auditing in the Region was informally transferred to the functional groups (that is, to Equipment and Operations, and to Engineering). With this change, the Safety Systems Overview Manager assumed an advisory role with respect to the conduct of SMS audits, including the development and testing of audit tools for the inspectors. However, with limited support from the functional groups in advancing the implementation of SMS, the Safety Systems Overview Manager was subsequently assigned other projects that were not necessarily related to SMS oversight.

### *1.25.1.3 Planning of inspections and audits*

In the third quarter of each year, TC begins a risk-based business planning process to identify and prioritize safety and program management issues and to determine the number of rail cars and locomotives, train crews, crossings, and miles of track to inspect. With this information as input, TC Headquarters develops a national inspection plan for the following year. The national inspection plan identifies the number of inspections and audits to be

---

[99] Regional railways are those railways that conduct activities in one of TC's Regions.

conducted by each TC Region, the time frame during which the inspections are to be completed, and the estimated level of effort required.

There are 3 components to the inspection system:

- The A-component inspection is a sampling process used to verify regulatory compliance and detect underlying safety issues. TC Headquarters, using a statistical model, identifies the number of inspections and target companies that are to receive these inspections.
- The B-component inspection is a planned inspection that focuses on specific recurring issues requiring closer monitoring. The TC Regions, using a risk-based method, identify the companies that are to receive these inspections.
- The C-component inspection is unplanned and responds to issues emerging through the year, such as derailments and ad hoc inspections.

Using the national inspection plan, each Region develops an operational plan to provide guidance to its RSIs on which companies, infrastructure locations, subdivision portions, operations, and maintenance employees to inspect. In TC Quebec Region, each functional group performs a risk assessment to rank the relevant subdivisions, yards, and maintenance facilities according to risk. Factors considered include accident history, compliance with standards and regulations, changes in operations, amount and type of traffic, hours of work, and type of work performed. From the risk assessment, the inspection sites are prioritized to ensure that the more risky sites are inspected in a timely manner.

TC Quebec Region is responsible for inspecting 3 national railways (CN, CPR, and VIA Rail Canada Inc. [VIA]) and 9 regional or inter-regional railways—1 passenger railway, 1 commuter railway, and 7 federally regulated short line railways. Together, these railways operate about 2900 miles of track in Quebec. Of this track, MMA operates 250 miles. In addition, TC Quebec Region inspects 8 provincially regulated short line railways, with another 1200 miles of track, on an as-requested basis.

TC Quebec Region is responsible for SMS audits at 4 regional railways, including MMA.

### *1.25.1.4 Operations*

In the TC Quebec Region Operations Group, each inspector completes about 80 inspections per year, spread out on a level-of-risk basis among all of the regulated railways. Approximately 30 of those will be A-component inspections conducted at CN, CPR, and VIA. The remaining 50 are A-component inspections of regional railways, and the B- and C-component inspections of all of the railways. From the railway infrastructure in Quebec, the group has identified 27 subdivisions to be ranked annually according to level of risk. In each of the last 5 years, the Adirondack and Sherbrooke Subdivisions have been assessed as having either the second or third highest risk level. Factors considered include accident history, compliance with standards and regulations, human factors, operational factors (train activity, staffing levels, management), and type of work performed, as well as health and safety.

Table 5 lists the number of Operations Group inspections completed per year at MMA. When action was taken to resolve any non-compliance, MMA would report the completion date to TC Quebec Region.

Table 5. Operations Group inspections at MMA

| Year | Number of inspections |
|---|---|
| 2009 | 16 |
| 2010 | 0[100] |
| 2011 | 20 |
| 2012 | 8 |
| 2013 (January to June) | 6 |

A list of TC interventions with MMA follows:

- May 2009: A notice was issued regarding non-compliance with Rule 104.5 (Derails) in a yard, citing a history that went back to 2005, as well as a history of non-compliance with Rule 112 (Securing Equipment), also cited back to 2005 when cars were improperly secured in the siding at Nantes.
- May 2009: An inspection noted a lack of provision of first-aid training to 2 train crews.
- October 2011: An inspection noted 26 cars in Sherbrooke Yard that had been left without proper hand brake securement.
- February 2012: A notice was issued citing numerous infractions at the RTC office in Farnham, noting that some RTCs were not conversant with parts of the CROR and that there was no formal process to ensure compliance with the CROR by the RTCs. It was also noted that 1 RTC was allowed to work for over a year with expired minimal rule qualifications.
- February 2012: Two directions were issued under the *Canada Labour Code*, Part II, for failure to protect the employees from workplace hazards in Sherbrooke Yard and Farnham Yard.
- March 2012: A notice was issued citing the handling of rolling stock in a manner that disregarded the protection of workers on the track provided by red flags.
- April 2012: A "letter for insufficient action taken" was issued citing deficiencies in MMA's response to the notice regarding infractions at the RTC office.
- May 2012: An inspection noted that a crew left equipment without performing a hand brake effectiveness test.
- August 2012: A letter of non-compliance was issued regarding trains immobilized by mechanical error on or near crossings.

#### *1.25.1.5 Equipment*

The TC Quebec Region Equipment Group divides the railway infrastructure in Quebec into 15 to 20 inspection stations and ranks them annually according to risk. The stations are inspected at least once per year. MMA's Farnham and Sherbrooke yards are listed as 1 station and were ranked ninth for the 2011–2012 operating year, and second and third for

[100] The inspector assigned to MMA was on a leave of absence during 2010.

the following 2 years. When assessing risk level, the Equipment Group used factors such as a railway's accident history, its history of compliance with standards and regulations, human factors, operational issues, and equipment activity.

Table 6 lists the number of Equipment Group inspections completed per year at MMA. When action was taken to resolve any infractions, MMA would report the completion date to TC Quebec Region.

**Table 6. Equipment Group inspections at MMA**

| Year | Number of inspections |
|---|---|
| 2009 | 4 |
| 2010 | 1 |
| 2011 | 2 |
| 2012 | 12 |
| 2013 (January to June) | 6 |

A list of TC Quebec Region interventions with MMA follows:

- January 2009: An inspection found that certified car inspectors were not qualified to perform single car air brake tests.
- January 2012: A letter of concern was issued regarding a broken truck side frame, 2 carmen without recent training, and 1 carman trainee performing safety inspections and a No. 1 brake test by himself without any training.
- June 2013: An inspection found that the employees performing the safety inspections were not qualified as certified locomotive inspectors.

#### *1.25.1.6 Engineering*

TC Headquarters determines segments of track to be inspected annually as part of the A-component inspections. The TC Quebec Region Engineering Group divides the remainder of the track into segments and rates each segment according to risk. These are the B-component inspections. Factors considered when determining risk include class of track; type and amount of traffic; derailment, inspection and maintenance histories; and environmental factors. Fifty-five different track segments were identified and rated. Since 2009, MMA's Sherbrooke Subdivision was ranked 13th most risky.

Tables 7 and 8 show the Engineering Group inspections on the Sherbrooke Subdivision and selected defects that were noted. Once action was taken to correct any defect, MMA would report the completion date to TC Quebec Region.

Table 7. Track and crossing inspections

| Year | Track inspections | Crossing inspections |
|---|---|---|
| 2009 | 12 | 3 |
| 2010 | 13 | 9 |
| 2011 | 9 | 11 |
| 2012 | 11 | 14 |
| 2013 (January to June) | 8 | 8 |

In each of these inspections, track defects were noted, with some of the track defects recurring. Recurring defects included rail corrugations, battered rail joints, crushed rail head, insufficient ballast, and excessive vegetation (Table 8).

Table 8. Defects from selected track and crossing inspections

| Date | Subdivision mileage | Defects noted | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Insufficient/ ineffective ties | Rail wear/ corrugation/ defects | Battered/ broken joints | Crushed heads/rail surface collapse | Defective crossing surface | Insufficient ballast | Excessive vegetation |
| July 2009 | 92.87 to 125.6 | X | | | | | | X |
| August 2009 | 0.28 to 124.9 | | | | | | | X |
| September 2009 | 101.8 to 115.85 | | | | | | | X |
| August 2010 | 41.6 to 87.0 | X | X | X | | | X | |
| September 2010 | 46.0 to 57.0 | X | X | X | | | | |
| August 2011 | 45.0 to 66.0 | X | X | | X | | X | X |
| July 2012 | 0.0 to 42.0 | | X | | X | | X | X |
| October 2012 | 38.0 to 87.0 | | X | | X | | | X |
| November 2012 | Not specified | | X | | X | | | |
| May 2013 | 0.0 to 87.0 | | X | | X | X | X | X |

On 24 July 2012, during a track inspection at the Megantic West turnout, the RSI observed that the fasteners on the frog, guard rail, and heel block were loose. On 14 May 2013, the RSI observed similar conditions at the turnout.

The following are engineering-related findings of a functional audit at MMA in April 2006:

- Some Engineering Group employees received incomplete track inspection training, received incomplete CWR maintenance training, and have not received proper fall-protection training, which is needed when working on bridges.
- Insufficient ties, insufficient rail restraint, rail wear beyond the limits, rail defects remaining in the track, battered joints and rails with crushed heads with no protection, insufficient ballast, and track geometry deviations between Mile 62.0 and Mile 125.5.

The following are the resulting interventions taken by TC Quebec Region:

- April 2006: A notice and order was issued restricting train speed from Mile 62.0 to Mile 125.5 to 10 mph, citing track conditions as a hazard. MMA worked in stages to have the speed restriction removed. Many speed restrictions remained at the time of the accident.
- October 2012: A letter of concern was issued regarding Mile 0.0 to 87.0, noting urgent track geometry defects, rail corrugation, gauge corner shelling and rail surface collapse, excessive rail end batter with marginal track surface profiles, and excessive vegetation.

### 1.25.2 *Railway safety management systems*

#### 1.25.2.1 *Safety Management System Regulations*

Traditional approaches to safety management were based primarily on compliance with regulations, reactive responses following accidents and incidents, and a "blame and punish, or retrain" philosophy.

An SMS is "a systematic, explicit and comprehensive process for managing safety risks."[101] It is a means to ensure that the railway has the processes in place to identify the hazards in its operation and mitigate the risks. SMS was designed around evolving concepts about safety that are believed to offer great potential for more effective risk management. Safety management systems were progressively introduced in the Canadian transportation industry because this approach to regulatory oversight, which seeks to ensure that organizations have processes in place to systematically manage risks, when combined with inspections and enforcement, is more effective in reducing accident rates.

One of the objectives of the RSA is to recognize the responsibility of companies to demonstrate, by using SMS and other means at their disposal, that they are continuously managing risks related to safety.

The *SMS Regulations* came into force on 31 March 2001. Section 2 states:

> 2. A railway company shall implement and maintain a safety management system that includes, at a minimum, the following components:
> *(a)* the railway company safety policy and annual safety performance targets and the associated safety initiatives to achieve the targets, approved by a senior company officer and communicated to employees;
> *(b)* clear authorities, responsibilities and accountabilities for safety at all levels in the railway company;
> *(c)* a system for involving employees and their representatives in the development and implementation of the railway company's safety management system;
> *(d)* systems for identifying applicable

---

[101] Transport Canada, TP15058E, *Railway Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 3, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

(i) railway safety regulations, rules, standards and orders, and the procedures for demonstrating compliance with them, and
(ii) exemptions and the procedures for demonstrating compliance with the terms or conditions specified in the notice of exemption;

*(e)* a process for
(i) identifying safety issues and concerns, including those associated with human factors, third-parties and significant changes to railway operations, and
(ii) evaluating and classifying risks by means of a risk assessment;

*(f)* risk control strategies;

*(g)* systems for accident and incident reporting, investigation, analysis and corrective action;

*(h)* systems for ensuring that employees and any other persons to whom the railway company grants access to its property, have appropriate skills and training and adequate supervision to ensure that they comply with all safety requirements;

*(i)* procedures for the collection and analysis of data for assessing the safety performance of the railway company;

*(j)* procedures for periodic internal safety audits, reviews by management, monitoring and evaluations of the safety management system;

*(k)* systems for monitoring management-approved corrective actions resulting from the systems and processes required under paragraphs *(d)* to *(j)*; and

*(l)* consolidated documentation describing the systems for each component of the safety management system.[102]

The *SMS Regulations* also require railway companies to:

- maintain records to permit the assessment of safety performance,
- submit documentation and records to the Minister that demonstrate compliance with the regulations, and
- produce safety management documentation upon request.

### 1.25.2.2 *Montreal, Maine & Atlantic Railway's safety management system*

MMA had an SMS manual that described how it would comply with each of the 12 mandatory components of the *SMS Regulations*. A summary of key sections of MMA's SMS manual follows:

- Safety goals and initiatives: The company sets corporate safety goals each year. The goals for year 2013 included outcome performance targets (that is, the number of incidents not to be exceeded in various categories). These performance targets would be achieved through "improved maintenance and capital improvements to the infrastructure of approximately $3.75 million in Canada."[103]

---

[102] Transport Canada, SOR/2001-37, *Rail Safety Management System Regulations* (09 January 2001), Section 2, available at http://laws-lois.justice.gc.ca/eng/regulations/SOR-2001-37/ (last accessed on 17 July 2014).

[103] Montreal, Maine & Atlantic Railway (MMA), *Safety Management System Manual* (effective 15 February 2013), section SMS-01.

- Risk management process: The identification of safety issues and concerns is a critical first step in managing risks. A list of the means by which safety issues would be identified was presented, including: OTIS, accident and incident investigations, a telephone number to report safety concerns, and internal and external audit reports.
- Operating officers were responsible for identifying safety risks that may develop due to major changes in operations.[104] A 1-page flowchart described the high-level steps included in the risk management process.[105] No guidance was provided on how to complete or document the steps.
- Risk control strategies: In the area of train operations, one of the risks identified was "unintended movements." Among the risk control strategies noted were ensuring compliance with operating rules through OTIS, training of railway employees to ensure that qualifications were current, review of procedures for risks identified through the risk management process, and evaluation of supervisors on safety performance on a semi-annual basis.[106]
- Safety audit and evaluation: "The Company has developed an internal auditing system to measure compliance with the procedures outlined in the Safety Management System and to evaluate the effectiveness of the System."[107]
- Operational Tests and Inspections (OTIS) Program: This program was used to ensure employee compliance with rules, regulations, and standards, among other purposes. A section of the manual was devoted to describing the OTIS program and documenting how it was to be carried out.

In addition, MMA had a safety committee on its Board of Directors, which met quarterly and discussed issues such as employee injuries, derailments, and other accidents. MMA also had multi-departmental local safety committees based at 6 MMA locations (including Farnham), which met monthly to discuss safety concerns.

MMA management conducted daily and weekly operating meetings, during which safety issues and the performance of each department were discussed.

MMA maintained databases showing injuries, derailments, and a summary of the Operational Tests and Inspections (OTIS) testing. Periodically, MMA internally issued safety information on accidents occurring on other railways, on conditions being reported, and on other railway industry safety awareness information.

Between 2009 and 2013, MMA took a number of disciplinary actions against employees in Canada for rules violations.

#### 1.25.2.3 *Transport Canada oversight of safety management systems*

TC's oversight of SMS is focused on verifying that the systems are in place, that they are being used, and that they are effectively improving safety.

---

[104] Ibid., p. 13.

[105] Ibid., section SMS-11.

[106] Ibid., section SMS-05.

[107] Ibid., p. 19.

Compliance with the *SMS Regulations* is established through TC's compliance monitoring program, which is designed to verify that:

- a railway's safety management system is in compliance with the minimum regulatory requirements;
- the railway is operating in accordance with the commitments, processes and procedures outlined in its SMS; and
- the SMS is effective in improving safety.[108]

The company's documented SMS is assessed using the following 3 processes:[109]

- An initial submission review, which verifies that the documentation required under section 4 of the *SMS Regulations* has been submitted to the Minister. Upon completion, a letter is provided to the company confirming compliance with section 4.
- A pre-audit, which verifies that a railway company has established the minimum processes required under section 2 of the *SMS Regulations*. A pre-audit report is issued to the railway describing deficiencies identified in documentation.
- A verification audit, which verifies that the required processes are being used and is intended to assess their effectiveness. An audit report is issued to the company, describing deficiencies in the implementation and maintenance of the SMS.

The procedural details for these reviews and audits include the following:

- The initial submission review and the pre-audit are conducted when a railway submits its SMS to the regulator for the first time.
- A verification audit can be conducted at any time after the pre-audit is completed, based on TC's risk-based planning process.
- There is no minimum frequency at which verification audits must be conducted, nor is there a requirement to conduct a verification audit on all components of a railway's SMS at any one time.
- The audit scope is determined by the convening authority.
- The procedure for conducting verification audits is described in TC's *Rail Safety Audit Procedure*.[110]
- Once an audit team determines its findings from the audit, the railway company must submit a corrective action plan.
- TC's follow-up action on the verification audit centres on the railway company's corrective action plan. The Audit Team Lead reviews the corrective action plan and notifies the railway if the plan is acceptable.

---

108 Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

109 Descriptions and outputs are adapted from the introduction to TC Quebec Region's MMA Preliminary Audit Report.

110 Transport Canada, Rail Safety Monitoring Directive, Rail Safety Audit Procedure, Directive 2TD (revised 23 October 2012).

- When an acceptable corrective action plan is received, the findings are closed.
- The audit report is forwarded to TC Headquarters and the regional managers for follow-up as required.
- The audit findings and corrective action plans serve as inputs to subsequent risk-based planning processes.

The *Railway Safety Management System Regulations* Enforcement Policy states:

> 3.3 While railway companies may be prosecuted for non-compliance to the *SMS Regulations,* they will not be prosecuted for deficiencies found in their implemented safety management systems.
>
> 3.4 In cases of serious deficiencies to railway companies safety management systems, section 32(3.1) Ministerial Order will be used [...][111]

Section 32 of the RSA states in part:

> (3.1) If the Minister is of the opinion that the safety management system established by a company has deficiencies that risk compromising railway safety, the Minister may, by notice sent to the company, order the company to take the necessary corrective measures.[112]

In practice, this means that railway companies are required to comply with the *SMS Regulations.* However, unless an RSI believes that there is an immediate threat, whatever deficiency is found concerning conformance with its SMS processes would not trigger an enforcement action, but would be flagged to the railway company as an opportunity to improve its system. Where a deficiency is found in the railway company's SMS that is serious enough to risk compromising safety, the Minister can issue an order under subsection 32(3.1) requiring the railway company to take the necessary corrective measures.

#### 1.25.2.3.1 *Railway Safety Act review*

In 2007, the *Railway Safety Act* (RSA) Review Panel examined the implementation of SMS in some detail. The panel noted that progress in implementing SMS by railways and by TC had been inconsistent and was not in line with the panel's expectations 7 years after the *SMS Regulations* came into force. Specific to TC, the panel noted that: "clear direction and support are required from national headquarters to overcome inconsistent approaches to delivery throughout TC's five regions."[113] The panel also noted that TC was not assessing the implementation and effectiveness of railway companies' SMS, stating "Transport Canada seems to consider that a railway is compliant with SMS requirements if the railway

---

[111] Transport Canada, *Railway Safety Management System Regulations Enforcement Policy* (23 April 2010), paragraphs 3.3–3.4.

[112] *Railway Safety Act* (1985, c. 32 [4th Supp.]), Section 32 (3.1).

[113] Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), p. 67, available at http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

demonstrates that the processes and management systems outlined in the SMS Regulations exist."[114]

The panel identified 2 significant obstacles for TC when overseeing the implementation of SMS. First, the panel noted that a significant shift in thinking was required to move toward a regulatory framework that places the onus on the operator to demonstrate that they are capable of operating safely. As a result, the panel highlighted a need for additional training to prepare TC inspectors to fill an auditing role, since audits and inspections require two distinctly different skill sets.[115] Second, the panel highlighted resourcing as an issue for TC, stating that: "Transport Canada is inadequately resourced to carry out its many responsibilities in the area of railway safety."[116] The effect of these challenges was described as follows:

> In the Panel's opinion, Transport Canada, Rail Safety was not provided with sufficient human and financial resources and the appropriate skill sets at the outset of the SMS program. This impeded the transition to a regulatory oversight program that focuses on risk assessment and performance-based auditing at the safety management systems level.[117]

The same year that the RSA Review Panel published its report, TC published a document entitled *Moving Forward: Changing the safety and security culture: A strategic direction for safety and security management*. Noting that it is possible for organizations to be compliant with prescriptive regulations without managing risks to acceptable levels, the document outlines TC's policy "for industry to be *accountable for systematically and proactively managing risks and threats within their transportation activities.*"[118] The document notes that meeting this policy will require a significant cultural change and a change in approach on the part of the regulator:

> In the past, TC intervened at the operational level. Under the new approach, TC (or a delegate) will audit and assess organizations at the organizational or system level and be able to verify that day to day operations are compliant. When an operator is found to have a system problem or a day to day problem that is left unresolved or mitigated poorly, TC will intervene at the appropriate level. TC will maintain the capability to apply its traditional compliance inspection and audit activity while augmenting its capability to perform system audits and assessments.[119]

*Moving Forward* recognized the same resourcing and skill-set challenges as the RSA Review Panel and provided strategies for overcoming the challenges associated with the transition to SMS both within TC and industry.

---

[114] Ibid., p. 81.

[115] Ibid., pp. 74–75.

[116] Ibid., p. 183.

[117] Ibid., p. 185.

[118] Transport Canada, TP 14678, *Moving Forward: Changing the safety and security culture: A strategic direction for safety and security management* (2007), p. 9. (Italics in original.)

[119] Ibid., p. 10.

TC Rail Safety's Strategic Plan (2010–2015) restated the commitment to implementing SMS:

> At Transport Canada, safety management systems (SMS) remain a priority and Rail Safety continues to focus its efforts on fostering and promoting SMS implementation and advancing safety culture within the rail industry."[120]

The plan notes progress in addressing the challenges identified by the RSA Review Panel and *Moving Forward*. Specifically, it mentions that an organizational review of the Rail Safety Directorate was undertaken between September 2008 and March 2010, and that additional resources were added to the Rail Safety Budget for 2009, allowing an additional 53 positions to be added to support the national Rail Safety Program. Strategies outlined in the plan indicate that Rail Safety is focused on ensuring that all inspectors are trained in audit and risk management and on improving recruitment and retention, to ensure adequate human resources.

#### *1.25.2.3.2 Report of the Auditor General of Canada: Oversight of Rail Safety – Transport Canada*

The Office of the Auditor General (OAG) conducted an audit of TC (Rail Safety) for the 2011–2012 fiscal year to examine whether it has adequately overseen the management of rail safety risks for federal railways. The OAG report, tabled in Parliament on 26 November 2013, stated:

> Transport Canada does not have the assurance it needs that federal railways have implemented adequate and effective safety management systems. Federal railways were required to implement such systems 12 years ago. At the same time, the government approved risk-funding for Transport Canada to oversee the systems. The Department has yet to establish an audit approach that provides a minimum level of assurance to senior management that federal railways have implemented adequate and effective safety management systems for managing their safety risks in day-to-day operations, and for complying with safety requirements.[121]

The audit noted that TC had made progress in addressing issues identified in previous reviews of SMS implementation, while highlighting that there was still work to be done. Specifically, the audit identified the following:

- TC had set a target of auditing federally regulated railways every 3 years, but had conducted only 26% of these audits.
- The scope of the audits was too limited and examined the effectiveness of only a small portion of SMS components.
- TC did not take any enforcement action to require railways to maintain adequate and effective safety management systems, even when deficiencies were identified that could affect safety.

---

[120] Transport Canada, TP 15083, *Rail Safety Strategic Plan 2010–2015* (November 2010), p. 5.

[121] Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.47, p. 24.

- Audit reports identified whether the SMS met regulatory requirements, but did not identify whether it had been effectively implemented.
- In almost all cases, there was no follow-up by TC inspectors to ensure that corrective action plans submitted by companies in response to SMS audit reports had been implemented.
- Inspector skill sets required for the effective oversight of SMS have not been assessed, and position descriptions have not been updated, to reflect the need for oversight of SMS.
- Approximately 1/3 of inspectors and 2/3 of managers had not attended the available training courses provided by TC on audit methodology and on SMS concepts and principles.

#### 1.25.2.4 *Introduction of Safety Management System Oversight Program*

In 2002, the introduction of the SMS program came under the jurisdiction of the Director, Audit and Quality Assurance, whose responsibilities included the implementation of the *SMS Regulations*, the delivery of national audits, the national training program, the quality assurance program, and the creation of oversight tools. The Safety Systems Overview manager in each Region participated as an audit team member or team leader in the national SMS audits.

The Director of Audit and Quality Assurance and 1 junior employee provided support related to SMS oversight to the regional inspectors, and produced audit procedures and guidelines. They were also responsible for reviewing the national railway's initial SMS submission and overseeing the auditing of the national railways. Each of TC's 5 Regions had 2 temporary employees to oversee the implementation of SMS in the regional railways.

In 2009, after the RSA Review Panel indicated that a lack of resources impeded the transition to an SMS-based regulatory oversight program, TC underwent a reorganization to integrate SMS as the key focus of its oversight activities. In addition, Budget 2009 provided $44 million over 5 years to TC for rail safety initiatives, such as enhancing its regulatory oversight and enforcement capacity, and conducting research, which included the development and publishing in 2010 of its *Guide for Developing, Implementing and Enhancing Railway Safety Management Systems*.

#### 1.25.2.5 *Auditor training*

TC Rail Safety's Audit, Enforcement and Risk Evaluation Group began delivering a 4-day training program for SMS auditing in the 2012–2013 fiscal year. The training program for RSIs and managers included a 1-day course on SMS and a 3-day course on auditing. Prior to this new course, other auditor training had been available to the RSIs. In 2001, the regional Manager of Safety Systems Overview and 1 inspector in that group attended auditor and lead auditor training. Between 2003 and 2004, the Safety Systems Overview Manager and 1 inspector each attended program evaluation or auditor training courses provided by third parties. In 2007 and 2008, a number of inspectors and managers from TC Quebec Region attended audit team member and audit team leader training provided by TC.

Table 9 shows which RSIs and managers in the TC Quebec Region attended these auditing courses.

**Table 9. TC Quebec Region's attendance of auditing courses**

| Group | Managers | | | Inspectors | | |
|---|---|---|---|---|---|---|
| | New Auditor Skills Course | Previous Team Leader Course | Previous Audit Member Course | New Auditor Skills Course | Previous Team Leader Course | Previous Audit Member Course |
| Equipment and Operations | No | No | No | 5/5 | 0/5 | 4/5 |
| Engineering | Yes | No | Yes | 5/7 | 2/7 | 5/7 |
| Safety Systems Overview | No | No | Yes | N/A | N/A | N/A |

Notes:

- The total number of inspectors represents positions that were filled at the time of the accident.
- The dates on which courses were attended are as follows:
  - New Auditor Skills Course: March–September 2011
  - Previous Team Leader Course: April 2007
  - Previous Audit Member Course: May 2007–May 2008

Within the TC Quebec Region, some RSIs felt unprepared to participate effectively in SMS audits, particularly as audit team leaders, even after attending the courses. Many felt that resources devoted to SMS audits were poorly deployed, given that they believed that there was little that could be done if a railway company was not conforming to its SMS processes.

### 1.25.2.6 *Safety management system audits*

#### 1.25.2.6.1 *Transport Canada Quebec Region*

TC Quebec Region was responsible for auditing the SMS of 4 regional railways. Table 10 shows a summary of the audits conducted and indicates whether they were performed to validate the existence of safety management processes and/or performed to validate the effectiveness of the processes in improving safety.

Table 10. Safety management system audits

| Railway | Year | Note |
| --- | --- | --- |
| Arnaud Railway | 2002–2003 | Document review and/or pre-audit. |
| MMA | 2002–2003 | Document review and pre-audit only (confirmed). |
| | 2006–2007 | Track audit. Did not examine existence or effectiveness of company's SMS track processes. |
| | 2009–2010 | Included evaluation of SMS components. |
| | 2012–2013 | Included evaluation of SMS components related to accident and incident reporting processes. |
| Quebec North Shore and Labrador Railway (QNS&L) | 2002–2003 | Document review and pre-audit only (confirmed). |
| | 2004–2005 | SMS-focused audit related to (1) accident/incident reporting, investigation and analysis; (2) CROR compliance; (3) data collection and analysis for CROR monitoring and accidents/ incidents; and (4) CROR qualifications and training. Convened in response to a number of incidents. |
| | 2005–2006 | Documentation provided relates to mechanical inspection of equipment. No validation of SMS processes. |
| | 2006–2007 | Documentation provided relates to mechanical inspection of equipment. No validation of SMS processes. |
| | 2013–2014 | SMS audit ongoing. Convened following accident at QNS&L. |
| St. Lawrence & Atlantic Railroad | 2002–2003 | Timing suggests that this was document review and/or pre-audit. |

Note:
A partial audit was conducted on Chemin de fer de la Matapédia et du Golfe in 2008. The railway was sold before the audit was completed.

In the 12 years since the *SMS Regulations* came into force, TC Quebec Region conducted initial pre-audits to verify that all 4 of the regional railways had documented the processes required by the *SMS Regulations*. From the time these pre-audits were completed to the date of the accident, only 3 audits were completed that were aimed at assessing the effectiveness of companies' SMS processes in improving safety. Two of these audits were conducted at MMA, and 1 was conducted at QNS&L. All 3 were limited in scope to part of the organization's SMS. An assessment of the effectiveness of all aspects of SMS has not been completed for the 4 regional railways in TC Quebec Region.

### *1.25.2.6.2 Montreal, Maine & Atlantic Railway*

#### *1.25.2.6.2.1 Initial submission and pre-audit (2002–2003)*

MMA made its initial submission to TC Quebec Region, as required under the *SMS Regulations*, in December 2002. TC reviewed the information submitted under section 4 of the regulations and found MMA to be compliant.

TC conducted a pre-audit at the MMA offices in Farnham on 23 and 24 January 2003. The pre-audit report recognized the efforts of MMA to develop an SMS, but found that its SMS did not meet the requirements of section 2 of the *SMS Regulations*. Areas of the SMS that were non-compliant or in need of improvement were described in detail. Some of the issues identified included the following:

- The documentation for safety-related roles, responsibilities, authorities, and relationships between management, employees and third parties was not detailed.
- The systems used by MMA to identify which regulations, rules, standards, and orders were applicable to operations were not clear.
- The means for approving and implementing risk control strategies were not documented.
- Occurrence reporting requirements were not clear, and the procedure for performing investigations was not complete.
- The procedures for collecting and analyzing safety data were incomplete.
- The procedure for periodic internal audits was incomplete.
- There was no procedure for monitoring the implementation of corrective action resulting from systems and processes contained in the SMS.

The overall result of the pre-audit was that MMA's SMS required a thorough review. TC provided MMA with the pre-audit report on 06 April 2003, and required the railway to provide a corrective action plan. On 11 September 2003, MMA submitted a revised SMS to TC.

*1.25.2.6.2.2 Period between the pre-audit and the first safety management system audit (2004–2009)*

MMA provided annual submissions required by section 5 of the *SMS Regulations* to TC Quebec Region in the spring of 2004, 2006, 2008, and 2009. There is no indication that TC solicited reports for the 2 missing years.

*1.25.2.6.2.3 Period surrounding the first safety management system audit (2010–2012)*

In March 2010, the TC Quebec Surface Regional Director convened an SMS audit of MMA. The on-site portion of the audit was conducted in Farnham and Sherbrooke yards between 15 and 24 March 2010. The audit was convened as a result of the number of non-conformances noted during inspections, the need to ensure that processes were in place to correct them, MMA's plan to implement SPTO, and its limited number of supervisory personnel.

The scope of the audit included elements of SMS and compliance with other rules, and was described as encompassing:

- systems for identifying applicable railway safety regulations, rules, standards, and orders, and the procedures for demonstrating compliance with them (subparagraph 2(d)(i) of the *SMS Regulations*);
- CROR 83, 103(c), 104(i), 104.5, and 112;
- freight car inspection and safety rules;
- freight and passenger train brake inspection and safety rules.

The audit report made 8 findings, the most significant of which was the fact that the SMS provided to TC Quebec Region had not been implemented. The auditors found that none of the 14 represented employees and managers interviewed during the audit had ever seen the SMS manual and that it had never been translated into French. MMA informed the auditors that it had been awaiting approval from TC following the 2003 submission of the revised SMS before proceeding with implementation. The company was informed that TC does not approve a railway's SMS. Under the *SMS Regulations*, it is the company's responsibility to implement and maintain an SMS and to submit documents to the Minister.

Other findings related to deficiencies in the company's SMS included the following:

- The risk management process was used solely by managers and only in the event of major operational changes or following employee injuries.
- Supervisors were not trained in how to perform efficiency tests under the company's OTIS.
- The company did not have a process in place for conducting an internal audit of its SMS and had never completed an internal audit.

Deficiencies related to employee training were also identified. Specifically, mechanical employees were not trained according to the CROR, and operating employees, as well as the rules instructor, were not properly qualified.

TC Quebec Region sent the audit report to MMA on 16 April 2010. A corrective action plan was provided on 28 May 2010. MMA indicated that its intention was to fully implement the SMS by 31 October 2010, following a review of the SMS manual by the Health and Safety Committee and translation into French. The corrective action plan also described the intention to involve employees more in risk mitigation through the health and safety committees, to conduct internal audits of the SMS by 31 August 2011, and to correct the various documentation and training deficiencies identified.

The corrective action plan was reviewed by the lead auditor when it was received, to verify that it addressed the findings. Only some of the findings were addressed with corrective action. No guidance was provided to the Regions stipulating who was the person responsible for ensuring that all of the findings were addressed with corrective action.

##### 1.25.2.6.2.4 *Period surrounding the second safety management system audit (2012-2013)*

The TC Quebec Surface Regional Director convened a second SMS audit of MMA in October 2012. The lead auditor was provided by TC Headquarters and was assisted by 2 RSIs from TC Quebec Region. The scope of the audit included SMS components 2(b), (d), (g), (h), (k), and (l), which relate to accident and incident reporting, and covered the period from January 2010 to the time of the audit. The audit was convened by the Surface Regional Director in response to an occurrence in which an MMA train had blocked a crossing for a significant period of time. Given that TC Quebec Region had learned about the event through the media, a review of available occurrence data was conducted, and it was determined that an audit focused on MMA's reporting processes would be appropriate.

The audit report included 4 findings—3 related to documentation and record keeping, and 1 related to 4 reportable occurrences that were not found in the TSB database, suggesting that they had never been reported. Further examination by TSB revealed that MMA had not reported 22 occurrences over a 7-year period (2007–2013).

The audit report was provided to MMA on 10 December 2012, and a corrective action plan was provided to TC Quebec Region on 30 January 2013. MMA's corrective action plan was reviewed by the audit team.

MMA provided the annual submission required by section 5 of the *SMS Regulations* to TC Quebec Region in the spring of 2013.

#### *1.25.2.6.3 Other Transport Canada Regions*

Regulatory oversight activities for regional railways in TC's Atlantic and Ontario Regions were reviewed for comparison purposes. Specifically, the SMS audits and follow-up activities for New Brunswick Southern Railway (NB Southern) and for Rail America, Inc. were examined.

It was determined that:

- NB Southern received a pre-audit of its SMS in 2003, a verification audit in 2004, and additional audits in 2005, 2006, 2007, 2009, 2012, and 2013. The Safety Systems Overview Group was involved in planning, managing, and following up on the audits. The audits were focused on the processes and procedures associated with components listed in the SMS. Audit findings were presented to the railway in audit reports; railway corrective action plans were evaluated, and their implementation was monitored. The scope of subsequent audits incorporated the findings from the previous audits to verify their implementation.
- Rail America, Inc. received a pre-audit in 2002 and a verification audit in 2005, and was audited again in 2006 and 2011. The Safety Systems Overview Group was active in the SMS auditing and follow-up processes. Corrective action plans were requested, and follow-up action was undertaken after the 2006 and 2011 audits. Some findings from previous audits were incorporated into the scope of subsequent audits. For example, the lack of a risk assessment process and an internal SMS auditing process was identified in the 2002 pre-audit. The 2005, 2006, and 2011 audits examined the risk assessment processes and the internal SMS auditing processes, and found that they were not being completed. Because of Rail America, Inc.'s perceived failure to implement and follow its internal SMS processes, TC Ontario Region began the process of issuing a ministerial order in 2007 to compel the company to do so. In 2012, after 5 years, it abandoned its initiative, stating that it had no authority to require a railway to follow its own SMS processes and procedures; rather, its authority was limited to requiring railways to develop adequate processes and procedures.

### *1.25.3 Other Transportation Safety Board rail investigations involving safety management systems*

The TSB has conducted a number of investigations[122] that found deficiencies in the implementation of SMS. Through these investigations, the TSB has highlighted the following issues:

- companies not conducting risk assessments for changes in operations, or not effectively identifying the risks associated with operational changes;
- SMS processes that were ineffective in identifying unsafe practices, or differences between practices and procedures; and
- lack of SMS audits or ineffective SMS audits.

Following the investigation into a 2006 runaway freight train (R06V0136, near Lillooet, British Columbia), the Board noted the absence of formal risk assessments prior to the implementation of significant operational changes that contributed to the accident. In light of this instance and a similar lack of risk assessment to identify and mitigate risks prior to operational changes that preceded 2 other major derailments, the Board issued Recommendation R09-03:

> Canadian National take effective action to identify and mitigate risks to safety as required by its safety management system, and the Department of Transport require Canadian National to do so.[123]
>
> **TSB Recommendation R09-03**

Shortly after this recommendation was issued, TSB's 2010 Watchlist[124] highlighted a problem with SMS for the air, rail and marine modes of transportation. In describing the Watchlist issue, the TSB stated:

> Implemented properly, safety management systems (SMS) allow transportation companies to identify hazards, manage risks, and develop and follow effective safety processes. However, Transport Canada (TC) does not always provide effective oversight of transportation companies transitioning to SMS, while some companies are not even required to have one.[125]

---

122 TSB rail investigation reports R03V0083, R05V0141, R06V0136, R06V0183, R07V0213 and R09T0057.

123 Transportation Safety Board (TSB), Rail Safety Recommendation R09-03: CN's SMS Requirements (issued 28 May 2009), available at http://www.tsb.gc.ca/eng/recommandations-recommendations/
rail/2009/rec_r0903.asp (last accessed on 16 July 2014).

124 The TSB Watchlist is a list of safety issues investigated by the TSB that pose the greatest risk to Canadians.

125 Transportation Safety Board, Watchlist issues: Safety Management Systems (added 16 August 2010), available at http://www.tsb.gc.ca/eng/surveillance-watchlist/multi-modal/2010/mm_1.asp#n6 (last accessed on 16 July 2014).

Specific to the rail mode, the Watchlist issue stated:

> Although SMS has been in place in the rail industry since 2001, recent investigations have shown that the railways are not always taking effective action to identify and mitigate risk through their safety management systems. The TSB has also found that regulatory audits are not always effective and may not consistently produce the expected benefits.[126]

Following the inclusion of SMS on TSB's Watchlist, CN and TC provided information describing their respective responses to Recommendation R09-03. For TC's part, it provided the following information in October 2011:

> TC and the rail industry have developed guidelines and tools to assist railway companies in implementing and improving their safety management systems. Also, TC has completed staffing technical positions and is providing training for the new Audit, Enforcement and Risk Evaluation Division to provide leadership and functional direction to the industry. For TC this issue is completed.[127]

In February 2012, the Board assessed the response to Recommendation R09-03 as Fully Satisfactory. As a result of the reported progress in addressing this safety issue, the most recent version of the TSB Watchlist, published in 2012, did not include SMS as a systemic issue for the rail mode.

### 1.25.4 *Substantial changes in railway operations: Increase in the transportation of crude oil by rail*

In recent years, the transportation of crude oil by rail has increased dramatically in North America. Shipments of crude oil by rail by Canadian Class 1 railways have increased from about 500 car loads in 2009 to 160 000 car loads in 2013.[128] In the United States, crude oil shipments have increased from 10 800 car loads in 2009 to about 400 000 in 2013.[129]

As North American production of oil continues to increase, shipments of oil by rail will continue to rise. In North America, roughly 1.0 million barrels per day (b/d) of crude is currently moved by rail, and the total volume of crude transported by rail is expected to grow to 4.5 million b/d in the next 10 years.

#### 1.25.4.1 *MMA's assessment of risk: Increase in the transportation of crude oil*

Between 2011 and 2012, the number of car loads of DGs handled by MMA in Canada increased by 280%. Almost the entire increase was due to the increase in crude oil unit

126 Ibid.

127 Ibid.

128 Railway Association of Canada, Without Borders: Canadian, U.S. railways push government to require better tank cars, *Interchange* (Winter 2014), p. 30, available at http://www.railcan.ca/assets/images/interchange/Winter_2013/RACQ0114.pdf (last accessed on 17 July 2014).

129 Source: Association of American Railroads (AAR).

trains. This was a significant change to railway operations, changing the risk profile of the railway.

As MMA began to carry more and more crude oil, it discussed operating longer, heavier trains, and the effects on traction and braking. However, it did not perceive the need to systematically assess all of the changes through a formal risk assessment, and all risks were not identified.

#### 1.25.4.2 *Transport Canada's response to Montreal, Maine & Atlantic Railway's operational changes*

Although there are annual SMS reporting requirements, there is no specific requirement to advise the regulator of major changes to operations, including changes to the risk profile of the goods being carried. However, in some other countries, such as Australia, major operational changes in railway operations, such as SPTO, must be reviewed and approved through assessment by the rail safety regulator.

Similarly, other transportation industries require direct involvement of the regulator when there is a substantial operational change. For example, in the pipeline industry, companies are required to monitor any change in land use or increase in population density within a specified area around their pipelines, and to submit to the regulator a proposed plan to deal with the changes. Likewise, regulatory approval is required when the maximum operating pressure of the pipeline is increased, or when the fluid type transported by the pipeline is changed. The regulator reviews the plans and interacts with the companies throughout the approval process to ensure that adequate safety measures are in place for the proposed change in operation.

In 2011, TC's TDG Directorate identified the significant increase in crude oil volumes being transported in unit trains as one of the emerging issues potentially requiring greater regulatory oversight. The TDG Directorate's risk assessment identified that the majority of the increased risks were related to the facilities where petroleum crude oil was loaded into rail tank cars. As a result, inspections of such facilities, which were not being inspected prior to 2011, were increased. The TDG Directorate's risk analysis did not identify the misclassification of petroleum crude oil as having an elevated level of risk.

At the Irving facilities in Saint John, the loading and unloading facilities were inspected 4 times between 2009 and 2012. These inspections found no instances of non-compliance. The accuracy of the classification of the petroleum crude oil being imported, handled, or transported was not verified by either sampling and testing of the product or by inspecting the company's classification processes.

TC did not ensure that an assessment of the operational risks inherent in transporting substantial volumes of crude oil by rail was performed. Nor did it specifically consider the risks presented by MMA carrying increasing volumes of crude oil from the Bakken region on its Canadian lines.

#### 1.25.4.3 *Canadian Transportation Agency's response to Montreal, Maine & Atlantic Railway's operational changes*

The Canadian Transportation Agency (CTA) is an independent, quasi-judicial tribunal and economic regulator. The role of the CTA in the regulation of Canada's rail transportation system is to consider applications for certificates of fitness (COF) for proposed construction or operation of railways under the *Canada Transportation Act*.

The *Canada Transportation Act* requires a person who is proposing to construct or operate a freight or passenger railway under federal jurisdiction to apply to the CTA for a COF. The CTA will issue the COF if it is satisfied that there will be adequate third-party liability insurance coverage[130] for the proposed construction or operation, as determined in accordance with the *Third Party Liability Coverage Regulations*.

When determining whether third-party liability insurance coverage is adequate, the CTA examines the risks associated with the proposed operation by considering information that is provided by the applicant, including information on passenger ridership, train miles, volume of traffic, class and volume of DGs transported, population areas served, number of level crossings, speed of trains, train crew size and training, method of train control and the overall safety record of the applicant. To obtain safety record data, the CTA contacts TC. The CTA identifies railways with similar risk profiles and compares their levels of insurance to make a determination of insurance adequacy.

Once a COF is issued, there is no requirement for renewal or for periodic reassessment of the applicant. However, on an ongoing basis, the certificate holder must notify the CTA whenever its liability insurance coverage is cancelled or altered, or whenever there is a change in construction or operation such that its liability insurance may no longer be adequate. The CTA does not proactively seek out this type of information. When an operational change, or a change to the construction of the railway occurs, the railway must apply for a variance to the certificate which would then trigger a CTA review. The magnitude and type of changes in operations that necessitate informing the CTA are subjective and left to the railway to determine. If the CTA determines that the insurance coverage is no longer adequate, it may suspend or cancel the COF.

The COF for MMA's freight operations in Quebec was issued in 2002. In 2003, MMA applied for and received a variance to its COF to reflect a reduction of track on which it operated. Again in 2003, MMA requested and received a variance to permit the operation of a passenger train for a 6-day period. In 2005, a third variance was obtained to permit the operation of passenger trains on its track.

When it came to more significant changes in operations, including the increase in DG traffic or the commencement of SPTO between Farnham and Lac-Mégantic, MMA did not seek a

---

[130] Third-party liability insurance coverage is adequate if there is sufficient insurance, including self-insurance, to compensate for third-party bodily injury or death, including injury or death to passengers; third-party property damage, excluding damage to cargo; and named perils pollution; that may arise out of an applicant's proposed construction or operation of a railway.

variance to its COF, nor increase its liability insurance. The CTA was not aware of changes in operations that may have affected MMA's COF.

### *1.25.5 Transportation of dangerous goods*

#### *1.25.5.1 Directorate*

TC's TDG Directorate regulates the transportation of DGs under the authority of the *TDG Act*. The *TDG Act* applies, for the purpose of transport, to every person that imports, offers for transport, handles or transports DGs by all modes of transportation in Canada.

The TDG Directorate develops policies, regulations, and standards. It registers facilities involved in the manufacture, inspection, maintenance, or repair of containers. It also reviews and approves ERAPs, and provides guidance during emergency response activities (through its Canadian Transport Emergency Centre [CANUTEC]). Furthermore, the TDG Directorate conducts research to improve safety, and administers compliance monitoring and enforcement programs.

#### *1.25.5.2 Compliance monitoring and enforcement*

TDG inspectors can inspect any facility or means of transport where DGs are handled, offered for transport or transported, as well as facilities where DG containers are manufactured, repaired, or tested.

The selection and prioritization of TDG inspection sites are determined by a risk-based methodology. Risk factors taken into account are:

- inspection and compliance history,
- regional and national issues,
- incident history,
- DG class and container type,
- facility type,
- the presence of an ERAP, and
- any emerging issues.

Inspections are carried out at the location where DGs enter the transportation system, commonly at the facility where they are offered for transport (such as where they are manufactured, produced, or shipped from). Inspections en route and at border crossings occur, but much less frequently.

Inspection of ERAPs or registered facilities that manufacture, repair, or test DG containers are also performed as part of the compliance monitoring activities.

During the course of an inspection, TDG inspectors may examine such things as safety marks and shipping documents, as well as loading and unloading operations. Inspections do not include verification of the accuracy of classification by either sampling and testing of the product or by examining the classification processes used by consignors.

All instances of non-compliance are documented in inspection reports. These are communicated to the person(s) responsible for the facility or activity that was inspected. Depending on the nature or seriousness of identified instances of non-compliance, notices of infractions may also be issued. Such notices are not explicitly authorized by the *TDG Act* and are used to warn companies that instances of non-compliance may result in stricter enforcement actions.

All instances of non-compliance are tracked in TDG's Inspection Information System (IIS). The sites for follow-up inspections (i.e., inspections to ensure that identified instances of non-compliance are remedied) are selected using a risk-based approach with data from the IIS. TDG inspectors may also take, as applicable, the following regulatory actions, in accordance with the procedures outlined in the TDG inspector manual, to address various types of non-compliance:

- Issuance of detention orders (section 17 of the *TDG Act*), and
- Issuance of directions (sections 7, 13, 17 and 19 of the *TDG Act*).

TDG inspectors may also initiate prosecutions by summary or indictable conviction pursuant to section 33 of the *TDG Act*, and have the option of issuing tickets[131] under the *Contraventions Act*. Only selected, more serious offences are considered for prosecution, due to the complexity, cost, and resource-intensive nature of the criminal prosecution process. When a prosecution is initiated, an investigation is undertaken in order to ensure that all evidence gathered is admissible in court.

The TDG legislation that was in effect at the time did not contain administrative monetary penalty provisions.[132]

### *1.25.5.3 Transportation of dangerous goods inspections*

There were approximately 11 000 TDG inspections performed over the past 5 years across Canada, of which 1650 were conducted in Quebec.

These inspections resulted in 186 actions taken to address identified instances of non-compliance (Table 11).

---

[131] The *Contraventions Regulations* (Schedule XV) were amended in October 2007 to designate as contraventions several offences under the *TDG Act* and to establish an applicable fine for each of them.

[132] An administrative monetary penalty system is a civil penalty regime designed to ensure compliance with legislative, regulatory or program requirements through the application of monetary penalties. It is more efficient and less costly than prosecution, since it is based on administrative, rather than criminal, processes.

Table 11. Transportation of dangerous goods inspections and actions taken (all modes)

| Year | No. of TDG inspections performed | Actions taken | | |
|---|---|---|---|---|
| | | No. of detention orders issued | No. of directions issued | No. of prosecutions initiated |
| 2009 | 2537 | 11 | 20 | 1 |
| 2010 | 2357 | 14 | 9 | 5 |
| 2011 | 2208 | 27 | 6 | 3 |
| 2012 | 2290 | 14 | 19 | 3 |
| 2013 | 1999 | 30 | 22 | 2 |
| Total | 11 391 | 96 | 76 | 14 |

Note:
2013 data represents January to June only.

#### 1.25.5.4 *Transportation of dangerous goods inspections – Rail mode*

TDG inspections involve the inspecting of facilities where DGs are being loaded, unloaded, and offered for transport by rail, as well as inspections of shippers and ERAP holders. From 2009 to 2013, there were approximately 1320 TDG inspections performed in Canada for the rail mode, of which 12 were in Quebec (which does not have TDG inspectors dedicated to the rail mode).

These inspections resulted in a total number of 22 actions taken to address identified instances of non-compliance (Table 12).

Table 12. Transportation of dangerous goods inspections and actions taken (rail mode only)

| Year | No. of TDG rail mode inspections performed | Actions taken | | |
|---|---|---|---|---|
| | | No. of detention orders issued | No. of directions issued | No. of prosecutions initiated |
| 2009 | 249 | 0 | 2 | - |
| 2010 | 239 | 7 | 0 | - |
| 2011 | 315 | 2 | 0 | - |
| 2012 | 277 | 0 | 4 | - |
| 2013 | 237 | 3 | 4 | - |
| Total | 1317 | 12 | 10 | 0 |

Note:
2013 data represents January to June only.

There were 3 TDG inspections at MMA in the past 5 years. No detention orders or directions were issued, and no prosecutions had been initiated, and there was no identified reason to do so.

# 2.0 Analysis

In this accident, a 4700-foot train transporting petroleum crude oil, that was parked on the main track, ran away, travelling 7.2 miles down a descending grade. The train gained speed and derailed at 65 mph in the town of Lac-Mégantic, Quebec. Sixty-three tank cars spilled approximately 6 million litres of crude oil, which ignited, levelling buildings, destroying the centre of the town, and killing 47 people. There was environmental contamination of the downtown area, as well as contamination of the adjacent river and lake.

The investigation into this accident was complex. Using data from the locomotive event recorder (LER), the rail traffic control recordings, the information gathered from the locomotives, and what remained of the tank cars, as well as the recollections of those involved, the TSB was able to piece together what happened. This information led to an understanding of how the train was secured, what role the locomotive fire played, why the train began to roll on the descending grade, and the events that followed. The derailment and subsequent failure of the tank cars, as well as the manner in which the crude oil caught fire and fuelled many other fires, is now well understood. These factors will be analyzed in this section of the report.

However, understanding what happened is only the first step; it is important to determine why such accidents happen. This analysis will therefore focus on the underlying factors that played a role in this accident, including Transport Canada's (TC) oversight, as well as on organizational factors, such as Montreal, Maine & Atlantic Railway's (MMA's) safety culture and the effectiveness of its safety management system (SMS). The analysis will then look beyond this accident, with the objective of improving rail safety in Canada.

## 2.1 The accident

On the evening before the accident, MMA-002 arrived at Nantes, Quebec, and the locomotive engineer (LE) parked the train on a grade on the main track. A replacement LE was scheduled to continue the trip east in the morning. This was standard company procedure, and the LE had regularly parked the train overnight in this manner.

After bringing the train to a stop using the automatic brakes, the LE applied the independent brakes to the locomotive consist. He began applying hand brakes and shutting down the trailing locomotives, including the 2 locomotives that were equipped with an auto-start system. The lead locomotive was left running to comply with United States air brake rules.

In order to test whether the number of hand brakes applied on the train was sufficient, the LE released the automatic air brakes, but the independent brakes were left applied. As such, the train was held in place by a combination of the hand brakes and by the independent brakes on the locomotives, as opposed to being held by the hand brakes alone. When the train did not move, the LE deemed the test successful and the train adequately secured.

During this time, the LE also noted that the lead locomotive engine was producing excessive amounts of black and white smoke. This smoke was the result of engine oil that had superheated after building up in the body of the turbocharger. The build-up was caused by failure of a non-standard engine repair. The LE discussed the smoke with the rail traffic controller (RTC) in Bangor, Maine. It was expected that the situation would improve and be dealt with in the morning.

Upon arrival of the taxi sent to pick up the LE, the taxi driver noted the smoke and mentioned that oil droplets from the locomotive were landing on the taxi's windshield. The LE acknowledged this and took no further action. The taxi left the area for the hotel. At 2340, a 911 call was made to report a fire on a train at Nantes. The Nantes Fire Department responded to the call and extinguished the fire. To do so, the firefighters shut off the locomotive's fuel supply, thus stopping the engine, and moved the electrical breakers inside the cab to the off position, which was in keeping with railway instructions. The employee who was dispatched by MMA to meet the firefighters was a track foreman with no locomotive operations background. As a result, another locomotive was not started. After notifying the RTC in Farnham, Quebec, of the train's condition, this employee soon left the site with the firefighters.

Normally, when the electrical breakers were moved to the off position, an automatic penalty brake would have been applied to the entire train. The reset safety control (RSC), however, was wired in such a way that this did not occur, nullifying a potential safety defence. Moreover, with the locomotive's engine shut down (and no other locomotive started), the compressor was no longer supplying air to the air brake system. As air began to slowly leak from components of the train's brake system, the main reservoirs began to be depleted. This gradually reduced the effectiveness of the independent brakes on the locomotive consist and, as the air pressure dropped further, the securement of the train became progressively more reliant on the hand brakes.

Eventually, when the air pressure dropped sufficiently, the combination of the independent brakes and hand brakes was no longer sufficient to hold the train, and it began to roll. As it proceeded down the grade, the train picked up speed, reaching 65 mph. The train derailed in the curve at the Megantic West turnout.

## 2.2 *Unattended trains*

MMA-002 was left unattended adjacent to a public highway, with the locomotive cab doors unlocked, the reverser on the LE seat, and the lead locomotive still running; it was therefore at increased risk of unauthorized access. Even if the train had been properly secured, the consequences of vandalism and of locomotive controls tampering can be serious. Although there is no evidence of unauthorized entry that night, there are risks to leaving locomotives unlocked in easily accessible locations with the reverser handle in the cab.

## 2.3 *Securement of MMA-002 at Nantes*

### 2.3.1 *Number of hand brakes*

As demonstrated in this accident, railway rules related to the securement of trains are important because of the potential consequences of improperly secured equipment.

MMA followed *Canadian Rail Operating Rule* (CROR) 112, which stated that a "sufficient" number of hand brakes must be applied and an effectiveness test must be performed to verify that the retarding force is adequate. In addition, MMA had supplementary rules in its

*General Special Instructions* and *Safety Rules*. These rules reference a chart detailing the minimum number of hand brakes to be applied — the "10% + 2" instruction. Since all air brake systems leak, MMA's instructions also explicitly stated that air brakes "must not be depended upon to prevent an undesired movement."[133]

Furthermore, the chart detailing the minimum number of hand brakes was only meant to be a guideline and, as stated in the *Safety Rules*, "additional hand brakes may be required" because of factors such as grade, the number of cars, the weight of a train, and weather conditions.

In addition, TSB tests have demonstrated that a variety of other factors can affect the performance of individual hand brakes, including the amount of force applied by a person, the mechanical condition and the efficiency of the hand brake, as well as the presence of foreign matter between the brake shoes and the wheels. It is therefore imperative that an LE properly verify the securement of a train by performing a hand brake effectiveness test.

In this accident, the 7 hand brakes that were applied correlated to approximately 10% of the cars. This number proved insufficient once the air from the brake system leaked off and the independent brakes no longer provided supplementary retarding force.

Therefore, this investigation examined why work is not always performed in accordance with written procedures, and how adaptations of procedures sometimes occur. More specifically, the investigation examined why the LE considered 7 hand brakes to be sufficient, and why he did not perform a proper effectiveness test.

One reason for this decision may have been that the LE was not fully conversant with relevant rules and special instructions on train securement. Although the LE's results from his requalification tests indicated that he had correctly answered questions relating to the minimum number of hand brakes, these questions were relatively simple and did not demonstrate that the LE possessed knowledge of the significance and rationale behind the rules. Furthermore, the LE was never tested on the procedures for performing a hand brake effectiveness test, nor did the company's Operational Tests and Inspections (OTIS) Program confirm that hand brake effectiveness tests were being conducted correctly. In addition, the LE did not have all of the required documents with him on board the train, and could not easily refer to rules and company instructions.

The LE's previous experiences might also have been a factor in his selection of the number of hand brakes. The LE had previously secured trains at this location using hand brakes on just 10% of the cars. Furthermore, at other locations, circumstances were different (less challenging terrain and gentler grades), and applying only 10% may well have been sufficient or permitted by special instructions. The absence of previous problems may have been taken as an indicator of future success.

The TSB's investigation revealed that the LE's use of the independent brakes at Nantes on previous occasions influenced his perception of the force provided by the hand brakes, leading him to conclude that just 10% was sufficient. The LE was not alone in this belief;

---

133 Montreal, Maine & Atlantic Railway (MMA), *General Special Instructions* (First Edition, 01 March 2012), Section 112-1: Hand Brakes.

some other MMA LEs also did not release the independent brakes when securing trains, which is indicative that poor train securement practices were not isolated to this accident.

In order to determine how many hand brakes would have been sufficient to hold MMA-002 on a 0.92% average descending grade—that is, without using the independent brakes on the locomotive consist—the TSB performed an extensive series of tests, taking into account a variety of factors affecting hand brake performance. The main conclusion of these tests was that 9 hand brakes, which is the minimum number set out in the MMA chart, would not have been sufficient to hold the train at Nantes.

In a scenario in which there was no application of automatic air brakes, and depending on the force applied,[134] the TSB concluded that the LE would have needed to apply between 18 and 26 hand brakes on the cars and locomotive consist.

Given that a 13-psi automatic air brake application was used to stop the train, the TSB concluded that, in this situation, the LE would have needed to apply between 15 and 20 hand brakes on the cars and locomotive consist.

The TSB also concluded that, since the hand brakes on the tank cars were more effective than the hand brakes on the locomotives, between 12 and 18 hand brakes would have been sufficient if the hand brakes were applied only to the cars.

The detailed results of these tests are shown in Appendix J.

However, as noted in the company's *Safety Rules*, the numbers set out in the chart are only minimums, and some conditions may require additional hand brakes. For this reason, the LE must determine, through a proper hand brake effectiveness test, the sufficient number of hand brakes.

Before the Lac-Mégantic accident, there had been no runaway trains as a result of unoccupied trains being left at Nantes or Vachon, Quebec. This was likely due to the fact that independent brakes were being used in addition to hand brakes to secure trains. Nonetheless, if a proper hand brake effectiveness test is not performed, equipment may not be adequately secured, increasing the risk of a runaway.

### 2.3.2 *Conducting a hand brake effectiveness test*

Locomotive independent air brakes can provide very effective braking force and are normally able to hold a train on their own. However, these brakes cannot be relied upon in all situations. If locomotives are shut down or become inoperative, system leakage will cause the brake cylinder pressure to drop and the air brakes to lose effectiveness. Hand brakes, which do not rely on air pressure, are therefore a critical defence, and must be able to hold a train on their own. Their effectiveness cannot be determined without a properly conducted effectiveness test.

---

134 Although the use of a train's automatic air brakes allows hand brakes to be applied more easily and allows significantly more brake force to be applied to the wheels, this practice is discouraged by railways, as it makes the brakes difficult to release, thus posing risk of personal injury and potential damage to brake components.

A hand brake effectiveness test involves isolating the effect of the hand brakes on the cars from that of any other brakes. This is done by releasing all of the air brakes on the train and on the locomotives, and allowing or causing the slack to adjust (through gravity or by applying throttle as necessary).

However, if, during a hand brake effectiveness test (when applying throttle), hand brakes are also applied on the operating locomotive(s), the retarding force from the locomotive hand brakes can give the false impression that the retarding force is that of the entire train. This can result in an inaccurate effectiveness test, increasing the risk of runaways. An LE would therefore have to compensate with a greater throttle application to overcome the retarding force of the locomotive hand brakes.

Because a locomotive was always left operating and therefore maintained the integrity of the independent brakes, there had been no previous train securement problems at Nantes. Therefore, any improperly conducted hand brake effectiveness test had not previously resulted in train movement.

### 2.3.3 *Locomotive hand brake maintenance*

Because the quick release brake (QRB) valve on MMA 5026 was defective, the brake cylinder air was not released when the hand brake was applied. Once the brake cylinder air leaked off, its hand brake force was lost. Consequently, only 6 of the 7 hand brakes applied were providing braking force. Therefore, in reality, even less hand brake force was being applied to the train than the LE had intended.

As a result of common malfunctions with QRB valves, MMA issued instructions on when and how to trip the QRB valve manually if it did not exhaust. The QRB valve on MMA 5026 had previously been modified to keep it working. However, the valve had sustained further wear and damage to the lifter, and the retaining disc was no longer operating. As a result, the QRB valve had to be manually tripped for the hand brake to be operational. Because the LE was not aware of these instructions, he did not know about the malfunction and did not manually trip the valve.

Furthermore, hand brake testing on the 5 locomotives determined that, at 100 foot-pounds of torque, only an average brake ratio of approximately 3.8% could be attained. Moreover, even at 150 foot-pounds of torque, the combined brake ratios of the hand brakes ranged from approximately 4.2% to 6.8% of the locomotives' gross weight on rail, which is below current Association of American Railroads (AAR) requirements. By comparison, the same testing on the occurrence tank cars determined that the cars generally met the AAR requirements, generating brake ratios in the range of 10% of their gross weight on rail. These ratios resulted in average brake shoe forces generated by the locomotives that were significantly less (below 2/3) than those generated by the tank cars when the same torque was applied. Therefore, hand brakes applied on 3 locomotives provided less brake shoe force than that of 2 tank cars.

Futhermore, hand brakes on some locomotives apply the brake shoes to only 2 wheels. Therefore, if a locomotive hand brake system is out of adjustment, the overall retarding brake force could be reduced. Although modern locomotives can have higher net braking ratios than do freight cars, older locomotives, especially if not well maintained, can be more susceptible to reduced effectiveness. Consequently, given the variable condition of locomotive hand brakes, counting them as part of the total number of required hand brakes can lead to an overestimation of the braking force, thereby increasing the risk of runaways.

## 2.4 *Locomotive fire on MMA-002*

In October 2012, 8 months before the accident, MMA 5017 was sent to the company's repair shop in Derby, Maine, following an engine failure. Given the significant resources (in time and money) required to carry out a standard repair to the engine block, as well as the need to return the locomotive to service because of increased traffic, the repair was performed using a non-standard and less costly method. This method involved the use of a polymeric material that lacked the required strength and durability.

This material eventually began to fail, leading to problems in the cam bearing area and, ultimately, to inadequate lubrication of the valves. The valve failure was not immediate, and the locomotive continued operating, but with increased engine oil consumption. As this slight increase was not unusual for an old locomotive, the underlying cause of this condition went undetected.

As the condition worsened, the engine began to surge, which was reported during the previous trip by another LE, and again by the accident LE when departing Farnham. Despite these reports, MMA did not immediately address the situation, either by removing the locomotive from service or by taking it out of the lead position.[135]

As the train worked up the grade toward Nantes, oil that was flowing from the damaged cylinder into the intake and exhaust manifold began to accumulate in the body of the turbocharger. There, it became superheated, creating the excessive black and white smoke observed by the LE.

The LE secured the train at Nantes and shut down all of the locomotives except the lead locomotive, including those with an auto-start system. The LE then had a discussion with the Bangor RTC, which did not resolve the situation. Despite MMA's safety rule regarding actions to be taken in the event of abnormal engine conditions, as well as the observed excessive smoke and significant mechanical problems, it was decided that no immediate remedial action was necessary. It was agreed that MMA 5017 would be assessed in the morning to address the engine performance issue, and the lead locomotive was left running.

Shortly after the LE departed by taxi for the hotel, the oil that had accumulated and superheated in the turbocharger caught fire. Neither the LE from MMA-001 or the LE from MMA-002 was called to return to Nantes, due to the impact that it would have on train departure time the following morning and due to mandatory rest provisions. Having to perform a No. 1 brake test the next morning may have been an inconvenience, but avoiding inconvenience was not a sufficient reason to bring the LE back to start another locomotive that night. Because another locomotive was not started, the pressure in the train's independent brakes was not maintained.

---

135 For the portion of the trip from Farnham to Nantes, this train required all 5 locomotives to be in operation to generate sufficient tractive effort.

The RTC, who had experience securing trains at Nantes, was aware that no locomotive was left running. However, he knew that train securement should not be dependent on a running locomotive, and assumed that the train had been adequately secured with sufficient hand brakes. Without a compelling cue to the contrary, the RTC did not consider that shutting down the locomotives would affect the securement of the train.

## 2.5 *Train movement and defences against runaways*

MMA-002 began to run away when the retarding brake force from the locomotives' independent brakes was reduced to a level that, combined with the force of the hand brakes, was insufficient to hold the train on a 0.92% grade.

The hand brakes applied by the LE were providing only about 48 600 pounds (1/3) of the approximate 146 700 pounds of retarding brake force[136] required to hold the train (based on the grade of the track, the weight of the train, and the estimated rolling resistance). However, the train was initially secured effectively because the independent brakes, which are quite powerful, were providing an additional 215 500 pounds of retarding brake force, for a total of 264 100 pounds.

Air brake systems are designed to prevent automatic brake applications that might arise from normal fluctuations in air flow. In this accident, once the lead locomotive was shut down, the average rate of air leakage was approximately 1 psi per minute. Although somewhat excessive, this rate was still within industry norms and less than what was required to activate the air brake control valves (approximately 3 psi per minute). No automatic brake application was therefore triggered. Had this automatic brake application occurred, it likely would have been sufficient to hold the train until morning.[137]

The critical threshold was reached approximately 1 hour after the lead locomotive was shut down, when the brake cylinder pressure dropped to 27 psi. At that point, the independent brake force was reduced to 97 400 pounds, reducing the total retarding brake force (including the hand brakes) to just 146 000 pounds. The train began to roll downhill.

In the rail industry, there are a number of physical and administrative defences to prevent runaways, including where and how trains are parked, crew transfers, derails and chocking devices, mechanical emergency devices, and electronically controlled pneumatic (ECP) brakes. The following measures are also available on most trains, including MMA-002:

- Reset safety control (RSC): Usually, an RSC is expected to initiate a penalty brake application when the rear electrical panel breakers are opened. However, no such penalty brake application occurred on MMA-002 because of the manner in which the device was wired. Although there is no standard way to wire an RSC, had a penalty brake application occurred when the power was shut down, the train would likely have remained safely secured.
- Auto-start system: One of the benefits of an auto-start system is that it will restart a locomotive when the brake cylinder pressure drops below a certain level, thereby maintaining the integrity of the independent brakes. In this accident, the LE did not

[136] Assuming a minimum coefficient of friction of 0.38

[137] Any train that leaks at a rate below 3 psi per minute could be at risk of eventually running away.

have detailed knowledge of the auto-start system and was not aware of MMA's instruction to leave locomotives with an auto-start system running. Therefore, when the 2 locomotives equipped with the auto-start system were shut down, their pressure-maintaining capabilities were nullified. Sometime later, when the lead locomotive was also shut down, there was nothing maintaining the brake cylinder pressure, and it began to drop.

- Application of the automatic brakes: While MMA instructions did not allow the automatic brakes to be set following a proper hand brake effectiveness test, doing so would have acted as a temporary secondary defence, one that likely would have kept the train secured, even after the eventual release of the independent brakes.

Ultimately, none of these defences were used, and some were nullified by design or human intervention. Thus, they were unavailable to prevent the runaway. If equipment is left unattended without additional physical safety defences, there is an increased risk that it will run away leading to an accident.

## 2.6 *Derailment*

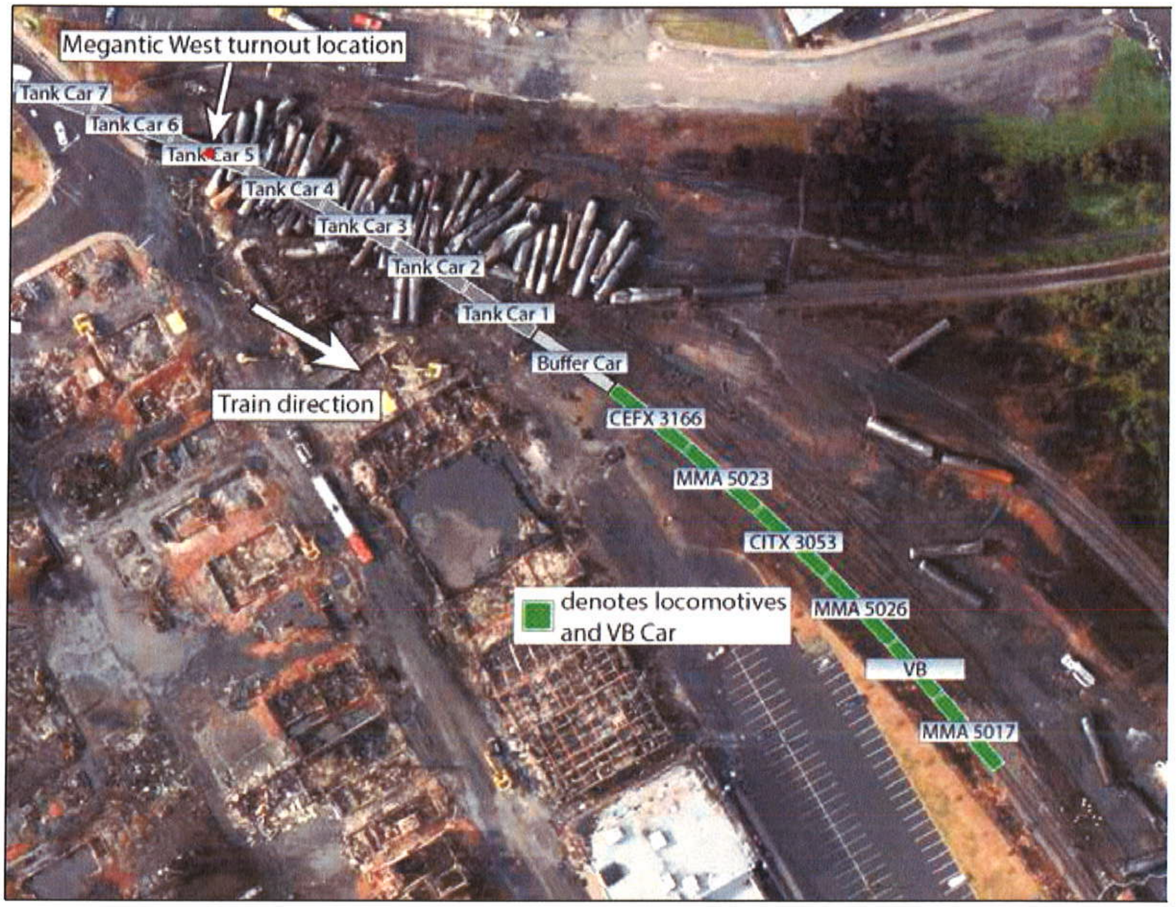
### 2.6.1 *Point of derailment and derailment sequence*

The train derailed near the Megantic West turnout as it negotiated the curve at 65 mph, which is more than 3 times the balanced speed of the track. The results of a dynamic simulation showed that in the body of the curve, where centrifugal forces would have been at their highest, the cars would have generated excessive lateral forces on the high rail and experienced complete wheel unloading on the low rail. Therefore, speed was the major contributing factor in the derailment.

Previously at this location, work had been performed to improve the geometry conditions recorded in 2012. However, without the use of mechanized equipment, the improvements were temporary; therefore, similar geometry conditions were likely present the day of the accident. The simulation showed that these conditions, although acceptable for 15-mph movements, would have exacerbated the effect of the centrifugal force and further destabilized the passing cars. Although the locomotives were able to negotiate the curve at about 65 mph without derailing, the tank cars—due to their rigidity and relatively high centre of gravity—could not.

The general trajectory of the derailed equipment also confirmed that the point of derailment (POD) was at or near the Megantic West turnout. To determine which cars were most likely the first to derail, the TSB analyzed LER information to establish the locations of the cars when the brake pipe pressure dropped to zero, as this indicated the moment of separation caused by the derailed equipment. Results show that tank cars 4 through 6 were closest to the POD at that time (Photo 29).

Photo 29. Location of the train when the brake pipe pressure dropped to 0 psi (sources: AeroPhoto and locomotive event recorder data)




An examination of the damage and of the final resting locations of the first derailed cars, starting from the front of the train, allowed the investigation to conclude that the derailment most likely occurred ahead of the sixth tank car.

It was determined that the knuckle on the leading end of the buffer car failed in torsion. The failure characteristics of the knuckle indicated that the buffer car was rolling toward the north when the knuckle failed. The marks on the trailing end of the buffer car indicated that the cars behind it derailed first, overturning the buffer car. The buffer car was relatively lightweight and was not severely damaged. It came to rest with its trucks still attached, and its wheel sets either with the trucks or located nearby. Its post-derailment condition and location close to the main track indicated that it did not travel an extended distance on its side.

The first tank car on the train came to rest on its side, with its trucks still attached. Its leading end was immediately next to the buffer car close to the main track, indicating that it had travelled toward that location when coupled to the buffer car. Two large pieces of rail ran through the car (1 through the head and 1 through the body bolster). The location of the rail through the body bolster indicated that the car was on its side when this occurred. Because the rails of the main track and of yard track 2 were relatively intact, these rails were likely picked up from the damaged yard track 1. Marks on the car draft gear indicated that the tank had rolled toward the north while coupled.

The draft gears of the second tank car indicated that it had been subjected to a torsional force from the third tank car. The second tank car most likely derailed after the third tank car and took the first tank car with it. The tank of the third tank car had rotated to the north relative to its draft system. The fourth tank car showed little sign of tank car rotation relative to its draft system; however, the lateral deformation of its stub sills indicated that its leading end had been derailed to the north. The fifth tank car was the only one of the first cars that had a broken coupler shank, and the damage to the bottom of the car's leading striker indicated that the coupler was exerting excessive force in that direction. Both the fourth and fifth cars showed more physical signs of overall damage than the first 3 cars, suggesting that they quickly lost their wheel sets.

The sixth and seventh cars showed little rotation of the coupler or draft sill components; however, both had extensive damage to the bottoms of the cars and significant denting of their heads or shells. This indicated that they came into contact with previously derailed equipment. Their trajectory, consistent with a tangent direction starting near the POD, indicated that the track was already destroyed at the time of their derailment. It is therefore most likely that the derailment occurred ahead of the sixth tank car.

### 2.6.2 *Separation of the locomotive consist during the derailment*

During the runaway and subsequent derailment, the locomotive consist separated into 2 sections at the same moment that (or just before) the consist separated from the rest of the train. The first section was comprised of MMA 5017, VB 1, and MMA 5026, and the second section was comprised of CITX 3053, MMA 5023, and CEFX 3166.

According to the LER, 1 sudden deceleration was recorded—the moment of derailment—at which point the brake pipe pressure dropped to zero.

Lab testing indicated that the knuckle that broke between locomotives MMA 5026 and CITX 3053 failed in tension, likely due to a pre-existing defect. As such, less tensile force would have been required to break it.

The second separation—due to a broken knuckle between the last locomotive (CEFX 3166) and the buffer car—occurred when the buffer car overturned. This failure occurred at the same moment as the initial separation or shortly thereafter; had it happened earlier, the LER would have recorded 2 notable decelerations instead of just 1. Moreover, both sections crossed de la Gare Street separated by 104 feet, and given the train speed (approximately 90 feet per second), that indicated that they were traveling just over 1 second apart.

The 2 sections of the locomotive consist then travelled an additional 4400 feet through Lac-Mégantic, eventually stopping approximately 475 feet apart. The first section came to rest on an approximately 1% grade, where it remained for about 90 minutes. As the independent brakes were no longer providing any retarding force, and the hand brake on MMA 5026 was defective, the first section was held only by the hand brakes on MMA 5017 and the VB car. This location was identified by the presence on the ground of the same black oily residue found on the ground at Nantes, where the engine fire had been extinguished. However, once the wheels and brake shoes sufficiently cooled, the first section began to move backwards, down the grade toward the downtown, due to the residual lessening of hand brake retarding force. It was travelling at about 8 mph when it collided with the stationary second section. Both sections then moved backwards for approximately 100 feet before coming to a final stop, and were held mainly by the retarding force from the hand brakes on the second section.

After the accident, MMA employees found the locomotive consist almost 1 mile east of the derailment site, and tightened the hand brakes on all 5 locomotives and the VB car. A hand brake that can be tightened is indicative of slack in the system; this slack was likely due to brake shoe wear from the uncontrolled movement.

Examination of the locomotive wheels also indicated that less than half of the wheels subjected to hand brake force showed full tread blueing or excessive brake shoe lining wear. This meant that several of the hand brakes had either not been applied securely, or could not have been applied securely, and confirms that the independent brakes had been providing most of the retarding force to hold the train on the grade at Nantes.

## 2.7 *Class 111 tank cars*

### 2.7.1 *Stub sills and couplers*

Almost every derailed tank car exhibited at least 1 damaged stub sill or coupler, and most were damaged on both ends. The last 2 derailed tank cars had significant impact damage to their stub sills and couplers. The damage was consistent with the generally severe impacts in this derailment.

Nine derailed tank cars exhibited separations at the stub sill attachments. One tank car separated at the fillet weld between the front sill pad and the tank, breaching the tank in 2 locations. This type of failure was present in a 2009 accident in Cherry Valley, Illinois, and resulted in U.S. National Transportation Safety Board (NTSB) Recommendation R-12-9.

### 2.7.2 *Tank heads and shells*

Damaged tank heads and shells were a major source of product loss. Fifty-nine of the 63 derailed tank cars exhibited some form of impact damage (denting or breach) to the heads or shells.

The majority of the tank cars exhibited impact damage (denting or breach) on the top portion of at least 1 head. This is not unexpected, as most of these cars came to rest on their sides, thereby bringing the top portion of the heads closer to the ground and increasing the probability of impacts with objects such as rail, couplers, and body bolsters. A full-head shield would have been beneficial, as half-head shields protect only the bottom portion of the head.

Almost 60% of the tank cars had a breached shell due to impact damage, and more than half of these breaches were of a size commensurate with the car's diameter, which would have caused an almost instantaneous release of the entire car's lading (Photo 30).

Photo 30. Concentration of large (orange) and medium (yellow) breaches toward the end of the derailment

About half of the cars with large breaches were clustered toward the end of the derailment. These cars would have encountered more severe derailment conditions than the conditions experienced by the cars located toward the front of the train, due to the large pileup ahead of them. This pileup likely acted as a wall for the cars derailing toward the end of the train. These highly constrained derailment conditions caused large-scale buckling and extreme tank deformations (that is, plastic collapse), which resulted in large shell ruptures. These cars derailed at a slower speed, and came to rest perpendicular to the track. Their thin wall construction (7/16 inch), as well as the absence of jackets, did not provide sufficient protection from the derailment forces. Consequently, large tank shell breaches occurred in a short period of time on about 1/3 of the derailed tank cars, which resulted in the rapid release of large quantities of petroleum crude oil.

### *2.7.3 Protection of tank car fittings*

With the majority of the tank cars coming to rest on their sides or upside down, the petroleum crude oil flowed from a number of damaged top fittings and fed the pool fire. Top fittings that were located within a housing that provided top discontinuity protection fared better than the top fittings that were not protected. Approximately 15% of the cars with impact-damaged top discontinuity protection housings had breached top fittings, whereas 62% of the cars with impact-damaged hinged housings had breached top fittings.

In addition, pressure relief device (PRD) survivability improved significantly when the fittings were located within a protective housing. About half of the PRDs were so protected, and only 9% of these exhibited release of product from impact damage. In the case of the unprotected PRDs, 29% exhibited impact damage resulting in product release. This comparison demonstrates that top discontinuity protection is effective in reducing the release of product from impact-damaged top fittings (including PRDs).

Examination of the derailed tank cars highlighted the need for a better bottom outlet valve (BOV) design, specifically with respect to ball valves equipped with handles. In most cases, the bottom outlet skid protection worked as intended, as the nozzles sheared off where designed (shear plane). However, some of the ball valves (7) opened due to handles being moved during the derailment. On cars equipped with an internal self-closing plug-style BOV, the valve's location inside the tank protected it from sliding damage, and the self-closing feature resulted in fewer valves being opened. Self-closing plug-style valves seem to perform better than external ball valves in preventing product loss during derailments.

Given that tank cars are prone to rollover in a derailment (due to their cylindrical shape), the need for enhanced protection of their fittings and valves is heightened. In this derailment, the high number of damaged unprotected top fittings, as well as the number of external ball valves that were opened, demonstrate the need for additional safety improvements in these areas. Without adequate top-fitting protection during a rollover, and without design improvements to BOVs, there is an increased risk of product release when general-service Class 111 cars are involved in derailments. If Class 111 tank cars that do not meet enhanced protection standards transport flammable liquids, there is an ongoing risk of product loss and significant damage to persons, property, and the environment when these cars are involved in accidents.

### 2.7.4 *Thermal tears and fire damage*

As no fragments of tank material were projected away from the tank cars, none experienced a BLEVE.[138]

There was no indication that the type of PRD on the cars that sustained thermal tears contributed to these tears. However, when some tank cars rolled over during the accident, their PRDs became located in the liquid space, reducing their ability to effectively relieve internal pressure. In the case of tank cars equipped with PRDs with low start-to-discharge (STD) pressure and high flow capacity, more vapours will vent faster, thereby reducing the risk of tank cars building up excessive internal pressure in a fire.

One of the tank cars that sustained a thermal tear came to rest adjacent to another car that did not sustain this type of tear. As these cars were both exposed to similar fire conditions, this configuration suggests that they experienced only a small difference in temperature and internal pressure. Therefore, a relatively modest improvement in fire survivability may prevent thermal tears. Thicker steel, jackets and thermal protection on tank cars, combined with adequate pressure-relief capacity, can significantly extend the time that these cars can survive in a pool fire. These features would also have helped better protect the 13 cars that lost product due to burn-throughs.

### 2.7.5 *Post-accident identification of tank cars*

The extent of the fire made identification of some cars difficult because car markings were illegible. This meant that the cars had to be identified by their identification plates or

---

[138] A BLEVE (boiling liquid expanding vapour explosion) is "an explosion resulting from the failure of a vessel containing a liquid at a temperature significantly above its boiling point at normal atmospheric pressure" (SFPE Handbook of Fire Protection Engineering, 4th Edition [National Fire Protection Association, 2008], pp. 2–213).

stampings. However, some of the cars' identification plates were secured with aluminum fasteners that were consumed in the fire or melted, resulting in identification plates falling off the cars. Also, some of these stampings were light and, when oxidized after the fire, were difficult to read. If cars are missing identification plates and have illegible stampings, severely damaged cars may not be correctly identified in a timely manner.

### 2.7.6 *Tank car: General*

The derailed tank cars were subjected to a range of impact speeds and forces depending on their position in the train. Even though some 15% of the tank cars derailed at estimated speeds of 40 mph or less, which are typical speeds for freight trains, these tank cars still experienced significant tank shell and head damage, as well as product loss.

The amount of product released could have been reduced had the tank car shells and heads been more impact-resistant. Specifically, tank cars built with thicker steel, full-head shields and tank jackets would have been better protected. In this accident, all but 4 of the 63 derailed Class 111 tank cars lost product from head or shell breaches, or through damaged valves and fittings.

This failure rate again demonstrates the poor performance in derailments of general-service Class 111 tank cars that are built to minimum requirements, and highlights the inability of these tank cars to withstand accident forces. Commodities posing significant risk must be shipped in safe containers, which include defences such as stronger tank shells, tank car jackets, full-height head shields, thermal protection, and high-capacity PRDs.

## 2.8 *Dangerous goods*

### 2.8.1 *Properties of petroleum crude oil*

The laboratory analysis of the petroleum crude oil samples determined that the product's properties were consistent with those of a light, sweet crude oil, with volatility comparable to that of gasoline. Given that the samples were taken at atmospheric pressure, the volatility of the crude oil may have been higher than measured at the time of the analysis. This is because some light hydrocarbons may have evaporated when the tank cars were opened for the first time to collect the samples.

The low flashpoint of the petroleum crude oil explains in part why it ignited so quickly once the tank cars were breached. The large quantities of spilled product, the rapid rate of release of the product, as well as the product's high volatility and low viscosity were the major contributors to the large post-derailment fireballs and pool fire.

### 2.8.2 *Safety data sheets*

The purpose of a safety data sheet (SDS) is to communicate the dangers of hazardous chemicals; it is therefore critically important that the information contained in these documents be accurate. For naturally occurring substances, such as petroleum crude oil, the preparation of generic representative SDSs for a range of products with similar characteristics was permitted by U.S. and Canadian legislation.

In this accident, each petroleum crude oil supplier provided a different SDS characterizing its product. However, the information in each SDS was inconsistent and sometimes contradictory. There was no systematic method of verifying or reconciling the information contained in the different SDSs; these inconsistencies and contradictions were not picked up, and corrective action was not initiated.

The safety of personnel who handle or come in contact with hazardous chemicals is largely dependent on an accurate characterization of the hazards of the substances. Therefore, when an SDS contains inaccurate information on the properties of the product or family of products, the usefulness of the SDS for communicating the dangers of the product is compromised, increasing the risks of injury.

In addition, the usefulness of SDSs alone for the purpose of product classification is limited in cases where products from different sources are blended together when loaded in large bulk containers.

### 2.8.3 *Testing and classification of dangerous goods*

An accurate characterization of the properties of a dangerous good is critical to ensuring its proper classification. This classification is required by federal regulations, and allows the dangerous good to be packaged in the appropriate container, as well as allowing for the proper equipment and procedures to be used when handling, loading, and unloading dangerous goods. The packing group (PG) is an integral part of the classification of Class 3 flammable liquids. It is dependent on determination of the product's flashpoint and initial boiling point through testing of representative samples. A system must be in place to determine, and then consistently validate, the classification of the product being offered for transport.

In this accident, the shipping documents for the majority of the cargo tank trucks used to transport the petroleum crude oil to the rail loading facility in New Town, North Dakota, correctly identified the product as PG II. However, this classification was not due to testing, but rather to a practice of considering crude oil from the Bakken region as PG II.

Although monthly tests on collected composite samples were being performed at the rail loading facility, these tests were not being carried out for product classification. Furthermore, the PG information in the rail cars' shipping documents was not reconciled with the corresponding information in the documents for the cargo tank trucks. Had this been done, the discrepancy could have been detected.

When the oil reached Irving's refinery in Saint John, New Brunswick, samples were collected and tests were performed, but mainly for operational reasons. There was neither determination nor verification of the product's initial boiling point and flashpoint, nor were these required or part of Irving's operational needs. Irving relied on its suppliers for proper classification of imported dangerous goods, as permitted by the *Transportation of Dangerous Goods Regulations* (*TDG Regulations*).

As a result, the petroleum crude oil being transported by the train was improperly classified, and remained that way throughout the transportation cycle. The product was assigned a PG III classification (lowest hazard), despite meeting the criteria for PG II. Therefore, its hazards were not correctly identified.

Moreover, as crude oil loaded in large bulk containers includes products from a variety of sources, the characteristics of the resultant blend may vary. If systematic testing is not conducted on representative samples of petroleum crude oil at an appropriate frequency, there is an increased risk that these dangerous goods will be improperly classified. When improperly classified and documented, dangerous goods may be moved and handled incorrectly, increasing the risk of injury to people, and of damage to property and the environment.

While proper classification of the petroleum crude oil would have allowed the railways to identify the true hazards of the product they were transporting, it is not known what effects (if any) this identification may have had on MMA's operating plans.

The incorrect classification did not result in the selection of an unauthorized container to package and transport the product. Federal regulations in effect at the time of the accident did not mandate the use of enhanced Class 111 tank cars similarly to the standards that the industry adopted on a voluntary basis in 2011 for transportation of petroleum crude oil in PG I and II. Furthermore, given that all of the tank cars involved in this accident were ordered before the effective date of that voluntary standard, none were covered by these industry provisions.

### 2.8.4 *Transportation of dangerous goods monitoring*

Between 2009 and 2013, TC's Transportation of Dangerous Goods (TDG) Directorate performed over 11 000 inspections throughout Canada, which resulted in the issuance of 99 notices of infractions, 96 detention orders, and 76 directions, as well as the initiation of 14 prosecutions.

In 2011, the TDG Directorate identified the rapid increase in the transportation by rail of petroleum crude oil as an emerging issue requiring greater regulatory oversight. As a result, the TDG Directorate started inspecting petroleum crude oil transloading facilities, focusing on specific areas of regulatory compliance in facility operations, such as tank car loading and securement practices. However, these inspections did not include verification of the classification of the petroleum crude oil being handled, offered for transport, transported, or imported. Such verifications would have included a review of company classification procedures to ensure that dangerous goods are being classified based on the appropriate tests. Without monitoring and effective enforcement of compliance with applicable classification provisions in the *TDG Regulations*, there is a risk that improperly classified dangerous goods will enter the transportation system.

## 2.9 *Emergency response*

The pileup of cars, combined with the large volume of petroleum crude oil on fire, made the firefighters' job extremely difficult. The 911 calls were received and responded to promptly, and the incident response protocols for response escalation worked as designed.

The firefighters were facing a major disaster involving a rail accident; this type of disaster was not specifically covered by their practical training. Nevertheless, the large emergency response was well coordinated, and the prompt assistance of other fire departments in the province and from the State of Maine was critical in the provision of adequate human resources and standard emergency-response equipment. The various fire departments were able to effectively coordinate their efforts and implement appropriate measures to protect the site, as well as ensure public safety after the derailment. The evacuations were conducted in a prompt and efficient manner. Despite the challenges of responding to a major disaster not specifically covered by many firefighters' practical training, the emergency response was conducted in a well coordinated and effective manner.

## 2.10 *Emergency response assistance plan*

When the *TDG Regulations* were amended in 2008 to extend emergency response assistance plan (ERAP) requirements to include 3 additional flammable liquids, petroleum crude oil was not considered. At that time, the volume of petroleum crude oil transported by unit trains was not significant.

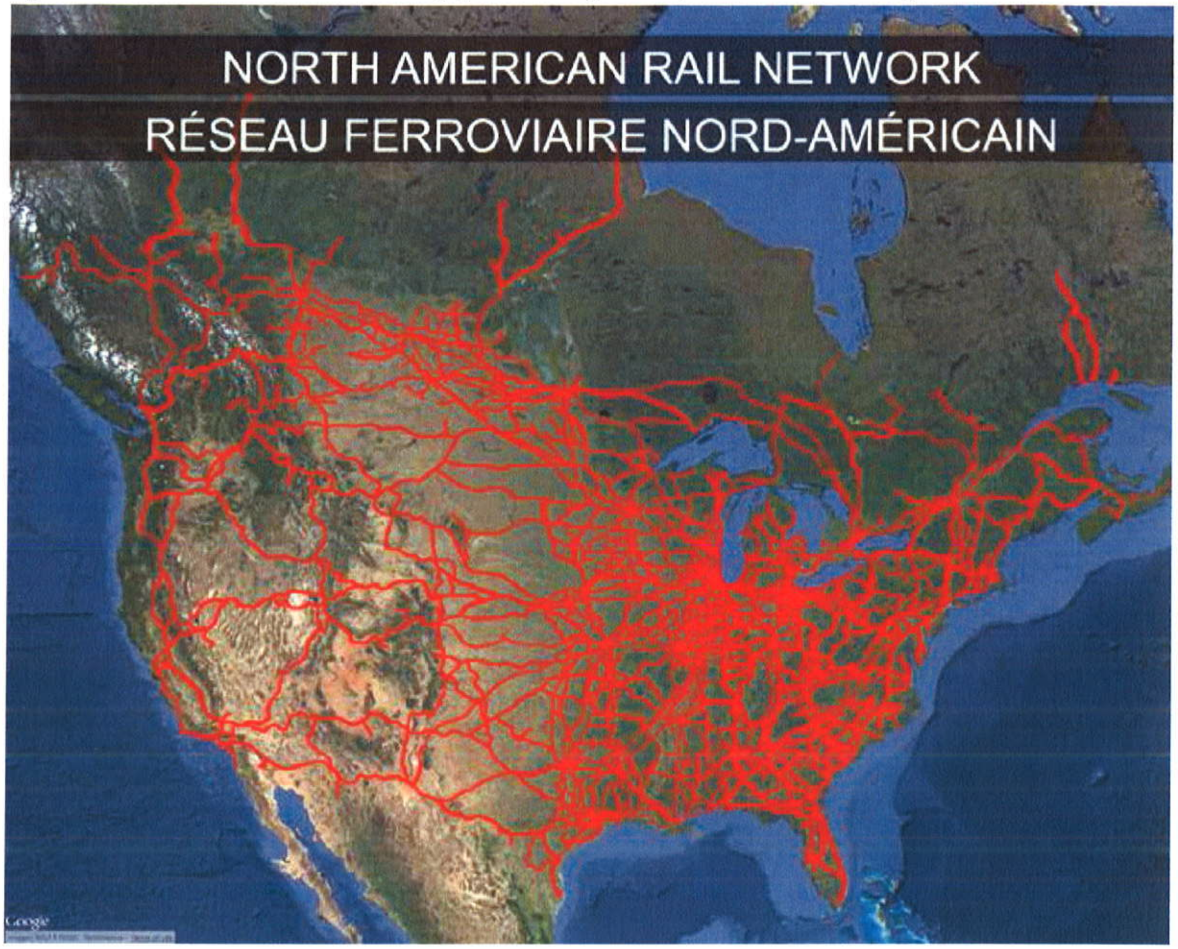
However, there has been a considerable increase in the shipment of petroleum crude oil by rail in the last 5 years, and it is projected to continue growing significantly in the coming decades. This increase is particularly true for crude oil from the Bakken field. Unit trains will continue to carry large volumes of petroleum crude oil over long distances and through populated areas. The large increase in the frequency of these unit trains, combined with the volumes of product transported by each train, have significantly increased the risks. One of the elements of an adequate defence system against these risks is ensuring that the consequences of any accident can be appropriately mitigated.

The release of dangerous goods transported by rail can jeopardize the health, safety, and welfare of railway employees and of residents living near railway tracks. The risks are even greater in the case of tracks running through urban areas. As demonstrated in this accident, petroleum crude oil can be highly flammable. Firefighters may not always be equipped or trained to handle flammable liquid spills and fires of this magnitude. If the shipper has not developed an adequate, regulator-approved ERAP, the required resources to assist local responders may not be available in the event of an accident involving large quantities of liquid hydrocarbons.

## 2.11 *Route planning and analysis*

A primary safety concern related to the transportation of dangerous goods by rail is prevention of a catastrophic release in a densely populated or environmentally sensitive area. Route planning for the transportation of dangerous goods identifies the route with the lowest overall risks to the public. Some railways have multiple lines servicing major centres, or pre-arranged running-right agreements with other carriers. Others railways offer logistical services, providing integrated transportation services from origin to destination. Route planning must cover the entire route, including any connecting railways that may form part of the transportation service. Each route needs to be evaluated to ensure that the safest route is chosen (Figure 8).

Figure 8. North American rail network map (source: Google Earth, with TSB annotations)




Once the safest route is selected, the risk of carrying dangerous commodities can be reduced by proactively examining all aspects of operations over the entire route to ensure that the identified risks are adequately mitigated. The measures included in Circular OT-55-N, such as restricting key trains to a maximum speed of 50 mph and requiring additional inspections on key routes, can reduce the risk when transporting dangerous goods. However, the level of mitigation provided by Circular OT-55-N may not be sufficient; as demonstrated in this accident, many tank cars that derailed, travelling at speeds below 50 mph, were heavily damaged and had severe loss of crude oil.

Once adequate mitigating measures are in place, periodic risk assessments will help ensure the continued safe movement of dangerous goods. If route planning, analysis, and follow-up risk assessments are not conducted by railways along routes where dangerous goods are carried, comprehensive safety measures to mitigate the risks may not be introduced.

## 2.12 *Single-person train operations at Montreal, Maine & Atlantic Railway*

Some railways have argued that there are potential safety benefits to single-person train operations (SPTO), such as increased attentiveness by the lone operator because of the absence of a second crew member on whom to rely. It is also said that there are fewer distractions from extraneous conversations. Although most of the benefits of joint compliance are lost when operating as a single person, some benefits can still be achieved by confirming critical actions with another person (e.g., the RTC), albeit remotely.

However, there are also demonstrated risks to SPTO, including reduced joint compliance (which can help catch errors), a tendency to take shortcuts, additional physical and time-related requirements for a single person to perform tasks, the possibility that individuals working alone will be subject to fatigue and cognitive degradations, and the need for additional training to properly prepare LEs to work alone. It is also important to consider how a single operator might deal with the abnormal conditions that may arise, as well as whether all safety-critical tasks (such as the application of hand brakes and the performance of a hand brake effectiveness test) can be performed in a reasonable amount of time.

Following the 1996 Quebec North Shore and Labrador Railway (QNS&L) accident, in which SPTO was found to be contributory, TC facilitated the creation of a consensus-based working group. This group required all key stakeholders (including management and employees) to collaborate in crafting clear operating conditions that would ensure safety levels equivalent to those of multi-person operations. Under the 2008 changes to the CROR, MMA was not required to adopt these conditions, but rather worked with TC to develop customized conditions applicable to its operations.

After the QNS&L accident, although TC suggested that the Railway Association of Canada (RAC) develop new rules pertaining to SPTO within the CROR, TC did not order the RAC to do so. In 2000, the RAC adopted internal SPTO guidelines based on the principles of risk assessment, mitigation, and monitoring. These guidelines stipulated that member railways had to develop a monitoring program to measure the safety performance of its SPTO, and that TC had to be provided with a description of this program. In 2012, a National Research Council (NRC) study, sponsored by TC, made several recommendations, including the creation of a 2-year pilot project with detailed monitoring and evaluation. However, none of these guidelines and recommendations were binding.

Following the 2008 revision of the CROR, railways no longer needed exemptions to implement SPTO. As a result, there were no rules preventing operations with 1-person crews, nor a mandatory requirement to have plans reviewed and approved in advance by TC. Consequently, there was no longer a requirement to directly involve TC in the process of implementing SPTO.

In July 2009, MMA indicated to TC that SPTO between the Maine–Quebec border and Lac-Mégantic represented a "test-bed", which could be expanded upon successful implementation. Prior to MMA's implementation of SPTO in 2010 (east of Lac-Mégantic) and 2012 (Farnham to Lac-Mégantic), TC insisted that risk assessments be completed. These risk assessments, which were reviewed by TC, identified several risks and mitigation measures, with a focus on trains in movement (given that, in the past, this aspect had represented the greatest concern). As securement was covered by both CROR 112 and MMA's own instructions, the risk assessments did not identify single-person train securement as a risk.

Subsequently, between April 2011 and June 2012, TC engaged MMA through meetings, site visits, and correspondence to ensure that a substantial review was performed by the company, including meetings with municipalities. To allay TC's concerns, MMA cited its previous experience with SPTO in the U.S., as well as its SPTO experience east of

Lac-Mégantic. Contrary to the RAC guidelines, MMA had no plan to further monitor and evaluate SPTO beyond its normal supervisory activity.

Meanwhile, TC—despite concerns of its regional inspectors and without detailed SPTO monitoring and evaluation, as recommended by its own study—did not follow up to verify that the mitigation measures identified in MMA's risk assessment had been implemented and were effective.

MMA's SPTO risk assessment identified mitigation measures, such as informing local authorities of single-person operations, instituting a procedure for a single operator to take control of an unattended train, allowing an LE to stop a train for a 20-minute nap, and requiring an LE to contact the RTC once every 30 minutes. However, contrary to what MMA had proposed, there was very limited SPTO training. The SPTO training did not include a review of securement rules and instructions. Furthermore, no job task analysis was discussed with employees, nor were all of the potential hazards associated with the tasks identified, notably the risks associated with single-operator train securement at the end of a shift. Consequently, no mitigation measure was identified for this critical task, such as confirming with an RTC how a train was secured, or even questioning the practice of leaving a train on the main track in Nantes when securement relied on a single operator. Finally, MMA did not conduct a single OTIS inspection to verify SPTO train securement in Nantes.

In some countries, regulators consider a company's ability to execute its plan before granting authority to implement SPTO. Others require the operator to be accredited, and narrowly circumscribe its SPTO program to the territory and type of application, with all changes requiring pre-approval by the regulator. The experience in operations around the world shows that SPTO can be done safely when risks are identified, and when technologies and processes are put in place to ensure the physical and cognitive risks inherent to 1-person operations are effectively and reliably mitigated.

Despite concern over MMA's elevated risk profile, and knowledge of the weaknesses in its risk assessment process (as documented in audits going back to 2003), TC did not require MMA to use processes and technological advancements to mitigate the risks of operating with 1 less crew member.

The investigation carefully examined whether SPTO played a role in the securement of the train at Nantes, and whether SPTO influenced how the abnormal condition of the locomotive was addressed.

With respect to train securement, TSB testing showed that it was possible for a single operator to apply a sufficient number of hand brakes within a reasonable amount of time. A TSB survey also determined that there were instances when MMA LEs working as single operators applied less than the minimum number of hand brakes. The minimum hand brake requirement was more consistently met when trains were operated by 2 crew members. On the basis of this survey, it cannot be concluded how many more (if any) hand brakes would have been applied had the LE been paired with a conductor. Furthermore, even if the LE had applied the minimum number of hand brakes required by MMA's *General Special Instructions* (GSIs) (9, based on the "10% plus 2" chart), TSB testing showed that this number would not have provided sufficient retarding force to hold the train once the air pressure in the independent brake system was reduced. Moreover, since the LE did not perform the hand brake effectiveness test properly, he likely would not have recognized the need for additional hand brakes, even with the presence of a second crew member.

Given that the conductor and LE operate as an integrated team, contributing knowledge and providing backup for each other as necessary, the TSB considered whether the presence of a second crew member could have influenced how the abnormal engine condition was handled. Although fatigue was not considered to be a contributing factor in this accident, after having been awake for more than 17 hours, there may have been a slight degradation of the LE's cognitive performance, which would have affected his ability to solve the issue surrounding the source of the excessive smoke. When discussing the engine's abnormal condition with the Bangor RTC, the LE sought a second opinion, which is an example of joint compliance. However, the LE presented the situation in a manner that suggested it would settle down and that no further action was required that night. The pair did not discuss the MMA procedure requiring that a locomotive be shut down due to abnormal smoke, and the only person to question the decision to leave the locomotive was the taxi driver, whose comments did not carry the same weight as a qualified railway employee. It is therefore not possible to conclude whether the presence of another crew member would have resulted in different actions that night (either shutting down the lead locomotive and starting another, or putting another locomotive in the lead and keeping it running).

On the whole, it could not be concluded whether SPTO contributed to the incorrect securement of the train or to the decision to leave the locomotive running at Nantes despite its abnormal condition. However, it is clear that MMA's implementation of SPTO did not address all critical risks, specifically how a single operator might deal with any abnormal conditions, the risks of single-person securement, or the need for joint compliance. Moreover, TC did not develop an oversight plan to ensure that MMA implemented SPTO in accordance with MMA's risk assessment. Despite being aware of significant operational changes at MMA, TC did not provide adequate regulatory oversight to ensure that the associated risks were addressed.

The number of required crew members is related to the tasks that must be performed to accomplish the work safely and efficiently. To ensure an equivalent level of safety is maintained when reducing the number of crew members, railways must analyze the impact of the reduction on the activities to be performed and determine what, if any, new risks may be introduced. Mitigation measures can then be put in place, followed by subsequent monitoring to assess their effectiveness.

If railways implement SPTO without identifying all risks, and if mitigation measures are not implemented, an equivalent level of safety to that of multi-person crews will not be maintained. Moreover, if there are no rules and regulations for SPTO, nor a requirement for TC to approve and monitor railways' plans for SPTO, then single-person trains may operate without all of the necessary defences in place.

## 2.13 *Montreal, Maine & Atlantic Railway operations*

### 2.13.1 *Additional defences against runaways*

Workers will sometimes deviate from written rules and procedures, either because they do not know the rule or procedure or do not understand its purpose, or to accomplish the work more efficiently. When there are no negative consequences, these employee adaptations can persist and become widespread. In doing so, this way of working becomes normalized and can erode the safety margins that the rules and procedures were intended to provide.

The practice of leaving trains unattended on the main track had been in place for several months at MMA. This decision was based on convenience and efficiency, given crew scheduling, the length of the trains, and the need to avoid blocking crossings in the town. At Nantes, leaving the train on the main track clear of the east switch allowed access to the siding where cars were stored. However, as the siding was equipped with a special derail, this practice resulted in a potential safety device not being used. Since leaving a train on the main track was not prohibited by regulation, it was not questioned by TC inspectors. Further, it had not resulted in any adverse consequence, and so MMA's management did not examine the practice.

The concept of "defence in depth" is one that has been adopted by some industries for many years. Layers of defences, or safety redundancy, have proven successful in ensuring that a single-point failure does not lead to catastrophic consequences. In the rail industry, physical defences can be used as additional defences to prevent runaways. These additional defences were not used by MMA, nor were they required by regulation. This risk was never assessed or addressed, and no additional physical safety defences were put in place to prevent the uncontrolled movement of trains left unattended on the main track.

### 2.13.2 *Excessive rail wear*

There was excessive rail wear (that is, exceeding the vertical wear limits in MMA's and other Class 1 railway standards) on some rail in the Lac-Mégantic area. Rail wear results in an increase in stresses and reduces rail fatigue life. Consequently, worn rail will become more susceptible to development and spread of cracks leading to rail breaks, thereby increasing the risk of derailment. Poor rail conditions, such as wear beyond limits, battered rail joints, and crushed head, were identified by TC during its many engineering inspections (53), resulting in a letter of concern being issued in the year prior to the accident.

If head wear exceeds 8 mm on 115-pound rail, standard joint bars can be struck by the wheel flanges of passing trains. This results in high impacts to wheels and rails, and can also increase the risk of derailment. The risk is elevated when wheel profiles have increased flange heights, or when new rail joint bars are applied to head-worn rail. Due to the extent of the vertical rail wear (as much as 25 mm in 1 location), impact marks were clearly visible on some rail joint bars during the TSB investigation; however, they had not been identified previously by MMA or TC inspections, nor had corrective action been taken. The application of maximum vertical rail wear limits and the use of high-clearance joint bars are intended to prevent such high impact forces, but these types of joint bars were not in use in MMA's track maintenance program.

Rail wear was normally accurately measured by the track geometry car used by MMA; however, due to the rail head's severely worn and deformed condition, a correct profile was not recorded. The condition of the rail (for example, whether there are shells, spalls, and corrugation) when conducting such inspections must also be taken into consideration. Therefore, although track geometry inspections were performed by MMA and TC, the excessive rail head wear was not identified, and maintenance crews were not being alerted to the severity of the wear. If poor rail and joint conditions are not addressed, there are increased stresses on wheels and rails, which may lead to damaged equipment or infrastructure, thus increasing the risk of derailment.

### 2.13.3 *Safety management*

All organizations must manage competing priorities; key among these priorities are safety, service, cost-effectiveness, technology, and return on investment. The challenge is to balance these priorities, while still reducing safety risks to an acceptable level. To do this, it is important that railways have the necessary safety processes in place to continually identify and mitigate the hazards and risks that may arise.

In 2001, TC developed regulations to further promote safety and to ensure that companies have a minimum standard for safety processes. Railways are required to implement and maintain an SMS that integrates safety in day-to-day operations, and that enables the company to find risks and take action before those risks lead to an accident. A well-implemented and actively used SMS promotes a highly-effective safety culture.

Although MMA had certain safety processes in place and had developed an SMS in 2002, the company did not begin implementing the program until 2010, and did so only in reaction to a TC audit. By 2013, many of the processes outlined in MMA's SMS manual were not contributing to the identification of hazards and mitigation of risks. For example, the company's toll-free number for reporting safety concerns was not being used.

There were 4 crucial indicators (analyzed in the next section) that MMA did not have a functioning SMS; these were:

- absence of an internal safety auditing process;
- weaknesses in the process for ensuring adequate employee training;
- weaknesses in the OTIS program, which limited its effectiveness in identifying areas of non-compliance; and
- inconsistently used risk assessment processes.

### 2.13.4 *Internal safety auditing*

Internal SMS audits play a critical role in the system's continual improvement, by providing the organization with an opportunity to observe whether SMS processes are being used as designed.

Although MMA's SMS manual indicated that a process was in place to conduct internal audits, no detail was provided. On 2 occasions, TC determined that MMA's procedures for conducting internal audits were incomplete. This issue was never resolved, and by the time of the accident, MMA had never conducted an internal audit to assess the effectiveness of its safety management processes.

The lack of internal audits caused other deficiencies in MMA's SMS to remain unidentified and unaddressed, which limited the company's ability to proactively identify hazards and manage risks.

### 2.13.5 *Training and requalification*

Rail transportation is a rules-based industry that requires knowledge and understanding of, as well as adherence to, many rules and regulations in order to ensure safe and efficient operations. Employees must therefore receive proper training and testing, as well as adequate requalification testing.

Each railway determines the methods for training and requalification, yet the 3-year time frame for this is mandated by TC. MMA did not consistently comply with this requirement. For example, the company provided the LE with 3-month extensions in both 2009 and 2013, resulting in the LE's requalification training being delayed beyond the 3-year time frame specified by regulation. Furthermore, in 2013, the LE was allowed to complete his exams at home, without classroom training.

Several other problems existed within MMA's training and requalification program for LEs:

- Exams remained relatively unchanged year after year. This meant that MMA was not using the requalification program to address deficiencies identified through monitoring, and rule changes or new operational instructions could not be addressed.
- The increasing use of multiple-choice questions limited the ability of instructors to evaluate comprehension.
- Requalification sometimes consisted of only a written exam, without classroom training; this negated an opportunity for interactive employee-instructor discussions.
- A lack of feedback on exam results meant that employees missed learning opportunities, increasing the risk of potential misunderstanding and subsequent misapplication of rules and instructions.

Although several exams show that the LE correctly answered multiple-choice questions related to the minimum number of hand brakes, these questions were relatively simple, and did not adequately demonstrate the LE's knowledge of the significance and rationale of securement rules. Furthermore, the LE was never tested on the procedures for performing a hand brake effectiveness test, or on the fact that the air brake system must not be depended upon to prevent an undesired movement. There was also an indication that the LE had limited knowledge of MMA's instructions, namely on the use of the auto-start system, and the procedure for QRB valves as well as their significance to the proper operation of a locomotive hand brake.

Therefore, MMA did not provide effective training to ensure crews understood and correctly applied rules governing train securement.

This issue goes beyond the training and requalification of 1 LE. Between 2006 and 2013, inspectors from TC Quebec Region noted numerous instances of improperly qualified employees working in different departments, such as the operations, engineering, and mechanical departments, as well as the rail traffic control centre. In addition, during SPTO implementation, MMA had planned to provide LEs with approximately 4 hours of training, covering rules, instructions, and procedures for SPTO, as well as issues related to working alone, first-aid, and fatigue and lifestyle planning. The actual SPTO training was often significantly abbreviated, and delivered within the hour preceding an operator's first train departure as a 1-person crew.

### 2.13.6 Rules compliance

In order to promote consistent operating practices, railways must provide clear rules and instructions to employees, and must verify that these rules and instructions are being followed.

Rules and instructions need to be clearly documented, and employees must be kept abreast when changes occur. In addition, employees must have access to the necessary reference materials (rulebooks, supplements, and other documents) while on duty.

The accident LE did not have all of the required documents at the time of the accident. The company was not ensuring that all employees were familiar with new operating bulletins. The company's rules, supplements, and general operating instructions were organized in multiple documents, which made it difficult to refer to these documents and increased the risk of misinterpreting rules.

Clear rules and instructions are only valuable if they are consistently applied in day-to-day operations. MMA's OTIS program sought to verify compliance by observing employees unannounced. For this approach to be effective, employees must be aware that they could be tested at any location and at any time. Unannounced tests must then be performed at a satisfactory frequency across the railway's network, and the employees must be made aware that the tests have been performed, regardless of the results.

This investigation identified a number of weaknesses in MMA's oversight program.

At MMA, employees were only informed of tests if they failed. However, because the failure rate was so low, and because managers did not conduct even the minimum number of tests required, employees were rarely informed of these tests and so remained unaware of the full extent of the program. In addition, testing was performed much less frequently east of Sherbrooke. For example, the LE, who had made 60 trips to Nantes in the previous 12 months, had never been tested on train securement at Nantes during the previous 4 years. He had only been tested either at Sherbrooke or further west.

Moreover, CROR 112 is identified as one of a few rules warranting a minimum number of monthly tests. However, when a Rule 112 test was performed, MMA managers usually only ensured that the required number of hand brakes had been applied (Rule 112[a]). Because of practical difficulties associated with the test, managers seldom checked that a proper hand brake effectiveness test was conducted (Rule 112[b]). Therefore, MMA's oversight of equipment securement rules and procedures did not effectively ensure that crews properly verified that the hand brake retarding force was sufficient to hold a train.

Consequently, MMA's employee oversight program was not effective in identifying the unsafe train-securement practices being used in the Lac-Mégantic area.

### 2.13.7 *Risk assessment*

Risk assessments are a cornerstone of a fully functioning and effective SMS, and are essential for a safe operating company. While important for day-to-day operations, risk assessments are particularly crucial when a company makes a change to its operations, since this is when new risks may emerge.

To be effective, a risk assessment process must be conducted for a sufficient range of situations, must encourage the identification of all anticipated hazards, and must ensure that mitigation measures have been effectively implemented. Although MMA had undertaken a few formal risk assessments, most risk-management initiatives were informal and undocumented.

This situation increased the likelihood that not all of the newly emerging risks would be properly assessed when significant operational changes were made. When increasing the number of unit oil trains, company personnel discussed issues surrounding the operation of the larger, heavier trains, such as traction and braking. However, no formal risk assessment was performed, and all of the risks of carrying increasingly more crude oil were neither evaluated nor mitigated.

Similarly, no risk assessment was conducted when the company moved the crew-change location to Nantes and began parking trains unattended on the main track on a descending grade. In this instance, it was believed that a risk assessment was not required, since rules and instructions governing train securement already existed, and trains had occasionally been parked at this location in the past. Securement relied on a single administrative line of defence: a properly conducted hand brake effectiveness test. As a result, this practice, although compliant with regulations, did not reduce risk to a level as low as reasonably practicable.

Finally, when implementing SPTO, the company only performed a formal risk assessment at TC's request. This risk assessment, however, did not address how the task of securing a train, previously performed by a crew of 2, would be completed, since the rules for train securement were already in place. In addition (as described in section 2.13.5), some of the mitigation measures identified in the assessment were not effectively implemented.

These weaknesses in MMA's use of risk assessments meant that, when making significant operational changes on its network, MMA did not thoroughly identify and manage the risks to ensure safe operations.

To help an organization manage risk, the required processes must be in place and used effectively. MMA submitted SMS documentation to TC in 2003 and was found compliant with the regulations. However, MMA's SMS was lacking key processes, and other processes were not being effectively used. As a result, MMA did not have a fully functioning SMS to effectively manage risk.

### 2.13.8 *Safety culture*

The 2007 report on the review of the *Railway Safety Act* (RSA)[139] notes, "The cornerstone of a truly functioning SMS is an effective safety culture." An effective safety culture in a railway can significantly reduce the number of accidents, and is the basis for an effective safety program. The strength of an organization's safety culture starts at the top, and is characterized by proactive measures to eliminate or mitigate operational risks. MMA was generally reactive in addressing safety issues. Furthermore, there were significant gaps between MMA's operating instructions and how work was actually conducted in day-to-day operations.

There were also other signs in MMA's operations that were indicative of a weak organizational safety culture, such as:

- MMA management's acceptance of rail wear on the main track that was well beyond industry norms and their own track standards;
- MMA management's tolerance of non-standard repairs (for example, to the locomotive engine and the QRB valve), which either subsequently failed, or did not return the parts to their proper operating condition;
- the systemic practice of leaving unattended trains on the main track, and on a descending grade, at Nantes for several hours without in-depth defences to prevent an uncontrolled movement;
- crews and single-person train operators not always correctly applying CROR 112 and MMA's instructions when securing trains at Nantes;
- inadequate company oversight to ensure the correct securement of trains at Nantes;
- MMA's inadequate recertification program and SPTO training that did not ensure that operating crews knew and understood the procedures for train securement;
- the giving of extensions for competency cards by MMA management, in some cases for several months beyond the mandatory limit of 3 years; and
- the fact that only local corrective action resulted from recurring deficiencies identified during TC inspections of MMA track and operations; the systemic issues contributing to these deficiencies were not fully analyzed by MMA, and thus persisted.

If instructions or rules are disregarded, and unsafe conditions and practices are allowed to persist, this leads to an increased acceptance of such situations. Deviations from the norm thus become the norm, and the likelihood of unsafe practices being reported and addressed is reduced. Although educational material about safety culture was provided to railway companies, safety culture was not formally assessed or documented within regulatory inspections or audits. MMA's weak safety culture contributed to the continuation of unsafe conditions and practices, and compromised MMA's ability to effectively manage safety.

---

[139] Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), available at
http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

## 2.14 *Transport Canada oversight*

### 2.14.1 *Regulatory oversight of Montreal, Maine & Atlantic Railway*

#### 2.14.1.1 *Regulatory inspection program at Montreal, Maine & Atlantic Railway*

TC Quebec Region had been inspecting and monitoring MMA's operations, equipment, and infrastructure. For several years, MMA had been identified as a railway company with an elevated level of risk requiring more frequent inspections. Through inspections, TC Quebec Region identified a number of ongoing safety deficiencies requiring safety action. TC Quebec Region issued numerous notices, notices and orders, letters of concern, and letters of non-compliance. Although MMA normally took action after the inspection to address the identified safety deficiency, it was not uncommon for similar deficiencies or risks to be identified in subsequent inspections. The following are examples of such safety deficiencies:

- Problems with train securement were identified on multiple occasions since 2005, and were still present at the time of the accident.
- Between 2006 and the time of the accident, training deficiencies were noted in several functional groups, including the mechanical group, operations and engineering group, and rail traffic control.
- Track condition was noted as an ongoing issue between 2006 and the time of the accident.

TC Quebec Region did not follow up to ensure that recurring safety deficiencies at MMA were effectively analyzed and corrected; consequently, unsafe practices persisted.

Moreover, following MMA's implementation of SPTO, TC's oversight was insufficient in verifying that SPTO had been implemented in a manner consistent with the mitigation measures outlined in MMA's risk assessment.

#### 2.14.1.2 *Safety management system audits at Montreal, Maine & Atlantic Railway*

TC's guidance material indicates that TC verifies that an operator has an SMS that is documented, employed, and effective in improving safety.[140] While inspections are critical in identifying unsafe conditions, SMS audits are complementary to the inspection process. SMS audits allow the reasons for underlying unsafe conditions to be explored, and for verification that the organization has effective processes in place to identify and mitigate similar conditions in the future.

At MMA, the first SMS audit to assess the effectiveness of the company's safety management processes took place in 2010, which was 7 years after the company was found to be in compliance with the *SMS Regulations*. During this audit, inspectors were informed that the SMS had not yet been implemented because the company was awaiting regulatory approval. TC then clarified with MMA that TC does not approve a railway's SMS. A second SMS audit was conducted in 2012, and focused on a very limited subset of SMS elements.

---

140 Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

Although TC Quebec Region reviewed the corrective action plans provided by MMA as a result of the audits, no specific follow-up was conducted to verify that the corrective action plans had been implemented. TC Quebec Region did not have a procedure in place for conducting such follow-ups. Moreover, no follow-up was conducted during the 2012 audit on the findings of the previous audit, since it was not within the scope of the audit as determined by the convening authority. Therefore, the auditors could not verify that effective corrective action plans had been developed to address previous identified deficiencies.

As a result, many of the deficiencies in MMA's SMS that came to light through the audit process were never resolved. For example, weaknesses in MMA's risk assessment process were identified during TC's pre-audit in 2003. The 2010 audit found that risk assessments were being conducted only for major operational changes. Since that time, very few risk assessments had been conducted, and no documented risk assessments were conducted for the practice of leaving unattended trains on a grade at Nantes.

The absence of an internal audit procedure at MMA was first identified during TC's pre-audit in 2003, and again in the 2010 SMS audit. An internal audit procedure had not been developed, and no internal SMS audits had taken place at MMA.

Other weaknesses in MMA's SMS, including the fact that the toll-free number for reporting safety concerns was not being used and that the required number of OTIS tests were not being conducted, were not identified during the verification process.

Although TC inspections identified problems at MMA between 2003 and 2010, and it was clear to TC that MMA's SMS was not effective, no SMS audits were conducted in that time frame. The 2010 TC audit determined that MMA had not implemented its SMS. The limited number and scope of SMS audits that were conducted by TC Quebec Region, as well as the absence of a follow-up procedure to ensure MMA's corrective action plans had been implemented, contributed to the fact that systemic weaknesses in MMA's SMS remained unaddressed.

If TC does not audit the SMS of railways in sufficient depth and frequency and confirm that corrective actions are effectively implemented, there is an increased risk that railways will not effectively manage safety.

### 2.14.2 *Transport Canada's monitoring of regional audits*

Given that the *SMS Regulations* came into force in 2001, TC Rail Safety should have had enough time to confirm that all railways have an SMS in place that is effectively improving safety.

In 2007, the RSA Review Panel found that, while improvements had certainly been made, progress in implementing SMS had been inconsistent. The review panel expressed concern over the regulator's ability to implement the use of SMS successfully, citing a number of challenges, including resourcing issues, the skill sets required of inspectors, and a belief that demonstrating the existence of processes was sufficient to demonstrate compliance. Since then, TC has taken steps to address the recommendations made by the panel. For example, in 2011, a group responsible for leading national audits, overseeing audit planning, and developing auditor training for all inspectors was created in TC Headquarters. Through this group, TC Headquarters increased its oversight of SMS programs.

However, as the Office of the Auditor General's (OAG's) examination of the adequacy of rail safety oversight in November 2013 revealed, this objective has not been met. The OAG concluded that, 12 years after the implementation of SMS, TC does not have adequate assurance that federal railways have implemented effective SMS.

Despite TC's efforts, this accident demonstrated that a number of weaknesses are still present in the oversight of safety programs.

The TC Regions were the convening authority for SMS audits, and were responsible for identifying the target and scope of the audits. TC Quebec Region had not been conducting sufficient audits to verify the effectiveness of SMS in the province's 4 regional railways. Although all railways were subject to a pre-audit shortly after the regulations came into force, only 3 audits examining the use and effectiveness of SMS procedures had been completed at the time of the accident.

Although audits should be conducted periodically, or triggered in reaction to results from compliance inspection activities, neither of these approaches were used in TC Quebec Region; instead, MMA was audited in response to a railway accident. Auditing in response to accidents does not effectively place the onus on the railway company to demonstrate that it is continuously managing risks, as outlined in objective 3(*c*) of the RSA. The limited number and scope of the audits conducted by TC Quebec Region meant that many aspects of railways' SMS had not been validated for effectiveness.

The lack of audits and follow-up on audit findings was due to a number of factors. There was a belief by TC regional personnel that it would not be possible to conduct periodic SMS audits convering all elements required under the *SMS Regulations* for all regional railways, given the personnel requirements of SMS audits. Furthermore, some railway safety inspectors (RSIs) felt unprepared to participate effectively in SMS audits, particularly as audit team leaders.

Many inspectors felt that resources devoted to SMS audits were wasted; they believed that there was little that could be done if an operator was not conforming to its SMS. This belief originated from TC's Railway SMS Regulations Enforcement Policy, which established that a railway company could be prosecuted for non-compliance with *SMS Regulations*, but not for deficiencies in the implementation of SMS. Although the RSA provides tools to take action when an immediate threat to safety exists, the deficiencies identified during the implementation of a company's SMS would be presented to the company as an opportunity for improvement. However, inspectors were provided with few tools to require improvements if a company was unwilling or unable to effectively implement the processes required under the *SMS Regulations*.

Many inspectors in TC Quebec Region were not engaged in SMS implementation, and saw SMS in the Region as being within the domain of the Safety Systems Overview group. However, the Safety Systems Overview group was not actively supported from colleagues and management.

As a result, TC Quebec Region was not ensuring that regional railways had an effective SMS in place.

Because regional railways were the responsibility of each TC Region, TC Headquarters did not provide leadership, but rather limited its role to providing support for the regional oversight of the SMS program. The support focused on helping Regions prepare and deliver audits of regional railways. TC Headquarters did not provide the minimum requirements regarding audit frequency or audit scope to the Regions. Moreover, TC Headquarters did not monitor regional auditing activities to ensure that the minimum standards were being met and that all activities, such as following up on audit findings, were consistently performed. Consequently, TC Headquarters was unaware of any weaknesses in oversight of regional railways in Quebec, and did not intervene to provide additional support. Without sufficient national monitoring, TC does not have adequate assurance that its Regions are providing effective oversight of regional railways to ensure that the risks to the public are being properly managed.

## 2.15 *Canadian Transportation Agency reporting requirements*

The *Canada Transportation Act* requires railways to carry adequate insurance to cover the risk of operations. The Canadian Transportation Agency (CTA) initially examines insurance coverage when issuing a certificate of fitness (COF). Subsequently, a review can be triggered when the agency is advised by a railway company of operational changes. At the time of the accident, the magnitude and type of operational changes that needed to be reported were subjective; therefore, railways determined what they would report to the CTA.

MMA had requested 3 variances to its COF as a result of changes in operations. However, the railway did not consider the increase in crude oil to be a significant operational change, and therefore did not inform the CTA of this change in its risk profile. Moreover, the CTA did not routinely seek out this type of information or conduct periodic assessments of certificate holders' insurance. Consequently, the CTA was not aware of operational changes at MMA affecting the adequacy of its insurance coverage.

The significant increase in the transportation of dangerous goods and, in particular, the increasing number of unit trains of petroleum crude oil, raised the risk profile of MMA's operations. However, the regulatory requirements in place at the time of this accident did not ensure that an increase in risk was reflected in MMA's insurance coverage.

# 3.0 *Findings*

## 3.1 *Findings as to causes and contributing factors*

1. MMA-002 was parked unattended on the main line, on a descending grade, with the securement of the train reliant on a locomotive that was not in proper operating condition.

2. The 7 hand brakes that were applied to secure the train were insufficient to hold the train without the additional braking force provided by the locomotive's independent brakes.

3. No proper hand brake effectiveness test was conducted to confirm that there was sufficient retarding force to prevent movement, and no additional physical safety defences were in place to prevent the uncontrolled movement of the train.

4. Despite significant indications of mechanical problems with the lead locomotive, the locomotive engineer and the Bangor, Maine, rail traffic controller agreed that no immediate remedial action was necessary, and the locomotive was left running to maintain air pressure on the train.

5. The failure of the non-standard repair to the lead locomotive's engine allowed oil to accumulate in the turbocharger and exhaust manifold, resulting in a fire.

6. When the locomotive was shut down as a response to the engine fire, no other locomotive was started, and consequently, no air pressure was provided to the independent brakes. Further, locomotives with an auto-start system were shut down and not available to provide air pressure when the air brake system began to leak.

7. The reset safety control on the lead locomotive was not wired to initiate a penalty brake application when the rear electrical panel breakers were opened.

8. Because air leaked from the train at about 1 pound per square inch per minute, the rate was too slow to activate an automatic brake application.

9. When the retarding brake force provided by the independent brakes was reduced to about 97 400 pounds, bringing the overall retarding brake force for the train to approximately 146 000 pounds, the train started to roll.

10. The high speed of the train as it negotiated the curve near the Megantic West turnout caused the train to derail.

11. About one third of the derailed tank car shells had large breaches, which rapidly released vast quantities of highly volatile petroleum crude oil, which ignited, creating large fireballs and a pool fire.

12. Montreal, Maine & Atlantic Railway did not provide effective training or oversight to ensure that crews understood and complied with rules governing train securement.

13. When making significant operational changes on its network, Montreal, Maine & Atlantic Railway did not thoroughly identify and manage the risks to ensure safe operations.

14. Montreal, Maine & Atlantic Railway's safety management system was missing key processes, and others were not being effectively used. As a result, Montreal, Maine & Atlantic Railway did not have a fully functioning safety management system to effectively manage risk.

15. Montreal, Maine & Atlantic Railway's weak safety culture contributed to the continuation of unsafe conditions and unsafe practices, and compromised Montreal, Maine & Atlantic Railway's ability to effectively manage safety.

16. Despite being aware of significant operational changes at Montreal, Maine & Atlantic Railway, Transport Canada did not provide adequate regulatory oversight to ensure the associated risks were addressed.

17. Transport Canada Quebec Region did not follow up to ensure that recurring safety deficiencies at Montreal, Maine & Atlantic Railway were effectively analyzed and corrected, and consequently, unsafe practices persisted.

18. The limited number and scope of safety management system audits that were conducted by Transport Canada Quebec Region, and the absence of a follow-up procedure to ensure Montreal, Maine & Atlantic Railway's corrective action plans had been implemented, contributed to the systemic weaknesses in Montreal, Maine & Atlantic Railway's safety management system remaining unaddressed.

## 3.2 *Findings as to risk*

1. If a proper hand brake effectiveness test is not performed, equipment may not be adequately secured, increasing the risk of a runaway.

2. If hand brakes are applied on the operating locomotive(s) during a hand brake effectiveness test, this may result in an inaccurate effectiveness test, increasing the risk of runaways.

3. Given the variable condition of locomotive hand brakes, counting them as part of the total number of hand brakes required can lead to overestimating the braking force, thereby increasing the risk of a runaway.

4. If equipment is left unattended without additional physical safety defences, there is an increased risk that it will run away, leading to an accident.

5. If railways implement single-person train operations without identifying all risks, and if mitigation measures are not implemented, an equivalent level of safety to that provided by multi-person crews will not be maintained.

6. If there are no rules and regulations for single-person train operations, nor a requirement for Transport Canada to approve and monitor railways' plans, then single-person trains may operate without all of the necessary defences in place.

7. If trains are left unattended in easily accessible locations, with locomotive cab doors unlocked and the reverser handle available in the cab, the risk of unauthorized access, vandalism, and tampering with locomotive controls is increased.

8. If poor rail and joint conditions are not addressed, there are increased stresses on wheels and rails, which may lead to damaged equipment or infrastructure, thus increasing the risk of derailment.

9. If systematic testing is not conducted on representative samples of petroleum crude oil at an appropriate frequency, there is an increased risk that these dangerous goods will be improperly classified.

10. If not properly classified and documented, dangerous goods may be moved and handled incorrectly, increasing the risk of injury to people, and of damage to property and the environment.

11. Without monitoring and effective enforcement of compliance with applicable classification provisions of the Transportation of Dangerous Goods Regulations, there is a risk that improperly classified dangerous goods will enter the transportation system.

12. If Class 111 tank cars that do not meet enhanced protection standards transport flammable liquids, there is an ongoing risk of product loss and significant damage to persons, property, and the environment when these cars are involved in accidents.

13. If the shipper has not developed an adequate, regulator-approved emergency response assistance plan, the required resources to assist local responders may not be available in the event of an accident involving large quantities of liquid hydrocarbons.

14. If route planning, analysis and follow-up risk assessments are not conducted by railways along routes where dangerous goods are carried, comprehensive safety measures to mitigate the risks may not be introduced.

15. If Transport Canada does not audit the safety management systems of railways in sufficient depth and frequency and confirm that corrective actions are effectively implemented, there is an increased risk that railways will not effectively manage safety.

16. Without sufficient national monitoring, Transport Canada does not have adequate assurance that its Regions are providing effective oversight of regional railways to ensure that the risks to the public are being properly managed.

## 3.3 *Other findings*

1. It could not be concluded whether single-person train operations contributed to the incorrect securement of the train or to the decision to leave the locomotive running at Nantes, Quebec, despite its abnormal condition.

2. The petroleum crude oil being transported by the train was improperly classified; it was assigned packing group III (lowest hazard), despite meeting the criteria for packing group II.

3. The Nantes Fire Department had to shut down the locomotive to stop the flow of oil, which was feeding the fire. Their actions were consistent with railway instructions.

4. The track geometry condition was adequate for the existing traffic and was acceptable for the speed allowed (15 mph) for trains travelling through Megantic Station.

5. Despite the challenges of responding to a major disaster not specifically covered by many firefighters' practical training, the emergency response was conducted in a well-coordinated and effective manner.

6. The regulatory requirements in place at the time of this accident did not ensure an increase in risk was reflected in Montreal, Maine & Atlantic Railway's insurance coverage.

# 4.0 *Safety action*

## 4.1 *Safety action taken*

### 4.1.1 *Montreal, Maine & Atlantic Railway*

To improve the safety of its rail operations, Montreal, Maine & Atlantic Railway (MMA) has:

- implemented all orders, directives, and safety advisories put in place by the Minister, Transport Canada (TC), the Transportation Safety Board (TSB), the United States Department of Transportation (DOT), and the Federal Railroad Administration (FRA);
- ceased, by agreement with the Canadian Transportation Agency (CTA), the handling of crude oil of any type from any location;
- addressed all TC notices, and notices and orders, regarding track and right-of-way;
- installed 1100 crossties at several locations to protect the integrity of the track structure;
- performed rail flaw detection and track geometry testing between St-Jean Station, Quebec, and the U.S. border, and addressed identified deficiencies;
- cut and removed brush between Magog, Quebec, and the U.S. border;
- eliminated single-person train operations (SPTO);
- increased field supervision as well as operating-rules testing and enforcement;
- instituted and complied with all procedures mandated or suggested by the Minister, TC, the TSB, or U.S. authorities. These included the securement of trains and locomotives, as well as the prohibition from leaving unattended trains containing dangerous goods on the main track;
- adopted the Association of American Railroads (AAR) Circular OT-55, titled *Recommended Railroad Operating Practices For Transportation of Hazardous Materials.*

### 4.1.2 *Transportation Safety Board rail safety recommendations*

On 23 January 2014, the TSB issued 3 recommendations.

#### 4.1.2.1 *Vulnerability of Class 111 tank cars to sustainment of damage*

The examination of the 63 general-service Class 111 tank cars that derailed in Lac-Mégantic revealed that 59 of the cars (94%) had released petroleum crude oil due to impact damage. The damage to the tank cars in Lac-Mégantic clearly indicates that product release could have been reduced had the tank car shells and heads been more impact-resistant. Recent accidents, including those that occurred in Aliceville, Alabama (November 2013), Casselton, North Dakota (December 2013), Plaster Rock, New Brunswick (January 2014), and Lynchburg, Virginia (April 2014), involving Class 111 tank cars, have again highlighted their vulnerability to accident damage and product release. Design improvements to these types of cars are needed to mitigate the risks of a dangerous goods release and the consequences observed in the Lac-Mégantic accident. Commodities posing significant risk must be shipped in safe containers that include defences, such as stronger tank shells, tank car jackets, full-height head shields, thermal protection, and high-capacity pressure relief devices. Given the magnitude of the risks, and given that tank car standards must be set for the North American rail industry, the Board recommended that:

> The Department of Transport and the Pipeline and Hazardous Materials Safety Administration require that all Class 111 tank cars used to transport flammable liquids meet enhanced protection standards that significantly reduce the risk of product loss when these cars are involved in accidents.
>
> **TSB Recommendation R14-01, issued January 2014**

In February 2014, both Class 1 Canadian railways (Canadian National [CN] and Canadian Pacific Railway [CPR]) announced a surcharge for customers using the pre-CPC-1232 Class 111 tank cars.

In March 2014, CPR and CN announced improvements to their Class 111 tank car fleets. CPR committed to phasing out or retrofitting its (fewer than 200) Class 111 tank cars. CN committed to phasing out or retrofitting its fleet of pre-CPC-1232 Class 111 tank cars. It will replace all 40 tank cars that it owns, and will replace the remaining 143 cars as their leases expire over the next 4 years.

In February 2014, Irving Oil Ltd. (Irving) stated that it intended to phase out by May 2014 the remainder of the pre-CPC-1232 Class 111 tank cars in its fleet. It further stated that 88% of its fleet already meets the Association of American Railroads (AAR) 2011 standard. It has also requested that all of its suppliers, by the end of the year, use cars that adhere to the AAR 2011 standard.

**Response from Transport Canada**

In response to TSB Recommendation R14-01, TC indicated that it will prohibit the use of the highest-risk group of pre-CPC-1232 Class 111 tanks cars. Under subsection 32(1) of the *Transportation of Dangerous Goods Act* (1992), Protective Direction No. 34 was issued on 23 April 2014 prohibiting the use of tank cars that have no continuous reinforcement of their bottom shell for carrying any Class 3 flammable liquids, including crude oil and ethanol. The industry had 30 days to fully comply.

TC further stated that it will require that all pre-CPC-1232/TP 14877 tank cars used for the transportation of crude oil and ethanol be phased out of service or retrofitted within 3 years.

In the interim, the train routing restrictions outlined in TC's response to Recommendation R14-02 (see section 4.1.2.2) are designed to reduce the associated risks. TC plans to meet or exceed any new U.S. standard; therefore, it will continue to work closely with its U.S. counterparts on the development of more stringent tank car construction and retrofit standards to further enhance safety of the integrated North American rail system.

In addition, TC will proceed expeditiously with the *Canada Gazette*, Part II, publication of the 13 updated means of containment standards, including the AAR 2011 CPC-1232 standard for DOT-111 tank cars, that were introduced for consultation in Canada on 11 January 2014.[141]

**Response from the Pipeline and Hazardous Materials Safety Administration**

In response to TSB Recommendation R14-01, the Pipeline and Hazardous Materials Safety Administration (PHMSA) indicated that on 30 April 2014, the DOT, on behalf of PHMSA and the FRA, submitted a notice of proposed rulemaking (NPRM). The NPRM, titled *Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains (HM-251)*,[142] was sent to the Office of Management and Budget's (OMB) Office of Information and Regulatory Affairs (OIRA) for review. This notice proposes a comprehensive approach to rail safety to improve tank car integrity, as well as to provide additional operational controls, enhance emergency response, and establish methods to improve the classification and characterization of hazardous materials.[143]

In addition, on 07 May 2014, PHMSA and the FRA issued Safety Advisory Notice No. 14-07: *Recommendations for Tank Cars Used for the Transportation of Petroleum Crude Oil by Rail*,[144] urging railroad carriers transporting petroleum crude oil from the Bakken formation in the Williston Basin to use the tank cars of the highest integrity within their existing fleet and to avoid using legacy DOT-111 tank cars to the extent practicable.

**Board assessment of Transport Canada's response to Recommendation R14-01**

TC immediately prohibited the use of some pre-CPC-1232 Class 111 tank cars, and will require the phasing-out or retrofitting of the existing fleet within 3 years. TC has also committed to expeditiously publishing updated regulations in the *Canada Gazette*, Part II, including the new standard TP 14877 (which adopts the AAR 2011 CPC-1232 standard for Class 111 tank cars), making it mandatory for new tank cars built for the transportation of dangerous goods (including crude oil and ethanol) in packing groups (PGs) I or II to include end-of-tank protection, thicker and more impact-resistant steel tanks, and protected top fittings, as a minimum, to improve accident performance.

However, the TP 14877 standard is not sufficiently robust to minimize the risk of dangerous goods releases when Class 111 tank cars are involved in a derailment. The railway industry is asking both the Canadian and U.S. regulators to go much further than the AAR 2011 CPC-1232 standard, and it would seem that both governments are actively discussing improvements.

The Board is encouraged by the safety actions and the immediate steps to mitigate the risks taken to date. However, the process of implementing safety enhancements to the North American fleet of tank cars will take time, and the specific improvements to new tank car designs will not be known until the process is finalized. Therefore, until all pre-CPC-

---

141 Subsequent to TC's response, amendments to the *TDG Regulations* were implemented on 02 July 2014. See section 4.1.6.

142 Docket No. PHMSA-2012-0082.

143 Subsequent to the response, PHMSA issued its NPRM on 23 July 2014. See updated information at the end of section 4.1.2.1.

144 Docket No. PHMSA-2014-0049; Safety Advisory No. 2014-01.

1232/TP 14877 tank cars are no longer used to transport flammable liquids, and a more robust tank car standard with enhanced protection is set for North America, the risk will remain.

**Board assessment of the Pipeline and Hazardous Materials Safety Administration's response to Recommendation R14-01**

PHMSA has accepted the recommendation, and an NPRM on enhanced tank car standards has been submitted for review. During the regulatory process, comments were received on a variety of topics, including on the redesign of DOT specification 111 tank cars, as well as operational practices such as speed limits, train securement, and track integrity.

However, because the process is ongoing, the final ruling on the enhanced tank car standards is not yet known. In the interim, the recommendations contained in Notice No. 14-07 (urging carriers to use the highest-integrity tank car specifications and recommending that they avoid use of the pre-CPC-1232—referred to as "legacy"—tank cars to the extent reasonably practicable) may in some small measure help reduce the risk of petroleum crude oil releases when tank cars are involved in a derailment. The Board is also encouraged by the actions taken to address issues raised in the NTSB safety recommendations (see section 4.1.12).

**Board rating of Transport Canada's and the Pipeline and Hazardous Materials Safety Administration's responses to Recommendation R14-01**

The Board notes favourably the close cooperation between Canada and the U.S. in addressing this issue, as it is important that federal regulations in both countries be harmonized to the greatest extent possible given that North America is an integrated market. However, the process of implementing safety enhancements to the North American fleet of tank cars will take time, and the specific improvements to new tank car designs will not be known until the process is finalized. Therefore, until all pre-CPC-1232/TP 14877 tank cars are no longer used to transport flammable liquids, and a more robust tank car standard with enhanced protection is set for North America, the risk will remain.

For these reasons, the Board assessed the TC and the PHMSA responses to Recommendation R14-01 as being Satisfactory in Part.

The TSB will continue to monitor progress on the development and implementation, on both sides of the border, of rules for tank cars used to transport flammable liquids to meet enhanced protection standards that significantly reduce the risk of product loss when these cars are involved in accidents.

Subsequently, on 18 July 2014, TC issued for consultation a proposal for a new class of tank car (TC-140). The proposal also included a retrofit schedule for older TC/DOT-111 tank cars and the CPC-1232/TP 14877 tank car. According to TC, the new car was specifically developed for the transportation of flammable liquids in Canada by rail, such as crude oil and ethanol, and would enhance the requirements of its TP 14877 standard. Stakeholders have 45 days to provide their comments. TC stated that it will expedite the pre-publication of the new requirements in the *Canada Gazette*, Part I, in the fall of 2014.

On 23 July 2014, PHMSA, in coordination with the FRA, issued an NPRM[145] proposing requirements for high-hazard flammable trains, such as unit trains carrying petroleum crude oil and ethanol. The NPRM included new operational requirements for certain trains transporting a large volume of Class 3 flammable liquids, improvements in tank car standards, and revision of the general requirements for offerors of hazardous materials to ensure the proper classification and characterization of mined gases and liquids. Comments were sought on 3 options for enhanced tank car standards. Stakeholders have 60 days to provide their comments.

#### 4.1.2.2 *Route planning and analysis for trains carrying dangerous goods*

A primary safety concern related to the transportation of dangerous goods by rail is prevention of a catastrophic release or explosion in a densely populated or environmentally sensitive area. The Lac-Mégantic accident heightened the public's awareness of the risks associated with the transportation of dangerous goods.

The AAR Circular OT-55-N, or similar operating restrictions, are necessary to alleviate many of the shortcomings identified during the Lac-Mégantic investigation and other investigations involving the release of dangerous goods. However, these measures need to be complemented by a more comprehensive and proactive approach. An approach based on Circular OT-55-N, strengthened with a requirement to conduct route planning and analysis as well as periodic risk assessments, would be a positive step toward improving the safety of transporting dangerous goods by rail. Therefore, the Board recommended that:

> The Department of Transport set stringent criteria for the operation of trains carrying dangerous goods, and require railway companies to conduct route planning and analysis as well as perform periodic risk assessments to ensure that risk control measures work.
>
> **TSB Recommendation R14-02, issued January 2014**

**Response from Transport Canada**

On 23 April 2014, in response to TSB Recommendation R14-02, TC issued an emergency directive under section 33 of the *Railway Safety Act* (RSA) requiring railways carrying dangerous goods to implement minimum critical operating practices, including speed restrictions, enhanced inspection and maintenance requirements, and risk assessments on key routes over which key trains operate. The emergency directive is in force for 6 months, and may need to be renewed to reflect further consultation with stakeholders and consideration of any additional U.S. requirements that may be established.

At the same time, TC also issued a ministerial order under section 19 of the RSA. This ministerial order requires railways carrying dangerous goods to formulate and submit for approval, within 180 days, new rules based on these above-described operating practices to further improve the safe transportation of dangerous goods by rail in the long term.

---

[145] Docket No. PHMSA-2012-0082, HM-251.

**Board assessment of Transport Canada's response to Recommendation R14-02**

On 18 June 2014, the TSB issued its assessment of TC's response to Recommendation R14-02, as follows:

> The Emergency Directive will require risk assessments to be conducted on key routes over which key trains operate. However, key routes are defined as a route over which 10 000 car loads of dangerous goods are transported annually. This threshold may limit the number of routes subject to these enhanced safety measures. A rigourous analysis should be conducted of the 10 000-car threshold to determine which routes will be excluded and whether the safety deficiency identified in R14-02 will be addressed.
>
> If the new rules developed pursuant to the Ministerial Order cover the same scope of activities or more, and are strengthened to include more railway routes, the risk posed by movements of dangerous goods could be significantly reduced. However, the proposed rules have not yet been developed, and the outcome cannot be known until the process is finalized.
>
> Therefore, the Board assessed the response to Recommendation R14-02 as having Satisfactory Intent.
>
> The TSB will monitor the railways' progress on the development and implementation of new rules to improve their operating practices for the safe transportation of dangerous goods.[146]

#### 4.1.2.3 *Requirements for emergency response assistance plans*

An emergency response assistance plan (ERAP) is required by the *Transportation of Dangerous Goods Regulations* for certain goods that pose a higher-than-average risk when transported in certain quantities. When an accident occurs, the handling of these dangerous goods requires special expertise, resources, supplies, and equipment. At the time of the accident, an ERAP was not required for the transportation of all large volumes of flammable liquids, such as petroleum crude oil. However, approved ERAPs help ensure that first responders consistently have access, in a timely manner, to the required resources and assistance to deal with an accident involving significant quantities of flammable liquids.

Following this accident, an emergency response working group was established by TC's Transportation of Dangerous Goods General Policy Advisory Council in November 2013. The working group, chaired by the Canadian Association of Fire Chiefs, was tasked to examine the possibility of extending the ERAP program to include flammable liquids, such as crude oil, or to recommend other emergency response solutions aimed at ensuring access to appropriate response capability and specialized supplies.

---

[146] Transportation Safety Board (TSB), Rail Recommendation R14-02: Route planning and analysis for trains transporting dangerous goods, Board assessment of response to R14-02 (June 2014), available at http://www.tsb.gc.ca/eng/recommandations-recommendations/rail/2014/rec-r1402.asp (last accessed on 24 July 2014).

The Board acknowledged this TC initiative. However, given the significant increase in the quantities of crude oil being transported by rail in Canada, as well as the potential for a large spill and the risks it would pose to the public and the environment, the Board recommended that, at a minimum:

> The Department of Transport require emergency response assistance plans for the transportation of large volumes of liquid hydrocarbons.
>
> **TSB Recommendation R14-03, issued January 2014**

**Response from Transport Canada**

On 23 April 2014, in response to TSB Recommendation R14-03, TC issued Protective Direction No. 33 under the *Transportation of Dangerous Goods Act* (1992). This protective direction, in effect 150 days from the issue date, requires an ERAP for certain higher-risk hydrocarbons and flammable liquids, including crude oil and ethanol, when offered for transport or imported by rail in 1 or more tank cars that are each filled to 10% of capacity or more.

TC indicated that it will establish an emergency response planning task force with members from key partners and stakeholders to provide a dedicated forum, and with support from a team of experts, to respond to recommendations of the emergency response working group of the Transportation of Dangerous Goods General Policy Advisory Council. The task force will focus on ERAP activation processes, cooperative industry approaches, development of information-sharing protocols, and promotion of unified incident command structures. The task force will also review and provide advice on the possible expansion of ERAP requirements to other Class 3 flammable liquids.

**Board assessment of Transport Canada's response to Recommendation R14-03**

In its assessment of TC's response to TSB Recommendation R14-03, issued on 18 June 2014, the TSB noted that the protective direction will require ERAPs for commonly transported hydrocarbons and flammable liquids that present a higher risk, even for volumes of 1 loaded tank car or more, and TC will also establish a task force to focus on ERAP requirements.

The protective direction ensures that there will be approved ERAPs in place for the shipment of higher-risk hydrocarbons and other flammable liquids, including ethanol. Therefore, the Board assessed the response to Recommendation R14-03 as Fully Satisfactory.

The TSB will continue to monitor progress of the industry task force on ERAPs for the transportation of large volumes of liquid hydrocarbons.

### 4.1.3 *Transportation Safety Board rail safety advisories*

#### 4.1.3.1 *Securement of locomotives, equipment, and trains left unattended*

On 18 July 2013, the TSB issued Rail Safety Advisory 08/13 to TC. The advisory stated that, given the importance of the safe movement of DGs and the vulnerability of unattended equipment, TC may wish to consider reviewing all railway operating procedures to ensure that trains carrying DGs are not left unattended on the main track.

Also on 18 July 2013, the TSB issued Rail Safety Advisory 09/13 to TC. The advisory stated that, given that there is considerable variability in the effectiveness of the hand brake system on rail cars, and that the hand brake effectiveness test used by railways to satisfy *Canadian Rail Operating Rules* (CROR) 112(b) does not always adequately verify whether the braking force of the hand brake application is sufficient to hold the cars, TC may wish to review CROR 112 and related railway special instructions to ensure that equipment and trains left unattended are properly secured in order to prevent unintended movements.

On 12 September 2013, in reply to Rail Safety Advisories 08/13 and 09/13, TC indicated that, on 23 July 2013, pursuant to section 33 of the RSA, it had issued an emergency directive[147] (which was to remain in effect until 31 December 2013) whereby all federally regulated railway companies and local railway companies operating equipment on federal railways were ordered to:

1. ensure that all unattended controlling locomotives on a main track and sidings[148] are protected from unauthorized entry into the cab of the locomotives;
2. ensure that reversers are removed from any unattended locomotive on a main track and sidings;
3. ensure that the company's special instructions on hand brakes referred to in CROR 112 are applied when any locomotive coupled to 1 or more cars is left unattended for more than 1 hour on a main track or sidings;
4. ensure that, when any locomotive coupled to 1 or more cars is left unattended for 1 hour or less on a main track or sidings, in addition to complying with the company's special instructions on hand brakes referred to in CROR 112, the locomotives have the automatic brake set in full service position and have the independent brake fully applied;
5. ensure that no locomotive coupled to 1 or more loaded tank cars transporting DGs is left unattended on a main track; and
6. ensure that no locomotive coupled to 1 or more loaded tank cars transporting DGs is operated on a main track or sidings with fewer than 2 persons qualified under the company's requirements for operating employees.

TC also indicated that it was following up on this emergency directive with all rail operators in federally regulated and local railway companies to ensure that the requirements contained therein were met. As a result of the emergency directive, several changes were made to the CROR, including Rules 62 and 112, as well as General Rule M. As for the order to not leave trains transporting dangerous goods unattended on the main track, this requirement does not appear to be covered in any subsequent rule change. Other conditions that appear to be less restrictive than the emergency directive relate to orders 3 and 4 (above) and CROR 112 (see 4.1.8 for more information).

---

147 Transport Canada, Emergency Directive Pursuant to Section 33 of the Railway Safety Act: Safety and Security of Locomotives in Canada (23 July 2013).

148 For the purpose of the emergency directive, "main track" and "sidings" do not include main track or sidings in yards and terminals.

#### 4.1.3.2 *Determination of petroleum crude oil properties for safe transportation*

On 11 September 2013, the TSB issued Rail Safety Advisory 12/13 to TC, which stated that the waybill information described the product carried in each tank car of MMA-002 as UN 1267, petroleum crude oil, Class 3, PG III.[149] However, the results of tests performed on the content of the 9 tank cars that did not derail indicated that the product sample was in the lower end of the petroleum crude oil flashpoint range, well below the PG III threshold, which corresponds to a product that is required to be identified as Class 3, PG II. Given that the safety of individuals who handle or otherwise come into contact with DGs during transport is dependent in large part on an accurate description of the product being transported, and considering the volatility of the type of petroleum crude oil involved in this accident and the potential consequences of its release during an accident, the advisory suggested that TC may wish to review the processes in place for suppliers and companies transporting or importing these products to ensure the product properties are accurately determined and documented for safe transportation.

TC responded that, on 17 October 2013, it issued Protective Direction No. 31, pursuant to section 32 of the *Transportation of Dangerous Goods Act* (*TDG Act*), requiring any person who imports, offers for transport or transports petroleum crude oil to:

- conduct classification testing of any petroleum crude oil being classified as UN 1267 or UN 1993 that has not been classification-tested since 07 July 2013;
- make those test results available to TC upon request;
- update their safety data sheets (SDSs) and immediately provide them to TC's CANUTEC (Canadian Transport Emergency Centre); and
- ship all petroleum crude oil classified as UN 1267 or UN 1993 as Class 3, flammable liquids, PG I, when shipping by rail, until classification testing has been completed.

In response to Rail Safety Advisory 12/13, TC published amendments to the *TDG Regulations* in the *Canada Gazette*, Part II, on 02 July 2014. These amendments include a requirement that the person who classifies a DG before transportation keep a record of classification of those goods, as well as a record of the sampling method for petroleum crude oil, and the requirement for consignors to certify that the person named on the shipping document has prepared the consignment to the regulations that apply.

Also on 11 September 2013, the TSB issued Rail Safety Advisory 13/13 to PHMSA on the same subject. On 23 September 2013, PHMSA responded that a joint safety advisory had been issued with the FRA on 02 August 2013, recommending that shippers of hazardous materials, including petroleum crude oil, reassess their operating procedures to ensure that the petroleum crude oil is properly classified and assigned the appropriate PG. This review is to include evaluation of the frequency of verification of flashpoint and boiling point, and the effects that blending of crude from different wells have on these characteristics. PHMSA also indicated that it continues to inspect shippers and carriers, and to monitor, among other things, the material classification of petroleum crude oil in the U.S. under a nationwide inspection campaign with the FRA.

---

[149] Petroleum crude oil Class 3 flammable liquids are further divided into packing groups (PGs), based on their properties such as flashpoint and boiling point, to indicate the degree of danger presented as either great, medium, or minor (packing group I, II, or III, respectively).

On 14 November 2013, PHMSA and the FRA issued Safety Advisory No. 2013-07, emphasizing the importance of proper characterization, classification, and selection of a packing group for Class 3 materials, and the corresponding requirements in federal hazardous materials regulations for safety and security planning. In addition, offerors by rail and rail carriers are expected to revise their safety and security plans, including the required risk assessments, to address the safety and security issues identified in the FRA's 02 August 2013 Emergency Order No. 28 and joint safety advisory.

The United Nations is also working on issues related to the classification and safe transportation of crude oil. A subcommittee of the Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals is soliciting feedback with respect to the classification and hazard-communication elements of the United Nations Model Regulations currently applicable to crude oil. This subcommittee includes participants from Canada and the U.S.

On 15 August 2014, the TSB issued a safety advisory to TC. Rail Safety Advisory 06/14 related to the classification accuracy of mined gases and liquids, such as petroleum crude oil.

#### 4.1.3.3 *Short line railway employee training*

On 15 August 2014, the TSB issued Rail Safety Advisory 07/14 to TC, which related to the adequacy of employee training programs by short line railways.

### 4.1.4 *Tranportation Safety Board rail safety information letters*

Following this accident, the TSB received a number of reports concerning potential problems with sections of MMA track and with MMA railway equipment. As a result, the TSB issued to TC the rail safety information letters described below.

On 18 July 2013, the TSB issued Rail Safety Information Letter 10/13 on the track conditions at Lac-Brome, Quebec. In response, TC indicated on 30 September 2013 that it had inspected all MMA main tracks using a track assessment vehicle. In addition, an examination of the subject section of track by a TC inspector revealed some anomalies in certain rail joints that did not meet MMA's standards. As a result, MMA lowered its train operating speed in this section to the equivalent of a Class 1 track.

Also on 18 July 2013, the TSB sent Rail Safety Information Letter 11/13 to TC regarding the track conditions at Sherbrooke Yard, Quebec. TC conducted an inspection of the MMA Sherbrooke Yard and identified several significant safety concerns with respect to the infrastructure on all yard tracks. As a result, on 26 July 2013, a TC railway safety inspector issued a notice informing MMA that a threat to safe railway operations existed due to the track condition in the Sherbrooke Yard. On 09 August 2013, MMA replied to the notice, indicating that the company would make repairs to certain conditions found, apply remediation to other conditions found, make tracks "excepted", or close tracks, and would adjust operations in Sherbrooke Yard as well as develop a plan for further usage.

On 22 July 2013, the TSB issued Rail Safety Information Letter 13/13 on the soil conditions in Sherbrooke, Quebec. In its response dated 30 September 2013, TC informed the TSB that inspection of the Sherbrooke Yard had revealed that a broken City of Sherbrooke water pipe had eroded the soil under a bike path and the MMA right-of-way. MMA made appropriate repairs, and the problem was resolved.

On 26 August 2013, the TSB sent Rail Safety Information Letter 16/13 to TC regarding the crossing condition at Agnès Street in Lac-Mégantic. On 27 September 2013, TC advised the TSB that the Ministry of Transport of Quebec was planning to replace the crossing surface in the fall to address the reported unsafe condition at the Agnès Street public crossing. Subsequently, the Ministry of Transport of Quebec made a temporary repair to the road surface by adding asphalt where the road crosses the main track; the spur leading to a local industrial facility was covered over with asphalt, as it had not been used for 2 years.

Also on 26 August 2013, the TSB issued Rail Safety Information Letter 17/13 on the drainage condition near Chemin du Versant in Lac-Mégantic. On 18 October 2013, TC indicated that it had conducted an extensive site visit, which indicated erosion affecting the head wall of the culvert and a need for the embankment to be stabilized. TC recommended that a 10-mph temporary slow order (TSO) be applied until the situation was corrected. MMA advised that it would be transferring this issue to the new operator and would be involving the town of Lac-Mégantic to discuss an eventual work plan. In the meantime, MMA will continue to monitor the situation during its weekly inspections, and TC will continue to follow up.

### *4.1.5 Other measures taken by the Transportation Safety Board*

On 08 October 2013, the TSB provided TC with the results of its examination of sections of track near Lac-Mégantic (see section 1.17.4 for details). TC combined this information with the results from its own inspections and followed up with MMA. In addition, on 09 October 2013, the TSB provided the same information to the municipality of Lac-Mégantic.

### *4.1.6 Transport Canada*

On 23 July 2013, pursuant to section 33 of the RSA, TC issued an emergency directive to federally regulated railway companies and local railway companies operating equipment on federal railways. The emergency directive clarified the regulatory regime with respect to unattended locomotives on main track and sidings, and the prohibition of trains transporting dangerous goods from being operated with fewer than 2 persons (see section 4.1.3.1). In connection with the emergency directive, and pursuant to section 36 of the RSA, federal and local railway companies were ordered to file with the Minister, within 7 days:

- their special instructions on hand brakes, referred to in CROR 112 and mentioned in item 3 of the directive; and
- their requirements for operating employees, mentioned in item 6 of the directive.

Also on 23 July 2013, pursuant to section 19 of the RSA, TC issued Ministerial Order 07-2013, ordering all federally regulated railway companies and local railway companies to formulate and, as the case may be, to revise, within 120 days (by 20 November 2013), rules respecting the safety and security of unattended locomotives, uncontrolled movements, and crew size requirements. The order specified that the rules should be based on an assessment of safety and security risks, and shall, at a minimum:

1. Ensure that the cab(s) of unattended controlling locomotives are secure against unauthorized entry;
2. Ensure that the reversers of unattended locomotives are removed and secured;
3. Prevent uncontrolled movements of railway equipment [...] due to tampering or accidental release of brakes from defective components [*by addressing relevant factors*];
4. Ensure the security of stationary railway equipment transporting "dangerous goods" [...];[150] and
5. Provide for minimum operating crew requirements considering technology, length of train, speeds, classification of dangerous goods being transported, and other risk factors.[151]

A revised Ministerial Order, no. 07.1-2013, was issued on 25 November 2013 to extend the deadline for some companies to submit new or revised rules, by an extra 120 days (to 20 March 2014), to allow for further consultation with TC.

On 17 October 2013, pursuant to section 32 of the *TDG Act*, TC issued Protective Direction No. 31, directing any person engaged in importing or offering petroleum crude oil for transport to immediately test its classification if no classification testing has been conducted since 07 July 2013. The protective direction also states that, until such testing is completed, all such products being shipped by rail must be classified as a Class 3 flammable liquid PG I. (See section 4.1.3.2 for more details.)

On 18 November 2013, the Minister of Transport requested that the House of Commons Standing Committee on Transport, Infrastructure and Communities (commonly referred to as SCOTIC) conduct an in-depth review of the Canadian regime regarding the safe transportation of dangerous goods, and the role of safety management systems across all modes of transportation. It was requested that an interim report be presented by June 2014, followed by a final report by December 2014. SCOTIC accepted the request, undertook the study, and tabled its preliminary report in Parliament on 13 June 2014.

In November 2013, TC announced the creation of 3 industry-led working groups on classification, emergency response, and means of containment. All 3 working groups provided a report to TC on 31 January 2014, which have been posted on TC's website. The reports' recommendations are under consideration.

On 20 November 2013, TC issued Protective Direction No. 32, directing Canadian Class 1 railways and persons who transport DGs by rail to periodically provide specified DG traffic information to each municipality through which DGs are transported by rail, and to notify municipalities of any significant changes to that information. This information must also be provided to TC, through CANUTEC.

In December 2013, TC developed an action plan to address the recommendations contained in the *2013 Fall Report of the Auditor General of Canada*. TC stated that most action items are to

[150] As defined in section 2 of the *Transportation of Dangerous Goods Act*.

[151] Transport Canada, 07-2013, Minister of Transport Order Pursuant to Section 19 of the *Railway Safety Act* (23 July 2013).

be completed by fall 2014, and the entire action plan is expected to be fully implemented by fall 2015.

On 24 December 2013, TC issued another emergency directive similar to the one issued on 23 July 2013. It was issued to local railway companies, some of which were not covered by the earlier directive. The emergency directive was to be in effect for 6 months (that is, until 01 July 2014) or until rules are approved for all companies.

On 26 December 2013, TC approved changes to the CROR (TC O 0-167), including a new General Rule M (iii), which states, "The minimum operating crew requirement for a freight train or transfer carrying one or more loaded tank cars of dangerous goods is two (2) crew members".

On 30 December 2013, TC issued an order under section 36 of the RSA to all Railway Association of Canada (RAC) member railways to file their special instructions on CROR 112, governing testing the effectiveness of hand brakes.

Amendments to the RSA came into force on 01 May 2013, and enabled the making of regulations in a number of areas that strengthen the Minister's enforcement powers. Therefore, on 15 March 2014, TC published *Railway Operating Certificate Regulations* in the *Canada Gazette*, Part I. These proposed regulations would require a railway company to hold a railway operating certificate (ROC) issued by the Minister of Transport. The Minister may suspend or cancel an ROC if the company has contravened a provision of the Act or the regulations made under this Act.

On 23 April 2014, in response to the 3 railway safety recommendations issued by the TSB on 23 January 2014, TC took the following measures:

- Under the *TDG Act*, it issued Protective Direction No. 33, requiring ERAPs for smaller volumes of commonly transported flammable liquids, such as crude oil and ethanol (see section 4.1.2.3).
- It issued Protective Direction No. 34, removing the least crash-resistant Class 111 tank cars from dangerous goods service (see section 4.1.2.1).
- It issued Order MO 14-01 pursuant to section 19 of the *Railway Safety Act*, requiring railway companies to formulate rules respecting the safe and secure operations of trains carrying certain dangerous goods and flammable liquids. In conjunction with Order MO 14-01, TC issued an emergency directive pursuant to section 33 of the RSA, requiring railways to implement minimum operating practices on key routes over which they operate key trains (see section 4.1.2.2).

On 17 May 2014, *Administrative Monetary Penalties Regulations* (*AMP Regulations*) were published in the *Canada Gazette*, Part I. These proposed regulations would allow for monetary penalties ranging from $5000 to $50 000 for individuals, and from $25 000 to $250 000 for corporations, for contraventions to various sections of the *Railway Safety Management System Regulations* (*SMS Regulations*).

In June 2014, TC advised that follow-up procedures both for audits and for inspections had been developed. These procedures are expected to be released in mid-2014. Furthermore, a baseline audit plan has been developed in order to assess railway companies' implementation of their SMS. A baseline audit will be conducted on each railway on a 5-

year cycle and will include the components of section 2 of the *SMS Regulations*, effective fiscal year 2014 – 2015.

On 02 July 2014, TC published amendments to the *TDG Regulations* in the *Canada Gazette*, Part II. These amendments include requirements to build, after 15 July 2014, all Class 111 tank cars used for the transport of DGs in PG I or PG II (other than toxic by inhalation substances) to specifications similar to the AAR CPC-1232 standard. The amended regulations also apply to tank cars used for the transport of PG III petroleum crude oil (UN 1267) and petroleum products not otherwise specified (UN 1268).

Revised *SMS Regulations* were published in the *Canada Gazette*, Part I, on 05 July 2014. These proposed regulations, which would come into force on 01 April 2015, would expand the scope of application to all companies that operate on federal track, would introduce new provisions, and would clarify existing provisions to facilitate more effective compliance and enforcement.

TC collaborated with the National Municipal Rail Safety Working Group of the Federation of Canadian Municipalities to discuss rail and TDG safety-related concerns, such as improving risk assessments, emergency planning and response capability, and increasing insurance requirements for railways and shippers.

#### 4.1.6.1 *Safety action taken by Transport Canada Quebec Region with respect to Montreal, Maine & Atlantic Railway*

TC Quebec Region took the following measures regarding safety concerns and safety deficiencies noted at MMA after the Lac-Mégantic accident:

- On 10 July 2013, a notice and order was issued to MMA regarding equipment left unattended.
- On 24 July 2013, a notice was sent to MMA and the Municipality of Eastman regarding damage on the overhead timber bridge crossing. This notice was superseded by the notice and order issued on 23 December 2013 and cited below.
- On 26 July 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on the Sherbrooke Subdivision.
- On 26 July 2013, a notice and order was issued regarding the state of the infrastructure on the Stanbridge Subdivision.
- On 26 July 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on all yard tracks in Sherbrooke Yard.
- On 09 August 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on the St-Guillaume Subdivision and in Farnham Yard.
- On 11 October 2013, a notice and order was issued regarding safety deficiencies of public and private crossings on the Sherbrooke Subdivision. On 31 October 2013, after a review and evaluation of actions taken by MMA, TC revoked the notice and order.
- On 31 October 2013, a notice and order was issued regarding rail wear and rail surface defects on the Moosehead Subdivision.

- On 31 October 2013, a notice and order was issued regarding the conditions of tracks on the Sherbrooke Subdivision.
- On 31 October 2013, a notice and order was issued regarding safety deficiencies of public and private crossings on the Sherbrooke Subdivision.
- On 23 December 2013, a notice and order was issued to MMA and to the Municipality of Eastman regarding the condition of the Chemin d'Orford-sur-le-Lac overhead bridge located in the Municipality of Eastman and crossing the MMA Sherbrooke Subdivision. On 28 January 2014, following a review and evaluation of actions taken by the Municipality of Eastman, TC revoked the notice and order, and issued a second notice and order regarding the condition of timber curbs, posts and handrails on the bridge. Repairs by the Municipality of Eastman were begun in the spring of 2014 and are ongoing.

### *4.1.7 Canadian Transportation Agency*

Following the derailment, on 13 August 2013, the CTA suspended MMA's certificate of fitness (COF). After MMA took a series of actions to improve the safety of its rail operations (see section 4.1.1) and demonstrated to the CTA's satisfaction that it had insurance in place, the CTA allowed the company to resume operations.

In the 16 October 2013 Speech from the Throne, the Governor General stated that the "government will require shippers and railways to carry additional insurance so they are held accountable." In the fall of 2013, the CTA conducted public consultations regarding the adequacy of the *Railway Third Party Liability Insurance Coverage Regulations*. After the first round of consultations ended in late January 2014, the CTA published a report entitled *What We Heard* and opened a second round of consultations, which closed on 09 May 2014. The CTA continues to work with TC on increased railway insurance requirements, and on a framework for railways and shippers to fund cleanup costs.

Regarding enhanced enforcement, the CTA is considering the introduction of administrative monetary penalties for non-compliance with regulatory requirements.

Furthermore, the CTA is expanding its memorandum of understanding with TC to include collaboration and information-sharing about federal railways to get a better understanding of the overall safety records of railways in connection with their COFs. The CTA is also aiming to have a similar memorandum in place with the TSB.

### *4.1.8 Railway Association of Canada*

On 20 November 2013, the RAC submitted to TC for approval a revised CROR 112 (Leaving Equipment Unattended). The revised rule, which was approved by TC on 26 December 2013, states the following:

> (a) Equipment must be secured if it is left unattended. The following are acceptable methods of ensuring securement:
> (i) Sufficient number of hand brakes;
> (ii) A mechanical device approved for use by a professional engineer;
> (iii) Equipment is left on a track designed to prevent the equipment from moving unintentionally (e.g. switching bowl or where grade

does not allow) and that design is approved by a qualified employee;
- (iv) Equipment is derailed or coupled to derailed equipment;
- (v) A movement secured as per paragraph (c) in this rule.

(b) While switching enroute, the standing portion must be protected as per paragraph (a) unless:
- (i) There are at least 15 cars;
- (ii) Not on a grade in excess of 1.25%;
- (iii) The equipment will not be left in excess of 2 hours;
- (iv) The air brake system is sufficiently charged to ensure proper air brake application; and
- (v) The brake pipe is fully vented at a service rate or an emergency application of the air brakes has been made, and the angle cock is left fully open.

Whenever it is possible that the portion left standing cannot be secured within the applicable time limit, the standing portion must be secured as per paragraph (a).

(c) A movement may be left unattended if:
- (i) Secured as per paragraph (a); or
- (ii) Left at a location where a derail protects the movement from unintentionally obstructing main track and
  - The air brake system is sufficiently charged to ensure proper brake application;
  - The locomotive controlling the air brake system maintains air pressure;
  - A full service or emergency air brake application is made; and
  - Independent brake is fully applied; or
- (iii) Air brake system is sufficiently charged to ensure a proper brake application and
  - The locomotive controlling the air brake system maintains air pressure;
  - A full service or emergency air brake application is made;
  - Independent brake is fully applied;
  - Hand brakes are applied on 10% of the equipment to a maximum of 5;
  - It is not on a grade exceeding 1.25%; and
  - Is not left in excess of 2 hours.

(d) Exceptional weather situations, such as high winds or other unusual conditions, must be considered and factored into securement decisions. Special instructions may contain location specific instructions where extreme weather events are prevalent.

(e) Instructions governing testing the effectiveness of hand brakes will be carried in special instructions.

(f) Application of hand brakes must not be made while equipment is being pulled or shoved.

(g) Before leaving equipment at any location, the employee securing such equipment must confirm with another employee the manner in which the equipment has been secured.

Following the issuance of TC's Order MO 14-01 in April 2014, the RAC established a working group to initiate the rule-making process in order to formulate rules respecting the safe and secure operations of trains carrying certain DGs and flammable liquids.

The RAC initiated the development of mutual aid agreements to improve DG accident response times and capabilities.

Railways and a number of industry stakeholders are collaborating and have initiated work to develop an ERAP process for liquid hydrocarbons and ethanol that will serve shippers, railways, and emergency response contractors.

Railways and a number of industry stakeholders have established the Canadian Training Coalition for Transportation Incidents. This coalition's objective is to raise awareness of and competence in handling fires involving liquid hydrocarbons and ethanol among local first responders.

### 4.1.9 *Canadian Pacific Railway*

In response to TC's order of 30 December 2013, CPR advised that its special instructions for CROR 112 state:

> Testing Hand Brake Effectiveness
>
> To ensure sufficient number of hand brakes are applied, release all air brakes and **allow or cause** the slack to adjust. It must be apparent when slack runs in or out, that the hand brakes are sufficient to prevent that equipment from moving. This must be done before uncoupling or before leaving equipment unattended.
>
> **IMPORTANT**: When brakes are released to test effectiveness, allow sufficient time for the air brakes to release.[152]

CPR and CN signed a joint mutual-aid agreement to improve DG accident response times and capabilities.

### 4.1.10 *Canadian National Railway*

In response to TC's order of 30 December 2013, CN advised that its special instructions for CROR 112 state:

---

152 Canadian Pacific Railway (CPR), General Operating Instructions (GOI) Section 4 – 02/20/2014: Hand Brakes – Leaving Equipment (20 February 2014), p. 2. (Bold text in original.)

> Handbrake effectiveness must be tested before uncoupling and leaving equipment unattended or riding equipment to rest. To test the effectiveness, release all air brakes and **allow or cause** the slack to adjust. It must be apparent when slack runs in or out, that the handbrakes are sufficient to prevent that equipment from moving. When brakes are released to test effectiveness, allow sufficient time for the air brakes to release. If unable or difficult to observe slack movement, or securing less than 10 cars, slightly move the car(s) to ensure sufficient retarding force.[153]

As previously mentioned in section 4.1.9, CN and CPR signed a joint mutual-aid agreement to improve DG accident response times and capabilities.

#### *4.1.11 Irving Oil Ltd.*

Following the accident, Irving took the following measures:

- amended its transportation of DGs training program to extend training to all company petroleum crude oil traders and rail logistics personnel;
- engaged petroleum crude oil suppliers and transloaders to ensure that they are correctly classifying the petroleum crude oil to be transported to Irving's facilities and providing accurate SDSs for the petroleum crude oil supplied;
- implemented processes to reconcile shipping documents with other product documentation (such as SDSs) to confirm the accuracy of the product's classification;
- conducted periodic testing for the classification of petroleum crude oil (for example, flashpoint and initial boiling point) at loading points to collect data in order to better understand the classification and the potential variability in petroleum crude oil from different producers and suppliers;
- increased its oversight of transloading facilities to ensure that all applicable regulatory provisions are met;
- continued working with its counterparts, including suppliers and transloading facilities, to determine how best to provide improved oversight on matters related to the transportation of DGs, given some of the unique commercial challenges presented by the transportation of petroleum crude oil.

#### *4.1.12 Safety action taken in the United States*

Following the Lac-Mégantic derailment, a number of measures were taken in the U.S. to enhance railway safety.

On 02 August 2013, the FRA issued Emergency Order 28 (EO-28), strengthening train securement rules by requiring the development and submission of each railroad's process for securing unattended trains carrying DGs on the main line. The order established certain securement requirements for unattended trains, such as use of locks or removal and securement of the reverser on a locomotive, communication between train dispatchers and train crews, recording of information, daily job briefings, and notification to railroad

---

153 Canadian National Railway (CN), CN GOI Section 9: Handbrakes (01 July 2014), 9.1.2(g) Testing Handbrake Effectiveness, p.2. (Bold text in original.)

employees. EO-28 was later amended by the FRA based on a petition by the AAR to modify 2 of its provisions.

Also on 02 August 2013, PHMSA and the FRA jointly issued a Safety Advisory No. 2013-06 to railroad owners and hazardous materials shippers detailing recommended actions the industry is expected to take to better ensure the safe transportation of hazardous materials. The recommendations include guidance on train crew size; on operating, testing and classification procedures; on system-wide evaluations of security and safety plans; and on risk mitigation.

On 07 August 2013, PHMSA and the FRA announced a comprehensive review of operational factors that affect the safety of the transportation of hazardous materials by rail (Title 49, *Code of Federal Regulations* [49 CFR], Part 174). On 27 and 28 August 2013, PHMSA and the FRA held a public meeting to solicit input from the public, stakeholders, and interested parties.

In August 2013, "Operation Classification"was initiated. This compliance activity, also known as the "Bakken Blitz", consisted of unannounced inspections and testing by PHMSA and the FRA to verify the material classification and packing group assignments selected and certified by offerors of petroleum crude oil.

On 06 September 2013, PHMSA issued an advanced notice of proposed rulemaking (ANPRM), which was published in the *Federal Register*. The ANPRM requested comments on enhancements to the standards for DOT-111 tank cars used to transport PG I and PG II petroleum crude oil and ethanol. On 30 April 2014, the U.S. DOT, on behalf of PHMSA and the FRA, submitted an NPRM pertaining to enhanced tank car standards for the OMB's review. PHMSA and the FRA continue to work with the OMB to ensure the NPRM is published as quickly as possible (see section 4.1.2.1).

On 14 November 2013, PHMSA and the FRA jointly issued Safety Advisory No. 2013-07, emphasizing the importance of proper characterization, classification, and selection of a PG for Class 3 materials, and the corresponding requirements in the federal hazardous materials regulations for safety and security planning.

FRA draft regulations provide requirements to continue SPTO in place prior to 01 January 2014. A special approval procedure will be required for railroads commencing SPTO after that date.

On 02 January 2014, PHMSA issued a safety alert notifying the general public, emergency responders, shippers, and carriers that the type of crude oil being transported from the Bakken region of North Dakota may be more flammable than traditional heavy crude oil.

On 16 January 2014, the Secretary of Transportation met with members of the rail and the petroleum industries in a call-to-action meeting, to address the risks associated with the transportation of crude oil by rail.

On 22 January 2014, the AAR confirmed its agreement to apply, by no later than 01 July 2014, the routing requirements (49 CFR subsection 172.820) to trains carrying more than 20 cars of crude oil, as discussed at the 16 January call-to-action meeting. The AAR also agreed to further address risks by restricting the speeds of trains carrying more than 20 cars of crude oil to 50 mph, and to 40 mph for such trains with at least one DOT-111 or non-specification tank car travelling through high-threat urban areas, as designated by the Department of Homeland Security.

On 23 January 2014, as a result of its participation in the TSB's investigation into the Lac-Mégantic accident, the U.S. National Transportation Safety Board (NTSB) issued the following 3 safety recommendations to the FRA:

> Work with the Pipeline and Hazardous Materials Safety Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 *Code of Federal Regulations* 172.820 to include key trains transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.
>
> NTSB Recommendation R-14-1

> Develop a program to audit response plans for rail carriers of petroleum products to ensure that adequate provisions are in place to respond to and remove a worst-case discharge to the maximum extent practicable and to mitigate or prevent a substantial threat of a worst-case discharge.
>
> NTSB Recommendation R-14-2

> Audit shippers and rail carriers of crude oil to ensure they are using appropriate hazardous materials shipping classifications, have developed transportation safety and security plans, and have made adequate provision for safety and security.
>
> NTSB Recommendation R-14-3

The NTSB also issued 3 safety recommendations to PHMSA, as follows:

> Work with the Federal Railroad Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 Code of Federal Regulations 172.820 to include key trains transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.
>
> NTSB Recommendation R-14-4

> Revise the spill response planning thresholds contained in Title 49 Code of Federal Regulations Part 130 to require comprehensive response plans to effectively provide for the carriers' ability to respond to worst-case discharges resulting from accidents involving unit trains or blocks of tank cars transporting oil and petroleum products.
>
> NTSB Recommendation R-14-5

> Require shippers to sufficiently test and document the physical and chemical characteristics of hazardous materials to ensure the proper classification, packaging, and record-keeping of products offered in transportation.
>
> NTSB Recommendation R-14-6

On 25 February 2014, the U.S. DOT issued an emergency restriction/prohibition order requiring all shippers to test petroleum crude oil from the Bakken region to ensure that it is properly classified before it is transported by rail. The order also states that Class 3 petroleum crude oil shipped by rail must only be treated as a PG I or PG II hazardous material. This order was later amended and restated on 06 March 2014 to clarify its provisions.

On 09 April 2014, the FRA announced its intention to issue a proposed rule establishing minimum crew-size standards for most main-line freight and passenger rail operations. The notice of proposed rulemaking (NPRM) would require a minimum of 2-person crews for most main-line train operations, including those trains carrying crude oil. The FRA plans to issue an additional NPRM that would prohibit certain unattended freight trains or standing freight cars on main track or sidings, and require railroads to adopt and implement procedures to verify securement of trains and unattended equipment for emergency responders. It would also require locomotive cabs to be locked and reversers to be removed and secured. Railroads would also be required to obtain advance approval from the FRA for locations where or circumstances in which cars or equipment may be left unattended.

On 07 May 2014, the U.S. DOT issued an emergency restriction/prohibition order requiring all railroad carriers that transport in a single train 1 000 000 gallons or more of petroleum crude oil (UN 1267) from the Bakken shale formation to notify the appropriate State Emergency Response Commission of expected movements of such trains through their jurisdiction.

On 07 May 2014, PHMSA and the FRA jointly issued Safety Advisory Notice No. 14-07, urging railroad carriers transporting petroleum crude oil from the Bakken formation to use tank cars of the highest integrity within their existing fleet (see section 4.1.2.1).

### 4.1.13 *Municipality of Nantes*

Following the accident, the municipality of Nantes initiated a review of its rail response protocols and procedures.

## 4.2 *Safety action in progress*

### 4.2.1 *Transport Canada oversight of regional railways*

TC oversees railway safety by conducting inspections and audits. While inspections look at conditions (that is, what is wrong), audits look at systems and processes (that is, to identify why the conditions exist). Inspections should be used to help target future audits and to help monitor the corrective action taken following previous audits.

TC Headquarters oversees SMS in national railways and assigns the oversight of regional railways (both inspections and SMS audits) to its regional offices. These offices make the decisions on which regional railways will be inspected or audited, the scope of each activity, when they will be conducted, and with which frequency at each railway.

TC Quebec Region was inspecting and monitoring the operations, equipment, and infrastructure at MMA. For several years, MMA had been identified as a railway company with an elevated level of risk, requiring more frequent inspections. Through inspections, TC Quebec Region identified a number of ongoing safety deficiencies requiring safety action. TC Quebec Region issued a number of notices, notices and orders, letters of concern, and letters of non-compliance. Although MMA normally took action after the inspection to address the identified safety deficiency, it was not uncommon for similar deficiencies or risks to be identified during subsequent inspections.

TC Quebec Region was performing very few SMS audits, and was not following up on the corrective action plans that railways submitted to ensure that each railway's SMS was effective at reducing safety risks. In contrast, the Atlantic and Ontario Regions were much more active in auditing and follow-up.

As TC Headquarters did not review the oversight activities of its Regions, it was unaware that the Quebec Region was not following up on railways' corrective action plans or risk-mitigation activities. Although meetings were held between Regions and Headquarters several times per year, these meetings did not focus on regional railways. Consequently, TC Headquarters was unaware of the extent to which regional railways were implementing SMS and of the impact, or lack thereof, that SMS was having on each railway's safety performance. Without adequate oversight of regional activities by TC Headquarters, TC Regions may not be effectively ensuring that all of their regional railways have fully implemented their SMS. Consequently, TC cannot be assured that each regional railway's SMS is effective and improving safety.

The *2013 Fall Report of the Auditor General of Canada* examined TC's quality management framework for its Rail Safety Program and found that TC had not assessed whether the oversight methodology for conducting audits and inspections met best practices, and whether audits and inspections were conducted according to that methodology. Consequently, the Office of the Auditor General (OAG) recommended that TC:

> develop a detailed quality assurance plan to assess its oversight methodology against best practices and to regularly evaluate audits and inspections against its methodology, with the goal of promoting continuous improvement.[154]

TC agreed with this recommendation, stating that it will, by the fall of 2014:

> strengthen its quality assurance program by including periodic assessments of its oversight methodology against best practices and assessing whether audits and inspections are being carried out in accordance with this methodology.[155]

---

[154] Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.47, p. 24.

[155] Transport Canada, Detailed Management Action Plan for the OAG's Audit of Oversight of Rail Safety, Quality Assurance: Recommendation 7.81: Detailed Action Plan, Completion Date: Fall 2014.

If implemented, this action by TC would lead to a more robust regulatory oversight regime and promote continuous improvements in every regional railway's SMS. However, because TC's quality assurance program has not yet been implemented, it cannot be determined at this time whether the planned changes will be sufficient to ensure adequate Headquarters oversight of activities in all of TC's Regions. The Board considers it crucial that TC Headquarters follow through with the implementation of processes for it to confirm that all regional offices are effectively overseeing regional railways, including their safety management systems.

## 4.3 *Safety action required*

### 4.3.1 *Prevention of runaway trains: Unattended equipment*

In this accident, a 4700-foot train transporting petroleum crude oil that was parked on the main track ran away. It travelled 7.2 miles down a descending grade, gained speed, and derailed at 65 mph in the town of Lac-Mégantic, Quebec. Sixty-three tank cars spilled approximately 6 million litres of crude oil, which ignited, levelling buildings, destroying the centre of the town, and killing 47 people. There was environmental contamination of the downtown and of the adjacent river and lake.

In this accident, the train was secured at Nantes with both hand brakes and air brakes. However, a proper hand brake effectiveness test had not been conducted to ensure that the hand brakes alone would hold the train. When the locomotive supplying air pressure to the train was shut down, the air brake system leaked off in less than 1 hour. The force from the hand brakes was not sufficient to secure the train, and the train ran away.

Both air brake and hand brake systems are subject to failure, as the technology is not fail-proof.

For example, air brakes are prone to leakage and suffer from limitations in maintaining brake cylinder pressure; when brake pressure is low, fail-safe functions are compromised. In this accident, it took less than 1 hour for the air to be depleted to a point where it was no longer capable of holding the train on the 0.92% grade.

Hand brakes also have significant limitations, in that they cannot provide feedback to the operator about the force applied, and often do not provide the necessary braking force required due to their design and other mechanical and physical factors. In this accident, only 6 of the 7 hand brakes applied by the LE were providing retarding force, and the total force provided by the hand brakes was 48 600 pounds. As a result, it is necessary that a proper effectiveness test, as prescribed by railway operating instructions, be carried out to ensure effective securement of unattended equipment.

In the rail industry, these limitations in technology are addressed with the expectation that there will always be strict compliance with rules. For equipment securement, reliance is placed on CROR 112, company special instructions, and training. When failures occur, it is often concluded that either the rule or the operator is deficient and must therefore be corrected.

Training can improve the effectiveness of rules application. However, the Board found that some MMA employees lacked the knowledge or had not demonstrated the skills required to

safely and competently perform their jobs. This included knowledge of the CROR and the performance of a proper hand brake effectiveness test. Similar deficiencies in training and rules compliance have been observed in a number of other TSB investigations. Of the 9 TSB investigations into runaway equipment carried out in the past 20 years, misinterpretation or misapplication of rules was identified in most to be a cause or contributing factor.
In a system where the final layer of defence is reliance on the application of hand brakes and an effectiveness test, there needs to be clear rules that are well understood and consistently applied. However, no matter how clear and comprehensive rules are, these are administrative defences and, invariably, there will be instances where practices in the field will deviate from these written rules and procedures. TSB investigations into the Lac-Mégantic accident and other runaways have revealed that the chain of events almost always included the application of an insufficient number of hand brakes to secure the train. This means that no matter how well the rule is worded, it will not always be strictly complied with, thereby introducing vulnerability into the safety system. The following TSB data suggest that these vulnerabilities are magnified at short line railways. Of 16 investigations involving short line railways in the past 20 years (including 6 runaways), deficiencies in rules compliance, misinterpretation and/or training have been identified as causal or contributing in 10 cases (62%).

Following this accident, regulators and industry examined the adequacy of CROR 112 with a view to strengthening the procedures. However, the new rule is convoluted, and in some cases, is less restrictive than its previous version. The rule contains a circular reference; paragraph (a) (v) refers to paragraph (c), whereas paragraph (c) (i) refers to paragraph (a). Further, the rule states that "instructions governing testing of hand brakes will be carried in special instructions" but does not explicitly state that the effectiveness of the hand brake(s) must be tested.

Furthermore, under certain circumstances while switching, the amended CROR 112 allows for trains to be left unattended for up to 2 hours on the main track on a grade of up to 1.25%, secured only with air brakes. This is in contrast with the previous rule that did not allow any equipment to be left unattended without hand brakes. The amended rule also does not take into consideration TC's emergency directive that did not allow any equipment carrying dangerous goods to be left unattended on main lines. The lack of clarity in wording of the rule, and its confusing construction, make it difficult to understand. Because this safety-critical rule is not well worded and is more permissive than the emergency directive with respect to dangerous goods, there is an increased risk that equipment will not be properly secured. The train in Nantes ran away in 1 hour. The TSB has investigated other occurrences in which air leakage has resulted in trains running away, such as in Dorée, Quebec (R11Q0056), where the uncontrolled movement occurred in 1 hour. In consideration of the above and the advice of air brake manufacturers that air brake systems not be relied upon for securement, there is a risk that the 2-hour limit has reduced the margin of safety.

Even with the right rules, it has been demonstrated over the years that depending solely on the correct application of rules is not sufficient to maintain safety in a complex transportation system. The concept of "defence in depth" has shaped the thinking in the safety world for many years. Layers of defences, or safety redundancy, have proven to be a successful approach in many industries, including the space and nuclear industries, to ensuring that a single-point failure does not lead to catastrophic consequences.

There are physical defences to protect against the risk of runaway rolling stock, which are available to mitigate the risk of air brake pressure loss, and these include derails, wheel chocks, mechanical emergency devices, and locomotive auto-start systems. New technology is available, such as GPS-equipped devices that can be applied to a hand brake chain, allowing for the remote monitoring of the hand brake status. In addition, some existing technology, such as reset safety controls and sense and braking units, with minor programming changes, can offer additional protection.

Advanced air brake control valves, such as electronically controlled pneumatic (ECP) brakes, can provide added protection by overcoming some of the inherent limitations of the traditional air brake systems. ECP brakes protect against brake cylinder leakage, and will monitor brake pipe pressure and automatically generate an emergency brake application if the brake pipe pressure gets low. The instantaneous application and release of ECP brakes greatly diminishes in-train forces, reducing the risk of derailment. With ECP brakes, the brake pipe is solely dedicated to continuously supplying air, to keep all of the reservoirs charged on the train. ECP brakes also provide valuable information about the status of the train, and feedback on factors such as brake system health, brake pipe continuity, and the number of operative brakes.

The NTSB recently made a recommendation to address the need for redundant protection, such as wheel chocks and derails, to protect against runaway trains (NTSB Recommendation R-14-03 Urgent). The recommendation is derived from the NTSB's investigation into the collision between 2 Chicago Transit Authority trains that occurred on 30 September 2013, in Forest Park, Illinois.

The TSB has pointed out the need for robust defences to prevent runaways since 1996 (Rail Investigation R96C0172), and since then, there have been over 120 runaways in Canada that have affected main-track operations. Equipment runaways are low-probability events, but as this accident demonstrates, they can have extreme consequences, particularly if they involve dangerous goods. As demonstrated in Lac-Mégantic, the cost to human life and our communities can be incalculable. For this reason, the Board recommends that:

> The Department of Transport require Canadian railways to put in place additional physical defences to prevent runaway equipment.

**TSB Recommendation R14-04**

### 4.3.2 *Safety management system audits and essential follow-up*

Managing risk to acceptable levels requires that railway companies analyze the findings of regulatory inspections and SMS audits, identify the underlying causes of these findings, and ensure that corrective actions are effectively implemented and are working. For railway companies to effectively manage risk using SMS, the related processes must not only be documented, they must be in place and actively used.

In addition, for effective regulatory oversight, the regulator must be assured that corrective action plans and measures to mitigate risks have been implemented. Furthermore, if they are not, the regulator must have the power to compel companies to improve their SMS.

Under TC Quebec Region, all railways had been the subject of a pre-audit to verify that the required SMS documentation was in place. However, audits assessing the effectiveness of the regional railways' SMS were extremely limited; some railways had never been the subject of an SMS audit, and none had been the subject of an audit of all SMS components. As such, the regulator could not know whether SMS at these railways was in place and working.

TC had identified a number of recurring problems at MMA. However, MMA had a poor history of analyzing and rectifying the systemic causes of these problems. Moreover, regional oversight did not identify or address this issue. Ten years after TC had informed MMA that it was in compliance with the *SMS Regulations*, MMA did not have a fully functioning SMS to effectively manage risk. The time between audits conducted at MMA, the limited scope of these audits, and the lack of regulatory follow-up on audit findings meant that the regulator remained unaware of the extent of the weaknesses in MMA's SMS. In contrast, other TC Regions were conducting more follow-ups to ensure corrective actions were addressing underlying causes or problems and were effectively improving safety.

In its 2013 report, the OAG concluded that "Transport Canada does not have the assurance it needs that federal railways have implemented adequate and effective safety management systems."[156] The OAG recommended, among other things, that TC establish a minimum level of oversight for SMS, that TC have its inspectors assess the quality and effectiveness of railways' SMS, and that TC require federal railways to correct deficiencies affecting the safety of their operations. It also recommended that TC "conduct timely follow-up on deficiencies affecting the safety of federal railways' operations, to assess whether they have been corrected."[157]

In response to these recommendations, TC indicated that it plans to improve procedures and training for inspectors and is pursuing a number of regulatory changes.

In the past, the *Railway Safety Act* and the *SMS Regulations* only allowed TC to require railway companies to have an SMS. They did not permit TC to assess the effectiveness of SMS components in order to determine whether the SMS was functioning properly and would therefore ensure a safe operation.

The 2013 amendments to the Act allow the Minister to order a company to take corrective measures where its SMS has deficiencies that risk compromising railway safety. The proposed *Railway Operating Certificate and Administrative Monetary Penalty Regulations* published in the *Canada Gazette*, Part I, in the spring of 2014, will also strengthen the Minister's enforcement powers. They are intended to provide the means for TC to encourage or require railway companies to address deficiencies without having to resort to prosecution. Whether monetary penalties or certificate action are a worthwhile tool in addressing an ineffective or poorly implemented SMS will depend largely on how and when these measures are applied.

Furthermore, proposed new *SMS Regulations*, if adopted in the spring of 2015, will provide greater accountability for SMS implementation within railways through, among other measures, the appointment of an accountable executive and requirements to designate persons responsible for individual processes and procedures outlined in a company's SMS.

---

156 Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.43, p. 24.

157 Ibid., section 7.58, p. 28.

The regulations should also make it easier to assess a company's SMS against the regulatory requirements, as the new regulations clearly describe the expectations related to required processes. For example, the requirements for a risk assessment would be expanded to include a number of defined triggers where risk assessment must be done, a requirement to identify remedial actions stemming from the risk assessment, and a process for following up to ensure these remedial actions are implemented.

With the legal framework and enforcement tools in place, TC will have the ability to determine whether a company has implemented an effective SMS and to require changes where it finds deficiencies that compromise rail safety. Further, it would appear that TC intends to audit to ensure that railway companies are effectively using their SMS to improve safety. The regulatory impact analysis statement accompanying the proposed *SMS Regulations* states:

> The oversight activities consist of a combination of inspections to verify compliance and audits to verify the effectiveness of company's safety management system. Once the proposed Regulations are in force, Transport Canada would continue to conduct a minimum baseline audit every five years for both railway and local companies. This audit cycle would be complemented by an emergent audit program where audits are conducted at any time during a year.[158]

However, although the impact statement specifies that audits would verify the effectiveness of a company's SMS, it is not clear how this would be carried out or whether the baseline audit would examine the effectiveness of all components of a company's SMS.

The success of this new approach in improving safety will depend on 2 factors. First, railways are rule-based cultures, and the full transition to SMS will require a cultural shift away from strict reliance on rules, to a culture that recognizes that administrative defences alone are not sufficient to maintain safe operations and that seeks to build multiple layers of defence to reduce risks.

Secondly, TC now has a legal and conceptual framework to require SMS implementation, but equally important is how the regulator uses these tools and what action it takes in the coming years. It is crucial that TC follow up on its commitments relating to SMS audits, and on truly ensuring that railways have an SMS in place that is capable of identifying risks and managing them to prevent accidents.

Until Canada's railways make the cultural shift to SMS, and TC makes sure that they have effectively implemented SMS, the safety benefits from SMS will not be realized. Therefore, the Board recommends that:

> The Department of Transport audit the safety management systems of railways in sufficient depth and frequency to confirm that the required processes are effective and that corrective actions are implemented to improve safety.

**TSB Recommendation R14-05**

---

[158] Government of Canada, *Canada Gazette*, Part I, Vol. 148, No. 27 (05 July 2014), Railway Safety Management System Regulations.

*This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 31 July 2014. It was officially released on 19 August 2014.*

*Visit the Transportation Safety Board's website (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.*

# Appendices

## Appendix A – Sequence of events

Notes:
- The data are from rail traffic control radio and telephone recordings, locomotive event recorder, 911 records, etc.
- For acronyms, see Appendix L – Glossary.

| Time | Description |
|---|---|
| 05 July 2013, 1100 | At Farnham, MMA-002 received a mechanical inspection by TC. |
| 1300 | MMA-002 received a brake continuity test with TC present. |
| 1330 | The LE reported for duty. Previously that morning, the LE had made a request to the Farnham RTC to delay the on-duty time from about 1230 to 1330. |
| 1357 | Shortly after departing Farnham, the LE advised the Farnham RTC that the lead locomotive (MMA 5017) could not attain full throttle power, and asked if anyone had reported engine surges on that locomotive. |
| 1456 | The LE advised the Farnham RTC that the train was losing speed, lead locomotive MMA 5017 could still not attain full throttle power, and it was affecting all the other locomotives in the consist. |
| 2000 (approx.) | The LE informed the Bangor RTC of problems with the lead locomotive. |
| 2249 | MMA-002 was stopped at the east siding switch on the main track at Nantes using an automatic air brake application. The locomotive independant air brakes were applied. The LE applied hand brakes to the train and shut down the 4 trailing locomotives. When the LE returned to the lead locomotive, the automatic air brake application was released; however, the independent air brakes remained fully applied. The hand brake effectiveness test was conducted without releasing the locomotive independent air brakes. |
| 2305 | The LE called the Farnham RTC after securing the train and asked the RTC to call a taxi. |
| 2315 | The LE called the Bangor RTC to tell him that the train was secured at Nantes, and that he had shut down 4 of the 5 locomotives. The LE also mentioned that, once he got to Nantes, he noted the excessive smoke from the lead locomotive, changing from black to white. The LE said that he expected it to settle on its own, but was not sure how the locomotive would be the next morning, considering the issues experienced during the day. They decided to leave the train as it was and they would deal with any locomotive performance issues in the morning.<br><br>As per normal practice, the train was left with the lead locomotive door unlocked, as well as the reverser removed and placed on the LE seat with the train's paperwork. |
| 2325 (approx.) | The taxi arrived at Nantes. The taxi driver noted the excessive smoke and oil droplets coming from the locomotive, and asked the LE whether it should be left like that, particularly considering the environmental pollution. |
| 2330 (approx.) | The taxi departed Nantes. |
| 2339 | The LE called the Farnham RTC to indicate his off-duty time of 2345. |
| 2340 | A 911 call was received reporting a fire on a train at Nantes. The call was assigned to the Nantes Fire Department. |

| Time | Description |
|---|---|
| 2350 | The Sûreté du Québec (SQ) informed the Farnham RTC of a fire on a train at Nantes. The SQ advised that firefighters and the SQ were on their way to the site. The Farnham RTC advised the SQ that the train was transporting crude oil. |
| 2352 | The Farnham RTC called the Manager of Operations to advise him of the fire at Nantes and inform him that it was a unit crude oil train. They decided that the closest MMA employee (a former LE and mechanic), residing in Marston, should be contacted and dispatched to Nantes. |
| 2353 | The Farnham RTC tried to reach the MMA employee in Marston twice on his company cellular phone, but was unsuccessful both times. |
| 2355 | The SQ called the Farnham RTC to inform him that the fire was on a locomotive and that the firefighters and SQ were on site. |
| 2358 | The Nantes Fire Department shut down the lead locomotive using the emergency fuel cut-off and opened the breakers on the back electrical panel located inside the locomotive cab. This was following an attempt to extinguish the fire using foam, which resulted in a black oily residue being dispersed onto the ground (discovered at Nantes and just east of where the locomotives were discovered on the Moosehead Subdivision). |
| 2359 | The MMA Track Manager for the Lac-Mégantic area called the Farnham RTC to advise that he had been contacted by the Nantes Fire Department, which had requested that a locomotive technician be sent to the site. After discussion with the fire department, the MMA Track Manager informed the Farnham RTC that the fire, which was on the lead locomotive, was under control, that the lead locomotive had been shut down, and that the Marston employee was on leave. The MMA Track Manager indicated that the MMA Track Foreman residing in Lac-Mégantic should be called and dispatched to the site. |
| 06 July 2013, 0000 | The Farnham RTC called the LE to ask which locomotives had been left running and to advise him of a fire, which he believed to be minor. The Farnham RTC informed the LE that the lead locomotive had been shut down. The LE advised the Farnham RTC that only the lead locomotive had been left running, and asked him if he was required to go to Nantes to start another locomotive. The LE was advised that the MMA Track Foreman was on his way and that they would wait until the morning to start the locomotives. |
| 0003 | The Farnham RTC advised the Bangor RTC that the lead locomotive on MMA-002 had caught fire, that it had been shut down, and that the MMA Track Foreman had been sent on site. They concluded that the lead locomotive would need to be removed and they discussed a workaround for the next morning. |
| 0018 | The SQ called the Farnham RTC to advise that the fire was under control, that the locomotive engine was stopped using the emergency fuel cut-off, and that the fire was in the smoke stack. The Farnham RTC mentioned that the lead locomotive was not usually shut down because of the air brake system. The SQ mentioned that there was damage to the lead locomotive due to the fire. |
| 0023 | The Manager of Operations called the Farnham RTC for an update. The Manager of Operations questioned why the lead locomotive was left running by the LE. The Farnham RTC replied that it was left running to avoid having to perform an air brake test the following day to meet U.S. requirements. |
| 0030 (approx.) | The MMA Track Foreman arrived at Nantes and met with 2 firefighters. |
| 0035 | The MMA Track Foreman informed the Farnham RTC that the fire was extinguished, that all locomotives were shut down and that the electrical breakers in the cab of the lead locomotive had been opened. The Farnham RTC told the MMA Track Foreman to leave things as they were and leave. |

| Time | Description |
|---|---|
| 0044 (approx.) | The MMA Track Foreman and the Nantes Fire Department left MMA-002. |
| 0044 | The Farnham RTC advised the Bangor RTC that the fire was in the smoke stack, that it had been extinguished and that the lead locomotive was shut down. They again discussed the workaround for the next day. |
| 0058 | When the air brake pressure leaked off, MMA-002 began to roll. |
| 0107 | MMA-002 reached a speed of 25 mph. |
| 0114 | MMA-002 reached a speed of 50 mph. |
| 0115 | At Mile 0.23 of the Sherbrooke Subdivision, cars derailed at 65 mph, resulting in a large loss of crude oil and large fire. |
| 0117 | A 911 call was received reporting a fire at Lac-Mégantic. The call was dispatched to the Lac-Mégantic Fire Department. |
| 0129 | The SQ informed the Farnham RTC that there were explosions at Lac-Mégantic and asked him to send someone as soon as possible. The Farnham RTC asked the SQ if the fire was at Nantes or Lac-Mégantic, because MMA-002 was at Nantes. The SQ asked if the Farnham RTC was certain that the train was still at Nantes. The Farnham RTC advised that someone from MMA would be dispatched. |
| 0131 | The Farnham RTC advised the MMA Track Manager of the fire at Lac-Mégantic and that the SQ thought that it involved the train from Nantes. The MMA Track Manager indicated that the MMA Track Foreman would be dispatched. |
| 0148 | The LE advised the Farnham RTC that the whole downtown was on fire and wondered what other cars were in the yard. The LE said that it was not MMA-002 or MMA-001, because they were tied up at Nantes and Vachon, respectively. The Farnham RTC confirmed that there were no dangerous goods in the yard. |
| Starting at 0150 | There were multiple telephone conversations within MMA to try to determine the cause of the fire. The Farnham RTC received reports that a train was seen travelling eastward into Lac-Mégantic. |
| 0239 | The MMA Track Foreman called from Nantes and confirmed to the Farnham RTC that MMA-002 was not there. |
| 0329 | The Farnham RTC told the LE that it was MMA-002 that had run away. The LE advised the Farnham RTC that the train was secured when he left Nantes, and that he had applied hand brakes on all locomotives, the VB car, and the buffer car. |
| 0330 (approx.) | The MMA Track Manager and MMA Track Foreman arrived at the location of the locomotives at Mile 116.41 of the Moosehead Subdivision and re-tightened hand brakes on the locomotives and the VB car. |
| 0436 | The Assistant Manager of Operations called the Farnham RTC who gave a summary of events and advised that hand brakes were applied on all locomotives, the VB car, and the buffer car. The Assistant Manager of Operations stated that this was not enough, and that it was supposed to be 10% + 1. The Farnham RTC mentioned that, normally, after applying hand brakes, they should be tested on the release, and if the LE had tested them, MMA-002 should have held. The Farnham RTC stated that the air likely leaked off and the emergency brakes did not apply. |
| 0539 | The LE advised the Farnham RTC that he had just finished moving the 9 tank cars at the end of the train that did not derail. |

## *Appendix B – MMA-002 train consist*

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| Locomotive 1 | MMA 5017 | 67 | 195 | Diesel-electric locomotive | N/A |
| 1 | VB 1 | 50 | 30 | Specialized caboose | N/A |
| Locomotive 2 | MMA 5026 | 56 | 195 | Diesel-electric locomotive | N/A |
| Locomotive 3 | CITX 3053 | 68 | 193 | Diesel-electric locomotive | N/A |
| Locomotive 4 | MMA 5023 | 56 | 195 | Diesel-electric locomotive | N/A |
| Locomotive 5 | CEFX 3166 | 68 | 196 | Diesel-electric locomotive | N/A |
| 2 | CIBX 172032 | 69 | 105 | Pebbles (used as buffer car) | N/A |
| 3 | TILX 316547 | 59 | 127 | Petroleum crude oil | Medium |
| 4 | WFIX 130608 | 59 | 127 | Petroleum crude oil | N/A |
| 5 | TILX 316359 | 59 | 127 | Petroleum crude oil | N/A |
| 6 | TILX 316338 | 59 | 127 | Petroleum crude oil | N/A |
| 7 | NATX 310428 | 59 | 128 | Petroleum crude oil | N/A |
| 8 | CTCX 735541 | 59 | 127 | Petroleum crude oil | N/A |
| 9 | DBUX 303879 | 59 | 126 | Petroleum crude oil | N/A |
| 10 | WFIX 130682 | 59 | 127 | Petroleum crude oil | N/A |
| 11 | TILX 316641 | 59 | 127 | Petroleum crude oil | N/A |
| 12 | TILX 316570 | 59 | 127 | Petroleum crude oil | Large |
| 13 | NATX 310457 | 59 | 128 | Petroleum crude oil | N/A |
| 14 | WFIX 130638 | 59 | 127 | Petroleum crude oil | Large |
| 15 | NATX 310473 | 59 | 128 | Petroleum crude oil | Small |
| 16 | TILX 316379 | 59 | 127 | Petroleum crude oil | N/A |
| 17 | ACFX 79709 | 59 | 128 | Petroleum crude oil | Large |
| 18 | TILX 316333 | 59 | 127 | Petroleum crude oil | N/A |
| 19 | TILX 316549 | 59 | 128 | Petroleum crude oil | N/A |
| 20 | CTCX 735527 | 59 | 127 | Petroleum crude oil | Large |
| 21 | NATX 310477 | 59 | 128 | Petroleum crude oil | N/A |
| 22 | WFIX 130603 | 59 | 127 | Petroleum crude oil | Large |
| 23 | TILX 316556 | 59 | 127 | Petroleum crude oil | Large |
| 24 | CTCX 735629 | 59 | 127 | Petroleum crude oil | Medium |
| 25 | ACFX 76605 | 59 | 128 | Petroleum crude oil | Large |
| 26 | PROX 44293 | 55 | 127 | Petroleum crude oil | N/A |
| 27 | NATX 310581 | 59 | 128 | Petroleum crude oil | N/A |
| 28 | PROX 44202 | 55 | 127 | Petroleum crude oil | Large |
| 29 | TILX 316234 | 59 | 128 | Petroleum crude oil | N/A |
| 30 | TILX 316584 | 59 | 127 | Petroleum crude oil | Medium |

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| 31 | WFIX 130571 | 59 | 127 | Petroleum crude oil | Medium |
| 32 | TILX 316330 | 59 | 128 | Petroleum crude oil | Large |
| 33 | NATX 310412 | 59 | 128 | Petroleum crude oil | N/A |
| 34 | TILX 316317 | 59 | 128 | Petroleum crude oil | N/A |
| 35 | WFIX 130545 | 59 | 128 | Petroleum crude oil | N/A |
| 36 | ACFX 79698 | 59 | 128 | Petroleum crude oil | N/A |
| 37 | NATX 302784 | 59 | 127 | Petroleum crude oil | N/A |
| 38 | ACFX 71505 | 59 | 128 | Petroleum crude oil | Medium |
| 39 | ACFX 71121 | 59 | 129 | Petroleum crude oil | Large |
| 40 | CTCX 735537 | 59 | 127 | Petroleum crude oil | Medium |
| 41 | NATX 303128 | 59 | 127 | Petroleum crude oil | Medium |
| 42 | CTCX 735572 | 59 | 127 | Petroleum crude oil | Medium |
| 43 | WFIX 130616 | 59 | 127 | Petroleum crude oil | Large |
| 44 | WFIX 130664 | 59 | 128 | Petroleum crude oil | Medium |
| 45 | WFIX 130630 | 59 | 128 | Petroleum crude oil | Small |
| 46 | TILX 316523 | 59 | 127 | Petroleum crude oil | Medium |
| 47 | TILX 316613 | 59 | 127 | Petroleum crude oil | Medium |
| 48 | TILX 316616 | 59 | 127 | Petroleum crude oil | Large |
| 49 | TILX 316206 | 59 | 128 | Petroleum crude oil | Large |
| 50 | TILX 316319 | 59 | 128 | Petroleum crude oil | Large |
| 51 | CTCX 735617 | 59 | 127 | Petroleum crude oil | Large |
| 52 | TILX 316572 | 59 | 127 | Petroleum crude oil | Large |
| 53 | CTCX 735526 | 59 | 127 | Petroleum crude oil | Large |
| 54 | TILX 316622 | 59 | 128 | Petroleum crude oil | Large |
| 55 | WFIX 130585 | 59 | 127 | Petroleum crude oil | Small |
| 56 | NATX 310508 | 59 | 128 | Petroleum crude oil | Small |
| 57 | CTCX 735525 | 59 | 127 | Petroleum crude oil | Large |
| 58 | ACFX 79383 | 59 | 128 | Petroleum crude oil | Medium |
| 59 | PROX 44428 | 59 | 127 | Petroleum crude oil | Large |
| 60 | PROX 44150 | 59 | 127 | Petroleum crude oil | N/A |
| 61 | TILX 316533 | 59 | 127 | Petroleum crude oil | N/A |
| 62 | ACFX 94578 | 59 | 129 | Petroleum crude oil | Large |
| 63 | NATX 310515 | 59 | 128 | Petroleum crude oil | N/A |
| 64 | TILX 316528 | 59 | 127 | Petroleum crude oil | N/A |
| 65 | NATX 310470 | 59 | 128 | Petroleum crude oil | N/A |
| 66 | NATX 310487 | 59 | 128 | Petroleum crude oil | N/A |
| 67 | NATX 310533 | 59 | 128 | Petroleum crude oil | N/A |

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| 68 | NATX 310572 | 59 | 128 | Petroleum crude oil | N/A |
| 69 | ACFX 73452 | 59 | 128 | Petroleum crude oil | N/A |
| 70 | NATX 310425 | 59 | 128 | Petroleum crude oil | N/A |
| 71 | PROX 44211 | 55 | 127 | Petroleum crude oil | N/A |
| 72 | WFIX 130629 | 59 | 127 | Petroleum crude oil | N/A |
| 73 | NATX 310406 | 59 | 128 | Petroleum crude oil | N/A |
| 74 | NATX 310595 | 59 | 128 | Petroleum crude oil | N/A |
| 75 | SBU 35924 | N/A | 0 | N/A | N/A |

# *Appendix C – Sources of measurable air leakage from each locomotive on MMA-002*

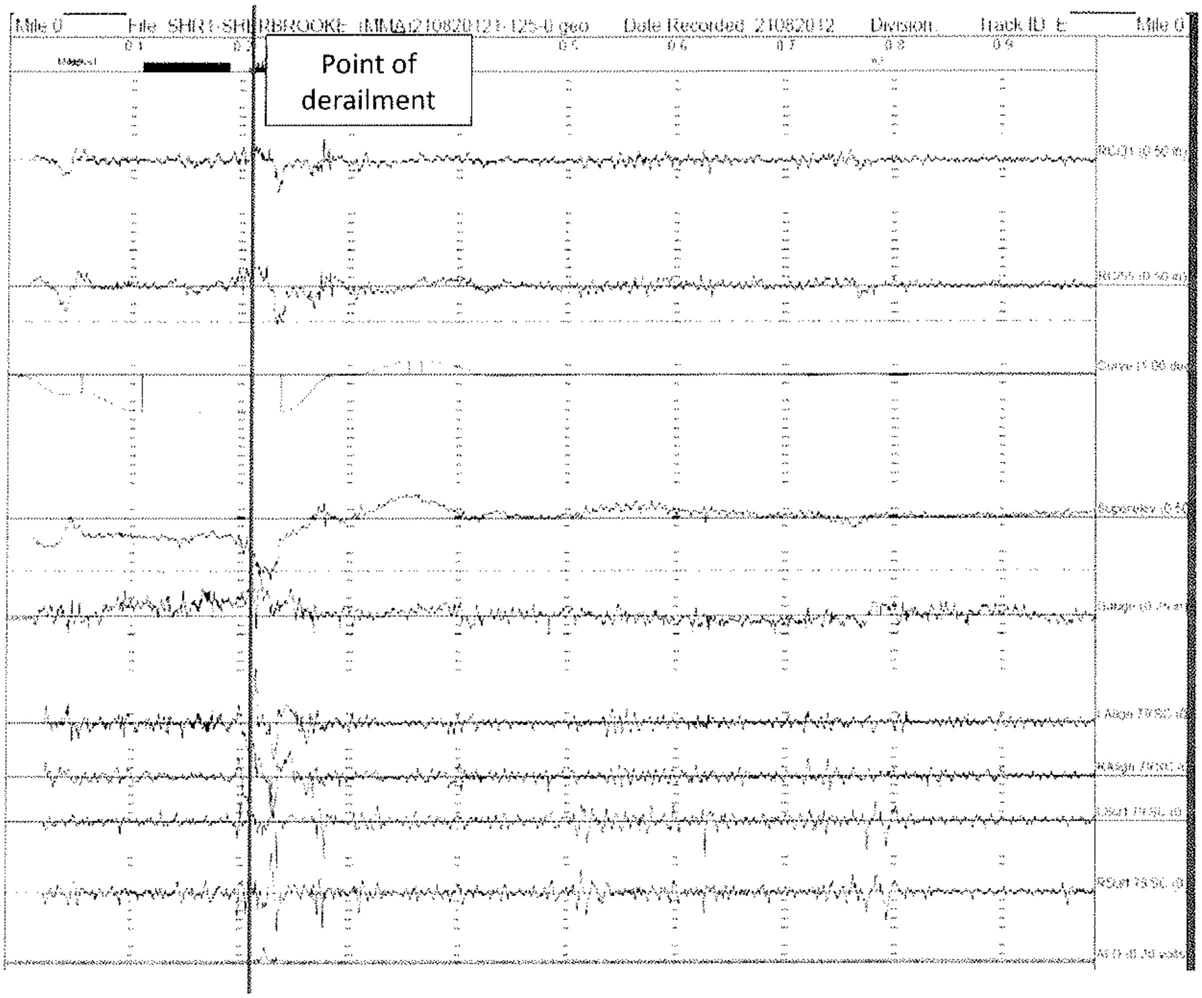
| | MMA 5017 | MMA 5026 | CITX 3053 | MMA 5023 | CEFX 3166 |
|---|---|---|---|---|---|
| Main reservoir | X | X | X | X | X |
| Main reservoir check valve | X | | | X | X |
| Brake pipe | X | X | | X | |
| Bell valve | X | | | | |
| N1 reducing valve | X | | | | |
| Dead engine regulating valve | | | | | X |
| Compressor relief valve | X | | | | |
| 20 line | | X | | X | X |
| Front truck | | X | X | X | X |
| Rear truck | X | | | | X |
| Equalizing valve | | | | | X |

## *Appendix D – Previous brake testing for other occurrences*

The TSB has investigated several other runaway train accidents where extensive hand brake tests were conducted (Coal Valley, Alberta, in 1995 [R95C0282]; Edson, Alberta, in 1996 [R96C0172]; and Dorée, Quebec, in 2011 [R11Q0056]). The following was determined:

- In the case of the 3 runaways, an average of 65 to 80 foot-pounds of torque had been applied on the hand brakes.
- For a constant torque (for example, 80 foot-pounds), the applied force on the wheels varied from 12 000 pounds to 21 000 pounds.
- With 8 hand brakes applied at 125 foot-pounds of brake wheel torque, the 55 cars would have moved down the 0.65% grade. (TSB Rail Investigation R95C0282)
- The cars remained stationary until the air brakes leaked off and released after approximately 7 hours in extreme cold. The retarding brake force was attributed to the applied hand brakes and the air brakes that had not completely released. (TSB Rail Investigation R95C0282)
- There was no guidance from the railway with respect to the sufficient number of hand brakes.( TSB Rail Investigation R95C0282)
- Hand brake operators do not receive any definitive feedback to confirm that sufficient brake shoe force has been attained. (TSB Rail Investigation R96C0172)
- Given the available guidelines and instructions, determining what is a sufficient hand brake application requires more information than the employees had available to them. (TSB Rail Investigation R96C0172)
- Training can provide a better understanding of the relevant variables affecting hand brake effectiveness. (TSB Rail Investigation R96C0172)
- The majority of the car brake cylinders leaked off after approximately 1 hour following the emergency brake application. The leakage was due to the poor condition of the cars. (TSB Rail Investigation R11Q0056)
- To determine the sufficient number of hand brakes to be applied, employees rely on their personal experience gained in situations where cars have either not moved or ran away. (TSB Rail Investigation R11Q0056)
- Without specific instructions that take into consideration local conditions, there is a risk that the number of hand brakes required to secure a train on a steep grade will be underestimated. (TSB Rail Investigation R11Q0056)

# *Appendix E – Track geometry inspection of the Montreal, Maine & Atlantic Railway Sherbrooke Subdivision, between Mile 0.0 and Mile 1.0 (21 August 2012)*[159]




159 Source: Montreal, Maine & Atlantic Railway

## *Appendix F – Summary of crude oil testing results*

The crude oil testing (Engineering Laboratory Report LP148/2013) focused on the characteristics relevant to the classification of the petroleum crude oil, as well as its behaviour and effects during the post-accident spill and fire.

| Characteristic determined | Method | Purpose | Results |
|---|---|---|---|
| Flashpoint (closed-cup) | ASTM[160] D93 | Determine the tendency of the product to form a flammable mixture with air under controlled conditions | < −35 °C |
| Initial boiling point (atmospheric distillation) | ASTM D86 | Determine the lightest fractions present in the product for the purpose of regulatory classification | 43.9 °C to 50.0 °C |
| Density | ASTM D5002 | Determine the tendency of the product to sink or float on water | 815.9 kg/m³ to 821.9 kg/m³ |
| API gravity | Calculated | | 41.8 to 40.5° |
| Reid vapour pressure | ASTM D323 Procedure A | Determine the rate at which the product will evaporate | 62.3 kPa to 66.1 kPa |
| Pour point | ASTM D5853 | - Determine the handling characteristics of the product at low temperatures<br>- Determine the rate at which spilled product in the environment will spread and the extent to which it will penetrate the soil | < −65 °C |
| Viscosity (kinematic) | ASTM D7042 | | 2.882 centistokes (cSt) to 3.259 cSt at 20 °C |
| Sulphur content (total) | ASTM D4294 | - Characterize the product as a sweet or sour crude oil<br>- Determine whether the product presents health hazards to on-site personnel | 0.096 mass % to 0.117 mass % |
| Volatile organic compounds (BTEX: benzene, toluene, ethylbenzene, xylene) | Gas chromatography mass spectrometry | Determine whether the product presents health hazards to on-site personnel | Benzene: 1470 ppm to 1850 ppm |
| | | | Toluene: 2770 ppm to 3170 ppm |
| | | | Ethylbenzene: 768 ppm to 852 ppm |
| | | | m/p-Xylene: 2890 ppm to 3500 ppm |
| | | | o-Xylene: 1500 ppm to 1660 ppm |

[160] American Society for Testing and Materials

| Characteristic determined | Method | Purpose | Results |
|---|---|---|---|
| Heat of combustion | ASTM D240 | Determine the total amount of energy that can be released when the product is burned to completion | 42.905 MJ/kg to 45.160 MJ/kg |

## *Appendix G – Safety data sheets of the product loaded in the accident train*

A review of the 10 safety data sheets (SDSs) of the product loaded in the accident train determined the following:

- While most of the SDSs were generic, 1 referred to the product as "Bakken crude".
- There were differences in the chemical composition information presented in the SDSs. For example, while most SDSs identified benzene concentration values ranging between 0% and 1% by weight, 2 SDSs identified benzene concentration values of 2% and 9% respectively.
- All 10 SDSs contained dangerous goods classification and transportation information. All 10 SDSs identified the product as UN 1267, petroleum crude oil, Class 3.
- With respect to packing groups (PGs), the following information was provided:
    - 3 SDSs indicated that the product was a PG I, including the one that described the product as "Bakken crude";
    - 1 SDS that described the product as "Alaska Beaver Creek Crude Oil" indicated that it was PG II;
    - 1 SDS indicated that the product was a PG III;
    - 1 SDS indicated that the product was a PG I or PG II;
    - 2 SDSs did not indicate a PG, but stated that the flashpoint and explosive limits are highly dependent on crude oil source; and
    - 2 SDSs indicated that it was necessary to "determine flashpoint to accurately classify packing group."

# *Appendix H – Other short line runaway train accidents investigated by the Transportation Safety Board*

Since 2005, the TSB has conducted 9 investigations into runaway train events. In addition to this accident, 5 others have involved short line railway operations.

**R11Q0056:** On 11 December 2011, in Dorée, Quebec, a Quebec North Shore & Labrador Railway (QNS&L) freight train, with 2 locomotives and 112 Labrador Iron Mines (LIM) gondola cars, was experiencing problems with its automatic and dynamic brakes. It had been secured by the locomotive engineer on a steep grade with the train air brakes and 35 hand brakes. One hour later, the train's air brakes released, and the 35 hand brakes proved insufficient to hold the train. The locomotive engineer, who was finishing applying hand brakes on the train and waiting for assistance, saw the train moving and jumped on board the lead locomotive. He applied the dynamic brakes, which were not working properly, but the train continued to accelerate as it descended the grade. The train finally stopped when the track leveled off. No one was injured. In March 2012, the Newfoundland and Labrador government ordered thorough brake inspections on each of the iron ore cars. Transport Canada (TC) conducted a safety inspection in Sept-Îles, Quebec, that revealed many air brake deficiencies (for example the brake cylinders were not remaining applied). On 09 February 2012, a notice was issued under section 31 of the *Railway Safety Act* (RSA) to QNS&L regarding damaged rail cars being placed in service or continuing to be in service. The Newfoundland and Labrador government ordered LIM to conduct single-car tests on all its cars. All the necessary work for the cars to comply with the Association of American Railroads (AAR) specifications was completed. QNS&L modified its inspection and brake-test procedures for LIM cars; it now conducts walking brake tests to examine brake cylinders and brake shoes. QNS&L also committed to define the minimum number of required hand brakes to secure cars on heavy grades.

**R09T0057:** On 11 February 2009, in Nanticoke, Ontario, a Southern Ontario Railway (SOR) 0900 Hagersville Switcher, consisting of 4 locomotives and 43 predominantly dangerous goods and special dangerous goods tank cars, ran uncontrolled from Mile 0.10 to Mile 1.9 of the Hydro Spur track. Although the train had a 3-person crew, it had been secured by a single crew member on a 1% grade. After the last crew member departed, the train's automatic brakes released, and the hand brakes were insufficient to hold the train. It ran away, reaching a speed of 20.7 mph, before travelling over a split-switch derail and derailing 9 loaded dangerous goods tank cars. The split-switch derail had been installed at this location because of a previous runaway train accident in 1996 at the same location.

Three Class 111 tank cars loaded with gasoline (UN 1203, flammable liquid) were breached and released approximately 31 000 litres of gasoline. The gasoline did not ignite during the derailment. Two nearby homes were evacuated.

The TSB report noted the following:

- Securing a train consisting predominantly of dangerous and special dangerous goods, adjacent to a major refinery on a descending grade, requires increased vigilance to safely complete the task.
- When only 1 crew member is left to complete train securement tasks at the end of a work shift, the risk for runaway equipment is increased.

- With only 1 crew member left at the end of the shift, the other crew members did not have the opportunity to verify whether the train was properly secured.
- Insufficient company oversight allowed deviations in standard operating practices to occur.

On 20 February 2009, TC issued a notice and order under subsection 31(3) of the RSA, which required SOR management to report in writing by 06 March 2009 how the company intended to resolve the hazard or condition resulting from the failure of SOR employees to properly secure unattended equipment on the Hydro Spur at Nanticoke. On the same day, SOR issued 2 operating bulletins relating to the practice of leaving unattended cars or trains on the Hydro Spur. TC conducted inspections under its audit program between May and August 2009, and conducted follow-up interviews with selected members of management and employees.

**R08V0270:** On 29 December 2008, in Waneta, British Columbia, a Kettle Falls International Railway assignment with 2 locomotives and 12 cars started moving while switching and quickly began to head down a steep grade. When the train, with insufficiently charged air brakes, accelerated to about 20 mph, the locomotive engineer jumped from the train into deep snow and sustained minor injuries. The runaway train collided with stationary cars after travelling 2.8 miles, causing it to derail, along with some of the stationary cars. Subsequent to the accident, TC performed a regulatory inspection which led to the issuance of a notice and a notice and order under Section 31 of the RSA on 12 January 2009. The notice indicated that the operation of movements on grade without a complete understanding of the operation of the air brake system and the functionality of locomotive control features may result in experiencing an uncontrolled movement with serious consequences. The notice and order indicated that the lack of clear train handling instructions related to switching and descending the grade can lead to operating crews descending this grade with less than adequate air and operative brakes to properly control the movement.

**R06V0183:** On 03 September 2006, in Log Cabin, British Columbia, a White Pass and Yukon Route (WP&YR) work train, consisting of 1 locomotive and 8 overloaded ballast cars, ran away down a steep grade. The train reached a speed of about 45 mph before the locomotive and 6 of the cars derailed on a sharp curve. One person was fatally injured, and 3 others were seriously injured. The TSB determined that the train was too heavy due to overloading, and it is likely that the brake systems on all of the ballast cars were functioning at a diminished capacity. On 23 November 2006, the TSB issued to TC Rail Safety Advisory 07/06, Pressure Retaining Valves on WP&YR Ballast Car, indicating that TC may wish to assess the extent to which management ensures that cars are properly equipped and maintained, and that train crews handling these cars have adequate instruction and training to ensure that sufficient control is exercised on mountain grades. On 30 November 2006, the TSB issued to TC Rail Safety Advisory 08/06, Overloading of WP&YR Ballast Cars, indicating that TC may wish to assess the loading practices of engineering service cars. On 12 December 2006, TC issued a letter of non-compliance and a notice to WP&YR citing violations of various TC regulations referenced under the RSA concerning hazards and conditions related to the ballast cars and to the operation of ballast trains. On 05 June 2007, TC issued a notice and order requiring that trains not operate in certain areas unless they are equipped with a system that ensures direct positive communication with the RTC and that facilitates emergency calling recognizable by the RTC. From 04 to 07 June 2007, TC conducted an SMS audit. Following are some of the findings relevant to this investigation:

- Risk assessments were not being carried out.
- WP&YR was in non-compliance with the *Railway Employee Minimum Qualification Standards Regulations* (1987-3).
- There was no documented process describing how the company carries out air brake tests and how it ensures compliance with the *Railway Freight and Passenger Train Brake Rules*.

On 11 June 2007, TC issued a notice to WP&YR concerning several hazards and conditions related to the reliance by the railway on employee familiarity for protection on the main track. TC also sent a letter in regard to train-operation monitoring activities, which revealed several safety-related deficiencies. On 31 July 2007, TC sent a letter to WP&YR directing them to conduct a formal risk assessment on the safe operation of rolling stock when descending grades are greater than 2% and to then develop written procedures. On 31 July 2007, a TC issued a direction to the WP&YR concerning their contravention of Part II of the *Canada Labour Code* regarding the provision of information, training, and instructions to operating employees. WP&YR replied to TC indicating that numerous measures had been taken, such as in training, communications, operating bulletins, and mechanical equipment. WP&YR also provided TC with its corrective action plan to address the findings in TC's report on the June 2007 audit.

**R05H0011:** On 02 May 2005, in Maxville, Ontario, an Ottawa Central Railway (OCR) freight train left 74 cars on the main track with the air bottled at Mile 34.65 of the Alexandria Subdivision while the head-end movement went to switch 2 cars into a customer's spur. As the movement entered the spur, the 74 cars rolled uncontrolled and collided with the movement. As a result of the collision, a Class 111 tank car loaded with denatured alcohol was punctured, and about 98 000 litres of product was released. Approximately 200 people were evacuated for 8 hours. There was no derailment and there were no injuries. After the accident, OCR informed all employees about the risks associated with the practice of bottling the air. For 2 months after the accident, OCR doubled the number of train crew observations, emphasizing the securement of unattended cars while performing en route switching. The number of safety audits performed in 2005 was doubled. OCR also purchased a portable input and display unit (IDU) for transportation supervisors to remotely monitor the end-of-train air brake pipe pressure.

In all these occurrences, the investigation into the operations of these railways identified safety deficiencies in training, oversight, and operational practices. Although the companies had filed safety management system documentation as required by TC, the safety management system was not being used to identify and proactively address deficiencies through formal risk assessment or continuous improvement processes.

# Appendix I – Single-person freight train operations

*Single-person train operations implementation outside Canada*

Single-person train operations (SPTO) have been implemented in other parts of the world, including the United States, Europe, Australia, and New Zealand. For example, Danish and Swedish railways use sophisticated automatic train control (ATC) technologies to enforce signal and speed regulations. British railways use an audio-visual safety device called an advance warning system, which warns the driver of signal aspects. A driver's failure to acknowledge the restrictive signal warnings results in the automatic braking of the train. Tranzrail uses a vigilance device that sounds an alarm and stops the train if the driver fails to respond to its demands.

As previously mentioned, SPTO has also been implemented in the United States.

In the 1990s, the SPTO technology later used by MMA was developed and introduced as an efficiency measure at Wisconsin Central Limited (WC). The Federal Railroad Administration (FRA) was not made aware that WC had started SPTO until after a serious train accident (involving a 2-person crew) in Weyauwega, Wisconsin, in March 1996. Operation, maintenance, training, and funding issues were identified at WC during the accident investigation, conditions also identified at a subsidiary company, Tranz Rail Holdings Limited (Tranz Rail), in New Zealand.

In December 2004, MMA's operations in the United States began running dark territory[161] SPTO trains. SPTO operations at MMA had also commenced without FRA awareness. After the FRA became aware of MMA's SPTO operations in 2006, MMA indicated that SPTO had been used successfully on its United States network for about 2 years. MMA was allowed to continue its SPTO. However, the FRA required MMA to produce written SPTO special operating instructions.

In Australia, the Rail Safety Regulators' Panel[162] produced a guidance document for driver-only operations (DOO, the equivalent term in Australia for SPTO). The related regulatory legislation was developed, in conjunction with the rail industry and rail unions. Key elements include:

- Responsibility for the granting and monitoring of accreditation of single-person train operators lies with the local regulators.
- The appropriateness of the operators' approach to SPTO is considered as part of the accreditation process.
- Accreditation is only for the SPTO program as narrowly defined. Any change to the program requires re-accreditation (for example, the introduction of dangerous goods unit trains).

---

161 Dark territory is a term used to describe areas of railway operations where train movements are not governed by train signals.

162 The panel consists of rail safety regulators from all states and northern territories of Australia and New Zealand.

- Risks need to be mitigated "so far as is reasonably practicable"(SFAIRP); this includes considering the likelihood, degree of harm, what can be reasonably known about the risk, the availability of risk-reducing means, and the cost of eliminating the risk.
- Crew cabs must be designed for SPTO, crews must be trained, and clearly defined operating limits must be enforced.
- SPTO must be validated through consultation with stakeholders, including written agreements and testing, as well as trialling before implementation.
- SPTO must be reviewed and approved through a robust assessment by the rail safety regulator, in a manner similar to any other aspect of the company SMS.
- The applicant must provide supporting documentation that demonstrates that SPTO risks have been identified and evaluated, and that controls have been established that achieve management of risk SFAIRP.
- The plan needs to address minimum operating standards in situations where the work conditions have degraded.
- All SPTO-compliant equipment must be documented.
- It should be recognized that the work conditions can skew a worker's willingness to accept SPTO work, and workers should be empowered to refuse work if appropriate controls are not functional. The document recognizes that, when commercial, social, and industrial pressures are applied, it may be unlikely that a worker will refuse to work, even if work conditions are degraded.
- All accreditation decisions and variations are to be documented.

# *Appendix J – Estimated number of hand brakes to secure MMA-002*

The table below shows a summary of the estimated number of hand brakes required to safely secure MMA-002 in various scenarios, based on the factors identified in section 2.3.1. and the brake testing results.

The highlighting in the table indicates the minimum and maximum estimated number of hand brakes required for each scenario (depending on torque and coefficient of friction).

| Scenario | Coefficient of friction | Number of hand brakes required | |
|---|---|---|---|
| | | 80 foot-pounds of operator-applied torque | 100 foot-pounds of operator-applied torque |
| With no air brake application on the cars and including hand brakes on the locomotive consist | 0.38 | 25.9 | 21 |
| | 0.45 | 22.2 | 18 |
| When hand brakes are applied after a 13-psi air brake application, including hand brakes on the locomotive consist (the accident scenario) | 0.38 | 19.9 | 16.4 |
| | 0.45 | 17.2 | 14.2 |
| With no air brake application on the cars and hand brakes applied on the cars only | 0.38 | 24.0 | 19.1 |
| | 0.45 | 20.3 | 16.1 |
| When hand brakes are applied after a 13-psi air brake application and applied on the cars only | 0.38 | 17.1 | 13.6 |
| | 0.45 | 14.5 | 11.5 |

Notes:
- The stationary coefficient of friction between brake shoe and wheel surfaces is 0.38 for normal condition (Wabtec source) and 0.45 for extremely dry clean.
- A rolling resistance of 2.15 pounds/ton is used.
- For scenarios showing a 13-psi air brake application, a 40% improvement in hand brake force was included based on testing.

# *Appendix K – TSB Laboratory reports*

The following TSB Laboratory reports were completed, and are available on the TSB's website at www.tsb.gc.ca:

- LP132/2013 – End of Train Telemetry Download and Analysis
- LP136/2013 – LER Data Retrieval and Analysis
- LP141/2013 – Lac-Mégantic Video Analysis
- LP148/2013 – Analysis of Crude Oil Samples
- LP149/2013 – Field Examination of Tank Cars
- LP151/2013 – Examination of Switch Frog
- LP152/2013 – Examination of Box Car Wheel Set
- LP165/2013 – Tank Car Volume Measurements
- LP167/2013 – Site Survey and Grade Calculations
- LP168/2013 – Metallurgical Analysis of Tank Car Coupons
- LP181/2013 – Locomotive Engine Fire Examination
- LP182/2013 – Examination of Locomotive Wheels and Brake Shoes
- LP184/2013 – Examination of Knuckle and Pin
- LP185/2013 – Examination of Locomotive Air Brake
- LP187/2013 – Brake Force Analysis
- LP188/2013 – Dynamic Simulation and Derailment Forces Analysis
- LP233/2013 – Locomotive Electrical Examination
- LP039/2014 – Derailment Speed Calculation

# *Appendix L – Glossary*

| | |
|---|---|
| AAR | Association of American Railroads (United States) |
| API | American Petroleum Institute |
| ASLRRA | American Short Line and Regional Railroad Association (United States) |
| ASTM | American Society for Testing and Materials |
| b/d | barrels per day |
| BOV | bottom outlet valve |
| CANUTEC | Canadian Transport Emergency Centre |
| CFM | cubic feet per minute |
| CFR | *Code of Federal Regulations* (United States) |
| CN | Canadian National |
| CPR | Canadian Pacific Railway |
| CROR | *Canadian Rail Operating Rules* |
| CSA | Canadian Standards Association |
| CTA | Canadian Transportation Agency |
| CTC | centralized traffic control |
| CWR | continuous welded rail |
| DG | dangerous good |
| DOT | Department of Transportation (United States) |
| ECP | electronically controlled pneumatic (braking system) |
| ERAP | Emergency response assistance plan |
| ERG | *Emergency Response Guidebook* |
| FRA | Federal Railroad Administration (United States) |
| GE | General Electric Company |
| GM | General Motors |
| GOI | General Operating Instructions |
| GSI | General Special Instructions |
| IIS | Inspection Information System (TC) |
| Irving | Irving Oil Ltd. |
| kip | kilopound (1 kip = 1000 pounds) |
| km/h | kilometres per hour |
| LE | locomotive engineer |
| LER | locomotive event recorder |
| m | metres |
| mm | millimetres |
| MMA | Montreal, Maine & Atlantic Railway |
| mph | miles per hour |
| NB Southern | New Brunswick Southern Railway |
| NRC | National Research Council of Canada |
| NTSB | National Transportation Safety Board (United States) |
| OAG | Office of the Auditor General |
| OB | Operating Bulletin |
| OTIS | Operational Tests and Inspections Program |
| PDD | proximity detection device |
| PG | packing group |
| PHMSA | Pipeline and Hazardous Materials Safety Administration (United States) |
| PRD | pressure relief device |

| | |
|---|---|
| psi | pounds per square inch |
| QNS&L | Quebec North Shore and Labrador Railway |
| QRB | quick release brake (valve) |
| QSR | Quebec Southern Railway |
| RAC | Railway Association of Canada |
| RODS | Rail Occurrence Database System (TSB) |
| RSA | *Railway Safety Act* |
| RSC | reset safety control |
| RSI | railway safety inspector |
| RTC | rail traffic controller |
| RWI | Rail World, Inc. |
| SBU | sense and braking unit |
| SDS | safety data sheet |
| SMS | safety management system |
| SMS Implementation Guide | *Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* |
| SMS Manual | Safety Management System Manual (MMA) |
| *SMS Regulations* | *Railway Safety Management System Regulations* |
| SOR | Southern Ontario Railway |
| SPTO | single-person train operations |
| SQ | Sûreté du Québec |
| SSO | Safety Systems Overview |
| SST | Strobel Starostka Transfer, LLC |
| STD | start-to-discharge (pressure) |
| TC | Transport Canada |
| TDG | transportation of dangerous goods |
| *TDG Act* | *Transportation of Dangerous Goods Act* |
| TDG Regulations | *Transportation of Dangerous Goods Regulations* |
| Tranz Rail | Tranz Rail Holdings Limited (New Zealand) |
| TSB | Transportation Safety Board of Canada |
| TSR | *Track Safety Rules* |
| UN | United Nations (product code) |
| VIA | VIA Rail Canada Inc. |
| WC | Wisconsin Central |
| WFSI | World Fuel Services, Inc. |
| 3D | three-dimensional |
| ° | degrees |
| °C | degrees Celsius |
| % | per cent |

# Operation Safe Delivery Update

## Executive Summary

Oil and gas production is at an historic high in the United States – a positive development for our economy and our energy independence – but the responsibilities that come along with that production are serious. More crude oil is being shipped by rail than ever before, and it is the U.S. Department of Transportation's responsibility to ensure these crude shipments travel safely.

USDOT is focused on ensuring the United States is the world leader in safely transporting energy, and we have taken more than two dozen steps to strengthen all the ways we deliver this oil, from issuing emergency orders to advancing new rail safety and tank car regulations.

On July 6, 2013, a train carrying 72 tank cars, each filled with 30,000 gallons of crude oil from the Bakken Shale Formation, derailed in a small resort village outside Quebec. A large part of the town, known as Lac-Megantic, was destroyed, and forty-seven of its people perished.

There were oil train derailments in North America before Lac-Megantic. There have been derailments since. And yet no event, as much as that one, has warned us to the dangers of transporting the continent's newfound bounty of energy.

The Lac-Megantic tragedy, along with other crude oil train derailments, made clear that we need to take steps to understand the risks associated with the transport of crude oil in growing volumes and better understand the characteristics of the product being shipped.

In August 2013, the Department embarked on Operation Classification in the Bakken Shale Formation, in the Williston Basin of North Dakota, where crude oil production has skyrocketed. Operation Classification is focused on ensuring shippers are properly classifying crude oil for transportation in accordance with federal regulations, and on better understanding the unique characteristics of mined gases and oils from this region.

We were particularly focused on the Bakken region because there was some question of whether the crude being produced there is more flammable, or more volatile, than most of the other types of crude being produced or shipped in this country. After months of unannounced inspections, testing, and analysis, Operation Classification has determined that the current classification applied to Bakken crude is accurate under the current classification system, but that the crude has a higher gas content, higher vapor pressure, lower flash point and boiling point and thus a higher degree of volatility than most other crudes in the U.S., which correlates to increased ignitability and flammability.

Importantly, our review of crude oil transportation data also confirmed that large volumes of this crude are moving at long distances across the country. At any given time, shipments of more than two million gallons are often traveling distances of more than one thousand miles. Put simply, Operation Classification determined that the U.S. is currently shipping a crude oil product with a higher gas content, lower flash point, lower boiling point and higher vapor pressure than other crude oils in large amounts and for long distances.

This report provides the Pipeline and Hazardous Materials Safety Administration's (PHMSA) and the Federal Railroad Administration's (FRA) testing results of Bakken crude oil as of May 2014.

## Background

The United States is in the midst of a historic increase in energy production. One significant area of domestic oil production is in Bakken Shale Formation, which covers approximately 200,000 square miles in Montana, North Dakota and Saskatchewan, Canada. Crude oil is the primary product being mined from the Bakken region, where oil production there has nearly tripled from 2010 to 2013.

Crude oil is being transported throughout North American and Canada through various modes of transportation, including pipelines, truck, barge and, increasingly, by rail.
In the vast majority of cases, these shipments reach their final destination without incident. Rail incidents have declined by 47 percent over the past decade and incidents involving the transportation of hazardous materials have declined by 16 percent.

Despite this progress, over the last year, a number of significant incidents involving Bakken crude have demonstrated the potential devastating consequences of a crude oil train derailment:

- Lac-Megantic, Quebec involving 63 tank cars out of 72;
- Aliceville, Alabama involving 26 tank cars out of 88;
- Casselton, North Dakota involving 20 tank cars out of 106;
- Lynchburg, Virginia involving 17 tank cars out of 105.

As the nation's regulator of hazardous materials by all modes, PHMSA requires the proper classification of hazardous materials. Proper classification of hazardous materials helps ensure the proper packaging is selected to safely transport the material. It also communicates the risks associated with the material to emergency responders and others who are likely to come in contact with the product as it moves through the transportation network, and in case of an incident.

Operation Classification activities include unannounced inspections, data collection and sampling at strategic terminal and loading locations for crude oil. PHMSA investigators continue to test samples from various points along the crude oil transportation chain: from cargo tanks that deliver crude oil to rail loading facilities, from storage tanks at the facilities, and from pipelines connecting storage tanks to rail cars that would move the crude across the country.

Operation Classification is part of DOT's broader effort called Operation Safe Delivery. Launched in 2013, Operation Safe Delivery is examining the entire system of crude oil delivery, from the well head to its final destination, and applying a comprehensive approach to ensure the safe transportation of crude oil moving by rail.

Additional DOT efforts to improve the safe transport of crude oil include:

- **Safety Communications and Alerts—**Concurrent with enforcement and rulemaking actions, the Department, FRA and PHMSA continue to address safety concerns by issuing emergency orders, safety advisories, safety alerts and other announcements. On May 7, 2014, for example, DOT required railroad carriers to inform first responders about crude oil being transported through their towns.
- **Regulatory Actions—**As recent derailments have proven, the current tank car most frequently used to transport crude oil – the DOT 111 – is not an adequate container for flammable crude oil involved in an incident or derailment. PHMSA and FRA have worked to update rail safety regulations, including those that address rail tank car standards as well as operating practices that would enhance rail safety.
- **A Call to Action—** On January 16, 2014, Secretary Foxx issued a Call to Action, to the rail and petroleum industries, to identify immediate actions to improve safety in the transportation of crude oil by rail. Following the Call to Action, railroad companies agreed to a series of significant safety measures, including speed reductions, increased inspections, the implementation of new brake technology, new routing protocols, and investments in first responder training.
- **Safety Education and Awareness—**PHMSA and FRA continue to provide resources to educate industry, the public, and emergency responders about safe transportation of hazardous materials.
- **Field Inspections, Testing and Enforcement Actions—**PHMSA and FRA continue to conduct hazardous materials field inspections, crude oil testing and, when necessary, issue enforcement penalties.

## The Classification of Petroleum Crude Oil

PHMSA issues the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) that prescribe requirements for the safe transportation of hazardous materials by all modes. The proper classification of any hazardous material is required prior to offering it into transportation. Packaging selection, marking, labeling, shipping papers and placarding are all dependent upon this first, critical step.

Each entity that offers hazardous materials for transportation is considered a shipper (i.e., both initial offerors and subsequent downstream offerors). It is the shipper's responsibility to properly classify and describe a hazardous material, including determining the constituents present and any multiple hazard classes present.

Each shipment of hazardous materials must be accompanied by a shipping paper that must include a statement certifying that the material is in compliance with all appropriate regulations, including classification and packaging. In summary, anyone offering a hazardous material for shipment must:

1. Properly identify all the **hazards** of the material.
2. Determine which of the **nine hazard classes** characterizes the hazards associated with the material.
3. Assign each material to a **packing group**, if applicable.

***Hazard Classes:*** The HMR has nine hazard classes that define the type of risk a hazardous material poses. Some materials meet the definition of more than one hazard class with primary risks and subsidiary risks. Some hazard classes contain divisions in order to further group materials with similar risks and designate higher degrees of a particular hazard. [See Hazardous Materials Hazard Class/Division Table 49 CFR § 173.2]

***Packing Group (PG):*** Once classified, some hazardous materials are assigned to one of three packing groups based upon their degree of hazard, from a great hazard (PG I) to a minor hazard (PG III) material. The quality, damage resistance, and performance standards of the package authorized in each packing group are designed for the hazards of the material transported.

The hazard class and packing group for a material meeting more than one of these hazard classes shall be determined using the precedence table in 49 CFR § 173.2a(b).

The following list illustrates the hazard classes and sub-divisions that need to be considered, at a minimum, for mined gases and liquids based on knowledge of the material.

(1) Class 2, Division 2.3 (poisonous gases) [49 CFR § 173.115]

(2) Class 2, Division 2.1 (flammable gases) [49 CFR § 173.115]

(3) Class 2, Division 2.2 (nonflammable gases) [49 CFR § 173.115]

(4) Class 6, Division 6.1 (poisonous liquids), PG I, poisonous-by-inhalation only [49 CFR § 173.132]

(5) Class 3 (flammable liquids) [49 CFR § 173.120]

(6) Class 8 (corrosive materials) [49 CFR § 173.136] or Division 6.1 (poisonous liquids or solids other than PG I, poisonous-by-inhalation) [49 CFR § 173.132]

(7) Class 3 (combustible liquids) [49 CFR § 173.120]

Provided a particular crude oil does not meet the definition of a gas or poisonous-by-inhalation liquid, and it meets the definition of a flammable liquid, it would be classified and transported as a flammable liquid.

***Flammable Liquid Hazard Class:*** A flammable liquid (Class 3) means a liquid having a flash point of not more than 140 °F, or any material in a liquid phase with a flash point at or above 100 °F that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging. There are five exceptions, see (HMR §173.120 (a) (1-5)). Flash point is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

For flammable liquids (Class 3), the packing groups are defined below.

**Hazardous Materials Packing Groups Table**

| Packing Group | Flash Point | Initial Boiling Point |
|---|---|---|
| **I** (Great Danger) | | ≤ 95 °F |
| **II** (Medium Danger) | < 73 °F | > (95 °F |
| **III** (Minor Danger) | ≥ 23 °C, ≤ 60 °C (140 °F) | > (95 °F |

On March 6, 2014, DOT issued an amended Emergency Order (EO) requiring all rail shippers to test product from the Bakken region. That way, they can ensure the proper classification of crude oil in accordance with the HMR before it's transported by rail.

The Emergency Order also requires those who ship bulk quantities of petroleum crude oil – and do so by rail with tank cars – to treat petroleum crude oil as a Class 3 PG I or PG II hazardous material only, even if it tests as PG III.

## Analysis and Classification

The intent of Operation Safe Delivery's sampling and analysis component is to determine if shippers are properly classifying crude oil for transportation. The intent is also to quantify the range of physical and chemical properties of crude oil.

Prior to the launch of our sampling and analysis, FRA identified that most crude oil loading facilities were basing classification solely on a generic Safety Data Sheet (SDS), formerly known as Material Safety Data Sheets (MSDS). This data can provide a wide range of material properties. SDSs provide workers and emergency personnel with procedures for handling or working with a substance in a safe manner, and include information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures. PHMSA observed that SDSs for crude oil were out-of-date with unverified information and provide ranges of chemical and physical property values instead of specific measured values. Further, these ranges may cross the threshold between PG I, II and III making it difficult to assign the proper packing group. Given the potential variability of crude oil, PHMSA and FRA believed that operators' reliance on generic information was a safety concern.

Based on the initial findings and shippers' reliance on SDS, the operation was expanded to take more samples and test for additional chemical composition and properties including vapor pressure, corrosivity and chemical components of the materials. PHMSA performed the following series of sampling and testing activities.

**Legend**

FP – Flash Point
BP – Initial Boiling Point
API – American Petroleum Institute Specific Gravity
ASTM – American Society for Testing of Materials
RVP – Reid Vapor Pressure
TVP – True Vapor Pressure
BTEX – Benzene/Toluene/Ethylbenzene/Xylene content

Comp – Gas/Liquid composition
W&S – Water & Sediment content
Sulfur – Sulfur content
H2S – Hydrogen Sulfide content
Corrosion – Steel/Aluminum

**PHMSA Sampling and Testing Activities Summary**

| # Samples Tested | Period | Tests Completed | Test Lab | Mean Ambient Temps |
|---|---|---|---|---|
| 14 | August, 2013 | FP | Minnesota Valley Test Lab | 78 °F |
| 21 | September – October, 2013 | FP, BP | Intertek | 44 °F - 66 °F |
| 12 | November, 2013 | FP, BP, API, RVP, Comp, W&S, Sulfur, H2S, BTEX | Intertek | 24 °F |
| 88 | February-May, 2014 | FP, BP, RVP, TVP, Comp, H2S, BTEX, Corrosion | Intertek | 10 °F - 55 °F |
| Total Samples Tested: 135 | | | | |

Below is a table summarizing the two phases of testing and sampling performed pursuant to Operation Safe Delivery.

| Date | August – November | February - May |
|---|---|---|
| **Summary** | The initial efforts of this phase were focused on determining and verifying hazard classes and packaging group selection. Tests focused on flash point and boiling point and then expanded to address other chemical characteristics of crude oil. | The goal of Phase 2 was to gain a more complete understanding (beyond flash and boiling points) of the properties of crude oil and collect a more representative sample of the transportation population. A continuous rotation of investigators was present in the Bakken region during this phase. These investigators collected more samples from various points in the transportation stream. |

| | | |
|---|---|---|
| **Samples Taken** | 47 Total Samples from rail loading facilities and cargo tanks, storage tanks, pipelines used to load rail cars and several were collected from cargo tanks. All samples were collected in accordance with ASTM 4057, "Standard Practice for Manual Sampling of Petroleum and Petroleum Products. | 88 Total Samples from rail loading facilities and cargo tanks, storage tanks, pipelines used to load rail cars and several were collected from cargo tanks. Samples were collected via a syringe-style cylinder in accordance with ASTM 4057, "Standard Practice for Manual Sampling of Petroleum and Petroleum Products. |
| **ASTM Tests Conducted** | Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method) (ASTM D323).<br><br>Standard Test Method for Determination of Individual Components of Crude Oil (ASTM D6730 MOD).<br><br>Standard Test Method for Water and Sediment in Crude Oil (ASTM D4007).<br><br>Standard Test Method for Sulfur in Petroleum and Petroleum Products (ASTM D4294).<br><br>Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils Hydrogen Sulfide Content (ASTM D5705).<br><br>Standard Test Method for Density and Relative Density for Crude Oil (ASTM D5002).<br><br>Standard Test Method for Flash Point by Tag Closed Cup Tester (ASTM D56).<br><br>Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure (ASTM D86). | Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method) (ASTM D323).<br><br>Standard Test Method for Determination of Individual Components of Crude Oil (ASTM D6730 MOD).<br><br>Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils Hydrogen Sulfide Content (ASTM D5705).<br><br>Standard Test Method for Flash Point (FP) by Tag Closed Cup Tester (ASTM D56).<br><br>Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure, Initial Boiling Point (IBP) (ASTM D86).<br><br>Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method) for both Vapor/Liquid ratios of 0.02 (at 122 °F) and 4 (at 100 $°^0$F).<br><br>U.N. Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Chapter 37 (corrosion to aluminum and carbon steel). |

## Summary and Test Results

**Total Samples Taken: 47 total samples (August – November, 2013)**

The first set of testing began with taking samples from several locations, and with limited analysis that included flash point and boiling point to determine if petroleum crude oil was being properly classified and packaged. The effort continued through the fall of 2013 based upon observations from investigators and testing results.

During the week of August 26-30, 2013, PHMSA and FRA investigators conducted joint activities at 14 crude oil transfer locations in North Dakota. The summary of the results from these samples are provided in Table A.

Investigators observed that facility analyses only determined viscosity, solid content, and sulfur content. PHMSA acquired a total of 14 samples at these locations. Analytical results indicated that the materials had a flash point less than 73°F, indicating that, at a minimum, PG II must be assigned to the material.

Boiling point information was not determined because the lab conducting the testing did not have adequate equipment to test for boiling point. So, final determination of a packing group was not possible. The results are provided in Table A.

**Table A**
**Crude Oil Samples (August 26-30, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| **#1** | New Town, ND | <73 | Not Analyzed | I or II |
| **#2** | New Town, ND | <73 | Not Analyzed | I or II |
| **#3** | Berthold, ND | <73 | Not Analyzed | I or II |
| **#4** | Stanley, ND | <73 | Not Analyzed | I or II |
| **#5** | Fairview, ND | <73 | Not Analyzed | I or II |
| **#6** | Trenton, ND | <73 | Not Analyzed | I or II |
| **#7** | Dore, ND | <73 | Not Analyzed | I or II |
| **#8** | Epping, ND | <73 | Not Analyzed | I or II |
| **#9** | Tioga, ND | <73 | Not Analyzed | I or II |
| **#10** | Ross, ND | <73 | Not Analyzed | I or II |
| **#11** | Dickinson, ND | <73 | Not Analyzed | I or II |
| **#12** | Dickinson, ND | <73 | Not Analyzed | I or II |
| **#13** | Belfield, ND | <73 | Not Analyzed | I or II |
| **#14** | Scranton, ND | <73 | Not Analyzed | I or II |

The week of September 9, 2013, PHMSA and FRA investigators collected samples at three additional rail loading facilities. The samples were analyzed for flash point and boiling point. Two of the samples met criteria as a PG II and one sample met criteria as a PG I. The results are provided in Table B.

**Table B**
**Crude Oil Samples (September 9, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| **#1** | Epping, ND | <40 | 96.5 | II |
| **#2** | Ross, ND | <40 | 96.2 | II |
| **#3** | Tioga, ND | <40 | 81 | I |

From October 8-10, 2013, PHMSA and Federal Motor Carrier Safety Administration (FMCSA) investigators collected 18 samples from cargo tank motor vehicles at roadside inspections or at loading/unloading terminals. Of the 18 samples tested, 10 samples met criteria as PG I and eight samples met criteria related to this testing as PG II. The results from these tests are provided in Table C.

**Table C**
**Crude Oil Samples (October 8-10, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| #1 | Portal, ND | < 50 | 102.7 | II |
| #2 | Portal, ND | < 50 | 123.8 | II |
| #3 | Docado--SWSW 11-162N-98W (Divide Cty, ND) | < 50 | 108.1 | II |
| #4 | Zimmerman 3-13H | < 50 | 96.8 | II |
| #5 | Plano 1-28H | < 50 | 103.7 | II |
| #6 | SW/SW sec.12-7151N- Rigaw (Mckenzie Cty, ND) | < 50 | 118.3 | II |
| #7 | Cora Martin Battery 12345 Tank #2380 | < 50 | 96.7 | II |
| #8 | Cora Martin Battery 12345 Tank #2395 | < 50 | 89 | I |
| #9 | BB- State H3 (McKenzie Cty, ND) | < 50 | 92.1 | I |
| #10 | SW-SE Section 34 Township 152 Dir N | < 50 | 92.6 | I |
| #11 | HA Nelson A Facility 152-95-3427 | < 50 | 91.9 | I |
| #12 | SW-SE Section 2 Township Dir N Tank Lact L8515 | < 50 | 89 | I |
| #13 | AV-Wrigley-163-94-0607H-1 (Burke Cty, ND) | < 50 | 96.2 | II |
| #14 | SESW-8-154-93 (Mountrail, ND) | < 50 | 88.9 | I |
| #15 | SE-SE Section 9 Township 156 Dir N Range 93 Dir W (Mountrax Cty, ND) | < 50 | 87.6 | I |
| #16 | SC Ellingsberg 32-29 H-2 25697 (Williams Cty, ND) | < 50 | 90.9 | I |
| #17 | Cora Martin Battery 12345 Tank #2377 | < 50 | 91.6 | I |
| #18 | Cora Martin Battery 12345 Tank #2388 | < 50 | 92.1 | I |

During the week of November 5, 2013, PHMSA investigators collected 12 samples, including eight samples from the discharge of cargo tanks into bulk storage tanks at rail loading facilities. The remaining four samples were taken from bulk storage tanks at a rail loading facility. The scope of testing was expanded to determine vapor pressure, gas and liquid composition, corrosivity, and toxicity, density, flash point and boiling point.

The results from these analyses are provided in Table D.

**Table D**
**Crude Oil Samples (Week of November 5, 2013)**

| Sample | Location | Reid Vapor Pressure (psia) | Methane (% Vol) | Ethane (% Vol) | Propane (% Vol) | Butane (incl. isomers) (% Vol) | Water & Sediment Content (% Vol) | Sulfur Content (% Wt) | Hydrogen Sulfide Content (ppm) | API Gravity @60$^{O}$F | Flash Point ($^{O}$F) | Initial Boiling Point ($^{O}$F) | Packing Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **#1** | Killdeer, ND | 10.4 | <0.01 | 0.12 | 1.17 | 2.94 | 0.05 | 0.123 | <5 | 39.9 | < 32 | 88.2 | I |
| **#2** | Beulah, ND | 10.05 | <0.01 | 0.13 | 1.17 | 2.89 | 0.05 | 0.121 | <5 | 40.0 | < 32 | 104.2 | II |
| **#3** | Killdeer, ND | 8.70 | <0.01 | 0.05 | 0.81 | 2.70 | 0.10 | 0.117 | < 5 | 41.4 | < 32 | 89.1 | I |
| **#4** | Beulah, ND | 8.80 | < 0.01 | 0.05 | 0.86 | 2.80 | 0.10 | 0.128 | < 5 | 41.5 | < 32 | 92.6 | I |
| **#5** | Killdeer, ND | 11.45 | < 0.01 | 0.06 | 1.00 | 3.19 | 0.05 | 0.112 | < 5 | 42.0 | < 32 | 91.1 | I |
| **#6** | Beulah, ND | 11.75 | < 0.01 | 0.07 | 1.14 | 2.21 | 0.10 | 0.111 | < 5 | 42.4 | < 32 | 84.6 | I |
| **#7** | Killdeer, ND | 9.20 | < 0.01 | 0.06 | 0.96 | 2.91 | 0.05 | 0.117 | < 5 | 41.1 | < 32 | 95.6 | II |
| **#8** | Tioga, ND | 10.80 | < 0.01 | 0.08 | 1.08 | 3.06 | 0.05 | 0.116 | < 5 | 41.4 | < 32 | 85.9 | I |
| **#9** | New Town, ND | 9.50 | < 0.01 | 0.04 | 0.76 | 2.72 | 0.05 | 0.148 | < 5 | 41.2 | < 32 | 93.7 | I |
| **#10** | New Town, ND | 10.90 | < 0.01 | 0.12 | 1.21 | 2.41 | 0.05 | 0.0844 | < 5 | 43.8 | < 32 | 85.5 | I |
| **#11** | Epping, ND | 7.70 | < 0.01 | 0.03 | 0.61 | 2.42 | 0.10 | 0.114 | < 5 | 42.0 | < 32 | 95.6 | II |
| **#12** | Dickinson, ND | 8.75 | < 0.01 | 0.06 | 0.82 | 2.68 | 0.10 | 0.0856 | < 5 | 42.8 | < 32 | 91.7 | I |

## Summary and Test Results

**Total Samples Taken: 88 total samples (February – May, 2014)**

The second phase of testing involved additional inspectors on a continual rotation in the Bakken region to collect samples. The majority of the samples were collected at rail loading facilities from storage tanks and pipelines that were used to load rail cars. Several were collected from cargo tanks. Four of the samples collected were drawn using a closed syringe-style cylinder connected to loading pipeline to determine if there were differences from previous samples collected using the open container sampling method. The results are provided as Table E. The following tests were conducted:

**Table E**
**Crude Oil Samples (February – May, 2014)**

| Company Name | City | State | Sample Date | Test Date | Flash Point (deg. F) | Initial Boiling Point (deg. F) | VPCR 0.02 @122 deg. F (psia) | VPCR 4 @ 100 deg. F (psia) | Methane (%Vol) | Ethane (% Vol) | Propane (% Vol) | Butane (% Vol) | Hydrogen Sulfide (ppm) | Corrosivity (% Weight Loss) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bakken Oil Express LLC | Dickinson | ND | 02/24/14 | 03/03/14 | < 50 | 88.1 | 27.0 | 11.1 | 0 | 0.2079 | 1.2461 | 3.1643 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 89.3 | 27.8 | 11.4 | 0 | 0.2256 | 1.2991 | 3.2295 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 97.5 | 25.7 | 11.1 | 0 | 0.2015 | 1.2461 | 3.1735 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 93.1 | 27.7 | 12.2 | 0 | 0.2586 | 1.4587 | 3.4972 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 89.0 | 29.8 | 12.5 | 0 | 0.2206 | 1.3773 | 3.423 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 93.6 | 28.3 | 12.7 | 0 | 0.2574 | 1.4409 | 3.3963 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.1 | 26.9 | 10.8 | 0 | 0.1746 | 1.0088 | 2.8672 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 89.4 | 26.7 | 10.7 | 0 | 0.1735 | 1.0093 | 2.8324 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.3 | 23.4 | 10.5 | 0 | 0.184 | 1.0543 | 2.9483 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 83.8 | 24.3 | 11.6 | 0 | 0.2233 | 1.3951 | 3.4341 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 86.2 | 28.2 | 12.4 | 0 | 0.2347 | 1.384 | 3.3272 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 87.2 | 30.2 | 12.5 | 0 | 0.2251 | 1.4192 | 3.4896 | <1 | |
| Dakota Plains/Strobel Starostka | New Town | ND | 02/25/14 | 03/03/14 | <50 | 90.5 | 31.2 | 13.1 | 0 | 0.2192 | 1.5254 | 3.735 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.8 | 28.6 | 11.8 | 0 | 0.1379 | 1.279 | 3.521 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02/25/14 | 03/02/14 | < 50 | 86.4 | 27.7 | 12.2 | 0 | 0.1359 | 1.2462 | 3.4476 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC | Beuthold | ND | 02/26/14 | 03/03/14 | < 50 | 93.5 | 26.7 | 11.2 | 0 | 0.1945 | 1.2662 | 3.2127 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 89 | 26.4 | 11.1 | 0 | 0.1975 | 1.2624 | 3.1692 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 92.5 | 26.8 | 11.2 | 0 | 0.2182 | 1.3064 | 3.2112 | <1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 02/25/14 | 03/03/14 | < 50 | 88.4 | 29.3 | 13.3 | 0 | 0.1194 | 1.1389 | 3.3152 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 85.7 | 28.5 | 13.3 | 0 | 0.2099 | 1.5419 | 3.7439 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 86.8 | 29.4 | 13.4 | 0 | 0.2112 | 1.5539 | 3.7434 | <1 | |
| | | | | | | | | | | | | | | |
| Plains Marketing, LP | Ross | ND | 02/26/14 | 03/02/14 | < 50 | 81.8 | 28.7 | 14.2 | 0 | 0.2005 | 1.7301 | 4.1952 | <1 | |
| | | | 02/26/14 | 03/02/14 | < 50 | 80.6 | 29.0 | 15.1 | 0 | 0.2858 | 1.9851 | 4.4043 | <1 | |
| | | | 02/26/14 | 03/02/14 | < 50 | 83.8 | 29.0 | 13.3 | 0 | 0.3158 | 2.0843 | 4.48 | <1 | |
| | | | | | | | | | | | | | | |
| Inergy Crude Logistics, LP | Epping | ND | 02/26/14 | 03/03/14 | < 50 | 85.5 | 28.3 | 13.5 | 0 | 0.3064 | 1.5878 | 3.5817 | <1 | 0** |
| | | | 02/26/14 | 03/03/14 | < 50 | 84.9 | 28.7 | 13.6 | 0 | 0.2963 | 1.5604 | 3.5526 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 84.7 | 29.8 | 13.6 | 0 | 0.2965 | 1.606 | 3.6625 | <1 | |
| | | | | | | | | | | | | | | |
| Great Northern Gathering & Marketing | Fryburg | ND | 02/26/14 | 03/10/14 | < 50 | 86.7 | 26.2 | 11.5 | 0 | 0.2635 | 1.399 | 3.3975 | <1 | |
| | | | 02/26/14 | 03/10/14 | < 50 | 87.0 | 27.1 | 11.3 | 0 | 0.3138 | 1.617 | 3.8413 | <1 | |
| | | | 02/26/14 | 03/10/14 | < 50 | 90.8 | 26.4 | 11.1 | 0 | 0.3204 | 1.5856 | 3.7071 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Stampede | Stampede | ND | 02/27/14 | 03/10/14 | <50 | 88.0 | 28.2 | 12.4 | 0 | 0.1719 | 1.2974 | 3.3689 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 88.1 | 25.5 | 12.5 | 0 | 0.2685 | 1.7044 | 3.8848 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 87.7 | 29.5 | 12.9 | 0 | 0.3153 | 1.9675 | 4.4686 | <1 | |
| | | | | | | | | | | | | | | |
| Musket Corp. | Dickinson | ND | 02/27/14 | 03/10/14 | <50 | 86.7 | 28.5 | 13.4 | 0 | 0.2329 | 1.5192 | 3.6576 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02/27/14 | 03/10/14 | <50 | 84.5 | 28.7 | 13.4 | 0 | 0.241 | 1.5076 | 3.6036 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 88.0 | 28.1 | 13.3 | 0 | 0.2711 | 1.6539 | 3.9135 | <1 | |
| | | | | | | | | | | | | | | |
| Red River Supply | Williston | ND | 02/27/14 | 03/10/14 | <50 | 88.7 | 28.4 | 13.0 | 0 | 0.2631 | 1.3361 | 3.0534 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 89.0 | 29.1 | 13.3 | 0 | 0.3444 | 1.7621 | 4.0086 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 87.5 | 28.6 | 12.9 | 0 | 0.3953 | 1.9241 | 4.3453 | <1 | |
| | | | | | | | | | | | | | | |
| Great Northern Gathering & Marketing | Fryburg | ND | 02/27/14 | 03/10/14 | <50 | 91.7 | 26.8 | 11.2 | 0 | 0.2265 | 1.4366 | 3.7671 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Beulah | Beulah | ND | 02/28/14 | 03/10/14 | <50 | 83.3 | 30.0 | 11.8 | 0 | 0.227 | 1.3635 | 3.5145 | <1 | |
| | | | 02/28/14 | 03/10/14 | <50 | 87.3 | 26.3 | 10.6 | 0 | 0.1877 | 1.3101 | 3.566 | <1 | |
| | | | 02/28/14 | 03/10/14 | <50 | 88.1 | 25.2 | 11.2 | 0 | 0.2195 | 1.4373 | 3.9621 | <1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 03/04/14 | 03/07/14 | < 50 | 87.9 | 26.6 | 12.1 | 0 | 0.2312 | 1.5577 | 3.7271 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 89.3 | 28.3 | 12.6 | 0 | 0.2393 | 1.5617 | 3.6901 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC | Berthold | ND | 03/04/14 | 03/07/14 | <50 | 93.6 | 26.4 | 11.4 | 0 | 0.1743 | 1.1727 | 3.062 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 88.9 | 26.1 | 11.3 | 0 | 0.1645 | 1.1517 | 3.0522 | <1 | |
| | | | | | | | | | | | | | | |
| Savage | Trenton | ND | 03/04/14 | 03/07/14 | <50 | 84.4 | 27.5 | 12.7 | 0 | 0.2583 | 1.5151 | 3.5849 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 87.1 | 28.7 | 13.1 | 0 | 0.248 | 1.4652 | 3.5252 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 88.8 | 30.0 | 13.1 | 0 | 0.2667 | 1.5277 | 3.5926 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 84.1 | 29.2 | 13.2 | 0 | 0.2743 | 1.5579 | 3.6289 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 85.0 | 26.1 | 13.1 | 0 | 0.2364 | 1.4313 | 3.4846 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 86.6 | 29.5 | 13.0 | 0 | 0.2251 | 1.4072 | 3.4837 | <1 | |
| | | | | | | | | | | | | | | |
| Plains All | New Town | ND | 03/04/14 | 03/11/14 | <50 | 83.7 | 31.2 | 13.3 | 0 | 0.2538 | 1.6544 | 3.9182 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American | | | | | | | | | | | | | | |
| | | | 03/04/14 | 03/11/14 | <50 | 82.7 | 28.1 | 13.4 | 0 | 0.2456 | 1.6288 | 3.8824 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 87.3 | 30.1 | 13.6 | 0 | 0.2062 | 1.5219 | 3.7927 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 87.3 | 29.7 | 13.4 | 0 | 0.2602 | 1.6871 | 3.9719 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 86.9 | 29.0 | 13.5 | 0 | 0.2584 | 1.6681 | 3.9274 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 86.7 | 32.1 | 14.1 | 0 | 0.2649 | 1.6666 | 3.8536 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Stampede | Stampede | ND | 03/10/14 | 03/17/14 | <50 | 88.5 | 28.6 | 12.8 | 0 | 0.2709 | 1.5797 | 3.7126 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 90.8 | 29.2 | 13.2 | 0 | 0.2988 | 1.6097 | 3.6708 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 86.7 | 28.0 | N/A | 0 | 0.259 | 1.5127 | 3.6046 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 89.2 | 27.8 | 13.0 | 0 | 0.2869 | 1.6188 | 3.7266 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 89.8 | 29.1 | 13.3 | 0 | 0.2495 | 1.4623 | 3.5335 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 91.3 | 27.2 | 13.2 | 0 | 0.294 | 1.6143 | 3.712 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Beulah | Beulah | ND | 03/11/14 | 03/17/14 | <50 | 92.3 | 24.9 | 10.1 | 0 | 0.1556 | 0.9818 | 2.7378 | <1 | |
| | | | | | | | | | | | | | | |
| Bakken Oil Express LLC | Dickinson | ND | 03/12/14 | 03/17/14 | <50 | 88.0 | 26.1 | 12.2 | 0 | 0.2476 | 1.3834 | 3.3223 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 87.7 | 26.3 | 11.7 | 0 | 0.232 | 1.3385 | 3.2275 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 88.9 | 20.3 | 11.6 | 0 | 0.2368 | 1.333 | 3.2269 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.9 | 26.8 | 11.7 | 0 | 0.2235 | 1.3089 | 3.2207 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 87.1 | 27.2 | 11.9 | 0 | 0.2034 | 1.241 | 3.1276 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.1 | 27.0 | 11.8 | 0 | 0.233 | 1.3208 | 3.2072 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.3 | 27.4 | 11.7 | 0 | 0.2211 | 1.2849 | 3.1663 | < 1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 03/13/14 | 03/18/14 | <50 | 89.6 | 27.20 | 12.24 | 0 | 0.1845 | 1.4065 | 3.5213 | <1 | |
| | | | 03/13/14 | 03/18/14 | <50 | 86.6 | 27.02 | 12.03 | 0 | 0.1849 | 1.3732 | 3.4601 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 03/13/14 | 03/18/14 | <50 | 94.0 | 26.80 | 12.24 | 0 | 0.1913 | 1.4155 | 3.5186 | <1 | |
| | | | | | | | | | | | | | | |
| Hess Corporation | Tioga | ND | 03/11/14 | 03/15/14 | <50 | 85.8 | 27.12 | 14.38 | 0 | 0.23 | 1.8 | 4.02 | <1 | |
| | | | | | | | | | | | | | | |
| Inergy Crude Logistics, LP | Epping | ND | 03/18/14 | 03/21/14 | <50 | 86.6 | 28.89 | 13.29 | 0 | 0.1961 | 1.3918 | 3.5 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 94.4 | 28.34 | 13.7 | 0 | 0.2251 | 1.51 | 3.626 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 88.4 | 29.84 | 13.82 | 0 | 0.2484 | 1.5539 | 3.649 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 92.3 | 23.04 | 10.22 | 0 | 0.0571 | 0.8493 | 3.0056 | <1 | |
| | | | | | | | | | | | | | | |
| Hess Corporation | Tioga | ND | 03/17/14 | 03/20/14 | <50 | 79.1 | 25.26 | 13.64 | 0 | 0.217 | 1.7327 | 4.1573 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC* | Berthold | ND | 04/28/14 | 05/01/14 | <50 | 88.5 | 39.36 | 11.31 | <0.01 | 0.19 | 1.2 | 3.07 | <1 | |
| | | | 04/26/14 | 05/01/14 | <50 | 87.2 | 24.71 | 10.97 | <0.01 | 0.21 | 1.32 | 3.31 | N/A | |
| | | | 04/26/14 | 05/01/14 | <50 | 85.9 | 26.35 | 11.29 | <0.01 | 0.21 | 1.29 | 3.24 | N/A | |
| | | | | | | | | | | | | | | |
| Plains Marketing, LP* | Ross | ND | 04/30/14 | 05/02/14 | <50 | 84.2 | 36.73 (0.05) | 14.28 | <0.01 | 0.29 | 1.95 | 4.44 | N/A | |
| Great Northern Gathering & Marketing* | Fryburg | ND | 05/01/14 | 05/05/14 | <50 | 86.7 | 37.21 | 11.12 | <0.01 | 0.2 | 1.16 | 3.05 | N/A | |
| Dakota Plains/Strobel Starostka* | Newtown | ND | 05/02/14 | 05/05/14 | <50 | 84.1 | 31.12 | 11.47 | <0.01 | 0.15 | 1.24 | 3.32 | N/A | |

## Conclusion

Based upon the results obtained from sampling and testing of the 135 samples from August 2013 to May 2014, the majority of crude oil analyzed from the Bakken region displayed characteristics consistent with those of a Class 3 flammable liquid, PG I or II, with a predominance to PG I, the most dangerous class of Class 3 flammable liquids. Based on our findings, we conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude– which correlates to increased ignitability and flammability.

Bakken crude's high volatility level – a relative measure of a specific material's tendency to vaporize – is indicated by tests concluding that it is a "light" crude oil with a high gas content, a low flash point, a low boiling point and high vapor pressure. The high volatility of Bakken crude oil, and its identification as a "light" crude oil, is attributable to its higher concentrations of light end hydrocarbons. This distinguishes it from "heavy" crude oil mined in other parts of the United States,

Given Bakken crude oil's volatility, there is an increased risk of a significant incident involving this material due to the significant volume that is transported, the routes and the extremely long distances it is moving by rail. Trains transporting this material, referred to as unit trains, routinely contain more than 100 tank cars, constituting at least 2.5 million gallons within a single train. Unit trains only carry a single type of product, in this case flammable crude oil. These trains often travel over a thousand miles from the Bakken region to refinery locations along the coasts.

PHMSA and FRA plan to continue the sampling and analysis activities of Operation Safe Delivery through the summer and fall of 2014 and to work with the regulated community to ensure the safe transportation of crude oil across the nation. The Department will continue to keep the public, regulated entities and emergency responders informed about our efforts.

# # #

This letter was not received in accordance with NDAC § 43-02-03-90.2 Therefore, it is not part of the evidentiary record of this case.

## Kadrmas, Bethany R.

**From:** Fine, Karlene K.
**Sent:** Tuesday, September 23, 2014 10:31 AM
**To:** Helms, Lynn D.; Hicks, Bruce E.; Kadrmas, Bethany R.
**Subject:** FW: Letter From Governor Mark Dayton, State of Minnesota, to Governor Jack Dalrymple, State of North Dakota
**Attachments:** 09.23.2014.Dalrymple.Jack.Governor.North.Dakota.Bakken.Oil.Transportation.pdf

**Importance:** High

Letter received in the Governor's Office today at 9:38 A.M. I don't believe the Governor has seen it as he has been at the hearing. Karlene

**From:** Strinden, Lauren
**Sent:** Tuesday, September 23, 2014 9:55 AM
**To:** Rauschenberger, Ron W.; Storbakken, Bonnie L.; Zent, Jeffrey L.; Fine, Karlene K.
**Subject:** FW: Letter From Governor Mark Dayton, State of Minnesota, to Governor Jack Dalrymple, State of North Dakota
**Importance:** High

**From:** Kostohryz, Kathy (GOV) [mailto:kathy.kostohryz@state.mn.us]
**Sent:** Tuesday, September 23, 2014 9:38 AM
**To:** Strinden, Lauren
**Subject:** Letter From Governor Mark Dayton, State of Minnesota, to Governor Jack Dalrymple, State of North Dakota
**Importance:** High

Good Morning Again Lauren –

Thanks for taking my call – it's always so great to talk to you!

Attached is the letter I called you about. This letter is for Governor Dalrymple's receipt and review as soon as possible, as it pertains to a hearing that is happening this afternoon.

Thank you again Lauren!

Kathleen Donnelly Kostohryz | Senior Aide / Executive Assistant to the Governor
Office of Governor Mark Dayton & Lt. Governor Yvonne Prettner Solon
116 Veterans Service Building – 20 West 12th Street, St. Paul, MN 55155
Office: 651-201-3436 |Cell: 651-238-6369 | Fax: 651-797-1886

**Working to Build a Better Minnesota**
Web | Twitter| Facebook

# STATE OF MINNESOTA

## Office of Governor Mark Dayton

116 Veterans Service Building ♦ 20 West 12th Street ♦ Saint Paul, MN 55155

September 23, 2014

The Honorable Jack Dalrymple
Governor
600 East Boulevard Avenue
Bismarck, North Dakota 58505

Dear Governor Dalrymple:

I am writing to urge you and the other Members of the North Dakota Industrial Commission to quickly establish oil conditioning standards that will decrease the volatility of Bakken oil being exported from North Dakota. Minnesota is one of the primary routes for this highly volatile oil; however, our state receives little direct benefit from its transport. Instead, Minnesotans experience the greatly increased risks in the event of a derailment.

The amount of Bakken crude oil being shipped through Minnesota has increased dramatically since 2009. Currently, hundreds of rail cars on about seven trains, which carry more than 23 million gallons of crude oil, pass through Minnesota every day. These train movements have significant impacts on almost 3.5 million of the state's 5 million residents who live in communities along Bakken oil train routes. We are told that the volume of crude oil being shipped through Minnesota will continue to increase over the next decade.

In Minnesota, we are doing our part to ensure the safety and security of our citizens and the communities in which they live. Last spring, I signed into law comprehensive prevention and emergency response improvements. However, only the State of North Dakota has direct control over the safety of the products being shipped into our state.

I recognize the challenge of regulating an industry that has so rapidly expanded in your state and your obligation to support your state's thriving economy. But not only will conditioning improve the safety of Minnesota residents and those along rail lines, it may also open up additional markets for the export of Bakken oil. The U.S. Commerce Department recently approved two U.S. companies to export crude oil that has been stabilized. These companies are from Texas, which already has stabilization requirements in law.

I appreciate your leadership to ensure that the maximum feasible safety measures are in place for all Minnesota and North Dakota residents, as well as the millions of other U.S. citizens, who live on Bakken oil train routes. If you have any questions, please contact either myself or Joanna Dornfeld, my Senior Policy Advisor, at 651-201-3423, or via email at joanna.dornfeld@state.mn.us.

Thank you for your consideration.

Sincerely,

Mark Dayton
Governor

cc: The Honorable Wayne Stenehjem, Attorney General of North Dakota
The Honorable Doug Goehring, Commissioner, North Dakota Department of Agriculture

This letter was not received in accordance with NDAC § 43-02-03-90.2 Therefore, it is not part of the evidentiary record of this case.

**Kadrmas, Bethany R.**

**From:** Timothy Truscott <empirestate@att.net>
**Sent:** Monday, September 22, 2014 11:40 PM
**To:** Kadrmas, Bethany R.
**Subject:** Comments for the North Dakota Industrial Commission
**Attachments:** NDIC Letter.pdf

Attached plese find my letter with comments for the North Dakota Industrial Commission.

Timothy C. Truscott
empirestate@att.net

Timothy C. Truscott
131 Jay St.
Albany NY 12210-1805
(518) 449-8450 voice
(518) 689-5923 fax
empirestate@att.net

September 22, 2014

Honorable Jack Dalrymple, Governor and Chair
North Dakota Industrial Commission, Oil and Gas Division
1000 E. Calgary Ave.
Bismarck, ND 58503

Dear Governor Dalrymple:

I am writing you regarding the September 23, 2014 hearing of the North Dakota Industrial Commission to consider amending field rules relating to the Bakken, Three Forks, and Sanish Pools. Those rules need to be changed significantly to reduce the environmental and public health risks associated with rail transportation of crude oil. I trust that this hearing will not be used as a mechanism to maintain the status quo so that record profits by the oil companies and railroads are protected at the expense of the public.

As you are aware, there have been at least 10 significant derailments in the U.S. and Canada in the last few years in which tank cars have ruptured and crude oil has spilled. Several of these derailments have resulted in huge and intense fires which were so hot that firefighters could not get close enough to fight them. In spite of these catastrophic events, rail shipments of crude oil have increased at an alarming rate with no significant improvements to any part of the infrastructure that handles this hazardous material. The number of crude oil rail shipments continues to rise.

I'm sure you are aware that, in spite of the supposed regulation of the railroads by our federal government, there is no federal requirement that either the railroads or the shippers provide a bond or other surety to cover the cost of cleaning up a spill or damage caused by one of these crude oil trains. In some states, like New York, there is a state oil spill fund which is intended to serve this purpose. This scheme operates by requiring shippers of petroleum to pay into this fund according to the volume of oil shipped into the state for sale or for transloading.

I understand the spill fund now contains about $20 million. I also understand the Lac-Megantic disaster has cost over One Billion Dollars so far, and costs keep rising.

Companies that sell their petroleum products in New York pay into the spill fund at a rate of 8 cents ($0.08) per barrel, with an additional 4.25-cent surcharge, for a total of $0.1225 per barrel. However, for some inexplicable reason, shippers transporting crude oil from North Dakota to New York pay only $0.015 per 42-gallon barrel, or $0.0003571 per gallon. I think this works out to about One Dollar for each DOT-111 tank car load of crude oil going into the spill fund.

In other words, shippers of crude oil from North Dakota pay into the spill fund at a rate of only a very small fraction of what shippers of petroleum products sold in New York pay, even though the North Dakota oil is much more dangerous.

But what is most galling is that shippers of North Dakota crude oil which is not transloaded in New York pay absolutely nothing into the spill fund, even though the risk they create is at least equal to the others.

This North Dakota "energy boom" has been poorly planned (actually, I'm not aware of any planning undertaken before it began) from the oil fields of North Dakota, over the rail lines and all the way to the refineries. The State of North Dakota has not upheld its responsibility to regulate oil extraction and shipping in order to make it safe. The *modus operandi* has been to ship the oil first, then fight any effort to make it safer.

North Dakota needs to require stabilization of its crude oil before shipment. There are no ifs, ands or buts about it. If it doesn't, I suspect that Citizens in other states may take action to force North Dakota to do it.

North Dakota should also be collecting a fee from the shippers, before the oil leaves the state, for the purpose of paying the costs of any spill of North Dakota oil anywhere in the U.S. and Canada. North Dakota and its businesses shouldn't be making their profits on the backs of other people who have no financial stake in the North Dakota oil industry.

I encourage you and the other Commission members to think about the individuals and municipalities in locations distant from North Dakota who are being put at risk by this surge in oil production and rail shipping, and that you make appropriate changes to the current field rules.

Best regards,

Timothy C. Truscott

Dakota Resource Council

watchdogs of the prairie

# Dakota Resource Council Comments re: Bakken Crude Volatility

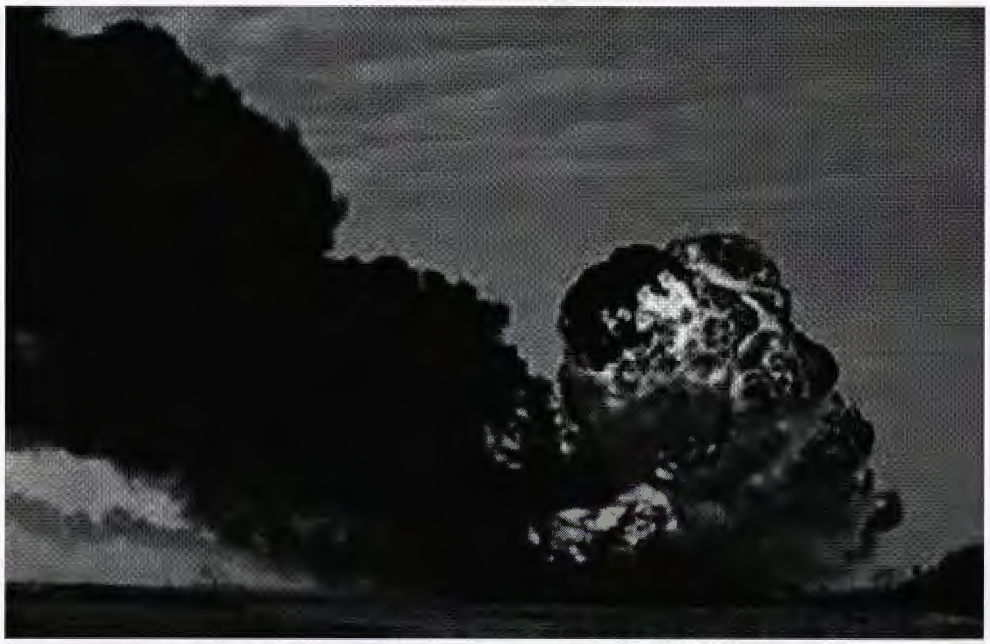


Photo: Casselton Derailment
Credit: Bloomberg

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Dakota Resource Council
Exhibit A
Identified By Bird Bear/ Skokos

Dakota Resource Council

Watchdogs of the prairie

# Bakken Crude is Volatile.

"the crude [Bakken] has a higher gas content, higher vapor pressure, lower flash point and boiling point and thus a higher degree of volatility than most other crudes in the U.S., which correlates to increased ignitability and flammability." –PHMSA July 2014

Dakota Resource Council

Watchdogs of the prairie

Industry Funded studies should be disregarded due to inherent conflicts of interest. I.e. North Dakota Petroleum Council funded study.

Dakota Resource Council

Watchdogs of the prairie

Cozy Relationships between regulators and the oil industry obscure regulators ability to put forth proper regulations and safeguards.

- Examples: Tioga Spill  response & regulation of flaring

Dakota Resource Council

watchdogs of the prairie

Early December 2013 Lynn Helms Quote: We need to produce a white paper "to dispel this myth that it (Bakken crude) is somehow an explosive, really dangerous thing to have traveling up and down rail lines."

2 weeks later this happened in Casselton:

Dakota Resource Council

Watchdogs of the prairie

The importance of this issue:

- 47 lives were lost when a train derailed in Lac Megantic in July 2013
- Fiery  derailments involving Bakken in Alabama, Virginia, and North Dakota have people living along the rails terrified.
- Only ND can regulate how to oil and gas operators treat their oil prior to shipping.

Dakota Resource Council

Watchdogs of the prairie

Two Methods that can make Bakken crude safer:

- Conditioning
- Stabilization: like in Texas

Dakota Resource Council

Watchdogs of the prairie

Oil Conditioning: short term solution

- Process that can be completed at well-sites
- Does not require infrastructure
- If chosen, it must be proven effective
- Conditioned oil should be tested prior to shipping

Oil Stabilization: like in Texas

- Currently used in the Eagle Ford Shale
- Known for an being effective method
- Requires infrastructure such as pipelines and micro-refineries
- It makes sense to invest in this infrastructure now before ND hits its potential peak at 50K- 70K active wells

Dakota Resource Council

watchdogs of the prairie

The case for slowing down permitting:

- Permitting needs to slow down until a solution can be properly implemented and enforced.

- 3 Viable Scenarios exist.

The case for slowing down permitting:

Scenario 1: Conditioning is required.

- Companies must prove to an expert competency in removing volatile elements.
- Companies cannot apply for new ADPs until they have proven competency.
- Crude must be tested to verify companies are doing conditioning. Fines and permitting restrictions will be levied to violators.

The case for slowing down permitting:

Scenario 2: Stabilization is required

- Concerted effort to comprehensively plan infrastructure is a must
- Slow down of permitting until sufficient infrastructure is built out.

Dakota Resource Council

Watchdogs of the prairie

The case for slowing down permitting:

Scenario 2: Phased Approach (Preferred option)

- Conditioning is used until stabilization infrastructure is built out.
- Same requirements and penalties as in scenario 1.
- Stabilizers must be used by producers if possible, state provides incentives to companies using stabilizers.

Conclusion:

- This is an issue of public safety
- Decision should be made based on safety, not in an effort to preserve oil industry profits.
- Slow down permitting until a viable solution can be implemented and enforced
- Permitting restrictions and fines should be levied to companies unable to comply
- Employing a phased/blended approach with both conditioning and stabilization is preferred.

US 20130306520A1

(19) **United States**

(12) **Patent Application Publication**

**NIKIFORUK**

(10) **Pub. No.: US 2013/0306520 A1**

(43) **Pub. Date: Nov. 21, 2013**

(54) **HYDROCARBON PROCESSING**

(71) Applicant: **Colin NIKIFORUK**, Calgary (CA)

(72) Inventor: **Colin NIKIFORUK**, Calgary (CA)

(21) Appl. No.: **13/896,979**

(22) Filed: **May 17, 2013**

**Related U.S. Application Data**

(60) Provisional application No. 61/648,750, filed on May 18, 2012.

**Publication Classification**

(51) **Int. Cl.**

| | |
|---|---|
| *C10L 3/10* | (2006.01) |
| *C10G 5/00* | (2006.01) |
| *F17C 7/00* | (2006.01) |

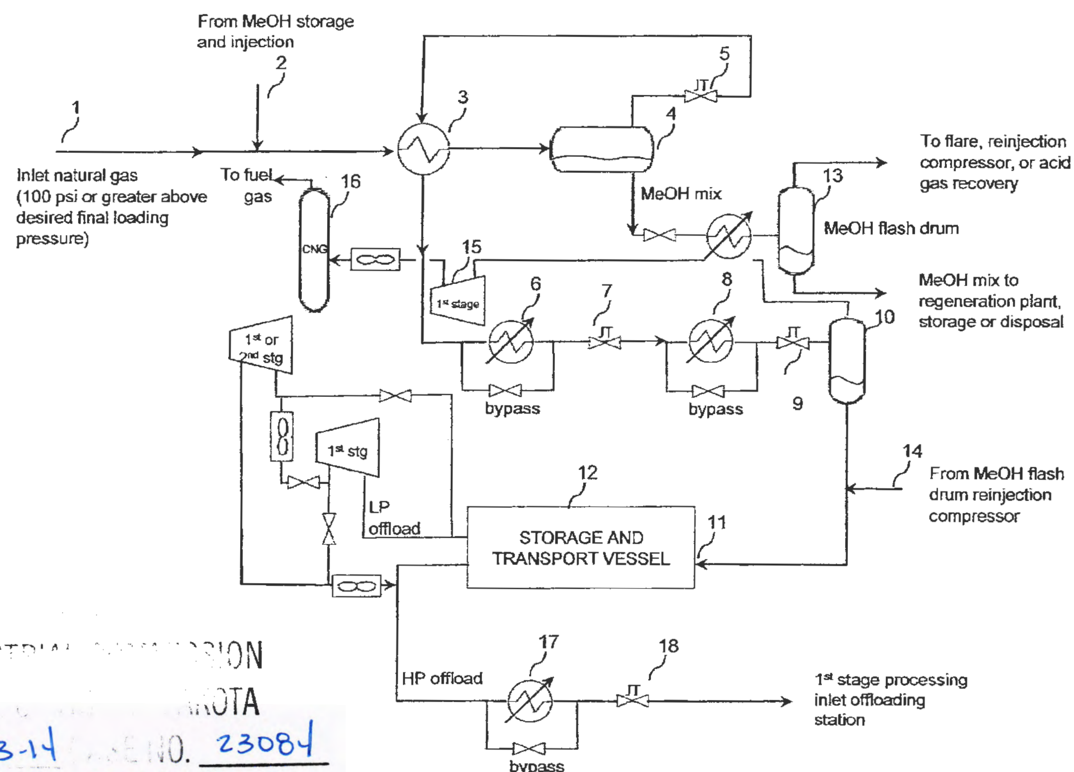
(52) **U.S. Cl.**

CPC . ***C10L 3/101*** (2013.01); ***F17C 7/00*** (2013.01); ***C10G 5/00*** (2013.01)

USPC .............. **208/187**; 222/3; 48/127.3; 208/370

(57) **ABSTRACT**

A method for processing raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the raw natural gas dense phase pressure, which includes the steps of receiving the raw natural gas in a flow path at an inlet pressure greater than the storage pressure; if necessary, dehydrating the raw natural gas; and continuously releasing the dehydrated raw natural gas from the flow path at a release pressure and a release temperature into a storage vessel until the pressure of the dehydrated raw natural gas in the storage vessel reaches the storage pressure, avoiding the solidification of any impurities in the raw natural gas. Also, a method of processing crude oil having dissolved raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the bubble point pressure, includes the steps of receiving the crude oil at an inlet pressure greater than the storage pressure, and loading the crude oil into the storage vessel until the crude oil reaches the storage pressure, without separating any dissolved raw natural gas from the crude oil. Alternatively, raw natural gas is separated from the crude oil, and compressed to at least the storage pressure, dehydrating the raw natural gas, and recombining the dehydrated raw natural gas with the crude oil prior to loading into the storage vessel, avoiding the solidification of any impurities in the raw natural gas.



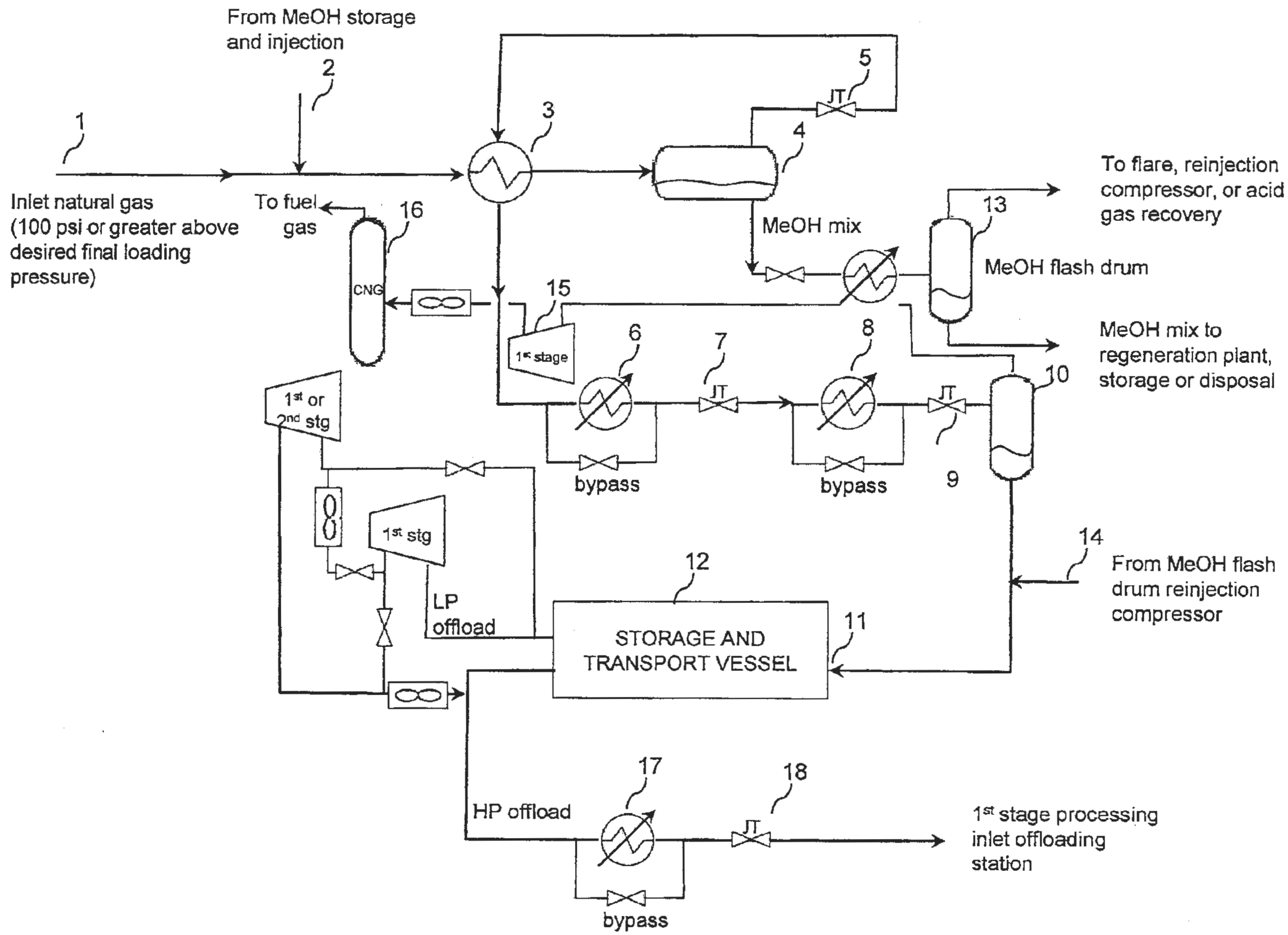

From MeOH storage
and injection
2
1
3
5
JT
4
Inlet natural gas
(100 psi or greater above
desired final loading
pressure)
To fuel
gas
16
CNG
MeOH mix
13
To flare, reinjection
compressor, or acid
gas recovery
MeOH flash drum
15
1st stage
6
7
JT
8
JT
10
MeOH mix to
regeneration plant,
storage or disposal
1st or
2nd stg
bypass
bypass
9
1st stg
14
From MeOH flash
drum reinjection
compressor
12
LP
offload
STORAGE AND
TRANSPORT VESSEL
11
17
18
HP offload
JT
1st stage processing
inlet offloading
station
bypass

FIG. 1

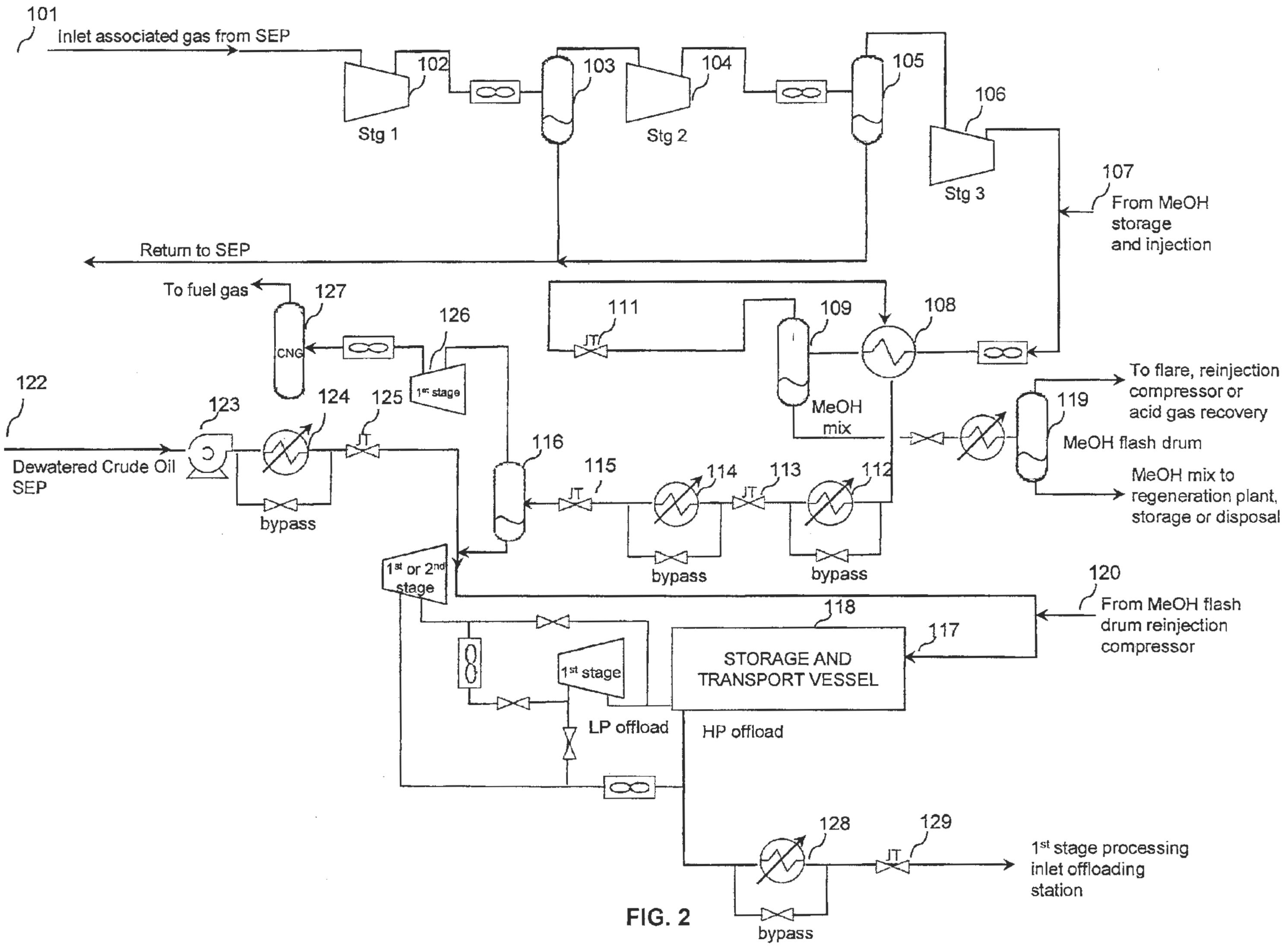

101
Inlet associated gas from SEP
102
Stg 1
103
104
Stg 2
105
106
Stg 3
107
From MeOH storage and injection
Return to SEP
To fuel gas
127
CNG
126
1st stage
111
JT
109
108
MeOH mix
122
123
124
125
JT
Dewatered Crude Oil SEP
bypass
116
115
JT
114
113
JT
112
bypass
bypass
To flare, reinjection compressor or acid gas recovery
119
MeOH flash drum
MeOH mix to regeneration plant, storage or disposal
1st or 2nd stage
120
From MeOH flash drum reinjection compressor
118
117
STORAGE AND TRANSPORT VESSEL
1st stage
LP offload
HP offload
128
129
JT
1st stage processing inlet offloading station
bypass

FIG. 2

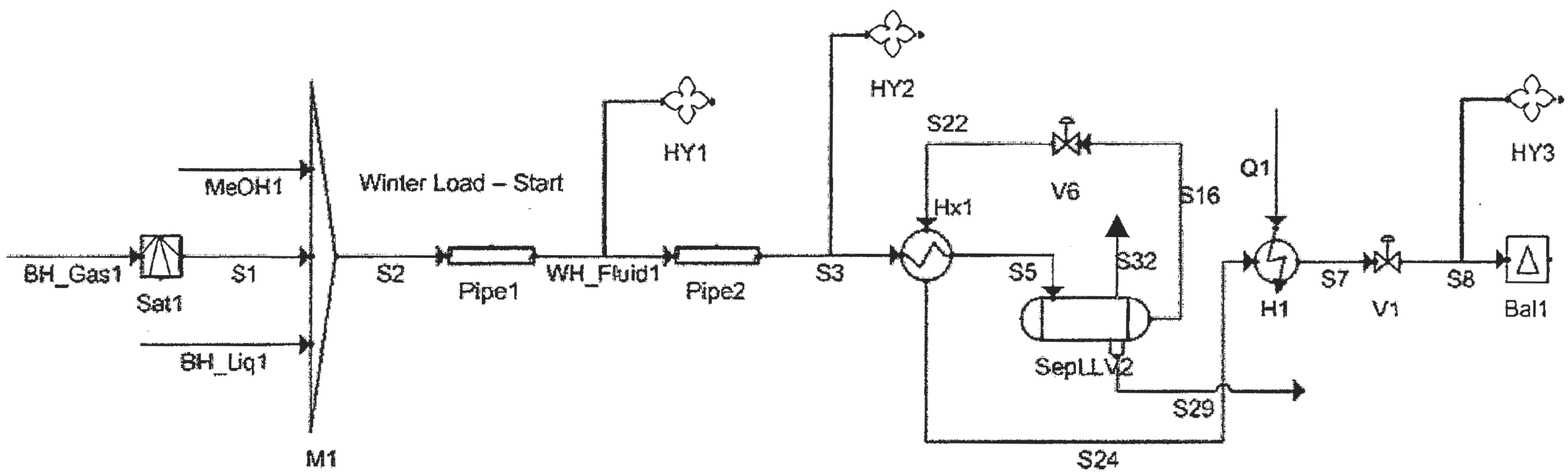

Winter Load – Start
MeOH1
BH_Gas1
Sat1
S1
BH_Liq1
M1
S2
Pipe1
WH_Fluid1
HY1
Pipe2
S3
HY2
S22
V6
S16
Hx1
S5
S32
SepLLV2
S29
S24
Q1
H1
S7
V1
S8
HY3
Bal1

FIG. 3

# HYDROCARBON PROCESSING

## CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the priority benefit of U.S. Provisional Application No. 61/648,750 filed on May 18, 2012 entitled "Hydrocarbon Processing", the contents of which are incorporated herein by reference.

## FIELD OF THE INVENTION

**[0002]** The present invention relates to methods for processing raw natural gas or crude oil with associated raw natural gas, for storage in a storage vessel, which may be used for transport and offloading.

## BACKGROUND OF THE INVENTION

**[0003]** Natural gas production sites and crude oil production sites producing associated natural gas may be situated at great distances from markets where the natural gas or crude oil and associated gas are ultimately consumed. Therefore, the natural gas or crude oil and associated natural gas must be treated and processed prior to being transported from the production site to the market where it can be offloaded.

**[0004]** One solution is to use a pipeline network. However, this presupposes that an existing pipeline network is available in the relative vicinity of the production and consumption site. If not, the time and capital required to extend a pipeline network to a remote production site can be cost prohibitive. Further, environmental and safety risks associated with the pipeline may deter the extension of the pipeline and its operation.

**[0005]** Another solution is to store the natural gas as compressed natural gas (CNG). Compressed natural gas is made by first treating raw natural gas to remove natural gas liquids (NGLs) and impurities such as acid gases, primarily carbon dioxide and hydrogen sulphide, and then compressing it in containers at high pressures (2900-3600 psi) into the dense phase for the specific treated raw natural gas composition. CNG is conventionally compressed to less than 1% of the volume it occupies at standard atmospheric pressure.

**[0006]** Another solution is to cryogenically convert raw natural gas to liquefied natural gas (LNG) for storage and transportation by truck, train or ship. Conventionally, the production of LNG involves pre-treating the raw natural gas to remove impurities such as nitrogen, water vapour, carbon dioxide, hydrogen sulphide, n-butane, neo-pentane, n-pentane, n-hexane, benzene, and cyclohexane, which would otherwise freeze, and mercury, which would amalgamate with the metal processing equipment. The treated natural gas is then condensed from a gaseous to an energy-dense liquid state by cooling the gas to approximately −160° C. at near atmospheric pressure. Although the energy density of LNG is greater than that of CNG, the production of LNG production is energy and capital-intensive and requires expensive specially-designed LNG carriers to maintain cryogenic conditions during transport, and expensive specially designed regasification facilities at the offloading point.

**[0007]** Crude oil is often produced with dissolved raw natural gas. Conventionally, the associated natural gas is separated from the crude oil at the production site or central processing facility and processed separately. The associated gas may be flared, consumed as fuel, re-injected into the reservoir, processed further into sales gas by removing impurities (such as $H_2S$ and $CO_2$) and NGLs, depending on available markets, economics, environmental considerations, and other factors. The crude oil may be treated to remove free-water, salts, and other impurities as required to meet specifications (such as BS&W, and vapour pressure) prior to transport by pipeline, truck, rail, or ship to markets for further processing into refined products.

**[0008]** In both cases of natural gas production and crude oil production, there is a need to reduce equipment needs and capital costs at production sites for loading storage and transport vessels.

**[0009]** Accordingly, there remains a need in the art for a method of storing, transporting, and offloading to market raw natural gas or crude oil and associated natural gas that is energy efficient, economical and practical to implement.

## SUMMARY OF THE INVENTION

**[0010]** Embodiments of the present invention seek to conserve the energy of the reservoir pressure and use it to load crude oil or raw natural gas into a storage vessel, for transport to an unloading site. In either case of compressed gas or compressed oil, the methods of the present invention are intended to result in reduced capital and operating costs by avoiding conventional processing techniques involved with CNG or crude oil production.

**[0011]** In a compressed gas method, the potential energy of raw natural gas is used internally within the process during dehydration, loading, and offloading stages. The method differs from conventional CNG processing in that there are no steps for removing natural gas liquids (NGLs) or impurities such as acid gases prior to compression. Therefore, the method may be applied to raw natural gas as it is received from the wellhead, and can be used for sour gas and natural gas rich in NGLs, without the need to remove acid gases, or separate NGLs from the gas prior to storage. In one embodiment, the method permits a portion of the dehydrated raw natural gas produced at an intermediate stage of the process to be treated, captured and stored as compressed natural gas, which can be used as fuel gas to power equipment associated with process or to transport the stored raw natural gas or crude oil and associated natural gas.

**[0012]** In a compressed oil method, if the reservoir pressure allows crude oil available at the inlet at or near pressures above the bubble point, the potential energy of the crude oil and dissolved natural gas is conserved and the natural pressure of the reservoir may be used to load a storage and transport vessel, without processing to separate and treat the gas.

**[0013]** A method of the present invention may be implemented at remote production sites, whether situated in an onshore or offshore environment, allowing for storage and transport to a centralized processing facility, where the product may then be further processed to separate raw natural gas, and remove NGLs and impurities such as acid gases.

**[0014]** Therefore, in one aspect, the invention comprises a method for processing raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the raw natural gas dense phase pressure, said method comprising the steps of:

**[0015]** (a) receiving the raw natural gas in a flow path at an inlet pressure, wherein the inlet pressure is greater than the storage pressure, or if the inlet pressure is not greater than the storage pressure, compressing the natural gas to a pressure greater than the storage pressure;

[0016] (b) if necessary, dehydrating the raw natural gas within the flow path to produce dehydrated raw natural gas;

[0017] (c) continuously releasing the dehydrated raw natural gas from the flow path at a release pressure and a release temperature into a storage vessel until the pressure of the dehydrated natural gas in the storage vessel reaches the storage pressure;

wherein the solidification or precipitation of any impurities in the raw natural gas in the storage vessel is limited or prevented by continuously controlling the release pressure or the release temperature, or both the release pressure and temperature.

[0018] In another aspect, the invention may comprise a method of processing crude oil having dissolved raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the bubble point pressure, said method comprising the steps of:

[0019] (a) receiving the crude oil in a flow path at an inlet pressure, wherein the inlet pressure is greater than the storage pressure, or if the inlet pressure is not greater than the storage pressure, pumping the crude oil to a pressure greater than the storage pressure;

[0020] (b) loading the crude oil into the storage vessel until the crude oil reaches the storage pressure, without separating any dissolved raw natural gas from the crude oil.

In one embodiment, the method further comprises the step of separating raw natural gas from the crude oil, compressing or maintaining the pressure of the raw natural gas to at least the storage pressure, dehydrating the raw natural gas, and recombining the dehydrated raw natural gas with the crude oil prior to loading into the storage vessel, wherein the solidification or precipitation of any impurities in the raw natural gas is limited or prevented by continuously controlling the release pressure or the release temperature, or both the release pressure and temperature of the dehydrated raw natural gas.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will now be described by way of exemplary embodiments with reference to the accompanying simplified, diagrammatic, not-to-scale drawings:

[0022] FIG. 1 is a process diagram showing one embodiment of a method of the present invention.

[0023] FIG. 2 is a process diagram showing an alternative embodiment of a method of the present invention.

[0024] FIG. 3 is a process diagram showing a further alternative embodiment of a method of the present invention. FIG. 3 represents the case where the natural gas reservoir provides the energy to load the storage and transport vessel, and the energy is conserved during transport and then utilized during off-loading as much as possible

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0025] When describing the present invention, all terms not defined herein have their common art-recognized meanings. To the extent that the following description is of specific embodiments or particular uses of the invention, it is intended to be illustrative only, and not limiting of the claimed invention. The following description is intended to cover all alternatives, modifications and equivalents that are included in the spirit and scope of the invention, as defined in the appended claims.

[0026] As used herein, the term "bubble point" in relation to crude oil at a particular temperature, refers to the pressure at which natural gas dissolved in the crude oil first begins to evolve as a vapour from the crude oil as the pressure is decreased.

[0027] As used herein, the term "crude oil" means generally any synthetic or naturally occurring liquid mixture of hydrocarbon compounds and any impurities.

[0028] As used herein, the term "compressed raw natural gas" or "CRNG" means natural gas that has not been treated to pipeline quality specifications or otherwise treated to remove impurities, and has been compressed to high pressure into the dense phase for the gas.

[0029] As used herein, the term "dense phase" as it relates to natural gas, raw, treated or otherwise, means the state of natural gas resulting from its compression above its cricodenbar (the maximum pressure above which the natural gas cannot be formed into the gas phase, regardless of temperature), at a temperature within a range defined by approximately its critical temperature (the temperature corresponding to the critical point, being the combination of pressure and temperature at which the intensive properties of the gas and liquid phases of the matter are equal) and approximately its cricondentherm (the maximum temperature above which the natural gas cannot be formed into the liquid phase, regardless of pressure). In the dense phase, natural gas has a viscosity similar to that of the gas phase, but can have a density closer to that of the liquid phase.

[0030] As used herein, the term "impurity", as used in the context of crude oil or natural gas, means any non-hydrocarbon component such as nitrogen, carbon dioxide, hydrogen sulphide, metals such as mercury, nitrogen, water, and certain hydrocarbons which are not typically present in treated pipeline quality natural gas, including natural gas liquids such as n-butane, n-pentane, n-pentane, n-hexane, benzene and cyclohexane.

[0031] As used herein, the term "JT valve" means a gas valve adapted to allow the adiabatic expansion of gas in accordance with the Joule-Thompson effect. JT valves are well known in the art, and are commercially available.

[0032] As used herein, the term "raw natural gas" means any mixture of hydrocarbon gases, natural gas liquids, and any impurities, and may include gases such as methane, ethane, propane, butane, pentane and C6+ gases and liquids. Typically, raw natural gas is as it is produced from a natural gas reservoir, without treatment or processing. As used herein "natural gas" means either raw natural gas or natural gas that has been treated to remove impurities. As used herein, the term "dehydrated natural gas" means raw or treated natural gas substantially free of any water.

[0033] In one aspect, the present invention provides a method for storing raw natural gas in a storage vessel at a storage pressure equal to or greater than the dense phase pressure of the natural gas (the compressed raw gas method).

[0034] In a second aspect, the present invention provides a method for storing crude oil and associated natural gas in a storage vessel at a storage pressure equal to or greater than the bubble point of the crude oil (the compressed oil method).

[0035] Generally speaking, embodiments of both the compressed raw gas method and the compressed oil method comprise a receiving stage, a dehydration stage, and a loading stage. The compressed raw gas or compressed oil may then be transported in storage and transport vessel, and offloaded at a different site. Accordingly, stages for both methods may be described together sequentially with any differences for the two methods being noted, by reference to the exemplary embodiments depicted in FIG. **1** (compressed raw gas method) and FIG. **2** (compressed oil method).

**[0036]** Each of the methods uses a flow path defined by elements (**1**) through (**11**) in the compressed gas method, and by elements (**101**) to (**117**) in the compressed oil method. As well, each of the methods uses a storage and transport vessel defined by element (**12**) in the compressed gas method, and by element (**118**) in the compressed oil method. In some embodiments, the flow path may extend downstream of the storage vessel (**12, 118**) as further defined by elements (**17**) to (**18**) in the compressed gas method, and by elements (**128, 129**) in the compressed oil method.

**[0037]** In the compressed gas method, the flow path receives natural gas at point (**1**). The flow path may receive the natural gas from an onshore or offshore natural gas producing reservoir, which may have a natural reservoir pressure greater than the storage pressure, as is contemplated in FIG. **1**. In applications where the natural gas inlet pressure is below the storage pressure, the natural gas can be compressed to a pressure greater than the intended storage pressure using conventional means including, for example, compressors.

**[0038]** If the water content of the raw natural gas is too high, the formation of gas hydrates may be problematic. Therefore, in one embodiment, the raw natural gas is dehydrated. The dehydration of the compressed raw natural gas may be effected using any conventional method. In one embodiment, the dehydration is effected by injecting methanol into the natural gas at a point (**2**) in the flow path. The amount of methanol injected into the natural gas is selected to produce a natural gas-methanol mixture with a suppressed hydrate point temperature for water. Injecting methanol at a rate of approximately 2 Bbl/MMscf is typically sufficient to suppress the hydrate point temperature for water to approximately −40° C. The suppressed hydrate point temperature for water can be selected according to specified storage requirements. Methanol is suitable for suppressing the hydrate point temperature for water to about −100° C. The resulting natural gas-methanol mixture is then cooled to a temperature which is low enough to condense methanol and water, but still above the suppressed hydrate temperature, by any conventional means, such as by passing it through a heat exchanger (**3**). The liquid methanol-water mixture is then separated from the natural gas using any conventional method. For example, the methanol-water mixture may be separated from the natural gas using a two-phase separator (**4**). The separated and dehydrated natural gas is then further cooled, for example, by passing it through a JT valve (**5**). The cooled natural gas may then be used to cool the incoming natural gas-methanol mixture by passing the cooled natural gas back through the heat exchanger (**3**).

**[0039]** In one embodiment, the condensed water-methanol mixture may include lighter gaseous components of the natural gas such as methane, nitrogen, carbon dioxide, or hydrogen sulphide, which may be separated as a vapour phase using any conventional method, such as by using a flash drum (**13**). In one embodiment, methanol may be regenerated from the separated water-methanol mix and may be re-used to dehydrate additional natural gas as it is received within the flow path by re-injecting the regenerated methanol at point (**2**) of the flow path after the water-methanol has been sufficiently purified and regenerated for re-use. In one embodiment any light vapour components of the natural gas such as methane, nitrogen, carbon dioxide, or hydrogen sulphide that flash out as a vapour phase in the MeOH flash drum, may be re-injected after being compressed in a flash drum overhead compressor (not shown) and released at point (**14**) of the flow path for release into the storage vessel (**12**).

**[0040]** Once dehydrated, the pressurized natural gas is then directed to the storage vessel (**12**). At the beginning of the loading stage, the contents of the storage vessel (**12**) will be at a certain starting temperature and a starting pressure considerably lower than the pressure of the dehydrated natural gas in the flow path. For example, the starting pressure in the storage vessel (**12**) may be equivalent to about one standard atmosphere. Accordingly, in order to prevent an uncontrolled release of dehydrated natural gas into the storage vessel (**12**), it is necessary to choke the pressure of the dehydrated natural gas by, for example, passing the dehydrated natural gas through JT valves (**7** and **9**). As the pressure within the storage vessel (**12**) increases, the required degree of choking will decrease.

**[0041]** As a consequence of choking the pressure of the dehydrated raw natural gas, the temperature of the natural gas will tend to decrease. If the temperature decreases sufficiently, the resulting combination of pressure and temperature in the storage vessel may result in the solidification of impurities, such as carbon dioxide, hydrogen sulphide, n-pentane, benzene, and cyclohexane of the dehydrated raw natural gas released into the storage vessel (**12**). In order to prevent the solidification of impurities, it may be necessary to control the temperature of the dehydrated natural gas within the flow path. This may be effected by any conventional means including, for example, passing the dehydrated raw natural gas through a heater such as a glycol or hot oil bath, or other heat medium heaters (**6** and **8**) in series with the JT valves (**7** and **9**). As the pressure within the storage vessel (**12**; **118**) increases, and the required degree of choking decreases, so too will the required degree of heating decrease.

**[0042]** The object of loading stage is to fill the storage vessel (**12**) with natural gas in the dense phase. This is achieved by continuously releasing the dehydrated natural gas at point (**11**) of the flow path into the storage vessel (**12**) until the pressure of the dehydrated natural gas in the storage vessel (**12**) reaches the desired storage pressure, which is at least the dense phase pressure of the natural gas. At the initial part of the loading stage, the pressure in the storage vessel (**12**) may be relatively low. Thus, the dehydrated natural gas released into the storage vessel (**12**), may initially be in a two-phase liquid-gas state. Accordingly, where the storage vessel (**12**) has a plurality of compartments, it may be necessary to use a manifold piping system to distribute the two-phase mixture equally to be simultaneously released into multiple compartments of the storage vessel (**12**), and pressurized above the cricodenbar for the compressed raw gas method.

**[0043]** The compressed oil method, shown schematically in FIG. **2**, may be used where the produced hydrocarbons at the wellhead substantially comprises crude oil. Generally, when the oil and any associated natural gas are at a pressure below the bubble point they are initially separated, pressurized separately, and recombined after the natural gas has been dehydrated.

**[0044]** In this case, the oil and natural gas are first separated in an initial separator. The crude oil may be dewatered using conventional methods. The flow path receives dewatered crude oil at point (**122**) and the separated natural gas at point (**101**). The flow path may receive the crude oil and natural gas from an onshore or offshore oil and natural gas producing reservoir. If the gas inlet (**101**) pressure is lower than the bubble point, it will be necessary to pressurize the raw associated natural gas, for example by using multiple compressors. In one embodiment, three compression stages (**102, 104, 106**) are provided, and after the first two compressor stages, any liquids which form, which may be heavier hydrocarbons, are separated in a separator (**103, 105**) and returned to the initial separator, to be mixed with the crude oil.

**[0045]** The natural gas from the initial separator, after pressurization, is then dehydrated, by any conventional method. In one embodiment, the dehydration is effected by injecting methanol into the natural gas at a point (**107**) in the flow path, in a process similar to that described above with respect to the compressed gas method. The resulting natural gas-methanol mixture is cooled to a temperature above the suppressed hydrate temperature by any conventional means, such as by passing it through a heat exchanger (**108**), to condense a methanol-water mixture. The condensed methanol-water mixture is then separated from the natural gas using any conventional method. For example, the methanol-water mixture is separated from the natural gas using a two-phase separator (**109**). The separated natural gas is then further cooled, for example, by passing it through a JT valve (**111**). The cooled natural gas may then be used to cool the incoming natural gas-methanol mixture by passing the cooled natural gas back through the heat exchanger (**108**).

**[0046]** The dehydrated, pressurized natural gas may then be introduced into the flow of crude oil through the bottom of the conventional two phase separator (**116**). If the gas pressure is significantly higher than the pressure in the crude oil flow and in the storage vessel (**118**), the pressure may be choked downward with a JT valve or valves (**113, 115**). As a consequence of choking the pressure of the dehydrated raw natural gas, the temperature of the natural gas will tend to decrease. If the temperature decreases sufficiently, the resulting combination of pressure and temperature may result in the solidification of impurities, such as carbon dioxide, hydrogen sulphide, neopentane, benzene, and cyclohexane of the dehydrated raw natural gas. In order to prevent the solidification of impurities, it may be necessary to control the temperature of the dehydrated natural gas within the flow path. This may be effected by any conventional means including, for example, passing the dehydrated raw natural gas through a glycol or hot oil bath, or other heat medium heaters (**112, 114**) in series with the JT valves (**113** and **115**). As the pressure within the storage vessel (**118**) increases, and the required degree of choking decreases, so too will the required degree of heating decrease.

**[0047]** In one embodiment, the water-methanol mixture may be separated from the lighter gaseous components of the natural gas such as methane, nitrogen, carbon dioxide, or hydrogen sulphide that flash out as a vapour phase using any conventional method. For example, the water-methanol mixture may be passed through a flash drum (**119**). In one embodiment, the separated water-methanol mix may be re-used to dehydrate additional natural gas as it is received within the flow path by re-injecting the methanol at point (**107**) of the flow path after the methanol has been sufficiently purified and regenerated for re-use. In one embodiment any light vapour components of the natural gas such as methane, nitrogen, carbon dioxide, or hydrogen sulphide that flash out as a vapour phase in the MeOH flash drum, may be re-injected after being compressed in a flash drum overhead compressor (not shown) and released at point (**120**) of the flow path for release into the storage vessel (**118**).

**[0048]** If the pressure of the dewatered crude oil at inlet (**122**) is lower than the bubble point and the desired storage pressure, the dewatered crude oil is pressurized by pump (**123**). If the pressure of the crude oil is greater than the bubble point and the desired storage pressure, the dewatered crude oil and dissolved gas enters the flow path at point (**122**) without the need for pumping. In some applications, such as with some offshore reservoirs, where the crude oil inlet pressure is sufficiently high, the associated natural gas may already be fully dissolved in the crude oil and can flow directly to the loading phase entering at point (**122**) and bypass pump (**123**) without the need to separate the crude oil from the associated natural gas and dehydrate the associated gas.

**[0049]** Generally, no further treatment of the crude oil is required, except that heating (**124**) and pressure control (**125**) may be employed during the loading stage. The object of loading stage is to fill the storage vessel with crude oil and dissolved associated natural gas. This is achieved by continuously releasing the dewatered crude oil with dissolved natural gas at point (**117**) of the flow path into the storage vessel (**118**) until the pressure of the crude oil in the storage vessel (**118**) is above the bubble point of the crude oil and reaches the desired storage pressure, and continues until the storage vessel is filled with crude oil.

**[0050]** In the case of the compressed oil method, at the initial part of the loading stage, the pressure in the storage vessel (**118**) may be relatively low, below the bubble point. Thus, natural gas may evolve from the crude oil, resulting in a two-phase liquid-gas state entering the storage vessel (**118**). Accordingly, where the storage vessel (**118**) has a plurality of compartments, it may be necessary to use a manifold piping system to distribute the two-phase mixture equally to be simultaneously released into multiple compartments of the storage vessel (**118**), and pressurized above the bubble point for the compressed crude oil.

**[0051]** In one embodiment, in the course of the loading stage of either the compressed raw gas scheme or the compressed oil scheme, a portion of the dehydrated natural gas stream can be diverted and stored as compressed natural gas (CNG), which can be used, for example, as a fuel. For example, the dehydrated natural gas can be passed through a JT valve (**9, 115**) through pressure range of approximately 500 to 700 psig and a two-phase separator (**10; 116**) to divert a portion of the natural gas as a treated gas (heavy liquid hydrocarbons removed), and a single stage compressor (**15; 126**) used to pressurize a compressed natural gas vessel (**16; 127**). The take off point for the compressed natural gas is preferably upstream of any MeOH flash drum vapour reinjection point (**14; 120**) in the flow path to minimize the amount of carbon dioxide or hydrogen sulphide in the treated compressed natural gas fuel. Depending on the composition of the raw natural gas fed into the system, the treated compressed natural gas may require additional treating before use. The compressed natural gas may used as a fuel gas for the equipment used to implement the method, or for the transportation of the storage vessel (**12; 118**).

**[0052]** Once the storage vessel (**12; 118**) has been pressurized with raw natural gas in the dense phase in the case of the compressed gas method, or with crude oil and dissolved raw natural gas in the case of the compressed oil method, the storage vessel (**12**; **118**) may be conveyed by conventional vehicles such as truck, train or ship. After the storage vessel (**12**; **118**) has been transported to the offloading site, the potential energy of the dehydrated natural gas in the dense phase or the associated natural gas dissolved in the crude oil can be utilized to unload the natural gas or crude oil, as the case may be, from the storage vessel (**12**; **118**) without the need for pumping, or at least with reduced pumping requirements. A heater (**17**; **128**) and JT valve (**18**; **129**) may be utilized to control the delivery pressure and temperature specified by the offloading site's first stage processing inlet. Compression is utilized for the final offloading to discharge the remaining raw natural gas for the compressed gas method or the associated gas for the compressed oil method that remains in the storage vessels below the offloading site receiving pressure to the desired final pressure (heel pressure in the storage vessel).

**[0053]** Example of Compressed Raw Gas Method

**[0054]** The following example is intended to illustrate an exemplary embodiment of the present invention, and not to limit the claimed invention in any manner.

**[0055]** FIG. **3** depicts a process diagram for an example of the compressed gas method. Table 1 below indicates the properties of the natural gas and methanol as they progress through the flow path as mathematically simulated using the process simulation software, VMGSim™ (Virtual Material Group, Inc.). The mathematical simulation assumes that the pressure in the storage vessel (Bal1) starts at 500 psig before any loading with natural gas.

**[0056]** Referring to FIG. **3** and Table 1 certain aspects of the method are noted below.

**[0057]** The natural gas is supplied into the flow path from a natural reservoir with a bottom hole at 2,700 m below the well head. The natural gas and the NGL at bottom hole location (BH_Gas**1** and BH_Liq**1**) have a temperature of 176.0° F. and a pressure of 4061.1 psia. The amount of NGL is equivalent to 40 Bbl/MMscf at 1000 psig.

**[0058]** It is assumed that by the time the natural gas has reached the well head location (WH_Fluid**1**), the natural gas has decreased in temperature to 103.5° F., due to the cooling effect of permafrost on the well bore, and decreased in pressure to 3288.6 psia.

**[0059]** Pipe **2** travels above ground and assumed to be under winter conditions at a northern latitude. By the time the natural gas has reached the end of pipe **2** in segment (S**3**), ambient winter conditions have chilled the natural gas to a temperature of −39.8° F. and further decreased the pressure to 3274.6 psia. Accordingly, in this example, the heat exchanger (Hx**1**) and the JT valve (V**6**) are not required to further cool the natural gas, but may be used to cool the natural gas in warmer ambient conditions.

**[0060]** Before entering the two-phase separator (SepLLV**2**), the mole fraction of water in the natural gas is 0.2828% in segment (S**5**). After separation in the two-phase separator (SepLLV**2**), the mole fraction of water in the natural gas is essentially nil in segment (S**16**), reflecting the dehydration of the natural gas.

**[0061]** The heater (H**1**) provides heat to the natural gas at a rate Q**1** equal to 320953.3 Btu/hr to raise the temperature of the natural gas from −39.9° F. in segment (S**24**) to 90.0° F. in segment (S**7**).

**[0062]** At the start of the loading stage, valve (V**1**) chokes the pressure of the natural gas in the flow path to decrease the pressure of the natural gas from 3255.0 psia in segment (S**7**) to 515.0 psia in segment (S**8**), which represents the storage and transport vessel. This results in the temperature of the natural gas decreasing from 90.0° F. to −4.6° F. As a result, the natural gas in segment (S**8**) is initially in a two-phase, gas-liquid state, having a vapour fraction of 0.9062.

**[0063]** As the storage vessel (Bal**1**) is pressurized, however, the amount of choking required decreases. At the end of the loading stage, valve (V**1**) chokes the pressure of the natural gas from 3255.0 psia in segment (S**7**) to 2465.0 psia in segment (S**8**), which is the storage pressure. This results in the temperature of the natural gas decreasing from 90.0° F. to 77.6° F. The natural gas in segment (S**8**) is now in the dense phase, having zero vapour fraction.

**[0064]** Additional aspects and advantages of the present invention will be apparent in view of the description, which follows. It should be understood, however, that the detailed description and the specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

TABLE 1

| In: Connected To<br>Out: Connected To | BH_Gas1/<br>Sat1.MainFeed | BH_Liq1/<br>M1.In0 | MeOH1/<br>M1.In2 | S1/<br>Sat1.Saturated/<br>M1.In1 | S2/<br>M1.Out/<br>Pipe1.In | WH_Fluid1/<br>Pipe1.Out/<br>Pipe2.In |
|---|---|---|---|---|---|---|
| VapFrac | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| T [F.] | 176.0 | 176.0 | 26.0 | 176.0 | 170.0 | 103.5 |
| P [psia] | 4061.1 | 4061.1 | 4061.1 | 4061.1 | 4061.1 | 3288.6 |
| MoleFlow [lbmole/h] | 439.197 | 24.813 | 3.183 | 440.116 | 468.113 | 468.113 |
| MassFlow [lb/h] | 8757.301 | 1539.849 | 102.000 | 8773.870 | 10415.719 | 10415.719 |
| StdLiqVolumeFlow [bbl/day] | 1761.909 | 180.000 | 8.777 | 1763.045 | 1951.822 | 1951.822 |
| StdGasVolumeFlow [MMSCFD] | 4.000 | 0.226 | 0.029 | 4.008 | 4.263 | 4.263 |
| Energy [Btu/hr] | 1727785.01 | 87725.44 | 39742.32 | 1730903.86 | 1778886.97 | 1298142.05 |
| MolecularWeight | 19.9394 | 62.0579 | 32.0419 | 19.9353 | 22.2505 | 22.2505 |
| MassDensity [lb/ft3] | 13.1833 | 36.0499 | 51.1099 | 13.1877 | 15.4574 | 16.2873 |
| CpMass [Btu/lb-F.] | 0.7512 | 0.5967 | 0.6812 | 0.7512 | 0.7526 | 0.7968 |
| ThermalConductivity [Btu/hr-ft-F.] | 0.0448 | 0.0616 | 0.1245 | 0.0449 | 0.0448 | 0.0439 |
| Viscosity [cp] | 0.0228 | 0.1452 | 0.8711 | 0.0229 | 0.0262 | 0.0272 |

TABLE 1-continued

| Mole Fraction | | | | | | |
|---|---|---|---|---|---|---|
| NITROGEN | 0.004895 | 0.000200 | 0.000000 | 0.004885 | 0.004604 | 0.004604 |
| CARBON DIOXIDE | 0.021580 | 0.013000 | 0.000000 | 0.021535 | 0.020936 | 0.020936 |
| METHANE | 0.836130 | 0.273400 | 0.000000 | 0.834383 | 0.798973 | 0.798973 |
| ETHANE | 0.079327 | 0.098300 | 0.000000 | 0.079161 | 0.079637 | 0.079637 |
| PROPANE | 0.035767 | 0.115300 | 0.000000 | 0.035692 | 0.039669 | 0.039669 |
| ISOBUTANE | 0.005095 | 0.028200 | 0.000000 | 0.005085 | 0.006275 | 0.006275 |
| n-BUTANE | 0.008592 | 0.071100 | 0.000000 | 0.008574 | 0.011830 | 0.011830 |
| ISOPENTANE | 0.001998 | 0.027600 | 0.000000 | 0.001994 | 0.003338 | 0.003338 |
| n-PENTANE | 0.001798 | 0.031000 | 0.000000 | 0.001795 | 0.003330 | 0.003330 |
| n-HEXANE | 0.001199 | 0.000000 | 0.000000 | 0.001196 | 0.001125 | 0.001125 |
| n-HEPTANE | 0.001499 | 0.000000 | 0.000000 | 0.001495 | 0.001406 | 0.001406 |
| n-OCTANE | 0.001199 | 0.341900 | 0.000000 | 0.001196 | 0.019248 | 0.019248 |
| WATER | 0.000920 | 0.000000 | 0.000000 | 0.003008 | 0.002828 | 0.002828 |
| ETHYLENE GLYCOL | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| METHANOL | 0.000000 | 0.000000 | 1.000000 | 0.000000 | 0.006800 | 0.006800 |

| In: Connected To<br>Out: Connected To | S3/<br>Pipe2.Out/<br>Hx1.InTube | S5/<br>Hx1.OutTube/<br>SepLLV2.In | S29/<br>SepLLV2.Liq1 | S32/<br>SepLLV2.Vap | S16/<br>SepLLV2.Liq0/<br>V6.In | S22/<br>V6.Out/<br>Hx1.InShell |
|---|---|---|---|---|---|---|
| VapFrac | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| T [F.] | −39.8 | −39.9 | −39.9 | −39.9 | −39.9 | −39.9 |
| P [psia] | 3274.6 | 3269.6 | 3269.6 | 3269.6 | 3269.6 | 3265.0 |
| MoleFlow [lbmole/h] | 468.113 | 468.113 | 3.655 | 0.000 | 464.458 | 464.458 |
| MassFlow [lb/h] | 10415.719 | 10415.719 | 98.128 | 0.000 | 10317.591 | 10317.591 |
| StdLiqVolumeFlow [bbl/day] | 1951.822 | 1951.822 | 8.104 | 0.000 | 1943.718 | 1943.718 |
| StdGasVolumeFlow [MMSCFD] | 4.263 | 4.263 | 0.033 | 0.000 | 4.230 | 4.230 |
| Energy [Btu/hr] | 96162.37 | 95786.21 | −53568.30 | 0.00 | 149354.51 | 149354.51 |
| MolecularWeight | 22.2505 | 22.2505 | 26.8504 | 22.2133 | 22.2143 | 22.2143 |
| MassDensity [lb/ft3] | 24.4705 | 24.4671 | 54.5305 | 24.3386 | 24.3395 | 24.3340 |
| CpMass [Btu/lb-F.] | 0.7479 | 0.7481 | 0.7662 | 0.7479 | 0.7479 | 0.7482 |
| ThermalConductivity [Btu/hr-ft-F.] | 0.0595 | 0.0595 | 0.1537 | 0.0586 | 0.0586 | 0.0586 |
| Viscosity [cp] | 0.0634 | 0.0634 | 7.9519 | 0.0588 | 0.0588 | 0.0588 |
| Mole Fraction | | | | | | |
| NITROGEN | 0.004604 | 0.004604 | 0.000213 | 0.004639 | 0.004638 | 0.004638 |
| CARBON DIOXIDE | 0.020936 | 0.020936 | 0.001584 | 0.021088 | 0.021088 | 0.021088 |
| METHANE | 0.798973 | 0.798973 | 0.008277 | 0.805211 | 0.805194 | 0.805194 |
| ETHANE | 0.079637 | 0.079637 | 0.000450 | 0.080257 | 0.080260 | 0.080260 |
| PROPANE | 0.039669 | 0.039669 | 0.000055 | 0.039977 | 0.039981 | 0.039981 |
| ISOBUTANE | 0.006275 | 0.006275 | 0.000001 | 0.006324 | 0.006325 | 0.006325 |
| n-BUTANE | 0.011830 | 0.011830 | 0.000003 | 0.011922 | 0.011923 | 0.011923 |
| ISOPENTANE | 0.003338 | 0.003338 | 0.000000 | 0.003363 | 0.003364 | 0.003364 |
| n-PENTANE | 0.003330 | 0.003330 | 0.000000 | 0.003356 | 0.003357 | 0.003357 |
| n-HEXANE | 0.001125 | 0.001125 | 0.000000 | 0.001133 | 0.001134 | 0.001134 |
| n-HEPTANE | 0.001406 | 0.001406 | 0.000000 | 0.001417 | 0.001417 | 0.001417 |
| n-OCTANE | 0.019248 | 0.019248 | 0.000000 | 0.019394 | 0.019399 | 0.019399 |
| WATER | 0.002828 | 0.002828 | 0.361957 | 0.000002 | 0.000002 | 0.000002 |
| ETHYLENE GLYCOL | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| METHANOL | 0.006800 | 0.006800 | 0.627460 | 0.001916 | 0.001917 | 0.001917 |

| In: Connected To<br>Out: Connected To | S24/<br>Hx1.OutShell/<br>H1.In | S7/<br>H1.Out/<br>V1.In | S8 Start/<br>V1.Out/<br>Bal1.In0 | S8 End/<br>V1.Out/<br>Bal1.In0 |
|---|---|---|---|---|
| VapFrac | 0.0000 | 0.0000 | 0.9062 | 0.0000 |
| T [F.] | −39.9 | 90.0 | −4.6 | 77.6 |
| P [psia] | 3260.0 | 3255.0 | 515.0 | 2465.0 |
| MoleFlow [lbmole/h] | 464.458 | 464.458 | 464.458 | 464.458 |
| MassFlow [lb/h] | 10317.591 | 10317.591 | 10317.591 | 10317.591 |
| StdLiqVolumeFlow [bbl/day] | 1943.718 | 1943.718 | 1943.718 | 1943.718 |
| StdGasVolumeFlow [MMSCFD] | 4.230 | 4.230 | 4.230 | 4.230 |
| Energy [Btu/hr] | 149730.67 | 1212470.31 | 1212470.31 | 1212470.31 |
| MolecularWeight | 22.2143 | 22.2143 | 22.2143 | 22.2143 |
| MassDensity [lb/ft3] | 24.3254 | 16.7743 | 3.0702 | 14.6745 |
| CpMass [Btu/lb-F.] | 0.7485 | 0.8029 | 0.5770 | 0.8601 |

TABLE 1-continued

| | | | | |
|---|---|---|---|---|
| ThermalConductivity [Btu/hr-ft-F.] | 0.0586 | 0.0438 | 0.0304 | 0.0392 |
| Viscosity [cp] | 0.0587 | 0.0276 | 0.0151 | 0.0224 |
| Mole Fraction | | | | |
| NITROGEN | 0.004638 | 0.004638 | 0.004638 | 0.004638 |
| CARBON DIOXIDE | 0.021088 | 0.021088 | 0.021088 | 0.021088 |
| METHANE | 0.805194 | 0.805194 | 0.805194 | 0.805194 |
| ETHANE | 0.080260 | 0.080260 | 0.080260 | 0.080260 |
| PROPANE | 0.039981 | 0.039981 | 0.039981 | 0.039981 |
| ISOBUTANE | 0.006325 | 0.006325 | 0.006325 | 0.006325 |
| n-BUTANE | 0.011923 | 0.011923 | 0.011923 | 0.011923 |
| ISOPENTANE | 0.003364 | 0.003364 | 0.003364 | 0.003364 |
| n-PENTANE | 0.003357 | 0.003357 | 0.003357 | 0.003357 |
| n-HEXANE | 0.001134 | 0.001134 | 0.001134 | 0.001134 |
| n-HEPTANE | 0.001417 | 0.001417 | 0.001417 | 0.001417 |
| n-OCTANE | 0.019399 | 0.019399 | 0.019399 | 0.019399 |
| WATER | 0.000002 | 0.000002 | 0.000002 | 0.000002 |
| ETHYLENE GLYCOL | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| METHANOL | 0.001917 | 0.001917 | 0.001917 | 0.001917 |

1. A method for processing raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the raw natural gas dense phase pressure, said method comprising the steps of:

(a) receiving the raw natural gas in a flow path at an inlet pressure, wherein the inlet pressure is greater than the storage pressure, or if the inlet pressure is not greater than the storage pressure, compressing the natural gas to a pressure greater than the storage pressure;

(b) if necessary, dehydrating the raw natural gas within the flow path to produce dehydrated raw natural gas;

(c) continuously releasing the dehydrated raw natural gas from the flow path at a release pressure and a release temperature into a storage vessel until the pressure of the dehydrated raw natural gas in the storage vessel reaches the storage pressure;

wherein the solidification or precipitation of any impurities in the raw natural gas in the storage vessel is limited or prevented by continuously controlling the release pressure or the release temperature, or both the release pressure and temperature.

2. The method of claim 1, wherein the flow path derives the inlet pressure from a natural reservoir pressure of the raw natural gas, or additional compression, or both.

3. The method of claim 1 wherein the inlet pressure exceeds the storage pressure by 100 psi or greater.

4. The method of claim 1, wherein the step of dehydrating the natural gas within the flow path comprises the sub-steps of:

(a) injecting a sufficient amount of methanol into natural gas to produce a natural gas-methanol mixture with a suppressed hydrate temperature for the gas;

(b) cooling the natural gas-methanol mixture to a temperature above the suppressed hydrate point to condense a liquid methanol-water mixture;

(c) separating the condensed methanol-water mixture from the natural gas;

(d) decreasing the pressure of the natural gas under adiabatic conditions to cool the natural gas; and

(e) optionally, using the cooled natural gas to cool the methanol-natural gas mixture in sub-step (b), above, as additional natural gas is received within the flow path.

5. The method of claim 4 wherein the suppressed hydrate temperature is between about −60° C. and −20° C.

6. The method of claim 4 further comprising the sub-step of recovering the condensed water-methanol mixture and regenerating the methanol for re-injection into the natural gas in sub-step (a) of claim 5 as additional natural gas is received within the flow path.

7. The method of claim 4 further comprising the sub-steps of:

(a) separating a gas phase from the condensed water-methanol mixture from step (b); and

(b) recombining the gas phase with the dehydrated raw natural gas.

8. The method of claim 1 further comprising the steps of:

(a) diverting a portion of the dehydrated natural gas from the flow path; and

(b) treating the dehydrated natural gas to be substantially free of any impurities, and storing the diverted natural gas as compressed natural gas.

9. The method of claim 1 further comprising the steps of transporting the storage vessel, and offloading the raw natural gas by releasing the natural gas in the dense phase from the storage vessel into a downstream flow path.

10. The method of claim 9, wherein the temperature or the pressure, or both of the raw natural gas is controlled in the offloading step.

11. A method of processing crude oil having dissolved raw natural gas for storage and transport in a storage vessel at a storage pressure greater than the bubble point pressure, said method comprising the steps of:

(a) receiving the crude oil in a flow path at an inlet pressure, wherein the inlet pressure is greater than the storage pressure, or if the inlet pressure is not greater than the storage pressure, pumping the crude oil to a pressure greater than the storage pressure;

(b) loading the crude oil into the storage vessel until the crude oil reaches the storage pressure, without separating any dissolved raw natural gas from the crude oil.

12. The method of claim 11 further comprising the step of separating raw natural gas from the crude oil, compressing or maintaining the pressure of the raw natural gas to at least the storage pressure, dehydrating the raw natural gas, and recombining the dehydrated raw natural gas with the crude oil prior to loading into the storage vessel, wherein the solidification or

precipitation of any impurities in the raw natural gas is limited or prevented by continuously controlling the release pressure or the release temperature, or both the release pressure and temperature of the dehydrated raw natural gas.

* * * * *

# Department of Mineral Resources (DMR) Public Hearing - Oil Conditioning Practices

September 23, 2014 - Bismarck, ND

Colin F. Nikiforuk, P.Eng – President
CRNG Energy Inc. (Calgary, AB Canada)
colin.nikiforuk@telus.net, Cell (403) 816-5929



## Colin F. Nikiforuk, P.Eng - Background

- BSc Mechanical Engineering – With Distinction, University of Calgary, 1988
- Professional Engineer with over 25 years of experience and advanced working level knowledge in the upstream, midstream and downstream sectors of the oil and gas industry
  - Design, construction, operations, maintenance, exploration, and drilling functions
  - Project, technology and business development
  - Technical and management roles in large integrated public corporations and a highly successful independent energy infrastructure company
  - Involved in start-up private E&P and technology ventures
  - Consulting for midstream companies in operations and business development
- Inventor and developer of new technologies for the oil and gas industry, focused on creative, common sense, and pragmatic solutions that integrate collective experience across all sectors

First and Foremost

Public Safety Issue

The fireball that followed the derailment and explosion of two trains, one carrying Bakken crude oil, on December 30, 2013, outside Casselton, N.D. (U.S. Pipeline and Hazardous Materials Safety Administration)



# Focus on Facts and Available Data

- Observations
- Context
- Problem definition
- Alternative solutions

# Observations

- 4 major rail incidents over the past year involving Bakken crude oil
- Volume of ND Bakken crude oil by rail; zero to 600,000+ in 3 years
- Formal testing, evaluations, and reports completed by American Fuel and Petrochemical Manufacturers, PHMSA & FRA Operations Classification, Transportation Safety Board of Canada, and Turner Mason and Company (NDPC report)
- Bakken crude oil is transported and classified per existing regulations as a Class 3 flammable liquid, Group I or II packaging



# Observations

- Railway investigation report R13D0054 – Transportation Safety Board of Canada (TSB)
  - TSB Laboratory Report LP148/2013, Conclusion 4.3

    "The occurence crude oil's properties were consistent with those of a light sweet crude oil, with volatility comparable to that of a condensate or gasoline product
- Light end gas fractions C2-C4 dissolved in the Bakken crude oil ranges from 3 to 12% by volume (based on a summary review of analysis results from the previously referenced publically available industry and regulatory agency reports on properties of Bakken crude oil)

# Context

- US Williston Basin has grown from a modest oil producing region to a production level of approximately 1.2 million Bbl/d over 5 years
- Represents approximately 10% of US domestic crude oil production and 1% of world crude oil production
- Creating challenges for regional and continental North American infrastructure and resources
- Industry and regulatory standards, practices, policies and procedures need to evolve quickly to match current operating realities



# Problem Definition

Risk to Public Safety

1. Low flashpoint crude oil being transported by rail over long distances and within corridors proximate to rural communities, towns and major population centers

2. The consequences are high when a spill occurs as a result of a train derailment and subsequent gas explosion and liquid pool fires (low flash point and highly volatile flammable liquid with ignition source)

# Alternative solutions

- Centralized crude oil stabilization facilities
- Conventional single or multi-well oil battery oil conditioning
- Compressed raw natural gas (CRNG™) US Patent Pending
- Compressed crude oil (CCO™) US Patent Pending

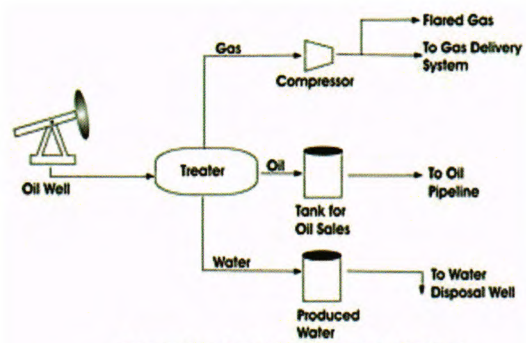


# Centralized crude oil stabilization facilities

- Substantial investment required for multiple large centralized refinery like facilities
- Extended timelines to implement
- Does not take advantage of existing investment in field oil battery facilities

# Conventional single or multi-well oil battery oil conditioning

- Utilize existing wellsite equipment
- Increase treater operating temperature
- Consequence is a significant increase in the volume and energy content of the flared gas



Example of a Single Well Oil Battery

Source Alberta Environment & Sustainable Resources (Website).



# Solution CRNG™ for existing wellsite facilities

patent pending technology (PCT/CA2013/050385, US 2013/0306520 A1)

- Utilize and integrate with existing site equipment
  - separator, heater treater, stock tanks, water storage, flare system etc.
- Further condition treated crude oil with-in CRNG™ process skid by heating to 180°F +/- to recover additional light ends (C2 to C4) to condition the oil
- Produce CNG for site fuel to power equipment
- CRNG™ product for storage, transport, and delivery to central gas plant for recovery of sales gas, C2, and NGL mix
- Produce a less volatile higher flash point crude oil product

## Solution CCO™ for new wellsite installations

**patent pending technology (PCT/CA2013/050385, US 2013/0306520 A1)**

- Produce CNG for site fuel to power equipment
- Produce a CCO™ product by recombining remaining associated gas and crude oil for storage and transport at pressures above the bubble point for the combined fluid
- Remove additional CNG as required to reduce the bubble point of the CCO™ product to a target <250 Psig to enable utilization of industry standard C3 and NGL storage and transport equipment
- Transport and deliver CCO™ to a central gas plant for recovery of sales gas, C2, and NGL mix products along with a less volatile higher flash point crude oil product
- Alternatively, transport CCO™ product directly to refinery for final processing



# Design Parameters:

## CRNG™ and CCO™ Technologies

# Estimated operating and capital cost parameters

**CRNG™**

- Power Consumption
  - GOR = 850 scf/Bbl = 0.3 Hp/Bbl
  - GOR = 1,750 scf/Bbl = 0.6 Hp/Bbl
- Fuel Consumption = 5 – 6%
- Methanol <0.015 usg/Bbl
- CRNG™ skid $3,000/Hp
- CNG trailer $1,000-1,250/scf
- Crude Oil trailer $125,000

**CCO™**

- Power Consumption
  - GOR = 850 scf/Bbl = 0.15 Hp/Bbl
  - GOR = 1,750 scf/Bbl = 0.3 Hp/Bbl
- Fuel Consumption = 4 – 5%
- Methanol <0.01 usg/Bbl
- CCO™ skid $4,500/Hp
- CNG trailer $1,000-1,250/scf
- C3/NGL trailer $125,000

Note: Assumes 50% of associated gas removed to reduce CCO™ product bubble point <250 psig



# Crude Oil Trailer vrs C3/NGL Trailer

- 250 Bbl Crude Oil Trailer
- $125,000 = $500/Bbl

- 250 Bbl C3/NGL Trailer 265 Psig
- $125,000 = $500/Bbl

Picture Source http://www.commercialtrucktrader.com/listing/2012-TREMCAR-Trailer-110811494

Picture Source http://rermag.com/site-files/rermag.com/files/uploads/2013/01/WEIN-Polar-Propane-trailer.jpg

# CNG Tube Trailers, Composite or Steel Tube

- Capacity range from 125 – 400 Mscf (20 – 65 Boe)
- Pressure range 2,500 – 3,500 Psig
- $125,000 to $500,000 ($6,000 to $7,000/ Boe)

Picture source product brochure Titan™ Composite Tube CNG Trailer – Hexagon Lincoln, Ne, USA

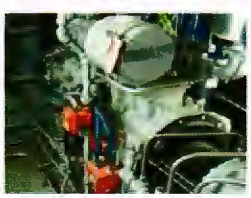
Picture source Fiba website Steel Tube CNG Trailer – FIBA Technologies Milbury, Ma, USA



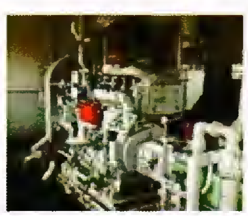
# Representative Equipment Sizing

Photos Courtesy: Gunning Investment Recovery Services Inc.

**100 Hp**



**400 Hp**



**1,400 Hp**

# Example CRNG™ 1,000 Bbl/d – GOR of 850

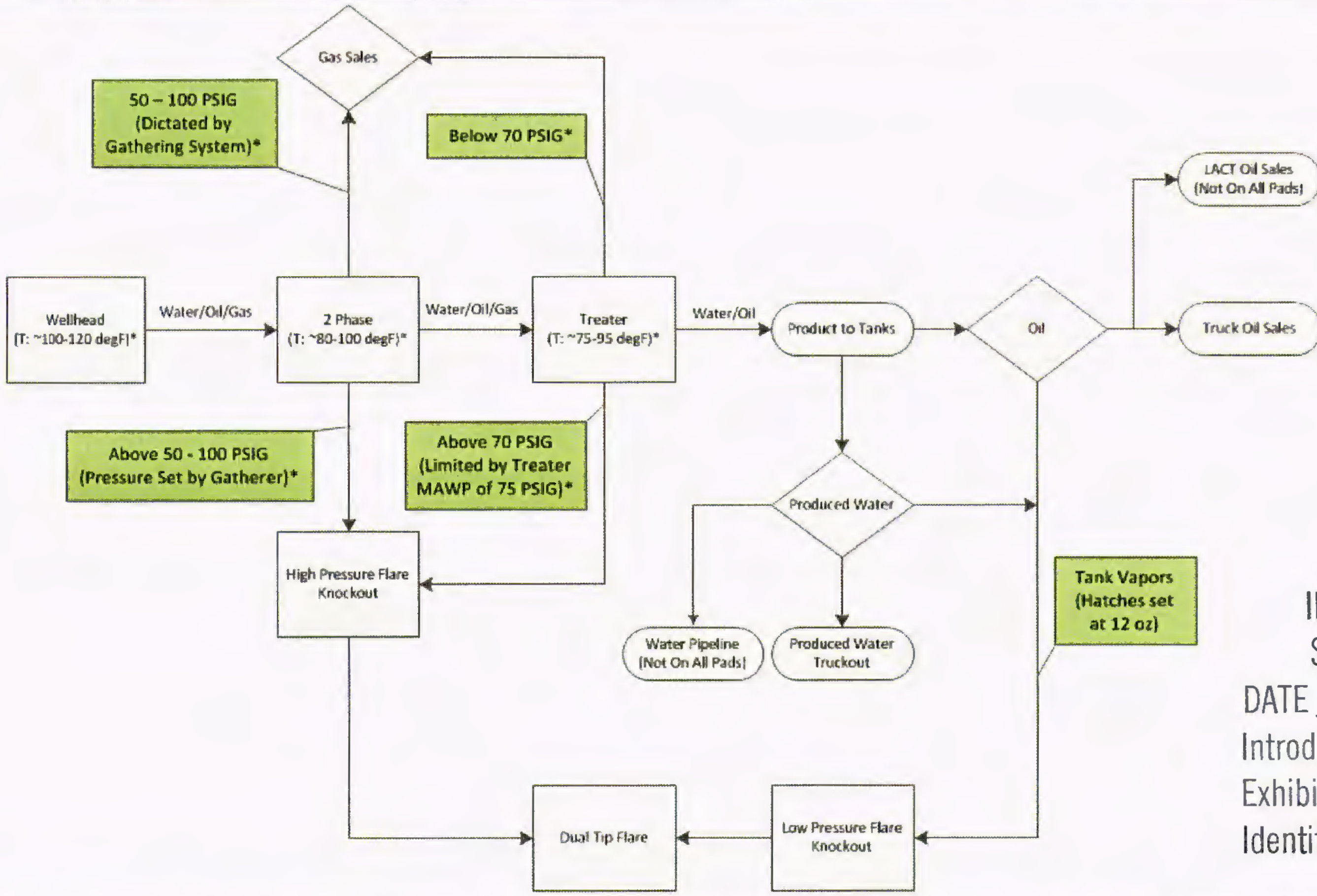
- Power consumption = 1,000 Bbl/d x 0.3Hp/Bbl = 300 Hp
- Methanol consumption = 1,000 Bbl/d x 0.015usg/Bbl = 15 usg/d
- CRNG™ skid cost = 300 Hp x $3,000/Hp = $900,000
- Gas produced = 1,000 Bbl/d x 850 scf/Bbl = 850,000 scf/d
- Assume trucking round trip including load and unload = 6 Hrs
  - 125,000 scf x 4 trips/d/trailer = 500,000 scf/trailer/d
- CNG trailers required for 850,000 scf/d less 5% shrinkage
  - 800,000 scf / 500,000 scf/trailer/d = 1.6 trailers/d = $200,000



# Bakken Reservoir Simplified Assumptions

- Roughly 300 MMscfd of gas being flared (75% recovery)
- 1,300 to 2,000 Btu/ft3 energy content
- Average initial well production 400 Bbl/d, 340 Mscfd
- Average well production after 3rd year 100 Bbl/d, 80 Mscfd
- GOR initial 850 scf/Bbl
- GOR 5+ years 1,750 scf/Bbl
- 300 MMscfd = 50,000 Boe/d
- Light ends in Bakken Crude 3 to 12% by volume, assume 5% average
- 1 million Bbl/d of conditioned oil produces roughly 50,000 Boe/d of additional very liquids rich associated gas
- 75% recovery = 12,500 Boe/d (75 MMscfd) remains as flared gas

# WELL FLOW DIAGRAM




INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Enerplus
Exhibit A
Identified By Lucero

*Note: Process conditions vary from well to well based on ambient conditions and position of well on gathering system.

enerPLUS


WHITING

# North Dakota- Hearing on Oil Conditioning Practices

September 23, 2014

## Whiting well site Oil Equipment

Wells and Pumping units

Heater Treaters

Tanks

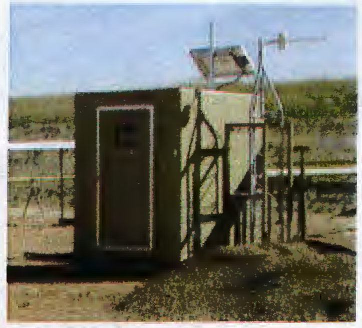
LACT

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Whiting
Exhibit A
Identified By Archer

NYSE: WLL

# Whiting well site Gas Equipment

Heater Treaters



Gas Sales Meter Building

Tanks

VRU

Combustor





# Whiting Heater Treater experience

Low pressure gas gathering system for Treater gas makes upstream separation unnecessary

One individual Treater works best for large wells
Two wells per Treater is sufficient for most wells
Vertical Treaters preferred in Sanish, Hidden Bench and Tarpon

Oil vapor pressure and NGL content is more dependent on Treater Pressure than Temperature. *i.e. Pressure reduction is better than temperature increase*

Treater temperatures above 120F are counter productive
- Minimal difference on oil vapor pressure and NGL content
- Salt precipitation leads to plugged/failed equipment

# Whiting Tank experience

One day of storage tank retention yields acceptable VPs
Summer: TVP 13/ RVP 12 psi *(TVP- ASTM D6377, RVP- ASTM D323)*
Winter: TVP 14/ RVP 13 psi

*HAZMAT Class 3 PG I Liquids allowed vapor pressure up to 43.5 psi*
*DOT-111 cars rated for 100 psig*

Tank operating pressure: 4-6 oz/sq-in
Pressure controlled by VRU with VFD and recycle
Alternative tank pressure control is by combustor/ engineered flare

Oil gathering system centrally controlled by live Operators via SCADA 24x7 to detect and address problems in real time adds significant value

-Tank level alarms
-LACT rates and BS&W status
-VRU or combustor downtime
-Tank pressure alarms

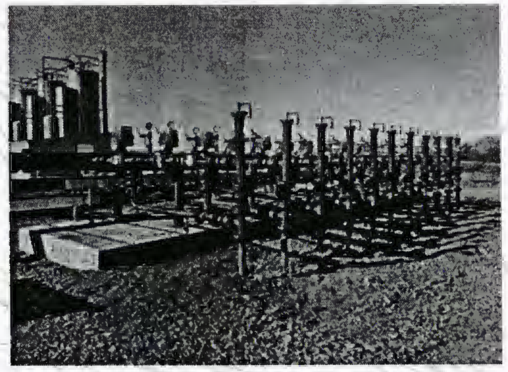
# Continental Resources, Inc.

## Bakken Central Tank Battery Design

## DMR Oil & Gas Division Hearing
## Case 23084 – Oil Conditioning
## September 23, 2014

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By CRI
Exhibit B
Identified By Hume

# CTB - Process for Conditioning the Oil Stream



Inlet Header: 104° F & 110 PSIG

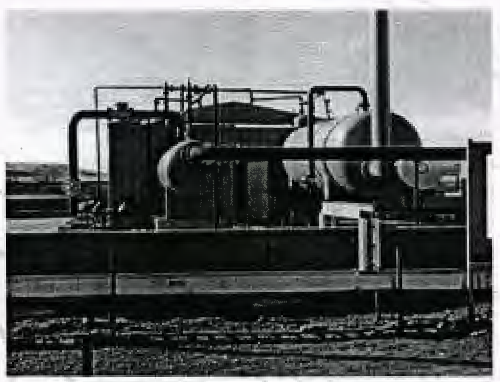
Testing Trains

Separator: 101° F & 60 PSIG
Heater Treater: 117° F & 30 PSIG

Transfer Pumps

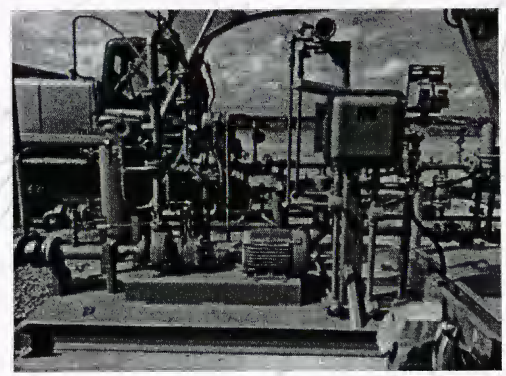
Truck Loads

Production Train



Separator: 101° F & 60 PSIG
FWKO: 96° F & 50 PSIG
Heater Treater: 117° F & 30 PSIG

Tanks: 112° F & 8 oz



LACT: 105° F & 50 PSIG

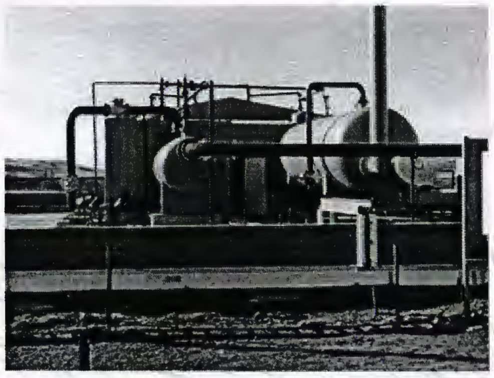




INDEPENDENT MEANS

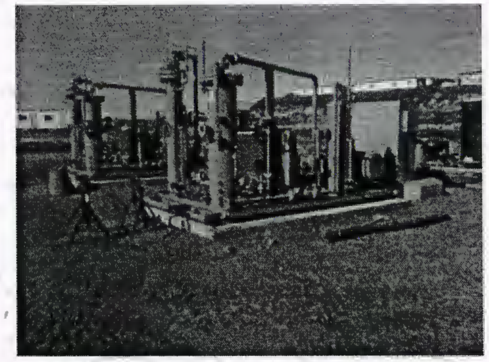
Continental Resources

# CTB - Process for the Gas Stream



Separator: 101° F & 60 PSIG

FWKO & Heater Treater: 117 °F & 30 PSIG



VRUs: 140° F & 90 PSIG

Tanks: 112° F & 8 oz

Normal Operation

Power Outage

Gas Sales Meter Building

Smokeless Flare

# CTB – Vessel Design Capacities

## Test Trains:

Vertical 2 Phase Separator: 3.5 MMSCFD & 1,100 BPD (emulsion)
Vertical Heater Treater: 450 BWPD & 600 BOPD

## Production Train:

Horizontal 2 Phase Separator: 15 MMSCFD & 14,000 BPD (emulsion)
Horizontal FWKO: 4,500 BPD (free water) & 9,000 BPD (emulsion)
Horizontal Heater Treater: 1,500 BWPD & 9,000 BOPD

# The North Dakota Petroleum Council Study on Bakken Crude Properties

## Bakken Crude Characterization Task Force

**Prepared for the**

NORTH DAKOTA PETROLEUM COUNCIL

**By**


Turner, Mason & Company
CONSULTING ENGINEERS

Suite 2920, LB 38
2100 Ross Avenue
Dallas, Texas 75201
www.turnermason.com


August 4, 2014


John R. Auers, P.E.
Ryan M. Couture
Dennis L. Sutton

## Table of Contents

## Figures



## Tables

**Appendices**

**The North Dakota Petroleum Council Study on Bakken Crude Properties**

**Bakken Crude Characterization Task Force**

**Project Coordinator: Turner, Mason & Company**

## Executive Summary

This report documents the detailed sampling and testing program recently conducted on Bakken crude oil. This program is the most thorough and comprehensive study of crude quality from a tight oil production basin to date.

In the past year, considerable attention has been focused on transportation and quality issues related to Bakken crude oil. As a result of several high profile railcar incidents in the U.S. and Canada, various investigations have been launched by governmental and industry groups to better understand the safety aspects of moving Bakken crude by rail. Questions as to whether Bakken is materially different from other crude oils and if the current railroad materials classification is appropriate have been raised. Investigations are ongoing as to the cause of the railcar accidents and potential hazards to the public associated with crude oil rail movements in general. In response to these concerns, the North Dakota Petroleum Council (NDPC) commissioned a comprehensive sampling and testing program to answer questions regarding the chemical and physical composition of Bakken, issues regarding proper classification and establish a Bakken quality baseline. This program collected samples from seven rail terminals and 15 well sites. The crude producers that provided the well samples account for over 50% of total North Dakota (ND) production, and the rail facilities sampled represent a similar proportion of total ND crude-by-rail capacity. The sampling locations cover the entire producing region and include both "old" and "new" wells, giving a good representation of any property variations that result either from geography, production rate, or during processing and transit. At this time, we are not aware of any field-level crude oil quality assessments as extensive or as controlled as this study in the Bakken or elsewhere.

The NDPC commissioned this program to establish Bakken crude properties (Quality Characterization) and to understand if these properties pose transportation and handling risks unique to Bakken compared to other light crude oils. The results from the study will be used to help establish and maintain a Bakken quality baseline to ensure continued crude quality and consistency. The study was also used to evaluate the impact of field-operating conditions (ambient temperature, tank settling times/production rates, and field equipment operating temperatures and pressures) on Bakken qualities. These study results, together with follow-up efforts, will be used to establish "management best practices" for operating production field equipment to minimize the light ends content and vapor pressure of Bakken crude sent to rail-loading facilities and to meet the proposed quality specifications.

NDPC engaged Turner, Mason & Company (TM&C), an internationally recognized engineering consultancy with over 40 years of experience in the petroleum industry (including a significant background in crude oil quality and processing), to serve as project coordinator. The TM&C team

included engineers with extensive refining and crude characterization/evaluation experience and a chemist with over 40 years of laboratory experience in crude oil analyses who serves as Executive Director of the Crude Oil Quality Association and on the Board of the Canadian Crude Quality Technical Association. Analyses of all primary samples were conducted by SGS, a global leader in testing and inspection with over 135 years in the business. Both the local North Dakota and U.S. Gulf Coast SGS labs participated in the sampling and testing process.

The key findings were as follows:

**Quality Characterization**

- Bakken crude is a light sweet crude oil with an API gravity generally between 40° and 43° and a sulfur content <0.2 wt.%. As such, it is similar to many other light sweet crude oils produced and transported in the United States.
    - As a point of reference, the Energy Information Administration (EIA) categorizes crude oil that has an API gravity between 35° and 50° and less than 0.3 wt% sulfur as light sweet. Bakken falls in the middle of those ranges for both properties.
- Although testing for sulfur, Total Acid Number (TAN) and other corrosivity-specific testing were outside the scope of this project. Results from other test programs, as summarized below in Table 1, indicate that Bakken has very low sulfur and TAN properties.
- Table 1 compares key Bakken qualities to other important domestic and international crude oils:
    - Note the quality data in Table 1 for crudes other than Bakken came from sources without the extensive controls and systematic sampling procedures used in the NDPC study.

**Table 1: Comparison of Crude Properties**

| Domestic Light Sweet Crudes | API Gravity | Sulfur (wt. %) | TAN (mg KOH) |
|---|---|---|---|
| Bakken (1) (2) | 40 to 43* | 0.1 | < 0.1 |
| WTI (4) (5) | 37-42 | 0.42 | 0.28 |
| LLS (2) (4) | 36-40 | 0.39 | 0.4 |
| Eagle Ford (2) | 47.7 | 0.1 | 0.03 |
| Eagle Ford Light (2) | 58.8 | 0.04 | 0.02 |

| International Crudes | API Gravity | Sulfur (wt. %) | TAN (mg KOH) |
|---|---|---|---|
| **Light Sweet** | | | |
| Brent (2) (6) | 37-39 | 0.4 | < 0.05 |
| **Medium** | | | |
| Arabian Light (2) | 33 | 1.98 | < 0.1 |
| Arabian Heavy (2) | 27.7 | 2.99 | < 0.1 |
| **Heavy** | | | |
| Western Canadian Select (Heavy Sour) (3) | 21.3 | 3.46 | 0.93 |
| Dalia (High TAN) (2) (7) | 23.1 | 0.51 | 1.6 |

| Sources: | |
|---|---|
| 1 - NDPC Study Data | 5 - Crude Oil Quality Association |
| 2 – Capline | 6 - BP Crude Assay |
| 3 - crudemonitor.ca | 7 - ExxonMobil Crude Assay |
| 4 - AFPM Bakken Report, 5/14/2014 | * Majority of NDPC samples in this range |

- The qualities of Bakken were very consistent within our sample population and throughout the supply chain – from wellhead to rail terminal to refining destination. Test results showed no evidence of "spiking" with Natural Gas Liquids (NGLs) before rail shipment.

- The test results from this study are also consistent with reported results from others, including the American Fuel & Petrochemical Manufacturers (AFPM) Bakken Report, the Pipeline and Hazardous Safety Materials Administration (PHMSA) Operation Safe Delivery Report, NDPC member-gathered data and other recent studies and presentations on the quality of Bakken crude oil.

**Table 2: Bakken Quality Comparison, NDPC to AFPM and PHMSA**

| | NDPC Rail Avg (1) | AFPM Report | PHMSA Report (5) |
|---|---|---|---|
| API Gravity | 41.7 | 42 | Not Reported |
| Vapor Pressure (psi) | 11.5 | 7.83 (2) | 12.3 |
| IBP (°F) | 100.3 | 69.6 (3) | 87.0 |
| Light Ends (C2-C4s) (Liq. Vol. %) | 4.95 | 3.5-11.9 (4) | 4.65 (6) |

**Comments:**

| |
|---|
| (1) Rail chosen because AFPM samples from Bakken at point of delivery, Rail data from NDPC closest to direct comparison. |
| (2) AFPM reported RVP, NDPC reported $VPCR_4$ (D6377) at 37.8°C. AFPM also reported $VPCR_4$ done at 50°C, results 13.9-16.7 psi. |
| (3) 87.3 Median, Multiple tests in AFPM data, some of which can report lower than D86, which skewed average lower. |
| (4) AFPM report, three respondents average 3.5%, fourth had 12 samples, range 5.9-11.9%. |
| (5) PHMSA data from Table E, data ranging from 3/17 to 5/2, to maximize overlap with NDPC study data timeframe. |
| (6) PHMSA does not report isobutane, and C2-C4 results do not appear to include isobutane. By comparison, NDPC C2-C4 without isobutane was 4.37 Liq. Vol. %. |

- While the test results from PHMSA's report agreed closely with the NDPC results, PHMSA did make some assertions in their Executive Summary which do not appear to be supported by their study or our findings.

- The PHMSA report makes the statement that, "We conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude." No comparative data was provided to support this statement; and, as we note elsewhere in this report, the limited data available on other crudes (that we were able to obtain) would not support that conclusion.

- PHMSA also claims that a higher degree of volatility "correlates to increased ignitability and flammability." Again, no support is provided for this statement in the report. While we are aware that some groups, including API, are studying this very complex subject, we are not aware of any results or conclusions from those studies to date.

- During the time frame of our sampling program, Bakken had an average vapor pressure of between 11.5 and 11.8 psi, which is more than 60% below the vapor pressure threshold limit for liquids under the Hazardous Materials Regulations (43.5 psi).
    - It should be noted that the vapor pressure testing was done using the EPA approved method for crude oils (ASTM D6377), which results in readings about 1 psi higher than if the Reid Vapor Pressure (RVP) test method (ASTM D323) was used.

    - Test data from an NDPC member's rail terminal taken over a seven-month period from August 2013 through March 2014 showed RVP's in the range of 8 to 11 psi; consistent with the NDPC test results when adjusted for seasonality and test method.

    - It is difficult to compare the "typical" vapor pressure of Bakken to other crudes because of the dearth of consistent data (regarding sampling and testing methodologies) for other crudes. Most data show Bakken vapor pressure to be within 2 to 3 psi of other light sweet crudes (some higher, others lower). The AFPM Bakken Report contained the following comparison (versus key crudes), shown below in Table 3. Comparisons from other studies (which are shown later in this report) show similar results.

**Table 3: AFPM Bakken Report, Crude Quality Comparison Table**

| | **RVP (psi)** | **Vol. % Light Ends (C2-C5s)** |
|---|---|---|
| LLS | 4.18 | 3.0 |
| WTI | 5.90 | 6.1 |
| Alberta Dilbit | 7.18 | 7.30 wt. % |
| DJ Basin | 7.82 | 8.0 |
| Bakken | 7.83 | 7.2 |
| Eagle Ford | 7.95 | 8.3 |
| Brent | 9.33 | 5.28 wt. % |

- The flash point of Bakken is below 73°F, and the Initial Boiling Point (IBP) generally averaged between 95°F and 100°F, both of which are in the normal range for a light crude oil.

- The data supports the current Department of Transportation (DOT) Pipeline and PHMSA classification for Bakken crude as a Class 3 Flammable Liquid (similar to other crude oils, as well as gasoline, ethanol and other materials containing light components).

- As a result, Bakken crude oil meets all specifications for transport using existing DOT-111 tank cars.

- This conclusion is consistent with the recent AFPM Bakken Report, which stated "Bakken crude oil does not pose risks significantly different than other crude oils or other flammable liquids authorized for rail transport. Bakken and other crude oils have been classified as flammable liquids. As noted, Bakken crude poses a lower risk than other flammable liquids authorized for transport by rail in the same specification tank cars."

- Flammable liquids fall into packing groups (PG) depending on their IBP as defined by the ASTM D86 method. The testing performed in this study highlighted the difficulty with using this test method for packing group determination. The results showed significant (10°F+) variability between labs on the same sample.

  - This is because D86 was not developed for *wide boiling range* materials like crude oil, with no specifically defined lab-operating parameters specified. Therefore, different labs used different operating conditions during testing, resulting in a wide variability of values for the IBP.

- Because of the difficulty with achieving consistent IBP results, groups including API are working on recommendations to update the current regulations.
  - Based upon the findings of this study, the NDPC encourages all members to classify their BKN crude as a Class 3 PG I flammable liquid until a more definitive testing protocol is established.

- It is critical to note that the determination of PG I versus PG II has no impact on the type of rail car used or on first responder response to an incident and had no impact on any of the incidents in which Bakken was involved.

- The accuracy and precision of our test program were ratified by a series of round-robin tests between both SGS laboratories (Williston, ND and St. Rose, LA) and a second internationally recognized testing company.

  - The results of the round-robin testing, using identical samples (from four locations) of Bakken (tested at each of the three laboratories) showed excellent agreement on API gravity and vapor pressure.

  - Significant variance did occur in the measured IBP from the D86 testing, as noted earlier.

    - A member company conducted a similar round-robin test comparison with samples of Bakken taken from four rail cars. Duplicate samples were sent to SGS and a second laboratory and the results of this testing also showed excellent agreement on API and vapor pressure and significant differences on D86 IBP.

- A series of side-by-side tests were performed using both the standard sealed glass jars (Boston Rounds, used for testing during the study) and Floating Piston Cylinders (FPCs) which have been suggested by some industry groups for testing vapor pressure.

    - Preliminary results proved inconclusive. Results of samples taken from the atmospheric tanks using the glass bottles came back with higher vapor pressure readings than when tested using either glass bottles or FPCs on the pressurized tank discharge.

    - Due to the requirement to sample from a pressurized tap with FPCs, there are difficulties with sampling and finding appropriate sample locations, which restricts where samples can be collected.

    - These initial results, though limited, indicate that sampling with the glass bottles was at least as representative as testing with FPCs for vapor pressure, and allowed for a greater variety of sample locations with greater consistency.

Table 4 below summarizes the results from the sampling and testing program.

- API gravity of Bakken was generally in the low 40's which falls in the range of what is considered a light crude oil.

- Vapor pressure (via ASTM D6377 at 37.8°C/100°F) was in a fairly tight range, averaging between 11.5 and 11.8 psi, with over 90% of well and 100% of rail samples measuring below 13 psi. As noted earlier, D6377 shows readings about 1 psi higher than the RVP test method (ASTM D323).

- D86 IBP showed a range of approximately 15°F on samples. All samples measured as either a PG I or II, with most of the test results close to the 95°F determination threshold. Because of the limitations of the test and variability of test conditions, the exact result varied depending on which laboratory conducted the testing.

- The light ends (C2-C4s) content of Bakken, which averaged just below 5.5 liquid volume %, is generally within 1 or 2% of other light crudes. Comprehensive data comparable to that obtained in this study for the other major Light Tight Oil (LTO) basins is not available. However, the data, which is available, indicates that Bakken light ends content is more consistent; and in many cases, lower than for most of the light crudes and condensates produced in the major LTO basins (including Eagle Ford, Utica, Niobrara and Permian basins).

- It is important to note that the DOT-111 cars used to transport this crude are rated for 100 psig, and the type of car used is the same for both PG I and PG II material transport.

**Table 4: NDPC Bakken Crude Sampling Data Summary**

| Sample Date Range | 3/25 to 4/24/2014 | | |
|---|---|---|---|
| **Total (152 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 41.0 | 36.7 | 46.3 |
| Vapor Pressure (psi) | 11.7 | 8.9 | 14.4 |
| D86 IBP (°F) | 99.5 (PG II) | 91.9 (PG I) | 106.8 (PG II) |
| Light Ends (C2-C4s) | 5.45 | 3.33 | 9.30 |
| **Rail (49 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 41.7 | 39.2 | 44.0 |
| Vapor Pressure (psi) | 11.5 | 9.6 | 12.9 |
| D86 IBP (°F) | 100.3 (PG II) | 96.7 (PG II) | 104.1 (PG II) |
| Light Ends (C2-C4s) | 4.95 | 3.91 | 6.44 |
| **Well (103 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 40.6 | 36.7 | 46.3 |
| Vapor Pressure (psi) | 11.8 | 8.9 | 14.4 |
| D86 IBP (°F) | 99.1 (PG II) | 91.9 (PG I) | 106.8 (PG II) |
| Light Ends (C2-C4s) | 5.69 | 3.33 | 9.30 |

The results indicate that the well-to-well quality of Bakken is very consistent. Testing across the geographic area showed very limited geographical variation in key properties such as API, vapor pressure and light ends content. Data provided by one of the NDPC member companies (which involved testing over an eight-month period) showed that while there was some seasonality in vapor pressure, it was not significant (3 psi lower in summer months vs. winter months) and it agreed very closely with the AFPM seasonality data. The data was also consistent with the NDPC test results during the period when the sampling overlapped.

Bakken quality, throughout the supply chain in our sample pool, was also consistent. There was no evidence of "spiking" of Bakken crude with NGLs between the well and rail terminals, with rail terminals showing less variation and tighter averages than well-readings. This was expected, given that regional rail facilities receive oil from many wells. Additionally, limited sampling at both the rail terminal and destination refinery showed no significant weathering or off-gassing of light ends in transit.

**Operating Conditions/Impact on Bakken Quality**

In addition to characterizing the quality of Bakken crude, our study looked at the impact that well site operating conditions have on the quality. These conditions include ambient temperature, production volume flow rates/field tank settling time, vapor capture status and field equipment operating parameters such as separator and treater temperatures and pressures. All of these measurements were recorded during the sampling program and have been correlated to determine how they impact test results. Based on this analysis, we offer the following observations and conclusions:

- The samples were gathered during the spring season (late March to late April) and ambient temperatures varied from a low of 10°F to a high of 65°F (average of about 34°F).

- Vapor pressure will vary by season with lower vapor pressures (lower levels of dissolved light ends) in the hotter summer months and higher vapor pressures (higher levels of dissolved light ends) in the colder winter months. This was confirmed by the member-contributed data referred to earlier in this section (and included later in this report).
- The results during this sampling program were in the intermediate range due to the mid range ambient temperatures experienced during sampling.
- Although the temperature range was limited, vapor pressure levels did correlate with temperatures (consistent with the more extensive member contributed data and the AFPM data), and with higher measured vapor pressure for crude sampled with lower ambient temperatures.

- While the companies operating in the Bakken, which participated in our sampling program, use a variety of well site production equipment and operating conditions (production rates, equipment operating pressures and temperatures) varied across the study, key crude qualities from our study were distributed across a fairly narrow range.
  - The data consistency indicates that field equipment is limited in its ability to significantly impact vapor pressure and light ends content.
  - This is consistent with the expected capabilities of the equipment.
  - The field equipment is designed to separate gas, remove water and break emulsions to prepare crude for transport, and not remove significant levels of dissolved light ends from the crude.
- Despite the limitations of the field equipment, the data did show that the content of some of the lighter components, specifically ethane and propane, was reduced in a measureable way by running the equipment at higher temperatures.
  - The difference between running cold (50°F) and running at close to the maximum practical temperature (150°F) resulted in an average reduction of 0.13 liquid vol. % ethane and 0.25 liquid vol. % propane, and about 0.40 liquid vol. % of total light ends reduction.
  - Total ethane levels were almost universally below 0.20 liquid vol. % (and often closer to 0.10 liquid vol. %) when treaters were run at temperatures above 140°F, compared to levels averaging around 0.30 liquid vol. % (and as high as 0.40%) when temperatures were less than 100°F.
  - It is important to note that true "plant tests" were not conducted where the field equipment temperatures and pressures were varied systematically at individual well sites, but rather results correlated across all samples at all locations.

- Production rates were also obtained at the time of sampling in an effort to determine whether higher flowing wells retained more light ends and had a higher vapor pressure than lower flowing wells where there was more opportunity to "weather" off the light components.
    - The data from the study showed very limited correlation between production rates and vapor pressure.
    - There was also little difference observed in vapor pressure between samples which were obtained from wells which were directly connected to a gathering system (no settling time) versus those which were obtained from stock tanks (where there was an opportunity for settling).
    - As with the analysis of treater conditions impact on crude quality, the fact that this analysis was not done under systematic "plant test" conditions does not confirm that there is not some impact on vapor pressure, but rather that the impact is likely limited.

**Conclusions and Recommended Action Steps**

- Bakken is a light sweet crude oil with very consistent properties throughout the entire production basin, and the properties measured meet all the requirements of 49 CFR 171-180 for safe transport by rail or truck.

- Based on the results of this study, the NDPC has developed a set of Field Operations Recommended Best Practices. These cover the operation of the field treating equipment, Bakken crude oil quality, testing procedures and shipping classification, and are detailed in Table 5 below:

**Table 5: BKN Field Operations Recommended Best Practices**

| Field Treating Equipment (In an effort to minimize light ends in crude oil presented for market) |
|---|
| • Design and operate all equipment within manufacturers recommended operating limits.<br>• Operate Gas/Liquid Separator (if utilized) at the lowest pressure to accommodate gas sales and fluid delivery to the Emulsion Separator/Heater Treater.<br>• Operate Emulsion Separator/Heater Treater pressure to the lowest operating pressure to safely accommodate gas sales and fluid delivery to the production tank battery.<br>• Maintain all fired treating equipment (Emulsion Heater Treater, etc.) temperature between 90° and 120° F+ year round.<br>• Provide maximum tank settling time possible prior to shipment.<br>• Reduce stock tank pressure to lowest pressure possible to maintain vapor collection equipment (engineered flare, vapor recovery, etc.) operational integrity. |

Typical **BKN** * Specifications (ranges reflect expected seasonality)

| | Range | Typical |
|---|---|---|
| • API Gravity (hydrometer at 60°F) | 35° to 45° | 42° |
| • Vapor Pressure (ASTM D6377 @ 100°F) | 8 to 15 psi | 11.5 psi |
| • Initial Boiling Point (ASTM D86) | 90°F to 105°F | 95°F |
| • Sulfur | <0.3% | 0.15% |
| • $H_2S$ | <10 ppm | <1 ppm |
| • Light Ends (C2 – C4s) | 3% to 9% | 5% |

***BKN** refers to light sweet crude aggregated at rail and pipeline terminals within the Williston Basin. This crude is predominantly sourced from the Bakken common source of supply, but also includes legacy production from various other producing formations located within the proximity of the Bakken field. **BKN** does not include nonstabilized condensate recovered from wet gas gathering pipelines or from product derived outside the U.S. Williston Basin. Individual well values may be higher or lower than the aggregated values observed at the rail terminals.

Testing Procedures

- Well Site Operators/Purchasers – Prior to each custody transfer or LACT EOM
  - API gravity corrected to 60° F using hydrometer
  - Basic Sediment & Water (BS&W) by field centrifugal grind-out
  - Spot test vapor pressure pending available field testing equipment
- Rail/Pipeline Terminal Operators
  - Test each unit train loading or tank shipment batch
    - API gravity corrected to 60° F using hydrometer
    - BS&W by field centrifugal grind-out
  - Test at least midmonth and EOM
    - ASTM D6377 @100° F vapor pressure using certified laboratory
- DOT PHMSA Hazmat Shipping Category
  - Flammable Liquid Category 3
  - Packing Group I**

** PG I is recommended even though the majority of samples tested for the study would fall within specifications for PG II. The margin of error for the test methodology can result in different labs testing the same sample with values meeting both PGs. PG I has the more stringent standards and is therefore recommended to avoid further confusion.

- Other recommended procedures
  - DO NOT deliver fluid recovered from gas pipe lines (a.k.a. "pigging operations") to crude oil sales system unless processed by stabilization unit capable of lowering vapor pressure below 10 psi at 100° F.
  - DO NOT blend non-Williston Basin crude oils into the BKN common stream.
  - DO NOT blend plant liquids (plant condensates, pentanes, butanes or propane) into the BKN common stream.

## Introduction

Bakken crude has been produced for over 60 years, recently passing the one-billion-barrel produced milestone. Bakken is moved by rail, pipeline and truck, and has been for decades. In the last few years, crude-by-rail has increased rapidly as production has topped one million barrels per day, and as such, the opportunities for incidents to occur have increased. Bakken is finding its way to refining markets across the country, including along new routes to the East and West Coasts, increasing rail traffic on those tracks. Recently, several high profile incidents in which Bakken crude was being transported brought public attention on the potential hazards of crude-by-rail. Bakken has had an increased focus recently, in large part due to the disaster in Lac Megantic, Quebec, in July 2013, where 47 persons lost their lives. While human error played a significant role in the cause of the accident, the DOT-111 rail cars involved have been heavily scrutinized. The reality is that no rail car is designed to always withstand the full force of a high-speed derailment; and once containment is breached during such an event, there are countless ignition sources.

Government focus on these accidents has brought up the potential for changing regulations around the transport of Bakken (or other light crudes). The oil and gas industry has been building newer style rail cars since 2011, moving toward replacing the older DOT-111 cars with revised cars that have thicker side shells and other safety improvements. Additionally, regulations imposed since the accident in Quebec have required both increased testing of crudes and notification of routes before shipment. Industry focus is on ensuring that all activities are conducted with a focus on safety, but the industry expresses concerns about additional testing requirements, regulations, or transitions to new transportation or handling methods without a scientific basis that those changes will have a significant safety impact. The industry supports regulations that are implemented through scientific investigation and factual basis, not implemented emotionally. The PHMSA Bakken Blitz study was started for that purpose. While the federal government has been criticized for not moving immediately, they recognized the importance of researching the material, railcars and railcar movements to propose rules that increase overall safety. It is with the focus on maintaining a scientific basis for decisions that this study was commissioned.

The scope of this NDPC study was to perform a comprehensive, controlled sampling of Bakken from a wide range of geographic locations at both individual wells and rail terminals. The controlled sampling ensured the same, consistent sampling techniques were used. Samples were sent to a single laboratory for testing, and thus the same methods and equipment were used. This ensured the data would be more consistent than data aggregated from many member companies, each using different labs and sometimes different test methods.

In addition to the direct sampling of the seven rail terminals and 15 well sites, additional data was collected. In order to evaluate the impact that shipping may have on crude; samples were taken at the rail terminal in Fryburg, ND, as well as upon receipt in St. James, LA. The same rail cars were sampled in both locations, and samples were sent to the same testing provider for analyses. Another set of testing on an individual well was performed to determine laboratory test variability. Samples were taken at the same time, but sent to two different labs: SGS (the primary lab used for this study) and a second internationally recognized lab. This resulted in some variance, primarily around D86 IBP measurements, which are critical for proper PG determination. A third test was performed to compare D86 measurements between two SGS labs. One lab also did testing by varying some of the test parameters around D86 instrument setup. The results highlighted the opportunity for significant variability of results and the limitations of using the D86 test method on crude oil samples, which have wider boiling ranges than the method was intended.

Testing was conducted starting March 25 and continued through April 24, 2014. Through the course of testing, sample data was collected, including the following:

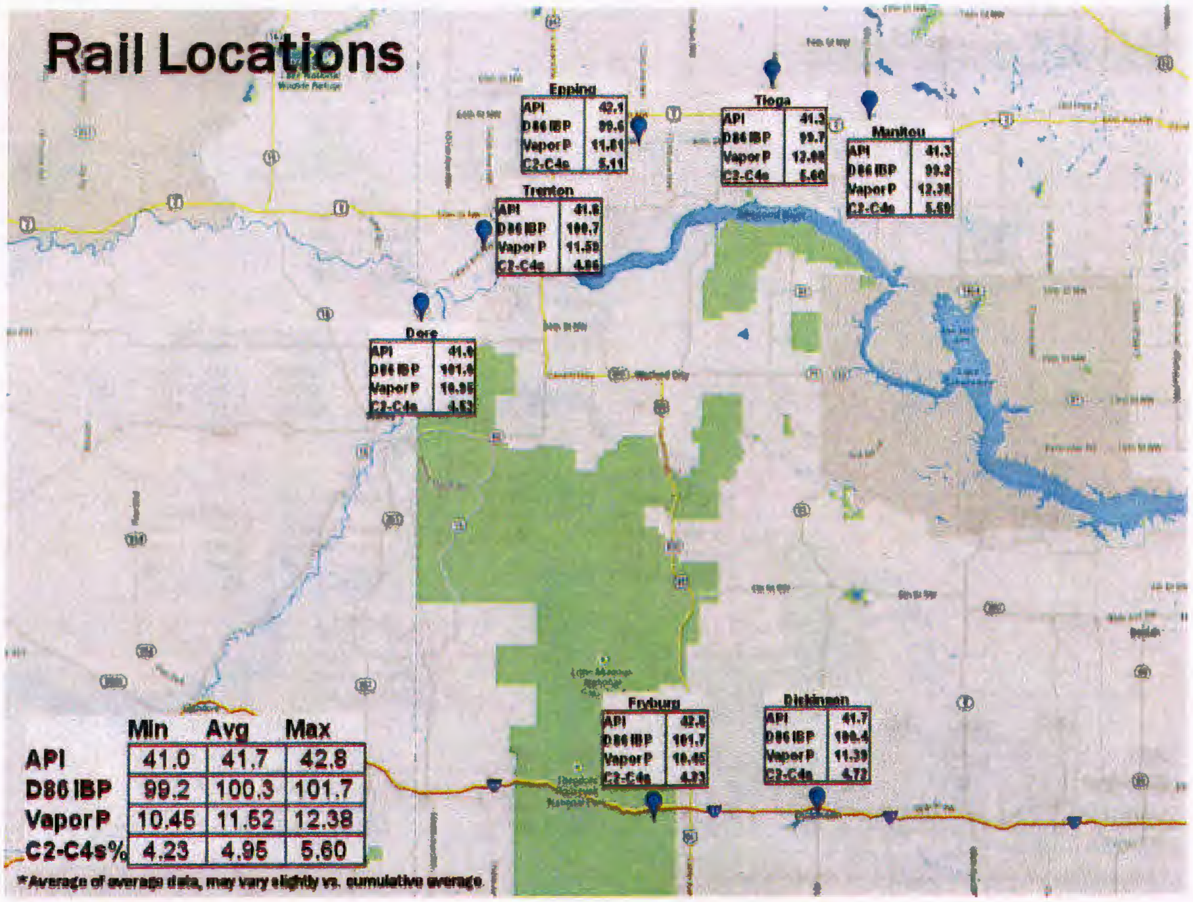
- Sample Date, Time, Company, Location (Geographic and Facility/Well ID);
- Ambient temperature at time of sampling;
- Size of tank where sample was pulled from;
- Location in tank (top, bottom, or composite) where sample was taken;
- For samples taken at well, operating conditions including treater/separator operating pressure and temperature, as well as production rates were recorded;
- API Gravity;
- D86 IBP;
- Vapor Pressure via D6377, as measured at 37.8°C/100°F with a 4:1 V/L ratio;
- Flash Point via D3278;
- Light Ends via IP344; and
- Simulated Distillation via D7169.

Details on the sample conditions at time of sampling were recorded to evaluate what parameters may have an impact on the sample results. All samples were taken in sealed one-quart glass bottles, consistent with testing for stock oil tanks. The process was similar to the procedure used for finished gasoline testing with RVPs up to 15 psi.

On the first visit to each location, samples were taken at both the top and bottom of the tank. This was done to determine if there was a variance or stratification taking place in tanks, either at the well or at the rail terminals. On subsequent visits, samples at each location were composite samples of the tanks.

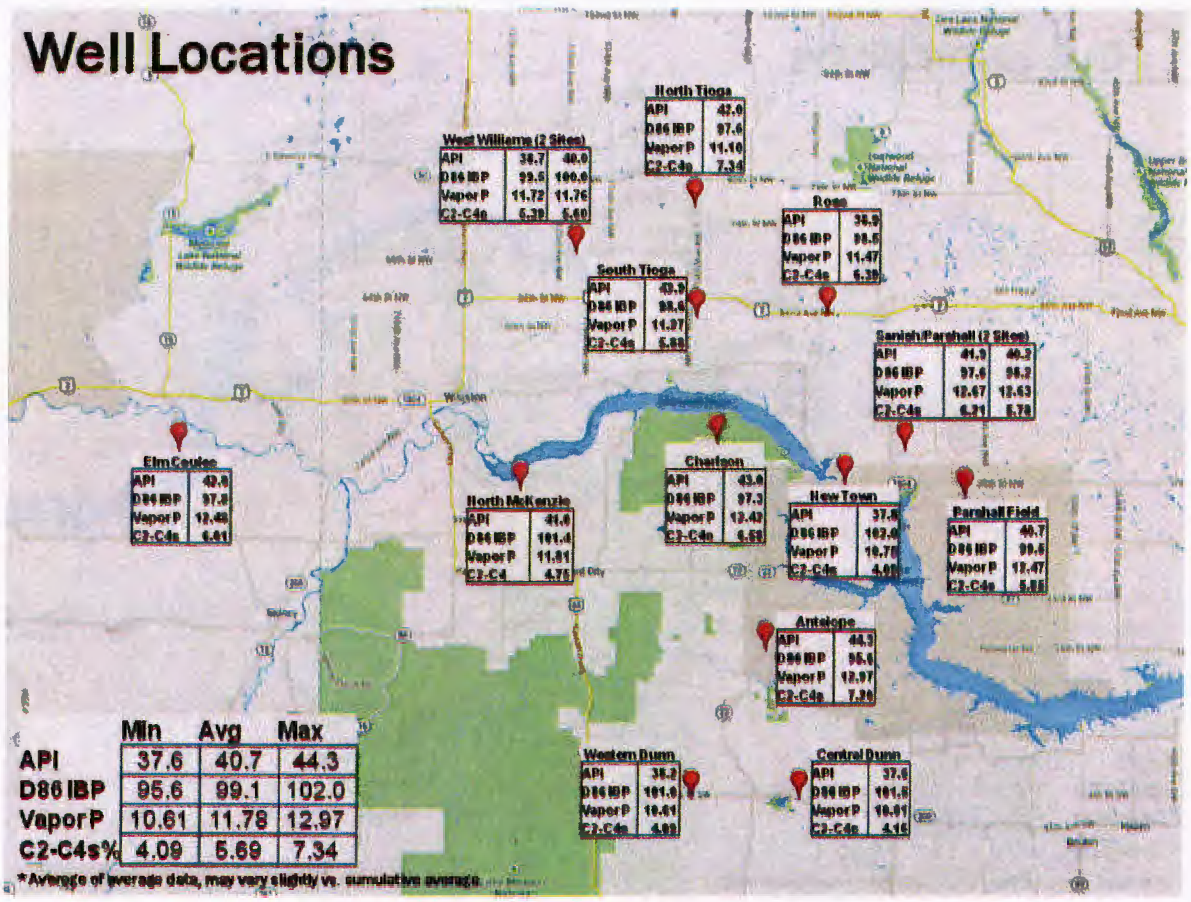
In order to capture any variances seen across the Bakken formation, sites were chosen to ensure a wide variety of locations. The points have been plotted on the maps below with corresponding average sample data for each location. The map of rail locations sampled, along with corresponding data is shown in Figure 1.

**Figure 1: Rail Sample Locations, With Average Sample Results**




The map of well locations sampled, along with corresponding data is shown in Figure 2.

**Figure 2: Well Sample Locations, With Average Sample Results**




## Test Results/Analyses

Sampling was conducted beginning March 25, 2014. Each site was sampled from their stock or storage tank. For each location, a top and bottom tank sample was taken once, with the remainder of samples taken as a composite. Samples were spaced every few days to gain the most representative snapshot during the test period. All testing was completed on April 24, 2014. A complete listing of sample dates/times by location (along with all data) can be seen in the appendix. A breakdown of the samples is as follows:

- API Gravity: 152 Samples;
- D86 Initial Boiling Point (IBP): 152 Samples;
- Vapor Pressure (D6377): 152 Samples;
- Flash Point (D3278): 152 Samples;
- Light Ends (IP344): 152 Samples; and
- Simulated Distillation (D7169): 111 Samples.

**API Gravity**

API Gravity was measured on all samples taken. API is a common property used to compare the relative density of a given petroleum liquid. While reported in degrees API gravity, it inversely correlates to the measured density of the liquid tested. For light crudes, the API gravity is generally around 40-45 API. Of all Bakken samples tested, the API gravity ranged from 36.7 to 46.3 API, averaging 41.0 API. The average for rail samples was slightly higher at 41.7 API, but with a tighter range of 39.2 to 44.0 API. These are all within the range expected for light crudes. By comparison, the common benchmark conventional light crudes, West Texas Intermediate (WTI) and Light Louisiana Sweet (LLS), measure 36-42 API. Bakken is not substantially lighter than other conventional light crudes. Higher API crudes may, but do not necessarily correlate with higher vapor pressure crudes. Figure 3 shows the distribution of API gravity data, and Figure 4 shows a plot of API gravity vs. measured vapor pressure.

**Figure 3: API Distribution; Total, Rail, Well**

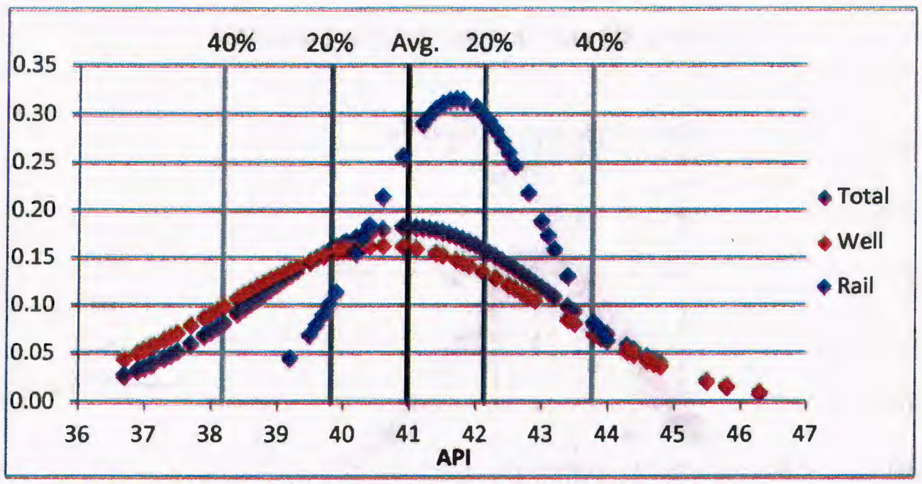
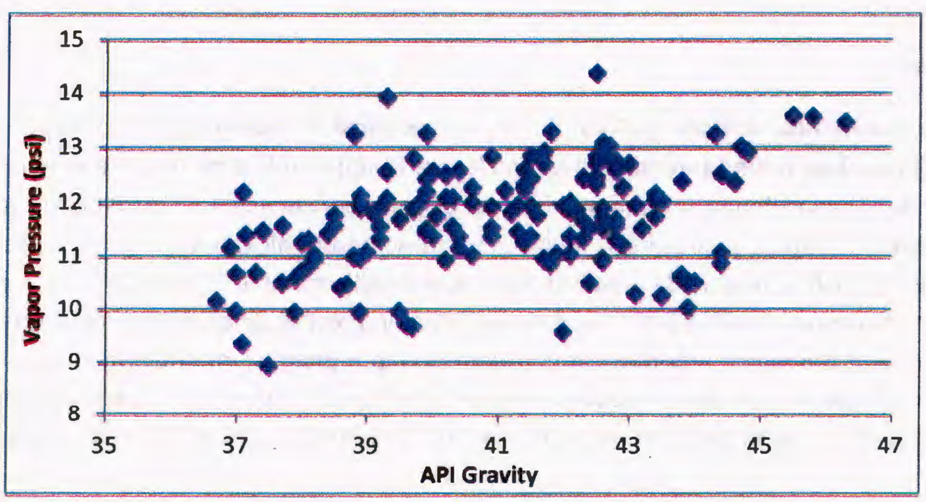


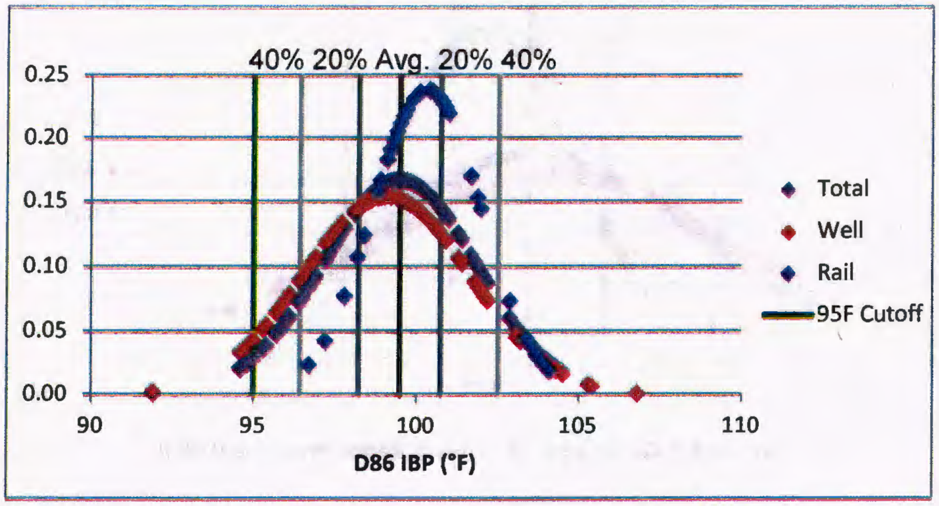

**Figure 4: API Gravity vs. Measured Vapor Pressure ($VPCR_4$)**



**D86 IBP**

D86 IBP measurements were conducted on all samples. As discussed in the summary section, the D86 distillation IBP is used for determining the appropriate PG for a flammable liquid. Measured D86 IBP ranged from 91.9°F to 106.8°F. Only 3 of the 152 readings, all of which were well samples, fell below the 95°F threshold for PG I versus PG II. The IBP results are clustered around the 95°F value. Thus, it is extremely difficult to properly define the PG because laboratory variance could indicate differing PG designations. While laboratory variance is a factor with any test, D86 is particularly susceptible because D86 distillation was never intended for wide boiling range materials; and, as a result, the test can have a significant amount of variance. Due to the importance of this test, and the proximity to the cutoff, additional laboratory comparisons were performed to determine the consistency of several properties, with special attention paid to D86 IBP. This will be discussed in detail in the section covering the interlaboratory (round-robin testing) later in this report. Figure 5 shows the distribution curve for measured D86 IBP measurements. The line in green shows the 95°F cutoff.

**Figure 5: D86 IBP Distribution; Total, Rail, Well**

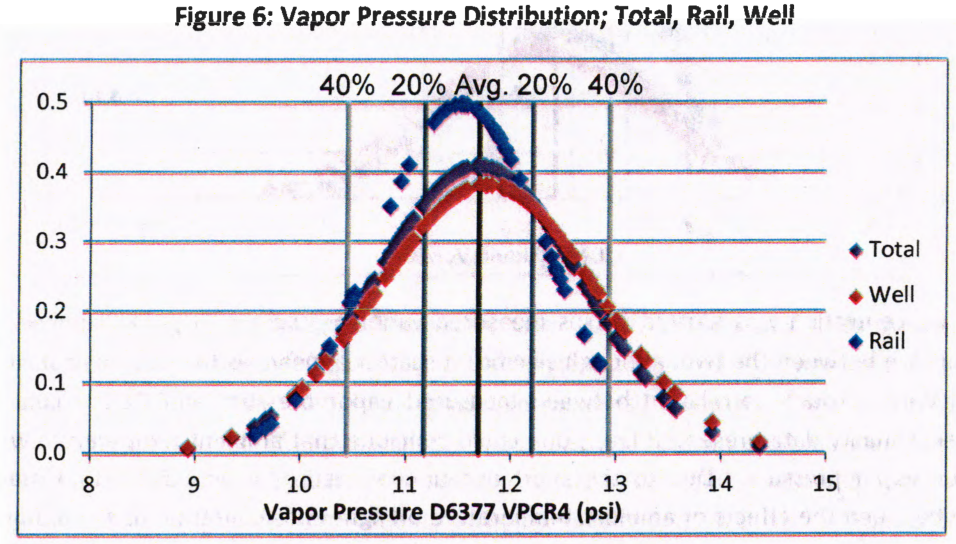



**Vapor Pressure**

Vapor pressure was measured using ASTM D6377, Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method) on all samples. It is important to note that the more traditional ASTM D323 Reid Vapor Pressure was not used. Within the past few years, ASTM D6377 has become widely accepted by industry and the U.S. EPA. For this reason, all vapor pressure analyses for this project were conducted using D6377, with the standard conditions of 100°F (37.8°C) and a vapor-liquid ratio of 4:1. In contrast, ASTM D323: Test Method for Vapor Pressure of Petroleum Products (Reid Method) is one of the oldest methods for determining vapor pressure of crude oils, and much of the older data in the public domain was obtained using this method. In the vapor pressure range of the samples tested in this study, the RVP values will tend to be about 1 psi lower than the VPCR values.

Vapor pressure samples in this study averaged 11.69 psi, well below the limit for the shipping classification. Rail averaged slightly lower at 11.52 psi, with a range of 9.57 to 12.85 psi. This is a more accurate representation of the quality being transported. This is in line with the vapor pressure of gasoline, which is transported under the same classification. Well vapor pressure averaged slightly higher at 11.77 psi, with a slightly broader range of 8.93 to 14.37 psi. The aggregation of crude and mixing that takes place at terminals, in addition to the potential slight losses of light ends during handling and storage, accounts for the difference in ranges and absolute vapor pressure seen between well and rail. Figure 6 shows the distribution of vapor pressures measured.

**Figure 6: Vapor Pressure Distribution; Total, Rail, Well**



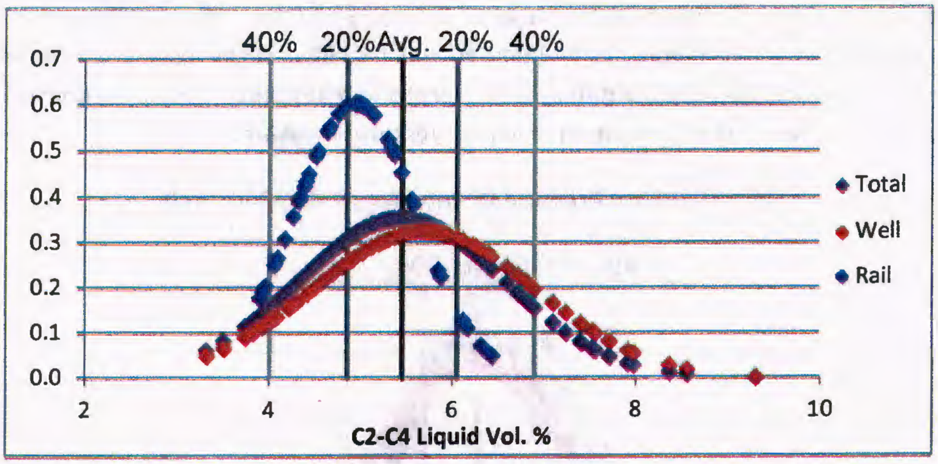

### Flash Point

Flash point tested via D3278 was performed on all samples. All flash point readings were <73°F (<23°C), which is the threshold value to distinguish between PG I or II and PG III. This threshold means all Bakken samples tested would fall in the PG I or PG II categories, and the ultimate PG I vs. II determination would be based on the D86 IBP, as discussed above. Because all samples were <73°F, no data analysis was performed.

### Light Ends

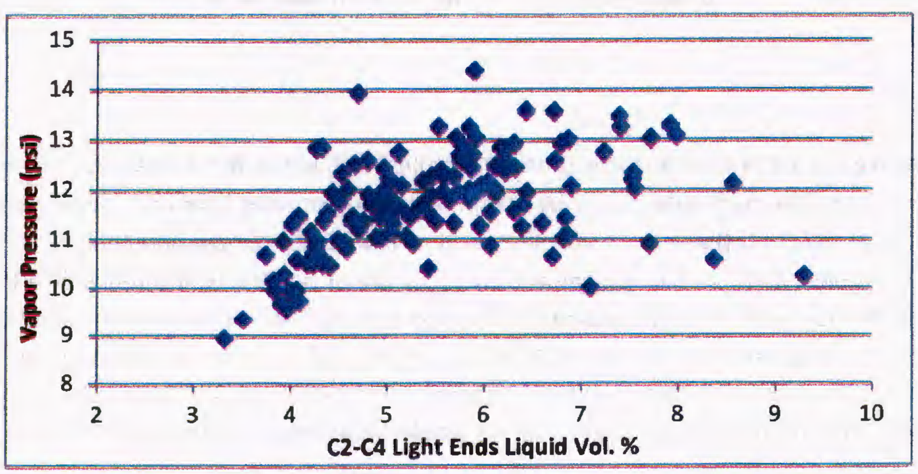
Light ends-testing via IP344 was performed on all samples. While the test measured concentrations of C1 (methane) to C6 (hexanes) individually by compound, the following light ends numbers account for the sum of C2-C4s only. Methane was excluded because it was at or below detection limits (0.01 liquid vol. %) for all samples, and C5+ has less impact on vapor pressure. The well samples had both a wider range (3.33-9.30 liquid vol. %) and average (5.69 liquid vol. %) concentration than rail (3.91-6.44 and 4.95 liquid vol. %, respectively). This is expected, as some small amount of light ends may be lost to storage tank vapor recovery systems while in atmospheric storage tanks at the well or rail terminals. Also, the mixing of various crudes into single tanks would help normalize any high or low concentration crudes. This corresponds with the vapor pressure readings in the previous section. Figure 7 shows the distribution of C2-C4s as measured.

**Figure 7: C2-C4 Distribution: Total, Rail, Well**




Light ends concentration was plotted versus measured vapor pressure on Figure 8, below. There is some correlation between the two, although significant scatter appears as the light ends concentration increases. With a rough correlation between measured vapor pressure and C2-C4s concentration, looking at seasonality data presented later, one could conclude that ambient temperature would have an effect on vapor pressure. Due to the short duration of testing, it was difficult to draw a clear correlation between the effects of ambient temperature on light ends content directly, although based on the seasonality data, colder temperatures would have the potential to leave greater amounts of light ends in the crude. The maps shown in the introduction section highlight the variance in properties from a geographic standpoint. While there is some variance in geographic measurements of light ends content, there does not appear to be any specific north to south or east to west correlations visible.

**Figure 8: Light Ends (C2-C4s) Concentration vs. Vapor Pressure**



**Simulated Distillation**

Simulated distillation (SimDist) via D7169 was conducted on 111 of the 152 samples. SimDist testing was performed on the first five samples for those samples that started on or around March 25, and three to four of the samples for the remaining few sites that had a more compressed sampling schedule. As testing progressed, the results appeared very consistent, and the importance of the SimDist results on overall analysis was determined to be limited. The test was subsequently excluded from later samples. Simulated distillation data showed consistent crude quality with the expected variance, ranging from an IBP of <97°F (minimum detection limit) to a final boiling point over 1200°F. Comparing Bakken to a pure liquid such as ethanol in a fire, the crude would vaporize more slowly in a fire should cars be heated versus ethanol, which has a single boiling point (173°F) where the entire cargo would vaporize. This temperature is roughly the SimDist 10% point for Bakken crude. Figure 9 and Table 6, below, show the distillation curve and average distillation data for well, rail and cumulative measurements.

**Figure 9: Bakken Crude Distillation Curve**

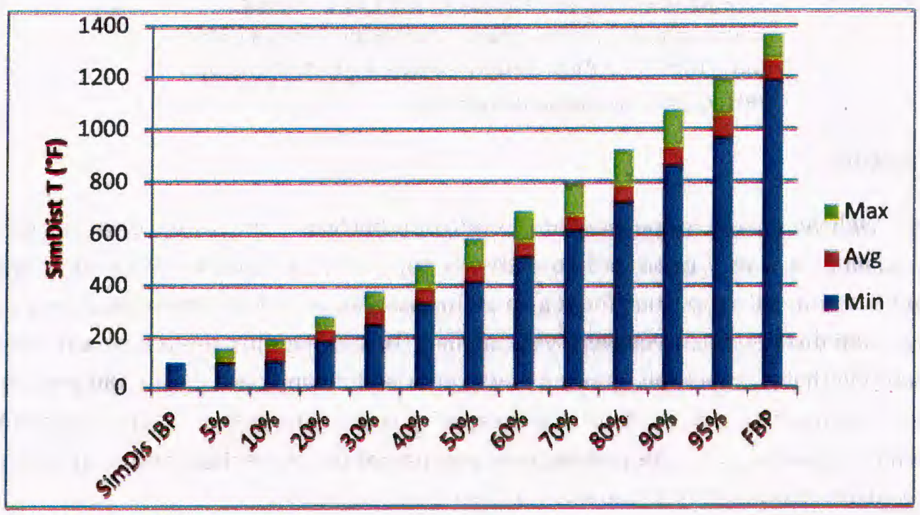


**Table 6: Distillation Data; Well, Rail, Total**

| SimDist | Well | Rail | Total |
|---|---|---|---|
| IBP | < 97 | < 97 | < 97 |
| 5%* | 106 | 113 | 108 |
| 10%* | 153 | 165 | 157 |
| 20% | 231 | 238 | 234 |
| 30% | 310 | 316 | 312 |
| 40% | 394 | 396 | 395 |
| 50% | 481 | 482 | 481 |
| 60% | 572 | 572 | 572 |
| 70% | 671 | 670 | 671 |
| 80% | 785 | 787 | 786 |
| 90% | 935 | 939 | 936 |
| 95% | 1053 | 1060 | 1056 |
| FBP* | 1305 | 1317 | 1309 |

All values shown are in °F.

*Adjusted averages to account for one or more values in group above/below detection limits (97 °F and 1382 °F). Adjusted by averaging detection limit for values, raw data in appendix.

**Sample Consistency**

Comparing the well versus rail properties for the API/D86 IBP/vapor pressure, as well as light ends and SimDist, the qualities are very close and consistently correlate, as expected, with some slightly lower light ends numbers for rail properties for reasons discussed above. The light ends showed on average lower numbers and distillation curves were very similar. This shows that there is no evidence of spiking of Bakken crudes with light materials as some news reports had conjectured. The rail terminals sampled accounted for approximately 50% of total rail capacity out of the Bakken. These terminals receive crudes from many regional wells, not just member companies that contributed data: and, given the span of testing, it is highly likely results would have reflected such activity.

**Table 7: Quality Comparison – Well vs. Rail Test Results**

| | Well | Rail |
|---|---|---|
| API Gravity | 40.6 | 41.7 |
| D86 IBP (°F) | 99.1 | 100 |
| VPCR D6377 (psi) | 11.8 | 11.5 |
| **Light Ends (Liquid Vol. %)** | | |
| Ethane | 0.24 | 0.23 |
| Propane | 1.63 | 1.39 |
| Isobutane | 0.65 | 0.58 |
| n-Butane | 3.16 | 2.75 |
| Isopentane | 1.52 | 1.42 |
| n-Pentane | 2.90 | 2.72 |
| C2-C4s | 5.69 | 4.95 |
| C2-C5s* | 10.12 | 9.10 |

*Excludes Cyclopentane

**Sample Methodology Comparison: Floating Piston Cylinder (FPC) versus Standard Glass Bottle**

The sampling methodology employed in the NDPC Study was the industry standard technique of capturing material from tanks at either the well site or rail location in a glass bottle and sealing them with a screw-on cap. These quart-sized (32oz) glass bottles, referred to as "Boston Rounds" are the standard for sampling crude, gasoline and other hydrocarbons with similar vapor pressures to Bakken crude. Recently, a new technique has begun to gain acceptance as an alternate method, which involves the use of a FPC. The sample is captured under pressure in a cylinder with a hydraulic piston which minimizes any vapor space. The purpose of this is to minimize potential gas losses that could flash off from a liquid sample as it is captured at atmospheric pressure in a bottle, or is lost to the vapor space left when capturing a sample in a bottle.

In order to determine if there was any variance between the standard bottle sampling technique and the FPC, a set of four comparison tests at rail locations were performed. Rail locations were chosen because the floating piston cylinders require a pressurized sample location in order to overcome the pressure of the hydraulic piston in the cylinder. In each case, the samples were taken at the tap (spigot) located downstream of the loading pumps from the storage tanks to the rail car loading racks. Samples were taken while the line was in service and had flow (and adequate pressure) to fill the FPC's. By comparison, the samples taken during the NDPC testing were from the tank itself at atmospheric pressure upstream of the loading pumps where the FPC samples were taken.

The initial results from this testing proved inclusive. While some samples showed excellent agreement both with historic NDPC sampling and between the glass bottle and FPC samples at the pressurized sample point, others showed variation, with samples taken off the line having lower vapor pressure values than the samples collected from the tank. This implies that samples taken at the pressurized sample point downstream of the tank somehow lost light ends by comparison. This brings into question sampling techniques, sample point location and effects of sampling while under pressure in some locations such as after a pump. Further evaluation, regarding the comparison of FPC results to standard sampling with Boston Round glass jars, is being considered and will be provided as an addendum to this report if conducted.

**Interlaboratory (Round-Robin) Testing**

Due to the importance of ensuring both accuracy and precision in testing, and to gain a better understanding of potential laboratory variability, a series of round-robin tests were performed. These tests were designed to determine what, if any, differences the individual labs had for identical samples. SGS (the testing provider for this study) participated using both their St. Rose, LA and Williston, ND laboratories. Additionally, a second internationally recognized testing company participated to provide a third-party comparison (referred to as Lab M, in the Tables below). Four different well locations were sampled during this test. Three identical samples were taken, and one was sent to each of the three labs. Tests for API gravity, vapor pressure and D86 IBP were performed.

The results of this round-robin showed extremely good consistency between labs on both API gravity and vapor pressure. The consistency validated that the integrity of the samples were not compromised during this test and that they were not affected by handling or shipping. Table 8 shows the consistency among samples. Most samples had near zero maximum deltas between readings, with the exception of one vapor pressure sample that was slightly lower than the others.

**Table 8: Round-Robin API and Vapor Pressure**

**API Gravity (Density, D5002)**

| Sample Location | Date @ Time | Lab M | SGS St. Rose | SGS Williston | Max Delta |
|---|---|---|---|---|---|
| 1 | 5/1/14 @ 16:30 | 40.2 | 40.2 | 40.2 | 0.0 |
| 2 | 5/1/14 @ 16:30 | 43.0 | 42.9 | 42.9 | 0.1 |
| 3 | 4/30/14 @ 16:00 | 43.6 | 43.6 | 43.6 | 0.0 |
| 4 | 5/1/14 @ 16:30 | 43.0 | 42.9 | 42.9 | 0.1 |

**Vapor Pressure (VPCR4, psi)**

| Sample Location | Date @ Time | Lab M | SGS St. Rose | SGS Williston | Max Delta |
|---|---|---|---|---|---|
| 1 | 5/1/14 @ 16:30 | 10.1 | 10.3 | 10.1 | 0.2 |
| 2 | 5/1/14 @ 16:30 | 15.0 | 15.4 | 13.8 | 1.6 |
| 3 | 4/30/14 @ 16:00 | 10.6 | 10.6 | 10.6 | 0.0 |
| 4 | 5/1/14 @ 16:30 | 11.4 | 11.5 | 11.2 | 0.3 |

The consistency did not carry through for the D86 testing. There was noticeable inconsistency between each lab, with samples varying by as much as 19.5°F for a given sample. While all samples tested during this would fall within a Class 3 Flammable liquid, depending on the lab used, the same sample could fall above or below the 95°F mark for PG I vs. PG II. Table 9 shows the readings for each sample, and the maximum deltas measured.

**Table 9: Round-Robin D86 IBP**

**D86 IBP (°F)**

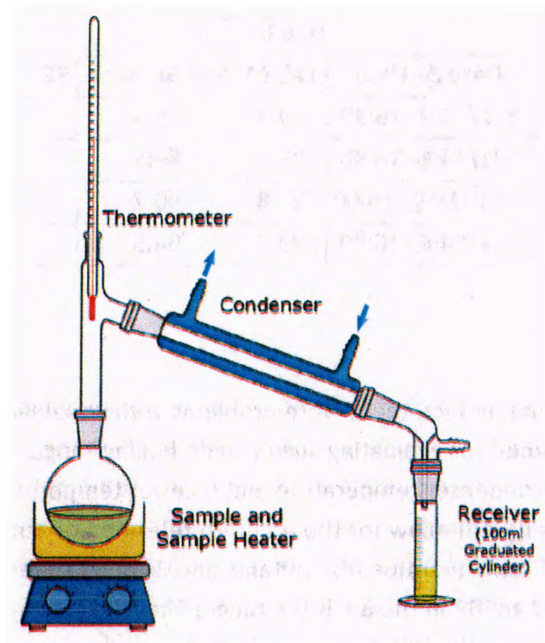
| Sample Location | Date @ Time | Lab M | SGS St. Rose | SGS Williston | Max Delta |
|---|---|---|---|---|---|
| 1 | 5/1/14 @ 16:30 | 89.9 | 95.4 | 101.8 | 11.9 |
| 2 | 5/1/14 @ 16:30 | 83.1 | 89.1 | 102.6 | 19.5 |
| 3 | 4/30/14 @ 16:00 | 87.8 | 90.7 | 105.5 | 17.7 |
| 4 | 5/1/14 @ 16:30 | 89.2 | 94.5 | 102.2 | 13.0 |

**D86 Variation**

The D86 testing showed that, in fact, there were problems with variability between labs. This is a result of the test not being designed for evaluating such a wide boiling range material, and thus different labs choose different heating, condenser temperature and receiver temperature parameters. In addition, the D86 distillation conditions do not allow for the accurate retention of butane and lighter material. Thus, samples containing significant quantities of butane and lighter material will not have this material detected and will still yield an IBP in the 80-100°F range. The C1-C4 compounds do not readily condense at the condenser temperatures the D86 test is conducted at, and thus are not accurately measured.

Before we discuss this further, a brief description of how a D86 distillation is performed is warranted. The setup consists of a flask of 100ml of liquid to be tested, a heater to boil the liquid, associated instrumentation to measure the temperature and volume, an overhead condenser which condenses the vapor boiled off and a receiver which collects the condensed material. While it is allowable to perform this test manually, almost all current analyses are conducted utilizing automatic instrumentation, which uses microprocessor controlled instrumentation to produce more precise results with minimal human intervention. All analyses conducted on this project utilized this type of automated instrumentation. Current D86 instruments are automatic; and typically, the type of liquid being tested will dictate parameters such as the condenser temperature and heat rate. The liquid is heated at the given rate dictated by the operator, and as it boils, it is condensed overhead, and drops into the receiver, which is maintained at a fixed temperature. The amount of liquid in the receiver is measured, and the distillation curve is generated. The liquid at the end is measured to determine the total recovery, as light components dissolved in the original sample can be lost if they are not able to be condensed at the condenser's operating temperature. Figure 10 shows a sample simple distillation, similar in principle to that used during D86 testing. The sample is heated, condenses, and is collected in the receiver. The volume at a given temperature is recorded to generate the distillation curve.

**Figure 10: Simple Distillation Apparatus**




Initial boiling point by D86 is defined as the overhead temperature (corrected for atmospheric pressure) observed at the instant the first drop of condensate falls from the lower end of the condenser tube. For a material such as gasoline, which typically has a boiling range of about 100-400°F, the liquid must first be heated at least some before enough vaporization occurs and vapor begins to condense. This is well above the condenser temperature, and as such, a more complete recovery is achieved. In the case of a light crude sample, which contains dissolved gases (C1-C4s) which do not condense at the typical condenser temperature, a lower recovery is achieved and less accurate actual IBP is measured.

The implications of this are that if parameters are not identical, the temperature with which the first drop is perceived to form can vary considerably. The difference for a given sample will normalize out as the 5% and 10% points are reached, but those values are not considered as part of the overall requirement for DOT classification. The rate at which the sample is heated can affect how well the sample was able to reach equilibrium temperature and drive off any light ends. The same goes for how cold the condenser is; the colder, the more it will condense. Faster heat rates and colder condenser temperatures tend to drive the IBP temperature lower than if the sample is more slowly heated with a higher condenser temperature.

Table 10 shows the impact that these parameters have on the boiling points. For the same sample, significant error can be introduced, over 14°F in the case of this set, for the same lab and same instrument, with slightly different operating parameters. This highlights a serious flaw in using the D86 test for compliance on determining PGs for materials such as Bakken crude. Because of the difficulty with achieving consistent IBP results, groups including API are working on recommendations to update the current regulations.

**Table 10: D86 IBP Variability Testing**

| Lab | SGS St. Rose | | SGS Williston | | SGS Williston | |
|---|---|---|---|---|---|---|
| Condenser Temp | 60°F | | 60°F | | 31°F | |
| Receiver Temp | 73°F | | 81°F | | 81°F | |
| Sample | D86 IBP | Time to IBP | D86 IBP | Time to IBP | D86 IBP | Time to IBP |
| 1 | 95.4 | 4 min 53 sec | 101.8 | 7 min 56 sec | 91.1 | 7 min 45 sec |
| 2 | 89.1 | 3 min 22 sec | 102.6 | 6 min 27 sec | 88.7 | 6 min 07 sec |
| 3 | 90.7 | 3 min 37 sec | 105.5 | 7 min 26 sec | 91.4 | 7 min 11 sec |
| 4 | 94.5 | 3 min 42 sec | 102.2 | 6 min 50 sec | 94.4 | 8 min 00 sec |

**Rail Testing**

A separate set of testing was conducted in order to evaluate whether there was merit in the claims that Bakken sees substantial weathering during transport. Five individual rail cars were sampled at their origin in Fryburg, ND, and destination of St. James, LA. Samples were tested by local labs in ND and LA of the same company for vapor pressure via D6377 at 100°F, flash point via D86, $H_2S$ in vapor phase at 77°F via ITM 3468 and light ends analysis by modified D6730. The results were then compared to average NDPC test results from the same rail terminal. The testing showed that throughout transportation, vapor pressure and C2-C4 concentration were consistent, indicating there were no light ends losses. Additionally, no detectable $H_2S$ was present in the samples. Comparing the samples tested at the two labs, the greatest variance in results was with the D86 IBP, for reasons discussed previously. Table 11 shows the table of average test data from both Fryburg and St. James and compares it to the other data collected at the Fryburg rail terminal. The appendix contains the full set of sample data for the cars.

**Table 11: Rail Car Source and Destination Testing**

| Test | Units | Avg. ND Rail Terminal 5 Car Samples | Avg. St. James Rail Terminal 5 Car Samples | Avg. NDPC Data for ND Rail Terminal |
|---|---|---|---|---|
| **VPCR 4 (37.8° C)** | psi | 10.47 | 10.61 | 10.45 |
| **IBP** | °F | 94.7 | 90.4 | 101.7 |
| **Flash Point** | °F | <50 | <50 | <73 |
| **$H_2S$ in Vapor Phase** | ppm v/v | <1 | <1 | |
| **C2-C4s** | Vol % | 4.00 | 4.08 | 4.23 |
| **C2-C5s*** | Vol % | 8.01 | 7.89 | 8.13 |

*Excludes Cyclopentane

**Member Contributed Data**

In addition to the data collected, member companies voluntarily submitted data to supplement data gathered in this study. The data contributed consisted of a smaller, less controlled round-robin sample test between one SGS laboratory and a second independent laboratory, and a NDPC member rail company terminal who contributed vapor pressure operating data collected over a seven-month period from late August 2013 to late March 2014.

A round-robin test was conducted by a NDPC member company who sent samples from four rail cars to both SGS and Lab M independently. The company had testing for API gravity, vapor pressure and D86 IBP measured on each sample. The results were similar to those found by NDPC conducted round-robin. API and vapor pressure had little variance, but the D86 IBP variance averaged over 13°F with a maximum variance of 15.6°F. This, again, highlights the difficulty with getting consistent and accurate D86 IBP measurements on a full boiling point material such as crude oil.

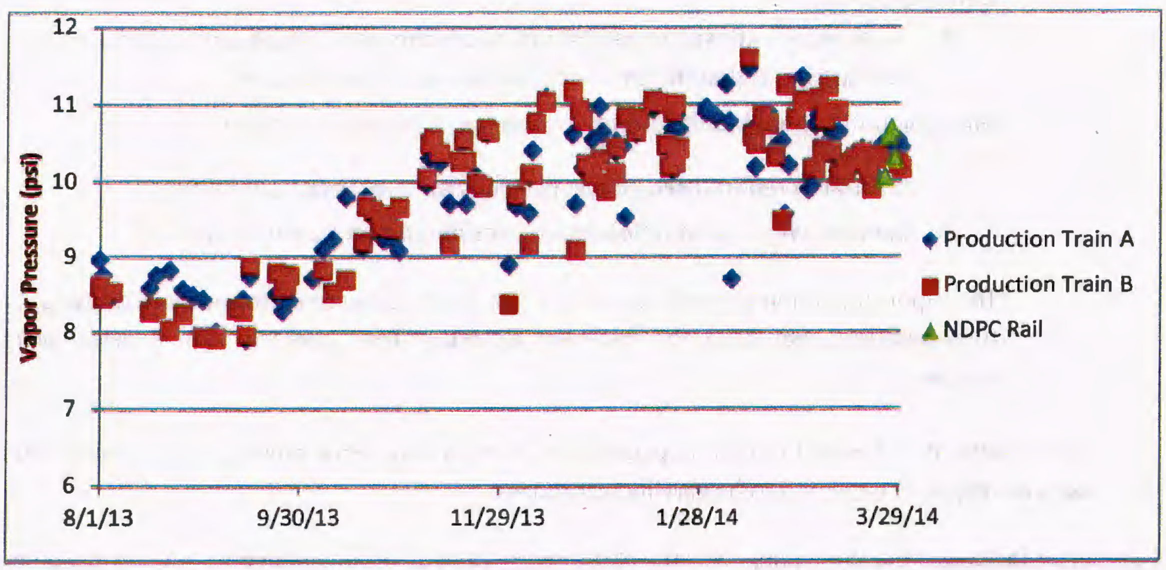
**Table 12: Member Company Laboratory Comparison (Round-Robin)**

| Sample ID | API Gravity | D86 IBP (°F) | VPCR4 D6377 (psi) |
|---|---|---|---|
| Sample 1: SGS | 44.0 | 101 | 10.52 |
| Sample 1: Lab M | 44.4 | 85.4 | 11.35 |
| Sample 2: SGS | 43.9 | 101.9 | 10.47 |
| Sample 2: Lab M | 44.3 | 92.4 | 11.47 |
| Sample 3: SGS | 42.4 | 100.5 | 10.50 |
| Sample 3: Lab M | 44.4 | 86.5 | 11.29 |
| Sample 4: SGS | 43.1 | 103.7 | 10.28 |
| Sample 4: Lab M | 44.2 | 89.9 | 11.29 |
| | | | |
| Avg. Variance | 1.0 | 13.2 | 0.91 |
| Max Variance | 2.0 | 15.6 | 1.01 |

A second member company contributed operating data collected over the course of normal operations on vapor pressure of Bakken crude being loaded into rail cars. It is known that as ambient temperature changes, the amount of light ends material separated from the raw crude at the wellhead, changes. Higher temperatures lead to higher gas separation, so winter and early spring conditions (when the NDPC test was performed) would highlight some of the higher vapor pressure Bakken crude throughout the year. The range of vapor pressure data collected shows that while there is some change, even the highest RVP readings in the winter peak at about 11 psi, nearly an order of magnitude below the 100 psig for which the DOT-111 rail cars are rated.

The samples from this member company were analyzed in their in-house lab and were measured for RVP versus $VPCR_4$ that was used throughout the NDPC testing. Due to the differences in test methodology, RVP readings typically are 1 psi lower than $VPCR_4$ readings. There was a brief overlap of time when sample data overlapped in late March, 2014. The data did correlate very well between measured vapor pressure at rail terminals tested compared to measurements at the member rail terminal when accounting for the testing difference. Figure 11 shows the chart of member contributed seasonality data, with NDPC test data overlaid, with the 1 psi correction.

**Figure 11: Seasonality Data Collected by Member Company**




The seasonality results are in line with the report from Transport Canada on the derailment in Quebec which showed RVP results ranging from 9.0-9.6 psi. The derailment took place in July 2013, and the RVP results recorded by Transport Canada are consistent with the summer results measured by the seasonality data above.

## AFPM Report Comparison

AFPM released a report on Bakken crude titled, *"A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transportation"* dated May 14, 2014. The report assembled a variety of Bakken data and compared its results to the parameters as laid out by DOT PHMSA and other international regulations for shipping. While raw data was not given for analysis, a statistical breakdown and walkthrough of each captured parameter gave a good overview of Bakken crude properties from a broad data set.

- The APFM report concluded that Bakken was not materially different and posed no special hazards versus other light crude oils.
  - These findings coincide with the findings from this NDPC report.
- The AFPM report came to the same conclusions regarding the safety of Bakken in DOT-111 rail cars.
  - Vapor pressure was well below the allowable pressure for DOT-111 rail cars.
  - Bakken was well within all specifications for a Class 3 flammable liquid.
- Despite the same conclusions, a direct comparison between AFPM and NDPC cannot be performed on all data points collected.

- The AFPM report collected voluntary data submissions from its members, instead of a controlled study.
  - Its members consist largely of fuel producers who sample and test the Bakken as it arrives at their facility, versus at the well or rail terminal.
- Sampling procedures and test methods were not uniform across all data.
  - The AFPM report listed all test methods used for various properties.
  - Samples were run at different labs, resulting in increased variability.
- The report did not indicate if tests of differing methods were correlated in any way prior to comparison, nor what the minimum detection limits were or how samples were handled.

- This variety of testing led to certain peculiarities, such as the initial boiling point or flash point data having what appeared to be varying test ranges.

Of particular focus was the IBP testing. For the NDPC report, all data in the main data set was tested by a single testing provider, SGS. Samples were consistently collected and handled throughout the testing process, with all testing using the same ASTM D86 testing protocol. In contrast, the AFPM report used five different test methods for distillation alone, as discussed in their appendix. This resulted in IBP data ranging down to 32°F (0°C). In particular, gas chromatographic methods are referenced as being used. These methods, e.g. D2887, are known to yield much lower IBPs than the D86 method. Thus, this data must be both used and compared with caution. Based on our earlier discussion of how D86 testing is conducted, the D86 test method does not lend itself to measuring boiling points that low. The condenser does not operate at a temperature low enough (it would have to operate below 32°F to condense materials boiling at that temperature). Additionally, the initial sample is not cooled to that level before testing and the collector is held at roughly room temperature, meaning any collected sample would evaporate. Thus, any IBP results below about 60°F must, therefore, have been conducted with another test method, assumed to be a gas chromatographic simulated distillation method. Since there was no indication that the data was correlated to D86, and the regulations are based around D86 testing, it raises questions about what the equivalent boiling points were for those samples, based on DOT requirements. Similarly, other data that used multiple test methods did not show an indication of a correlation between the two methods and makes the data good for information only, but not from which to draw firm conclusions or correlations. Table 13 shown below gives a brief comparison of the results of the two tests.

**Table 13: Comparison of NDPC to AFPM Study Data**

| | NDPC Average | | | AFPM Study | | Comments |
|---|---|---|---|---|---|---|
| | Well | Rail | Range | | | |
| API Gravity | 40.6 | 41.7 | 36.7-46.3 | API Gravity | 42 | Reported in crude comparison table. |
| D86 IBP (°F) | 99.1 | 100.3 | 91.9-106.8 | IBP (Various Tests) | 69.6 | 87.3 median IBP, multiple tests in AFPM data, some of which can report lower than D86, which skewed average lower. |
| Vap. P D6377 (37.8C) (psi) | 11.8 | 11.5 | 8.9-14.4 | RVP (psi) (Various Tests) | 7.83 | RVP reported by AFPM. Also reported D6377 done at 50C (higher than NDPC), with range 13.9-16.7 psi. |
| Seasonality RVP (psi) | - | 9.98 | 7.9-11.6 | Seasonality RVP (psi) | 8-12.5 | AFPM 807 data points to 215 for NDPC, greater variety of locations. |

| NDPC Light Ends (Liquid Vol. %) | Well | Rail | Range | AFPM Light Ends (Liquid Vol. %) | | Comments |
|---|---|---|---|---|---|---|
| Ethane | 0.24 | 0.23 | 0.08-0.67 | Ethane | 0.5 | |
| Propane | 1.63 | 1.39 | 0.84-3.13 | Propane | <1-2% | |
| Isobutane | 0.65 | 0.58 | 0.35-0.95 | Isobutane | | |
| n-Butane | 3.16 | 2.75 | 2.00-4.55 | n-Butane | 3-4% | Reported as ranges only. |
| Isopentane | 1.52 | 1.42 | 1.10-1.93 | | | |
| n-Pentane | 2.90 | 2.72 | 2.07-3.70 | n-Pentane | - | |
| C2-C4s | 5.69 | 4.95 | 3.52-9.30 | C2-C4s | 3.5-11.9% | AFPM report, three respondents average 3.5%, fourth had 12 samples, range 5.9-11.9% |
| C2-C5s* | 10.12 | 9.10 | 6.77-14.71 | C2-C5 | 7.2 | *Excludes Cyclopentane |

The AFPM report did include additional data, which was not tested as part of the NDPC study. Many samples were tested for hydrogen sulfide ($H_2S$) in the vapor phase, and they were able to capture some samples that contained detectable $H_2S$. It is known that select pockets in legacy ND wells contain higher $H_2S$ concentrations, but that crude is typically segregated from low $H_2S$ Bakken crude for safety reasons. The AFPM study was also able to gather data on corrosivity using National Association of Corrosion Engineers (NACE) TM 172 testing, which confirmed the low corrosivity of Bakken crude. The AFPM paper also summarized data gathered on the pressure of rail cars measured as they reached their final destination. Over 380 cars were sampled, with a majority arriving to the refinery in the 7-10 psig range. The highest reported pressure recorded was 11.3 psig, well below the rated operating pressure of the DOT-111 rail cars or their minimum relief valve setting of 35 psig.

Despite the inability to draw a direct comparison between the AFPM and NDPC data, the results of both studies lead to the same conclusion. Bakken crude is a consistent product that clearly fits the classification of a Class 3 Flammable Liquid. The only point of debate would be the PG designation that is used, PG I versus PG II. That falls back to D86 testing of full boiling range materials, and the need for a reevaluation as to whether that is the most appropriate test method for the classification of materials such as Bakken for shipment.

## The Pipeline and Hazardous Materials Safety Administration (PHMSA) Report Comparison

PHMSA released a report on July 23, 2014, which included the results of their findings as part of *Operation Safe Delivery*. PHMSA found that, "Operation Classification has determined that the current classification applied to Bakken crude is accurate under the current classification system." The PHMSA report outlined the efforts of their testing program, which began in August 2013, and spanned through May 2014. Sampling was unannounced and intended to capture a representative sample of Bakken crude. The initial phase, from August-November 2013, was focused on verifying that appropriate hazard classes that were being used; and as such, testing was limited to flash point and boiling point. The second phase from February-May 2014 was to gain a complete understanding of Bakken properties and more closely align with the NDPC study. This data from Phase 2 was the data used to compare to the NDPC report.

The results outlined showed good agreement with the data collected as part of the NDPC study, especially when comparing data collected for the same general time period. Since the NDPC testing was done during the period from late March to late April 2014, the data points that fell in this general time frame were separated out and compared (11 total samples), as was the entire data set (88 total samples). Since the last round of PHMSA sampling was conducted at rail-loading facilities, for consistency, comparisons were made specifically with the NDPC rail data. As seen in Table 14 below, the results agreed very well, despite not being identical samples nor identical locations. The variation is minimal, and ranges agree well, with a trend toward slightly lower D86 IBP readings from PHMSA; although as discussed earlier, those results are subject to variation based on exact testing parameters and procedures.

**Table 14: Comparison of NDPC to PHMSA Study Data**

| | PHMSA Data Table E Mar-May (11 Samples) | | | NDPC Data Rail Only (49 Samples) | | |
|---|---|---|---|---|---|---|
| | Dates: | 3/17/14 | to 5/2/14 | Dates: | 3/25/14 | to 4/18/14 |
| | Average | Min | Max | Average | Min | Max |
| Flash Point (°F) | <50 | - | - | <73 | - | - |
| D86 IBP (°F) | 87.0 | 79.1 | 94.4 | 100.3 | 96.7 | 104.1 |
| VPCR 4 @ 100 °F (psi) | 12.28 | 10.22 | 14.28 | 11.52 | 9.57 | 12.85 |
| Ethane (% Vol) | 0.20 | 0.06 | 0.29 | 0.23 | 0.13 | 0.33 |
| Propane (% Vol) | 1.38 | 0.85 | 1.95 | 1.39 | 1.02 | 1.95 |
| Butane* (% Vol) | 3.49 | 3.01 | 4.44 | 3.32 | 2.63 | 4.24 |
| C2-C4 | 4.65 | 0.00 | 6.68 | 4.95 | 3.91 | 6.44 |

| | PHMSA Data Table E Total (88 Samples) | | | NDPC Data Total (152 Samples) | | |
|---|---|---|---|---|---|---|
| | Dates: | 2/24/14 | to 5/2/14 | Dates: | 3/25/14 | to 4/24/14 |
| | Average | Min | Max | Average | Min | Max |
| Flash Point (°F) | <50 | - | - | <73 | - | - |
| D86 IBP (°F) | 88.1 | 79.1 | 97.5 | 99.5 | 91.9 | 106.8 |
| VPCR 4 @ 100 °F (psi) | 12.42 | 10.10 | 15.10 | 11.69 | 8.93 | 14.37 |
| Ethane (Liq Vol %) | 0.23 | 0.06 | 0.40 | 0.24 | 0.08 | 0.67 |
| Propane (Liq Vol %) | 1.45 | 0.85 | 2.08 | 1.55 | 0.84 | 3.13 |
| Butane* (Liq Vol %) | 3.55 | 2.74 | 4.48 | 3.66 | 2.35 | 5.50 |
| C2-C4s | 5.17 | 0.00 | 6.88 | 5.45 | 3.33 | 9.30 |

*PHMSA report does not specify if isobutane was included in their measurements. For comparison purposes, this report assumes butane includes n-butane and isobutane.

In the conclusion of the report, PHMSA did note that, "We conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude." While PHMSA does say Bakken is currently classified appropriately as a Class 3 Flammable Liquid, PG 1 or 2, depending on D86 IBP, they claim that Bakken has "higher gas content, lower flash point, lower boiling point and higher vapor pressure than other crude oils." PHMSA makes this claim without testing or reporting what the values are for these other crude oils.

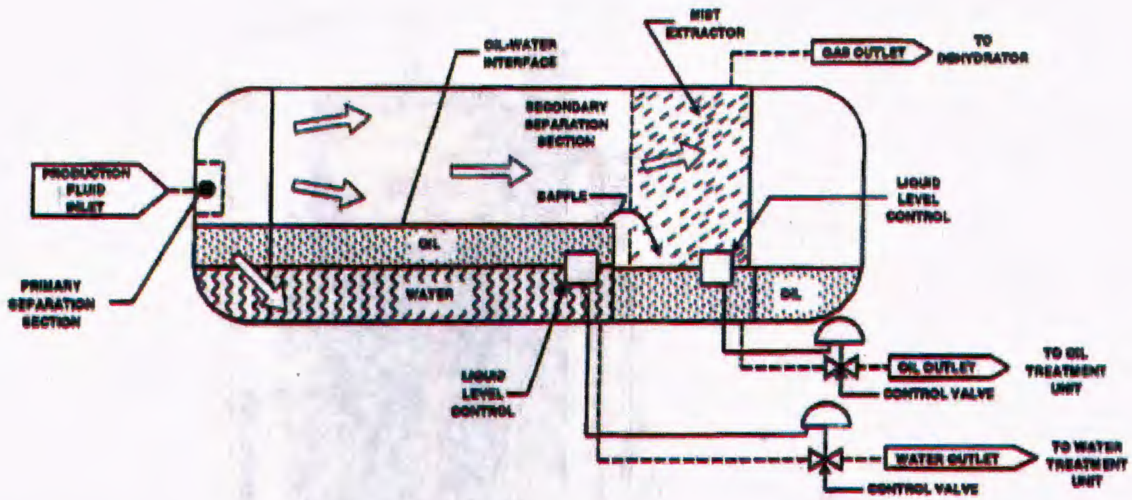
As we have noted previously, there have been no extensive or controlled sampling and testing programs for other light sweet crude oils, such as was done in both this NDPC study and the PHMSA program for Bakken; and, therefore, it is not possible to make a broad generalization on comparative properties. Based on limited information from the AFPM study, as well other publicly available data Bakken appears to be generally similar in vapor pressure and light ends content to most light crude oils, and there are certainly crudes, particularly those produced from tight oil formations, which are higher in those parameters. Additionally, making the claim that vapor pressure and light ends content correlates to increased ignitability and flammability is a broad statement that without extensive and complicated testing cannot be factually stated or supported.

## Operating Conditions

As part of the sampling program, operating conditions at the time of sample collection were taken for each well location sampled. This was done in order to determine if there were additional factors which may affect crude qualities. The conditions recorded included ambient temperature, separator and treater temperature and pressure, well production rate, equipment size and configuration, and for wells not attached to a gathering system, the time the stock tank was isolated from the well.

In order to better understand the impact the operational conditions play, a brief overview of wellhead crude processing is warranted. Raw crude, as it comes out of the ground, is a mix of gas, liquid hydrocarbons and water. The amount of each varies depending on geology and ambient temperature. The raw crude stream requires separation to remove the gas phase and separate entrained water before it is transferred to the stock tank. This is achieved by passing the crude through a separator and/or treater unit before it is stored and transported. Often, a standard three-phase (gas/oil/water) separator drum is used to separate the bulk water and gas from the hydrocarbon stream, as seen in Figure 12. The raw crude stream enters the separator drum and settles. Gas passes over and through a mist extractor, essentially a fine metal mesh, to collect and knock out entrained liquid before passing out of the drum to either be flared or captured. The liquid settles and separates as it flows through the vessel. In a three-phase separator, the liquid level is controlled so that the oil layer passes over a baffle and out of the vessel to tankage or for additional treatment. The water, which collects behind the baffle, is drained off and treated. Some wells may instead use a simple gas/liquid separator followed by a second liquid/liquid separator. In this configuration the liquid passes out without separating water and hydrocarbons, which then passes directly to a second separator or treater designed to separate the liquid hydrocarbons and water.

**Figure 12: Horizontal Three Phase (Gas/Liquid/Water) Separator Diagram**[1]

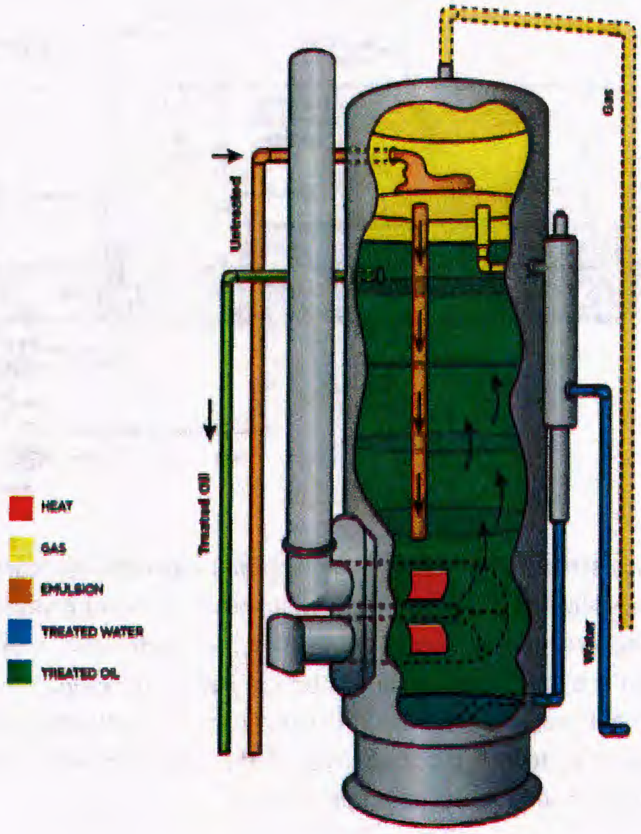



Often, the hydrocarbon stream that leaves a conventional separator still contains an emulsion of some water, the severity of which varies from well to well and on ambient conditions. In order to minimize water in the crude, the stream is often sent to a treater. A treater unit is, in effect, a second separator designed to help break the emulsion via the addition of heat and passing the crude through a coalescer or series of baffles to help separate out the remaining water. Heating the stream aids in separation of the oil and water in part by lowering the viscosity of the oil, which aids in coalescence of small water droplets to larger ones that can more easily separate.

Figure 13 shows how the untreated hydrocarbon stream, in orange, flows into the vessel and down through the heated section. In this section, the stream is heated and the water has a chance to separate. Similar to the separator, additional dissolved gasses evolved when the crude is heated are separated as well, and are either flared or collected. Some wells that do not have a lot of water in the crude, may use only a treater for oil treatment.

[1] Image: http://www.netl.doe.gov/Image%20Library/technologies/pwmis/BasSep_3PhaseSeparator.jpg

**Figure 13: Vertical Treater Diagram**[2]




The separator and treater operate at relatively constant conditions as set by the well operator. Typically, they operate under pressure (a range of 8-80 psig was recorded in this study) as the flow follows through the separator and treater to tankage. Adequate pressure is required to overcome any head pressure and allow movement of oil into the stock tank. When a treater is used, the stream is heated only enough to maximize separation of the emulsion (range up to 160°F was observed in this study), while minimizing the temperature to which the stream needs to be heated. There are several reasons to limiting temperature, including energy cost of heating, increased hydrocarbon losses to flare and potential for increased tank emissions.

Due to the difficulty and hazards associated with sampling a raw well stream, crude was sampled from the stock tank after it passed through the separator and/or treater. This is consistent with measuring the quality of the crude that would be transported via rail. Additional notes were taken on whether the wells were connected to gathering systems; small pipeline networks designed to take the oil to central facilities to be loaded to rail or major pipeline systems. Other wells fill stock tanks and require trucks to

[2] Image: http://www.des-co.com/portfolioentry/heater-treaters/

haul crude away. Wells not on gathering systems were sampled from their full stock tanks after they were safely filled and isolated from the well.

As discussed previously, on the first visit to each location, samples were taken at both the top and bottom of the tank. This was done to determine if there was a variance or stratification taking place in tanks, either at the well or at the rail terminals. No stratification was observed, with relative uniformity of properties from the top to bottom. On subsequent visits, samples at each location were composite samples of the tanks. The average delta (top-bottom) for rail, well and overall samples is summarized in Table 15, with complete data available in the appendix.

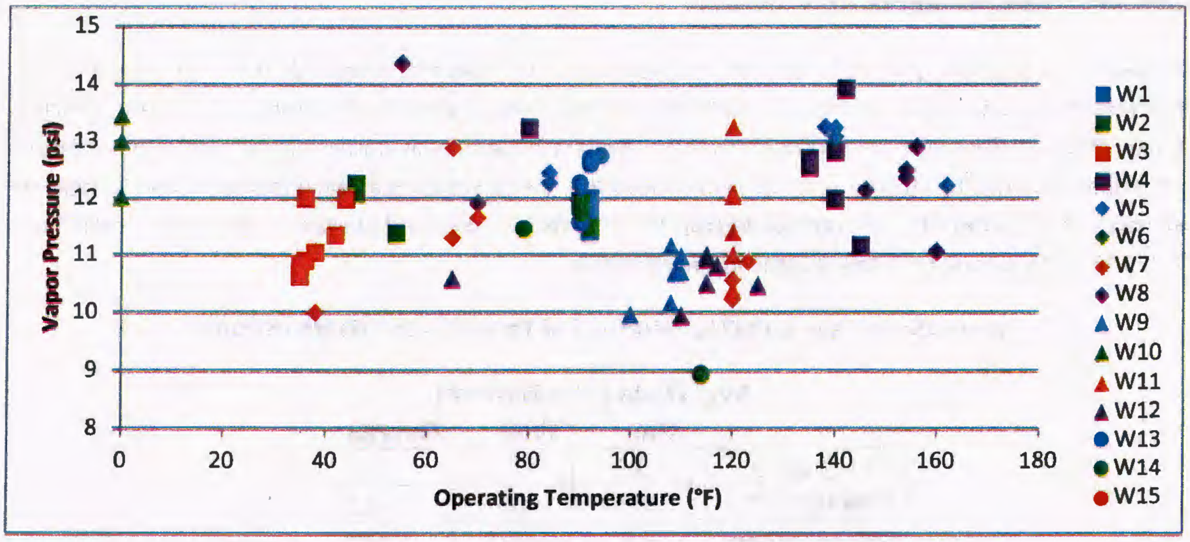
**Table 15: Average Delta (Top-Bottom) of Tank, Rail and Overall Samples**

| | Avg. Delta (Top-Bottom) | | |
|---|---|---|---|
| | Rail | Well | Overall |
| API Gravity | 0.0 | 0.2 | 0.1 |
| D86 IBP (°F) | 0.5 | -0.9 | -0.5 |
| Vapor P (psi) | 0.12 | 0.01 | 0.05 |
| **Light Ends (Liquid Vol. %)** | | | |
| Ethane | 0.00 | 0.02 | 0.01 |
| Propane | 0.00 | 0.05 | 0.03 |
| Isobutane | 0.00 | 0.01 | 0.01 |
| n- Butane | 0.00 | 0.05 | 0.03 |
| Isopentane | 0.00 | 0.01 | 0.01 |
| n- Pentane | 0.01 | 0.03 | 0.02 |
| Cyclopentane | 0.00 | 0.00 | 0.00 |
| C2-C4s | -0.01 | 0.12 | 0.08 |
| C2-C5s* | 0.00 | 0.15 | 0.10 |

*Excludes Cyclopentane

Vapor pressure showed no clear correlation with operating conditions. Production rate did not show any appreciable impact on the vapor pressure (this is covered later in this report). The same was seen with both operating pressure and temperature. The measured vapor pressure was scattered throughout the range of temperatures and pressures, with no clear correlation. Figure 14, below, shows a plot of vapor pressure versus operational temperature. A plot of vapor pressure versus operating pressure can be seen in Figure 1-1 in the Appendix.

**Figure 14: Vapor Pressure versus Operating Temperature**




The results of the testing did show a slight correlation between operating temperature and light ends (ethane/propane) content, which would be expected. Otherwise, there was no clear correlation between either operating pressure or production rate and the subsequent vapor pressure or ethane/propane content in the crude. While both the separator and treater separate out gas phase from the mixed stream, they are not designed as "stabilizers" to treat the crude. Their purpose is to remove entrained gases and water. Stabilizers, often used in condensate (crude API 50°+) service separate out the lightest components from a given hydrocarbon stream. Those components are then transported separately as liquefied petroleum gas (LPG) and NGLs in pressurized rail cars alongside Bakken crude. This would ultimately be shifting responsibility from one type of rail car to another, concentrating and magnifying potential risks. As with any crude oil, some dissolved light ends will exist in Bakken, and will only be completely removed when the crude is fully fractionated in a refinery setting. This is true of any light crude oil, regardless of the separator and treater setup is used.

Figure 15 and Figure 16 show the effect of operating temperature on the ethane and propane concentrations. There is a slight trend toward lower concentrations at higher temperatures. This is plausible, as some of the lightest components will be driven off as the crude is heated. This would be most apparent in winter months when this test was conducted and ambient temperatures are low. In the summer months, ambient temperatures may reach 100°F or more, making use of the treater less impactful. Figures 1-2 through 1-5 in the Appendix show the charts of the ethane and propane versus operating pressure and production rate, for reference.

Figure 15: Ethane Liquid Vol. % versus Operating Temperature

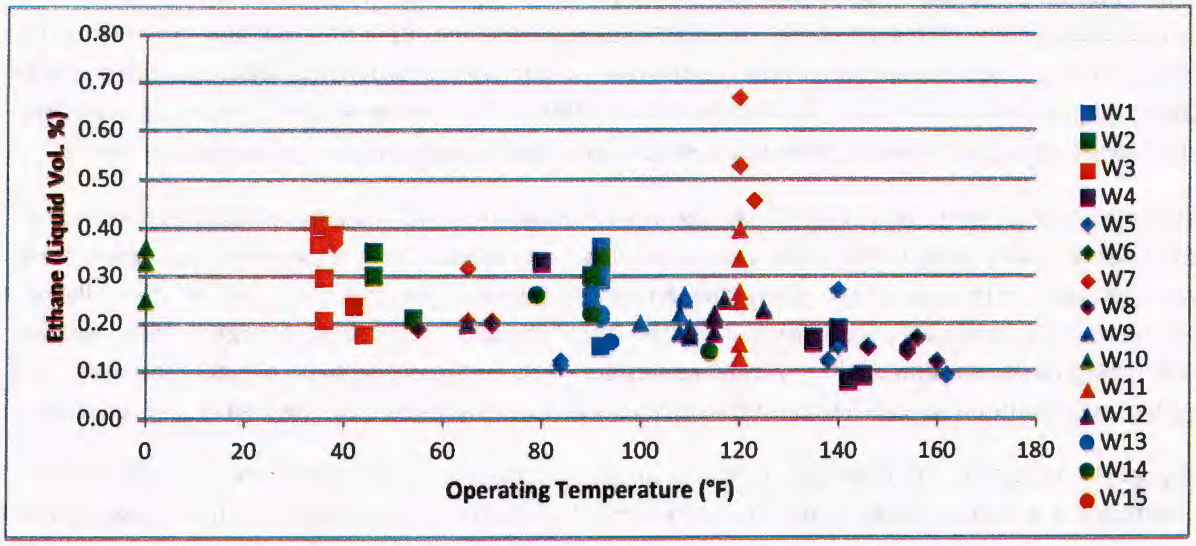
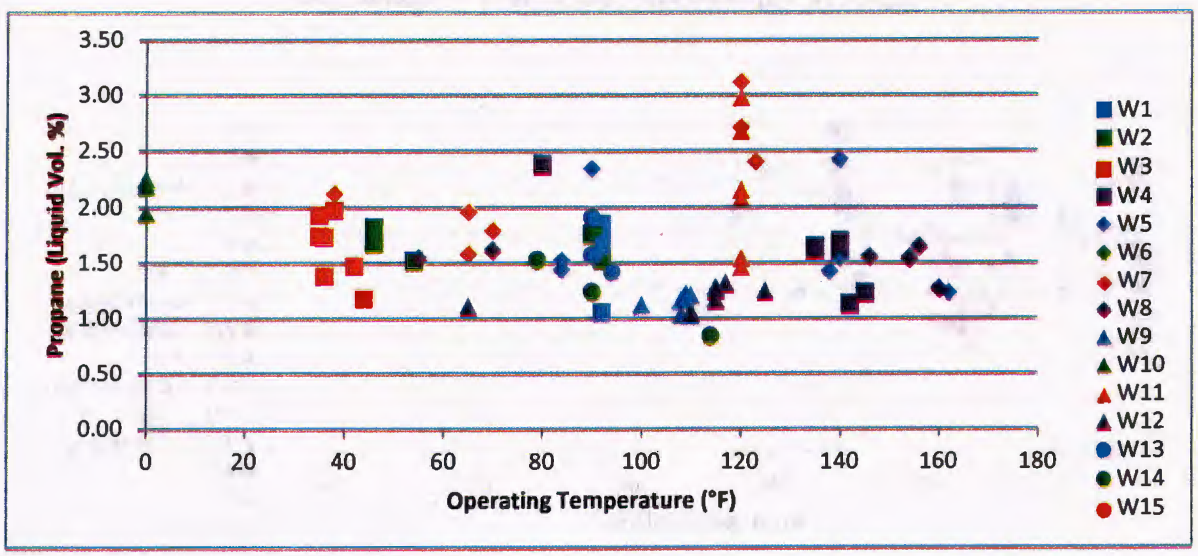



Figure 16: Propane Liquid Vol. % versus Operating Temperature




Based on these findings, a general correlation between the operating temperature of the treater and the ethane or propane concentration was developed. Excluding the few points that were anomalous from W7, the following correlations were developed (charts can be seen in the Appendix, Figures 1-6 and 1-7):

1. Ethane (Liquid Vol %) = -0.0013 * Temp (°F) + 0.3568; and
2. Propane (Liquid Vol %) = -0.0025 * Temp (°F) + 1.8414.

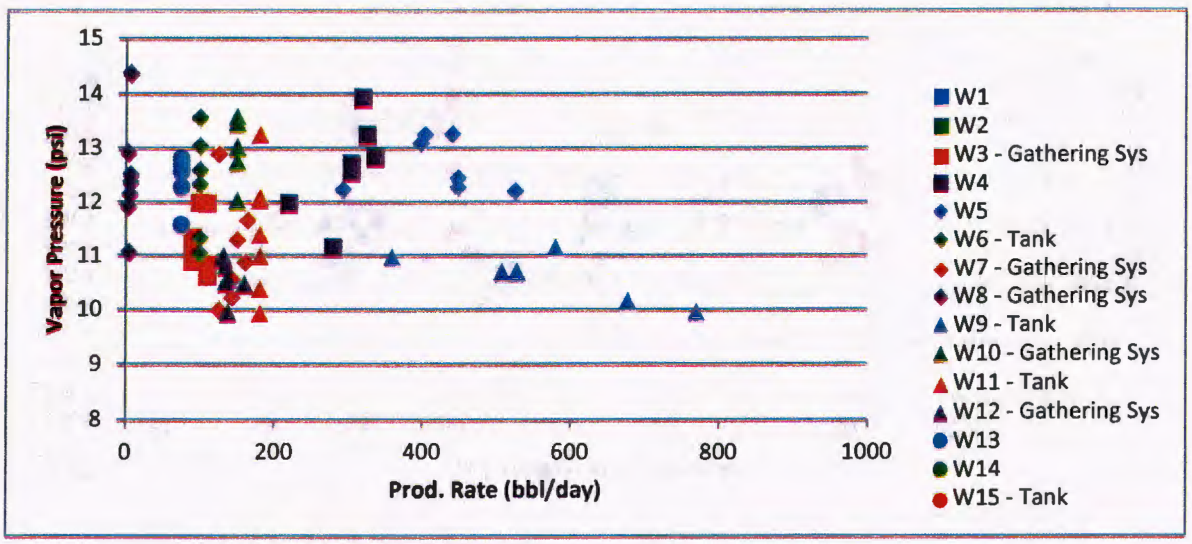
These equations hold that the difference in concentration between 50°F and 150°F operation is 0.13 and 0.25 liquid vol. % for ethane and propane, respectively. This represents approximately 0.4 liquid vol. %

of the total crude stream. It would stand that operating the treaters toward the higher end of their operating range would ensure maximum reduction of the light ends fractions of the crude oil with current equipment. Because of this, the NDPC recommends that operators run their treaters at the highest feasible operational temperature that allows for safe and consistent operation, to help minimize these components in the crude. This recognizes the limits of both treater design and the limits set forth for the safe storage of crude in stock tanks, which have upper bounds on crude storage temperature.

The impact of stock tanks for crude storage versus being connected to a gathering system on vapor pressure was also considered. Stock tanks hold produced crude and sit for a short time before being pumped out. In the case of this study, the duration between a filled stock tank and sample collection was as much as a day and a half. Because of this, there is a small opportunity for light ends to weather off. The comparison showed there was no appreciable trend between samples collected from wells on a gathering system versus those that used a stock tank and were isolated from the well before collection.

Figure 17 shows the data for this comparison, plotted for those wells with which we had distinct information on their configuration. This is expected, as tanks are designed to minimize evaporative emissions; so significant changes in vapor pressure would indicate the possibility of high tank emissions.

**Figure 17: Vapor Pressure versus Well Production Rate**




## Overview of Sampling, Analytical Methods and Quality Control/Quality Assurance

### Sampling

All samples were obtained at both the well and rail facilities by trained SGS personnel, based out of Williston, ND, following accepted industry practices for collection of crude oil samples. Sampling procedures in API Chapter 8.1 "Manual Sampling of Petroleum and Petroleum Products" formed the basis for their sampling methodology. SGS has also written in-house sampling procedures that supplement the API document, as part of their standard operating procedures.

The crude oil samples were collected in chilled one-quart glass bottles, immediately sealed, chilled, and transported to the Williston lab. This is very similar to sampling procedures used for finished gasoline, which has a RVP of up to 15 psi. All analyses in Williston were conducted within a few days of receipt.

As discussed before, on the first visit to each site, individual "top" and "bottom" level samples were obtained and analyzed. This was conducted to evaluate tank stratification. On subsequent visits to each site, "average" tank samples were collected.

On samples obtained from the last two visits to each site, the D7169 simulated distillation analysis was excluded. Results from this test were showing good consistency, and the continued analysis was adding little to the understanding of the light ends portion of the crude oil.

**Analytical Methods and Quality Control/Quality Assurance**

SGS, the primary contact lab utilized for the collection and analyses of the Bakken crude oil well and rail loading facility samples, is ISO 9001 certified at the corporate level. The St. Rose, LA lab, used to conduct the more sophisticated light ends and D7169 gas chromatographic simulated distillation analyses, is fully certified. The more recently acquired Williston, ND lab, used for the sample collection, API gravity, flash point, IBP by D86, and vapor pressure by D6377 analyses, is in the process of obtaining ISO 9001 certification.

ISO 9001:2008 is based on eight quality management principles:

- Customer focus;
- Leadership;
- Involvement of people;
- Process approach;
- System approach;
- Continual improvement;
- Fact-based decision making; and
- Mutually beneficial supplier relationships.

SGS follows standard ASTM methods. They ensure use of the most current standards by subscription to Tracker Alert biweekly, which provides prompt update notification. The updates are stored electronically for analyst referral at both labs.

Corporately, approximately 50 of the SGS labs participate in the ASTM Crude Oil Proficiency Program. This program, commonly referred to as a "round-robin" program, involves ASTM periodically preparing and supplying identical crude oil samples to labs all over the world. The labs then conduct their analyses and submit their results to ASTM. ASTM compiles the results and publishes the data, using lab code numbers to protect the identity of the labs. Each lab receives their own code number so they know their performance and how their results compare to the other participating labs, but do not know the identity of other participants. Programs such as this are vital for laboratories to evaluate their performance, take corrective action, and continually improve.

Specific QA/QC procedures for each of the analytical methods are described below.

- API Gravity by ASTM D5002 "Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Meter" - This method is specifically for the measurement of crude oils. The instrumentation is calibrated with freshly distilled water as described in Section 10 of the method.

- Flash Point by ASTM D3278 (Williston lab) or ASTM D56 (St. Rose lab) - Flash point measures the tendency of the material to form a flammable mixture with air under controlled laboratory conditions. Section §173.120 of Hazardous Material Regulations allows for the use of either ASTM D56 or D3828. Both D56 and D3278 are very similar. ASTM D56 is the "Standard Method for Flash Point by Tag Closed Cup Tester," while ASTM D3278 is "Standard Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus." Para-Xylene is used as a calibration/check standard for this method, and records were provided by SGS showing acceptable results for this material.

  In the case of flash point, it was not necessary to determine the exact flash point, but only to determine whether the value was above or below the critical value of 73°F, which distinguishes between PG II and PG III.

- IBP by ASTM D86 "Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure" - This method, originally approved by ASTM in 1921 is still utilized for certification of petroleum products such as gasoline and diesel fuel. Temperature bias is determined using reagent grade toluene as a standard, as described in Section 9 of the method. To verify the temperature measurement, pure n-hexadecane is used. SGS provided examples of the instrument printouts for the analyses of both of these reference materials.

  It should be noted that full boiling range crude oils are not within the scope of this method as described in Section 1. Thus, various labs have employed different conditions for the condenser and receiver temperatures. These parameters were shown to have a significant impact on the recorded IBP of whole crudes. However, these differences have only a minimal effect on the analysis of the standard materials. Thus, acceptable results on the standard materials do NOT ensure correct IBPs on whole crude.

- Vapor Pressure of Crude Oil (VPCRx) by ASTM D6377 "Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method)" - This newer method (originally published in 1999) has become the method of choice for vapor pressure measurements of whole crude oils, and EPA recommended its use in a recent publication for determining storage tank compliance. Section 11 of the method describes Quality Control Checks and indicates that Pentane, 2,2-Dimethylbutane, or 2,3-Dimethylbutane may be used as acceptable reference fluids. SGS uses 2,2-Dimethylbutane, and provided results showing all values within the acceptable limits of 10.58 psi – 10.92 psi for this standard material.

- Light Ends in Crude Oil by IP344-88 (2010) "Determination of light hydrocarbons in stabilized crude oils- Gas Chromatography method" - This is an Institute of Petroleum (IP) method. IP is the British equivalent of ASTM. This is an internal standard gas chromatography (GC) method. No reference standard is used, but participation in the ASTM Crude Oil Proficiency program is used to evaluate the accuracy of the results from this analysis.

- Boiling Range Distribution by ASTM D7169 "Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography" - This newer method (originally published in 2005) is an external standard approach to obtain distillation type data for full-range crude oils. A reference gas oil is used for determination of detector response and evaluation of boiling points. This standard is run regularly. Blank runs are made to determine the baseline correction.

Documentation was also provided showing calibration information for balances and thermometers used in various laboratory methods.

## Appendix 1: Additional Figures

**Figure 1-1: Vapor Pressure versus Operating Pressure**

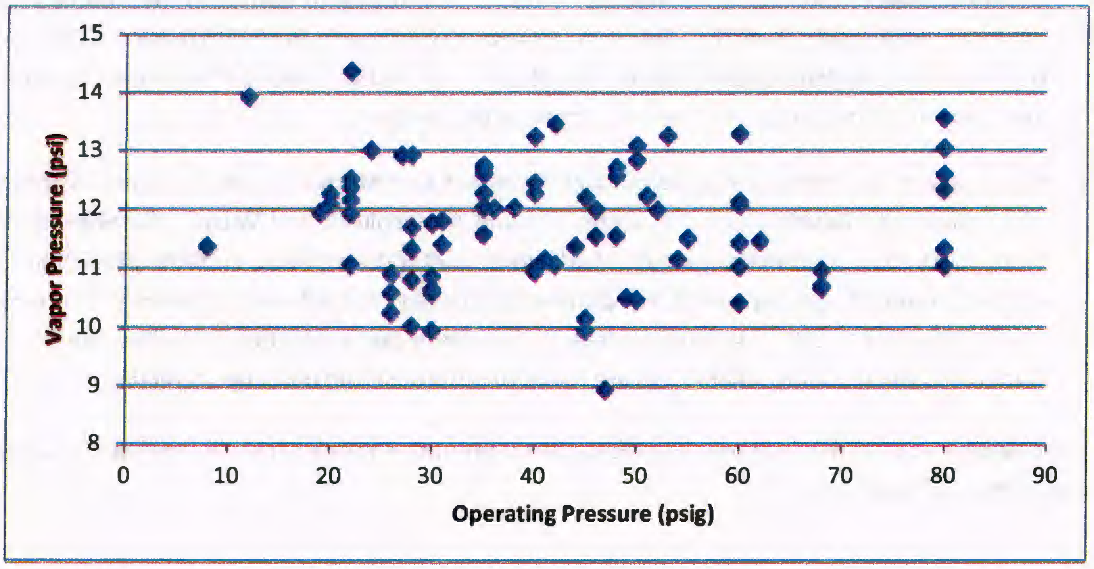
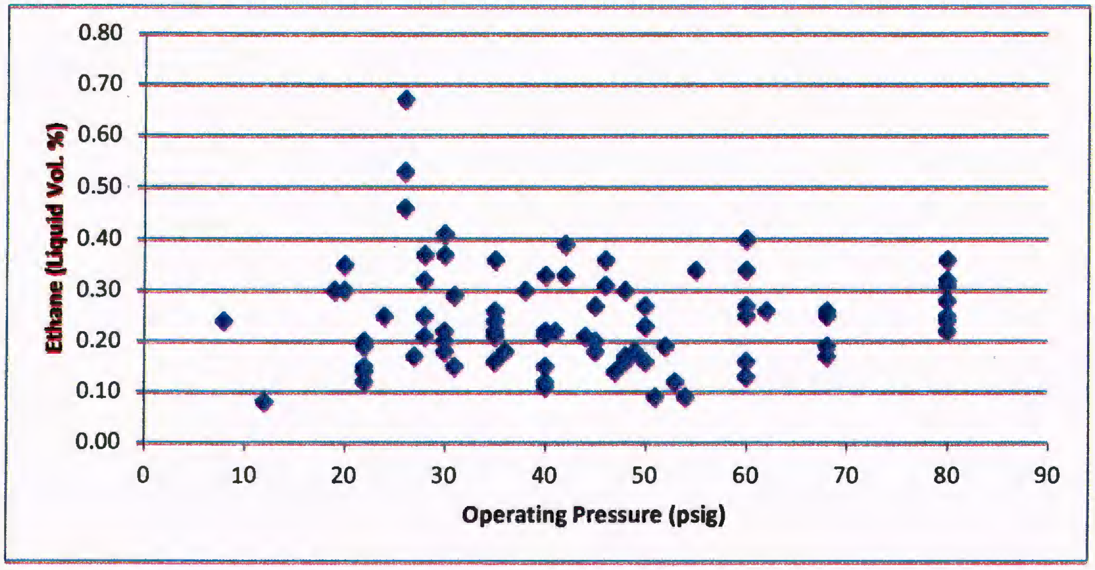



**Figure 1-2: Ethane Liquid Vol. % versus Operating Pressure**



## Appendix 1: Additional Figures

**Figure 1-3: Ethane Liquid Vol. % versus Production Rate**

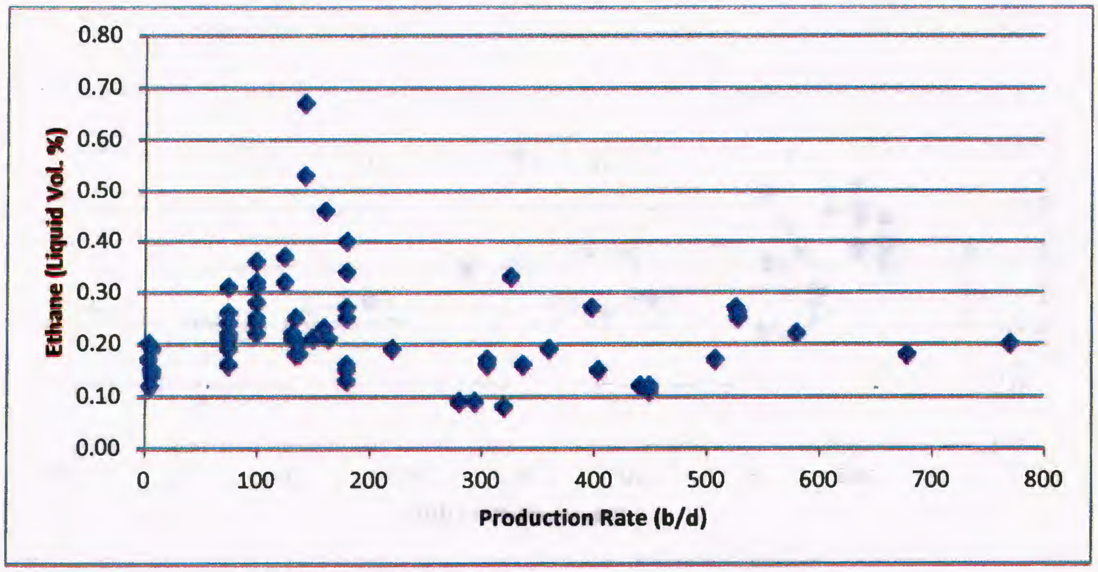
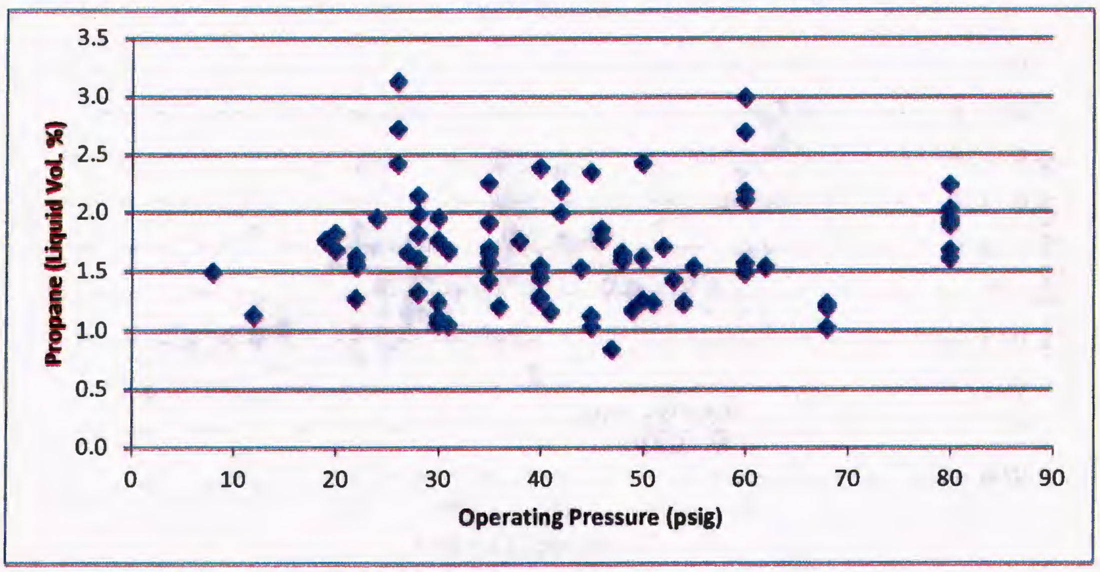



**Figure 1-4: Propane Liquid Vol. % versus Operating Pressure**



## Appendix 1: Additional Figures

**Figure 1-5: Propane Liquid Vol. % versus Production Rate**

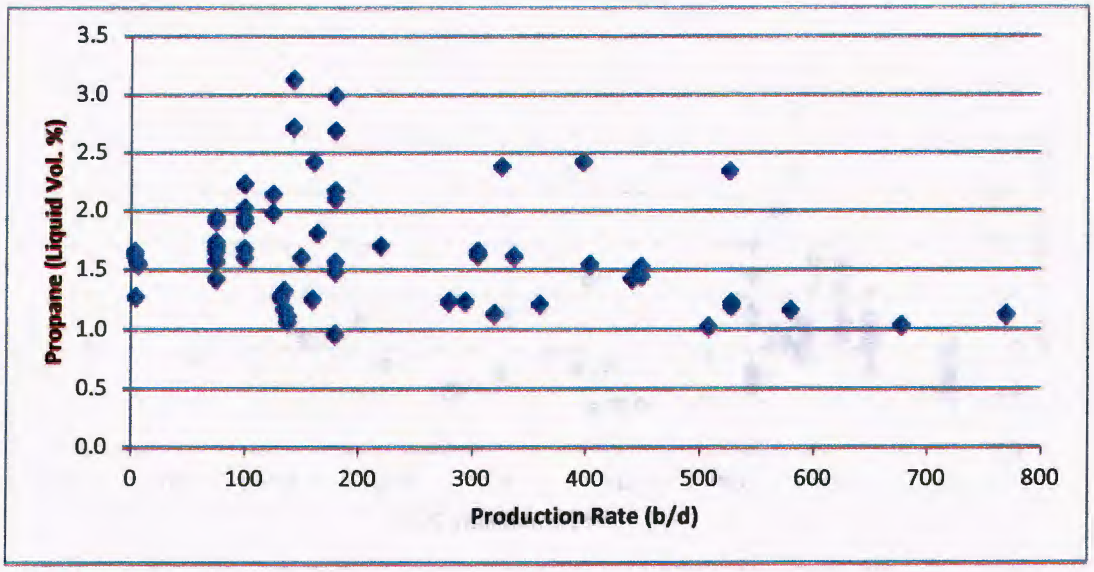
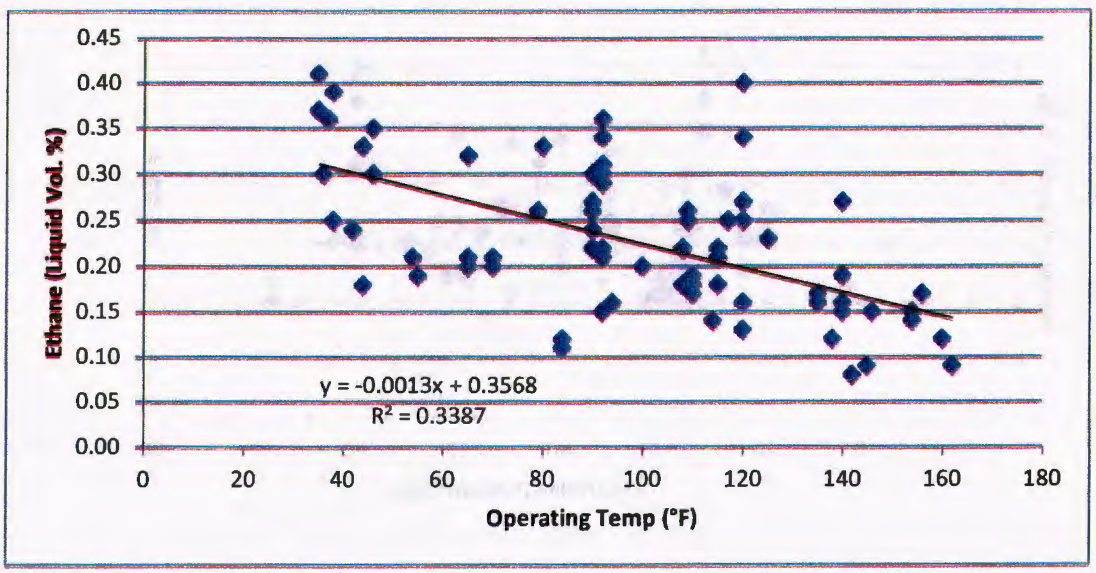


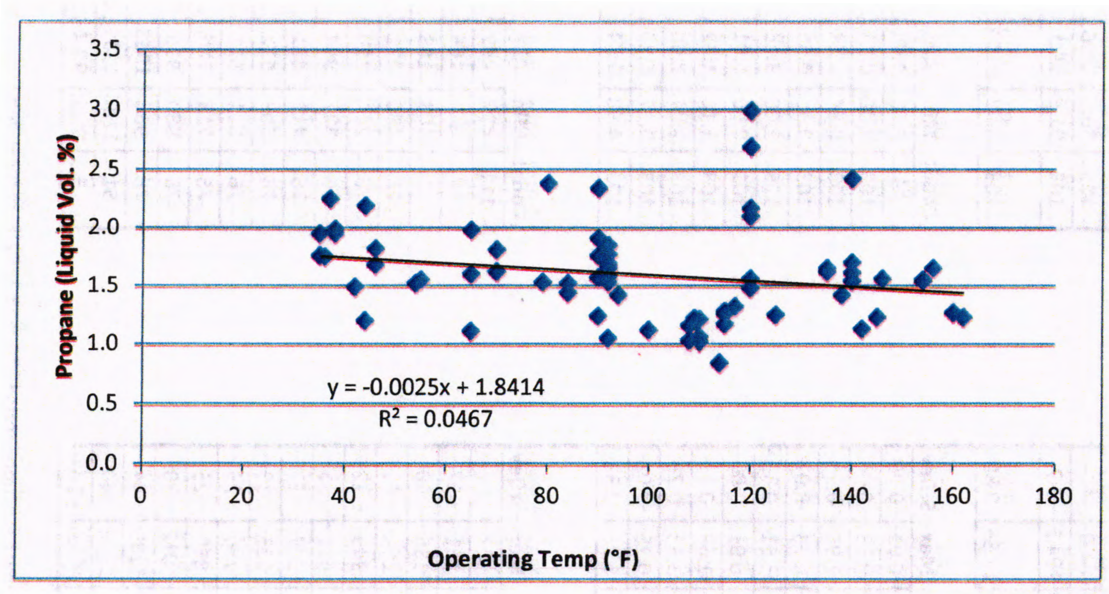

**Figure 1-6: Ethane Liquid Vol. % versus Operating Temperature: Correlation**

Note: anomalous readings from W7 excluded to improve correlation.



**Appendix 1: Additional Figures**

**Figure 1-7: Propane Liquid Vol. % versus Operating Temperature: Correlation**
Note: anomalous readings from W7 excluded to improve correlation.



## Appendix 2 - Summary Data

**Total**

| | Count | Min | Avg | Max | StDev |
|---|---|---|---|---|---|
| **Ambient Temp (°F)** | 108 | 10.0 | **33.8** | 65.0 | 13.7 |
| **API Gravity** | 152 | 36.7 | **41.0** | 46.3 | 2.2 |
| **D86 IBP (°F)** | 152 | 91.9 | **99.5** | 106.8 | 2.4 |
| **Vapor P via D6377 (100°F, 4:1 V/L) (psi)** | 152 | 8.93 | **11.69** | 14.37 | 0.97 |
| **Light Ends via IP344** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **Methane** | 152 | 0.00 | **0.00** | 0.01 | 0.00 |
| **Ethane** | 152 | 0.08 | **0.24** | 0.67 | 0.08 |
| **Propane** | 152 | 0.84 | **1.55** | 3.13 | 0.41 |
| **Isobutane** | 152 | 0.35 | **0.63** | 0.95 | 0.13 |
| **n- Butane** | 152 | 2.00 | **3.03** | 4.55 | 0.56 |
| **Neopentane** | 150 | 0.00 | **0.01** | 0.01 | 0.00 |
| **Isopentane** | 152 | 1.10 | **1.49** | 1.93 | 0.20 |
| **n- Pentane** | 152 | 2.07 | **2.84** | 3.70 | 0.38 |
| **Cyclopentane** | 152 | 0.17 | **0.22** | 0.30 | 0.03 |
| **Hexanes** | 152 | 4.98 | **6.33** | 7.64 | 0.56 |
| **Simulated Distillation via D7169** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **IBP** | 111 | <97 | **<97** | <97 | |
| **5%*** | 111 | 97 | **108** | 151 | 17 |
| **10%*** | 111 | 103 | **157** | 188 | 17 |
| **20%** | 111 | 180 | **234** | 278 | 20 |
| **30%** | 111 | 244 | **312** | 375 | 25 |
| **40%** | 111 | 327 | **395** | 476 | 29 |
| **50%** | 111 | 412 | **481** | 578 | 33 |
| **60%** | 111 | 508 | **572** | 684 | 35 |
| **70%** | 111 | 611 | **671** | 796 | 39 |
| **80%** | 111 | 718 | **786** | 920 | 42 |
| **90%** | 111 | 860 | **936** | 1069 | 43 |
| **95%** | 111 | 966 | **1056** | 1192 | 52 |
| **FBP*** | 111 | 1186 | **1309** | 1362 | 44 |
| **Recovery (weight %)** | 111 | 95.7 | **99.3** | 100.0 | 1.1 |

**Rail**

| | Count | Min | Avg | Max | StDev |
|---|---|---|---|---|---|
| **Ambient Temp (°F)** | 37 | 10.0 | **28.7** | 47.0 | 9.8 |
| **API Gravity** | 49 | 39.2 | **41.7** | 44.0 | 1.3 |
| **D86 IBP (°F)** | 49 | 96.7 | **100.3** | 104.1 | 1.7 |
| **Vapor P via D6377 (100°F, 4:1 V/L) (psi)** | 49 | 9.57 | **11.52** | 12.85 | 0.80 |
| **Light Ends via IP344** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **Methane** | 27 | 0.00 | **0.00** | 0.01 | 0.00 |
| **Ethane** | 49 | 0.13 | **0.23** | 0.33 | 0.04 |
| **Propane** | 49 | 1.02 | **1.39** | 1.95 | 0.24 |
| **Isobutane** | 49 | 0.46 | **0.58** | 0.73 | 0.07 |
| **n- Butane** | 49 | 2.17 | **2.75** | 3.51 | 0.33 |
| **Neopentane** | 49 | 0.00 | **0.01** | 0.01 | 0.00 |
| **Isopentane** | 49 | 1.17 | **1.42** | 1.69 | 0.11 |
| **n- Pentane** | 49 | 2.12 | **2.72** | 3.33 | 0.23 |
| **Cyclopentane** | 49 | 0.17 | **0.21** | 0.25 | 0.02 |
| **Hexanes** | 49 | 5.46 | **6.33** | 6.96 | 0.32 |
| **Simulated Distillation via D7169** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **IBP** | 111 | <97 | **<97** | <97 | |
| **5%*** | 21 | 98 | **113** | 151 | 17 |
| **10%*** | 35 | 143 | **165** | 186 | 10 |
| **20%** | 35 | 216 | **238** | 264 | 11 |
| **30%** | 35 | 289 | **316** | 346 | 12 |
| **40%** | 35 | 364 | **396** | 436 | 15 |
| **50%** | 35 | 443 | **482** | 527 | 17 |
| **60%** | 35 | 527 | **572** | 623 | 19 |
| **70%** | 35 | 620 | **670** | 730 | 23 |
| **80%** | 35 | 733 | **787** | 850 | 25 |
| **90%** | 35 | 888 | **939** | 1012 | 30 |
| **95%** | 35 | 1000 | **1060** | 1180 | 44 |
| **FBP*** | 21 | 1217 | **1317** | 1342 | 40 |
| **Recovery (weight %)** | 35 | 95.9 | **99.3** | 100.0 | 1.1 |

**Well**

| | Count | Min | Avg | Max | StDev |
|---|---|---|---|---|---|
| **Ambient Temp (°F)** | 71 | 11.0 | **36.5** | 65.0 | 14.7 |
| **API Gravity** | 103 | 36.7 | **40.6** | 46.3 | 2.4 |
| **D86 IBP (°F)** | 103 | 91.9 | **99.1** | 106.8 | 2.6 |
| **Vapor P via D6377 (100°F, 4:1 V/L) (psi)** | 103 | 8.93 | **11.77** | 14.37 | 1.04 |
| **Light Ends via IP344** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **Methane** | 79 | 0.00 | **0.00** | 0.01 | 0.00 |
| **Ethane** | 103 | 0.08 | **0.24** | 0.67 | 0.09 |
| **Propane** | 103 | 0.84 | **1.63** | 3.13 | 0.45 |
| **Isobutane** | 103 | 0.35 | **0.65** | 0.95 | 0.15 |
| **n- Butane** | 103 | 2.00 | **3.16** | 4.55 | 0.60 |
| **Neopentane** | 101 | 0.00 | **0.01** | 0.01 | 0.00 |
| **Isopentane** | 103 | 1.10 | **1.52** | 1.93 | 0.23 |
| **n- Pentane** | 103 | 2.07 | **2.90** | 3.70 | 0.43 |
| **Cyclopentane** | 103 | 0.17 | **0.23** | 0.30 | 0.03 |
| **Hexanes** | 103 | 4.98 | **6.34** | 7.64 | 0.64 |
| **Simulated Distillation via D7169** | **Count** | **Min** | **Avg** | **Max** | **StDev** |
| **IBP** | 111 | <97 | **<97** | <97 | |
| **5%*** | 28 | 97 | **106** | 150 | 18 |
| **10%*** | 71 | 103 | **153** | 188 | 19 |
| **20%** | 76 | 180 | **231** | 278 | 23 |
| **30%** | 76 | 244 | **310** | 375 | 29 |
| **40%** | 76 | 327 | **394** | 476 | 34 |
| **50%** | 76 | 412 | **481** | 578 | 38 |
| **60%** | 76 | 508 | **572** | 684 | 41 |
| **70%** | 76 | 611 | **671** | 796 | 45 |
| **80%** | 76 | 718 | **785** | 920 | 48 |
| **90%** | 76 | 860 | **935** | 1069 | 48 |
| **95%** | 76 | 966 | **1053** | 1192 | 55 |
| **FBP*** | 51 | 1186 | **1305** | 1362 | 45 |
| **Recovery (weight %)** | 76 | 95.7 | **99.4** | 100.0 | 1.1 |

* Items with astricks were adjusted averages, to account for one or more values that were above or below detection limits (97°F and 1382°F, respectively).
Those items were adjusted by averaging the detection limit for those values, and thus the averages may be slightly above or below the actual value.
Raw data can be seen in the other sheets for reference.

## Appendix 3 - Sample Conditions - Rail Locations

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | 32 | Glass Bottle | 100,000 | 10ft | Top |
| R1 | 3/25/2014 | 17:00 | 32 | Glass Bottle | 100,000 | 10ft | Bottom |
| R1 | 3/27/2014 | 17:26 | 33 | Glass Bottle | 100,000 | 10ft | All Levels |
| R1 | 3/31/2014 | 14:08 | 19 | Glass Bottle | 100,000 | 16ft 2in | All Levels |
| R1 | 4/9/2014 | 10:38 | | Glass Bottle | 100,000 | | All Levels |
| R1 | 4/16/2014 | 15:30 | | Glass Bottle | 100,000 | | All Levels |
| R1 | 4/18/2014 | 11:00 | | Glass Bottle | 100,000 | | All Levels |
| R2 | 3/25/2014 | 18:00 | 20 | Glass Bottle | 250,000 | | Top |
| R2 | 3/25/2014 | 18:00 | 20 | Glass Bottle | 250,000 | | Bottom |
| R2 | 3/27/2014 | 10:30 | 25 | Glass Bottle | 250,000 | | All Levels |
| R2 | 3/31/2014 | 12:30 | 13 | Glass Bottle | 250,000 | 46ft 9in | All Levels |
| R2 | 4/8/2014 | 10:20 | 45 | Glass Bottle | 250,000 | 43ft | All Levels |
| R2 | 4/15/2014 | 11:30 | | Glass Bottle | 250,000 | 39ft 6in | All Levels |
| R2 | 4/18/2014 | 10:20 | 34 | Glass Bottle | 250,000 | 34ft | All Levels |
| R3 | 3/26/2014 | 14:30 | 29 | Glass Bottle | 50ft | 41ft | Top |
| R3 | 3/26/2014 | 14:30 | 29 | Glass Bottle | 50ft | 41ft | Bottom |
| R3 | 3/28/2014 | 13:30 | 32 | Glass Bottle | 50ft | 42ft | All Levels |
| R3 | 4/1/2014 | 16:10 | 17 | Glass Bottle | 50ft | 33ft | All Levels |
| R3 | 4/10/2014 | 14:50 | | Glass Bottle | 50ft | | All Levels |
| R3 | 4/15/2014 | 14:15 | 46 | Glass Bottle | 50ft | 42ft | All Levels |
| R3 | 4/17/2014 | 13:00 | 32 | Glass Bottle | 50ft | 42ft | All Levels |
| R4 | 3/25/2014 | 14:30 | 20 | Glass Bottle | 250,000 | 23ft | Top |
| R4 | 3/25/2014 | 14:30 | 20 | Glass Bottle | 250,000 | 23ft | Bottom |
| R4 | 3/27/2014 | 11:50 | 19 | Glass Bottle | 250,000 | 18ft | All Levels |
| R4 | 3/31/2014 | 11:20 | 10 | Glass Bottle | 250,000 | 17ft | All Levels |
| R4 | 4/7/2014 | 13:45 | 47 | Glass Bottle | 250,000 | 18ft | All Levels |
| R4 | 4/16/2014 | 12:35 | | Glass Bottle | 250,000 | | All Levels |
| R4 | 4/18/2014 | 12:05 | 37 | Glass Bottle | 250,000 | 23ft | All Levels |

**Appendix 3 - Sample Conditions - Rail Locations**

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| R5 | 3/26/2014 | 12:00 | 36 | Glass Bottle | 45ft | 39ft | Top |
| R5 | 3/26/2014 | 12:00 | 36 | Glass Bottle | 45ft | 39ft | Bottom |
| R5 | 3/28/2014 | 12:00 | 32 | Glass Bottle | 45ft | 32ft | All Levels |
| R5 | 4/1/2014 | 14:30 | 15 | Glass Bottle | 45ft | 39ft | All Levels |
| R5 | 4/10/2014 | 13:15 | | Glass Bottle | 45ft | | All Levels |
| R5 | 4/15/2014 | 12:50 | 44 | Glass Bottle | 45ft | 40ft | All Levels |
| R5 | 4/17/2014 | 11:40 | 32 | Glass Bottle | 45ft | 28ft | All Levels |
| R6 | 3/26/2014 | 15:30 | 29 | Glass Bottle | 250,000 | | Top |
| R6 | 3/26/2014 | 15:30 | 29 | Glass Bottle | 250,000 | | Bottom |
| R6 | 3/27/2014 | 15:30 | 33 | Glass Bottle | 250,000 | | All Levels |
| R6 | 3/31/2014 | 14:00 | 13 | Glass Bottle | 250,000 | 27ft 4in | All Levels |
| R6 | 4/7/2014 | 15:00 | | Glass Bottle | 250,000 | | All Levels |
| R6 | 4/15/2014 | 14:00 | | Glass Bottle | 250,000 | 34ft 6in | All Levels |
| R6 | 4/17/2014 | 12:00 | | Glass Bottle | 250,000 | 38ft 6in | All Levels |
| R7 | 3/26/2014 | 19:30 | 28 | Glass Bottle | 250,000 | 40ft | Top |
| R7 | 3/26/2014 | 19:30 | 28 | Glass Bottle | 250,000 | 40ft | Bottom |
| R7 | 3/28/2014 | 13:00 | 46 | Glass Bottle | 250,000 | 42ft | All Levels |
| R7 | 3/31/2014 | 17:00 | 22 | Glass Bottle | 250,000 | 35ft 6in | All Levels |
| R7 | 4/11/2014 | 10:50 | | Glass Bottle | 250,000 | | All Levels |
| R7 | 4/14/2014 | 12:30 | 27 | Glass Bottle | 250,000 | 40ft | All Levels |
| R7 | 4/18/2014 | 10:00 | | Glass Bottle | 250,000 | 33ft | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 18 | Glass Bottle | 400 | 15ft | Top |
| W1 | 3/25/2014 | 19:45 | 18 | Glass Bottle | 400 | 15ft | Bottom |
| W1 | 3/27/2014 | 18:15 | 26 | Glass Bottle | 400 | 15ft | All Levels |
| W1 | 3/30/2014 | 16:00 | 39 | Glass Bottle | 400 | 15ft | All Levels |
| W1 | 4/1/2014 | 11:00 | | Glass Bottle | 400 | | All Levels |
| W1 | 4/7/2014 | 12:20 | 31 | Glass Bottle | 400 | 18ft | All Levels |
| W1 | 4/16/2014 | 11:30 | | Glass Bottle | 400 | 14ft | All Levels |
| W2 | 3/26/2014 | 12:45 | 30 | Glass Bottle | 400 | 14ft | Top |
| W2 | 3/26/2014 | 12:45 | 30 | Glass Bottle | 400 | 14ft | Bottom |
| W2 | 3/29/2014 | 15:00 | 52 | Glass Bottle | 400 | 10ft | All Levels |
| W2 | 3/31/2014 | 10:00 | 12 | Glass Bottle | 400 | 15ft | All Levels |
| W2 | 4/7/2014 | 13:05 | 51 | Glass Bottle | 400 | 16ft | All Levels |
| W2 | 4/16/2014 | 12:00 | | Glass Bottle | 400 | | All Levels |
| W2 | 4/19/2014 | 9:00 | | Glass Bottle | 400 | | All Levels |
| W3 | 3/25/2014 | 12:30 | 15 | Glass Bottle | 400 | 10ft | Top |
| W3 | 3/25/2014 | 12:30 | 15 | Glass Bottle | 400 | 10ft | Bottom |
| W3 | 3/27/2014 | 10:00 | 24 | Glass Bottle | 400 | 10ft | All Levels |
| W3 | 3/31/2014 | 10:00 | 11 | Glass Bottle | 400 | 10ft | All Levels |
| W3 | 4/7/2014 | 12:50 | 42 | Glass Bottle | 400 | 12ft | All Levels |
| W3 | 4/16/2014 | 10:30 | | Glass Bottle | 400 | 12ft | All Levels |
| W3 | 4/18/2014 | 11:20 | 37 | Glass Bottle | 400 | 10ft | All Levels |
| W4 | 3/26/2014 | 12:00 | 30 | Glass Bottle | 400 | 6ft | Top |
| W4 | 3/26/2014 | 12:00 | 30 | Glass Bottle | 400 | 6ft | Bottom |
| W4 | 3/28/2014 | 13:15 | 23 | Glass Bottle | 400 | 5ft 9in | All Levels |
| W4 | 4/3/2014 | 17:25 | 37 | Glass Bottle | 400 | 9ft | All Levels |
| W4 | 4/7/2014 | 18:14 | 49 | Glass Bottle | 400 | 10ft 6in | All Levels |
| W4 | 4/15/2014 | 16:00 | | Glass Bottle | 400 | 7ft 7in | All Levels |
| W4 | 4/17/2014 | 14:30 | | Glass Bottle | 400 | 7ft 2in | All Levels |

**Appendix 4 - Sample Conditions - Well**

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W5 | 3/26/2014 | 15:50 | 30 | Glass Bottle | 400 | 5ft 6in | Top |
| W5 | 3/26/2014 | 15:50 | 30 | Glass Bottle | 400 | 5ft 6in | Bottom |
| W5 | 3/28/2014 | 13:50 | 23 | Glass Bottle | 400 | 5ft | All Levels |
| W5 | 4/4/2014 | 17:28 | 39 | Glass Bottle | 400 | 3ft | All Levels |
| W5 | 4/7/2014 | 19:08 | 46 | Glass Bottle | 400 | 6ft | All Levels |
| W5 | 4/15/2014 | 17:00 | 48 | Glass Bottle | 400 | 13ft 3in | All Levels |
| W5 | 4/17/2014 | 15:30 | 46 | Glass Bottle | 400 | 7ft 7in | All Levels |
| W6 | 4/6/2014 | 14:55 | 58 | Glass Bottle | 400 | 12ft 10.5in | Top |
| W6 | 4/6/2014 | 14:55 | 58 | Glass Bottle | 400 | 12ft 10.5in | Bottom |
| W6 | 4/8/2014 | 13:50 | 70 | Glass Bottle | 400 | 14ft 7in | All Levels |
| W6 | 4/15/2014 | 17:05 | 49 | Glass Bottle | 400 | 16ft 5.5in | All Levels |
| W6 | 4/17/2014 | 14:05 | 39 | Glass Bottle | 400 | 14ft 7.75in | All Levels |
| W6 | 4/21/2014 | 16:30 | 63 | Glass Bottle | 400 | 13ft 9in | All Levels |
| W6 | 4/24/2014 | 11:20 | 48 | Glass Bottle | 400 | 13ft 6in | All Levels |
| W7 | 3/25/2014 | 17:00 | 28 | Glass Bottle | 400 | 18ft | Top |
| W7 | 3/25/2014 | 17:00 | 28 | Glass Bottle | 400 | 18ft | Bottom |
| W7 | 3/27/2014 | 13:00 | 25 | Glass Bottle | 400 | 16ft | All Levels |
| W7 | 3/31/2014 | 13:00 | 16 | Glass Bottle | 400 | 15ft | All Levels |
| W7 | 4/7/2014 | 16:00 | 47 | Glass Bottle | 400 | 19ft | All Levels |
| W7 | 4/16/2014 | 14:20 | | Glass Bottle | 400 | 7ft | All Levels |
| W7 | 4/21/2014 | 13:45 | 65 | Glass Bottle | 400 | 18ft | All Levels |
| W8 | 3/25/2014 | 14:53 | 27 | Glass Bottle | 400 | 13ft | Top |
| W8 | 3/25/2014 | 14:33 | 27 | Glass Bottle | 400 | 13ft | Bottom |
| W8 | 3/27/2014 | 15:30 | 32 | Glass Bottle | 400 | 7ft | All Levels |
| W8 | 3/31/2014 | 12:42 | 15 | Glass Bottle | 400 | 10ft | All Levels |
| W8 | 4/9/2014 | 12:30 | 65 | Glass Bottle | 400 | 8ft | All Levels |
| W8 | 4/16/2014 | 17:00 | | Glass Bottle | 400 | 8ft 3in | All Levels |
| W8 | 4/18/2014 | 13:00 | | Glass Bottle | 400 | 9ft | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W9 | 4/1/2014 | 11:20 | 13 | Glass Bottle | 400 | 13ft 6in | Top |
| W9 | 4/1/2014 | 12:10 | 13 | Glass Bottle | 400 | 13ft 6in | Bottom |
| W9 | 4/3/2014 | 13:00 | 25 | Glass Bottle | 400 | 13ft | All Levels |
| W9 | 4/8/2014 | 11:25 | 45 | Glass Bottle | 400 | 6ft 11in | All Levels |
| W9 | 4/15/2014 | 12:33 | 43 | Glass Bottle | 400 | 15ft | All Levels |
| W9 | 4/22/2014 | 11:35 | 63 | Glass Bottle | 400 | 12ft 1in | All Levels |
| W9 | 4/24/2014 | 14:20 | 53 | Glass Bottle | 400 | 18ft | All Levels |
| W10 | 4/15/2014 | 15:40 | 48 | Glass Bottle | 400 | 4ft | Top |
| W10 | 4/15/2014 | 15:40 | 48 | Glass Bottle | 400 | 4ft | Bottom |
| W10 | 4/17/2014 | 12:50 | 37 | Glass Bottle | 400 | 4ft | All Levels |
| W10 | 4/21/2014 | 15:30 | 58 | Glass Bottle | 400 | | All Levels |
| W10 | 4/24/2014 | 12:35 | 50 | Glass Bottle | 400 | 8ft | All Levels |
| W10 | 4/29/2014 | 11:00 | 32 | Glass Bottle | 400 | 10ft | All Levels |
| W11 | 4/7/2014 | 16:35 | 50 | Glass Bottle | 400 | 19ft | Top |
| W11 | 4/7/2014 | 16:35 | 50 | Glass Bottle | 400 | 19ft | Bottom |
| W11 | 4/11/2014 | 14:55 | 55 | Glass Bottle | 400 | 19ft | All Levels |
| W11 | 4/15/2014 | 15:00 | | Glass Bottle | 400 | 16ft 4in | All Levels |
| W11 | 4/17/2014 | 13:30 | | Glass Bottle | 400 | 12ft 2in | All Levels |
| W11 | 4/20/2014 | 11:00 | | Glass Bottle | 400 | 17ft 2in | All Levels |
| W11 | 4/23/2014 | 13:00 | | Glass Bottle | 400 | 16ft 4in | All Levels |
| W12 | 3/27/2014 | 12:46 | 27 | Glass Bottle | 400 | 12ft | Top |
| W12 | 3/27/2014 | 12:16 | 27 | Glass Bottle | 400 | 12ft | Bottom |
| W12 | 3/30/2014 | 13:00 | 42 | Glass Bottle | 400 | 18ft | All Levels |
| W12 | 4/1/2014 | 13:40 | 15 | Glass Bottle | 400 | 14ft | All Levels |
| W12 | 4/8/2014 | 13:20 | 59 | Glass Bottle | 400 | 10ft | All Levels |
| W12 | 4/17/2014 | 15:10 | 43 | Glass Bottle | 400 | 13ft | All Levels |
| W12 | 4/17/2014 | 15:30 | 35 | Glass Bottle | 400 | 8ft | All Levels |

**Appendix 4 - Sample Conditions - Well**

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | 31 | Glass Bottle | 400 | 11ft | Top |
| W13 | 3/26/2014 | 17:00 | 31 | Glass Bottle | 400 | 11ft | Bottom |
| W13 | 3/28/2014 | 15:30 | 25 | Glass Bottle | 400 | 6ft | All Levels |
| W13 | 4/4/2014 | 15:15 | 39 | Glass Bottle | 400 | 6ft | All Levels |
| W13 | 4/8/2014 | 11:00 | 46 | Glass Bottle | 400 | 16ft | All Levels |
| W13 | 4/15/2014 | 19:30 | | Glass Bottle | 400 | | All Levels |
| W13 | 4/19/2014 | 14:00 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/6/2014 | 16:20 | | Glass Bottle | 400 | | Top |
| W14 | 4/6/2014 | 16:20 | | Glass Bottle | 400 | | Bottom |
| W14 | 4/4/2014 | 11:55 | 34 | Glass Bottle | 400 | 2ft 6in | All Levels |
| W14 | 4/8/2014 | 12:30 | 50 | Glass Bottle | 400 | 6ft | All Levels |
| W14 | 4/18/2014 | 16:30 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/20/2014 | 14:00 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/22/2014 | 11:00 | | Glass Bottle | 400 | | All Levels |
| W15 | 4/9/2014 | 17:20 | | Glass Bottle | 40,000bbl/50 ft | 30ft 6in | Top |
| W15 | 4/9/2014 | 17:20 | | Glass Bottle | 40,000bbl/50 ft | 30ft 6in | Bottom |
| W15 | 4/18/2014 | 19:30 | | Glass Bottle | 40,000bbl/50 ft | 22ft 9in | All Levels |
| W15 | 4/21/2014 | 18:30 | | Glass Bottle | 40,000bbl/50 ft | 36ft 2in | All Levels |
| W15 | 4/23/2014 | 13:00 | | Glass Bottle | 40,000bbl/50 ft | 37ft 4in | All Levels |
| W15 | 4/24/2014 | 16:30 | 57 | Glass Bottle | 40,000bbl/50 ft | 32ft 9in | All Levels |

| Client ID | Sample Date | Sample Time | Tank Vapor Capture - Flare Stack or VRU | Production Rates from Producer(b/d) | Last Movement from Tank (Date and Time) | Separator Size | Separator Operating Pressure (psig) | Separator Operating Temp (°F) | Treater/Emulsion Heater Size | Treater/Emulsion Heater Operating Pressure (psig) | Treater/Emulsion Heater Operating Temp (°F) | Treater/Emulsion Heater Oil Line Dia (inches) | Treater/Emulsion Heater Oil Dump Valve Size/Style | Additional Field Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/14 | 19:45 | | | | | | | | 46 | 92 | | | Treater |
| W1 | 3/25/14 | 19:45 | | | | | | | | 46 | 92 | | | Treater |
| W1 | 3/27/14 | 18:15 | | | | | | | | 48 | 92 | | | Treater |
| W1 | 3/30/14 | 16:00 | | | | | | | | 31 | 92 | | | Treater |
| W1 | 4/1/14 | 11:00 | | | | | | | | | | | | |
| W1 | 4/7/14 | 12:20 | | | | | | | | 31 | 92 | | | |
| W1 | 4/16/14 | 11:30 | | | | | | | | | | | | |
| W2 | 3/26/14 | 12:45 | | | | | | | | 20 | 46 | | | Treater |
| W2 | 3/26/14 | 12:45 | | | | | | | | 20 | 46 | | | Treater |
| W2 | 3/29/14 | 15:00 | | | | | | | | 19 | 90 | | | Treater |
| W2 | 3/31/14 | 10:00 | | | | | | | | 55 | 92 | | | Treater |
| W2 | 4/7/14 | 13:05 | | | | | | | | 44 | 54 | | | Treater |
| W2 | 4/16/14 | 12:00 | | | | | | | | | | | | |
| W2 | 4/19/14 | 9:00 | | | | | | | | | | | | |
| W3 | 3/25/14 | 12:30 | | 110 | N/A | | | | 6' x 20' | 30 | 35 | 3" | 3" Kimray | |
| W3 | 3/25/14 | 12:30 | | 110 | N/A | | | | 6' x 20' | 30 | 35 | 3" | 3" Kimray | |
| W3 | 3/27/14 | 10:00 | | 90 | N/A | | | | 6' x 20' | 42 | 38 | 3" | 3" Kimray | |
| W3 | 3/31/14 | 10:00 | | 100 | N/A | | | | 6' x 20' | 38 | 36 | 3" | 3" Kimray | |
| W3 | 4/7/14 | 12:50 | | 110 | N/A | | | | 6' x 20' | 36 | 44 | 3" | 3" Kimray | |
| W3 | 4/16/14 | 10:30 | | 90 | N/A | | | | 6' x 20' | 44 | 36 | 3" | 3" Kimray | |
| W3 | 4/18/14 | 11:20 | | 90 | N/A | | | | 6' x 20' | 8 | 42 | 3" | 3" Kimray | |
| W4 | 3/26/14 | 12:00 | Flare Stack | 305 | | N/A | N/A | N/A | 6' x 22' | 48 | 135 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 3/26/14 | 12:00 | Flare Stack | 305 | | N/A | N/A | N/A | 6' x 22' | 48 | 135 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 3/28/14 | 13:15 | Flare Stack | 337 | | N/A | N/A | N/A | 6' x 22' | 50 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/3/14 | 17:25 | Flare Stack | 280 | | N/A | N/A | N/A | 6' x 22' | 54 | 145 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/7/14 | 18:14 | Flare Stack | 320 | | N/A | N/A | N/A | 6' x 22' | 12 | 142 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/15/14 | 16:00 | Flare Stack | 220 | | N/A | N/A | N/A | 6' x 22' | 52 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/17/14 | 14:30 | Flare Stack | 326 | | N/A | N/A | N/A | 6' x 22' | 40 | 80 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/26/14 | 15:50 | Both (Stack/VRU) | 449 | | N/A | N/A | N/A | 6' x 22' | 40 | 84 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/26/14 | 15:50 | Both (Stack/VRU) | 449 | | N/A | N/A | N/A | 6' x 22' | 40 | 84 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/28/14 | 13:50 | Both (Stack/VRU) | 404 | | N/A | N/A | N/A | 6' x 22' | 40 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/4/14 | 17:28 | Both (Stack/VRU) | 294 | | N/A | N/A | N/A | 6' x 22' | 51 | 162 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/7/14 | 19:08 | Both (Stack/VRU) | 441 | | N/A | N/A | N/A | 6' x 22' | 53 | 138 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/15/14 | 17:00 | Both (Stack/VRU) | 526 | | N/A | N/A | N/A | 6' x 22' | 45 | 90 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/17/14 | 15:30 | Both (Stack/VRU) | 398 | | N/A | N/A | N/A | 6' x 22' | 50 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W6 | 4/6/14 | 14:55 | | 100 | 4/5/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/6/14 | 14:55 | | 100 | 4/5/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/8/14 | 13:50 | | 100 | 4/7/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/15/14 | 17:05 | | 100 | 4/14/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/17/14 | 14:05 | | 100 | 4/16/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/21/14 | 16:30 | | 100 | 4/20/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/24/14 | 11:20 | | 100 | 4/23/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W7 | 3/25/14 | 17:00 | Flare Stack | 143 | N/A | 30" x 10' | | | 6' x 20' | 26 | 120 | 3" | 3" float operated | |
| W7 | 3/25/14 | 17:00 | Flare Stack | 143 | N/A | 30" x 10' | | | 6' x 20' | 26 | 120 | 3" | 3" float operated | |
| W7 | 3/27/14 | 13:00 | Flare Stack | 161 | N/A | 30" x 10' | | | 6' x 20' | 26 | 123 | 3" | 3" float operated | |
| W7 | 3/31/14 | 13:00 | Flare Stack | 125 | N/A | 30" x 10' | | | 6' x 20' | 28 | 38 | 3" | 3" float operated | |
| W7 | 4/7/14 | 16:00 | Flare Stack | 150 | N/A | 30" x 10' | | | 6' x 20' | 28 | 65 | 3" | 3" float operated | |
| W7 | 4/16/14 | 14:20 | Flare Stack | 125 | N/A | 30" x 10' | | | 6' x 20' | 28 | 65 | 3" | 3" float operated | |
| W7 | 4/21/14 | 13:45 | Flare Stack | 164 | N/A | 30" x 10' | | | 6' x 20' | 28 | 70 | 3" | 3" float operated | |

| Client ID | Sample Date | Sample Time | Tank Vapor Capture - Flare Stack or VRU | Production Rates from Producer(b/d) | Last Movement from Tank (Date and Time) | Separator Size | Separator Operating Pressure (psig) | Separator Operating Temp (°F) | Treater/Emulsion Heater Size | Treater/Emulsion Heater Operating Pressure (psig) | Treater/Emulsion Heater Operating Temp (°F) | Treater/Emulsion Heater Oil Line Dia (inches) | Treater/Emulsion Heater Oil Dump Valve Size/Style | Additional Field Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W8 | 3/25/14 | 14:33 | Flare Stack | 7 | N/A | 30" x 10' | | | 6' x 20' | 22 | 154 | 3" | 3" float operated | |
| W8 | 3/27/14 | 15:30 | Flare Stack | 4 | N/A | 30" x 10' | | | 6' x 20' | 27 | 156 | 3" | 3" float operated | |
| W8 | 3/31/14 | 12:42 | Flare Stack | 6 | N/A | 30" x 10' | | | 6' x 20' | 22 | 146 | 3" | 3" float operated | |
| W8 | 4/9/14 | 12:30 | Flare Stack | 5 | N/A | 30" x 10' | | | 6' x 20' | 22 | 160 | 3" | 3" float operated | |
| W8 | 4/16/14 | 17:00 | Flare Stack | 4 | N/A | 30" x 10' | | | 6' x 20' | 22 | 70 | 3" | 3" float operated | |
| W8 | 4/18/14 | 13:00 | Flare Stack | 7 | N/A | 30" x 10' | | | 6' x 20' | 22 | 55 | 3" | 3" float operated | |
| W9 | 4/1/14 | 11:20 | Flare Stack | 528 | 3/31/14 8:30 | | | | 6' x 20' | 68 | 109 | | D3 | Sunny, Still weather |
| W9 | 4/1/14 | 12:10 | Flare Stack | 528 | 3/31/14 8:30 | | | | 6' x 20' | 68 | 109 | | D3 | Sunny, Still weather |
| W9 | 4/3/14 | 13:00 | Flare Stack | 508 | 4/3/14 10:20 | | | | 6' x 20' | 68 | 110 | | D3 | Windy and Cloudy |
| W9 | 4/8/14 | 11:25 | Flare Stack | 360 | Note Indicates N/A | | | | 6' x 20' | 68 | 110 | | D3 | Partially Cloudy |
| W9 | 4/15/14 | 12:33 | Flare Stack | 580 | 4/14/14 12:33 | | | | 6' x 20' | 41 | 108 | | D3 | Partially Cloudy and windy |
| W9 | 4/22/14 | 11:35 | Flare Stack | 678 | 4/21/14 0:00 | | | | 6' x 20' | 45 | 108 | | D3 | Sunny 20-25 mph winds |
| W9 | 4/24/14 | 14:20 | Flare Stack | 770 | 4/24/14 9:05 | | | | 6' x 20' | 45 | 100 | | D3 | Sunny |
| W10 | 4/15/14 | 15:40 | | 150 | N/A (Comingled) | | | | 6' x 20' | 35 | 37 | | | Observed: 0.05% BS&W |
| W10 | 4/15/14 | 15:40 | | 150 | N/A (Comingled) | | | | 6' x 20' | 35 | 37 | | | Observed: 0.05% BS&W |
| W10 | 4/17/14 | 12:50 | | 150 | N/A (Comingled) | | 35 | 37 | 6' x 20' | 35 | 37 | | | |
| W10 | 4/21/14 | 15:30 | | 150 | N/A (Comingled) | | 42 | 44 | 6' x 20' | 42 | 44 | | | |
| W10 | 4/24/14 | 12:35 | | 150 | N/A (Comingled) | | 24 | 38 | 6' x 20' | 24 | 38 | | | |
| W10 | 4/29/14 | 11:00 | | 150 | N/A (Comingled) | | | | 6' x 20' | 5 | 39 | | | |
| W11 | 4/7/14 | 16:35 | Flare Stack | 180 | 4/7/14 16:35 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W11 | 4/7/14 | 16:35 | Flare Stack | 180 | 4/7/14 16:35 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W11 | 4/11/14 | 14:55 | Flare Stack | 180 | 4/11/14 14:55 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 32 API at 76F, 0.05% BS&W |
| W11 | 4/15/14 | 15:00 | Flare Stack | 180 | 4/15/14 15:00 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 34 API at 72F, 0.05% BS&W |
| W11 | 4/17/14 | 13:30 | Flare Stack | 180 | 4/17/14 13:30 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 34 API at 73F, 0.05% BS&W |
| W11 | 4/20/14 | 11:00 | Flare Stack | 180 | 4/20/14 11:00 | 30" x 10' | 36 | | 6' x 22' | | | 3" | 3" | Observed: 36 API at 73F, 0.05% BS&W |
| W11 | 4/23/14 | 13:00 | Flare Stack | 180 | 4/23/14 15:30 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W12 | 3/27/14 | 12:46 | Flare Stack | 132 | N/A | 30" x 10' | | | 6' x 20' | 40 | 115 | 3" | 3" float operated | |
| W12 | 3/27/14 | 12:16 | Flare Stack | 132 | N/A | 30" x 10' | | | 6' x 20' | 40 | 115 | 3" | 3" float operated | |
| W12 | 3/30/14 | 13:00 | Flare Stack | 160 | N/A | 30" x 10' | | | 6' x 20' | 50 | 125 | 3" | 3" float operated | |
| W12 | 4/1/14 | 13:40 | Flare Stack | 135 | N/A | 30" x 10' | | | 6' x 20' | 28 | 117 | 3" | 3" float operated | |
| W12 | 4/8/14 | 13:20 | Flare Stack | 135 | N/A | 30" x 10' | | | 6' x 20' | 49 | 115 | 3" | 3" float operated | |
| W12 | 4/17/14 | 15:10 | Flare Stack | 138 | N/A | 30" x 10' | | | 6' x 20' | 30 | 110 | 3" | 3" float operated | |
| W12 | 4/17/14 | 15:30 | Flare Stack | 138 | N/A | 30" x 10' | | | 6' x 20' | 30 | 65 | 3" | 3" float operated | |
| W13 | 3/26/14 | 17:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 92 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 3/26/14 | 17:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 92 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 3/28/14 | 15:30 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 90 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/4/14 | 15:15 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 94 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/8/14 | 11:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 36 | 90 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/15/14 | 19:30 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | | | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/19/14 | 14:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | | | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W14 | 4/6/14 | 16:20 | | | | | | | | | | | | |
| W14 | 4/6/14 | 16:20 | | | | | | | | | | | | |
| W14 | 4/4/14 | 11:55 | | | | | 30 | 90 | | 30 | 90 | | | |
| W14 | 4/8/14 | 12:30 | | | | | 62 | 79 | | 62 | 79 | | | |
| W14 | 4/18/14 | 16:30 | | | | | | | | | | | | |
| W14 | 4/20/14 | 14:00 | | | | | | | | | | | | |
| W14 | 4/22/14 | 11:00 | | | | | 47 | 114 | | 47 | 114 | | | |
| W15 | 4/9/14 | 17:20 | | | 4/9/14 17:20 | | | | | | | | | Observed 43 API |
| W15 | 4/9/14 | 17:20 | | | 4/9/14 17:20 | | | | | | | | | Observed 43 API |
| W15 | 4/18/14 | 19:30 | | | 4/18/14 19:30 | | | | | | | | | Observed 43 API |
| W15 | 4/21/14 | 18:30 | | | 4/21/14 18:30 | | | | | | | | | Observed 43 API |
| W15 | 4/23/14 | 13:00 | | | 4/23/14 13:00 | | | | | | | | | Observed 43 API |
| W15 | 4/24/14 | 16:30 | | | 4/24/14 16:30 | | | | | | | | | Observed 43 API |

## Appendix 6 - Lab Data - Rail

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | 39.6 | 100.5 | 9.73 | 67.1 | <73 |
| R1 | 3/25/2014 | 17:00 | 39.5 | 102.9 | 9.96 | 68.7 | <73 |
| R1 | 3/27/2014 | 17:26 | 39.7 | 103.9 | 9.67 | 66.7 | <73 |
| R1 | 3/31/2014 | 14:08 | 42.8 | 100.5 | 11.31 | 78.0 | <73 |
| R1 | 4/9/2014 | 10:38 | 41.6 | 100.8 | 11.76 | 81.1 | <73 |
| R1 | 4/16/2014 | 15:30 | 42.1 | 98.4 | 11.85 | 81.7 | <73 |
| R1 | 4/18/2014 | 11:00 | 41.4 | 99.9 | 12.33 | 85.0 | <73 |
| R2 | 3/25/2014 | 18:00 | 43.4 | 99.9 | 11.73 | 80.9 | <73 |
| R2 | 3/25/2014 | 18:00 | 42.8 | 100.7 | 11.68 | 80.5 | <73 |
| R2 | 3/27/2014 | 10:30 | 43.8 | 99.5 | 12.39 | 85.4 | <73 |
| R2 | 3/31/2014 | 12:30 | 43.2 | 99.4 | 11.52 | 79.4 | <73 |
| R2 | 4/8/2014 | 10:20 | 40.3 | 100.5 | 11.55 | 79.6 | <73 |
| R2 | 4/15/2014 | 11:30 | 42.0 | 97.8 | 11.94 | 82.3 | <73 |
| R2 | 4/18/2014 | 10:20 | 39.2 | 99.6 | 11.89 | 82.0 | <73 |
| R3 | 3/26/2014 | 14:30 | 42.4 | 103.5 | 11.53 | 79.5 | <73 |
| R3 | 3/26/2014 | 14:30 | 42.6 | 101.9 | 11.70 | 80.7 | <73 |
| R3 | 3/28/2014 | 13:30 | 42.6 | 100.9 | 11.53 | 79.5 | <73 |
| R3 | 4/1/2014 | 16:10 | 41.7 | 102.0 | 10.95 | 75.5 | <73 |
| R3 | 4/10/2014 | 14:50 | 40.9 | 97.2 | 11.53 | 79.5 | <73 |
| R3 | 4/15/2014 | 14:15 | 41.3 | 98.2 | 11.46 | 79.0 | <73 |
| R3 | 4/17/2014 | 13:00 | 40.6 | 98.8 | 11.02 | 76.0 | <73 |
| R4 | 3/25/2014 | 14:30 | 41.3 | 99.9 | 11.95 | 82.4 | <73 |
| R4 | 3/25/2014 | 14:30 | 41.4 | 99.2 | 11.25 | 77.6 | <73 |
| R4 | 3/27/2014 | 11:50 | 43.1 | 99.9 | 11.95 | 82.4 | <73 |
| R4 | 3/31/2014 | 11:20 | 41.5 | 99.5 | 12.44 | 85.8 | <73 |
| R4 | 4/7/2014 | 13:45 | 41.5 | 99.5 | 12.85 | 88.6 | <73 |
| R4 | 4/16/2014 | 12:35 | 40.3 | 99.1 | 12.08 | 83.3 | <73 |
| R4 | 4/18/2014 | 12:05 | 39.8 | 100.5 | 11.99 | 82.7 | <73 |

## Appendix 6 - Lab Data - Rail

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| R5 | 3/26/2014 | 12:00 | 44.0 | 101.0 | 10.52 | 72.5 | <73 |
| R5 | 3/26/2014 | 12:00 | 43.9 | 101.9 | 10.47 | 72.2 | <73 |
| R5 | 3/28/2014 | 12:00 | 42.4 | 100.5 | 10.50 | 72.4 | <73 |
| R5 | 4/1/2014 | 14:30 | 43.1 | 103.7 | 10.28 | 70.9 | <73 |
| R5 | 4/10/2014 | 13:15 | 42.6 | 100.4 | 10.95 | 75.5 | <73 |
| R5 | 4/15/2014 | 12:50 | 41.8 | 100.8 | 10.85 | 74.8 | <73 |
| R5 | 4/17/2014 | 11:40 | 42.0 | 103.4 | 9.57 | 66.0 | <73 |
| R6 | 3/26/2014 | 15:30 | 42.6 | 99.7 | 12.84 | 88.5 | <73 |
| R6 | 3/26/2014 | 15:30 | 42.5 | 98.9 | 12.47 | 86.0 | <73 |
| R6 | 3/27/2014 | 15:30 | 43.0 | 98.9 | 12.71 | 87.6 | <73 |
| R6 | 3/31/2014 | 14:00 | 41.2 | 99.4 | 11.82 | 81.5 | <73 |
| R6 | 4/7/2014 | 15:00 | 39.9 | 96.7 | 12.43 | 85.7 | <73 |
| R6 | 4/15/2014 | 14:00 | 40.2 | 100.8 | 12.52 | 86.3 | <73 |
| R6 | 4/17/2014 | 12:00 | 39.7 | 100.1 | 11.88 | 81.9 | <73 |
| R7 | 3/26/2014 | 19:30 | 42.3 | 104.1 | 11.66 | 80.4 | <73 |
| R7 | 3/26/2014 | 19:30 | 42.8 | 99.7 | 11.57 | 79.8 | <73 |
| R7 | 3/28/2014 | 13:00 | 42.6 | 99.5 | 11.89 | 82.0 | <73 |
| R7 | 3/31/2014 | 17:00 | 42.2 | 101.9 | 11.86 | 81.8 | <73 |
| R7 | 4/11/2014 | 10:50 | 40.9 | 99.3 | 11.37 | 78.4 | <73 |
| R7 | 4/14/2014 | 12:30 | 41.5 | 98.9 | 11.37 | 78.4 | <73 |
| R7 | 4/18/2014 | 10:00 | 40.4 | 101.7 | 11.39 | 78.5 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 40.6 | 98.2 | 11.99 | 82.7 | <73 |
| W1 | 3/25/2014 | 19:45 | 39.2 | 102.1 | 11.55 | 79.6 | <73 |
| W1 | 3/27/2014 | 18:15 | 40.3 | 99.7 | 11.55 | 79.6 | <73 |
| W1 | 3/30/2014 | 16:00 | 39.1 | 99.2 | 11.81 | 81.4 | <73 |
| W1 | 4/1/2014 | 11:00 | 37.1 | 98.8 | 12.18 | 84 | <73 |
| W1 | 4/7/2014 | 12:20 | 37.1 | 99.9 | 11.40 | 78.6 | <73 |
| W1 | 4/16/2014 | 11:30 | 37.7 | 98.6 | 11.57 | 79.8 | <73 |
| W2 | 3/26/2014 | 12:45 | 41.4 | 100.6 | 12.26 | 84.5 | <73 |
| W2 | 3/26/2014 | 12:45 | 40.2 | 100.3 | 12.08 | 83.3 | <73 |
| W2 | 3/29/2014 | 15:00 | 41.5 | 100.7 | 11.94 | 82.3 | <73 |
| W2 | 3/31/2014 | 10:00 | 39.9 | 101.9 | 11.50 | 79.3 | <73 |
| W2 | 4/7/2014 | 13:05 | 40.0 | 98.9 | 11.37 | 78.4 | <73 |
| W2 | 4/16/2014 | 12:00 | 38.0 | 98.1 | 11.27 | 77.7 | <73 |
| W2 | 4/19/2014 | 9:00 | 38.9 | 99.8 | 11.91 | 82.1 | <73 |
| W3 | 3/25/2014 | 12:30 | 43.8 | 96.8 | 10.65 | 73.4 | <73 |
| W3 | 3/25/2014 | 12:30 | 44.4 | 99.7 | 10.86 | 74.9 | <73 |
| W3 | 3/27/2014 | 10:00 | 44.4 | 98.6 | 11.07 | 76.3 | <73 |
| W3 | 3/31/2014 | 10:00 | 43.4 | 98.1 | 12.02 | 82.9 | <73 |
| W3 | 4/7/2014 | 12:50 | 42.1 | 99.4 | 12.01 | 82.8 | <73 |
| W3 | 4/16/2014 | 10:30 | 40.2 | 98.4 | 10.92 | 75.3 | <73 |
| W3 | 4/18/2014 | 11:20 | 42.1 | 98.9 | 11.37 | 78.4 | <73 |
| W4 | 3/26/2014 | 12:00 | 40.0 | 98.5 | 12.56 | 86.6 | <73 |
| W4 | 3/26/2014 | 12:00 | 41.7 | 97.7 | 12.71 | 87.6 | <73 |
| W4 | 3/28/2014 | 13:15 | 42.5 | 98.6 | 12.84 | 88.5 | <73 |
| W4 | 4/3/2014 | 17:25 | 40.4 | 98.2 | 11.15 | 76.9 | <73 |
| W4 | 4/7/2014 | 18:14 | 39.3 | 97.3 | 13.92 | 96 | <73 |
| W4 | 4/15/2014 | 16:00 | 38.9 | 97.4 | 11.98 | 82.6 | <73 |
| W4 | 4/17/2014 | 14:30 | 38.8 | 99.5 | 13.24 | 91.3 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W5 | 3/26/2014 | 15:50 | 42.9 | 97.3 | 12.27 | 84.6 | <73 |
| W5 | 3/26/2014 | 15:50 | 42.3 | 99.6 | 12.44 | 85.8 | <73 |
| W5 | 3/28/2014 | 13:50 | 44.3 | 98.2 | 13.24 | 91.3 | <73 |
| W5 | 4/4/2014 | 17:28 | 41.1 | 100.9 | 12.23 | 84.3 | <73 |
| W5 | 4/7/2014 | 19:08 | 39.9 | 94.6 | 13.26 | 91.4 | <73 |
| W5 | 4/15/2014 | 17:00 | 39.9 | 95.4 | 12.20 | 84.1 | <73 |
| W5 | 4/17/2014 | 15:30 | 42.6 | 97.5 | 13.08 | 90.2 | <73 |
| W6 | 4/6/2014 | 14:55 | 42.6 | 97.2 | 13.04 | 89.9 | <73 |
| W6 | 4/6/2014 | 14:55 | 42.6 | 96.5 | 13.04 | 89.9 | <73 |
| W6 | 4/8/2014 | 13:50 | 42.1 | 97.7 | 11.04 | 76.1 | <73 |
| W6 | 4/15/2014 | 17:05 | 42.5 | 96.7 | 12.33 | 85 | <73 |
| W6 | 4/17/2014 | 14:05 | 42.8 | 97.4 | 12.59 | 86.8 | <73 |
| W6 | 4/21/2014 | 16:30 | 42.3 | 98.9 | 11.33 | 78.1 | <73 |
| W6 | 4/24/2014 | 11:20 | 45.8 | 96.4 | 13.56 | 93.5 | <73 |
| W7 | 3/25/2014 | 17:00 | 43.5 | 97.6 | 10.25 | 70.7 | <73 |
| W7 | 3/25/2014 | 17:00 | 43.8 | 98.3 | 10.59 | 73 | <73 |
| W7 | 3/27/2014 | 13:00 | 42.6 | 99.9 | 10.91 | 75.2 | <73 |
| W7 | 3/31/2014 | 13:00 | 43.9 | 96.9 | 10.02 | 69.1 | <73 |
| W7 | 4/7/2014 | 16:00 | 39.2 | 96.7 | 11.33 | 78.1 | <73 |
| W7 | 4/16/2014 | 14:20 | 41.7 | 94.8 | 12.92 | 89.1 | <73 |
| W7 | 4/21/2014 | 13:45 | 39.5 | 99 | 11.69 | 80.6 | <73 |
| W8 | 3/25/2014 | 14:53 | 44.4 | 95 | 12.52 | 86.3 | <73 |
| W8 | 3/25/2014 | 14:33 | 44.6 | 99.2 | 12.37 | 85.3 | <73 |
| W8 | 3/27/2014 | 15:30 | 44.8 | 99 | 12.92 | 89.1 | <73 |
| W8 | 3/31/2014 | 12:42 | 43.4 | 97.5 | 12.15 | 83.8 | <73 |
| W8 | 4/9/2014 | 12:30 | 39.0 | 101.3 | 11.07 | 76.3 | <73 |
| W8 | 4/16/2014 | 17:00 | 40.9 | 96.1 | 11.92 | 82.2 | <73 |
| W8 | 4/18/2014 | 13:00 | 42.5 | 96.8 | 14.37 | 99.1 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W9 | 4/1/2014 | 11:20 | 38.0 | 104.3 | 10.70 | 73.8 | <73 |
| W9 | 4/1/2014 | 12:10 | 37.0 | 104 | 10.67 | 73.6 | <73 |
| W9 | 4/3/2014 | 13:00 | 37.3 | 101.4 | 10.69 | 73.7 | <73 |
| W9 | 4/8/2014 | 11:25 | 38.2 | 102 | 10.96 | 75.6 | <73 |
| W9 | 4/15/2014 | 12:33 | 36.9 | 101.4 | 11.15 | 76.9 | <73 |
| W9 | 4/22/2014 | 11:35 | 36.7 | 105.4 | 10.15 | 70 | <73 |
| W9 | 4/24/2014 | 14:20 | 38.9 | 91.9 | 9.95 | 68.6 | <73 |
| W10 | 4/15/2014 | 15:40 | 42.7 | 95 | 13.02 | 89.8 | <73 |
| W10 | 4/15/2014 | 15:40 | 42.8 | 95.4 | 12.75 | 87.9 | <73 |
| W10 | 4/17/2014 | 12:50 | 43.5 | 97.3 | 12.02 | 82.9 | <73 |
| W10 | 4/21/2014 | 15:30 | 46.3 | 95 | 13.46 | 92.8 | <73 |
| W10 | 4/24/2014 | 12:35 | 44.7 | 95.3 | 13.01 | 89.7 | <73 |
| W10 | | | 45.5 | 95.8 | 13.58 | 93.6 | <73 |
| W11 | 4/7/2014 | 16:35 | 38.6 | 96 | 10.41 | 71.8 | <73 |
| W11 | 4/7/2014 | 16:35 | 38.2 | 97.3 | 11.02 | 76 | <73 |
| W11 | 4/11/2014 | 14:55 | 41.8 | 95.7 | 13.29 | 91.6 | <73 |
| W11 | 4/15/2014 | 15:00 | 38.4 | 98.1 | 11.43 | 78.8 | <73 |
| W11 | 4/17/2014 | 13:30 | 39.3 | 99.4 | 12.07 | 83.2 | <73 |
| W11 | 4/20/2014 | 11:00 | 37.0 | 104.5 | 9.96 | 68.7 | <73 |
| W11 | 4/23/2014 | | 38.9 | 98.3 | 12.13 | 83.6 | <73 |
| W12 | 3/27/2014 | 12:46 | 38.8 | 100.1 | 10.99 | 75.8 | <73 |
| W12 | 3/27/2014 | 12:16 | 38.2 | 101.3 | 10.94 | 75.4 | <73 |
| W12 | 3/30/2014 | 13:00 | 38.7 | 101.9 | 10.47 | 72.2 | <73 |
| W12 | 4/1/2014 | 13:40 | 38.1 | 102.2 | 10.81 | 74.5 | <73 |
| W12 | 4/8/2014 | 13:20 | 37.7 | 98.9 | 10.50 | 72.4 | <73 |
| W12 | 4/17/2014 | 15:10 | 37.9 | 101.8 | 9.95 | 68.6 | <73 |
| W12 | 4/17/2014 | 15:30 | 37.9 | 100.7 | 10.59 | 73 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | 42.5 | 100.4 | 12.71 | 87.6 | <73 |
| W13 | 3/26/2014 | 17:00 | 41.4 | 99.9 | 12.60 | 86.9 | <73 |
| W13 | 3/28/2014 | 15:30 | 40.6 | 100.7 | 12.27 | 84.6 | <73 |
| W13 | 4/4/2014 | 15:15 | 42.7 | 99.4 | 12.75 | 87.9 | <73 |
| W13 | 4/8/2014 | 11:00 | 38.5 | 98.9 | 11.57 | 79.8 | <73 |
| W13 | 4/15/2014 | 19:30 | 39.3 | 98.3 | 12.56 | 86.6 | <73 |
| W13 | 4/19/2014 | 14:00 | 39.7 | 99 | 12.81 | 88.3 | <73 |
| W14 | 4/6/2014 | 16:20 | 37.4 | 99.8 | 11.47 | 79.1 | <73 |
| W14 | 4/6/2014 | 16:20 | 38.1 | 98.3 | 11.31 | 78 | <73 |
| W14 | 4/4/2014 | 11:55 | 38.5 | 103.1 | 11.76 | 81.1 | <73 |
| W14 | 4/8/2014 | 12:30 | 37.4 | 100.7 | 11.46 | 79 | <73 |
| W14 | 4/18/2014 | 16:30 | 38.9 | 100.2 | 10.96 | 75.6 | <73 |
| W14 | 4/20/2014 | 14:00 | 37.1 | 105.3 | 9.35 | 64.5 | <73 |
| W14 | 4/22/2014 | 11:00 | 37.5 | 106.8 | 8.93 | 61.6 | <73 |
| W15 | 4/9/2014 | 17:20 | 40.1 | 100 | 11.75 | 81 | <73 |
| W15 | 4/9/2014 | 17:20 | 39.9 | 101.3 | 11.44 | 78.9 | <73 |
| W15 | 4/18/2014 | 19:30 | 40.9 | 101.8 | 12.84 | 88.5 | <73 |
| W15 | 4/21/2014 | 18:30 | 40.4 | 103.2 | 12.59 | 86.8 | <73 |
| W15 | 4/23/2014 | 13:00 | 41.9 | 99.9 | 11.04 | 76.1 | <73 |
| W15 | 4/24/2014 | 16:30 | 42.9 | 102.2 | 11.21 | 77.3 | <73 |

## Appendix 8 - Light Ends Data - Rail

| Client ID | Sample Date | Sample Time | Light Ends IP344 - All results in liquid volume % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
| R1 | 3/25/2014 | 17:20 | <0.01 | 0.18 | 1.16 | 0.49 | 2.27 | 0.01 | 1.22 | 2.21 | 0.21 | 5.64 |
| R1 | 3/25/2014 | 17:00 | <0.01 | 0.17 | 1.14 | 0.49 | 2.27 | 0.01 | 1.22 | 2.21 | 0.21 | 5.66 |
| R1 | 3/27/2014 | 17:26 | 0.00 | 0.18 | 1.10 | 0.46 | 2.17 | 0.00 | 1.17 | 2.12 | 0.20 | 5.46 |
| R1 | 3/31/2014 | 14:08 | <0.01 | 0.25 | 1.46 | 0.62 | 2.73 | 0.01 | 1.46 | 2.67 | 0.21 | 6.48 |
| R1 | 4/9/2014 | 10:38 | 0.00 | 0.25 | 1.46 | 0.62 | 2.74 | 0.01 | 1.44 | 2.67 | 0.20 | 6.38 |
| R1 | 4/16/2014 | 15:30 | 0.01 | 0.23 | 1.35 | 0.60 | 2.78 | 0.01 | 1.59 | 2.84 | 0.21 | 6.68 |
| R1 | 4/18/2014 | 11:00 | 0.00 | 0.20 | 1.23 | 0.55 | 2.56 | 0.01 | 1.41 | 2.65 | 0.20 | 6.50 |
| R2 | 3/25/2014 | 18:00 | <0.01 | 0.28 | 1.56 | 0.62 | 2.91 | 0.01 | 1.46 | 2.87 | 0.21 | 6.49 |
| R2 | 3/25/2014 | 18:00 | <0.01 | 0.27 | 1.55 | 0.62 | 2.90 | 0.01 | 1.47 | 2.86 | 0.21 | 6.49 |
| R2 | 3/27/2014 | 10:30 | <0.01 | 0.26 | 1.60 | 0.66 | 3.04 | 0.01 | 1.57 | 2.98 | 0.21 | 6.88 |
| R2 | 3/31/2014 | 12:30 | 0.01 | 0.26 | 1.45 | 0.59 | 2.75 | 0.01 | 1.44 | 2.74 | 0.21 | 6.56 |
| R2 | 4/8/2014 | 10:20 | 0.00 | 0.25 | 1.46 | 0.58 | 2.74 | 0.01 | 1.38 | 2.66 | 0.21 | 6.10 |
| R2 | 4/15/2014 | 11:30 | 0.00 | 0.18 | 1.16 | 0.52 | 2.58 | 0.01 | 1.41 | 2.79 | 0.21 | 6.60 |
| R2 | 4/18/2014 | 10:20 | 0.00 | 0.21 | 1.37 | 0.56 | 2.81 | 0.01 | 1.43 | 2.80 | 0.23 | 6.49 |
| R3 | 3/26/2014 | 14:30 | <0.01 | 0.27 | 1.46 | 0.58 | 2.69 | 0.01 | 1.37 | 2.62 | 0.19 | 6.45 |
| R3 | 3/26/2014 | 14:30 | <0.01 | 0.25 | 1.39 | 0.57 | 2.63 | 0.01 | 1.35 | 2.58 | 0.20 | 6.08 |
| R3 | 3/28/2014 | 13:30 | 0.01 | 0.28 | 1.44 | 0.58 | 2.68 | 0.01 | 1.36 | 2.62 | 0.19 | 6.13 |
| R3 | 4/1/2014 | 16:10 | 0.00 | 0.20 | 1.18 | 0.50 | 2.39 | 0.01 | 1.27 | 2.46 | 0.18 | 5.61 |
| R3 | 4/10/2014 | 14:50 | 0.00 | 0.21 | 1.20 | 0.52 | 2.46 | 0.01 | 1.33 | 2.55 | 0.19 | 6.19 |
| R3 | 4/15/2014 | 14:15 | 0.00 | 0.25 | 1.31 | 0.54 | 2.55 | 0.01 | 1.35 | 2.59 | 0.19 | 6.22 |
| R3 | 4/17/2014 | 13:00 | 0.01 | 0.24 | 1.35 | 0.58 | 2.77 | 0.01 | 1.49 | 2.88 | 0.22 | 6.96 |
| R4 | 3/25/2014 | 14:30 | <0.01 | 0.33 | 1.95 | 0.73 | 3.43 | 0.01 | 1.60 | 3.13 | 0.22 | 6.60 |
| R4 | 3/25/2014 | 14:30 | <0.01 | 0.32 | 1.92 | 0.73 | 3.42 | 0.01 | 1.60 | 3.13 | 0.22 | 6.62 |
| R4 | 3/27/2014 | 11:50 | <0.01 | 0.28 | 1.62 | 0.64 | 3.04 | 0.01 | 1.48 | 2.93 | 0.22 | 6.46 |
| R4 | 3/31/2014 | 11:20 | <0.01 | 0.27 | 1.81 | 0.73 | 3.51 | 0.01 | 1.69 | 3.33 | 0.24 | 6.52 |
| R4 | 4/7/2014 | 13:45 | 0.00 | 0.13 | 1.09 | 0.51 | 2.60 | 0.01 | 1.37 | 2.74 | 0.20 | 5.97 |
| R4 | 4/16/2014 | 12:35 | 0.00 | 0.22 | 1.44 | 0.60 | 2.89 | 0.01 | 1.49 | 2.97 | 0.21 | 6.69 |
| R4 | 4/18/2014 | 12:05 | 0.00 | 0.20 | 1.35 | 0.58 | 2.84 | 0.01 | 1.47 | 2.93 | 0.21 | 6.62 |
| R5 | 3/26/2014 | 12:00 | <0.01 | 0.19 | 1.10 | 0.50 | 2.39 | 0.01 | 1.33 | 2.60 | 0.18 | 6.36 |
| R5 | 3/26/2014 | 12:00 | <0.01 | 0.22 | 1.20 | 0.53 | 2.46 | 0.01 | 1.34 | 2.60 | 0.18 | 6.29 |
| R5 | 3/28/2014 | 12:00 | <0.01 | 0.21 | 1.17 | 0.52 | 2.44 | 0.01 | 1.33 | 2.60 | 0.19 | 6.33 |
| R5 | 4/1/2014 | 14:30 | 0.01 | 0.18 | 1.04 | 0.47 | 2.25 | 0.01 | 1.25 | 2.42 | 0.17 | 5.69 |
| R5 | 4/10/2014 | 13:15 | 0.01 | 0.23 | 1.25 | 0.54 | 2.50 | 0.01 | 1.34 | 2.59 | 0.18 | 6.21 |
| R5 | 4/15/2014 | 12:50 | 0.01 | 0.20 | 1.13 | 0.51 | 2.43 | 0.01 | 1.35 | 2.62 | 0.19 | 6.48 |
| R5 | 4/17/2014 | 11:40 | 0.00 | 0.17 | 1.02 | 0.48 | 2.30 | 0.01 | 1.30 | 2.54 | 0.19 | 6.33 |

## Appendix 8 - Light Ends Data - Rail

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R6 | 3/26/2014 | 15:30 | <0.01 | 0.26 | 1.84 | 0.69 | 3.38 | 0.01 | 1.56 | 2.96 | 0.25 | 6.38 |
| R6 | 3/26/2014 | 15:30 | <0.01 | 0.26 | 1.81 | 0.69 | 3.36 | 0.01 | 1.56 | 2.96 | 0.25 | 6.40 |
| R6 | 3/27/2014 | 15:30 | <0.01 | 0.25 | 1.71 | 0.66 | 3.26 | 0.01 | 1.54 | 2.94 | 0.25 | 6.43 |
| R6 | 3/31/2014 | 14:00 | <0.01 | 0.26 | 1.71 | 0.66 | 3.22 | 0.01 | 1.53 | 2.95 | 0.24 | 6.49 |
| R6 | 4/7/2014 | 15:00 | 0.00 | 0.19 | 1.38 | 0.57 | 2.83 | 0.01 | 1.40 | 2.71 | 0.22 | 5.89 |
| R6 | 4/15/2014 | 14:00 | 0.00 | 0.14 | 1.20 | 0.54 | 2.79 | 0.01 | 1.46 | 2.85 | 0.23 | 6.53 |
| R6 | 4/17/2014 | 12:00 | 0.00 | 0.22 | 1.53 | 0.62 | 3.08 | 0.01 | 1.52 | 2.93 | 0.24 | 6.61 |
| R7 | 3/26/2014 | 19:30 | <0.01 | 0.25 | 1.48 | 0.60 | 2.80 | 0.01 | 1.42 | 2.74 | 0.20 | 6.30 |
| R7 | 3/26/2014 | 19:30 | <0.01 | 0.29 | 1.55 | 0.61 | 2.85 | 0.01 | 1.43 | 2.74 | 0.20 | 6.27 |
| R7 | 3/28/2014 | 13:00 | <0.01 | 0.22 | 1.35 | 0.56 | 2.68 | 0.01 | 1.40 | 2.71 | 0.20 | 6.38 |
| R7 | 3/31/2014 | 17:00 | 0.01 | 0.28 | 1.45 | 0.58 | 2.71 | 0.01 | 1.39 | 2.67 | 0.20 | 6.25 |
| R7 | 4/11/2014 | 10:50 | 0.00 | 0.23 | 1.34 | 0.56 | 2.63 | 0.01 | 1.37 | 2.64 | 0.19 | 6.27 |
| R7 | 4/14/2014 | 12:30 | 0.00 | 0.22 | 1.29 | 0.55 | 2.58 | 0.01 | 1.36 | 2.62 | 0.19 | 6.21 |
| R7 | 4/18/2014 | 10:00 | 0.01 | 0.21 | 1.18 | 0.51 | 2.45 | 0.01 | 1.34 | 2.57 | 0.20 | 6.34 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Light Ends IP344 - All results in liquid volume % Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 0.01 | 0.31 | 1.77 | 0.65 | 3.12 | 0.01 | 1.46 | 2.73 | 0.25 | 6.02 |
| W1 | 3/25/2014 | 19:45 | 0.01 | 0.36 | 1.85 | 0.67 | 3.19 | 0.01 | 1.48 | 2.76 | 0.25 | 6.02 |
| W1 | 3/27/2014 | 18:15 | 0.01 | 0.30 | 1.58 | 0.60 | 2.94 | 0.01 | 1.42 | 2.68 | 0.25 | 6.04 |
| W1 | 3/30/2014 | 16:00 | 0.01 | 0.29 | 1.67 | 0.63 | 3.06 | 0.01 | 1.45 | 2.73 | 0.25 | 6.13 |
| W1 | 4/1/2014 | 11:00 | 0.01 | 0.31 | 1.59 | 0.59 | 2.88 | 0.01 | 1.39 | 2.64 | 0.24 | 5.94 |
| W1 | 4/7/2014 | 12:20 | 0.00 | 0.15 | 1.05 | 0.46 | 2.39 | 0.01 | 1.28 | 2.46 | 0.23 | 5.75 |
| W1 | 4/16/2014 | 11:30 | 0.01 | 0.25 | 1.50 | 0.60 | 2.96 | 0.01 | 1.47 | 2.78 | 0.26 | 6.37 |
| W2 | 3/26/2014 | 12:45 | <0.01 | 0.30 | 1.68 | 0.61 | 3.00 | 0.01 | 1.42 | 2.71 | 0.24 | 6.10 |
| W2 | 3/26/2014 | 12:45 | 0.01 | 0.35 | 1.82 | 0.65 | 3.15 | 0.01 | 1.47 | 2.81 | 0.25 | 6.29 |
| W2 | 3/29/2014 | 15:00 | 0.01 | 0.30 | 1.76 | 0.63 | 3.05 | 0.01 | 1.42 | 2.73 | 0.24 | 6.14 |
| W2 | 3/31/2014 | 10:00 | 0.01 | 0.34 | 1.53 | 0.53 | 2.62 | 0.01 | 1.28 | 2.48 | 0.23 | 5.92 |
| W2 | 4/7/2014 | 13:05 | 0.00 | 0.21 | 1.52 | 0.56 | 2.75 | 0.01 | 1.31 | 2.52 | 0.23 | 5.43 |
| W2 | 4/16/2014 | 12:00 | 0.00 | 0.29 | 1.79 | 0.66 | 3.22 | 0.01 | 1.49 | 2.84 | 0.25 | 6.36 |
| W2 | 4/19/2014 | 9:00 | 0.00 | 0.26 | 1.78 | 0.66 | 3.18 | 0.01 | 1.46 | 2.77 | 0.24 | 6.12 |
| W3 | 3/25/2014 | 12:30 | 0.01 | 0.41 | 1.95 | 0.75 | 3.60 | 0.01 | 1.76 | 3.55 | 0.24 | 7.01 |
| W3 | 3/25/2014 | 12:30 | 0.01 | 0.37 | 1.76 | 0.68 | 3.26 | 0.01 | 1.59 | 3.21 | 0.21 | 6.79 |
| W3 | 3/27/2014 | 10:00 | 0.01 | 0.39 | 1.99 | 0.78 | 3.71 | 0.01 | 1.81 | 3.65 | 0.24 | 7.17 |
| W3 | 3/31/2014 | 10:00 | <0.01 | 0.30 | 1.75 | 0.70 | 3.36 | 0.01 | 1.63 | 3.28 | 0.22 | 7.00 |
| W3 | 4/7/2014 | 12:50 | 0.00 | 0.18 | 1.20 | 0.54 | 2.68 | 0.01 | 1.38 | 2.82 | 0.19 | 5.95 |
| W3 | 4/16/2014 | 10:30 | 0.00 | 0.21 | 1.40 | 0.61 | 3.05 | 0.01 | 1.57 | 3.19 | 0.22 | 6.93 |
| W3 | 4/18/2014 | 11:20 | 0.00 | 0.24 | 1.49 | 0.64 | 3.13 | 0.01 | 1.58 | 3.21 | 0.22 | 6.91 |
| W4 | 3/26/2014 | 12:00 | <0.01 | 0.17 | 1.65 | 0.66 | 3.33 | 0.01 | 1.54 | 2.87 | 0.26 | 6.22 |
| W4 | 3/26/2014 | 12:00 | <0.01 | 0.16 | 1.62 | 0.65 | 3.32 | 0.01 | 1.53 | 2.85 | 0.26 | 6.19 |
| W4 | 3/28/2014 | 13:15 | <0.01 | 0.16 | 1.61 | 0.66 | 3.36 | 0.01 | 1.57 | 2.43 | 0.26 | 6.34 |
| W4 | 4/3/2014 | 17:25 | 0.00 | 0.09 | 1.23 | 0.58 | 3.14 | 0.01 | 1.53 | 2.90 | 0.26 | 6.36 |
| W4 | 4/7/2014 | 18:14 | 0.00 | 0.08 | 1.13 | 0.55 | 2.94 | 0.00 | 1.49 | 2.79 | 0.25 | 6.13 |
| W4 | 4/15/2014 | 16:00 | 0.00 | 0.19 | 1.70 | 0.67 | 3.38 | 0.00 | 1.58 | 2.95 | 0.27 | 6.49 |
| W4 | 4/17/2014 | 14:30 | 0.01 | 0.33 | 2.38 | 0.81 | 3.89 | 0.01 | 1.66 | 3.02 | 0.30 | 6.31 |
| W5 | 3/26/2014 | 15:50 | <0.01 | 0.11 | 1.44 | 0.65 | 3.49 | 0.01 | 1.66 | 3.14 | 0.28 | 6.77 |
| W5 | 3/26/2014 | 15:50 | <0.01 | 0.12 | 1.52 | 0.67 | 3.56 | 0.01 | 1.68 | 3.17 | 0.28 | 6.81 |
| W5 | 3/28/2014 | 13:50 | <0.01 | 0.15 | 1.54 | 0.66 | 3.50 | 0.01 | 1.66 | 3.15 | 0.28 | 6.84 |
| W5 | 4/4/2014 | 17:28 | 0.00 | 0.09 | 1.23 | 0.57 | 3.13 | 0.01 | 1.53 | 2.89 | 0.26 | 6.10 |
| W5 | 4/7/2014 | 19:08 | 0.00 | 0.12 | 1.42 | 0.63 | 3.36 | 0.01 | 1.61 | 3.06 | 0.27 | 6.60 |
| W5 | 4/15/2014 | 17:00 | 0.00 | 0.27 | 2.34 | 0.86 | 4.06 | 0.01 | 1.86 | 3.46 | 0.30 | 7.23 |
| W5 | 4/17/2014 | 15:30 | 0.00 | 0.27 | 2.42 | 0.88 | 4.41 | 0.01 | 1.88 | 3.51 | 0.29 | 7.19 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W6 | 4/6/2014 | 14:55 | 0.00 | 0.24 | 1.67 | 0.73 | 3.28 | 0.01 | 1.61 | 3.11 | 0.17 | 6.38 |
| W6 | 4/6/2014 | 14:55 | 0.00 | 0.22 | 1.60 | 0.71 | 3.18 | 0.01 | 1.56 | 3.01 | 0.17 | 6.19 |
| W6 | 4/8/2014 | 13:50 | 0.00 | 0.32 | 2.02 | 0.83 | 3.65 | 0.01 | 1.72 | 3.30 | 0.18 | 6.82 |
| W6 | 4/15/2014 | 17:05 | 0.00 | 0.36 | 2.23 | 0.92 | 4.03 | 0.01 | 1.88 | 3.60 | 0.20 | 7.40 |
| W6 | 4/17/2014 | 14:05 | 0.00 | 0.31 | 1.94 | 0.82 | 3.66 | 0.01 | 1.76 | 3.38 | 0.19 | 7.07 |
| W6 | 4/21/2014 | 16:30 | 0.00 | 0.25 | 1.89 | 0.82 | 3.64 | 0.01 | 1.74 | 3.34 | 0.19 | 6.96 |
| W6 | 4/24/2014 | 11:20 | 0.00 | 0.28 | 1.93 | 0.83 | 3.68 | 0.01 | 1.75 | 3.35 | 0.21 | 6.87 |
| W7 | 3/25/2014 | 17:00 | 0.01 | 0.67 | 3.13 | 0.95 | 4.55 | 0.01 | 1.82 | 3.58 | 0.27 | 6.74 |
| W7 | 3/25/2014 | 17:00 | <0.01 | 0.53 | 2.72 | 0.88 | 4.24 | 0.01 | 1.78 | 3.50 | 0.27 | 6.84 |
| W7 | 3/27/2014 | 13:00 | 0.01 | 0.46 | 2.42 | 0.82 | 4.01 | 0.01 | 1.74 | 3.47 | 0.27 | 6.96 |
| W7 | 3/31/2014 | 13:00 | <0.01 | 0.37 | 2.14 | 0.77 | 3.82 | 0.01 | 1.71 | 3.41 | 0.27 | 6.96 |
| W7 | 4/7/2014 | 16:00 | 0.00 | 0.21 | 1.60 | 0.63 | 3.25 | 0.01 | 1.52 | 3.05 | 0.24 | 6.30 |
| W7 | 4/16/2014 | 14:20 | 0.00 | 0.32 | 1.98 | 0.74 | 3.75 | 0.01 | 1.72 | 3.43 | 0.27 | 7.06 |
| W7 | 4/21/2014 | 13:45 | 0.00 | 0.21 | 1.81 | 0.72 | 3.66 | 0.01 | 1.70 | 3.39 | 0.27 | 7.03 |
| W8 | 3/25/2014 | 14:53 | <0.01 | 0.15 | 1.55 | 0.83 | 3.73 | 0.01 | 1.93 | 3.37 | 0.28 | 7.26 |
| W8 | 3/25/2014 | 14:33 | <0.01 | 0.14 | 1.54 | 0.83 | 3.71 | 0.01 | 1.93 | 3.37 | 0.28 | 7.26 |
| W8 | 3/27/2014 | 15:30 | <0.01 | 0.17 | 1.65 | 0.83 | 3.66 | 0.01 | 1.89 | 3.40 | 0.27 | 7.53 |
| W8 | 3/31/2014 | 12:42 | <0.01 | 0.15 | 1.56 | 0.80 | 3.53 | 0.01 | 1.80 | 3.25 | 0.25 | 7.22 |
| W8 | 4/9/2014 | 12:30 | 0.00 | 0.12 | 1.27 | 0.68 | 3.13 | 0.01 | 1.68 | 3.20 | 0.26 | 6.84 |
| W8 | 4/16/2014 | 17:00 | 0.00 | 0.20 | 1.62 | 0.79 | 3.51 | 0.01 | 1.80 | 3.19 | 0.27 | 7.37 |
| W8 | 4/18/2014 | 13:00 | 0.00 | 0.19 | 1.55 | 0.76 | 3.40 | 0.01 | 1.80 | 3.27 | 0.30 | 7.64 |
| W9 | 4/1/2014 | 11:20 | 0.01 | 0.25 | 1.19 | 0.47 | 2.33 | 0.01 | 1.18 | 2.21 | 0.21 | 5.27 |
| W9 | 4/1/2014 | 12:10 | 0.01 | 0.26 | 1.22 | 0.47 | 2.36 | 0.01 | 1.19 | 2.23 | 0.21 | 5.30 |
| W9 | 4/3/2014 | 13:00 | 0.00 | 0.17 | 1.02 | 0.42 | 2.14 | 0.00 | 1.10 | 2.07 | 0.19 | 4.98 |
| W9 | 4/8/2014 | 11:25 | 0.00 | 0.19 | 1.21 | 0.48 | 2.41 | 0.01 | 1.20 | 2.24 | 0.20 | 5.24 |
| W9 | 4/15/2014 | 12:33 | 0.01 | 0.22 | 1.16 | 0.47 | 2.37 | 0.01 | 1.22 | 2.29 | 0.21 | 5.52 |
| W9 | 4/22/2014 | 11:35 | 0.01 | 0.18 | 1.03 | 0.43 | 2.19 | <0.01 | 1.15 | 2.18 | 0.20 | 5.35 |
| W9 | 4/24/2014 | 14:20 | <0.01 | 0.20 | 1.12 | 0.45 | 2.24 | 0.01 | 1.14 | 2.15 | 0.20 | 5.19 |
| W10 | 4/15/2014 | 15:40 | 0.00 | 0.37 | 2.29 | 0.94 | 4.12 | 0.01 | 1.91 | 3.70 | 0.20 | 7.41 |
| W10 | 4/15/2014 | 15:40 | 0.00 | 0.29 | 2.08 | 0.90 | 3.97 | 0.01 | 1.89 | 3.67 | 0.20 | 7.49 |
| W10 | 4/17/2014 | 12:50 | 0.00 | 0.36 | 2.25 | 0.92 | 4.03 | 0.01 | 1.88 | 3.64 | 0.19 | 7.36 |
| W10 | 4/21/2014 | 15:30 | <0.01 | 0.33 | 2.19 | 0.90 | 3.98 | 0.01 | 1.82 | 3.52 | 0.19 | 7.02 |
| W10 | 4/24/2014 | 12:35 | <0.01 | 0.25 | 1.95 | 0.86 | 3.81 | 0.01 | 1.82 | 3.54 | 0.19 | 7.23 |
| W10 | | | 0.00 | 0.20 | 1.76 | 0.81 | 3.66 | 0.01 | 1.78 | 3.46 | 0.19 | 7.09 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W11 | 4/7/2014 | 16:35 | 0.00 | 0.16 | 1.56 | 0.62 | 3.09 | 0.01 | 1.42 | 2.63 | 0.24 | 5.62 |
| W11 | 4/7/2014 | 16:35 | 0.00 | 0.13 | 1.48 | 0.60 | 3.01 | 0.01 | 1.39 | 2.58 | 0.24 | 5.52 |
| W11 | 4/11/2014 | 14:55 | 0.00 | 0.34 | 2.69 | 0.86 | 4.03 | 0.01 | 1.60 | 2.91 | 0.26 | 5.99 |
| W11 | 4/15/2014 | 15:00 | 0.00 | 0.25 | 2.10 | 0.77 | 3.72 | 0.01 | 1.62 | 2.98 | 0.27 | 6.41 |
| W11 | 4/17/2014 | 13:30 | 0.00 | 0.27 | 2.17 | 0.77 | 3.69 | 0.01 | 1.59 | 2.92 | 0.27 | 6.23 |
| W11 | 4/20/2014 | 11:00 | 0.00 | 0.15 | 0.96 | 0.41 | 2.32 | 0.01 | 1.24 | 2.59 | 0.23 | 6.22 |
| W11 | 4/23/2014 | | <0.01 | 0.40 | 2.99 | 0.92 | 4.25 | 0.01 | 1.65 | 2.98 | 0.26 | 6.00 |
| W12 | 3/27/2014 | 12:46 | 0.00 | 0.21 | 1.26 | 0.50 | 2.53 | 0.01 | 1.26 | 2.41 | 0.21 | 5.57 |
| W12 | 3/27/2014 | 12:16 | 0.00 | 0.22 | 1.28 | 0.51 | 2.56 | 0.01 | 1.28 | 2.42 | 0.22 | 5.59 |
| W12 | 3/30/2014 | 13:00 | 0.01 | 0.23 | 1.25 | 0.49 | 2.45 | 0.01 | 1.22 | 2.31 | 0.21 | 5.48 |
| W12 | 4/1/2014 | 13:40 | 0.01 | 0.25 | 1.32 | 0.51 | 2.51 | 0.01 | 1.24 | 2.35 | 0.21 | 5.52 |
| W12 | 4/8/2014 | 13:20 | 0.00 | 0.18 | 1.17 | 0.48 | 2.41 | 0.01 | 1.22 | 2.32 | 0.21 | 5.42 |
| W12 | 4/17/2014 | 15:10 | 0.01 | 0.18 | 1.06 | 0.45 | 2.30 | 0.00 | 1.22 | 2.35 | 0.22 | 5.77 |
| W12 | 4/17/2014 | 15:30 | 0.01 | 0.20 | 1.11 | 0.46 | 2.30 | 0.01 | 1.21 | 2.32 | 0.21 | 5.63 |
| W13 | 3/26/2014 | 17:00 | <0.01 | 0.22 | 1.69 | 0.69 | 3.25 | 0.01 | 1.49 | 2.72 | 0.22 | 5.85 |
| W13 | 3/26/2014 | 17:00 | <0.01 | 0.21 | 1.65 | 0.68 | 3.22 | 0.01 | 1.49 | 2.72 | 0.22 | 5.88 |
| W13 | 3/28/2014 | 15:30 | 0.01 | 0.24 | 1.57 | 0.63 | 3.02 | 0.01 | 1.45 | 2.68 | 0.22 | 5.93 |
| W13 | 4/4/2014 | 15:15 | 0.00 | 0.16 | 1.42 | 0.61 | 2.93 | 0.01 | 1.38 | 2.52 | 0.20 | 5.34 |
| W13 | 4/8/2014 | 11:00 | 0.00 | 0.26 | 1.91 | 0.74 | 3.40 | 0.01 | 1.51 | 2.73 | 0.22 | 5.84 |
| W13 | 4/15/2014 | 19:30 | 0.00 | 0.19 | 1.73 | 0.74 | 3.56 | 0.01 | 1.69 | 3.10 | 0.25 | 6.84 |
| W13 | 4/19/2014 | 14:00 | 0.00 | 0.31 | 1.94 | 0.68 | 3.29 | 0.01 | 1.47 | 2.80 | 0.24 | 6.12 |
| W14 | 4/6/2014 | 16:20 | 0.01 | 0.22 | 1.12 | 0.43 | 2.32 | 0.01 | 1.20 | 2.49 | 0.21 | 5.63 |
| W14 | 4/6/2014 | 16:20 | 0.01 | 0.21 | 1.10 | 0.42 | 2.29 | 0.00 | 1.20 | 2.48 | 0.21 | 5.63 |
| W14 | 4/4/2014 | 11:55 | <0.01 | 0.22 | 1.24 | 0.48 | 2.57 | 0.01 | 1.32 | 2.73 | 0.23 | 6.35 |
| W14 | 4/8/2014 | 12:30 | 0.00 | 0.26 | 1.53 | 0.56 | 2.89 | 0.01 | 1.38 | 2.81 | 0.23 | 6.20 |
| W14 | 4/18/2014 | 16:30 | 0.01 | 0.16 | 1.00 | 0.42 | 2.35 | 0.01 | 1.25 | 2.58 | 0.22 | 6.11 |
| W14 | 4/20/2014 | 14:00 | 0.01 | 0.16 | 0.89 | 0.37 | 2.10 | 0.00 | 1.16 | 2.45 | 0.22 | 6.13 |
| W14 | 4/22/2014 | 11:00 | <0.01 | 0.14 | 0.84 | 0.35 | 2.00 | <0.01 | 1.11 | 2.33 | 0.21 | 5.84 |
| W15 | 4/9/2014 | 17:20 | 0.00 | 0.25 | 1.41 | 0.58 | 2.67 | 0.01 | 1.38 | 2.61 | 0.20 | 6.12 |
| W15 | 4/9/2014 | 17:20 | 0.00 | 0.24 | 1.42 | 0.58 | 2.69 | 0.01 | 1.38 | 2.62 | 0.20 | 6.14 |
| W15 | 4/18/2014 | 19:30 | 0.00 | 0.21 | 1.16 | 0.50 | 2.40 | 0.01 | 1.33 | 2.55 | 0.20 | 6.22 |
| W15 | 4/21/2014 | 18:30 | <0.01 | 0.24 | 1.38 | 0.56 | 2.62 | 0.01 | 1.36 | 2.59 | 0.20 | 6.13 |
| W15 | 4/23/2014 | 13:00 | <0.01 | 0.24 | 1.40 | 0.58 | 2.67 | 0.01 | 1.38 | 2.60 | 0.20 | 6.13 |
| W15 | 4/24/2014 | 16:30 | 0.00 | 0.18 | 1.31 | 0.56 | 2.66 | 0.01 | 1.40 | 2.66 | 0.21 | 6.26 |

## Appendix 10 - Simulated Distillation Data - Rail

### Simulated Distillation by ASTM D7169- All results reported in °F

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | <97 | 151 | 186 | 264 | 343 | 430 | 517 | 609 | 710 | 823 | 967 | 1071 | 1278 | 100.0 | Oil Temp 35°F |
| R1 | 3/25/2014 | 17:00 | <97 | 151 | 183 | 263 | 346 | 436 | 527 | 623 | 730 | 850 | 1012 | 1150 | >1382 | 97.6 | |
| R1 | 3/27/2014 | 17:26 | <97 | 104 | 176 | 252 | 332 | 423 | 513 | 608 | 713 | 828 | 973 | 1076 | 1307 | 100.0 | |
| R1 | 3/31/2014 | 14:08 | <97 | 127 | 177 | 239 | 315 | 391 | 473 | 559 | 650 | 760 | 903 | 1009 | 1217 | 100.0 | |
| R1 | 4/9/2014 | 10:38 | <97 | <97 | 153 | 222 | 300 | 376 | 459 | 549 | 647 | 761 | 909 | 1019 | 1246 | 100.0 | |
| R1 | 4/16/2014 | 15:30 | | | | | | | | | | | | | | | |
| R1 | 4/18/2014 | 11:00 | | | | | | | | | | | | | | | |
| R2 | 3/25/2014 | 18:00 | <97 | 135 | 168 | 235 | 313 | 388 | 470 | 557 | 651 | 763 | 909 | 1017 | 1226 | 100.0 | |
| R2 | 3/25/2014 | 18:00 | <97 | 138 | 178 | 246 | 320 | 388 | 477 | 564 | 659 | 772 | 921 | 1033 | 1317 | 99.7 | |
| R2 | 3/27/2014 | 10:30 | <97 | 98 | 158 | 223 | 289 | 364 | 443 | 527 | 620 | 733 | 888 | 1013 | >1382 | 99.1 | |
| R2 | 3/31/2014 | 12:30 | <97 | 107 | 164 | 232 | 302 | 376 | 454 | 540 | 630 | 742 | 889 | 1000 | 1219 | 100.0 | |
| R2 | 4/8/2014 | 10:20 | <97 | <97 | 143 | 216 | 295 | 379 | 468 | 561 | 664 | 783 | 936 | 1048 | 1257 | 100.0 | |
| R2 | 4/15/2014 | 11:30 | | | | | | | | | | | | | | | |
| R2 | 4/18/2014 | 10:20 | | | | | | | | | | | | | | | |
| R3 | 3/26/2014 | 14:30 | <97 | 112 | 175 | 245 | 325 | 405 | 488 | 576 | 675 | 788 | 933 | 1039 | 1244 | 100.0 | Oil Temp 37°F |
| R3 | 3/26/2014 | 14:30 | <97 | 146 | 177 | 251 | 326 | 408 | 492 | 581 | 679 | 791 | 935 | 1040 | 1256 | 100.0 | Oil Temp 37°F |
| R3 | 3/28/2014 | 13:30 | <97 | <97 | 157 | 235 | 317 | 403 | 490 | 583 | 686 | 805 | 957 | 1073 | 1309 | 100.0 | Oil Temp 49°F |
| R3 | 4/1/2014 | 16:10 | <97 | <97 | 162 | 235 | 320 | 405 | 496 | 591 | 696 | 820 | 994 | 1180 | >1382 | 95.9 | |
| R3 | 4/10/2014 | 14:50 | <97 | <97 | 158 | 238 | 317 | 398 | 486 | 577 | 678 | 795 | 946 | 1062 | >1382 | 99.1 | |
| R3 | 4/15/2014 | 14:15 | | | | | | | | | | | | | | | |
| R3 | 4/17/2014 | 13:00 | | | | | | | | | | | | | | | |
| R4 | 3/25/2014 | 14:30 | <97 | 111 | 156 | 234 | 314 | 393 | 480 | 573 | 674 | 796 | 962 | 1107 | >1382 | 99.8 | |
| R4 | 3/25/2014 | 14:30 | <97 | 133 | 167 | 237 | 318 | 399 | 484 | 574 | 673 | 792 | 950 | 1077 | >1382 | 98.9 | |
| R4 | 3/27/2014 | 11:50 | <97 | <97 | 163 | 238 | 320 | 403 | 489 | 581 | 682 | 800 | 954 | 1072 | 1318 | 100.0 | |
| R4 | 3/31/2014 | 11:20 | <97 | 103 | 168 | 239 | 318 | 399 | 486 | 575 | 674 | 791 | 945 | 1065 | >1382 | 99.1 | |
| R4 | 4/7/2014 | 13:45 | <97 | <97 | 157 | 233 | 305 | 385 | 474 | 563 | 663 | 779 | 925 | 1029 | 1220 | 100.0 | |
| R4 | 4/16/2014 | 12:35 | | | | | | | | | | | | | | | |
| R4 | 4/18/2014 | 12:05 | | | | | | | | | | | | | | | |
| R5 | 3/26/2014 | 12:00 | <97 | 117 | 168 | 236 | 314 | 390 | 475 | 563 | 660 | 775 | 927 | 1049 | >1382 | 98.7 | |
| R5 | 3/26/2014 | 12:00 | <97 | <97 | 159 | 234 | 315 | 394 | 481 | 575 | 675 | 796 | 959 | 1089 | 1341 | 100.0 | |
| R5 | 3/28/2014 | 12:00 | <97 | <97 | 160 | 233 | 311 | 389 | 475 | 564 | 662 | 777 | 924 | 1037 | 1276 | 100.0 | |
| R5 | 4/1/2014 | 14:30 | <97 | <97 | 151 | 227 | 306 | 385 | 474 | 569 | 671 | 792 | 957 | 1116 | >1382 | 96.6 | |
| R5 | 4/10/2014 | 13:15 | <97 | <97 | 158 | 236 | 306 | 385 | 466 | 555 | 651 | 764 | 910 | 1019 | 1272 | 99.8 | |
| R5 | 4/15/2014 | 12:50 | | | | | | | | | | | | | | | |
| R5 | 4/17/2014 | 11:40 | | | | | | | | | | | | | | | |

## Appendix 10 - Simulated Distillation Data - Rail

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R6 | 3/26/2014 | 15:30 | <97 | 116 | 156 | 232 | 310 | 388 | 471 | 558 | 650 | 758 | 900 | 1008 | 1342 | 99.5 | |
| R6 | 3/26/2014 | 15:30 | <97 | 131 | 165 | 235 | 315 | 394 | 476 | 562 | 654 | 762 | 900 | 1004 | 1230 | 100.0 | |
| R6 | 3/27/2014 | 15:30 | <97 | <97 | 162 | 236 | 315 | 395 | 481 | 570 | 665 | 778 | 929 | 1056 | >1382 | 98.5 | |
| R6 | 3/31/2014 | 14:00 | <97 | 106 | 168 | 237 | 320 | 404 | 490 | 580 | 680 | 797 | 962 | 1126 | >1382 | 96.7 | |
| R6 | 4/7/2014 | 15:00 | <97 | <97 | 152 | 225 | 302 | 383 | 466 | 555 | 650 | 763 | 909 | 1021 | 1308 | 100.0 | |
| R6 | 4/15/2014 | 14:00 | | | | | | | | | | | | | | | |
| R6 | 4/17/2014 | 12:00 | | | | | | | | | | | | | | | |
| R7 | 3/26/2014 | 19:30 | <97 | 138 | 171 | 237 | 316 | 394 | 479 | 570 | 668 | 783 | 931 | 1040 | 1278 | 100.0 | |
| R7 | 3/26/2014 | 19:30 | <97 | 146 | 179 | 255 | 330 | 418 | 504 | 596 | 700 | 822 | 987 | 1122 | >1382 | 98.7 | |
| R7 | 3/28/2014 | 13:00 | <97 | 114 | 176 | 242 | 322 | 403 | 488 | 580 | 683 | 803 | 962 | 1086 | >1382 | 98.8 | |
| R7 | 3/31/2014 | 17:00 | <97 | 127 | 179 | 254 | 327 | 409 | 496 | 587 | 691 | 811 | 971 | 1099 | >1382 | 98.4 | |
| R7 | 4/11/2014 | 10:50 | <97 | <97 | 154 | 236 | 313 | 391 | 480 | 575 | 647 | 792 | 941 | 1052 | 1297 | 100.0 | |
| R7 | 4/14/2014 | 12:30 | | | | | | | | | | | | | | | |
| R7 | 4/18/2014 | 10:00 | | | | | | | | | | | | | | | |

**Simulated Distillation by ASTM D7169- All results reported in °F**

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | <97 | 135 | 178 | 259 | 342 | 428 | 517 | 610 | 713 | 827 | 974 | 1086 | 1329 | 100.0 | |
| W1 | 3/25/2014 | 19:45 | <97 | 150 | 188 | 272 | 355 | 442 | 531 | 623 | 725 | 839 | 987 | 1102 | 1337 | 100.0 | |
| W1 | 3/27/2014 | 18:15 | <97 | 119 | 179 | 257 | 334 | 422 | 510 | 601 | 703 | 815 | 958 | 1071 | >1382 | 98.8 | |
| W1 | 3/30/2014 | 16:00 | <97 | 142 | 180 | 262 | 344 | 432 | 524 | 621 | 726 | 846 | 1011 | 1176 | >1382 | 96.7 | |
| W1 | 4/1/2014 | 11:00 | <97 | <97 | 148 | 224 | 310 | 396 | 488 | 584 | 688 | 803 | 947 | 1050 | 1248 | 100.0 | |
| W1 | 4/7/2014 | 12:20 | | | | | | | | | | | | | | | |
| W1 | 4/16/2014 | 11:30 | | | | | | | | | | | | | | | |
| W2 | 3/26/2014 | 12:45 | <97 | 143 | 179 | 261 | 342 | 424 | 508 | 596 | 693 | 803 | 952 | 1072 | 1328 | 100.0 | |
| W2 | 3/26/2014 | 12:45 | <97 | 140 | 184 | 263 | 342 | 422 | 505 | 590 | 685 | 793 | 937 | 1050 | 1303 | 100.0 | |
| W2 | 3/29/2014 | 15:00 | <97 | 108 | 165 | 237 | 318 | 400 | 482 | 569 | 661 | 768 | 903 | 1004 | 1248 | 99.7 | |
| W2 | 3/31/2014 | 10:00 | <97 | 136 | 178 | 255 | 329 | 412 | 492 | 577 | 670 | 774 | 910 | 1013 | 1244 | 100.0 | |
| W2 | 4/7/2014 | 13:05 | <97 | <97 | 154 | 235 | 316 | 398 | 481 | 570 | 664 | 772 | 911 | 1018 | 1316 | 100.0 | |
| W2 | 4/16/2014 | 12:00 | | | | | | | | | | | | | | | |
| W2 | 4/19/2014 | 9:00 | | | | | | | | | | | | | | | |
| W3 | 3/25/2014 | 12:30 | <97 | <97 | 157 | 232 | 304 | 383 | 462 | 548 | 639 | 748 | 895 | 1016 | >1382 | 98.6 | |
| W3 | 3/25/2014 | 12:30 | <97 | <97 | 161 | 234 | 310 | 384 | 464 | 547 | 638 | 744 | 886 | 995 | 1283 | 99.8 | |
| W3 | 3/27/2014 | 10:00 | <97 | <97 | 159 | 230 | 300 | 374 | 456 | 545 | 638 | 750 | 903 | 1037 | >1382 | 98.1 | |
| W3 | 3/31/2014 | 10:00 | <97 | 97 | 159 | 230 | 298 | 371 | 453 | 537 | 629 | 737 | 879 | 990 | >1382 | 99.4 | |
| W3 | 4/7/2014 | 12:50 | <97 | <97 | 154 | 224 | 297 | 372 | 453 | 537 | 628 | 737 | 880 | 992 | 1329 | 100.0 | |
| W3 | 4/16/2014 | 10:30 | | | | | | | | | | | | | | | |
| W3 | 4/18/2014 | 11:20 | | | | | | | | | | | | | | | |
| W4 | 3/26/2014 | 12:00 | <97 | 100 | 158 | 236 | 318 | 406 | 491 | 579 | 675 | 788 | 940 | 1076 | >1382 | 97.7 | |
| W4 | 3/26/2014 | 12:00 | <97 | 110 | 165 | 239 | 319 | 405 | 488 | 575 | 667 | 774 | 914 | 1023 | >1382 | 99.4 | |
| W4 | 3/28/2014 | 13:15 | <97 | 119 | 169 | 243 | 322 | 409 | 493 | 581 | 678 | 792 | 947 | 1082 | >1382 | 98.2 | |
| W4 | 4/3/2014 | 17:25 | <97 | <97 | 104 | 207 | 286 | 373 | 460 | 552 | 648 | 760 | 904 | 1014 | 1273 | 100.0 | |
| W4 | 4/7/2014 | 18:14 | <97 | <97 | 152 | 233 | 315 | 402 | 490 | 582 | 683 | 801 | 966 | 1121 | >1382 | 98.3 | |
| W4 | 4/15/2014 | 16:00 | | | | | | | | | | | | | | | |
| W4 | 4/17/2014 | 14:30 | | | | | | | | | | | | | | | |
| W5 | 3/26/2014 | 15:50 | <97 | 101 | 160 | 234 | 312 | 390 | 475 | 562 | 656 | 767 | 914 | 1028 | 1289 | 100.0 | |
| W5 | 3/26/2014 | 15:50 | <97 | <97 | 146 | 216 | 292 | 374 | 458 | 548 | 642 | 753 | 898 | 1008 | 1257 | 100.0 | |
| W5 | 3/28/2014 | 13:50 | <97 | <97 | 156 | 225 | 300 | 377 | 458 | 547 | 640 | 751 | 896 | 1010 | 1272 | 100.0 | |
| W5 | 4/4/2014 | 17:28 | <97 | <97 | 132 | 205 | 280 | 366 | 454 | 548 | 645 | 757 | 903 | 1020 | >1382 | 98.7 | |
| W5 | 4/7/2014 | 19:08 | <97 | <97 | 135 | 209 | 285 | 364 | 448 | 538 | 633 | 747 | 894 | 1009 | 1322 | 100.0 | |
| W5 | 4/15/2014 | 17:00 | | | | | | | | | | | | | | | |
| W5 | 4/17/2014 | 15:30 | | | | | | | | | | | | | | | |
| W6 | 4/6/2014 | 14:55 | <97 | <97 | 129 | 204 | 277 | 349 | 436 | 528 | 629 | 751 | 914 | 1037 | >1382 | 98.9 | |
| W6 | 4/6/2014 | 14:55 | <97 | <97 | 103 | 189 | 264 | 336 | 420 | 513 | 613 | 734 | 891 | 1004 | 1218 | 99.9 | |
| W6 | 4/8/2014 | 13:50 | <97 | <97 | 156 | 236 | 304 | 377 | 461 | 554 | 658 | 789 | 977 | 1157 | >1382 | 96.6 | |
| W6 | 4/15/2014 | 17:05 | <97 | <97 | <97 | 188 | 257 | 331 | 419 | 510 | 611 | 734 | 895 | 1010 | 1217 | 100.0 | |
| W6 | 4/17/2014 | 14:05 | <97 | <97 | 145 | 206 | 278 | 348 | 433 | 521 | 622 | 741 | 899 | 1011 | 1214 | 100.0 | |
| W6 | 4/21/2014 | 16:30 | | | | | | | | | | | | | | | |
| W6 | 4/24/2014 | 11:20 | | | | | | | | | | | | | | | |

## Appendix 11 - Simulated Distillation Data - Well

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 3/25/2014 | 17:00 | <97 | 118 | 155 | 231 | 302 | 376 | 453 | 536 | 623 | 727 | 867 | 975 | 1220 | 100.0 | |
| W7 | 3/25/2014 | 17:00 | <97 | 135 | 177 | 252 | 326 | 404 | 484 | 568 | 661 | 777 | 955 | 1192 | >1382 | 95.7 | |
| W7 | 3/27/2014 | 13:00 | <97 | <97 | 104 | 204 | 285 | 366 | 450 | 538 | 633 | 747 | 905 | 1035 | 1328 | 100.0 | |
| W7 | 3/31/2014 | 13:00 | <97 | <97 | 156 | 221 | 296 | 372 | 453 | 536 | 627 | 735 | 883 | 1007 | >1382 | 98.7 | |
| W7 | 4/7/2014 | 16:00 | <97 | <97 | 132 | 208 | 282 | 356 | 437 | 520 | 611 | 718 | 860 | 971 | 1220 | 100.0 | |
| W7 | 4/16/2014 | 14:20 | | | | | | | | | | | | | | | |
| W7 | 4/21/2014 | 13:45 | | | | | | | | | | | | | | | |
| W8 | 3/25/2014 | 14:53 | <97 | 128 | 157 | 231 | 305 | 386 | 471 | 560 | 653 | 766 | 932 | 1121 | >1382 | 96.5 | |
| W8 | 3/25/2014 | 14:33 | <97 | 112 | 153 | 217 | 290 | 370 | 452 | 535 | 623 | 726 | 861 | 966 | 1198 | 100.0 | |
| W8 | 3/27/2014 | 15:30 | <97 | <97 | 158 | 219 | 294 | 376 | 461 | 549 | 643 | 755 | 914 | 1079 | >1382 | 96.9 | |
| W8 | 3/31/2014 | 12:42 | <97 | 104 | 163 | 232 | 311 | 391 | 477 | 566 | 660 | 776 | 937 | 1060 | 1293 | 100.0 | |
| W8 | 4/9/2014 | 12:30 | <97 | <97 | 153 | 222 | 301 | 381 | 459 | 545 | 629 | 734 | 870 | 976 | 1230 | 100.0 | |
| W8 | 4/16/2014 | 17:00 | | | | | | | | | | | | | | | |
| W8 | 4/18/2014 | 13:00 | | | | | | | | | | | | | | | |
| W9 | 4/1/2014 | 11:20 | <97 | 141 | 187 | 278 | 373 | 470 | 570 | 672 | 783 | 903 | 1044 | 1139 | 1320 | 100.0 | Stock Tank ID 43047 |
| W9 | 4/1/2014 | 12:10 | <97 | 137 | 180 | 276 | 375 | 476 | 578 | 684 | 796 | 920 | 1069 | 1182 | >1382 | 97.8 | Stock Tank ID 43047 |
| W9 | 4/3/2014 | 13:00 | <97 | 97 | 178 | 265 | 358 | 456 | 558 | 660 | 772 | 893 | 1037 | 1134 | 1362 | 99.7 | Stock Tank ID 43043 |
| W9 | 4/8/2014 | 11:25 | <97 | <97 | 174 | 263 | 353 | 451 | 549 | 649 | 758 | 879 | 1025 | 1124 | 1331 | 100.0 | Stock Tank ID 43043 |
| W9 | 4/15/2014 | 12:33 | <97 | <97 | 157 | 243 | 341 | 439 | 538 | 641 | 754 | 876 | 1023 | 1118 | 1284 | 100.0 | Stock Tank ID 43054 |
| W9 | 4/22/2014 | 11:35 | | | | | | | | | | | | | | | Stock Tank ID 43054 |
| W9 | 4/24/2014 | 14:20 | | | | | | | | | | | | | | | Stock Tank ID 43048 |
| W10 | 4/15/2014 | 15:40 | <97 | <97 | 126 | 200 | 267 | 344 | 432 | 525 | 631 | 754 | 912 | 1019 | 1209 | 100.0 | |
| W10 | 4/15/2014 | 15:40 | <97 | <97 | 145 | 205 | 278 | 349 | 437 | 528 | 630 | 750 | 901 | 1005 | 1186 | 100.0 | |
| W10 | 4/17/2014 | 12:50 | <97 | <97 | <97 | 182 | 251 | 330 | 419 | 513 | 621 | 749 | 906 | 1013 | 1209 | 100.0 | |
| W10 | 4/21/2014 | 15:30 | <97 | <97 | <97 | 180 | 244 | 327 | 413 | 509 | 615 | 740 | 900 | 1010 | 1222 | 100.0 | |
| W10 | 4/24/2014 | 12:35 | <97 | <97 | <97 | 181 | 246 | 327 | 412 | 508 | 613 | 738 | 896 | 1005 | 1219 | 100.0 | |
| W10 | | | | | | | | | | | | | | | | | |
| W11 | 4/7/2014 | 16:35 | <97 | <97 | 132 | 211 | 289 | 375 | 466 | 560 | 657 | 769 | 913 | 1023 | 1255 | 100.0 | |
| W11 | 4/7/2014 | 16:35 | <97 | <97 | 131 | 213 | 292 | 377 | 467 | 561 | 658 | 771 | 915 | 1025 | 1260 | 100.0 | |
| W11 | 4/11/2014 | 14:55 | <97 | <97 | 150 | 219 | 298 | 383 | 469 | 561 | 656 | 769 | 913 | 1023 | >1382 | 99.2 | |
| W11 | 4/15/2014 | 15:00 | <97 | <97 | 146 | 213 | 289 | 371 | 455 | 546 | 639 | 752 | 898 | 1007 | 1210 | 100.0 | |
| W11 | 4/17/2014 | 13:30 | <97 | <97 | <97 | 204 | 283 | 370 | 459 | 554 | 653 | 769 | 916 | 1026 | 1241 | 100.0 | |
| W11 | 4/20/2014 | 11:00 | | | | | | | | | | | | | | | |
| W11 | 4/23/2014 | | | | | | | | | | | | | | | | |
| W12 | 3/27/2014 | 12:46 | <97 | <97 | 164 | 254 | 343 | 439 | 536 | 636 | 748 | 869 | 1015 | 1114 | 1327 | 100.0 | |
| W12 | 3/27/2014 | 12:16 | <97 | <97 | 168 | 260 | 346 | 443 | 542 | 642 | 754 | 877 | 1025 | 1127 | >1382 | 99.4 | |
| W12 | 3/30/2014 | 13:00 | <97 | 141 | 181 | 267 | 354 | 451 | 547 | 647 | 756 | 878 | 1022 | 1120 | 1308 | 100.0 | |
| W12 | 4/1/2014 | 13:40 | <97 | 146 | 184 | 270 | 359 | 454 | 552 | 652 | 763 | 886 | 1036 | 1140 | >1382 | 99.0 | |
| W12 | 4/8/2014 | 13:20 | <97 | 100 | 179 | 266 | 355 | 453 | 550 | 651 | 762 | 885 | 1031 | 1130 | 1337 | 100.0 | |
| W12 | 4/17/2014 | 15:10 | | | | | | | | | | | | | | | |
| W12 | 4/17/2014 | 15:30 | | | | | | | | | | | | | | | |

**Appendix 11 - Simulated Distillation Data - Well**

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | <97 | 110 | 165 | 240 | 327 | 418 | 503 | 589 | 684 | 792 | 938 | 1063 | >1382 | 98.5 | |
| W13 | 3/26/2014 | 17:00 | <97 | <97 | 155 | 231 | 313 | 403 | 490 | 578 | 674 | 783 | 924 | 1042 | >1382 | 98.9 | |
| W13 | 3/28/2014 | 15:30 | <97 | 120 | 175 | 247 | 332 | 425 | 514 | 602 | 702 | 814 | 978 | 1165 | >1382 | 96.5 | |
| W13 | 4/4/2014 | 15:15 | <97 | <97 | 136 | 219 | 303 | 394 | 488 | 582 | 683 | 797 | 959 | 1141 | >1382 | 96.2 | |
| W13 | 4/8/2014 | 11:00 | <97 | <97 | 154 | 233 | 313 | 400 | 488 | 576 | 670 | 777 | 913 | 1018 | 1270 | 100.0 | |
| W13 | 4/15/2014 | 19:30 | | | | | | | | | | | | | | | |
| W13 | 4/19/2014 | 14:00 | | | | | | | | | | | | | | | |
| W14 | 4/6/2014 | 16:20 | <97 | <97 | 149 | 229 | 315 | 397 | 484 | 574 | 670 | 780 | 926 | 1044 | >1382 | 99.5 | |
| W14 | 4/6/2014 | 16:20 | <97 | <97 | 168 | 248 | 325 | 409 | 495 | 584 | 679 | 789 | 936 | 1053 | 1298 | 100.0 | |
| W14 | 4/4/2014 | 11:55 | <97 | <97 | 137 | 217 | 300 | 384 | 473 | 563 | 661 | 774 | 923 | 1039 | 1262 | 100.0 | |
| W14 | 4/8/2014 | 12:30 | <97 | <97 | 155 | 236 | 315 | 392 | 477 | 565 | 660 | 768 | 910 | 1018 | 1257 | 100.0 | |
| W14 | 4/18/2014 | 16:30 | <97 | 98 | 174 | 244 | 328 | 411 | 496 | 585 | 681 | 790 | 931 | 1035 | 1225 | 100.0 | |
| W14 | 4/20/2014 | 14:00 | <97 | 110 | 181 | 250 | 331 | 416 | 500 | 587 | 683 | 792 | 931 | 1035 | 1225 | 100.0 | |
| W14 | 4/22/2014 | 11:00 | <97 | <97 | 153 | 238 | 320 | 403 | 489 | 579 | 677 | 789 | 932 | 1040 | 1262 | 100.0 | |
| W15 | 4/9/2014 | 17:20 | <97 | <97 | 158 | 237 | 313 | 390 | 477 | 570 | 671 | 789 | 942 | 1053 | 1282 | 100.0 | |
| W15 | 4/9/2014 | 17:20 | <97 | <97 | 154 | 235 | 309 | 388 | 476 | 570 | 672 | 790 | 945 | 1058 | 1307 | 100.0 | |
| W15 | 4/18/2014 | 19:30 | <97 | <97 | 153 | 232 | 307 | 389 | 478 | 572 | 674 | 794 | 947 | 1054 | 1251 | 100.0 | |
| W15 | 4/21/2014 | 18:30 | <97 | <97 | 147 | 221 | 301 | 383 | 472 | 566 | 670 | 791 | 946 | 1055 | 1263 | 100.0 | |
| W15 | 4/23/2014 | 13:00 | | | | | | | | | | | | | | | |
| W15 | 4/24/2014 | 16:30 | | | | | | | | | | | | | | | |

## Appendix 12 - Seasonality Data (Member Contributed)

| DATE | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 8/1/2013 | 8.96 | 8.62 |
| 8/2/2013 | 8.75 | 8.47 |
| 8/5/2013 | 8.48 | 8.54 |
| 8/16/2013 | 8.58 | 8.28 |
| 8/18/2013 | 8.75 | 8.33 |
| 8/22/2013 | 8.82 | 8.04 |
| 8/26/2013 | 8.56 | 8.25 |
| 8/29/2013 | 8.48 | |
| 9/1/2013 | 8.43 | 7.94 |
| 9/5/2013 | 7.99 | 7.93 |
| 9/11/2013 | 8.29 | 8.31 |
| 9/13/2013 | 8.43 | 8.29 |
| 9/14/2013 | 7.90 | 7.96 |
| 9/15/2013 | 8.73 | 8.89 |
| 9/23/2013 | 8.50 | 8.80 |
| 9/25/2013 | 8.27 | 8.57 |
| 9/26/2013 | 8.43 | 8.63 |
| 9/27/2013 | 8.41 | 8.77 |
| 10/4/2013 | 8.70 | |
| 10/7/2013 | 9.09 | 8.83 |
| 10/10/2013 | 9.22 | 8.53 |
| 10/14/2013 | 9.79 | 8.70 |
| 10/19/2013 | 9.10 | 9.20 |
| 10/20/2013 | 9.79 | 9.69 |
| 10/22/2013 | 9.53 | 9.63 |
| 10/24/2013 | | 9.44 |
| 10/25/2013 | 9.24 | 9.40 |
| 10/26/2013 | 9.24 | 9.56 |
| 10/28/2013 | 9.21 | 9.38 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 10/30/2013 | 9.08 | 9.67 |
| 11/7/2013 | 9.96 | 10.05 |
| 11/8/2013 | 10.30 | 10.50 |
| 11/9/2013 | 10.38 | 10.57 |
| 11/11/2013 | 10.24 | 10.38 |
| 11/14/2013 | 9.71 | 9.18 |
| 11/17/2013 | 10.33 | 10.28 |
| 11/18/2013 | 10.49 | 10.56 |
| 11/19/2013 | 9.70 | 10.28 |
| 11/22/2013 | 10.06 | 9.99 |
| 11/24/2013 | 9.94 | 9.94 |
| 11/25/2013 | 10.62 | 10.69 |
| 11/26/2013 | 10.69 | 10.66 |
| 12/2/2013 | 8.89 | 8.38 |
| 12/4/2013 | 9.67 | 9.82 |
| 12/8/2013 | 10.06 | 10.10 |
| 12/8/2013 | 9.58 | 9.18 |
| 12/9/2013 | 10.40 | 10.10 |
| 12/10/2013 | 10.76 | 10.77 |
| 12/13/2013 | 11.08 | 11.04 |
| 12/21/2013 | 10.61 | 11.18 |
| 12/22/2013 | 9.70 | 9.10 |
| 12/23/2013 | 10.90 | 10.94 |
| 12/24/2013 | 10.17 | 10.81 |
| 12/25/2013 | 10.21 | 10.23 |
| 12/27/2013 | 10.54 | 10.09 |
| 12/29/2013 | 10.96 | 10.29 |
| 12/30/2013 | 10.63 | 10.00 |
| 12/31/2013 | 9.89 | 9.89 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 1/3/2014 | 10.51 | 10.12 |
| 1/3/2014 | 10.38 | 10.44 |
| 1/5/2014 | 10.45 | |
| 1/6/2014 | 9.53 | 10.84 |
| 1/9/2014 | 10.62 | 10.66 |
| 1/10/2014 | 10.75 | 10.83 |
| 1/14/2014 | 10.93 | 11.05 |
| 1/16/2014 | 11.07 | 11.02 |
| 1/18/2014 | 10.42 | 10.48 |
| 1/19/2014 | 10.56 | 10.20 |
| 1/20/2014 | 10.14 | 10.91 |
| 1/20/2014 | 10.67 | 10.98 |
| 1/21/2014 | 10.86 | 11.01 |
| 1/21/2014 | 10.85 | 10.25 |
| 1/22/2014 | 10.67 | 10.44 |
| 1/30/2014 | 10.95 | |
| 1/30/2014 | 10.89 | |
| 2/2/2014 | 10.83 | |
| 2/5/2014 | 11.25 | |
| 2/6/2014 | 10.77 | |
| 2/7/2014 | 8.70 | |
| 2/12/2014 | 11.45 | 11.60 |
| 2/13/2014 | 10.66 | |
| 2/13/2014 | 10.62 | 10.60 |
| 2/14/2014 | 10.18 | 10.50 |
| 2/16/2014 | 10.81 | 10.86 |
| 2/18/2014 | 10.88 | 10.75 |
| 2/20/2014 | 10.43 | 10.33 |
| 2/22/2014 | 10.52 | 9.49 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 2/23/2014 | 9.56 | 11.25 |
| 2/24/2014 | 10.21 | |
| 2/26/2014 | 10.83 | 10.82 |
| 2/28/2014 | 11.34 | 11.04 |
| 3/2/2014 | 9.89 | |
| 3/3/2014 | 9.94 | 10.17 |
| 3/4/2014 | 10.73 | 10.17 |
| 3/5/2014 | 10.85 | 11.07 |
| 3/6/2014 | 10.43 | 10.41 |
| 3/7/2014 | 10.73 | 10.79 |
| 3/7/2014 | 10.91 | 10.89 |
| 3/8/2014 | 11.23 | 11.23 |
| 3/9/2014 | 10.62 | 10.38 |
| 3/11/2014 | 10.23 | 10.08 |
| 3/11/2014 | 10.63 | 10.92 |
| 3/13/2014 | 10.25 | 10.12 |
| 3/15/2014 | 10.15 | 10.24 |
| 3/16/2014 | 10.37 | 10.30 |
| 3/18/2014 | 10.41 | 10.37 |
| 3/20/2014 | 10.12 | 10.11 |
| 3/21/2014 | 10.11 | 9.91 |
| 3/22/2014 | 10.25 | 10.30 |
| 3/22/2014 | 10.25 | 10.30 |
| 3/23/2014 | | 10.33 |
| 3/24/2014 | 10.46 | |
| 3/28/2014 | 10.41 | |
| 3/29/2014 | 10.52 | 10.24 |
| 3/30/2014 | 10.43 | 10.18 |

## Appendix 13 - Interlaboratory (Round-Robin) Data

| Lab | Sample | API | Vapor P D6377 (kPa) | Vapor P D6377 (psi) | D86 IBP (°F) | Condenser T (°F) | Reciever T (°F) |
|---|---|---|---|---|---|---|---|
| Lab M | 1 | 42.98 | 103.3 | 14.98 | 83.1 | 32.9 | 60.0 |
| SGS (St. Rose) | | 42.91 | 106.5 | 15.44 | 89.1 | 60 | 73 |
| SGS (Williston) | | 42.86 | 95.0 | 13.78 | 102.6 | 60 | 81 |
| | | | | | 88.7 | 31 | 82 |
| Lab M | 2 | 40.22 | 69.7 | 10.11 | 89.9 | 32.9 | 60.0 |
| SGS (St. Rose) | | 40.18 | 70.7 | 10.26 | 95.4 | 60 | 73 |
| SGS (Williston) | | 40.17 | 69.7 | 10.11 | 101.8 | 60 | 80 |
| | | | | | 91.1 | 31 | 82 |
| Lab M | 3 | 43.63 | 73.2 | 10.62 | 87.8 | 32.9 | 60.0 |
| SGS (St. Rose) | | 43.56 | 73.4 | 10.64 | 90.7 | 60 | 73 |
| SGS (Williston) | | 43.61 | 73.0 | 10.59 | 105.5 | 60 | 81 |
| | | | | | 91.4 | 31 | 81 |
| Lab M | 4 | 42.97 | 78.8 | 11.43 | 89.2 | 32.9 | 60.0 |
| SGS (St. Rose) | | 42.89 | 79.5 | 11.53 | 94.5 | 60 | 73 |
| SGS (Williston) | | 42.88 | 77.3 | 11.21 | 102..2 | 60 | 81 |
| | | | | | 94.4 | 31 | 82 |

| **Lab** | SGS (St. Rose) | | SGS (Williston) | | SGS (Williston) | |
|---|---|---|---|---|---|---|
| **Condenser Temp (°F)** | 60 | | 60 | | 31 | |
| **Receiver Temp (°F)** | 73 | | 81 | | 81 | |
| **Sample** | **D86 IBP** | **D86 IBP (°F)** | **D86 IBP (°F)** | **Time to IBP** | **D86 IBP (°F)** | **Time to IBP** |
| 1 | 89.1 | 3 min 22 sec | 102.6 | 6 min 27 sec | 88.7 | 6 min 07 sec |
| 2 | 95.4 | 4 min 53 sec | 101.8 | 7 min 56 sec | 91.1 | 7 min 45 sec |
| 3 | 90.7 | 3 min 37 sec | 105.5 | 7 min 26 sec | 91.4 | 7 min 11 sec |
| 4 | 94.5 | 3 min 42 sec | 102.2 | 6 min 50 sec | 94.4 | 8 min 00 sec |

## Appendix 14 – Glossary of Terms

AFPM – American Fuel & Petrochemical Manufacturers

API – American Petroleum Institute

ASTM – American Society for Testing and Materials

BKN – Bakken

BS&W – Basic Sediment & Water

DOT – Department of Transportation

EPA – Environmental Protection Agency

FPCs – Floating Piston Cylinders

$H_2S$ – Hydrogen Sulfide

IBP – Initial Boiling Point

LLS – Light Louisiana Sweet

LPG - Liquefied Petroleum Gas

LTO – Light Tight Oil

NACE – National Association of Corrosion Engineers

ND – North Dakota

NDPC – North Dakota Petroleum Council

NGL – Natural Gas Liquids

PG – Packing Group

PHMSA – Pipeline and Hazardous Safety Materials Administration

psi – Pounds per Square Inch

psig – Pounds per Square Inch Gauge

QA/QC – Quality Assurance/ Quality Control

RVP – Reid Vapor Pressure

SGS – Laboratory Testing Provider

**Appendix 14 – Glossary of Terms**

SimDist – Simulated Distillation

TAN – Total Acid Number

TM&C – Turner, Mason & Company

VPCR – ASTM D6377 Vapor Pressure

WTI – West Texas Intermediate

# Oasis Facility Operations

**September 23, 2014**

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Oasis
Exhibit A
Identified By Bayes

# Agenda

- Oasis Overview
- Single Well Facilities
- Central Tank Batteries
- Surface Equipment

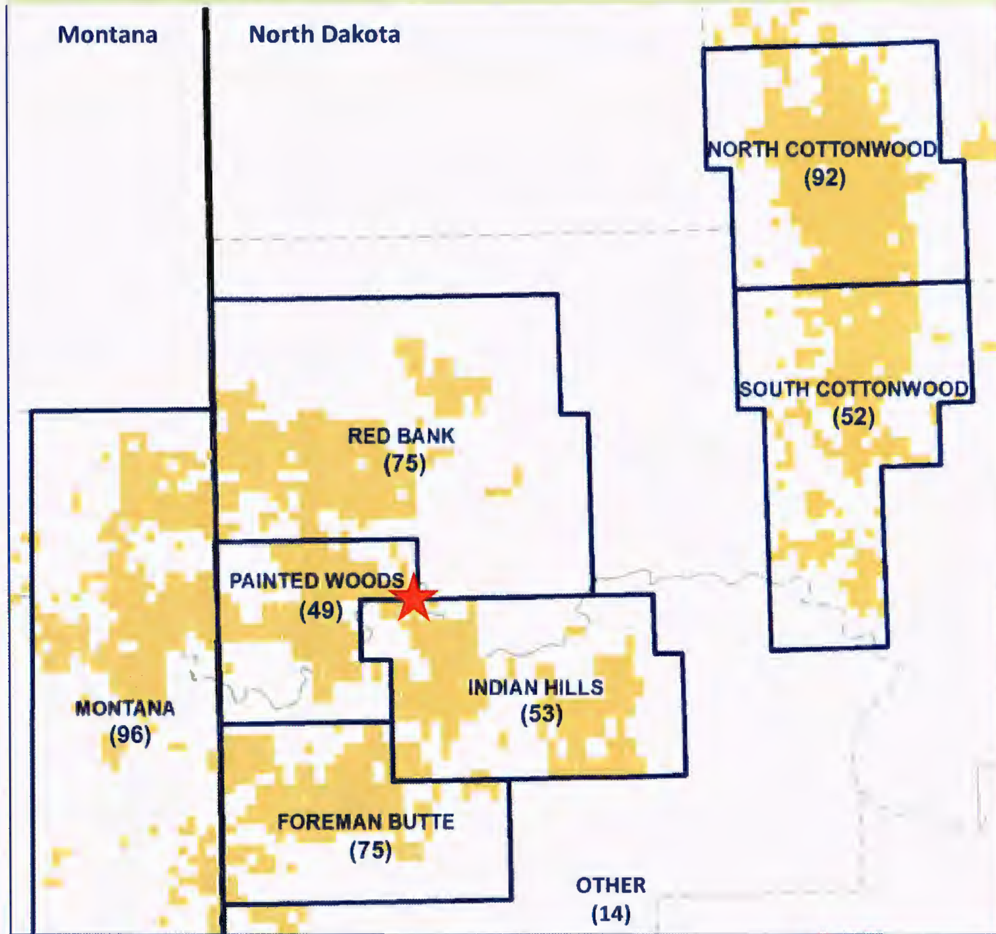

OASIS PETROLEUM

# Oasis Petroleum – Overview[1]

## Highlights

- Significant position in Williston Basin: 507k net acres
  - West Williston: 362K net acres
  - East Nesson: 145K net acres
- Wide areal acreage distribution leads to multiple facility configurations
  - Well Performance
  - Infrastructure Capacity
  - Asset Life-cycle
- Variable facilities yield consistent product

## West Williston | East Nesson

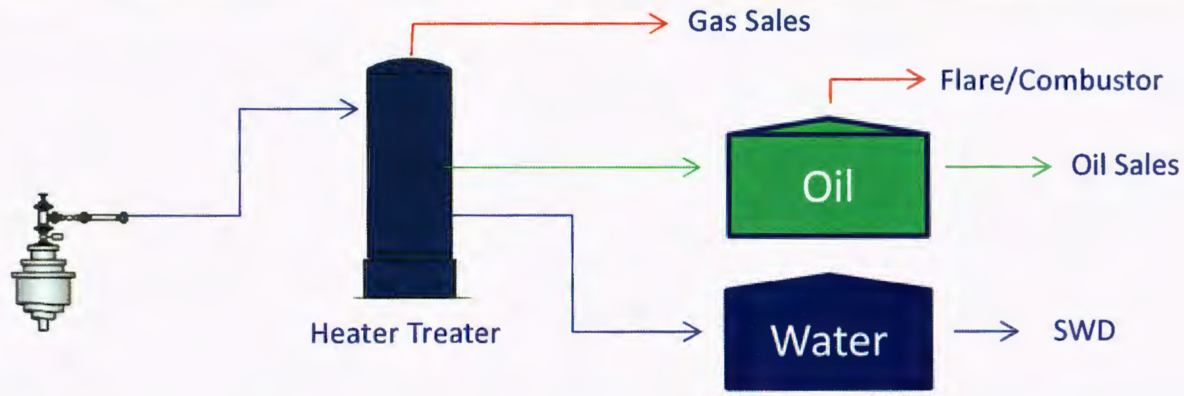



*Acreage in 000s in parenthesis

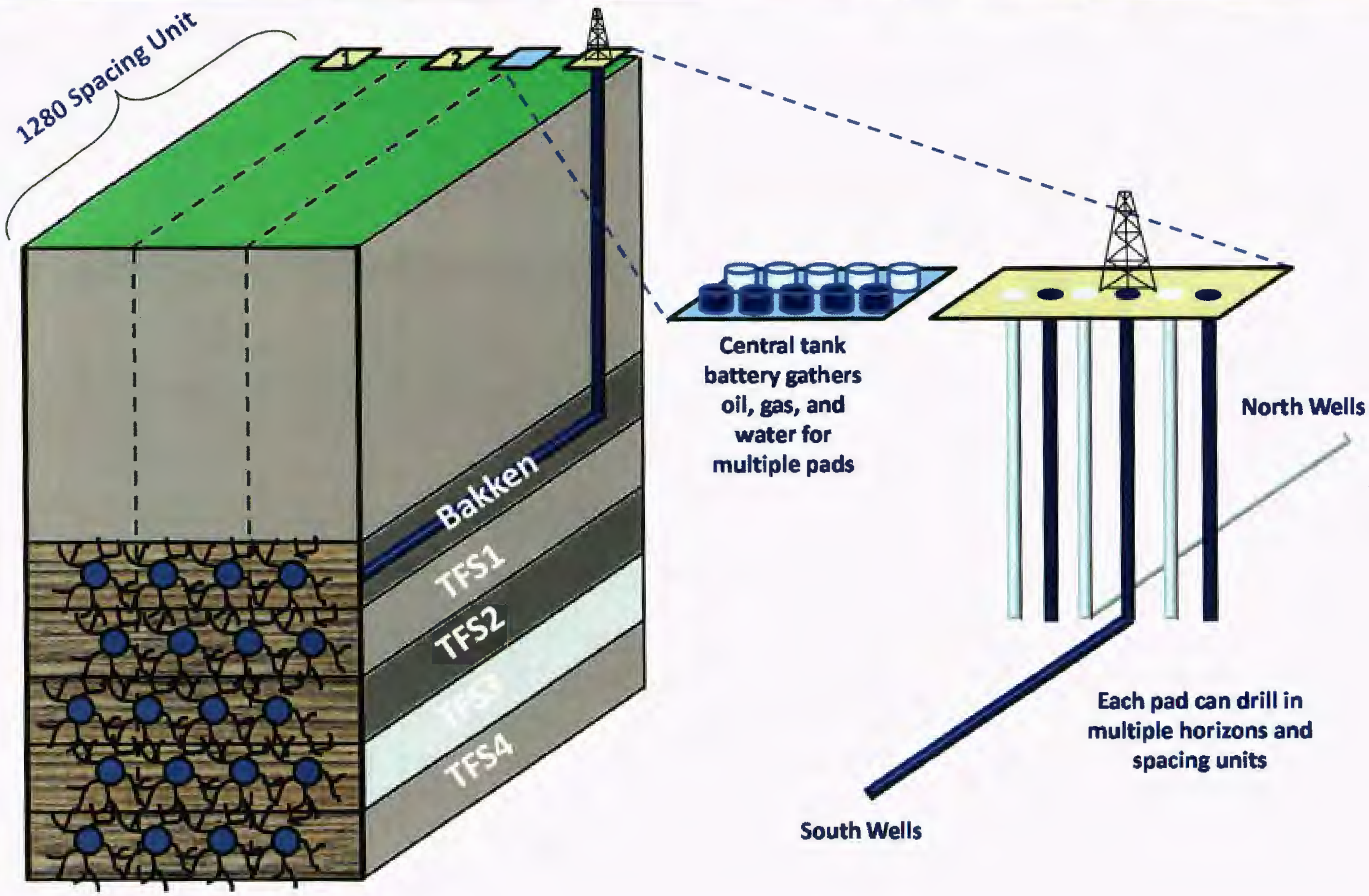
- WILLISTON

(1) As of 12/31/13 and does not include acreage associated with Sanish that was divested in March 2014

# Single Well Facilities




# Oasis Central Tank Batteries

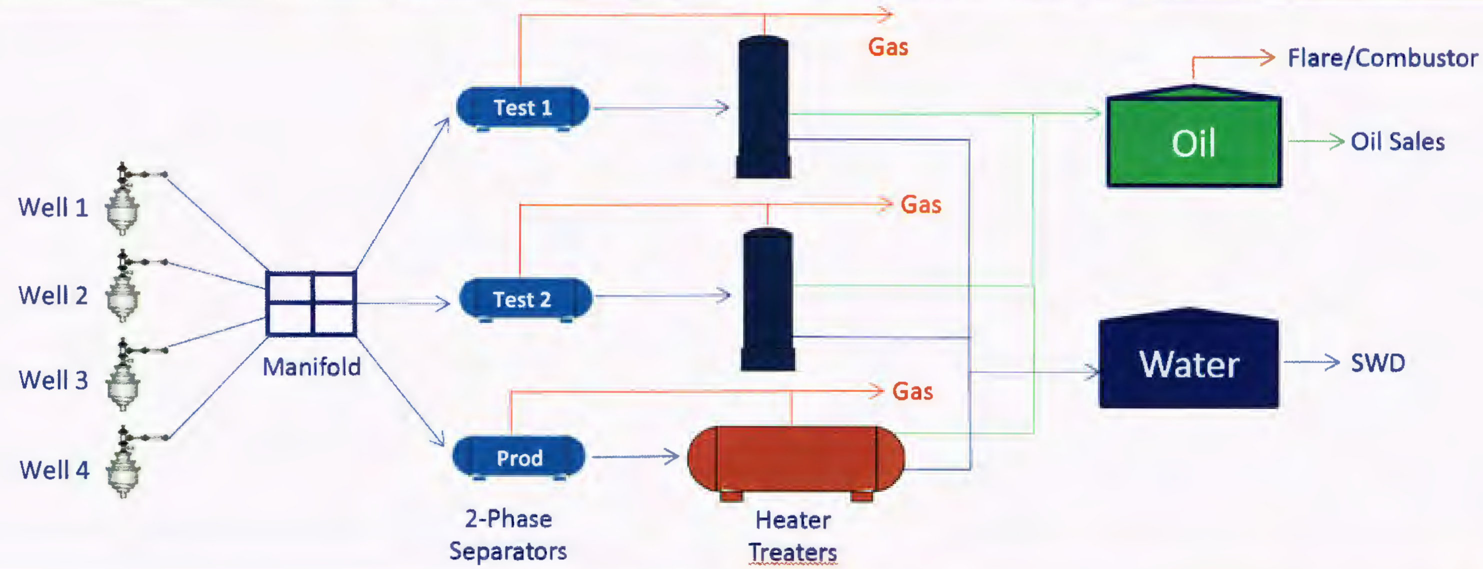


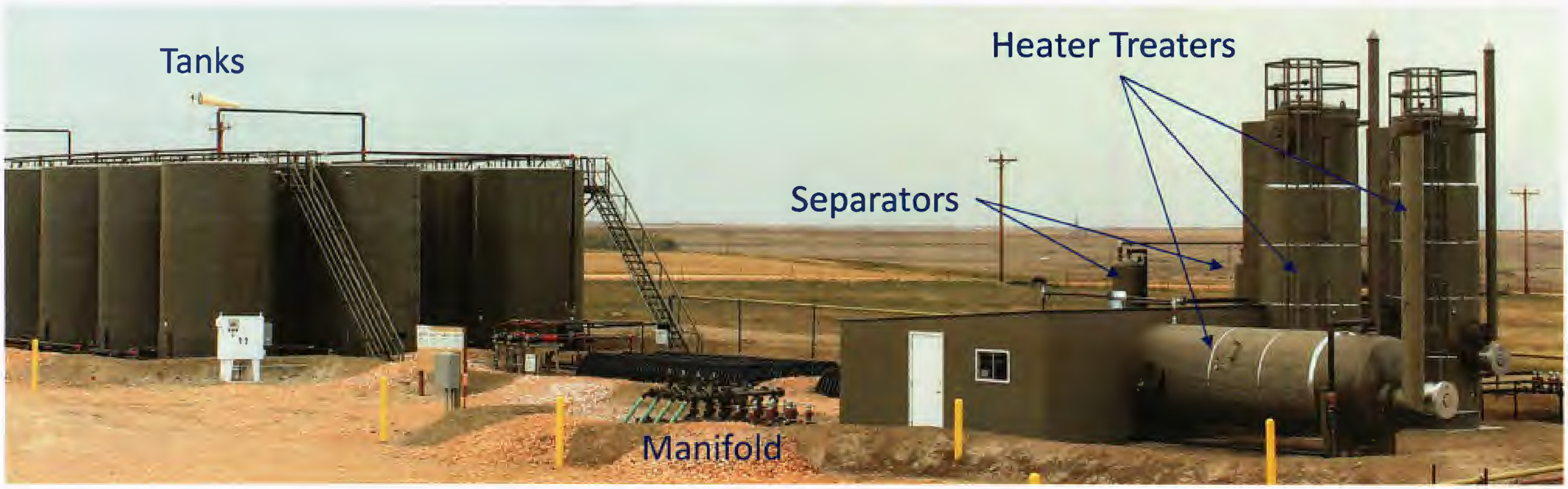

**Minimizes equipment and simplifies infrastructure construction**



OASIS PETROLEUM

# Central Tank Batteries



# Surface Separation Equipment

## 2-Phase Separator

- Pressure: 75 - 150 psig
- Temperature: 60° - 150°F
- Retention: 1 – 15 min as per manufacturer spec

## Heater Treaters

- Pressure: 40 – 70 psig
- Temperature: 90° - 150°F
- Retention: 30 – 150 min as per manufacturer spec

# Summary

- Separator/Treater operating temperature driven by flow rate, BHT, and added heat
- Operating pressure typically minimum required to move fluid and maximize gas sales
- Facility variation dependent primarily on infrastructure needs and DSU development cycle
- Variable facilities yield consistent product

Statoil

Good morning and thank you for the opportunity to address the NDIC and the state of North Dakota in regards to crude oil conditioning in the Bakken. My name is Keith Lilie and I am the Operations & Maintenance Manager for Statoil in the Bakken. Statoil entered the Williston Basin with the acquisition of Brigham Oil & Gas in late 2011. We currently operate over 460 Bakken and Three Forks wells and 4 central oil gathering facilities in Mountrail, McKenzie and Williams Counties respectively. Current gross daily production is approximately 60,000 bbls of crude oil per day. The O&M Team is responsible for the proper design and operation of the upstream and midstream facilities to ensure that the crude oil exported from the basin is properly conditioned for the safest possible export out of the basin.

Over the past 6 years oil production from the basin has exploded. Along with this increased production comes the responsibility that each and every operator in the basin has to ensure that the crude oil exported from the basin is as safe as possible for export. Safe and responsible operations are our license to operate and we take this very seriously.

Statoil believes that the current conditioning of crude oil from the lease level to the midstream gathering facilities is sufficient for safely transporting Bakken crude oil by truck, rail or pipeline. The North Dakota Petroleum Council solicited the professional advice of Turner, Mason & Co. to perform an analysis of the Bakken crude oil qualities across the Williston basin. This study included crude oil samples from 7 rail terminals and 15 well sites. The sampling was representative of all wells across the basin both new and old from various locations and various operators throughout the basin. The conclusive results from this basin wide study indicate that Bakken crude is very similar to other light crudes.

- The Energy Information Administration (EIA) categorizes crude oil that has an API gravity between 35° and 50° and less than 0.3 wt. % sulfur as light sweet crude. The Bakken crude oil has an API gravity between 40° to 43° API and a sulfur content <0.2wt.%is and is therefore by definition a light sweet crude oil.
- The vapor pressure testing on the Bakken Crude had an average vapor pressure of 11.7 psi which is more than 60% below the vapor pressure threshold limit for liquids under the Hazardous Materials Regulations of 43.5 psi. This testing was carried out with the ASTM D6377 measurement method.

Additional stabilization of Bakken Crude oil beyond the current practices that are being implemented in the field would result in a product that still remains a flammable liquid. This would also create a second stream of more volatile hydrocarbons that would have to be exported out of the basin via rail due to the limited pipeline export capacity from the basin.

Statoil currently samples our crude oil twice a month from our central gathering oil export facilities. The testing protocol includes vapor pressure according to ASTM D6377, API Gravity, Sulfur Content and Initial Boiling point according to AST D86. Based on the testing to date all samples have been typical of light crude oil and are classified as flammable liquids according to federal regulations.

Statoil currently exports over 80% of its operated crude production via rail. The crude oil is classified as Hazard Class 3, Packing Group 1 to ensure that the strictest regulations are followed in regards to transporting the crude. Additionally, all rail cars utilized by Statoil to export crude oil out of the basin are newly constructed and meet the latest Association of American Railroads CPC-1232 Standards.

Statoil

Statoil currently utilizes two main types of crude oil conditioning at our well sites. First is the typical set up that we have utilized over the past 7 years which consists of a two phase gas/liquid separator, a fired heater treater and steel crude oil storage tanks. Recently we have been utilizing a new method of well site crude conditioning which consists of a three phase separator, a vapor recovery tower and steel crude oil storage tanks. Both methods of crude oil conditioning supply sufficient holding time and/or heating requirements to ensure that the post processing crude oil is properly stabilized to be transported safely by truck, pipeline or rail.

Before the NDIC moves forward with additional conditioning requirements for the Bakken crude we believe that the guiding principles must be based on scientific information and real data acquired from operations in the Bakken. Additionally, any new proposal must ensure that we are not creating new risks or shifting the risks to other midstream operations. Statoil is committed to work with regulators and all stakeholders to ensure public safety in the handling, packaging and transportation of crude oil in North America.

I want to thank you for the opportunity to present to you today and we look forward to working with you in the future.

Thank you,

Keith Lilie

Statoil Bakken O&M Manager

DEPA
Domestic Energy Producers Alliance

Testimony presented to the North Dakota Industrial Commission on behalf of the
Domestic Energy Producers Alliance (DEPA)
Well Site Conditioning
Tuesday, 23 September 2014

On behalf of the Domestic Energy Producers Alliance ("DEPA"), I offer these comments pertaining to the topic of well site conditioning of light sweet crude in North Dakota.

DEPA is a unique organization with a grassroots approach to domestic onshore energy advocacy and education. We are an alliance of producers, royalty owners, and oilfield service companies, as well as state and national independent oil and gas associations, representing the small businessmen and women of the energy industry. Our members are devoted to the survival of U.S. domestic crude oil and natural gas exploration and production. The Domestic Energy Producers Alliance is a nationwide collaboration of 15 coalition associations – from California to West Virginia, Texas to Montana and North Dakota – representing about 10,000 individuals and companies engaged in domestic onshore oil and natural gas exploration and production (E&P). We believe in seeking common ground, and in common sense solutions to the challenges that we face in our businesses, including our relationship with the federal legislative and executive branches of government. In only its fifth year, DEPA now represents a majority of the individuals and companies responsible for the current renaissance in American oil and natural gas production. On behalf of the members of DEPA, we thank The North Dakota Industrial Commission for the opportunity to comment on this very critical issue.

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By DEPA
Exhibit A
Identified By Kelley

DEPA members' collectively represent literally hundreds of years of experience in the exploration, production and marketing of crude oil. The development of the light tight shale crudes has created a renaissance of energy production, which has brought this country to a level of energy security that is vital to our nation's future. Over half of the crude oil in the U.S. is produced in Texas, Oklahoma and North Dakota and a large percentage of that volume is light crude extracted from tighter shale formations. In some areas, infrastructure has been sufficient to facilitate transportation of these crudes to market via truck and pipeline with some rail shipment. In the case of the North Dakota Bakken fields, this same infrastructure is not yet available, such that rail shipment has played a much larger transportation role. Reportedly, 60% of Bakken crude was transported by rail in the month of July.

There have been a relatively small number of major railway mishaps involving Bakken crude oil which have raised questions regarding the chemical composition and physical characteristics of light sweet crude and the ability of Bakken crude to be transported safely under the current regulatory environment as administered by the Pipeline and Hazardous Materials Safety Administration (PHMSA).

Independent studies[1] commissioned by the American Fuel and Petrochemical Manufacturers, the North Dakota Petroleum Council and the Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation have now shown that Bakken

---

[1] *A Survey of Bakken Crude Oil Characteristics Assembles For the U.S. Department of Transportation*, 14 May 2014 o *Submitted* by American Fuel & Petrochemical Manufacturers, Prepared by Dangerous Goods Transport Consulting, Inc.

*The Turner Mason & Company Study on Bakken Crude Properties,* 16 July 2014 o Submitted by the Bakken Crude Characterization Task Force, Prepared by Turner, Mason & Co. Consulting Engineers

*Operation Safe Delivery*, July 2014, including *Operation Classification*, August 2013, as pertaining to Bakken Crude *o* Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation

crude is not unique, but is in fact very similar in composition and physical parameters to other North American light, sweet crude oils produced not only from the tighter shale formations, but also from conventional formations in Texas and Oklahoma. All of these light, sweet crudes fall under the classification of a Class 3 flammable liquid.

The preamble to the recent rule proposed by PHMSA – "Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains", stated that:

> *"...the number of mainline train accidents involving crude oil has increased from zero in 2010 to five in 2013 and thus far five in 2014."*

During this same time frame, the volume of Bakken crude shipped by rail had increased tremendously. This preamble continued however by stating that:

> *"...across the entire rail network, the number of train accidents and hazardous materials releases are decreasing; while total shipment volume has increased, the total number of train accidents has declined by 43 percent since 2003, and accidents involving a hazardous materials release has declined by 16 percent since 2003."*

It should follow that the number of rail accidents involving crude oil should assume the same declining trend as the other Class 3 flammable shipments have experienced as described in this preamble. One would not expect that a train carrying crude or any other Class 3 flammable substance would tend to experience more accidents attributed solely to the substance being carried.

The NDPC has commissioned Turner Mason and Company, engineering consultants with extensive crude oil expertise, to conduct a study of the physical characteristics of the North Dakota Bakken crude. John Auers, executive vice president of Turner Mason called this study "the most comprehensive and thorough study of a crude oil and shale oil basin in the United States, to date." The Turner Mason study found that the vapor pressure of Bakken crude oil is not the highest or the lowest of crude oils transported in the United States but is 4 times less than the regulatory limit and 10 times less than the design capability of railcars. This study also showed that Bakken crude oil has the same composition throughout the Williston Basin and maintains this composition during transport.

Light sweet crude oils across the U.S. now make up 60% of the domestic crude oil produced and continue to dominate the market as new discoveries are made. Just as a matter of comparison, the Eagle Ford crude produced in south Texas has an API gravity of up to 58° and is classified as a condensate. Condensate is a class of light crude oil containing natural gas liquids, often referred to as natural gasoline, which has an API gravity of over 50°. Bakken crude has an average API gravity of 42°. WTI has an average API gravity is 41°, and Brent crude - 38°. The U.S. Energy Information Administration lists crude oils with API gravity of greater than 35° as light crude oils. Therefore, neither Bakken nor most other Texas or Oklahoma light sweet crudes are to be considered condensate.

This hearing has been called to address the need and possible process for stabilization or conditioning of crude at the well site or the associated oil handling facility. The purpose of conditioning as we understand it is to lower the vapor pressure of the crude oil by driving off the light ends. The current separation equipment employed at the oil handling facilities prior to lease custody transfer has proven successful in reducing the vapor pressure of Bakken crude to a acceptable range variable by season. The same type equipment that has been used for years to separate the oil from the gas and from the produced water effectively accomplishes this goal, when operated properly. The separation equipment is designed on the parameters of temperature, pressure and residence time required to effectively and most efficiently separate these three phases of the produced stream. Various designs have evolved through technological research over the many years of oil and gas production and have been modified and improved to accomplish this separation with the greatest efficiency. Our members either design, manufacture or use this separation equipment.

The heated separator, referred to as the "heater treater" has as its main purpose to break out oil/water emulsions to augment the crude for market quality specifications. The other types of separation equipment employed at these facilities also serves to modify the oil and gas streams to market quality specs. As the produced stream is routed through each separation vessel, it experiences a drop in pressure drop in pressure which allows for evolution of lower chain volatile fractions. These tanks used to store the crude oil are operated at or near near ambient pressure and temperature, or if a vapor recovery unit is used to control VOC emissions, a slight vacuum is imposed on the tank contents. The lighter fractions of the crude column flash at the lower pressures to evolve the methane/ethane fraction to the gas stream. In fact, the EPA considers the crude tank overhead gases to be 100% volatile organic liquids (i.e. C3+) unless otherwise sampled and analyzed.

The actions taken by North Dakota have the potential to affect the treatment and transportation of light crudes all across the United States. DEPA feels that the operators in North Dakota and across the U.S. have developed extensive experience in oil/gas/water separation, driven primarily by market quality specifications for their products. And we believe that the record will show that the same separation equipment that has been employed for these purposes has also produced the vapor pressures and other physical criteria that PHMSA considers safe for transportation of these light tight crudes, which are bringing this country energy security.

Thank you very much on behalf of the Domestic Energy Producers' Alliance and its members.

**North Dakota Industrial Commission**
Hearing – Case No. 23084
September 23, 2014

Good morning, my name is Brent Lohnes and I am the Director for Field & Plant Operations for Hess Corporation. I want to thank the State, and the North Dakota Industrial Commission, for giving Hess the opportunity to participate in this important hearing today.

Safety has always been a core value of both Hess and the oil and natural gas industry, and we are committed to working with regulators and all stakeholders to ensure public safety in the handling, packaging and transportation of crude oil. Any new proposals for operator requirements must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations.

Today I am testifying on behalf of Hess Corporation as well as the American Petroleum Institute, the national trade association representing America's oil and natural gas industry. API has more than 600 members, including integrated companies, as well as exploration and production, refining, marketing, pipeline, marine businesses, and service and supply firms.

Hess has a long history of operating in North Dakota – we have been here since 1951 when our company drilled the first production oil well in the state. We are proud to say that generations of Hess employees have called, and will continue to call, North Dakota home. Today, Hess is one of the largest producers in the entire region, with a 17 rig program and over 800 wells of which Hess is the primary operator. In the Bakken, we are expecting to produce approximately 80,000 barrels of oil equivalent per day on a net basis, with plans to reach 125,000 barrels of oil equivalent per day by 2016.

With the substantial increase in production of Bakken crude from North Dakota, the industry is experiencing constraints on pipeline capacity for transporting the product, which has resulted in a larger amount of Bakken crude to be shipped out of the state via rail. Several high profile rail incidents involving transport of Bakken crude have caused greater speculation and scrutiny around the chemical characteristics of the product, causing federal regulators and others to question whether or not transportation of crude by rail is safe. As the debate continues on the potential changes to rail regulations at the federal level, we are here today to discuss the practices of oil conditioning processes in the field – which we believe are sufficient in preparing Bakken crude for transport by rail, pipeline, or truck.

The North Dakota Petroleum Council, in conjunction with Turner, Mason & Co., has conducted Bakken quality assurance tests that studied the range and variability of Bakken crude oil qualities. The Turner Mason study was based on original data collected from both well sites and rail sites, and was representative of the entire Bakken field by using samples from older wells, newer wells, areas of different geography, and from different operators. The results of this study have shown that Bakken crude oil is very similar to other light crude oils. All samples were typical of light crude oil and classified as flammable liquids according to federal regulations. The study found no meaningful change in transit,

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Hess
Exhibit A
Identified By Lohnes

little geographical variation, and no evidence of corrosiveness – showing that Bakken crude is extremely consistent across the entire basin, and from load to delivery point.

The results of the study support our position that there is no practical difference in the characteristics of Bakken crude and other light crudes, and that it is suitable for shipment in current rail tank cars. Hess currently operates CPC-1232 tank cars, which exceed today's required specifications for safe transport of flammable liquids as prescribed by the Department of Transportation. Hess also incorporates strict safety protocols into our day-to-day management of crude shipments, and will continue to do so. As such, the transportation safety of crude oil should be considered holistically by evaluating the product, the package, and the operations. Turner Mason's study and API's work on a standard for classification address the characteristics of the product and the proper classification and loading of crude oil in rail tank cars.

In fact, the NDPC testified recently before Congress that three independent studies have now shown that Bakken crude is similar to other North American light, sweet crude oils in gravity, vapor pressure, flash point and initial boiling point – the key parameters in proper classification. According to these studies, Bakken crude oil chemical properties attest to its proper classification as a Class 3 flammable liquid.

An across-the-board requirement to stabilize crude oil beyond the current practices taking place would still likely result in a product that remains a flammable liquid, as defined by the Department of Transportation. To date, no evidence has been presented to suggest that measureable safety improvements would result from processes beyond current oil conditioning. Furthermore, additional oil conditioning would create two separate product streams of flammable liquids for transport. Because of the lack of existing infrastructure in North Dakota, this would be even more flammable liquids that would still have to be transported by rail. We believe Bakken crude oil is sufficiently prepared for transport in the field using conventional separation equipment already in place at well sites – for example, separators and heater-treaters, as Hess employs in our operations. Furthermore, oil conditioning at the well site is conducted to prepare the oil for market by separating the oil, water, and gas components. While practices will differ between operators – due to equipment or infrastructure constraints – we are confident that current oil conditioning practices by industry, including Hess, already meet transportation requirements.

It is important to note that all operating conditions must be carefully optimized to stay within equipment design limits, as well as product quality and general operability constraints. For example, increasing heater-treater temperature to the upper end of the design limits can have the undesirable and unacceptable consequence of increasing internal tube failures and driving excessive amounts of crude oil range material ($C_4^+$) into the gas stream.

Hess feels there is merit in assuring a standard level of conditioning being employed at all well sites. However, as stated before, we believe that any new safety solutions – at any level of government – must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations. Doing anything else could cause unintended consequences to the safety and production of Bakken crude, while potentially putting economic constraints on business decisions in the state.

API and the oil and gas industry remain committed to the safe production and transportation of crude oil. When evaluating potential standards or provisions, API encourages this committee to consider actions that will make a measurable improvement to safety.

Thank you, again, for allowing us to participate today.

**North Dakota Petroleum Council**
**Bakken Crude Characterization Task Force**

**DMR Oil & Gas Division Hearing**
**Case 23084 – Oil Conditioning**
**September 23, 2014**

Good morning. I am Jeff Hume, Chairman of the NDPC Bakken Crude Oil Characterization Task Force. Thank you for the opportunity to address the Commission on this important topic.

The Bakken Crude Oil Characterization Task Force (Task Force) was created to address allegations that Bakken crude oil (BKN) does not meet DOT standards for a Class 3, Packing Group I or II Flammable Liquid for rail transportation in DOT 111 tank cars, and further, that Bakken crude is more volatile than other domestic light sweet crude oils that may be shipped by rail. Due to the complex and scientific nature of the allegations, the Task Force engaged Turner Mason & Company (TM&C) to make recommendations for the testing and analysis to address these issues.

TM&C proposed a scientific testing program to analyze multiple samples from numerous wells and rail loading terminals located across all geographic areas of the Bakken field within the US Williston Basin. The plan was approved by the Committee and TM&C was contracted to manage all phases of the study.

A team of experts in the field of crude oil testing and characterization was assembled by TM&C and SGS Laboratories, an internationally recognized testing laboratory, was contracted to perform the sample and field data collection, and to conduct the prescribed testing. Strict sample procurement and chain of custody protocol was established, along with comprehensive field operating data collection. Each sample was subjected to a specific slate of testing to provide data for characterization analysis. The results of the study were presented to the NDIC on September 15, 2014 by TM&C. The study findings and conclusions made by TM&C indicate that BKN crude oil is similar to other light sweet crude oils and meets specifications outlined in Title 49 CFR 171-180 for safe transport by rail or truck.

The TM&C report included a list of recommend best practices for field operations to insure the established quality specifications will be continually met or improved upon. These recommendations should be reviewed as part of this hearing and include:

- General operating conditions for lease treating equipment;
- Periodic testing to insure expected property specifications identified in the study are maintained;

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By NDPC
Exhibit A
Identified By Hume

- Acknowledgement that legacy production from various producing formations located within the proximity of the Bakken field is part of the production stream and permissible;
- Continued prohibition of plant NGLs being added to the crude oil stream;
- Elimination of any non-stabilized liquids recovered from wet-gas gathering pipelines being commingled with the BKN; and
- Insure blending of crudes from outside the US Williston Basin does not occur to prevent sulfur and other contaminants that may degrade the low corrosivity of the BKN.

The study recognized that various types of lease processing equipment are being utilized to condition crude oil for market across the basin. However, the sample testing indicated fairly tight distribution of physical properties, especially at the rail terminals where crude oil from many wells operated by a variety of companies is aggregated in large storage tanks for shipping. This tight distribution indicates that the various equipment designs and configurations are performing their function with very similar results.

Another observation of the study data is that only minor changes to light end composition can be made by optimizing the operating conditions of the production equipment, specifically temperature and pressure. A comparison of temperature and pressure to percent ethane and propane for wells with fired equipment showed only slight reduction with increased temperature and even slighter improvement with lower operating pressure. However, this data indicates that equipment specific optimization could potentially reduce the amount of ethane and propane remaining in the conditioned crude oil.

Today you will hear testimony from several operators on how they approach production operations to optimize conditioning of both oil and gas for market. The variety of equipment deployed and the operational limitations provide fairly tight variation for optimization. However, optimization can be achieved on a lease-by-lease basis if properly addressed.

Thank you for the opportunity to share this information and answer any questions that you may have regarding the study conducted by the Task Force.

NORTH DAKOTA PETROLEUM COUNCIL

# Bakken Crude and Conditioning

### Light Crude vs. Condensate

The U.S. Energy Information Administration and industry uses API gravity to define crude oil as heavy, light or, in some cases, condensate. Heavy crudes, such as the oil produced in Canada's Tar Sands, have an API gravity of less than 35 degrees, while light crudes, such as Bakken crude, have a gravity of between 35 and 49. Condensate is a class of light crude oil containing a high concentration of natural gas liquids and having an API gravity greater than 50 degrees.

Bakken crude has an average weight of 42 degrees, which is comparable to West Texas Intermediate – a common benchmark crude used to price oil – with an API gravity of 41 degrees. Similarly, Brent crude - a crude produced in the North Sea and used as a major benchmark price for purchases of oil worldwide - is 38 degrees. These crudes are classified as light crudes and do not require stabilization for storage and transport. Conversely, some crudes, such as Eagle Ford crude oil with an API gravity of 58 degrees, is classified as condensate and requires stabilization to meet federal regulations for storage and transport.

### Stabilization

Many have stated that stabilization of Bakken crude is needed to enhance safety, but what is stabilization and is it necessary?

Crude oil produced at the well head contains "light ends," which are dissolved hydrocarbons that have a lower boiling point such as butane, ethane and propane. "Stabilization" is the process of removing light ends from crude oil.

There is a lot of confusion about the term stabilization. Part of this confusion is due to the fact that industry has used the term to describe two different processes: stabilization at the well site, or well-site conditioning, and post-well site stabilization.

Stabilization at the well site is often called *well site conditioning*, while post-well site stabilization occurs at offsite commercial stabilization units that separate condensate to market to petrochemical plants. These plants produce the chemicals needed to manufacture plastics, fertilizers and other important products we use every day.

Stabilization offsite will lower the vapor pressure of crude oil down to 9 to 12 pounds per square inch (psi).

### Well Site Conditioning

In North Dakota, crude oil is conditioned or *stabilized* at the well head. All wells are required to have conditioning equipment such as separators, heater treaters or equivalent devices, and stock tanks to *condition* (or "stabilize") crude oil at the well site. This conditioning equipment is installed at a cost between $200,000 and $400,000 per well. After well site conditioning, Bakken vapor pressure is in the range of 8 – 12 pounds per square inch (psi) - the same range of vapor pressure as stabilized condensate. This characteristic of Bakken crude is uniform throughout the Bakken and does not change in transportation.

### Conclusion

North Dakota has the proper regulations in place to properly treat and condition Bakken crude to meet federal specifications of the product by rail. Because Bakken crude is not condensate and can be considered a stabilized crude, not needing additional offsite conditioning. In fact, additional offsite conditioning would be a redundant process that would not yield any additional safety benefits. Rather, the result could be separate set of flammable liquids or flammable gases being transported by truck or rail because North Dakota does not have a petrochemical market to process those light ends here, nor does it have the pipeline infrastructure in place to transport it to a market out of state.

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By NDPC
Exhibit C
Identified By Cutting

# CRUDE BY RAIL



Table 1: Ten Major Accidents Involving Crude-by-Rail in USA and Canada, 2013-2014

| Date | Location | Railroad | Crude Source | Fire? | Spill Volume (U.S. Gallons) | Type of Incident |
|---|---|---|---|---|---|---|
| Mar 27, 2013 | Parkers Prairie, Minnesota | Canadian Pacific | Canada, possibly tar sands | No | 10,000-15,000 | Derailment |
| Jul 5, 2013 | Lac-Megantic, Quebec, Canada | Montreal, Maine & Atlantic Railway | Bakken, North Dakota | Yes | >26,500 | Derailment |
| Oct 19, 2013 | Gainford, Alberta, Canada | Canadian National | Unknown | Yes | Unknown | Derailment |
| Nov 8, 2013 | Aliceville, Alabama | Genesee & Wyoming | Bakken, North Dakota | Yes | <748,400 | Derailment |
| Dec 30, 2013 | Casselton, North Dakota | BNSF | Bakken, North Dakota | Yes | ~400,000 | Derailment |
| Jan 7, 2014 | Plaster Rock, New Brunswick, Canada | Canadian National | Unknown, Western Canada | Yes | Unknown | Derailment |
| Feb 3, 2014 | Wisconsin/Minnesota | Canadian Pacific | Unknown | No | <12,000 | Leak from tank car over 70 miles of track |
| Feb 13, 2014 | Vandergrift, Pennsylvania | Norfolk Southern | Tar Sands Bitumen, Alberta, Canada | No | 4,550 | Derailment |
| Apr 30, 2014 | Lynchburg, Virginia | CSX | Bakken, North Dakota | Yes | <50,000 | Derailment |
| May 9, 2014 | LaSalle, Colorado | Union Pacific | Niobrara, Colorado | No | 6,500 | Derailment |

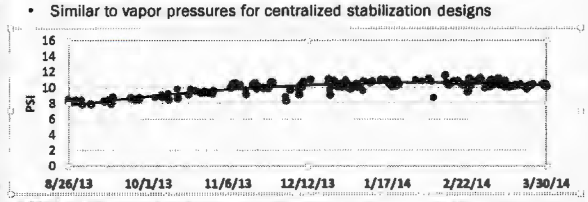
## API number

| CRUDE NAME | ORIGIN | API |
|---|---|---|
| Eagle Ford Light | Texas | 58 |
| Arabian Super Light | Saudi Arabia | 51 |
| Eagle Ford | Texas | 48 |
| Agbami | Nigeria | 48 |
| DJ Basin | Colorado | 45 |
| Sarahan Blend | Algeria | 43 |
| Bakken | North Dakota | 42 |
| West Texas Intermediate | Tex/New Mexico | 41 |
| Brent | United Kingdom | 38 |
| LLS | Louisiana | 36 |
| Alvheim Blend | Norway | 35 |
| Arabian Heavy | Saudi Arabia | 28 |
| Alberta Dilbit | Alberta | 21 |



## Vapor Pressure

- BKN Average Vapor pressure 11.5-11.8 psi (Mar-Apr—Turner Mason report)
  - 61% below regulatory threshold
- Seasonal Variation: summer 8-10 psi, winter 10-12 psi
- Measurements are True Vapor Pressure not Reid Vapor Pressure
- Similar to vapor pressures for centralized stabilization designs

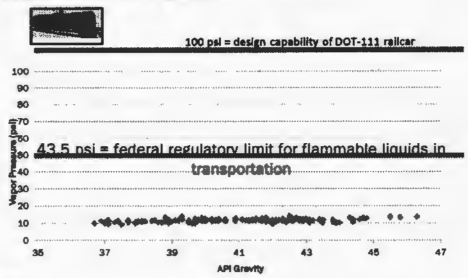





INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By NDPC
Exhibit B
Identified By Cutting

## API gravity vs. Vapor Pressure

- DOT regulations allow transport of vapor pressure to 43.5 psi; Railcars designed to 100 psi or greater






## Recommended Testing Procedures

- Well Site Operators/Purchasers – Prior to each custody transfer or LACT EOM
  - API gravity corrected to 60° F using hydrometer
  - Basic Sediment & Water (BS&W) by field centrifugal grind-out
  - Spot test vapor pressure pending available field testing equipment
- Rail/Pipeline Terminal Operators
  - Test each unit train loading or tank shipment batch
    - API gravity corrected to 60° F using hydrometer
    - BS&W by field centrifugal grind-out
  - Test at least midmonth and EOM
    - ASTM D6377 @100° F vapor pressure using certified laboratory



## Other recommended practices

- DO NOT deliver fluid recovered from gas pipe lines (a.k.a. "pigging operations") to crude oil sales system unless processed by stabilization unit capable of lowering vapor pressure below 10 psi at 100° F.
- DO NOT blend non-Williston Basin crude oils into the BKN common stream.
- DO NOT blend plant liquids (plant condensates, pentanes, butanes or propane) into the BKN common stream.



## Bakken typical specification ranges

| | Range | Typical |
|---|---|---|
| • API Gravity (hydrometer at 60°F) | 35° to 45° | 42° |
| • Vapor Pressure (ASTM D6377 @ 100°F) | 8 to 15 psi | 11.5 psi |
| • Initial Boiling Point (ASTM D86) | 90°F to 105°F | 95°F |
| • Sulfur | <0.3% | 0.15% |
| • $H_2S$ | <10 ppm | <1 ppm |
| • Light Ends (C2 – C4s) | 3% to 9% | 5% |

## BKN specifications

- Define BKN specifications
- Value:
  - Producers will follow specific field standards to meet BKN specs
  - Ensure proper BKN oil characterization, now and future
  - Create reference point for buyers and sellers

www.northdakotaoilcan.com | www.ndoil.org

NORTH DAKOTA PETROLEUM COUNCIL

NORTH DAKOTA PETROLEUM COUNCIL | We keep North Dakota going strong

# Questions?

10

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By NDPC
Exhibit A
Identified By Cutting

**North Dakota Petroleum Council**

**DMR hearing on well site conditioning**

**September 23, 2014**

Good morning, my name is Kari Cutting, Vice President of the North Dakota Petroleum Council. Thank you for the opportunity to comment on transportation safety and marketability of Bakken crude oil.

The North Dakota Petroleum Council (NDPC) represents more than 550 companies engaged in all aspects of oil and gas activities in North Dakota, South Dakota, and the Rocky Mountain region. NDPC members produce 98% of all oil and gas in North Dakota.

North Dakota is now the second largest oil-producing state in the nation and reached 1 million barrels of daily production in May 2014, up from 100,000 barrels per day in 2007. Although North Dakota's oil and gas production has grown substantially in recent years, pipeline capacity to key markets has not, requiring 60 percent of Bakken crude to be hauled via rail in July.

In the last eighteen months, there have been ten railway incidents involving crude oil. Four of the trains contained Bakken crude oil. Six incidents involved fire. Nine of the incidents involved derailment and the remaining incident was a leaky valve. The root cause of at least of two of the accidents was significant human error, and another was due to washout of the tracks from heavy rails. Some are still under investigation. The material contained in these railcars was not the cause of the accident.

As a result, questions have been raised regarding the chemical composition and physical characteristics of Bakken crude, how it compares with other flammable liquids under U.S. Department of Transportation regulations, and whether it can be safely transported across North America under the current regulatory environment as enforced by the Pipeline and Hazardous Materials Safety Administration (PHMSA).

**Three independent studies[1] have now shown that "Bakken crude is not a unique flammable liquid"**, and that it is properly classified as a Class 3 Flammable Liquid. The flammable liquids category contains common fuels including ethanol, gasoline, diesel fuel, jet fuel, and other fuel and petrochemical feed stocks offered for transportation in the United States.

One of the referenced studies was commissioned by the NDPC. The study included a comprehensive sampling and analysis plan and was conducted by Turner Mason & Company, an internationally known and recognized group of engineering consultants with extensive crude oil expertise. John Auers,

---

[1] *A Survey of Bakken Crude Oil Characteristics Assembles For the U.S. Department of Transportation*, 14 May 2014 o *Submitted* by American Fuel & Petrochemical Manufacturers, Prepared by Dangerous Goods Transport Consulting, Inc.

*The Turner Mason & Company Study on Bakken Crude Properties,* 16 July 2014 o Submitted by the Bakken Crude Characterization Task Force, Prepared by Turner, Mason & Co. Consulting Engineers

*Operation Safe Delivery*, July 2014, including *Operation Classification*, August 2013, as pertaining to Bakken Crude *o* Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation

executive vice president of Turner Mason stated that this study was **"the most comprehensive and thorough study of a crude oil and shale oil basin in the United States, to date."**

**Turner Mason Study Conclusions:**

1. **Bakken crude oil as a light sweet crude oil, is low in sulfur content but rich in valuable gasoline, diesel fuel, and jet fuel components, making it extremely desirable to the refining community.**

2. **The vapor pressure of Bakken crude oil is not the highest or the lowest of crude oils transported in the United States but its vapor pressure is four times less than the regulatory limit and 10 times less than the design capability of railcars.**

3. **Bakken crude oil has the same composition throughout the Williston Basin and maintains this composition during transport.**

**Stabilization:**

When Bakken was first called volatile, there were many in the petrochemical industry who assumed that Bakken must be condensate and therefore, required stabilization. The U.S. Energy Information Administration and industry uses API gravity, or the measure of how heavy or light a crude oil is, to determine what crude oils are considered condensate. Condensate is a class of light crude oil containing a high concentration of natural gas liquids and having an API gravity greater than 50 degrees, while crudes having an API gravity of 35 to 49 are considered light crudes. Other light crudes are West Texas intermediate with an API gravity of 41 degrees and Brent crude with 38 degrees. Eagle Ford condensate has an average API gravity of 58 degrees.

There is a lot of confusion about the term stabilization. Part of this confusion is due to the fact that industry has used the term to describe two different processes: treatment or conditioning at the well site and post-well site stabilization. The Energy Information Agency has recently defined stabilization as a distillation process utilizing temperature gradients maintained by an outside heat source.

Post well site stabilization units are commonly used to remove valuable and saleable natural gas liquids from condensate and to reduce its vapor pressure to meet EPA requirement for storage in floating roofed tanks or for the commercial purpose of selling some its component to produce fuels or petrochemicals. Many have stated that stabilization of Bakken crude is needed to enhance safety, but that is neither necessary nor is it an effective safety measure.

North Dakota has frequently been compared to Texas, but like comparing Bakken crude to Eagle Ford condensate, this is an unfair comparison. The state of Texas has infrastructure in place to support the movement of the products separated from the condensate stream during stabilization. The state has ample pipeline infrastructure for transport and petrochemical plants as a ready market for those feedstocks. North Dakota does not have the petrochemical markets that Texas already has in place. Commercial stabilization at centralized locations in North Dakota could necessitate another layer of pipeline infrastructure..

It is important to note that since North Dakota lacks a market for products separated in the stabilization process, these products would be hauled by rail by truck to a market out of state. Furthermore, stabilization of Bakken crude oil would still yield a Class 3 flammable liquid, Packing Group I or II for transportation.

**Well –Site Conditioning:**
NDPC applauds the Department of Mineral Resources for using the terminology ***well site conditioning*** to distinguish the use of equipment on the well site from a commercially driven stabilization unit.

Currently, all wells in North Dakota are required to have conditioning equipment such as separators, heater treaters or equivalent devices, and stock tanks which are sufficient to condition (or "stabilize") crude oil at the well site. This conditioning equipment was installed at a cost of between $200,000 and $400,000 per well. With more than 11,280 wells producing in North Dakota, this means an investment of anywhere between $2.26 and $4.51 billion in crude oil conditioning equipment.

After well site conditioning, Bakken vapor pressure is four times below the 43.5 psi regulatory threshold to be properly transported by truck or rail and is 10 times below the railcar design pressure.

Taking all of this information into consideration, requiring stabilization beyond current conditioning practices would be a costly, redundant process that would not yield any additional safety benefits. Rather, the result could be separate set of flammable liquids or flammable gases being transported by truck or rail.

**Safety:**

Safety is a core value of the oil and gas industry and we remain committed to ensuring we are doing all we can to produce and transport this important natural resource as safely as possible. Using the scientific evidence gathered from the Turner Mason study (as well as comparable data pulled from other studies), the NDPC has recommended a set of best practices to ensure Bakken crude is being treated the same by all producers and ensure uniformity in crude quality and handling. Additionally, NDPC members are developing a set of typical specifications based on the Turner Mason study that along with well site conditioning, will ensure that emergency responders have sufficient information to effectively respond to an incident involving Bakken crude oil or other flammable liquids transported by rail in Packing Group I or II.

The oil and gas industry, in partnership with the railroads, is working to develop a common educational tool to be distributed broadly to fire departments either through web portal or DVDs. This information will also be available for companies to use in continued interaction with fire departments and other EMS personnel. Rail and oil industries in many states have worked collaboratively on drills and exercises, development of additional response resources, and periodic meetings to keep the lines of communication open in order to maximize information sharing of the latest data on emergency response for crude incidences.

The NDPC and its members believe rail safety improvements must be developed using a holistic, comprehensive, and systematic approach that examines prevention, mitigation, and response. PHMSA recently issued a Notice of Potential Rulemaking that addresses the durability of the railcar and infrastructure as well as training for emergency response personnel. These components are necessary to affect rail safety improvement for the transportation of all flammable liquids in the United States.

NDPC encourages the U.S. Department of Energy to utilize the national laboratories to study all domestic crudes. We believe it is important that the testing of crude oils continues to provide comparative scientific data and enhance information and training provided to emergency responders. The oil and gas industry in North Dakota supports further testing of Bakken crude oil and monitoring to guarantee Bakken quality and consistency.

We look forward to continuing our work with state leaders to enhance safety by taking science-based steps to ensure Bakken crude oil maintains its consistent characteristics from the well site and rail loading facility, so that we may always bring this product to market safely and ensure our state can continue to improve our energy security by providing a reliable energy resource for our nation.

# RAILROAD INFRASTRUCTURE DEVELOPMENT NEEDS

for the

# INCREASED CRUDE OIL TRANSPORT REQUIREMENTS

in the

# PUGET SOUND REGION METROPOLITAN AREA

Prepared by

Hal B. H. Cooper, Jr., Ph.D., P.E.
CP&Y Incorporated
11715 N.E. 145th Street
Kirkland, Washington 98034

Presented to the

Freight Mobility Roundtable Meeting
of the Puget Sound Regional Council
1011 Western Avenue, Suite 500
Seattle, Washington 98104

February 7, 2014

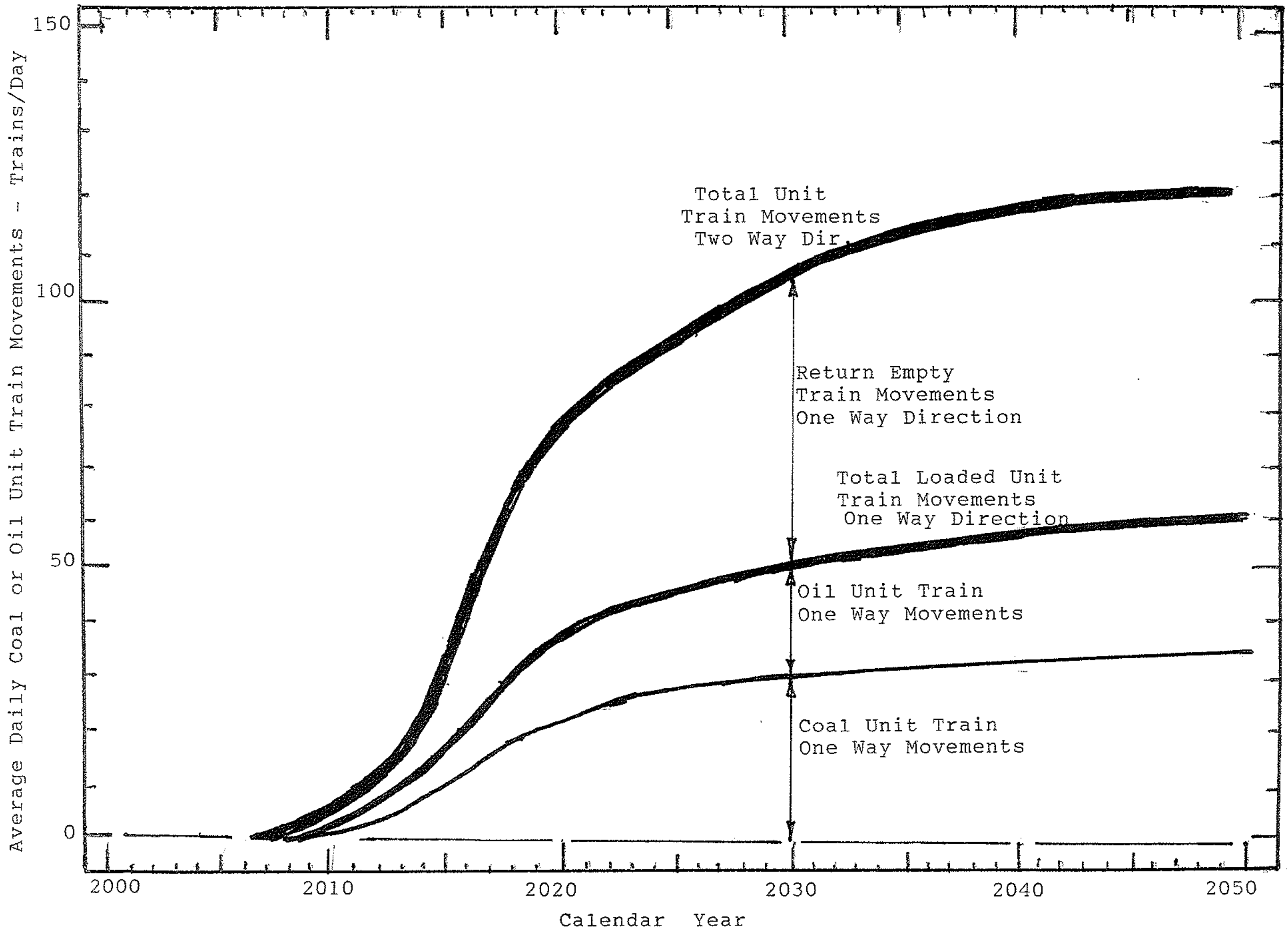
## SUMMARY

An analysis of future oil train traffic flows into the State of Washington from the Bakken Formation oil fields in North Dakota could be as much as 1,100,000 barrels per day by 2020. This oil train traffic would necessitate increases of up to 37 train movements on a daily basis over the Great Northern Corridor from North Dakota to Washington. This increased freight train traffic resulting from oil shipments would essentially double the existing freight traffic volumes over the Great Northern Corridor and would necessitate double tracking the entire line from Everett, Washington to Williston, North Dakota. These crude oil shipments to Washington refineries of 600,000 barrels per day and 500,000 barrels per day to California refineries would essentially consume essentially all of the expected crude oil available for export from North Dakota by 2020 in the estimated amount of 1,100,000 barrels per day.

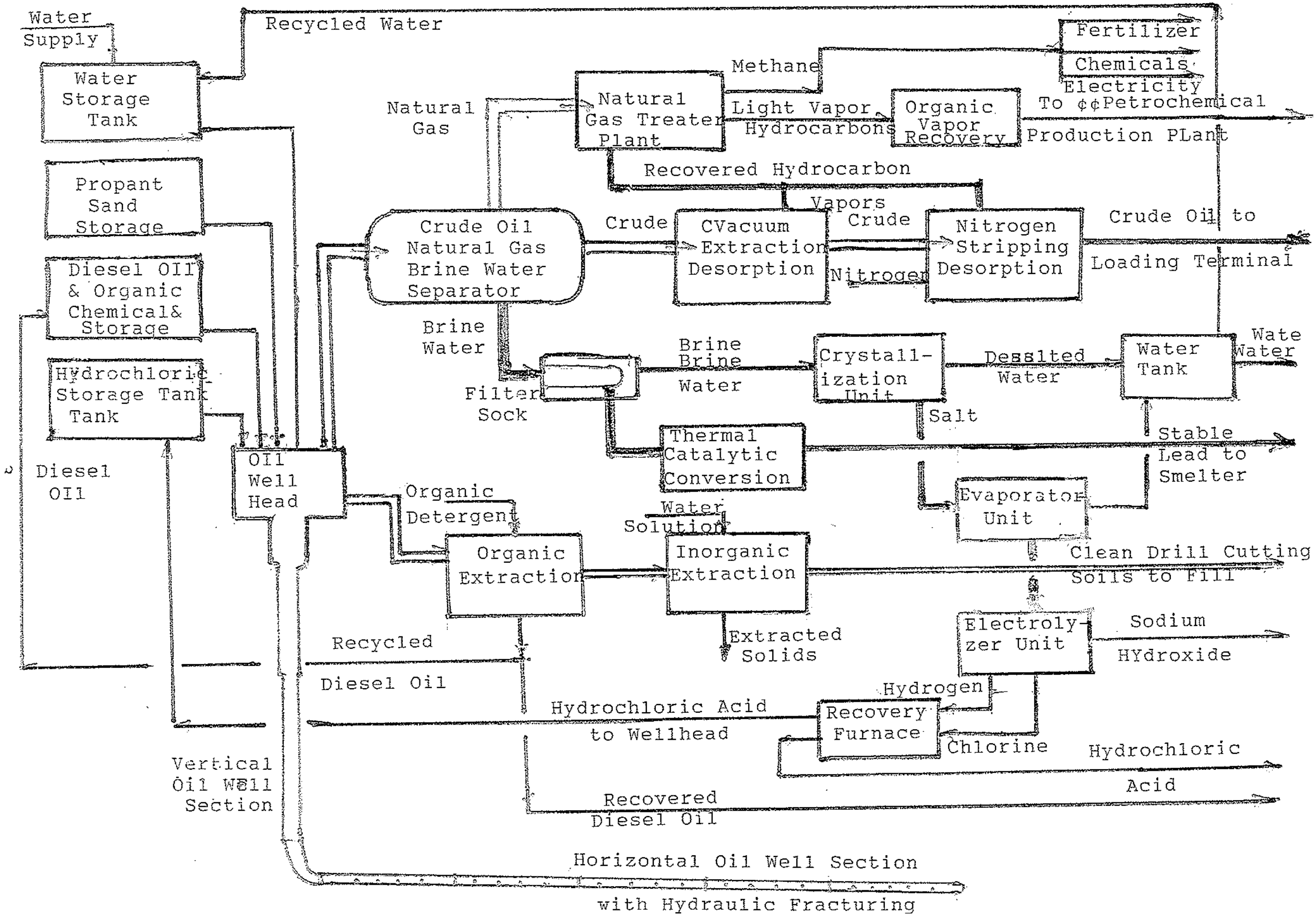
The light sweet crude oil being shipped from the Bakken Formation in North Dakota should be considered as being potentially hazardous in terms of flammability and volatility and should be tested before shipment by rail. This light sweet crude oil from the Bakken Formation in North Dakota should be subjected to either or both vacuum distillation and /or nitrogen desorption to remove the volatile light molecular weight aliphatic hydrocarbons as well as benzene and other aromatic organic hydrocarbons from the crude oil. The devolatilized crude oil can then be placed in tank cars for rail shipment to refineries in Washington and California. As an additional precaution, there should be a bypass of these oil until trains around Spokane between Havre, Montana and Ephrata, Washington over the former Milwaukee Railroad line with a new tunnel under St. Louis Pass at the Idaho-Montana border to the south of the Great Northern Corridor.

It is suggested that there be a new tunnel built at Stevens Pass between Skykomish and Leavenwor th with a second tube in parallel to the existing tube in a similar pattern with a west side downslope favorable to heavy unit trains. A combination railroad tunnel at Stevens Pass could then handle both intermodal container trains to and from the Ports of Seattle and Tacoma as well as coal and oil unit trains. It is also possible that a second new double track railroad tunnel could be built at Stampede Pass as well as at Stevens Pass but its eastside gradient requirements would be more sever and more new rail line would need to be constituted, In addition, it would also be necessary to double track the existing BNSF Railway Columbia River Line from Pasco to Vancouver with additional expansion of theWishram to Sacramento roads sections in Oregon and California.

EXPECTED INCREASES IN COAL AND CRUDE OIL UNIT TRAIN MOVEMENTS OVER THE GREAT NORTHERN RAILROAD CORRIDOR ACROSS THE NORTHERN TIER FROM NORTH DAKOTA TO WASHINGTON: 2000-2050



# PROCESS FLOW DIAGRAM OF AN OIL PRODUCTION WELL WITH RESIDUAL WASTE STREAM TREATMENT SYSTEM



The proposed Cascade Foothill Corridor would need to be built between Tenino, Washington and Mission, British Columbia as the future main rail freight route for north-south traffic through the Puget Sound metropolitan area. The oil unit trains entering the Puget Sound region would then come from Stampede Pass or Stevens Pass to the north from Palmer or Snohomish to Sedro Woolley to the Anacortes refineries or to Wickersham and Bellingham to the Ferndale and Cherry Point refineries. The container trains going to and from the Port of Seattle would go from Monroe to Palmer over the Cascade Foothill Corridor and to Ravensdale on the Auburn line and then over a new Maple Valley line from Ravensdale to Renton and Tukwila or alternatively to Auburn. The container trains going to and from the Port of Tacoma would go from Palmer to Ravensdale and Auburn to the freight line of the Union Pacific rail corridor with the passenger trains to the BNSF line by way of Kent and Puyallup.

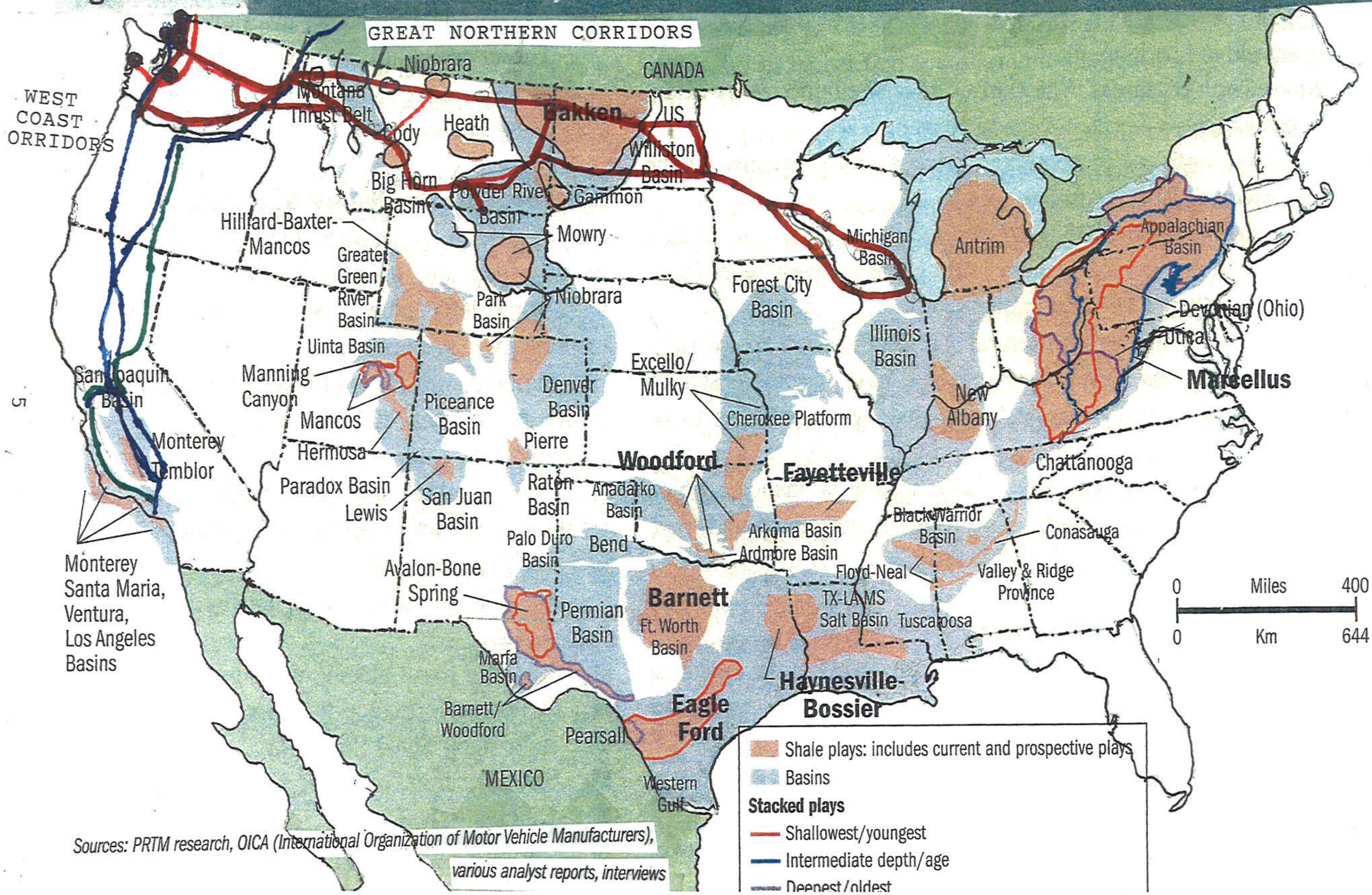
It is suggested that there be a basic rebuilding of the BNSF Railway line south of Tacoma into separate freight and passenger lines to Portland. The freight trains would then go by way of the BNSF existing line while then passenger trains would go by way of the rebuilt former Milwaukee Railroad line to Longview and then to Vancouver, Washington. Crude oil could also be offloaded at the Port of Vancouver, Washington and shipped by barge to the Northwest Washington refineries by way but marine oil spills could be a concern in the rough waters of the Pacific Ocean. The existing BNSF Railway main line from Seattle to Everett and Bellingham should become a primarily passenger corridor to the north with the main freight carried by the Cascade Foothills Corridor to the east. In addition, a passenger commuter loop railroad line could then be built around Lake Washington between Seattle, Tukwila, Bellevue and Everett with intercity passenger trains.

It will become desirable for purposes of economic growth and development to construct a large marine oil loading terminal near Grays Harbor at Aberdeen in order to ship crude oil by barge to refineries in Northwest Washington as well as in the Bay Area and Southern California along the Pacific Coast. It will be even more important to develop the Grays Harbor oil loading terminal for the future export of crude oil from North Dakota as well as for finished refined products. It will be essential to develop and implement methods for preventing future oil spills in Grays Harbor for the purpose of protecting fish and shellfish from potential oil spill contamination. The development of a future alliance between the Interior resource Indian Tribes in North Dakota and Montana for shipping crude oil with the Coastal fishing Indian Tribes through joining owned transportation facilities will be essential to promote this effort.

LOCATIONS OF THE MAJOR CRUDE OIL AND NATURAL GAS SHALE FORMATIONS IN THE UNITED STATES

LOCATIONS OF THE MAJOR CRUDE OIL AND NATURAL GAS SHALE FORMATIONS IN THE UNITED STATES

**Figure 1:** Lower 48 States Shale Plays



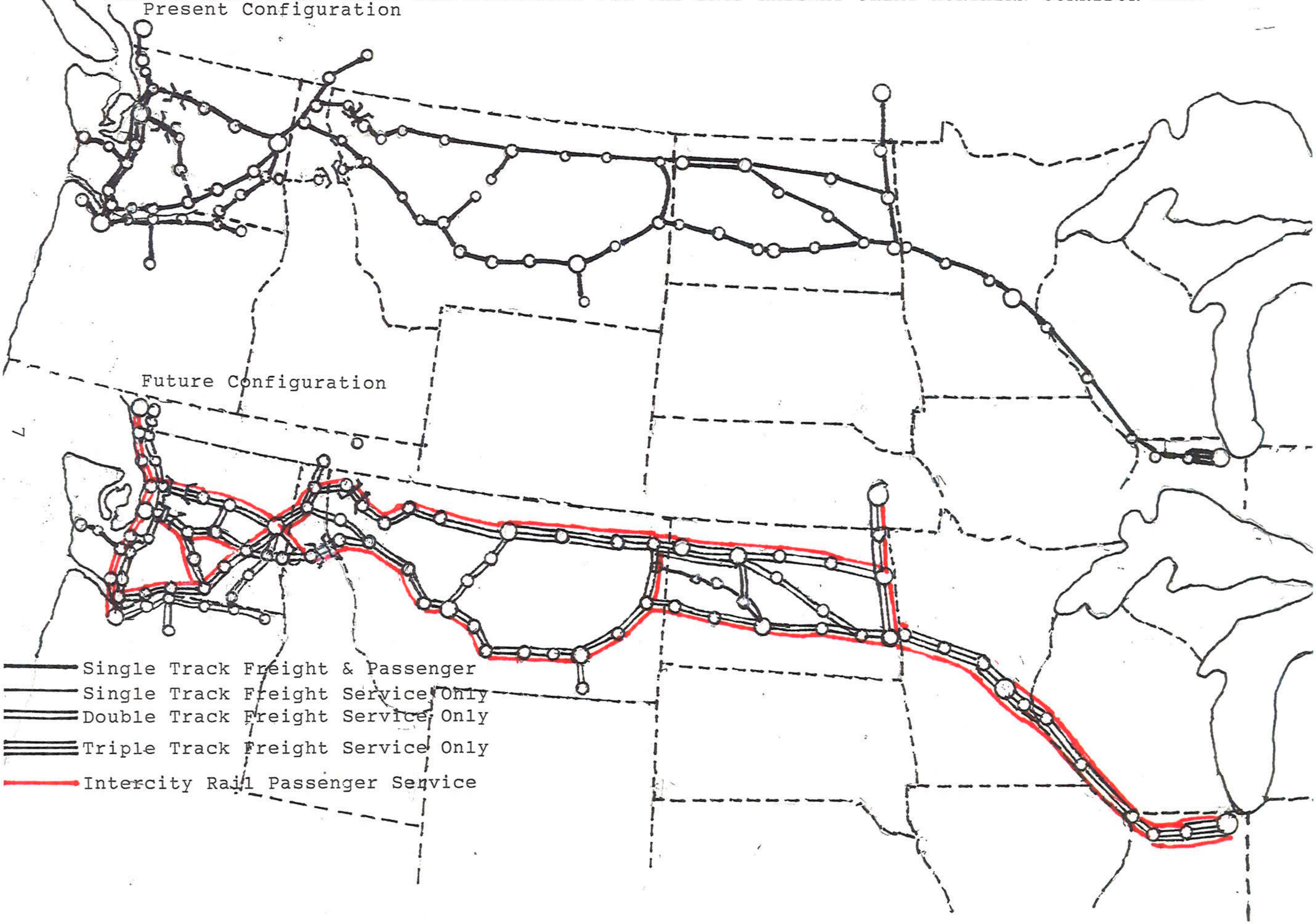

*Sources: PRTM research, OICA (International Organization of Motor Vehicle Manufacturers), various analyst reports, interviews*

Lastly, the major crude oil shipment potential by rail from North Dakota to Washington should merit not just a Strength Weaknesses Opportunity and Threats (SWOT) analyses of the Great Northern Corridor by the Montana Department of Transportation in conjunction with the respective ports and the States of Washington, Oregon, Idaho, Montana, Minnesota and Wisconsin. It would also be beneficial for Governor Dalrymple of North Dakota and Governor Inslee of Washington to take the lead in conjunction with the Governor KItzhaber of Oregon, Otter of Idaho, Bullock of Montana, Dayton of Minnesota and Walker of Wisconsin to work together to formulate formal arrangements to facilitate the safe and efficient transport of crude oil and coal plus intermodal containers and grain and other commodities across the Northern Tier. All of this effort is part of a plan to wean the United States off of foreign oil imports so that it can become energy self-sufficient as well as a future net oil exporter.

The implementation plan for the proposed new freight and passenger rail system across the Northern Tier will go over the Great Northern Corridor between Portland and Seattle on the west end to Milwaukee and Chicago on the east over the existing Burlington Northern Santa Fe Railway line. It is proposed that this corridor be expanded from its present largely single track configuration with mixed traffic to a separate parallel double track freight line and a single track passenger line over the entire route along common rights-of-way. It is further proposed that here be a major new freight double track rail bypass around Spokane over the former Milwaukee Railroad line from Havre, Montana to Ephrata, Washington along with the Cascade Foothills Corridor around the Puget Sound area. A new double track tunnel at St. Louis Pass in eastern Idaho as well as a new double track railroad tunnel at Stampede Pass and a triple track tunnel at Stevens Pass will be needed in order to handle the increased traffic.

It is proposed that there be a new rail oil loading terminal at Mandaree on the Fort Berthold Indian Reservation in western North Dakota built in conjunction with a major marine oil terminal complex to be built at Grays Harbor with the Quinault Indian Tribe in southwest Washington as a joint Tribal venture with tank car oil transport. A similar proposal exists for the Crow Indian Tribe in Montana for coal transport by rail to new coal terminals in Washington operated with Indian Tribal participation. It is intended that the proposed project be financed and built through the private sector by the BNSF Railway for the freight portion and by a new private sector company for the passenger portion at a total estimated capital cost of $25 to 45 billion through long term low interest financing instruments.

# PRESENT AND FUTURE TRACK CONFIGURATIONS FOR THE BNSF RAILWAY GREAT NORTHERN CORRIDOR LINE



It is recommended that there be oversight bodies for the proposed Great Northern Corridor across the Northern Tier representing the specific State Governments as well as of the Indian Tribes. It is anticipated that the new private sector company would purchase the operating rights to the Amtrak Empire Builder and then initiate service over separate tracks on the BNSF rights-of-way. This future passenger service would begin with two to four round trips per day to haul oil workers to and from North Dakota at train speeds initially of 90 to 110 miles per hour as well as to an from other locations as well. This service would have an initial single track operation with passing sidings at 10 to 15 mile intervals. This initial passenger service on a single separate track with periodic passing sidings would later be expanded to between four and eight round trips per day on both the northern and southern routes across Montana and North Dakota along the Great Northern Corridor between Chicago and Seattle at train speeds of 125 to 150 to miles per hour separate from freight train movements.

The proposed rail passenger service between Chicago and Seattle over the Great Northern Corridor would intend to be supplemental by the hauling of express cargoes and packages through private third party carriers such as Federal Express, United Parcel Service, the U.S. Postal Service and others in the future. This express cargo service on the passenger tracks would be operated separately from the existing BNSF Railway intermodal freight service for both trailers and containers and would be administered as a joint venture between the passenger operating company and the BNSF Railway. This express cargo service along the passenger tracks would be intended to operate at speeds of 110 to 150 miles per hour would be in tandem with passenger trains operating in the same speed range. Maximum train speeds could ultimately be increased to real high speed operation with further line improvements to speeds of between 175 and 200 miles per hour as perhaps the first long distance cross country high speed rail service which can be expanded into a national network.

It may become possible to electrify the Great Northern Corridor for rail passenger and freight service on separate parallel tracks of common railroad rights-of-way between Chicago and Seattle if the future. The existing power plants and hydroelectric dams and wind power farms alone the route can then be used to supply the electricity requirements the electrified railway for freight and passenger service along with new power plants. The provision of the additional electricity required for the passenger and freight trains propulsion will need to be added on to the future electric power demands for oil and gas production plus population growth along the Northern Tier with a particular need in North Dakota and Montana.

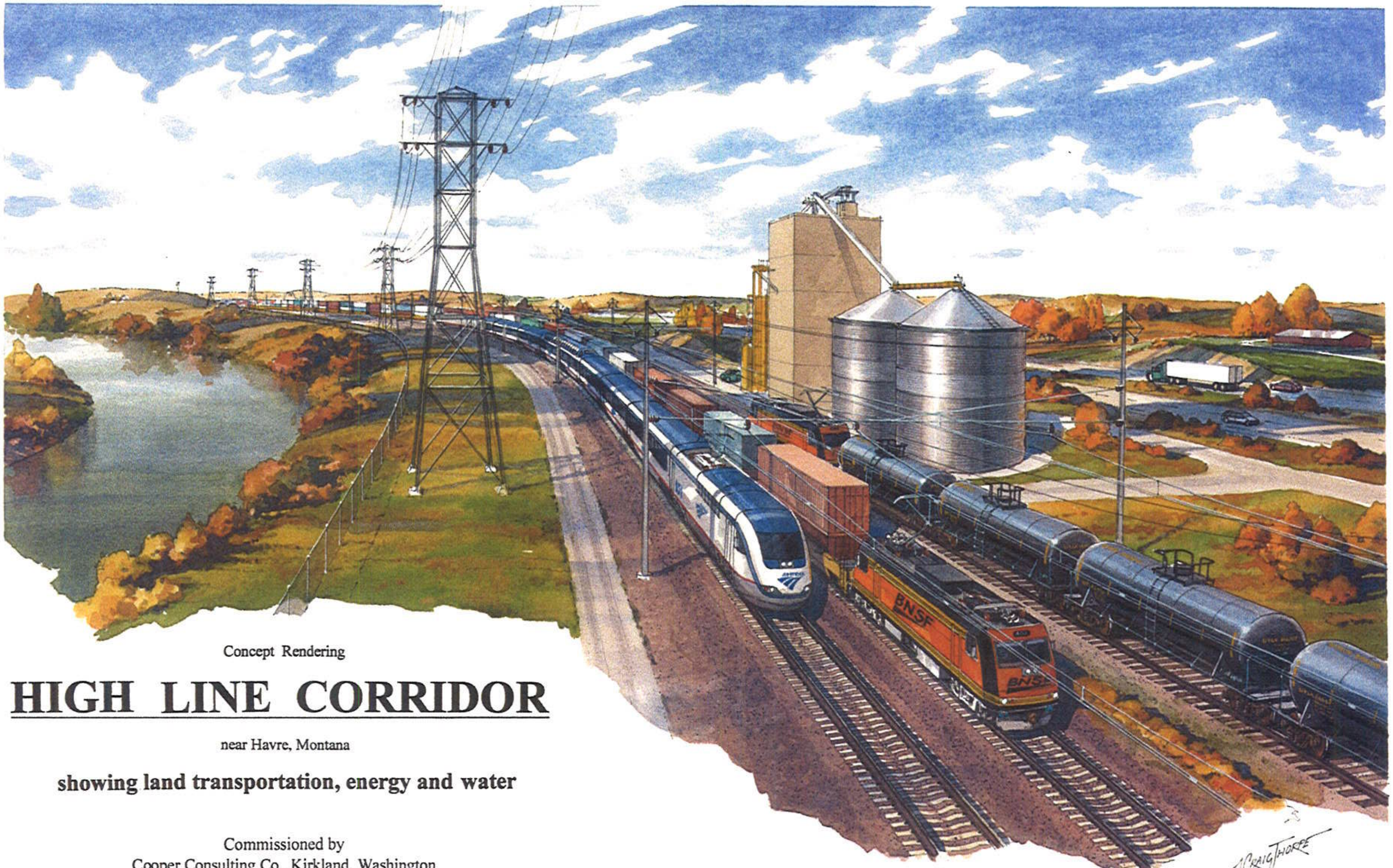
## PROPOSED MAJOR RAILROAD TUNNEL INFRASTRUCTURE PROJECTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE RAILWAY BETWEEN CHICAGO AND SEATTLE

| Tunnel Name | Tunnel Location | Distance In Miles | Number Of Tracks |
|---|---|---|---|
| Stevens Pass | Skykomish, Washington<br>Leavenworth, Washington | 7.9 | 3 |
| Stampede Pass | Lester, Washington<br>Easton, Washington | 8.5 | 2 |
| Flathead Tunnel | Stryker, Montana<br>Libby, Montana | 7.78 | 2 |
| St. Louis Pass | Avery, Idaho<br>Saltese, Montana | 10.5 | 2 |

## PROPOSED FINANCIAL MECHANISMS FOR RAILROAD INFRASTRUCTURE IMPROVEMENTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE

| Infrastructure Category | Number of Tracks | Financing Mechanism | Financing Source |
|---|---|---|---|
| Freight Railroad | 2 to 3 | Low Interest<br>Loans Equity & Bond | Private Sector |
| Passenger Railroad | 1 to 2 | Low Interest<br>Equity Funds & Loans | Private Sector |
| Stations and Terminals | 4 to 12 | Public Investment<br>Equity & Loans | Private Sector<br>Private Sector |
| Grade Separations | 2 to 4 Tracks<br>2 to 4 Lanes | Governmental<br>Appropriations | Public Sector |
| Major Tunnels | 2 to 3 | Private Low Interest<br>+ Governmental Support | Private Funds<br>+ Public Sector |

ARTIST"S CONCEPTION OF THE GREAT NORTHERN CORRIDOR FOR PASSENGER AND FREIGHT RAIL TRANSPORT




Concept Rendering

# HIGH LINE CORRIDOR

near Havre, Montana

**showing land transportation, energy and water**

Commissioned by
Cooper Consulting Co., Kirkland, Washington
for the
**Burlington Northern Santa Fe Railway Co.**
**Fort Worth, Texas**

# TABLE OF CONTENTS

## INTRODUCTION

The United States is at a crossroads in its efforts to maintain its energy and economic security in terms of its present and future supply and demand for oil. The United States has been an oil-importing nation since 1948 and especially after 1973 when the original oil embargo in the Middle East occurred as the result of the Arab-Israeli conflict. This situation resulted in gas lines at stations from constrained supplies with dramatic increases in the prices of gasoline and diesel fuel. A further oil shock occurred in 1979 following the Iranian hostage crisis which resulted in further temporary oil supply shortages and even greater increases in crude oil prices than had occurred in the early 1970's.

Although no immediate oil supply crises have occurred since that time, there has been a generally steady increase in crude oil prices since that time starting with $3.00 per barrel in 1973 to $10.00 per barrel in 1975 to $40.00 per barrel in 1981. Prices have tended to fluctuate since that time but reached a level of $90.00 per barrel in 1991 during the Iraq was and increased to as much as $150.00 per barrel briefly in 2008. Crude oil prices then reached to a low of $40.00 per barrel during the depths of the 2009 - 2010 Recession and have increased to between $80.00 and 100.00 per barrel since that time with a slowly improving economy.

The Puget Sound metropolitan area has been no exception to these increasing crude oil price trends over this period from 1970 to the present. There were several oil refineries built in the Puget Sound metropolitan area between the 1950's and 1970's in the northwest part of Washington. These refineries in Skagit and Whatcom Countries near Anacortes and Ferndale with direct marine water access to the Strait of Juan de Fuca and the Pacific Ocean with one additional small oil refinery in Tacoma. These oil refineries were built primarily to serve the local petroleum markets for gasoline, diesel oil and aviation fuel in western Washington and Oregon plus the adjacent areas in Montana and Idaho and elsewhere.

The initial refining capacity of these refineries has increased in parallel to the ongoing population growth of the Puget Sound metropolitan area. The production capacity of the local oil refineries has increased from 300,000barrels per day in the early 1970's to 450,000 barrels per day in the 1980's to the present 625,000 barrels per day in 2014. Petroleum refining in the State of Washington began in the 1950's and has continued to expand since that time in order to serve the Pacific Northwest.

LOCATIONS OF OIL AND GAS WELL DISTRIBUTION IN THE UNITED STATES BY GEOGRAPHIC REGION

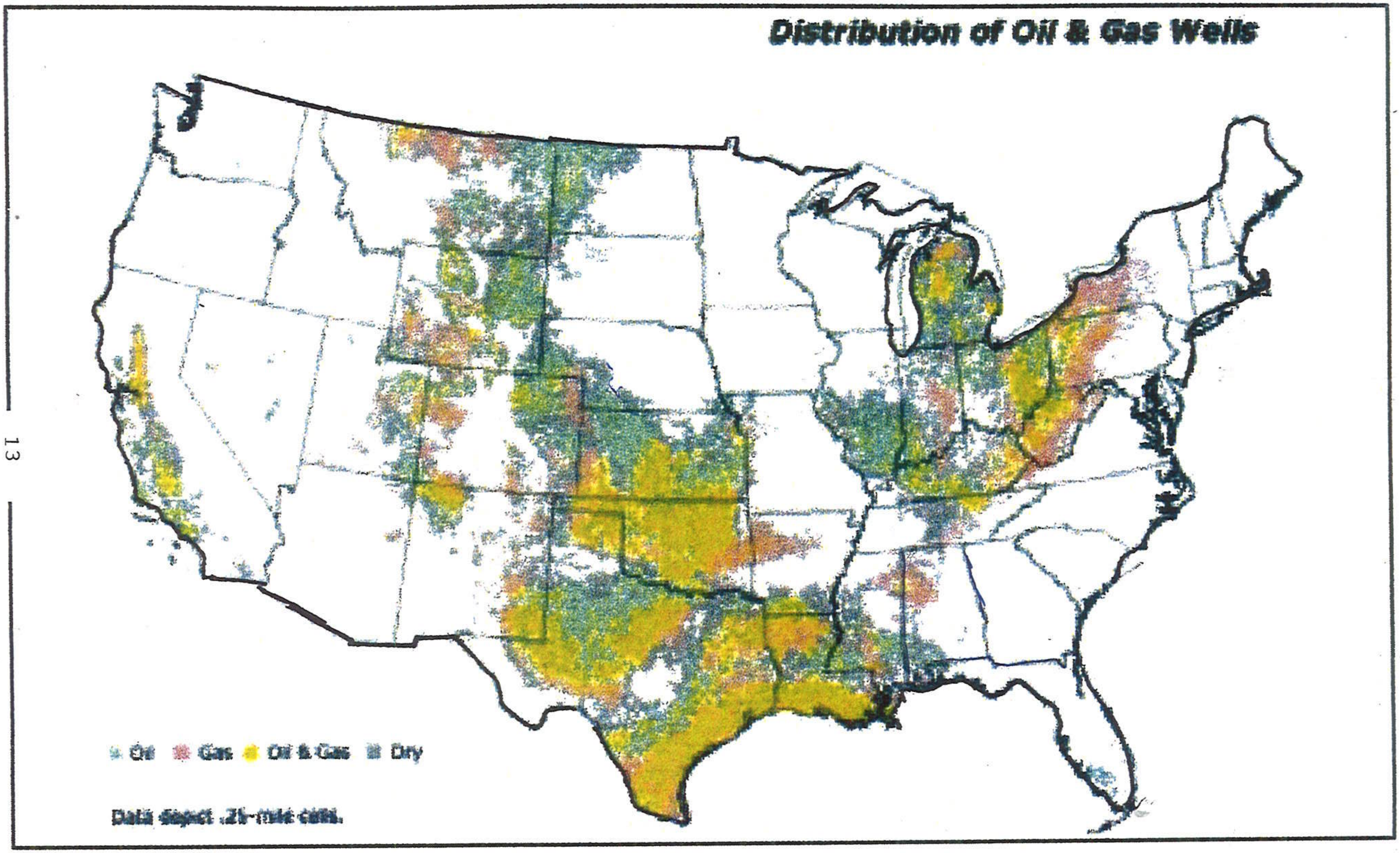
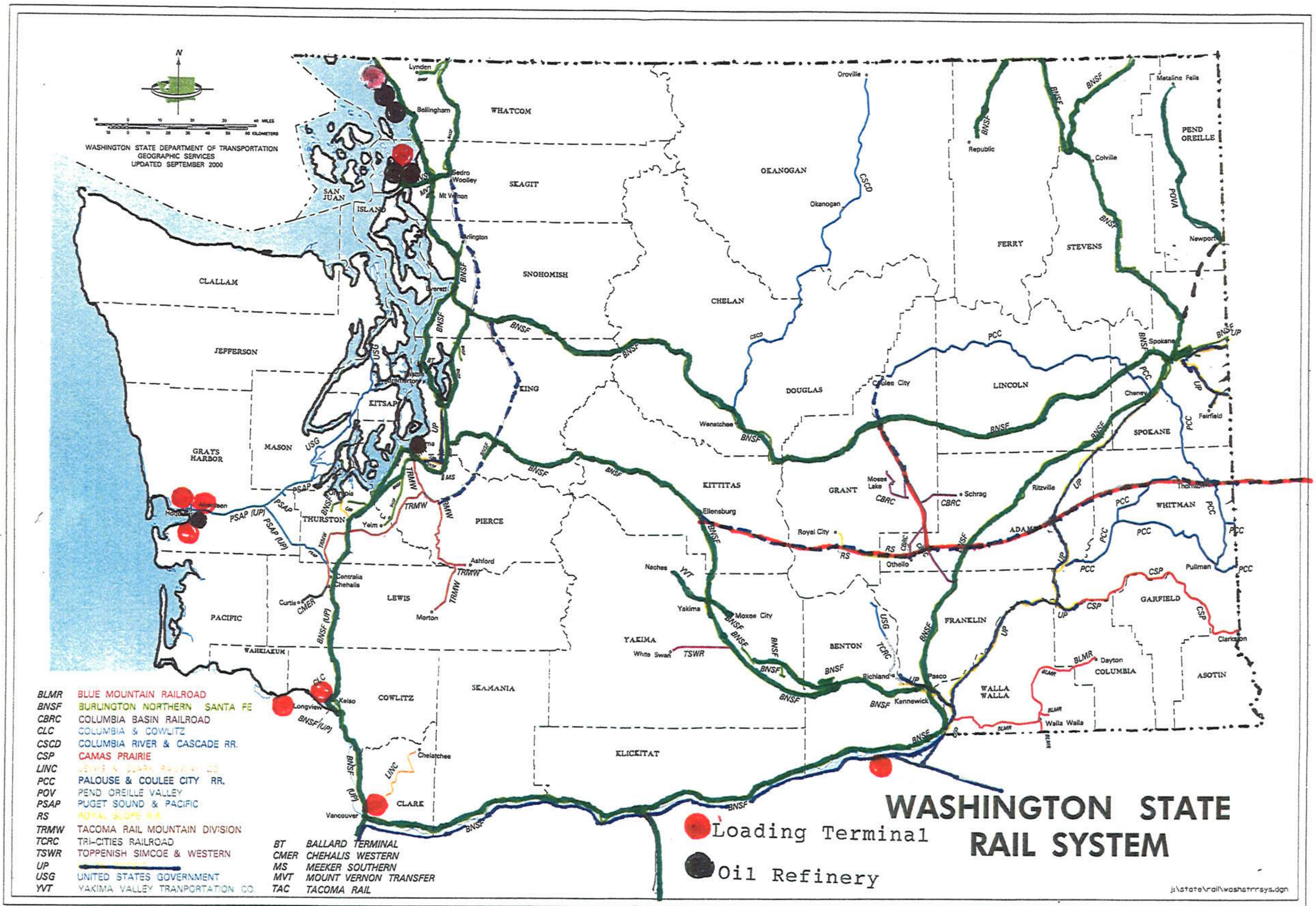



**Figure 2. Distribution of Oil and Gas Wells in the U.S. Derived from a USGS map by Mast et al, 1998**

ROUTE LOCATIONS OF THE EXISTING RAILROAD LINE NETWORK IN THE STATE OF WASHINGTON FOR 2013 AND THE EXISTING PETROLEUM REFINERIES AT ANACORTES AND FERNDALE AND TACOMA AND ABERDEEN



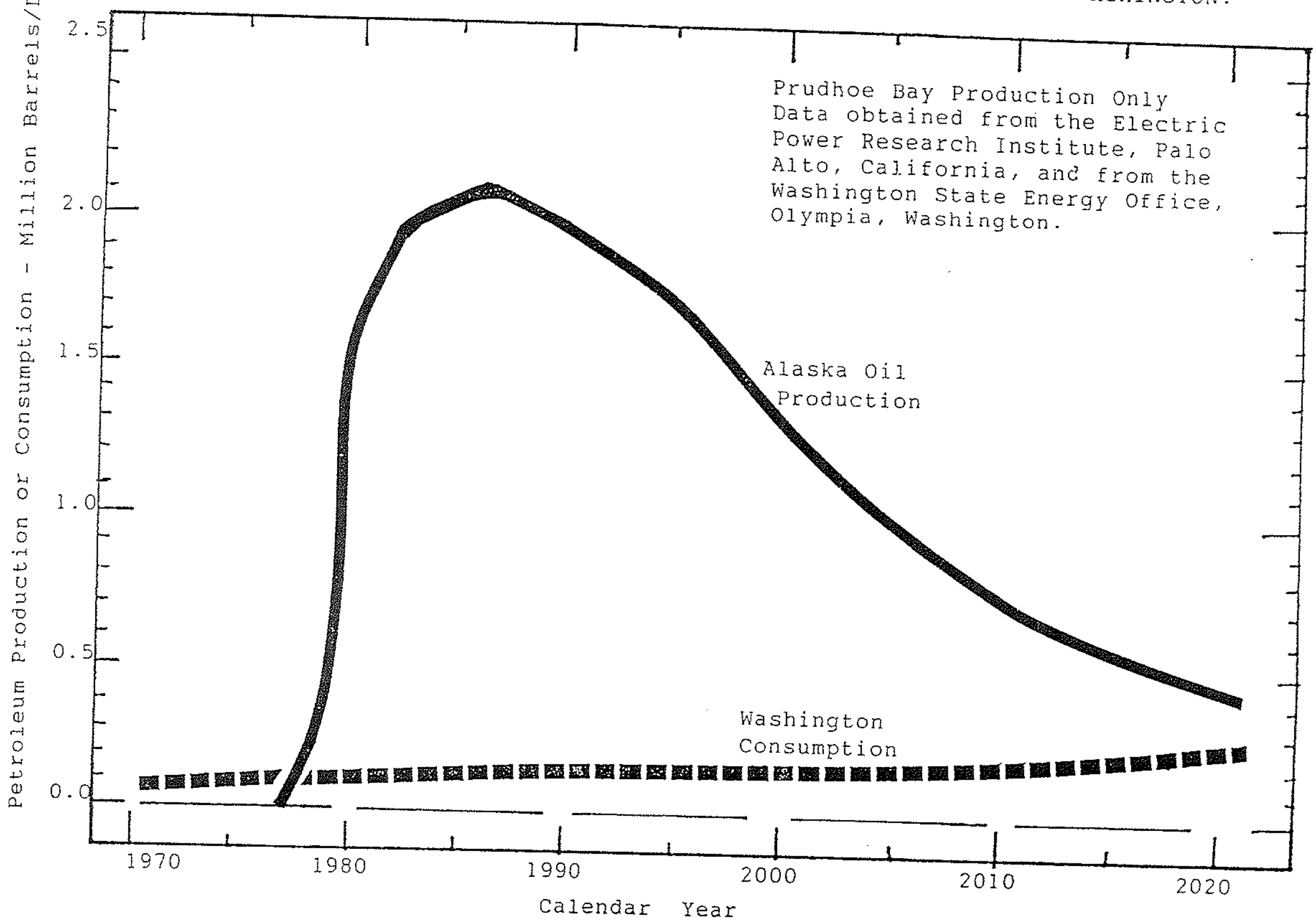
Production has increased primarily through a progressive series of expansions at the existing facilities with no new refinery construction in recent years except for a small bio-diesel at Group Harbor. It is expected that any future increases in production capacity at the existing refineries will only occur in small increments if at all. The major reason for this plateauing of oil use if at all because population increase is being offset by improved gasoline fuel efficiencies in automobiles with diesel truck fuel and traffic use the only major area of expansion as well as the use of electric vehicles.

The Puget Sound area oil refineries were all developed and built around the assumption that crude oil from the Prudhoe Bay field in Alaska would be delivered by ship to facilities located along Puget Sound and the Georgia Strait. This trend began with the startup of each refinery and has continued up until the present as long as Alaska crude oil was available in sufficient quantities at a reasonable price along with a limited amount imported from overseas locations. However, all of this began to change with the advent of major new crude oil production increases from the Bakken Formation in North Dakota at the same time that crude oil production in Alaska was significantly decreasing over time.

The real concern with regard to crude oil supply in the State of Washington is that production from the existing Prudhoe Bay field has been steadily declining since the early 1980's. The crude oil produced from the Prudhoe Bay field at one time served essentially all of the required crude oil supplies for the refineries in both California and Washington, even though confidence was questioned following the Prince William Sound tanker oil spill in 1988. The present decline in crude oil supplies from the Prudhoe Bay field in Alaska is forcing the consideration of alternative crude oil supply sources for all of the West Coast refineries, with foreign imports as an increasingly questionable options for the State of Washington.

The recent required decline in crude oil availability from Alaska for Washington refineries and to some extent for California is the major shale oil deposits in the United States because of horizontal drilling and hydraulic fracturing. The most important new shale oil reserve in the United States for supplying crude oil to replace the declining production in Alaska is from the Bakken Formation in western North Dakota. The reminder of the present report will be devoted primarily to the use of Bakken Formation crude oil in the State of Washington as its major future crude oil supply source.

OBSERVED AND EXPECTED TRENDS IN TOTAL CRUDE OIL PRODUCTION FROM THE PRUDHOE BAY FIELD IN ALASKA RELATIVE TO PETROLEUM CONSUMPTION IN THE STATE OF WASHINGTON.



## REFINING FACILITIES

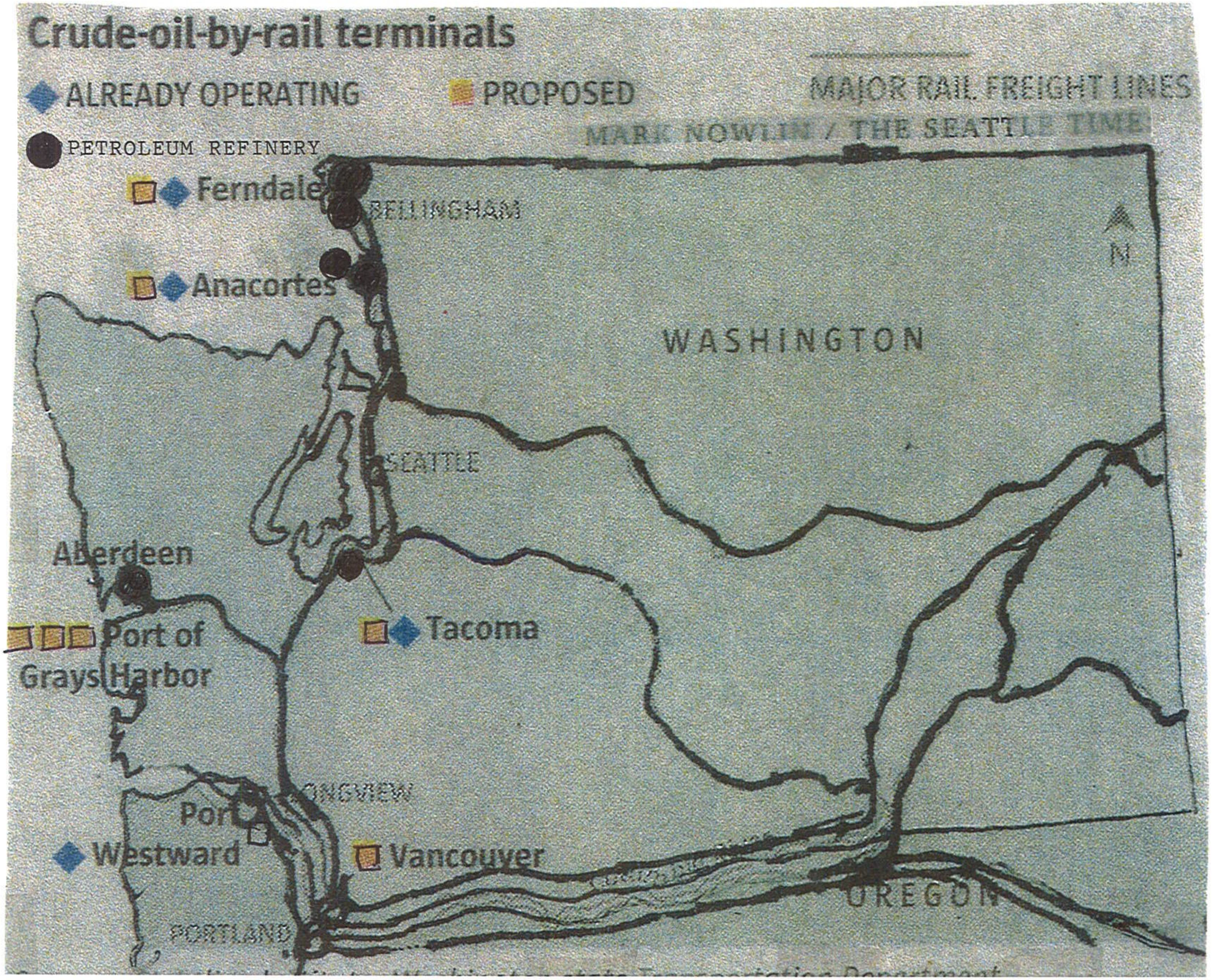
The present paper will be devoted to the subject of the expected trends which will occur in the Puget Sound metropolitan area's transportation infrastructure as the result of the expected ongoing shift from ship marine – delivered Alaskan crude oil to rail-land-delivered North Dakota crude oil. The initial consideration is that Alaskan crude oil production began in 1977 with the opening of the Prudhoe Bay field and the Alaskan oil pipeline and reached a peak in production in 1987 at 2,100,000 barrels per day. Oil production from the Prudhoe Bay field has been split between oil refineries in California and Washington with California receiving the greatest proportions of as much as 900,000 barrels per day.

Crude oil production from the Prudhoe Bay field has slowly but steadily decreased since that time to 1,500,000 barrels per day in 2000 and to an estimated 850,000 barrels per day in 2010. The present crude oil production from the Prudhoe Bay field has since further decreased by late 2013 to somewhat greater than 500,000 barrels per day and is continuing to decrease at a rate of approximately 5.0 percent per year. Crude oil production from the Prudhoe Bay field is expected to further decrease to as low as 300,000 barrels per day before 2020, when it may no longer be able to operate because of possible freezing in the Alaska pipeline.

The present crude oil demand in the State of Washington is initially estimated as 250,000 to 300,000 barrels per day. There is also an expected additional estimated demand of 150,000 to 200,000 barrels per day overall consumption in the State of Oregon plus another 50,000 to 100,000 barrels per day of oil demand elsewhere in the Pacific Northwest. As a result, the total estimated petroleum products demand in the Pacific Northwest which can be supplied on an intermittent or continuous basis is between 450,000 and 600,000 barrels per day from the refineries in northwest Washington.

There are five petroleum refineries in the State of Washington plus one bio-diesel refinery with a total refining capacity of 622,580 barrels per day. These are two refineries operated by Tesoro and Shell along Fidalgo Inlet at Anacortes as well as two refineries located near Birch Bay to the north at Cherry Point and Ferndale plus a smaller refinery in the Port of Tacoma. These refineries range in capacity from 225,000 barrels per day at Cherry Point with British Petroleum (BP) as the largest to 35,000 barrels per day at Tacoma for U.S. Oil and Refining Company as the smallest.

LOCATIONS OF THE EXISTING OIL REFINERIES AND THE OPERATING AND PROPOSED OIL TERMINALS



## ESTIMATED PETROLEUM PRODUCTS DEMAND REQUIREMENTS BY STATE OR REGION IN THE PACIFIC NORTHWEST

| State or Region | Population Served | Petroleum Demand Barrels/ Day |
|---|---|---|
| Washington | 7,000,000 | 250,000 – 300,000 |
| Oregon | 5,300,000 | 150,000 – 200,000 |
| Other* | 1,700,000 | 50,000 – 100,000 |
| Total | 13,000,000 | 450,000 – 600,000 |

## PRESENT PRODUCTION CAPACITIES OF EXISTING PETROLEUM REFINERIES IN NORTHWEST WASHINGTON

| Producing Company | Refinery Location | Refining Capacity Barrels/ Day |
|---|---|---|
| Tesoro | Anacortes | 108,000 |
| Shell | Anacortes | 145,000 |
| British Petroleum | Cherry Point | 225,000 |
| Conoco Phillips | Ferndale | 105,000 |
| U.S. Oil & Refining | Tacoma | 35,000 |
| Imperial Renewable | Grays Harbor | 4,580 (Biodiesel) |
| Total | — | 622,580 |

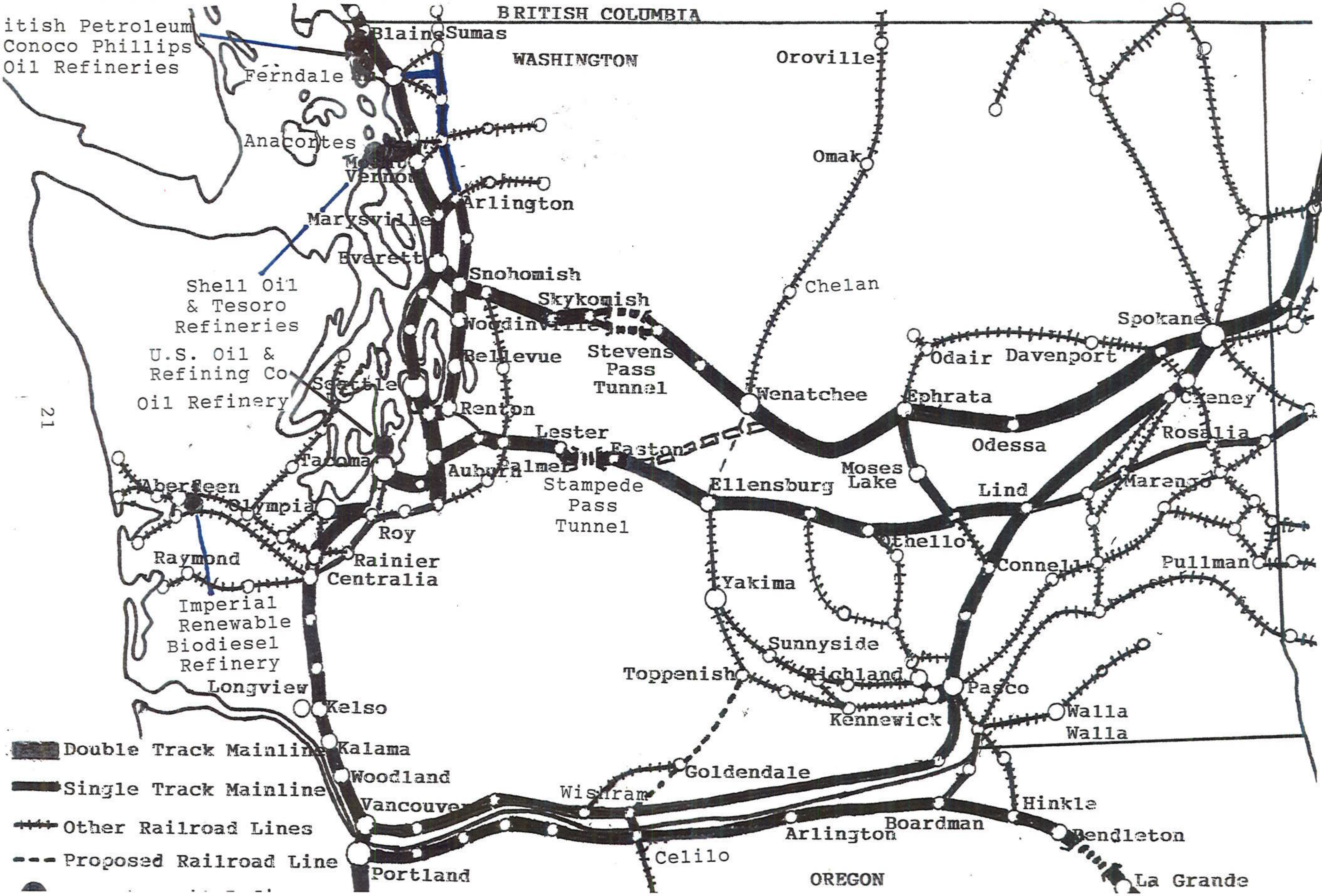
Other intermediate size oil refineries include the Conoco Phillips facility at Ferndale with 105,000 barrels per day along with the two refineries at Anacortes with Tesoro at 108,000 barrels per day and Shell at 145,000 barrels per day. There is also the small bio-diesel non-petroleum refinery of Imperium Renewables at Grays Harbor with a capacity of 4,580 barrels per day now in operation as a crude oil supplement.

All of the five petroleum-based refineries in Washington relied on Prudhoe Bay oil from Alaska as their primary crude oil source until recently with some foreign crude oils from Indonesia and elsewhere. However, in the past year the 108,000 barrels per day Tesoro refinery at Anacortes has been retooled to process the light sweet crude oil from the major Bakken Formation in North Dakota so that it is now the refinery's only crude oil source. The conversion of the Tesoro refinery from Alaska to North Dakota crude oil is logical in view of the fact that Tesoro operates the only refinery in North Dakota at 60,000 barrels per day, and also has extensive oil well production and a pipeline network in North Dakota. The U.S. Oil and Refining Company refinery in Tacoma is reportedly using 10,000 barrels per day of North Dakota crude oil plus 25,000 barrels per day of Alaskan crude for a total of 35,000 barrels per day.

The above reported data for the total North Dakota crude oil usage is that 118,000 barrels per day is being transported to Washington by railroad as there are no pipelines between North Dakota and Washington. When based on a unit train loading of 55,000 barrels per train, that is equivalent to 2.5 unit trains per day of Bakken Formation crude oil or 15 unit trains per week. This level of crude oil usage of 118,000 barrels per day is now equivalent to 19 percent of the total maximum crude oil production capacity of 622,500 barrels per day for the State of Washington. This level of crude oil shipment is also equivalent to 11 percent of the total estimated crude oil production of 1,050,000 barrels per day in North Dakota reached in January of 2014 following a year of steady production increases.

The State of North Dakota has undergone nothing less than an enormous increase in its crude oil production of less than 100,000 barrels per day in 2006 to 300,000 barrels per day in 2010 and to 1,050,000 barrels per day at the beginning of 2014 nearly 1,100 percent. Only 60,000 barrels per day of crude oil are presently being refined in North Dakota at the Tesoro refinery at Mandan and there are approximately 10,000 barrels per day for other uses as a direct fuel or for chemicals.

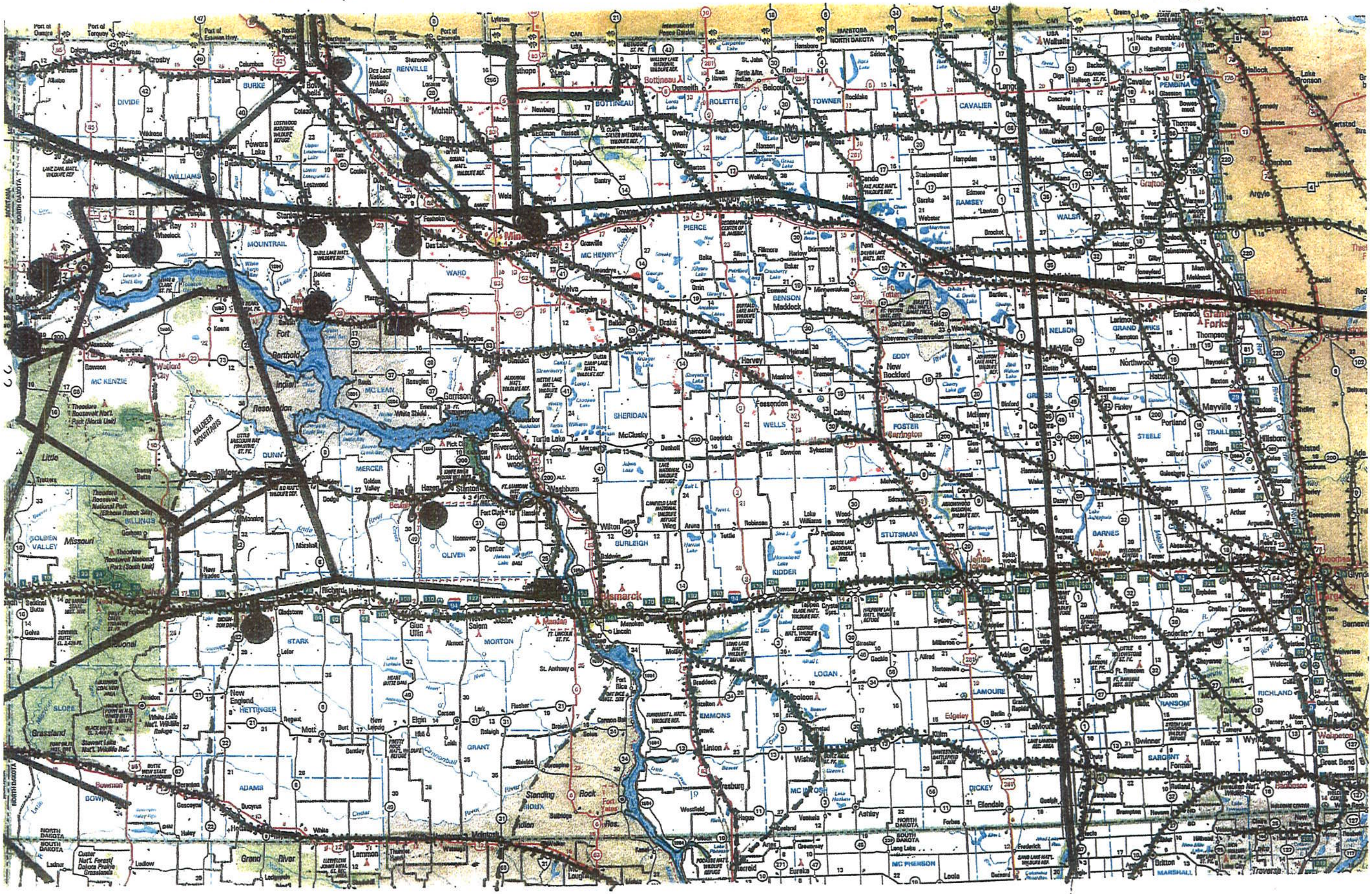
LOCATIONS OF THE EXISTING OIL REFINERIES AND THE RAILROAD LINE NETWORK IN WASHINGTON




21

ROUTE LOCATIONS OF THE MAJOR HIGHWAY RAILROAD AND PIPELINE INFRASTRUCTURE IN NORTH DAKOTA

Railroad Existing — Railroad Proposed — Oil Pipeline — Oil Terminal



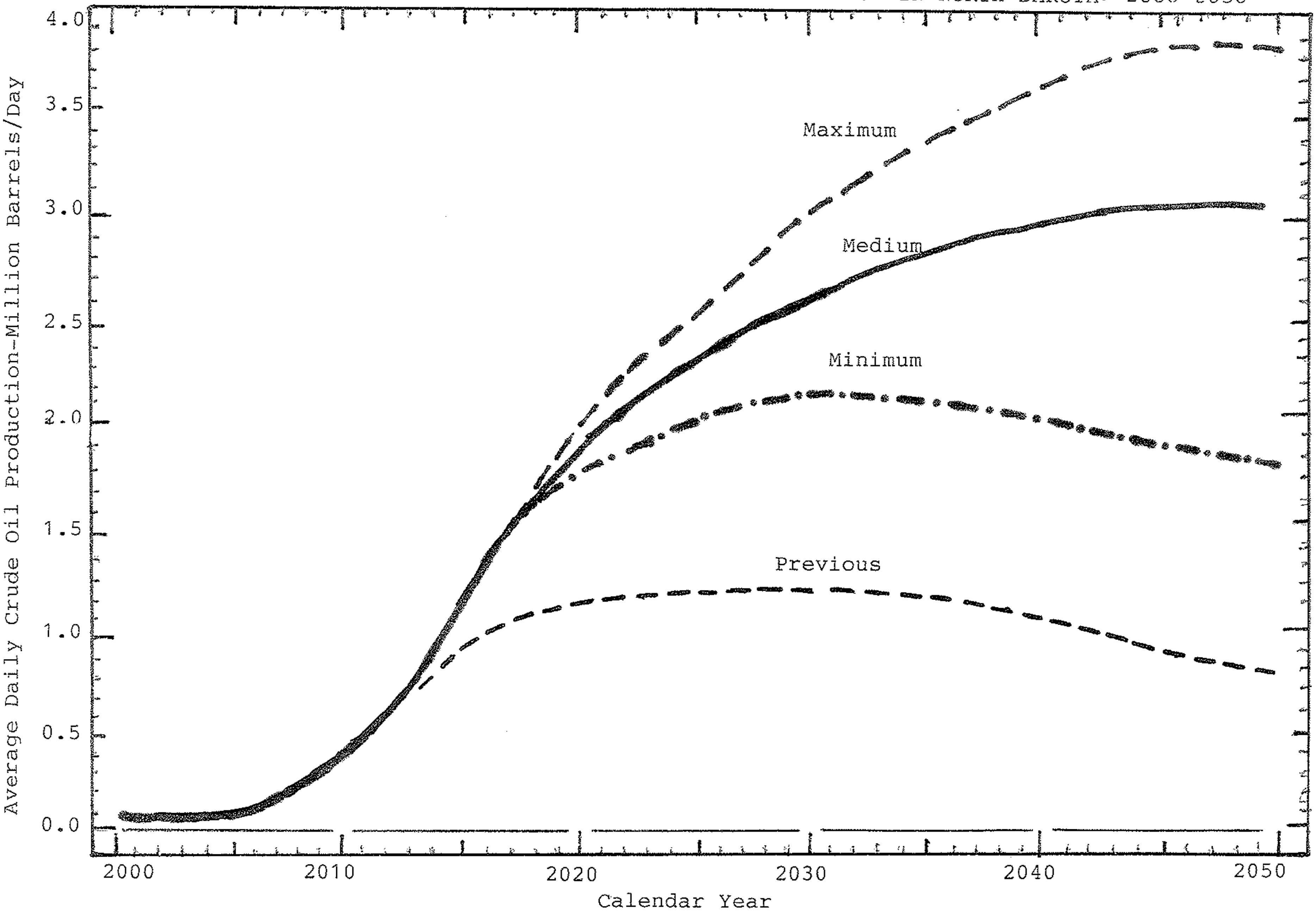
With 70,000 barrels per day of internal consumption, a total of 980,000 barrels per day of crude oil had to transported out of North Dakota by some means by pipeline or railroad to other States.

There is also several additional small oil refineries planned in North Dakota which can be readily permitted with their small sizes. In addition, there is 15,000 barrels per day Black Thunder refinery now being built near Makoti on Native lands by the Three Affiliated Tribes on the Fort Berthold Indian Reservation in west central North Dakota. There is also a second 20,000 barrel per day diesel fuel refinery being constructed by a subsidiary of Montana Dakota Utilities Resource Company in South Heart in southwestern North Dakota to the west of Dickinson. In addition, there is another small oil refinery proposed to be built at Trenton near Williston in northwestern North Dakota with a capacity of 20,000 barrels per day plus a second at Bowman in southwestern North Dakota with a capacity estimated at 15,000 barrels per day, all of which are expected to produce daily volumes of 20,000 barrels per day or less.

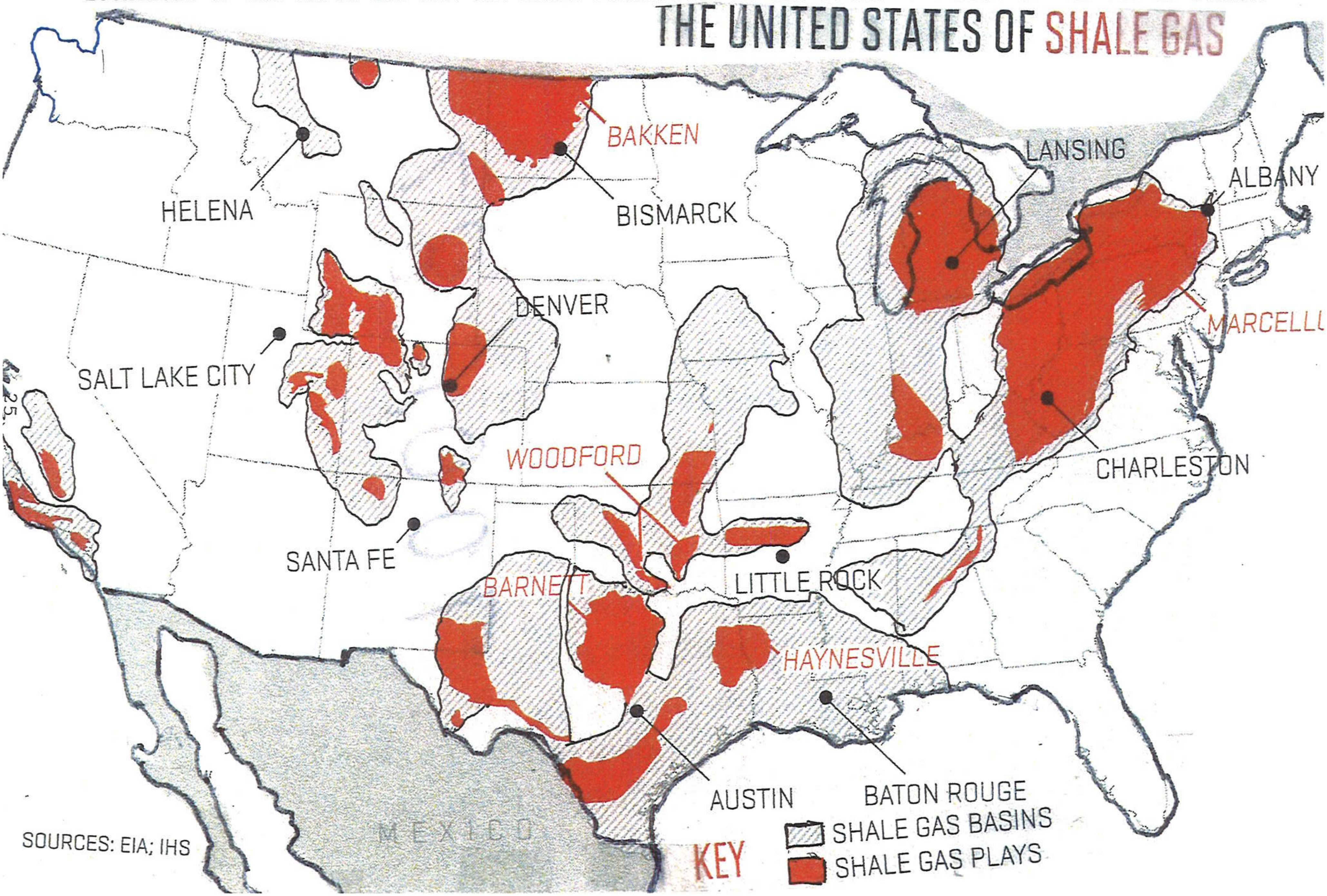
These proposed expansions will result in the State of North Dakota's refining capacity being increased from 60,000 barrels per day in 2013 to 95,000 barrels per day in 2014 to as much as 135,000 barrels per day in 2015 in all of these proposed refineries actually go into service. These estimates are based on the most optimistic projections for increased oil refining capacity in North Dakota. The State's total crude oil production is expected to increase from 950,000 barrels per day in December of 2013 to 1,200,000,000 barrels per day in 2014 to 1,350,000 barrels per day in 2015. The overall crude oil production in North Dakota is expected to then further increase to 1,600,000 barrels per day by 2017 and then to 2,000,000 barrels per day by 2022.

The very limited existing pipeline capacity in North Dakota available for crude oil shipments of 250,000 to 300,000 barrels per day at present has meant that 70 to 75 percent of its production would have to be carried out by railroad, or between 680,000 and 730,000 barrels per day out of North Dakota in January of 2014. It is expected that the percentage of crude oil transported out of North Dakota by rail is expected to increase to as much as 85 to 90 percent of the total as its overall crude oil production increases to between 1,600,000 and 2,000,000 barrels per day over the next five to ten years. At present, only 12 percent of North Dakota's total crude oil shipments go to the State of Washington, or 118,000 barrels per day but these shipments constitute 16 percent of the total rail shipments.

ALTERNATIVE PROJECTIONS OF EXPECTED CRUDE OIL PRODUCTION IN NORTH DAKOTA: 2000-2050



LOCATIONS OF THE MAJOR GAS AND OIL SHALE FORMATIONS IN THE LOWER 48 STATES OF THE UNITED STATES



## OIL PRETREATMENT

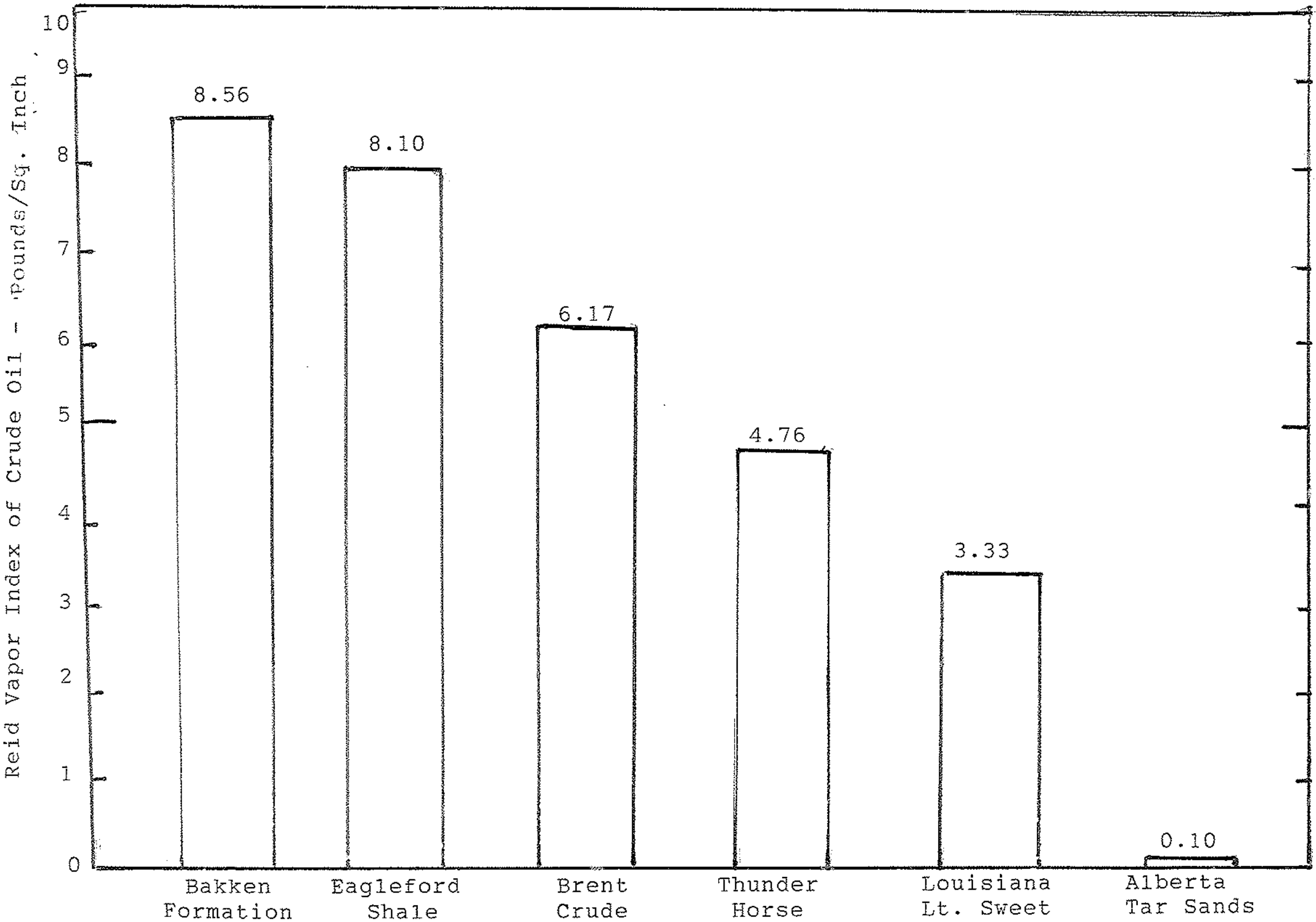
The North Dakota crude oil is a light sweet grade of liquid petroleum which has a low bulk density and low sulfur content with a low metals impurities level. The Bakken Formation crude oil can be easily refined and in many ways is very similar in grade to the diesel oil used in trucks which can even in some cases be directly utilized in truck engines. Bakken Formation crude oil is also classified as a so-called "wet" oil which has a relatively high content of light volatile low molecular weight hydrocarbons from ethane to hexane which will normally be evolved with the methane fraction in the natural gas released when the extracted crude oil is brought up to the ground from the well and placed in the separator.

This relatively high content of light volatile vapors with the Bakken Formation crude oil tends to give it its propensity for high vapor pressure. The production of crude oil with hydraulic fracturing requires the injection of sand as so-called "propants" to assist in facilitating oil flows as well as to fracture the shale rock formation in which the oil molecules are encased. Hydrochloric acid is also injected with the sand to help dissolve and break up the shale rock to help induce oil molecule flow as well as to release the gases and vapors. Then a proprietary combination of various organic and inorganic chemicals are added to reduce the surface tension between the shale rock and oil molecules so that they can flow up to the ground through the oil well pipelines along with the gases and vapors.

The crude oil molecules plus the methane and various organic hydrocarbon vapors and the salt brine liquids then flow up under natural pressure or through pumping to the ground level from the shale rock formation at 8,000 to 11,000 feet below ground. This combined liquid and gas phase material along with some entrained shale rock solids then flow into a horizontal gas-liquid-solid phase separation units. This multiple gas-liquid-solid phase mixture is then divided into three separate streams.

These three individual primarily gas and liquid phase stream then flow out of the separation unit and are dispensed as follows. The natural gas phase then flows out the top which contains the methane and various light hydrocarbon vapors. In addition, the crude oil is drained from the center stream of the separation unit as a liquid with some entrained volatile hydrocarbon gases and vapors plus benzene and other aromatic organic compounds being released from the liquid phase.

COMPARISON OF REID VAPOR PRESSURE MEASUREMENTS FOR ALTERNATIVE CRUDE OIL SAMPLES



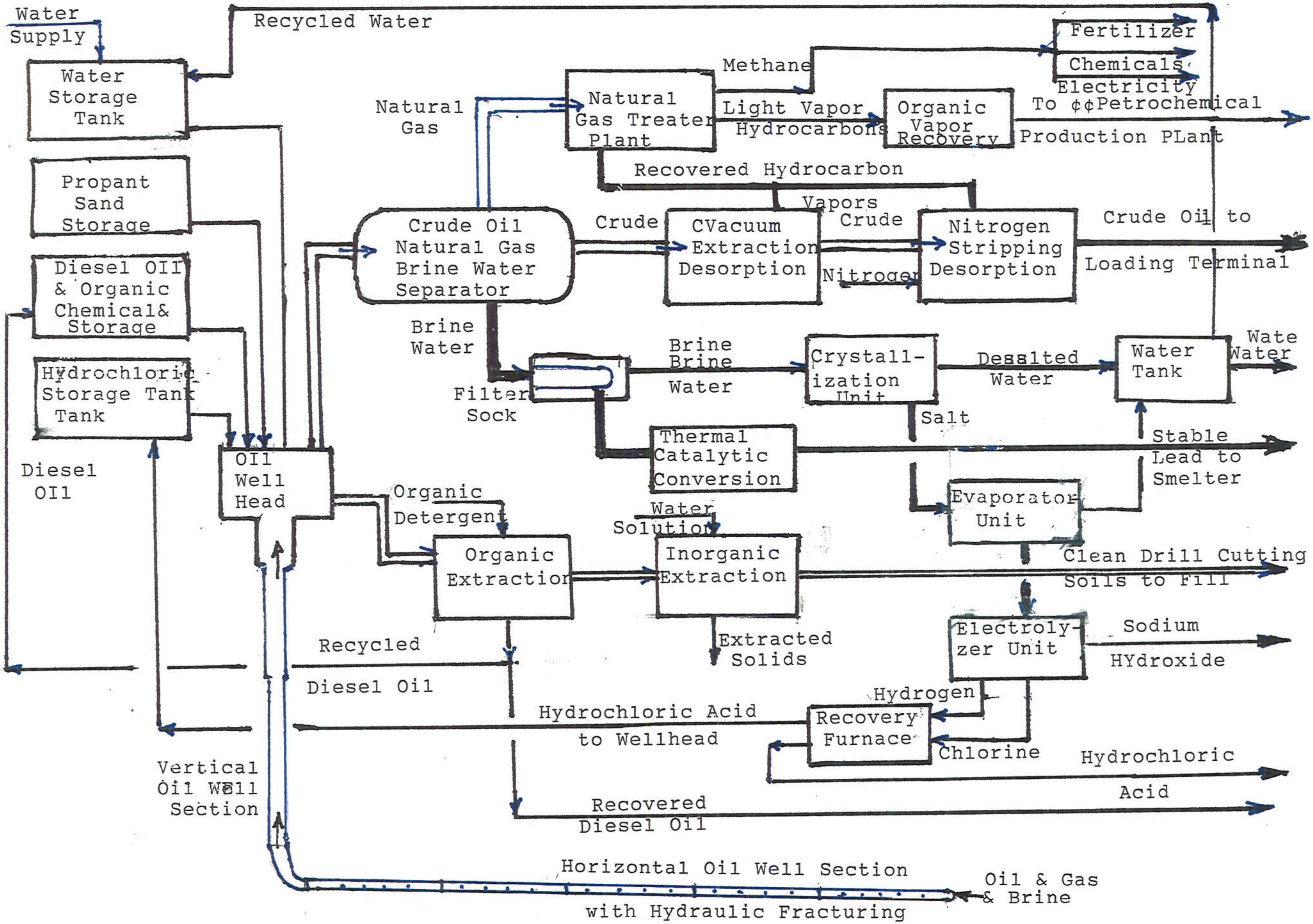
The heavier salt brine liquid then than flows out the bottom of the separation unit along with any entrained shale rock solids which includes the trace metals as solids and radioactive nuclides primarily as radium solids particles which are then removed by the filter socks.

The relatively high volatile hydrocarbon contents of the Bakken Formation crude oils resulting from the low molecular weight ethane through hexane plus benzene and other aromatic compounds have a high vapor pressure level when unplanned events which may occur. The cause exposure to air at the top vapor space in tank cars or from a tank cars breakup in case of derailments to create an explosion hazard. The gas-liquid phase separation units are designed to achieve a given level of separation of the vapor phase from the liquid phase but the relatively high "wet phase" hydrocarbon vapor content may result in their design capacity of gas-liquid separation to be exceeded for some but not all Bakken Formation crude oils so that larger units may be required.

It will probably be necessary to add a second stage gas-liquid phase separation unit downstream of the existing separation units in order to achieve increased removed of these volatile aliphatic and aromatic organic hydrocarbon vapors on the crude oil streams in order to minimize the potential explosion hazards for some of these Bakken Formation crude oils. This additional removal of volatile organic hydrocarbon vapors on some but not all of the Bakken Formation crude oil can then be accomplished by vacuum distillation evaporation units which recover the light organic vapors and the aromatic compounds while leaving the heavier crude oil molecules in the liquid phase in order to achieve a proper level of separation.
In addition, a system of nitrogen or carbon dioxide gas purging of the crude oil can also achieve additional removal of the volatile light aliphatic and heavier aromatic hydrocarbon vapors from the crude oil.

These light volatile hydrocarbon vapors ranging from ethane to hexane and alone plus benzene and other aromatic are recovered by means of condensation using liquid nitrogen cooling and/or by other existing technologies. The vapors coming from vacuum distillation extraction unit are basically pure organics which can be readily condensed while multiple phase separation will generally be required for the nitrogen or carbon gas purging well probably be necessary. This additional volatile vapor separation step could be done at the wellhead or at the central loading terminal or at crude oil storage facilities. However, its relative complexity would probably favor location at a central facility, if possible.

PROCESS FLOW DIAGRAM OF AN OIL PRODUCTION WELL WITH RESIDUAL WASTE STREAM TREATMENT SYSTEM



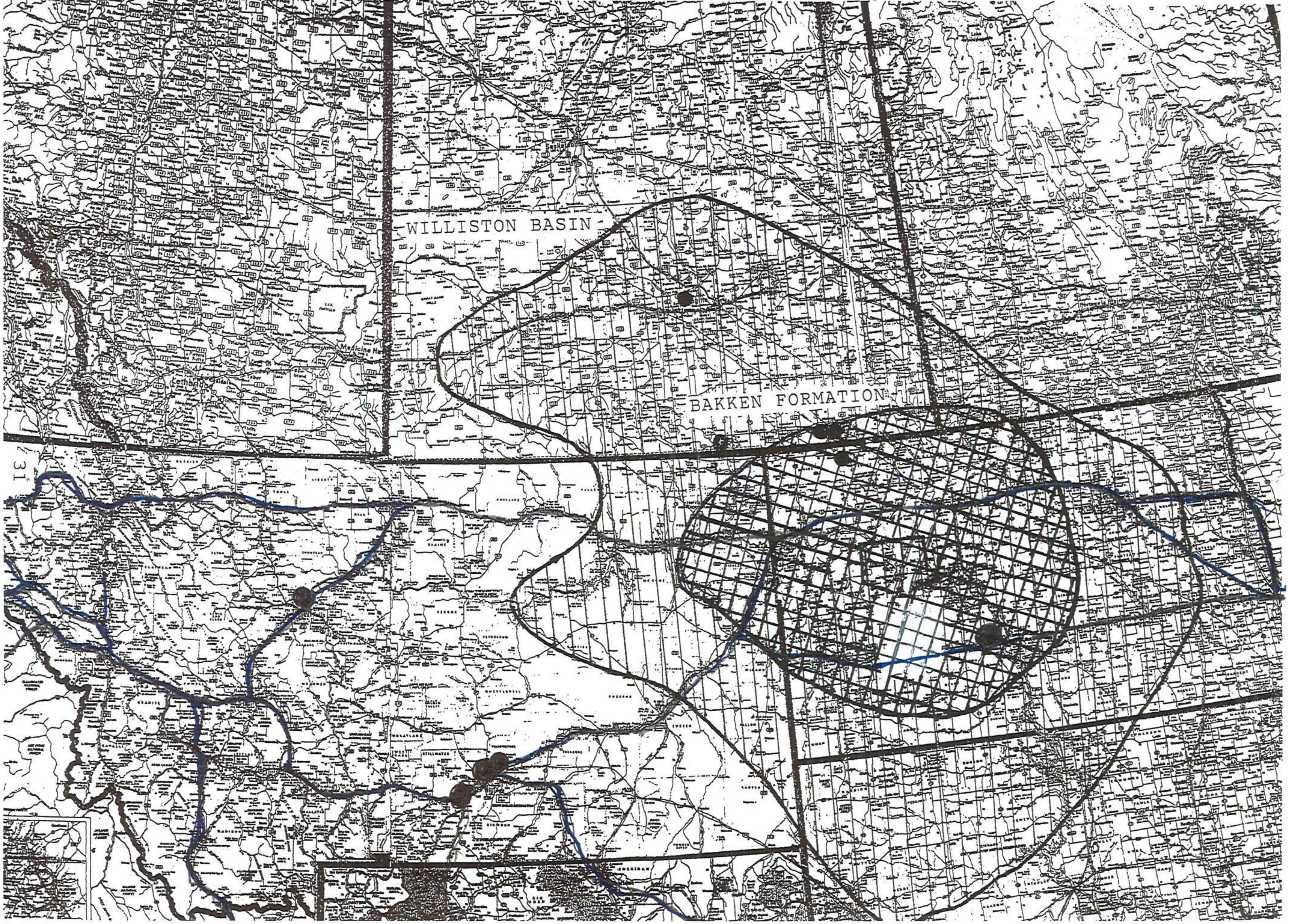
Natural gas treatment plants are generally used for the separation of the volatile hydrocarbon vapors from the crude oil liquids in most oil fields, including in North Dakota. However, there is presently an insufficient number of natural gas treating plants in North Dakota to handle the massive amount of natural gas being produced at the present time. As a result, up to one-third of the natural gas in North Dakota is burned off by flaring as compared to recovery as a useful byproduct.

The recovery of volatile organic hydrocarbon vapors may become a useful necessity as a pretreatment step prior to the loading of crude oil into tank cars before shipment of the Bakken Formation for the North Dakota light crude oil from the Bakken Formation by rail. Safety efforts to date have suggested volatility testing of crude oils from North Dakota will probably be necessary in the future. A special effort will need to be made to identify variations between individual formations and fields and layers. The retrofitting of tank cars and the construction of new tank cars to meet safety standards is already happening but crude oil pretreatment may also be necessary in addition to the tank car modifications.

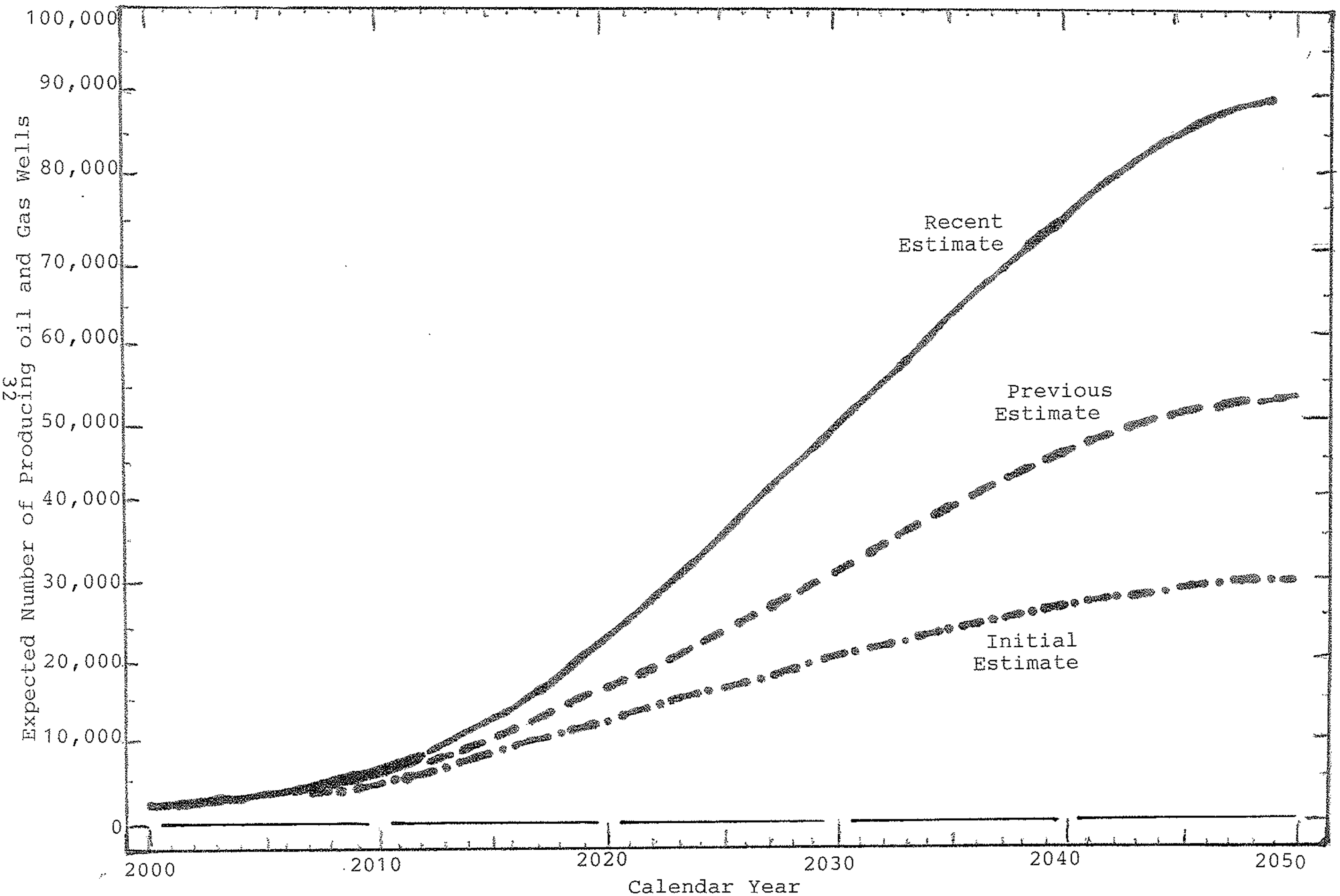
There is a massive amount of crude oil lying underneath North Dakota in as many as 11 individual layers in at least five major formations. The layers include the Bakken Formation plus the Three Forks Sanish Formation along with the Pronghorn, Antelope, Tyler and Red River Formation at depth ranging from 5,000 to 15,000 feet. The total estimated oil resource in the Bakken Formation is between 300 and 500 billion barrels of which between 4 and 6 billion barrels at a minimum to as much as 25 to 50 billion barrels at a maximum is considered as being presently recoverable. The total resource is as much as one trillion barrels of oil from all of the oil fields in North Dakota, making it more than Saudi Arabia.

It is emphasized that the present oil well drilling technologies only recover an average of 6 percent of the oil present in the Bakken Formation with a combination of vertical drilling, horizontal drilling and hydraulic fracturing. Each oil well in North Dakota being drilled requires 3,000,000 to 5,000,000 gallons of water and over 100,000 tons of sand for hydraulic fracturing. Each well being drilled in North Dakota produces 1,000 cubic feet of natural gas produced for every barrel of oil recovered. Each oil well drilled in North Dakota requires an average of 2,000 truck trips per well along with 1,000 truck trips per year for each year when production begins. There are presently nearly 10,000 producing oil wells in North Dakota today which is expected to increase to as many as 90,000 wells by between 2040 and 2050 as the production is steadily expanded.

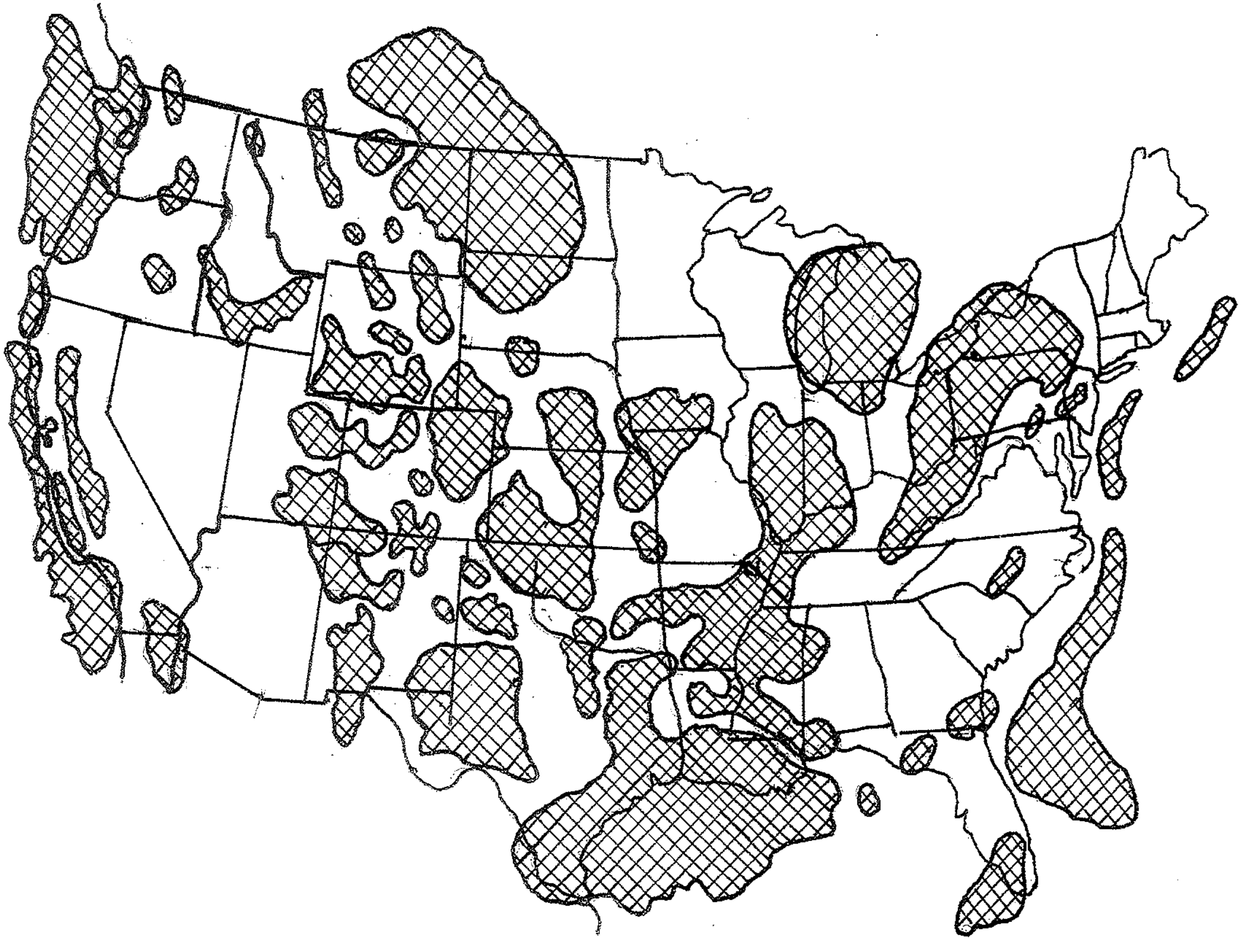
APPROXIMATE BOUNDARIES OF THE BAKKEN FORMATION AND WILLISTON BASIN OIL PRODUCING AREAS



EXPECTED INCREASES IN THE NUMBER OF PRODUCING OIL AND GAS WELLS IN NORTH DAKOTA: 2000-2050



LOCATIONS OF THE MAJOR POTENTIAL OIL AND NATURAL GAS PRODUCING REGIONS OF THE UNITED STATES

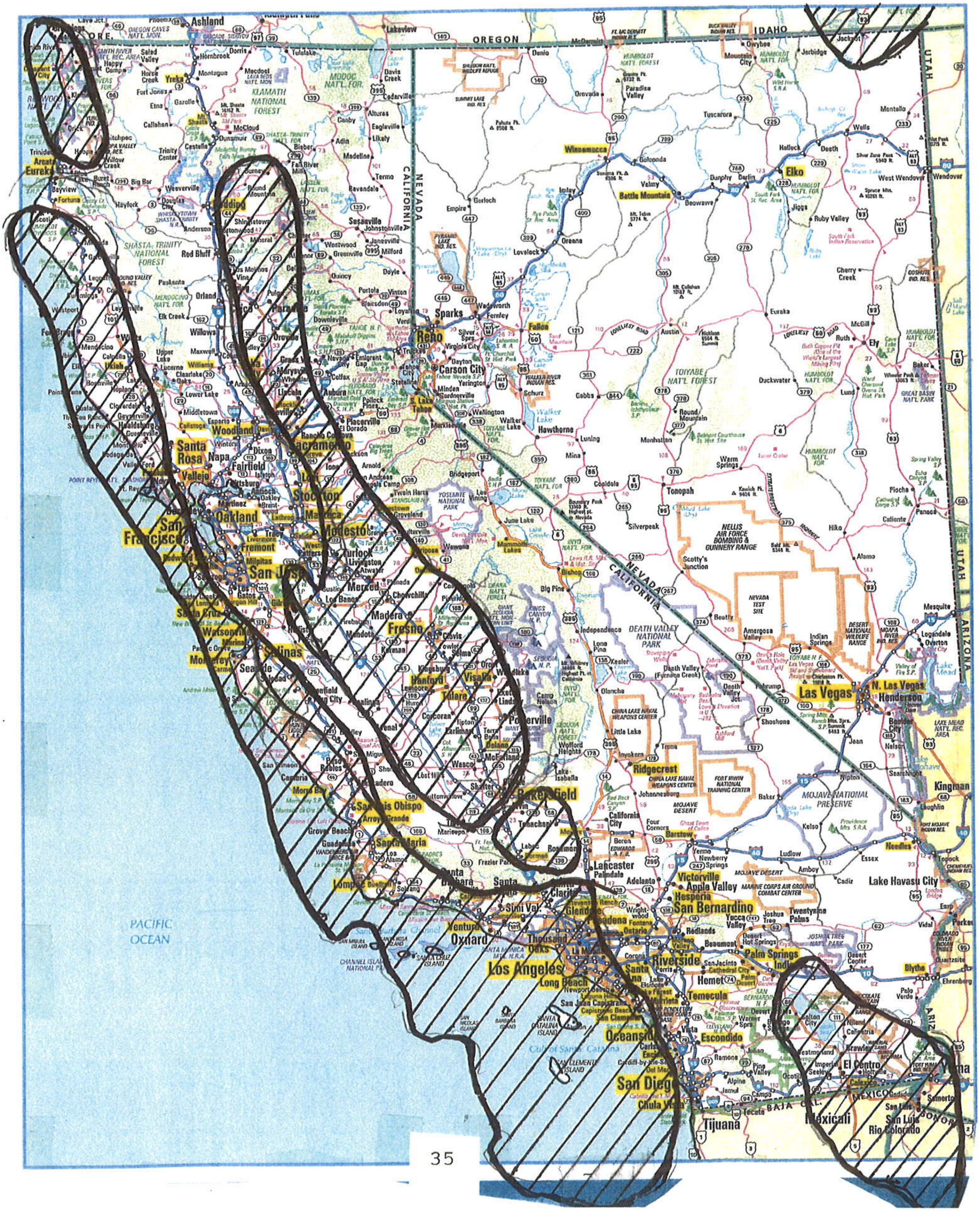


The major shale oil reserves in North Dakota are located within the Williston Basin which also has underneath portions of Montana and South Dakota in the United States plus the neighboring regions of Saskatchewan, Montana and Alberta in Canada. In addition, there are sedimentary deposits where the presence of crude oil and natural gas is favored which can include some shale oil deposits favoring horizontal drilling and hydraulic fracturing while some non- shale deposits require vertical and horizontal drilling. These sedimentary deposits favorable to the presence of crude oil and natural gas are located in both onshore and offshore fields with varying degrees of availability for being accessed in terms of present and future production.

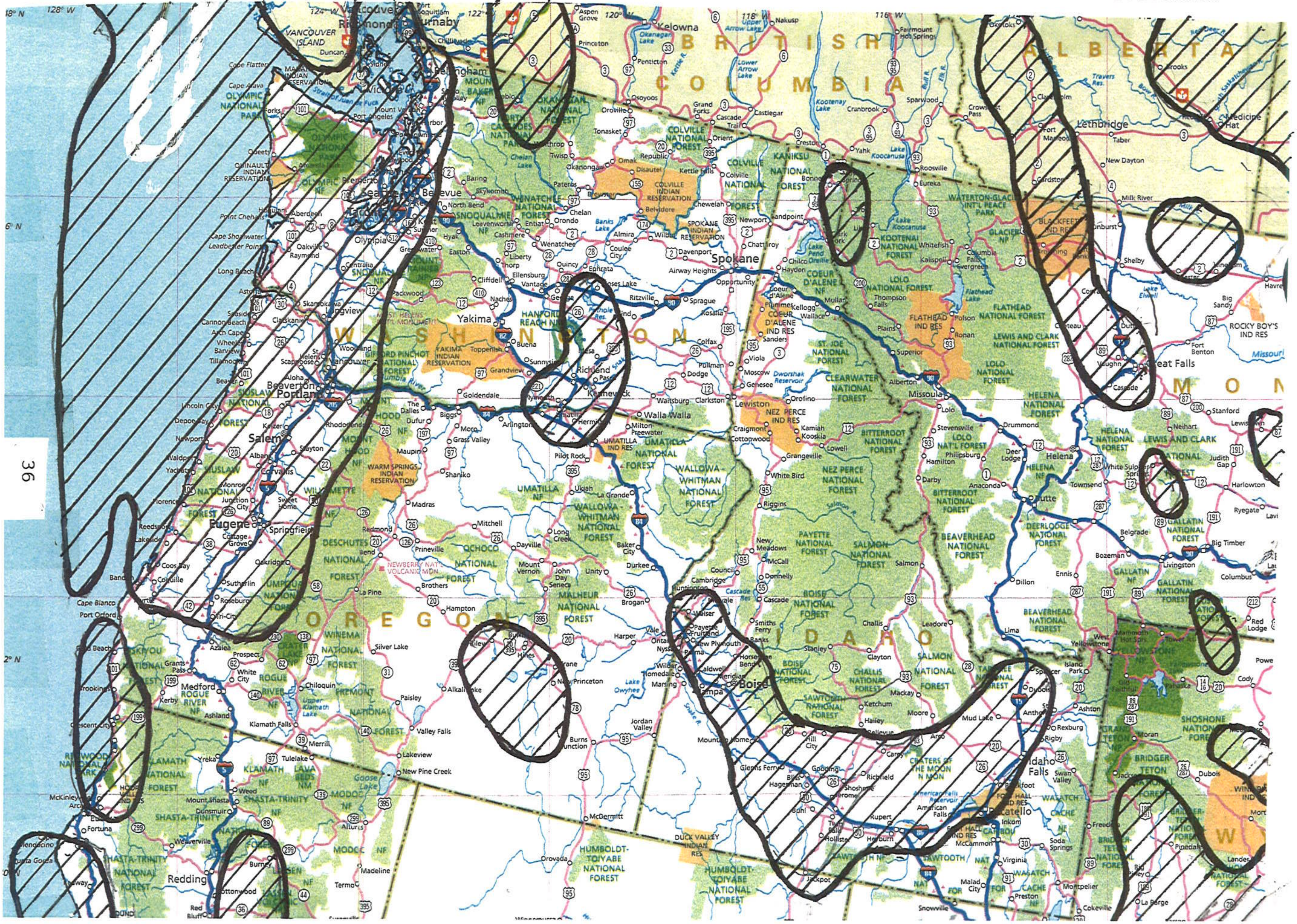
In the western United States, there are large deposits in California, which is primarily heavy oil which has high liquid densities plus elevated sulfur and metals contents but low vapor pressures and explosiveness hazard potentials. In contrast, the light sweet crude oils from the Bakken Formation in North Dakota and the Eagleford Shale in South Texas have low liquid densities with low sulfur and metals contents but relatively high vapor pressures and resultant explosiveness hazard potentials. The California crude oil reserves are primarily located in the San Joaquin Valley and the Los Angeles Basin with significant offshore oil deposits as well along the Pacific Coast.

There are also areas in the Pacific Northwest where sedimentary basins may be amenable to the presence of oil and gas reserves, especially along the Pacific Coastal areas of western Washington and Oregon. There are also areas of potential oil and gas reserves in eastern Washington and Oregon as well as in southern Idaho and in western Montana along the Overthrust Balt on the east side of the Rocky Mountains. However, there has been relatively little exploration of the oil and gas reserve potential in the Pacific Northwest as the result of significant public and environmental opposition to development.

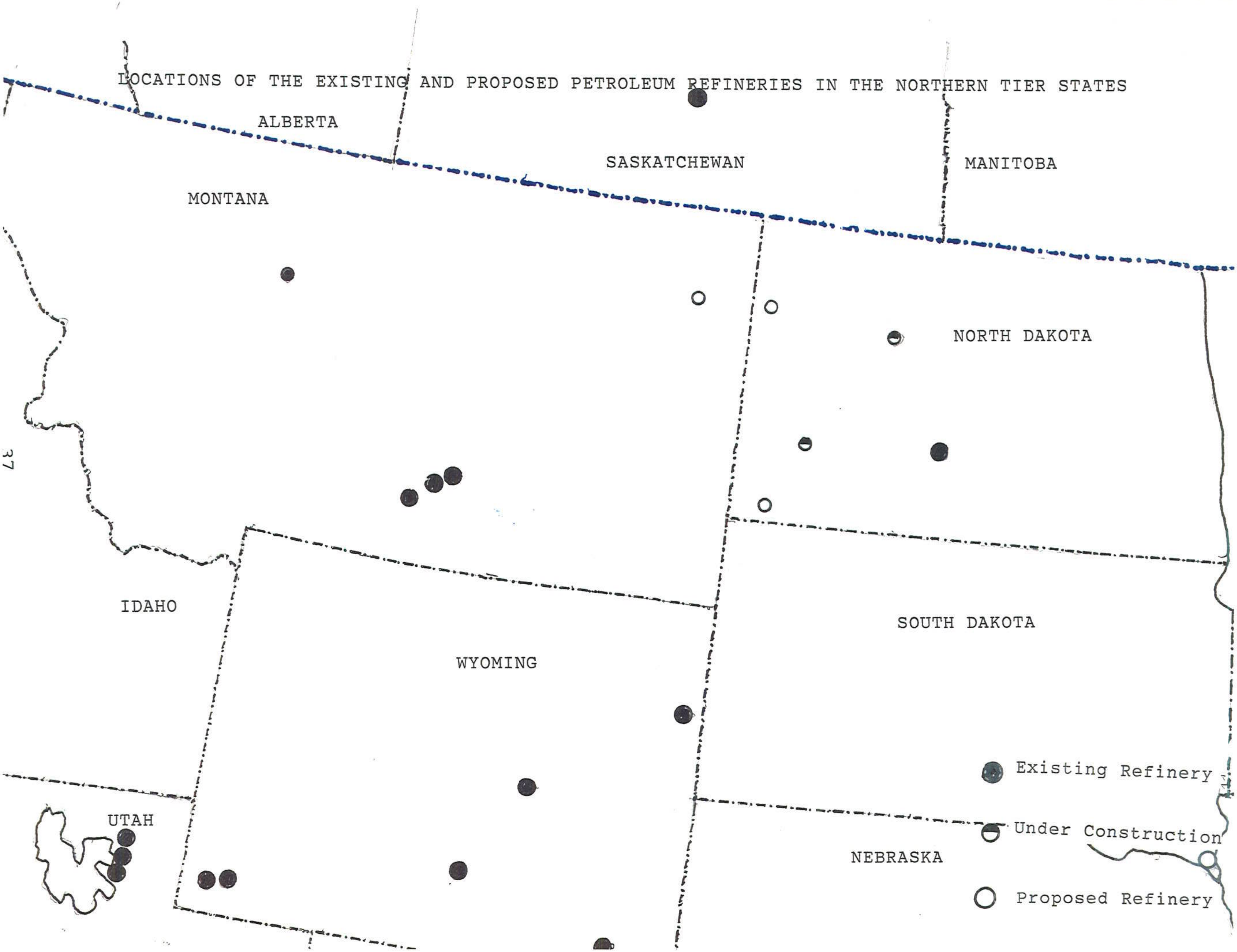
# LOCATIONS OF GEOLOGIC FORMATIONS FAVORABLE TO OIL AND GAS RESERVES IN THE STATES OF CALIFORNIA AND NEVADA AND NEIGHBORING STATE BOUNDARIES



LOCATIONS OF GEOLOGIC FORMATIONS FAVORABLE TO OIL AND GAS RESERVES IN THE PACIFIC NORTHWEST



## LOCATIONS OF THE EXISTING AND PROPOSED PETROLEUM REFINERIES IN THE NORTHERN TIER STATES



## TRANSPORT LOGISTICS

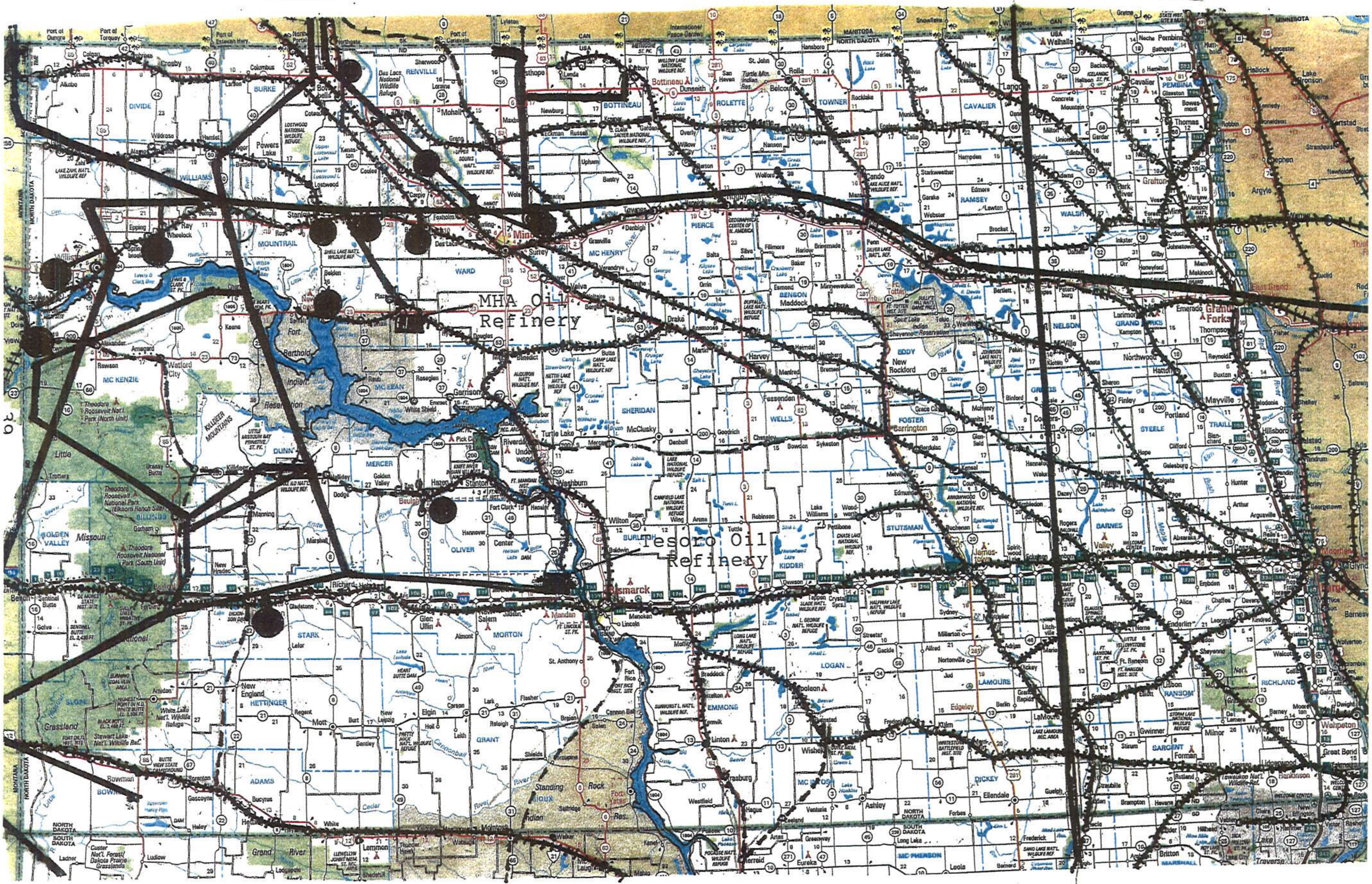
There is a potential for a very large number of trains carrying crude oil out of North Dakota to refineries on the East Coast and the West Coast plus the Gulf Coast and elsewhere in the future. The Wall Street Journal reported in a recent article that in October of 2013 that crude oil transport by rail was 732,518 barrels per day on an average basis. This value is compared to a total crude oil production in North Dakota of 976,667 barrels per day on an average daily basis as reported by the North Dakota State Oil and Gas Division of the Department of Mineral Resources under the North Dakota Industrial Commission in Bismarck, North Dakota.

The amount of crude oil transported by rail out of North Dakota of 732,518 barrels per day in October of 2013 was carried by the States two major railroads. It is estimated that the amount of crude oil transported by the Burlington Northern Santa Fe Railway (BNSF) was approximately 620,000 barrels per day. This value constitutes 85 percent of the total volume hauled by rail and 63 percent of the North Dakota State total oil production and was hauled to the east west and south. The remaining 112,518 barrels per day of crude oil transported out of North Dakota was carried by the Canadian Pacific Railway (CPR) to the north to Alberta to be used as a tar sands oil bitumen diluent as well as to the south to a limited number of refineries. The crude oil transported by the Canadian Pacific Railway constituted 15 percent of the total moved by rail and 12 percent of the North Dakota State total in 2013.

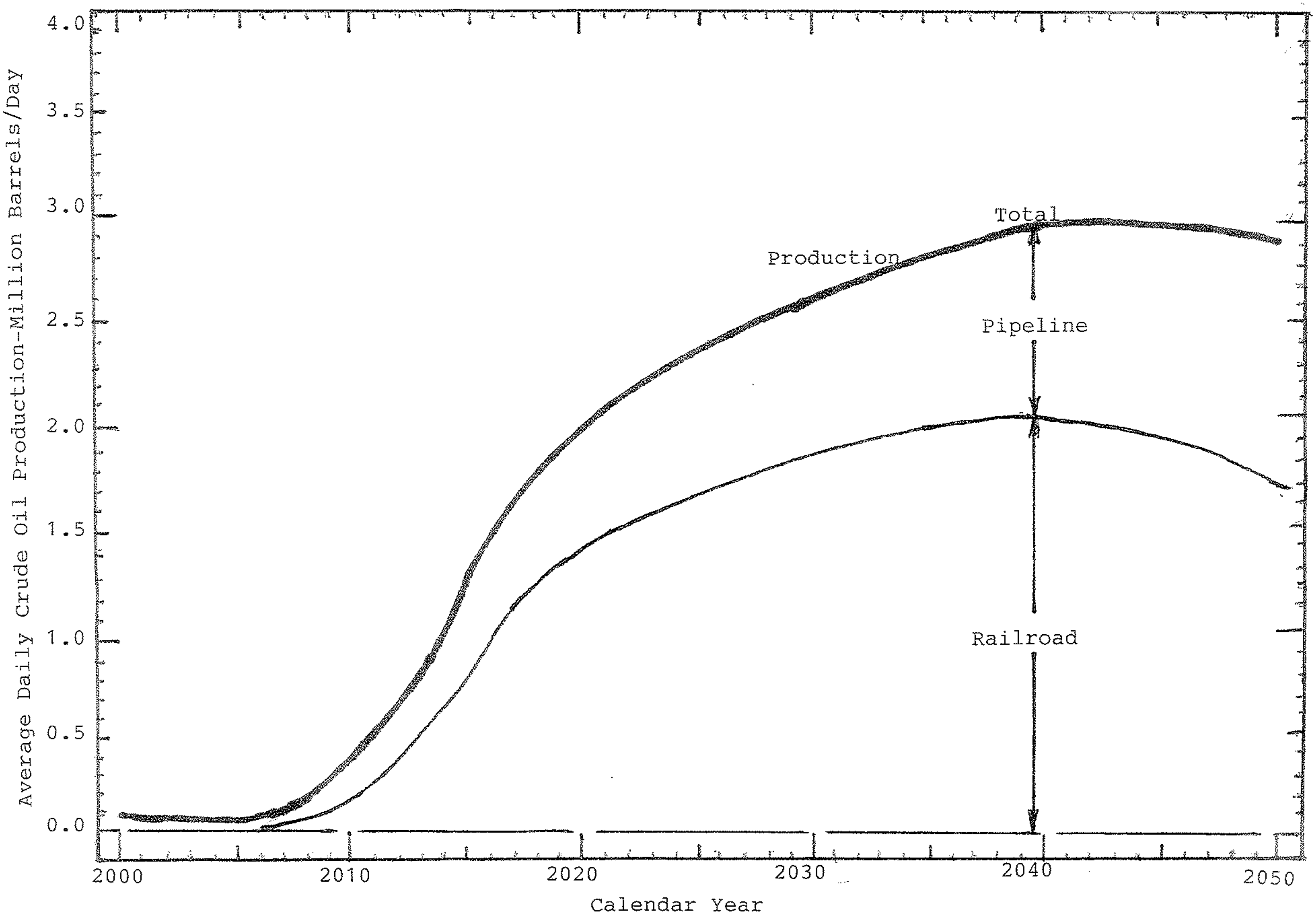
The proportion of the overall production of crude oil per October of 976,667 barrels per day in North Dakota hauled by rail of 732,518 barrels per day comprised 75 percent of the State total. With 58,000 barrels per day of crude oil refined at the Tesoro refinery in Mandan plus an estimated 10,000 barrels per day used internally for other purposes, these internal uses constituted another 7 percent of the North Dakota State total. The remaining 176,149 barrels per day of crude oil production moved by the existing pipeline network comprised only 18 percent of the North Dakota State total as a result. This oil was primarily shipped out of North Dakota to central pipeline collection points located to the east to Clearbrook, Minnesota and to the southwest to Guernsey, Wyoming with only a very small amount hauled by truck to the three existing refineries in Billings, Montana from western North Dakota.

ROUTE LOCATIONS OF THE MAJOR HIGHWAY RAILROAD AND PIPELINE INFRASTRUCTURE IN NORTH DAKOTA

Railroad Existing — Railroad Proposed — Oil Pipeline — Oil Terminal



EXPECTED TRENDS IN CRUDE OIL TRANSPORT BY RAILROAD AND PIPELINE FROM NORTH DAKOTA



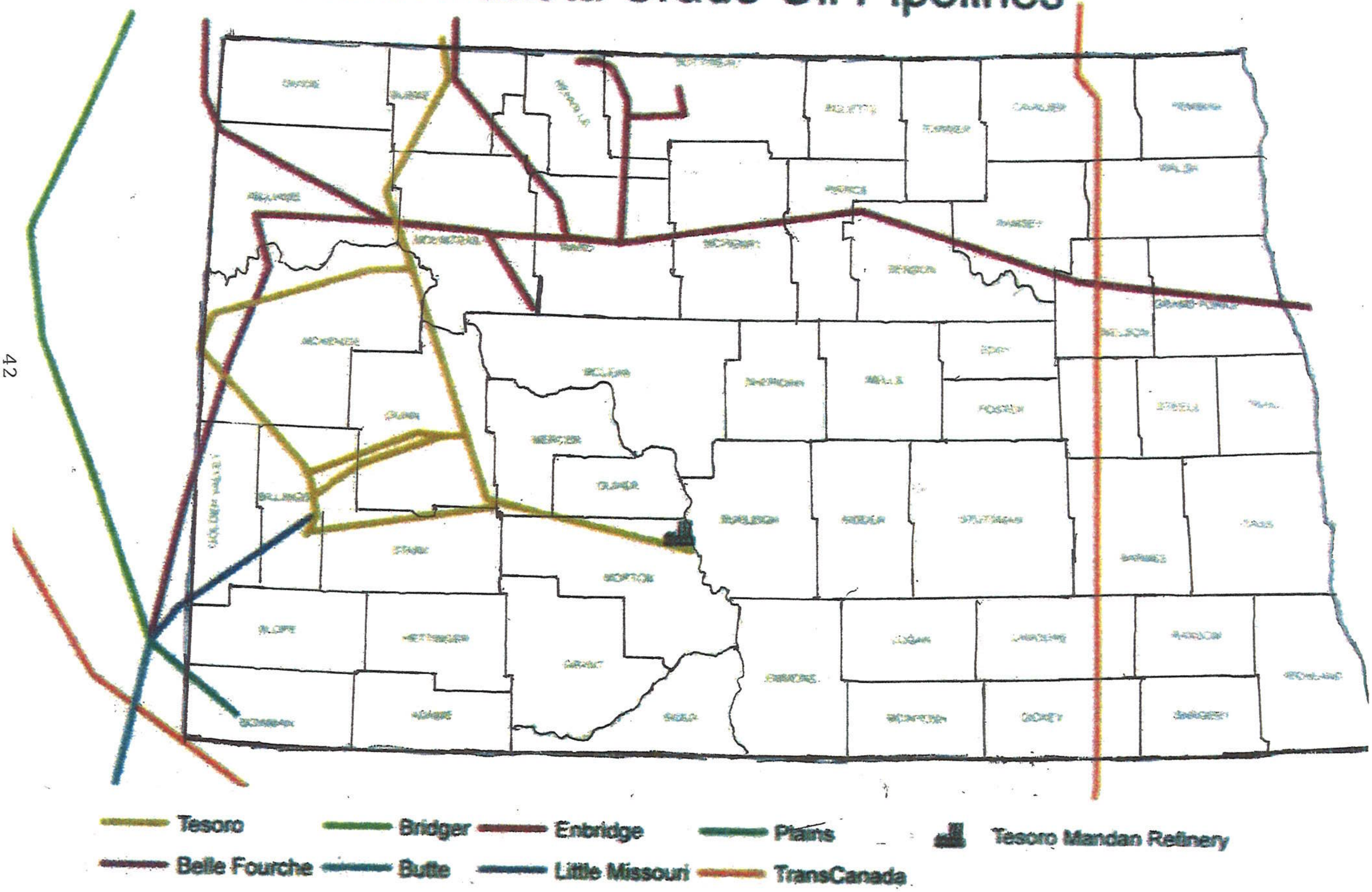
The primary reason that there is such limited pipeline capacity for moving crude oil out of North Dakota is that the Bakken Formation development occurred so suddenly and rapidly. The initial drilling began in 2006 and expanded in 2008 and then expanded in 2010 that no one was prepared for the massive and rapid increase in oil well drilling which has occurred. The number of oil wells operating in North Dakota has increased from approximately 3,000 in 2006 to 5,000 in 2010 to nearly 9,000 at the end of 2013, and is expected to reach as many as 90,000 wells by 2040.

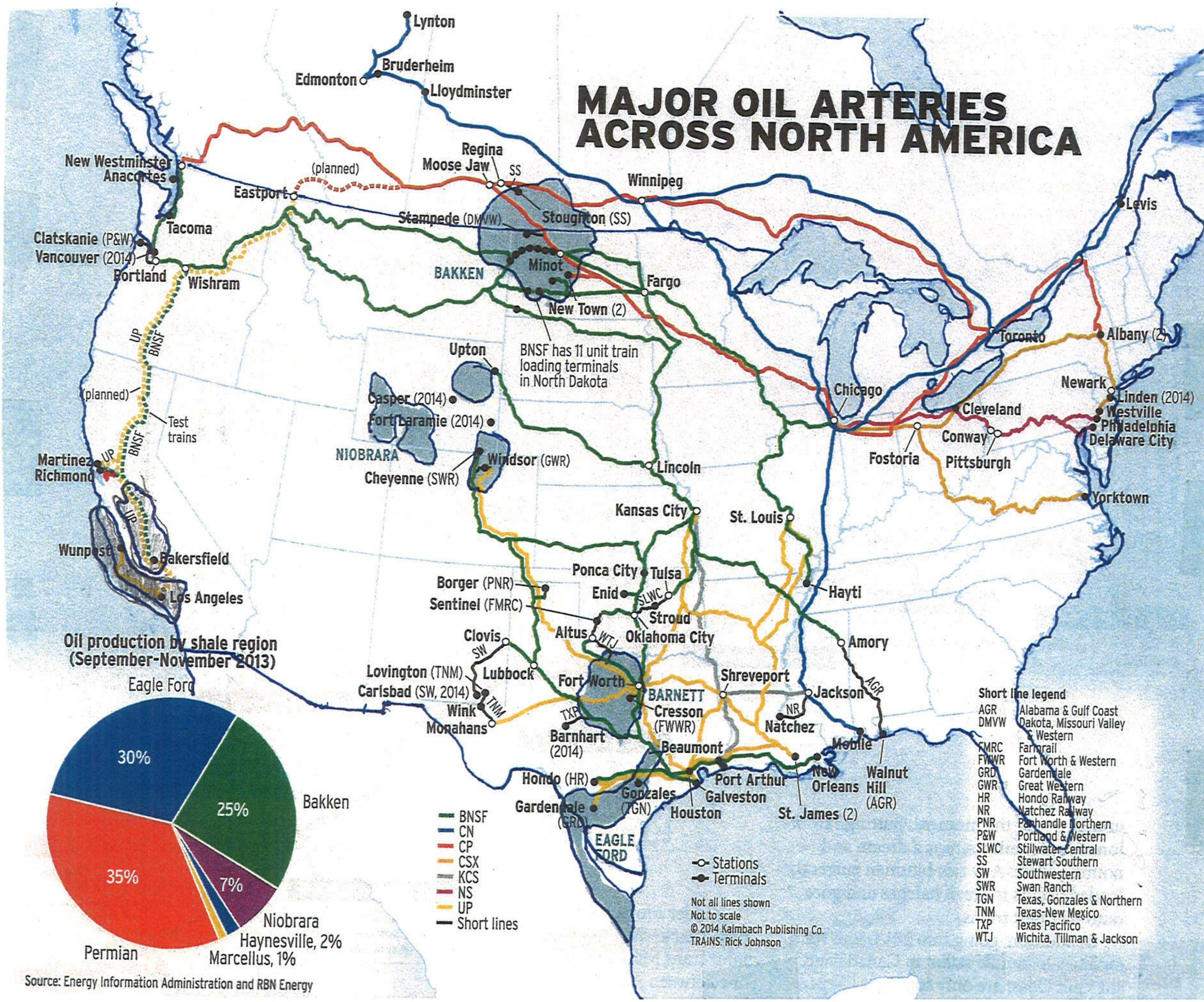
The production of crude oil from newly drilled wells is generally very high in the first year with typical peak values ranging from 1,000 to 2,500 barrels per day per well. However, the oil production tends to drop off rapidly afterwards to between 300 and 500 barrels per day by the third year and between 100 and 200 barrels per day by the fifth year and to between 30 and 50 barrels per day by the tenth year to as little as 10 to 25 barrels per day by the $30^{th}$ year. As a result, overall lifetime crude oil production for wells in North Dakota is expected to range from between 100 and 200 barrels per well per year over a 30 to 40 year period.

The above figures are based on an average overall oil recovery yields of 6 percent of the total in each field with values ranging from 3 to 11 percent for individual fields. Expected future advances in oil well drilling technologies along with enhanced secondary and tertiary recovery techniques may be able to increase overall oil field recovery yields to between 15 and 25 percent and perhaps as high as 40 percent in the future for existing and future wells. As a result, it may become possible to greatly increase the proportion of crude oil to be actually recovered from the earlier estimates of 4 to 6 billion barrels to the more recent 6 to 11 billion barrels to the 25 to 50 billion barrel range at 10 to 12 percent recovery to as much as 60 to 120 billion barrels for 20 to 25 percent recovery to as much as between 120 and 180 billion barrels at 40 percent recovery.

All of these values point to a vast amount of crude oil which may be able to be transported out of North Dakota in the future. The total crude oil production in January of 2014 reached just over 1,000,000 barrels per day and is expected to reach 1,600,000 barrels per day by 2017 and as much as 2,000,000 barrels per day by 2020 to 2022. It is even possible that overall crude oil production in North Dakota could reach as much as 3,000,000 +-barrels per day by 2030 and have a peak oil production of 3,400,000 to 3,600,000 barrels per day by 2035 to 2037 and then begin to decline to between 2,000,000 and 3,000,000 barrels per day by 2050.

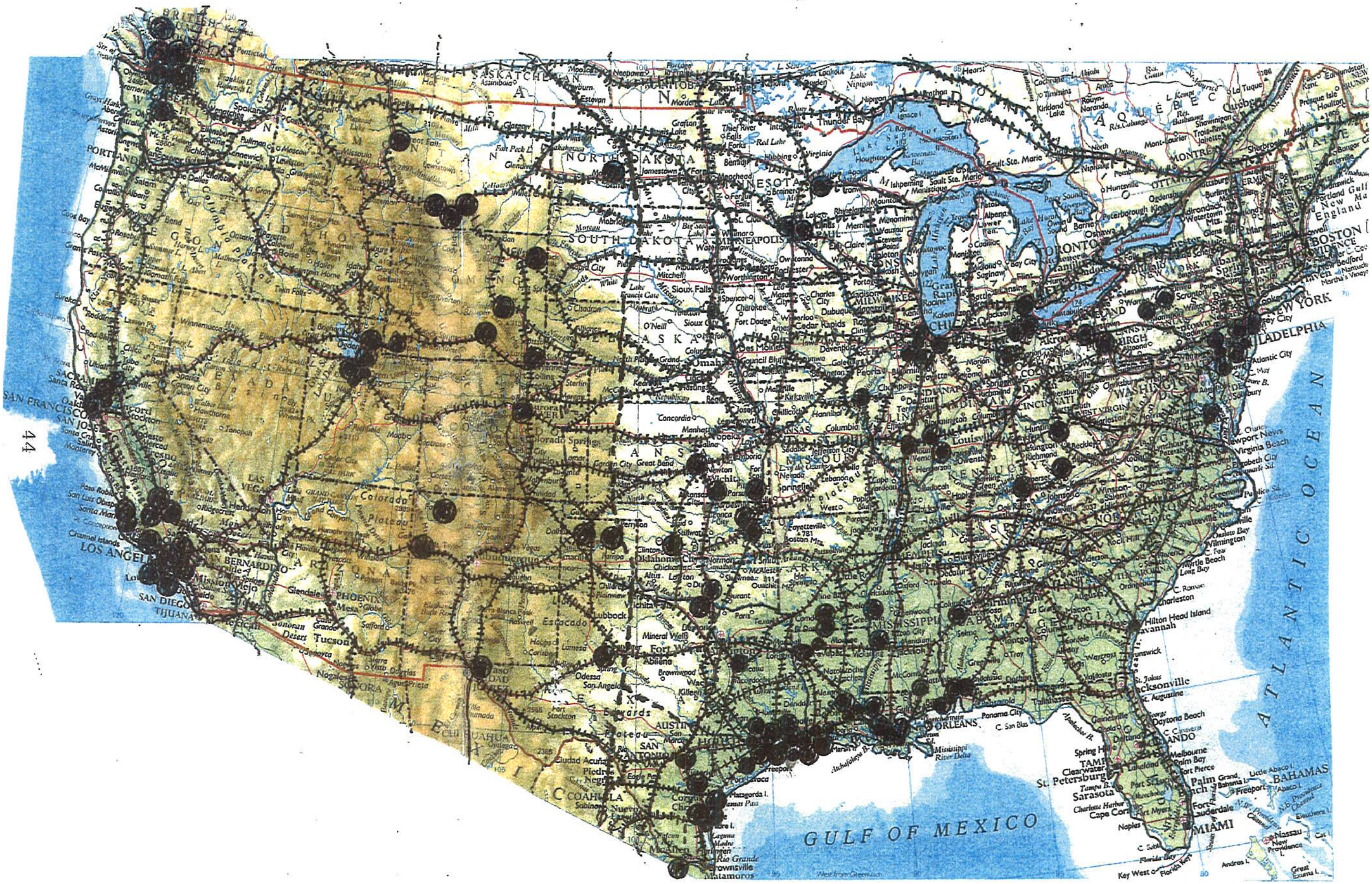
# North Dakota Crude Oil Pipelines





MAJOR OIL ARTERIES ACROSS NORTH AMERICA
Lynton
Bruderheim
Edmonton
Lloydminster
Regina
Moose Jaw
SS
Winnipeg
New Westminster
Anacortes
(planned)
Eastport
Stampede (DMVW)
Stoughton (SS)
Tacoma
Clatskanie (P&W)
Vancouver (2014)
Portland
Wishram
BAKKEN
Minot
Fargo
New Town (2)
Levis
UP
BNSF
Upton
BNSF has 11 unit train loading terminals in North Dakota
Toronto
Albany (2)
Newark
Linden (2014)
Westville
Philadelphia
Delaware City
(planned)
Test trains
Casper (2014)
Fort Laramie (2014)
Chicago
Cleveland
Conway
Pittsburgh
Fostoria
Martinez
Richmond
NIOBRARA
Windsor (GWR)
Cheyenne (SWR)
Lincoln
Yorktown
Kansas City
St. Louis
Wunpost
Bakersfield
Los Angeles
Ponca City
Tulsa
Borger (PNR)
Enid
SLWC
Hayti
Sentinel (FMRC)
Stroud
Altus
WTJ
Oklahoma City
Clovis
SW
Amory
Lovington (TNM)
Lubbock
Carlsbad (SW, 2014)
Wink
TNM
Monahans
Fort Worth
BARNETT
Cresson (FWWR)
TXP
Barnhart (2014)
Shreveport
Jackson
AGR
NR
Natchez
Mobile
Beaumont
Walnut Hill (AGR)
Port Arthur
New Orleans
Hondo (HR)
Gonzales (TGN)
Galveston
Houston
St. James (2)
Gardendale (GRD)
EAGLE FORD
Oil production by shale region (September-November 2013)
Eagle Ford
Bakken
30%
25%
35%
7%
Niobrara
Haynesville, 2%
Marcellus, 1%
Permian
Source: Energy Information Administration and RBN Energy
BNSF
CN
CP
CSX
KCS
NS
UP
Short lines
Stations
Terminals
Not all lines shown
Not to scale
© 2014 Kalmbach Publishing Co.
TRAINS: Rick Johnson
Short line legend
AGR Alabama & Gulf Coast
DMVW Dakota, Missouri Valley & Western
FMRC Farmrail
FWWR Fort Worth & Western
GRD Gardendale
GWR Great Western
HR Hondo Railway
NR Natchez Railway
PNR Panhandle Northern
P&W Portland & Western
SLWC Stillwater Central
SS Stewart Southern
SW Southwestern
SWR Swan Ranch
TGN Texas, Gonzales & Northern
TNM Texas-New Mexico
TXP Texas Pacifico
WTJ Wichita, Tillman & Jackson

LOCATIONS OF THE EXISTING PETROLEUM REFINERIES IN THE UNITED STATES AND CONNECTING RAILROADS



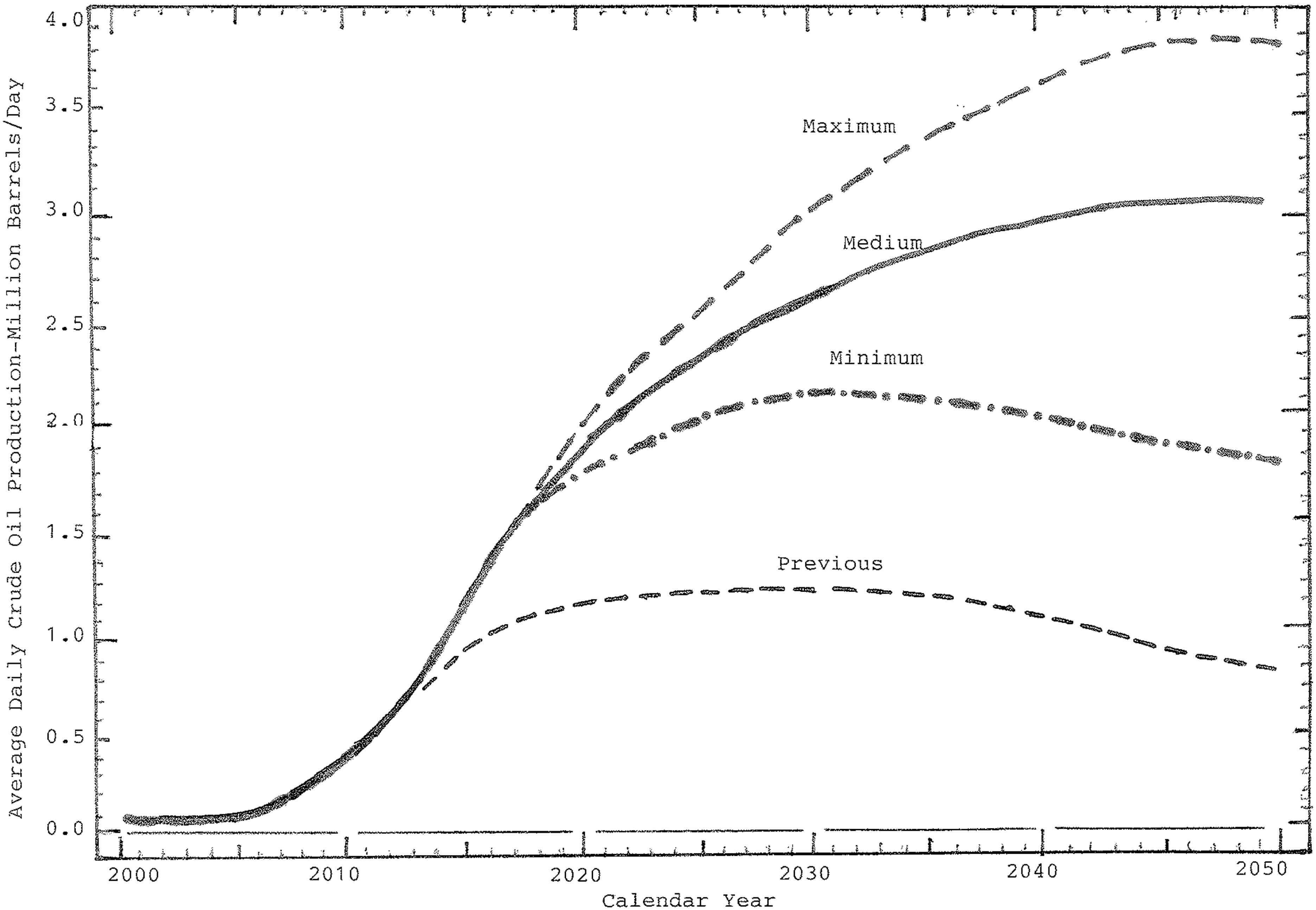
However, the above expected continuing increases in overall crude oil production in North Dakota are based on significant increases in overall increases in percentage yields through improved recovery techniques.

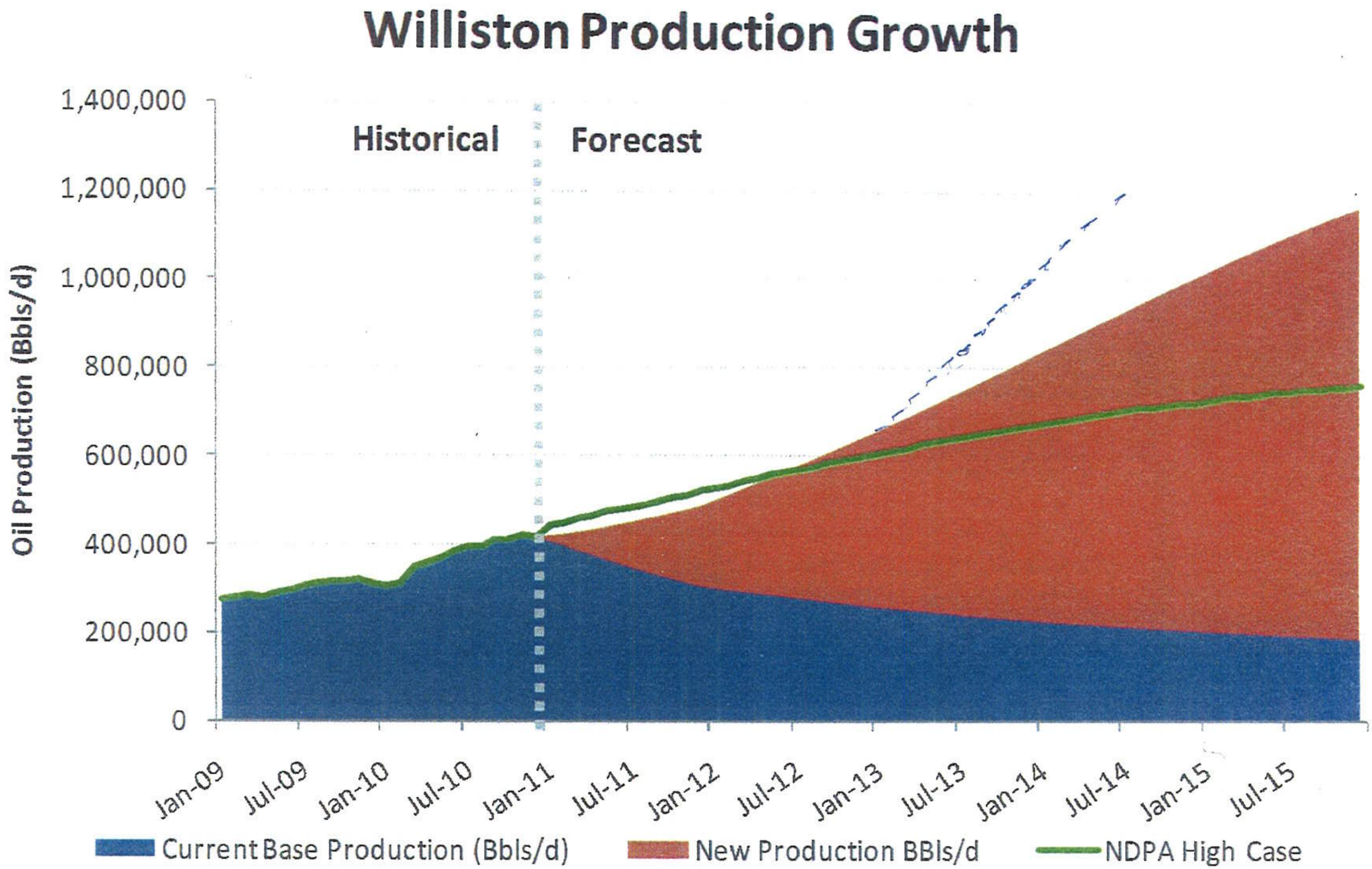
The reported crude oil pipeline oil capacity in North Dakota is reported to be between 225,000 and 250,000 barrels per day. However, the values reported previously indicate that there is presently only 150,000 barrels per day of crude oil being transported out of North Dakota plus 60,000 barrels per day sent to the Mandan refinery plus another 30,000 barrels per day transported by Arrow Pipeline to the Dore, North Dakota loading terminal and into Montana. Several new oil pipeline projects have been proposed to be built to Clearbrook, Minnesota and to Billings, Montana which are expected to be between 250,000 and 300,000 barrels per day plus the added 100,000 barrels per day to the Keystone pipeline as a diluent if it is ultimately approved by President Barack Obama.

All of the above pipeline projects to together provide a total transport capacity of 650,000 to 700,000 barrels per day if they are all built. There have in the past several years a total of between 1,200,000 and 1,700,000 barrels per day of crude oil pipeline capacity proposed to move oil out of North Dakota. Most of these pipeline projects are only proposals because they require commitments of 20 to 25 year long term contracts at a fixed price. In addition, pipeline companies have tended to discount prices paid to oil companies ranging from $5.00 to 20.00 per barrel or more based on ostensive over capacity subscriptions.

The end result of the pipeline capacity constraints has been a major transfer of crude oil transport to rail since 2008 primarily through the leadership of the Burlington Northern Santa Fe Railway. Crude oil transport by rail has steadily increased from less than 10,000 barrels per day in 2008 to over 100,000 barrels per day by 2011 and to an estimated 620,000 barrels per day in late 2013. If North Dakota's overall crude oil production increases to 1,600,000 barrels per day in 2017, the amount of crude oil moved by rail over the BNSF rail lines is expected to reach as much as 1,000,000 barrels per day and up to 1,300,000 barrels per day by 2022. North Dakota is expected to provide a major portion of the overall national crude oil production after 2025 with as much as 3,500,000 barrels per day by 2040 while Texas may be producing as much as 5,000,000 barrels per day in the same period. With the Monterey Shale in California and other formations, the total crude oil production in the United States would reach 10,000,000 barrels per day or more often 2035 as a net oil exporter.

ALTERNATIVE PROJECTIONS OF EXPECTED CRUDE OIL PRODUCTION IN NORTH DAKOTA: 2000-2050



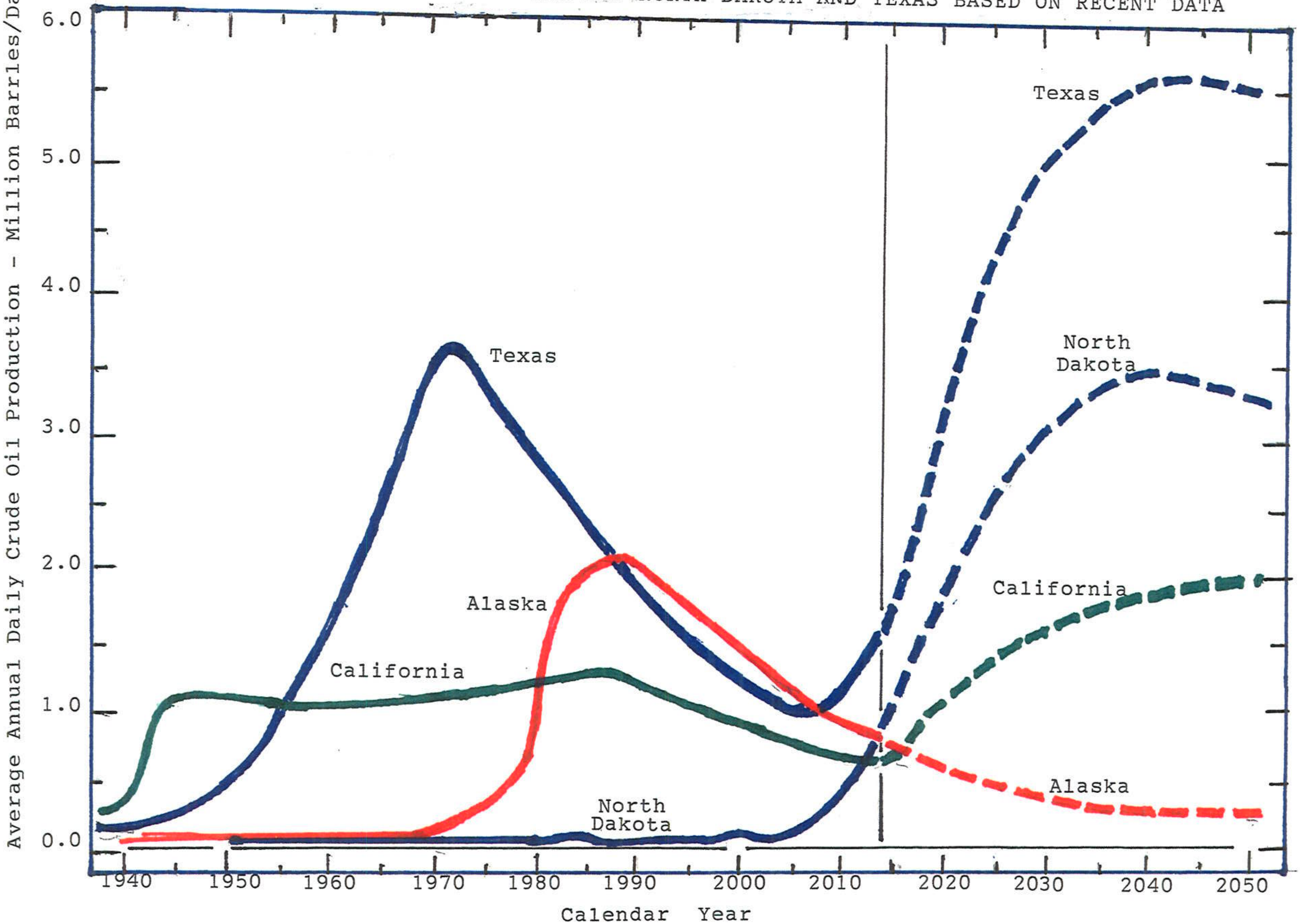



Source: Raymond James, NDPA

# Crude Oil Production – 1.2 MMBpl/d in 2015?

Rangeland Energy, LLC

ESTIMATES OF PAST AND FUTURE TRENDS IN CRUDE OIL PRODUCTION BETWEEN 1940 AND 2050 FOR THE STATES OF ALASKA AND CALIFORNIA AND NORTH DAKOTA AND TEXAS BASED ON RECENT DATA



## TRAFFIC PROJECTIONS

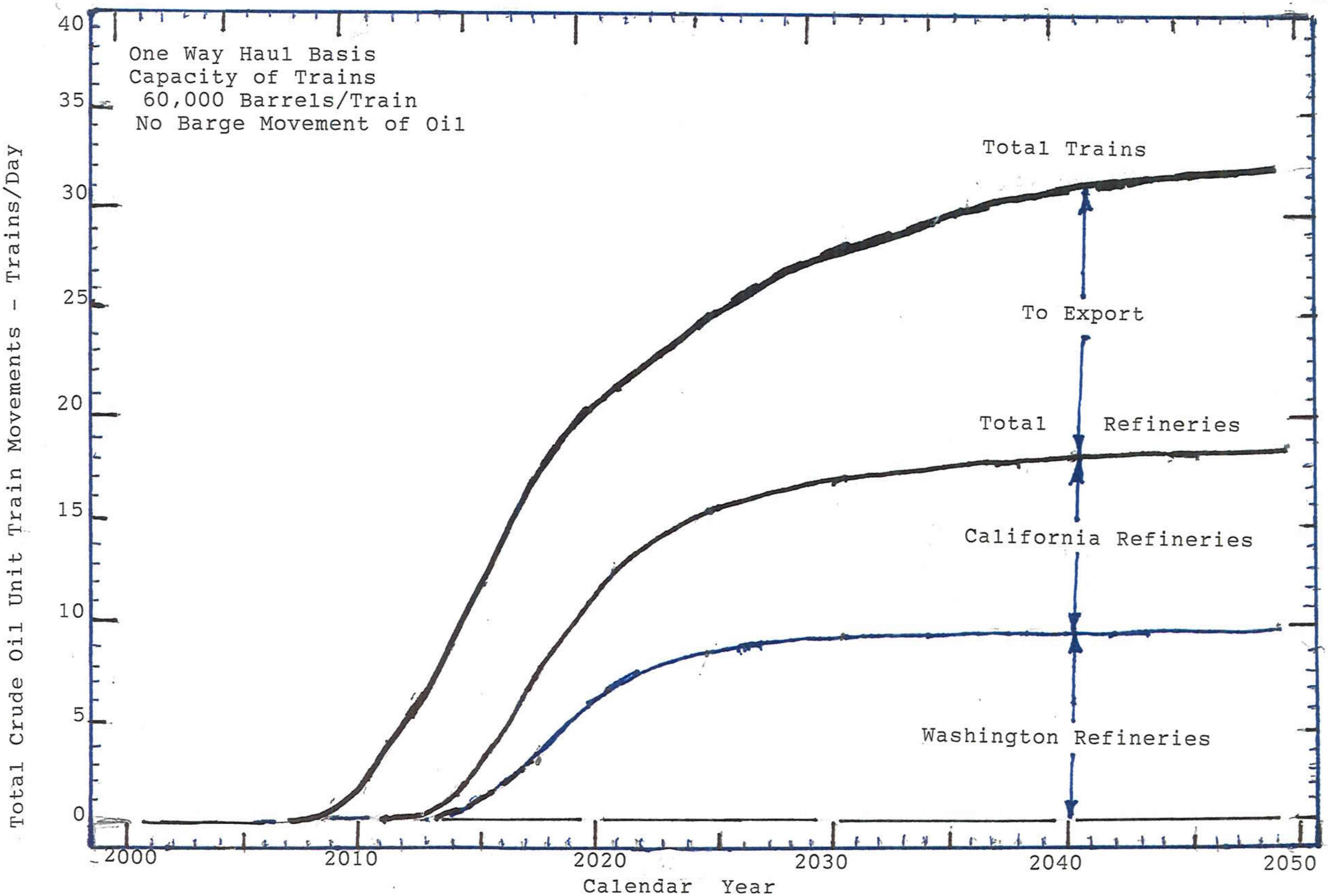
The above stated crude oil traffic levels indicate that overall crude oil shipments over the BNSF Railway are presently approximately 10 to 11 unit train loads per day with a total of 20 to 22 trains per day when including empty back hauls when based on 620,000 barrels per day. The earlier estimates of oil train movements to refineries in the State of Washington were 11 unit train loads per week or 22 total oil train movements or 1.6 loaded unit trains per day when based on a total movement of 85,000 barrels per day in 2013. These values assumed that only the Tesoro and U.S. Refining refineries were receiving oil by train from North Dakota.

Since that time it has been reported that crude oil from North Dakota now being shipped to the British Petroleum and Conoco Phillips refineries near Ferndale. As a result, it is now estimated that there are as many as 15 to 16 unit train loads per week of crude oil being shipped to the State of Washington over the BNSF Railway. This additional crude oil traffic would then constitute shipments of approximately 120,000 barrels per day of crude oil, which translates into 2.2 unit train loads per day or almost 4.5 total additional trains per day over the BNSF Railway line.

In addition, there is also crude oil being hauled from North Dakota to Portland over the BNSF Railway and then transferred to the Portland Western short line for Hauling to Clatskanie, Oregon. This oil is then transloaded onto barges for shipment to refineries in California from the lower Columbia River. The exact amount of oil being shipped is unknown, but it is estimated to be at least 4 unit train loads per week to average another 35,000 barrels per day with 0.6 unit train loads per day and 1.2 total unit train movements. The Savage Terminals Company has also proposed to build a similar oil loading terminal along the Columbia River at Vancouver, Washington for the shipment of crude oil by barge to refineries in both northwest Washington as well as in California. Three terminals have also been proposed for operation at Gray Harbor near Aberdeen.

There are presently 17 operating oil refineries in California with an aggregate petroleum refining capacity of 1,965,570 barrels per day in four locations of the Bay Area, the Central Coast, the San Joaquin Valley and Southern California in the Los Angeles Basin. These 17 refineries in California are in addition to the 6 refineries in Washington with a total petroleum (and bio-fuel) refining capacity of 2,588,070 barrels per day. This total of 23 refineries has an average daily production of 152,240 barrels per day refinery with individual capacities ranging from 4,580 to 276,000 barrels per day for the refineries in California and Washington.

EXPECTED INCREASES IN TOTAL CRUDE OIL UNIT TRAIN MOVEMENTS FROM NORTH DAKOTA TO WASHINGTON

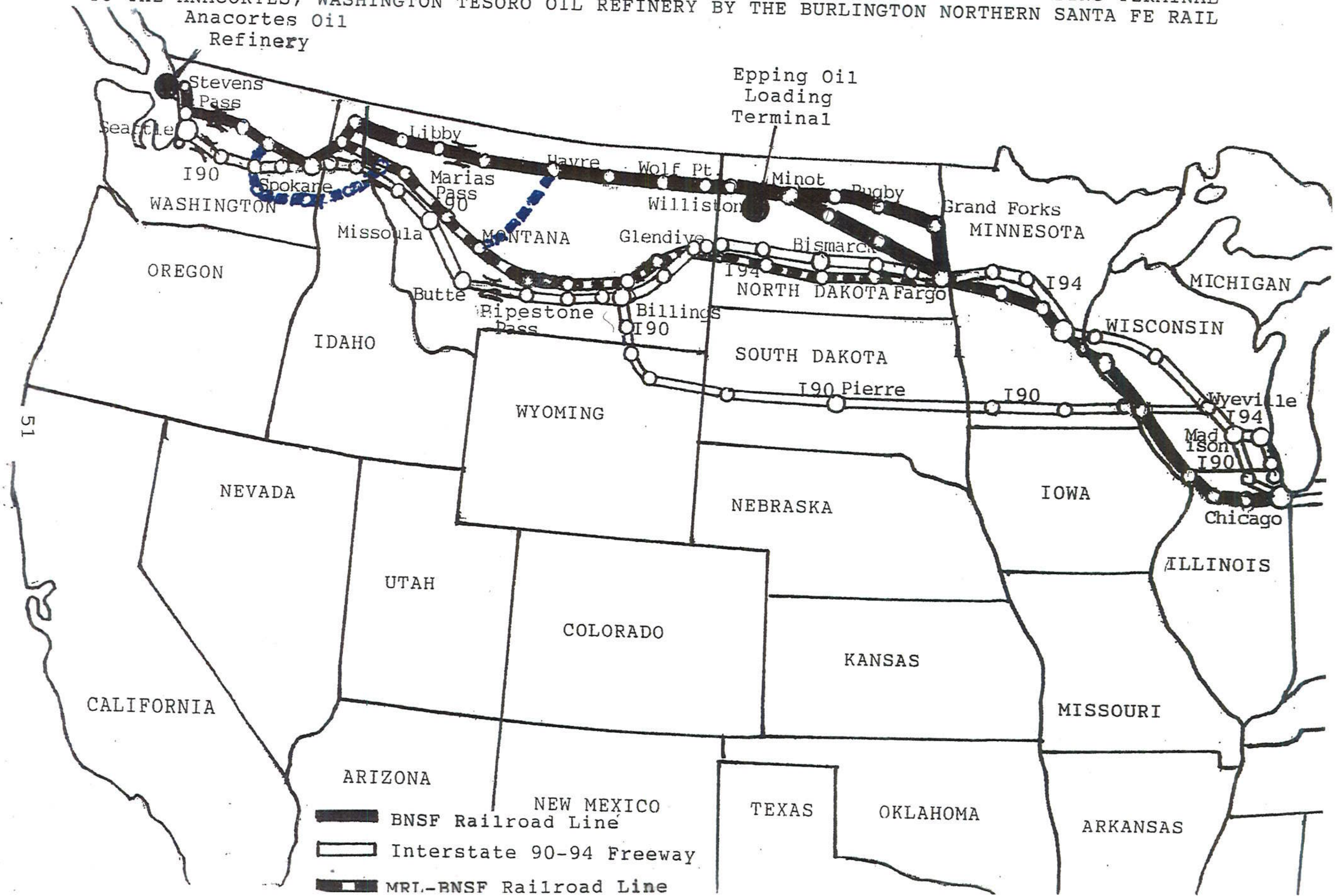


These oil refineries in California have in the past been utilized largely for the intermediate grade crude oil supplies from Alaska from ships in addition to the generally heavy crude oils produced in California from pipelines along with imports from Indonesia and Malaysia of light crude oils by ships. The Washington refineries have relied primarily on the crude oils from Alaska along with some imported crude oils from Indonesia and Malaysia and elsewhere all of which is delivered by ship. Also, there is no present crude oil production in either Oregon or Washington, although there are crude oil reserves along the Pacific Coast and in the interiors of both States.

The steadily declining crude oil production in Alaska in recent years from the heretofore abundant Prudhoe Bay field has significantly altered the crude oil supply logistics for the oil refineries in both California and Washington. In Washington, the refineries have the choice of importing foreign oil at Brent crude World oil prices or hauling oil by rail from the Bakken Formation in North Dakota as there are no existing crude oil pipelines between Washington and North Dakota. In California, there is a choice between locally produced heavy crude oils from the San Joaquin Valley or Los Angeles Basin coastal fields or crude oils brought by rail from either North Dakota or Texas or foreign crude oils brought by ship.

The result of the crude oil supply changes creates the trade of between North Dakota light crude oils from the Bakken Formation for refineries in Northern California and alternative light or intermediate density crude oils from the Eagleford Shale in South Texas or the Permian Basin in West Texas. These crude oils would be delivered to California by rail from either North Dakota or Texas as there are no existing crude oil pipelines for these routes. Also, a recent attempt by the Kinder Morgan Energy Partners to solicit interest in a new crude oil pipeline from Mc Camey, Texas to Bakersfield and Los Angeles, California was withdrawn after drawing no interest from the involved oil companies in signing long term supply contracts. In addition, there is one operating rail-to-barge crude oil transport service from Clatskanie Oregon to refineries in California as well as a proposed rail-to-barge service from North Vancouver, Washington to northwest Washington refineries with three terminals proposed at Gray Harbor plus additional facilities located at Ferndale, Anacortes, and Tacoma.

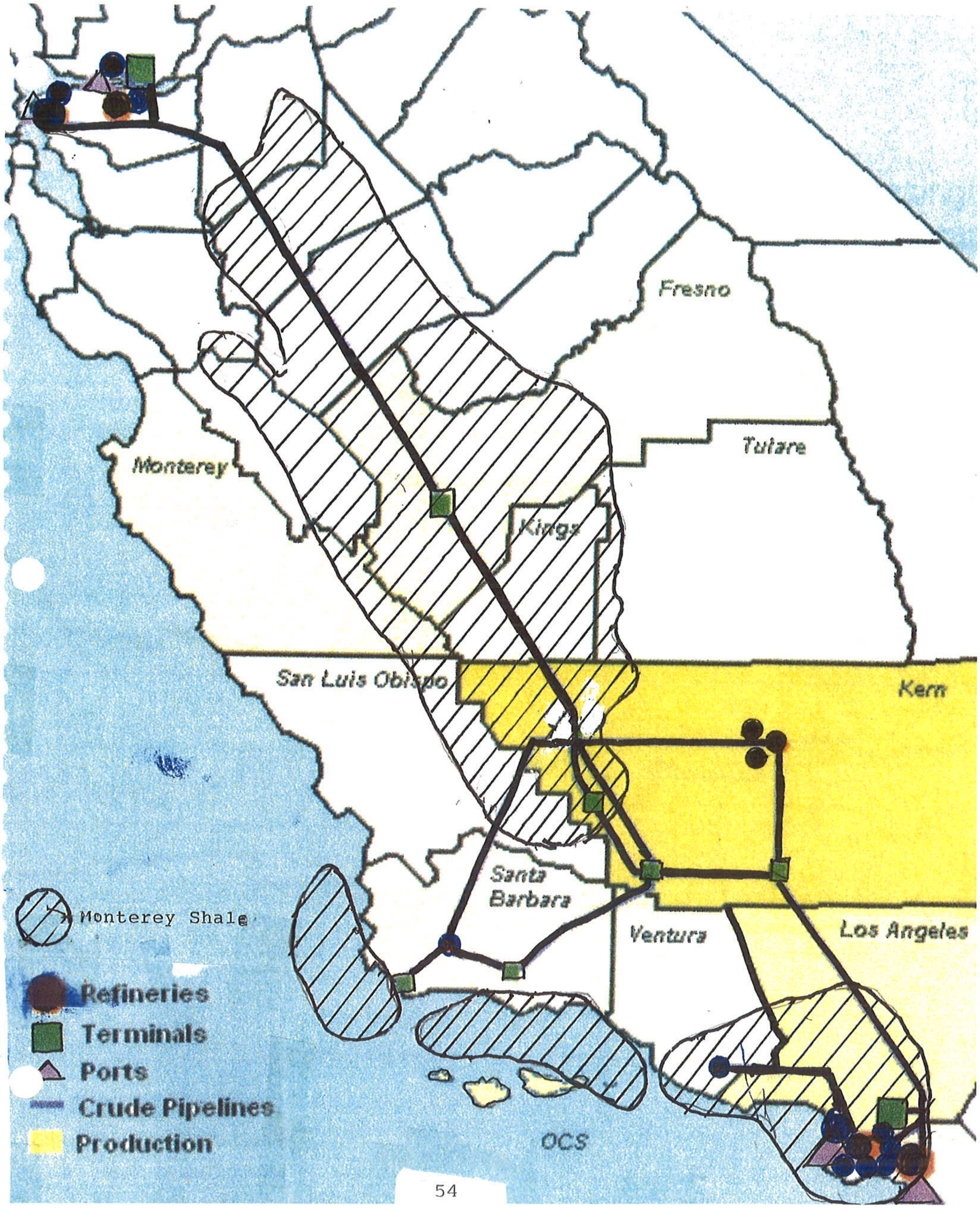
PLANNED ROUTE OF THE CRUDE OIL UNIT TRAINS FROM THE EPPING, NORTH DAKOTA LOADING TERMINAL TO THE ANACORTES, WASHINGTON TESORO OIL REFINERY BY THE BURLINGTON NORTHERN SANTA FE RAIL



## EXISTING PETROLEUM REFINERIES IN CALIFORNIA

| State or Region | Operating Company | Refinery Location | Capacity Barrels/ Day |
|---|---|---|---|
| Bay Area | Chevron | Richmond | 245,670 |
| | Phillips | Rodeo | 120,200 |
| | Shell | Martinez | 156,400 |
| | Tesoro | Martinez | 166,000 |
| | Valero | Benecia | 132,000 |
| | Sub Total | — | 820,270 |
| Central Coast | Greka Energy | Santa Maria | 9,500 |
| | Sub Total | — | 9,500 |
| San Joaquin Valley | Alon | Bakersfield | 60,000 |
| | Kern Oil & Refinery | Bakersfield | 26,000 |
| | San Joaquin Refinery | Bakersfield | 15,000 |
| | Sub Total | — | 101,000 |
| Southern California | Chevron | El Segundo | 276,000 |
| Los Angeles Basin | Exxon Mobil | Torrance | 149,500 |
| | Linday Thagard | South Gate | 8,500 |
| | Paramount Petroleum | Paramount | 54,000 |
| | Phillips | Wilmington | 139,000 |
| | Tesoro | Carson | 226,000 |
| | Tesoro | Wilmington | 103,800 |
| | Valero | Wilmington | 78,000 |
| | Sub Total | — | 1,034,800 |
| Entire State | Total | All Facilities | 1,965,570 |

LOCATIONS OF THE CENTRAL CRUDE OIL PIPELINE AND OIL TERMINALS IN CALIFORNIA



California is also the home of the Monterey Shale intermediate and heavy oil formation in the San Joaquin Basin in the Central Valley plus at the Pacific Coast in portions of the Santa Maria, Ventura and Los Angeles Basins in Southern California which can be utilized as a major energy resource. The Monterey Shale Formation in California is reported to hold up to three times the recoverable oil of the Bakken Formation in North Dakota although both formations are estimated to have total reserves of 300 to 500 billion barrels of oil. Efforts are being made to produce small amount of oil from the Monterey Shale provided that the considerable environmental obstacles can be overcome. If the Monterey Shale oil formation were to be fully developed, California's present crude oil production of 350,000 barrels per day could than be increased to between 1,000,000 and 1,500,000 barrels per day. This level of production from the Monterey Shale could then service most or all of California's present refining needs provided that all of the affected refineries were configured to process the heavy oil.

If such an event were to occur with the Monterey Shale, there would then be no need to bring crude oil from either North Dakota or Texas by rail, pipeline or by barge into California for refining. However, it is expected that as much as 1,000,000 barrels per day of the lighter oils could be refined in California which could be evenly split between the refineries in Northern and Southern California using crude oils from North Dakota and Texas. Then there could be as many as 8.35 unit train movements of crude oil per day from North Dakota to Washington or 17 trains either to the Columbia River for barging or directly by rail to the refineries, which is equivalent to 58 to 60 unit train loads per week and 116 to 120 total train movements to and from California based on 500,000 barrels per day of total crude oil shipments by rail in 2014.

It is estimated that crude oil shipments by rail from North Dakota to Washington's refineries could be as much as 600,000 barrels per day for internal use by its refineries alone minus any exports and with no capacity expansions. There would then be an estimated 10.00 unit train movements of oil per day or 70 unit train loads per week, which would be equivalent to 20 train movement per day and 140 trains per week over the BNSF Railway between North Dakota and Washington. When the Washington and California refinery unit train movements are combined, there would be a total of 18.35 additional unit train loads of oil hauled per day with a total of nearly 37 additional total train movements per day.

## ESTIMATED TRENDS IN CRUDE OIL PRODUCTION IN CALIFORNIA BY BASIN

| Producing Region | Oil Production - (Barrels / Day) 2000 | 2002 | 2003 |
|---|---|---|---|
| *San Joaquin Valley* | 554,000 | 524,000 | 505,000 |
| *Los Angeles Basin* | 86,000 | 68,000 | 65,000 |
| *Coastal Onshore* | 53,000 | 68,000 | 75,000 |
| *Coastal Offshore* | 41,000 | 53,000 | 60,000 |
| *Total* | 734,000 | 714,000 | 705,000 |

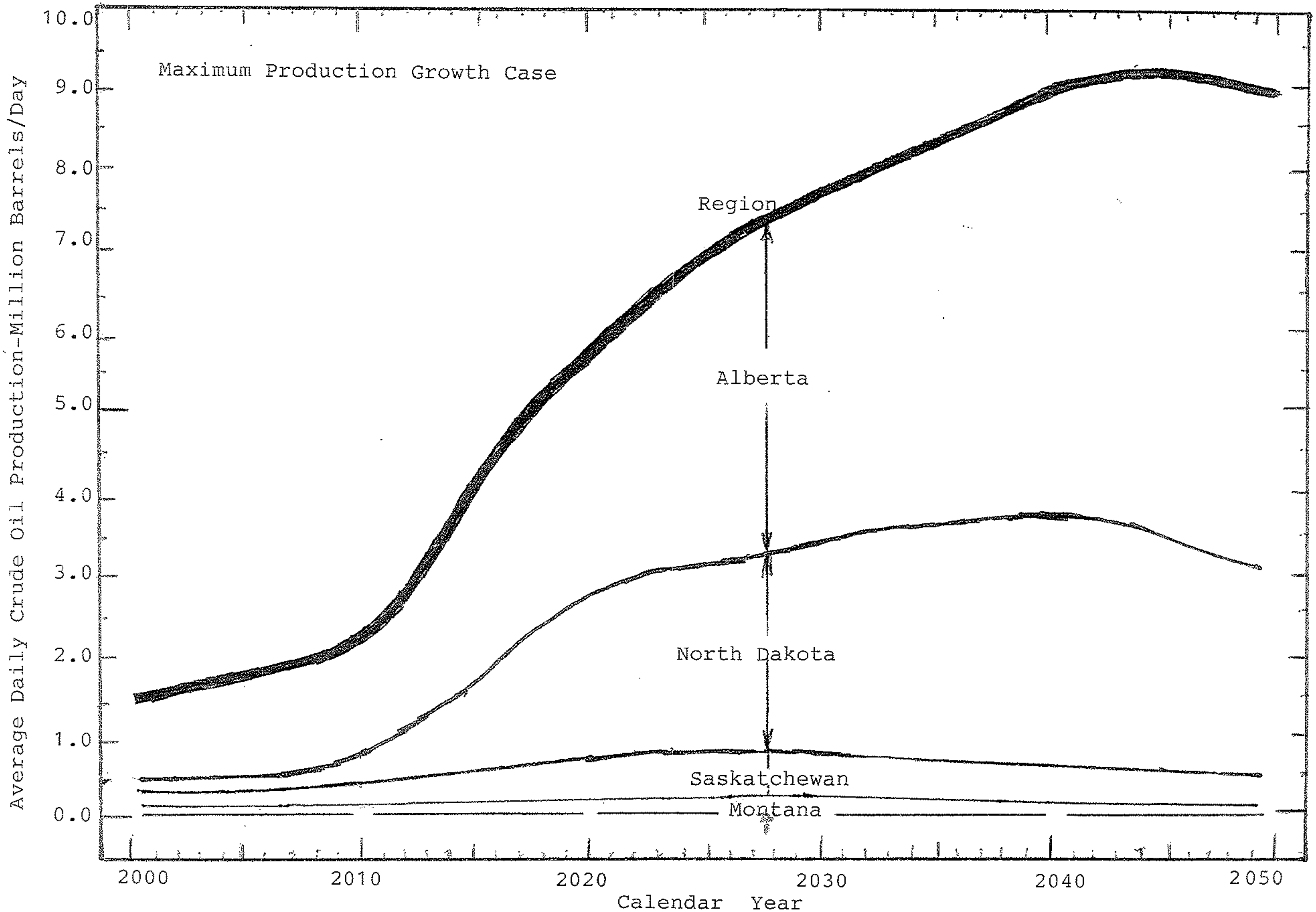
## ESTIMATED PROVEN CRUDE OIL RESERVES IN CALIFORNIA IN 2003

| Producing Region | Producing Million Barrels | Non-producing Million Barrels | Total Resource Million Barrels |
|---|---|---|---|
| *San Joaquin Valley* | 2,565 | 110 | 2,675 |
| *Los Angeles Basin* | 319 | 117 | 436 |
| *Coastal Onshore* | 395 | 61 | 512 |
| *Coastal Offshore* | 173 | 25 | 198 |
| *Total* | 3,452 | 313 | 3,765 |

## EXISTING CRUDE OIL PRODUCTION CAPACITIES FROM FIELDS IN THE SAN JOAQUIN VALLEY AND THE LOS ANGELES BASIN IN CALIFORNIA

| Affected Basin | Specific Oil Field | Existing Oil Barrels/Day | Crude Oil Production Barrels/Year |
|---|---|---|---|
| San Joaquin | Midway Sunset | 155,340 | 56,700,000 |
| | Kern River | 123,015 | 44,900,000 |
| | Belridge South | 113,150 | 41,300,000 |
| | Cymric | 56,165 | 20,500,000 |
| | Elk Hills | 47,395 | 17,300,000 |
| | Lost Hills | 30,135 | 11,000,000 |
| | Coalinga | 21,645 | 7,900,000 |
| | Kern Front | 8,495 | 3,100,000 |
| | Other Fields | 84,385 | 30,800,000 |
| | Sub Total | 639,725 | 233,500,000 |
| Los Angeles | Wilmington | 43,835 | 16,000,000 |
| | Inglewood | 7,395 | 2,700,000 |
| | Huntington Beach | 4,930 | 1,800,000 |
| | Beverly Hills | 3,015 | 1,100,000 |
| | Brea Olinda | 1,945 | 700,000 |
| | Other Fields | 7,210 | 2,640,000 |
| | Sub Total | 68,330 | 24,940,000 |
| Coastal Onshore | San Ardo | 13,150 | 4,800,000 |
| | Ventura | 12,600 | 4,600,000 |
| | Arroyo Grande | 1,645 | 600,000 |
| | Other Fields | 41,795 | 15,255,000 |
| | Sub Total | 69,190 | 25,255,000 |
| Coastal Offline | Elwood South | 12,410 | 3,400,000 |
| | Other Fields | 40,070 | 15,755,000 |
| | Sub Total | 52,480 | 19,155,000 |
| Total | All Fields | 829,725 | 302,850,000 |

EXPECTED INCREASES IN CRUDE OIL PRODUCTION ON THE NORTHERN TIER REGION: 2000 - 2050

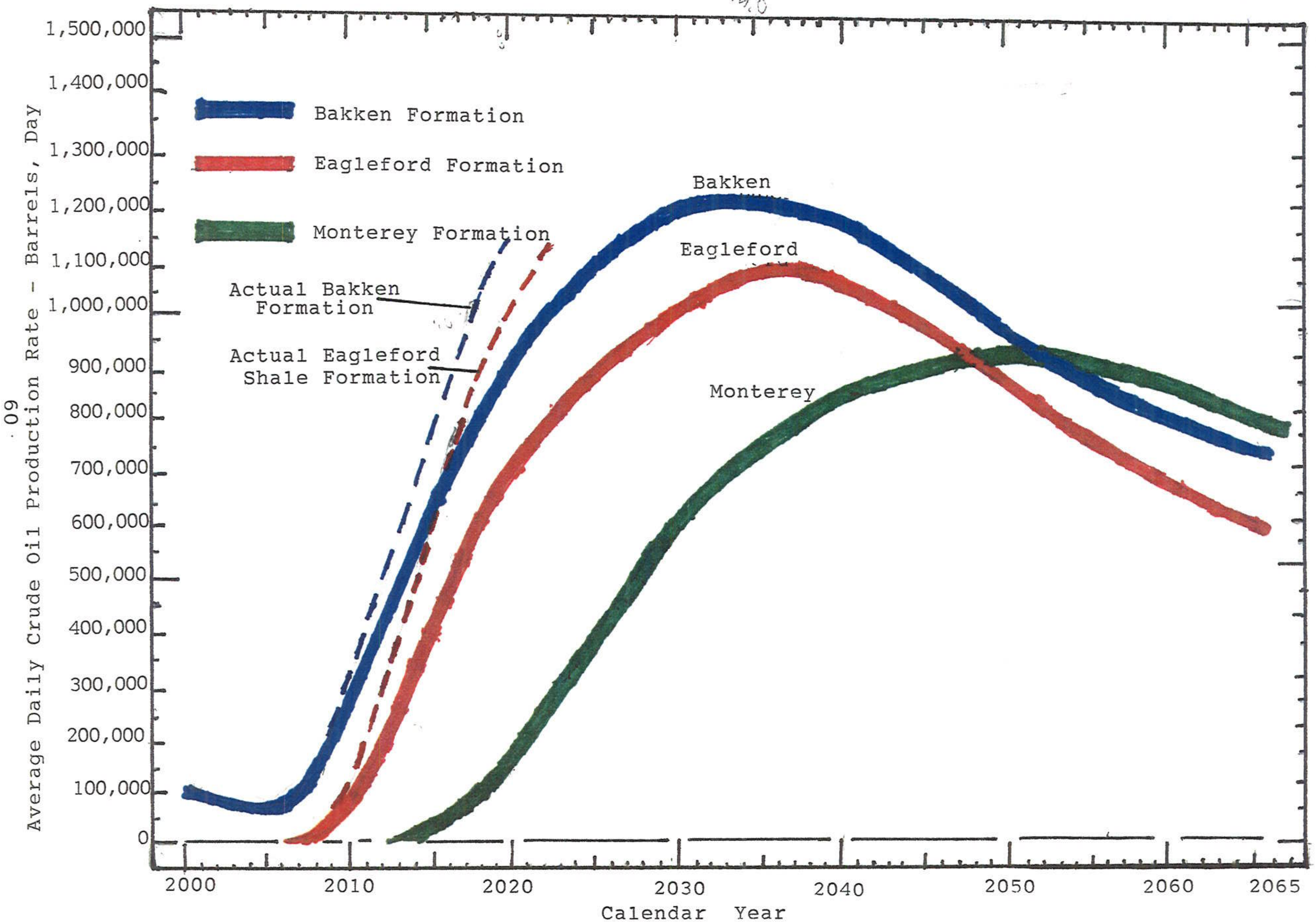


The total one way unit train movements of crude oil over at least a part of the distance from North Dakota to Washington would then be as many as 260 unit train loads per week with a total increased train traffic of 560 trains per week over the BNSF Railway line or lines across the Northern Tier. Major oil production is possible along the Northern Tier in Canada and the United States which will add to the freight traffic volumes along the Great Northern Corridor between Chicago and Seattle as well as on the rail lines which cross it which serve the Bakken Formation and the Alberta tar sands plus other oil formations. The transport of as much as 1,100,000 barrels per day of crude oil could add as many as 37 total train movements resulting from up to 18 unit train loads of crude oil along the Northern Tier over the Great Northern Corridor.

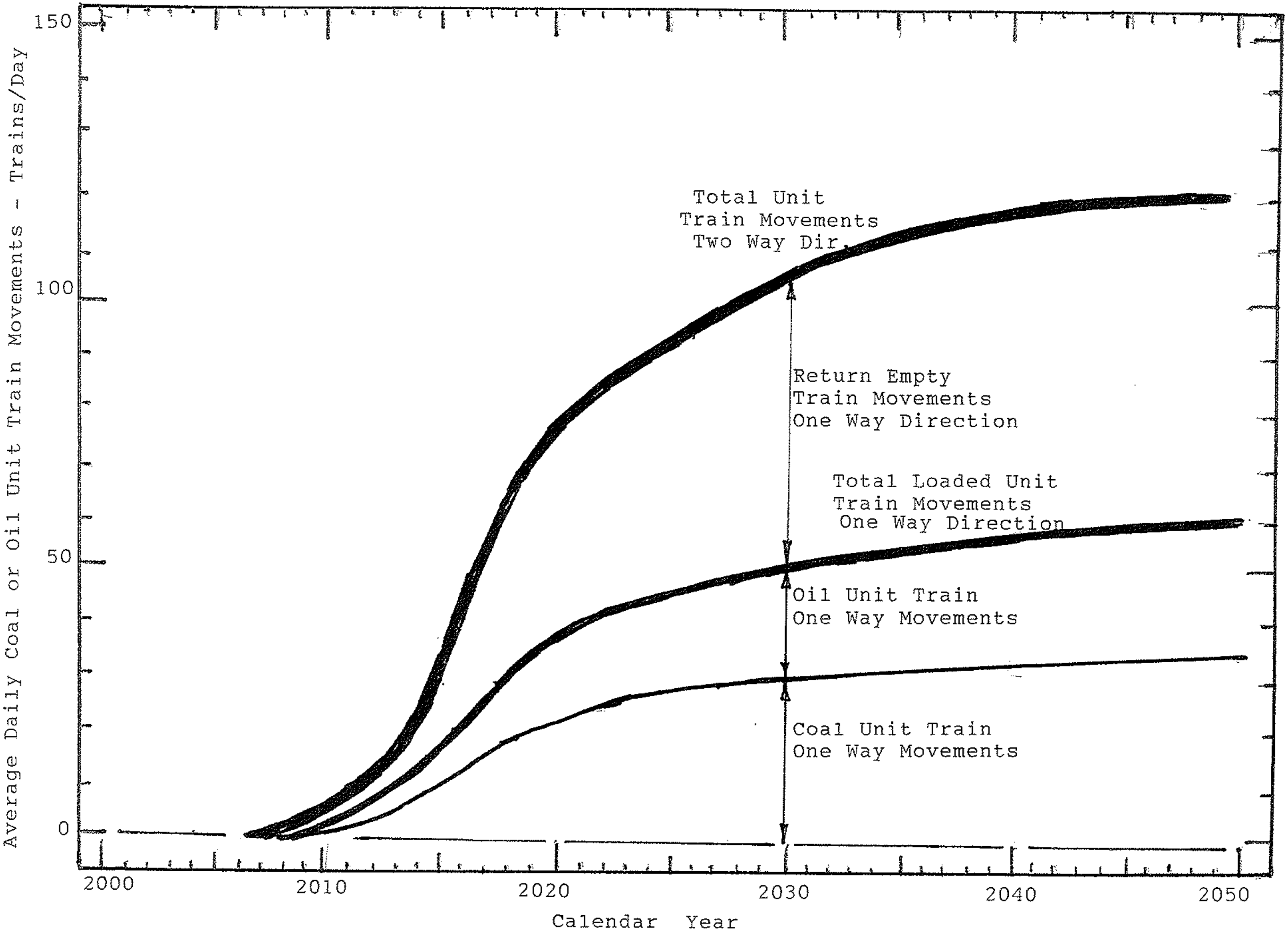
A series of new crude oil loading terminals are being proposed to be built in the State of Washington at Vancouver along the Columbia River at Grays Harbor on the Washington Coast and at the refineries along northern Puget Sound at Anacortes and at Cherry Point near Bellingham. The proposed oil loading terminal at Cherry Point could handle both Bakken Formation light crud e oil from North Dakota as well as the heavy syncrude oil from Alberta. All of the other terminals are intended to load the light sweet crude oil from North Dakota into barges for domestic coastal shipments as well as for possible future exports to foreign countries. The construction of all of these terminals in western Washington would conceivably double the number of oil unit trains on the Great Northern Corridor provided that there was sufficient track capacity available and that the supplies of crude oil from North Dakota would indeed be able to be produced.

There are also a series of new coal loading terminals proposed to be built in the Pacific Northwest at Vancouver, Washington along the Columbia River, perhaps at Grays Harbor and at Cherry Point near Bellingham which would be in addition to those in British Columbia. The construction of all of these terminals could result in the additional shipment of up to 100 million tons of coal per year with as many as 25 unit train loads per day over the Great Northern Corridor with a total traffic impact of as many as 50 additional train movements per day. The combustion of coal and oil unit train movements would add as many as 43 to 45 unit trains loads per day with as many as 85 to 90 additional trains movements per day to the Great Northern Corridor freight traffic flow.

EXPECTED FUTURE TRENDS IN ESTIMATED CRUDE OIL PRODUCTION LEVELS FOR THE NORTH DAKOTA BAKKEN, TEXAS EAGLEFORD AND CALIFORNIA MONTEREY SHALE FORMATIONS FROM 2000 TO 2060



EXPECTED INCREASES IN COAL AND CRUDE OIL UNIT TRAIN MOVEMENTS OVER THE GREAT NORTHERN RAILROAD CORRIDOR ACROSS THE NORTHERN TIER FROM NORTH DAKOTA TO WASHINGTON: 2000-2050

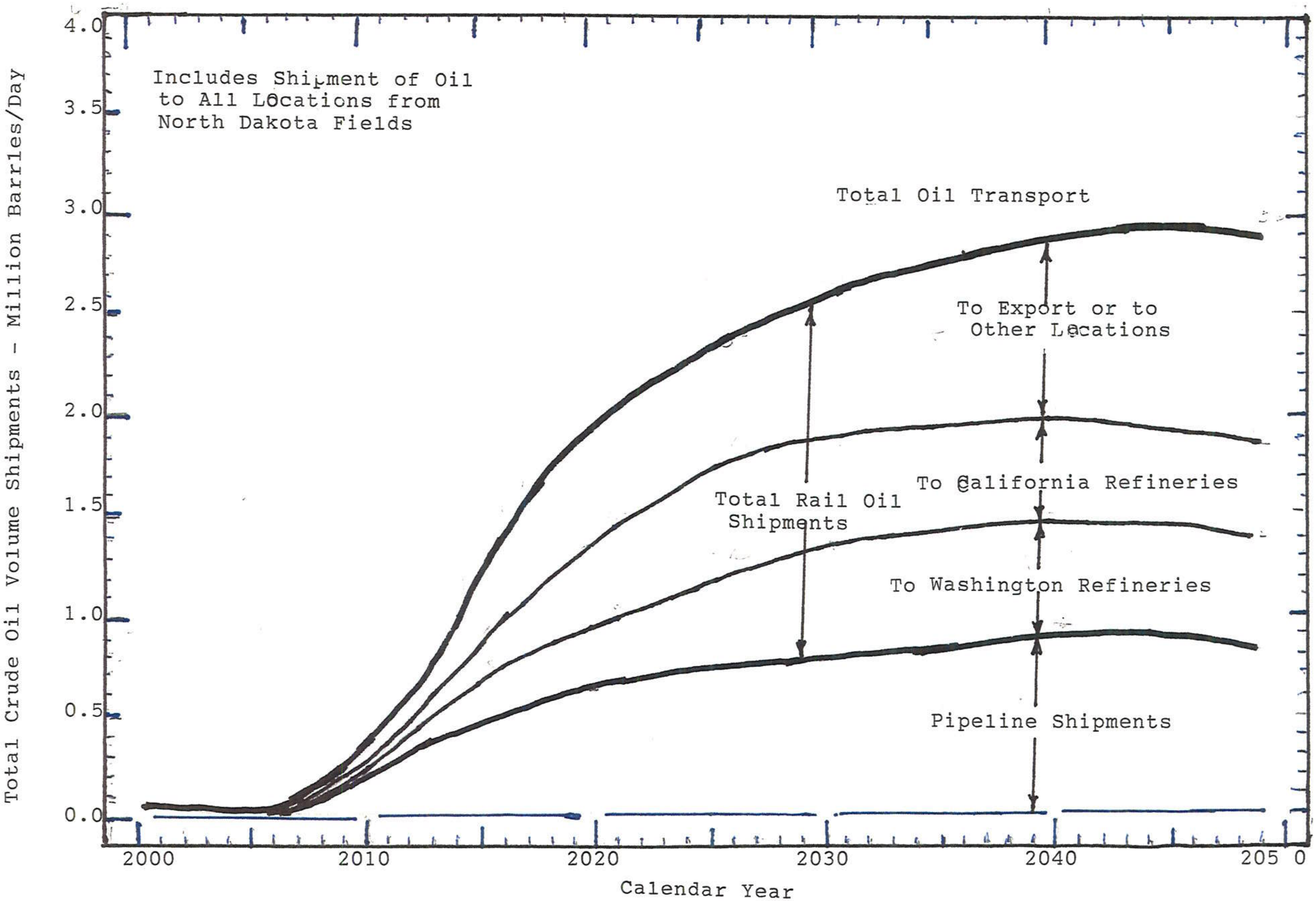


California is also the home of the Monterey Shale intermediate and heavy oil formation in the San Joaquin Basin in the Central Valley plus at the Pacific Coast in portions of the Santa Maria, Ventura and Los Angeles Basins in Southern California which can be utilized as a major energy resource. The Monterey Shale Formation in California is reported to hold up to three times the recoverable oil of the Bakken Formation in North Dakota although both formations are estimated to have total reserves of 300 to 500 billion barrels of oil. Efforts are being made to produce small amount of oil from the Monterey Shale provided that the considerable environmental obstacles can be overcome. If the Monterey Shale oil formation were to be fully developed, California's present crude oil production of 350,000 barrels per day could than be increased to between 1,000,000 and 1,500,000 barrels per day. This level of production from the Monterey Shale could then service most or all of California's present refining needs provided that all of the affected refineries were configured to process the heavy oil.

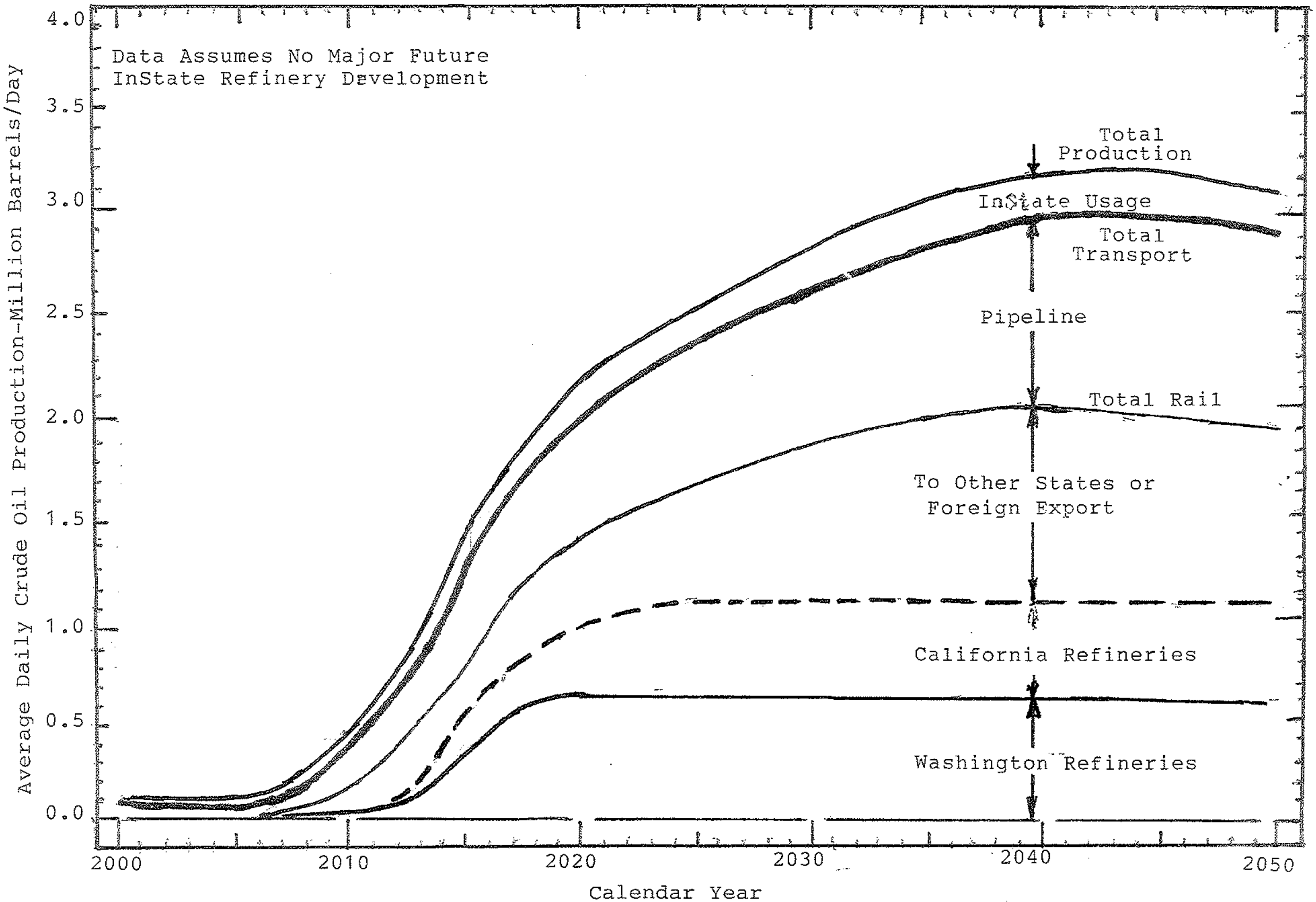
If such an event were to occur with the Monterey Shale, there would then be no need to bring crude oil from either North Dakota or Texas by rail, pipeline or by barge into California for refining. However, it is expected that as much as 1,000,000 barrels per day of the lighter oils could be refined in California which could be evenly split between the refineries in Northern and Southern California using crude oils from North Dakota and Texas. Then there could be as many as 8.35 unit train movements of crude oil per day from North Dakota to Washington or 17 trains either to the Columbia River for barging or directly by rail to the refineries, which is equivalent to 58 to 60 unit train loads per week and 116 to 120 total train movements to and from California based on 500,000 barrels per day of total crude oil shipments by rail in 2014.

It is estimated that crude oil shipments by rail from North Dakota to Washington's refineries could be as much as 600,000 barrels per day for internal use by its refineries alone minus any exports and with no capacity expansions. There would then be an estimated 10.00 unit train movements of oil per day or 70 unit train loads per week, which would be equivalent to 20 train movement per day and 140 trains per week over the BNSF Railway between North Dakota and Washington. When the Washington and California refinery unit train movements are combined, there would be a total of 18.35 additional unit train loads of oil hauled per day with a total of nearly 37 additional total train movements per day.

ESTIMATED TRENDS IN CRUDE OIL VOLUME SHIPMENTS FROM NORTH DAKOTA TO WASHINGTON TO 2050



EXPECTED TRENDS IN CRUDE OIL TRANSPORT BY RAILROAD AND PIPELINE FROM NORTH DAKOTA



## NORTHERN TIER

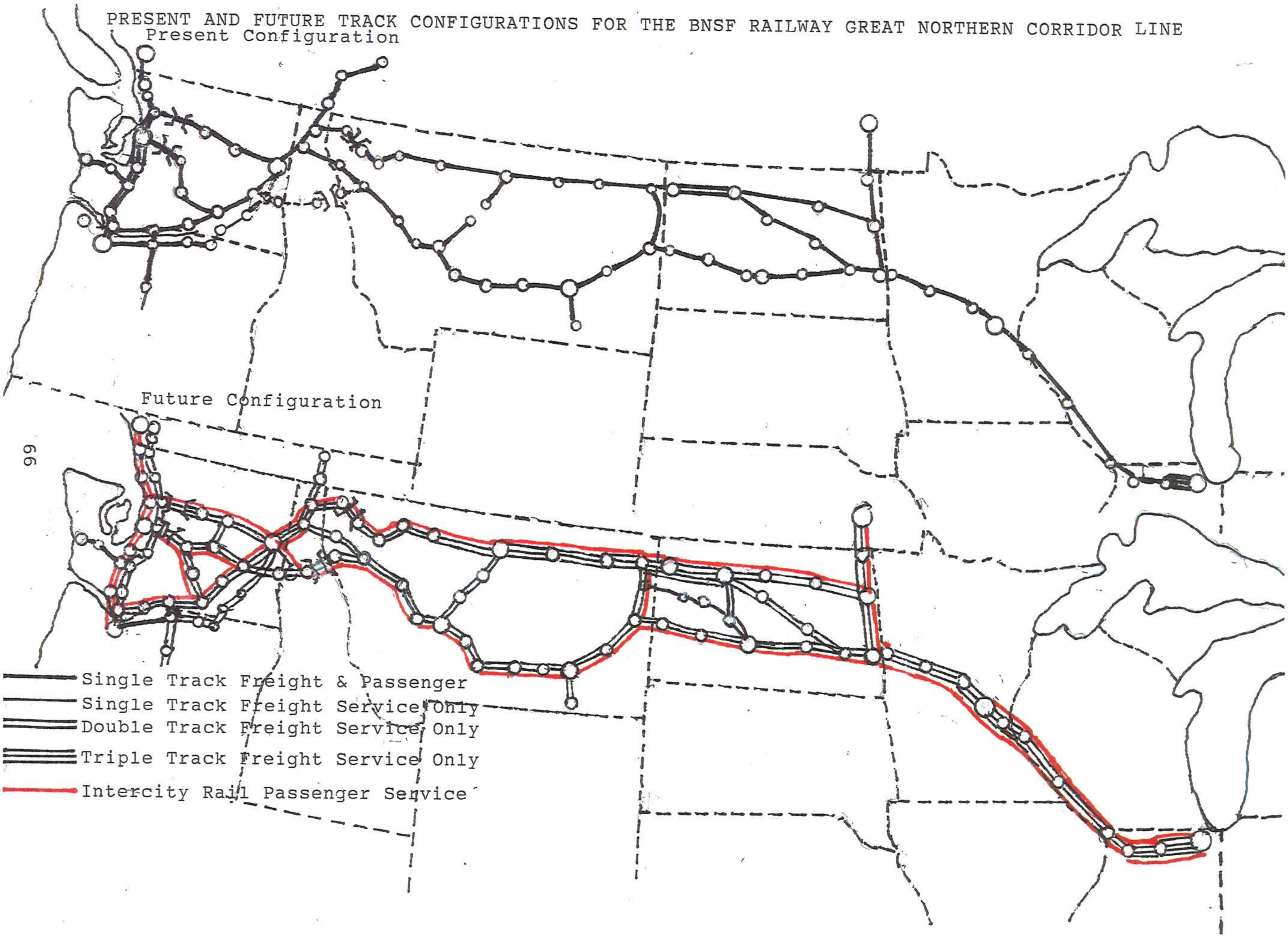
The above freight traffic movements for crude oil shipments indicate volumes of up to 1,100,000 barrels per day across the Northern Tier from North Dakota to Washington by 2017. The amounts of crude oil required to serve the refineries in California and Washington would then nearly equal the expected overall crude oil production available for export from North Dakota which is estimated as approximately 1,250,000 barrels per day in 2017. The end result is that there would then be virtually no crude oil available for shipment to refineries anywhere else in the United States other than to the Pacific Coast states with a total refining capacity of 2,588,070 barrels per day from North Dakota.

The expected unit train movements of crude oil across the Northern Tier over the BNSF Railway from North Dakota to Washington of up to 37 total trains per day by 2017 before would effectively double the present freight train traffic which is estimated as much as 35 to 40 trains per day. The movement of up to 75 trains per day over the presently largely single track route from Culbertson, Montana to Spokane, Washington would then greatly exceed its present capacity of up to 50 trains per day. There are presently considerable delays in freight train movements being experienced over this so-called new Great Northern Corridor. The incremental addition of less than five oil trains per day to the largely train and intermodal container train movement have aggravated the frequent lateness and delays being experienced by the two trains per day Amtrak Empire Builder over this route for intercity passenger service.

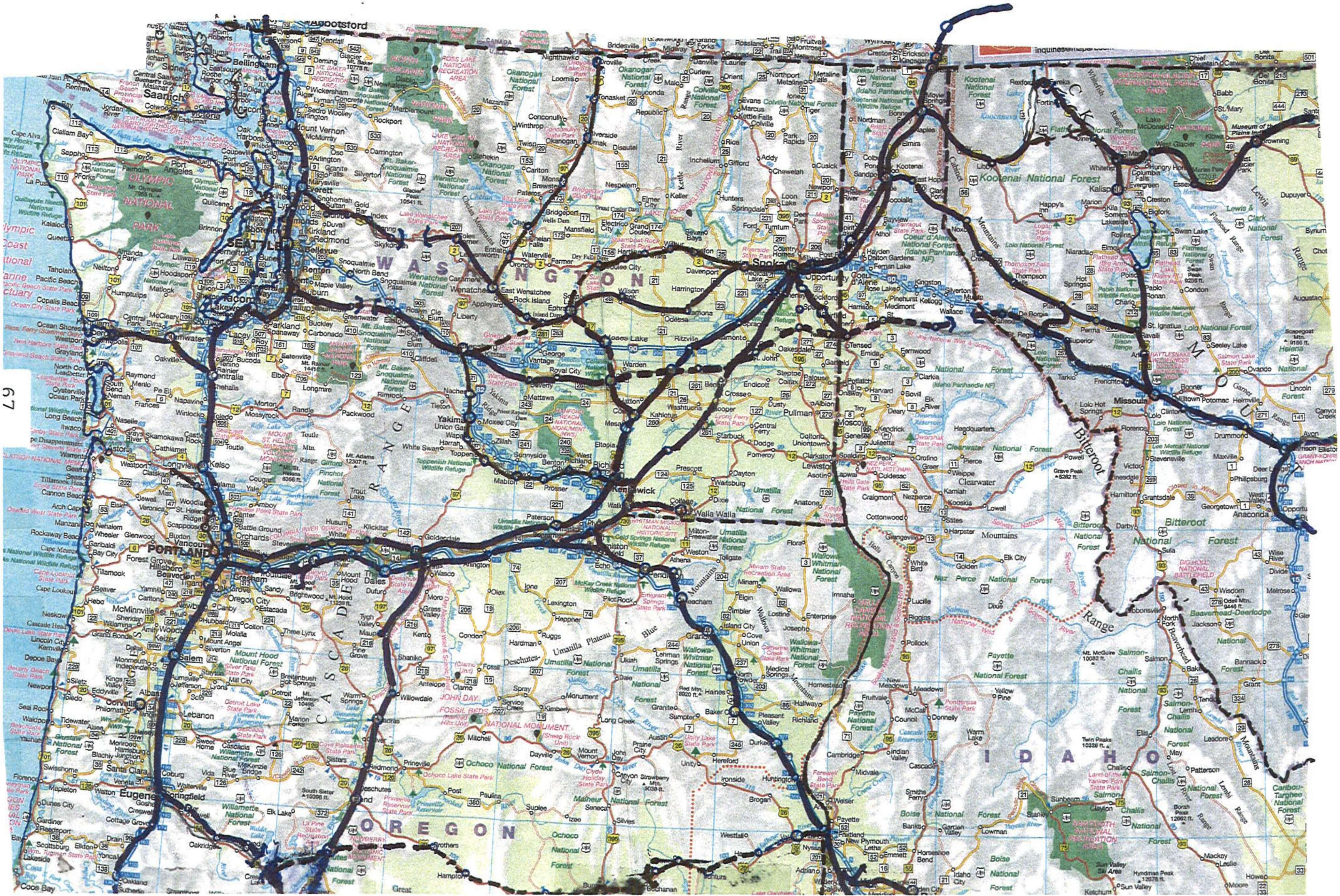
It is going to be necessary to add a second main track over the entire route of the Great Northern Corridor from Seattle and Everett to Spokane and Williston to Fargo and to Chicago in order to allow these additional crude oil train movements. It is also going to be necessary to add a third main track between Culbertson, Montana and Minot, North Dakota to follow up on the present installation of a second main track between Williston and Minot, North Dakota. In addition, there will need to be second tubes installed at the Stevens Pass tunnel through the Cascade Mountains in Western Washington as well as at the Flathead Tunnel through the Rocky Mountains in Northwestern Montana for the Great Northern Corridor.

The major concern with freight trains carrying crude oil relates to liquid volatility and the potential for fires and explorations with derailments such as was recently experienced on the BNSF Railway line in Casselton, North Dakota on December 30, 2013 and at Aliceville, Alabama.

## PRESENT AND FUTURE TRACK CONFIGURATIONS FOR THE BNSF RAILWAY GREAT NORTHERN CORRIDOR LINE



ALTERNATIVE ROUTES ACROSS THE CASCADE AND ROCKY MOUNTAINS FOR THE GREAT NORTHERN CORRIDOR



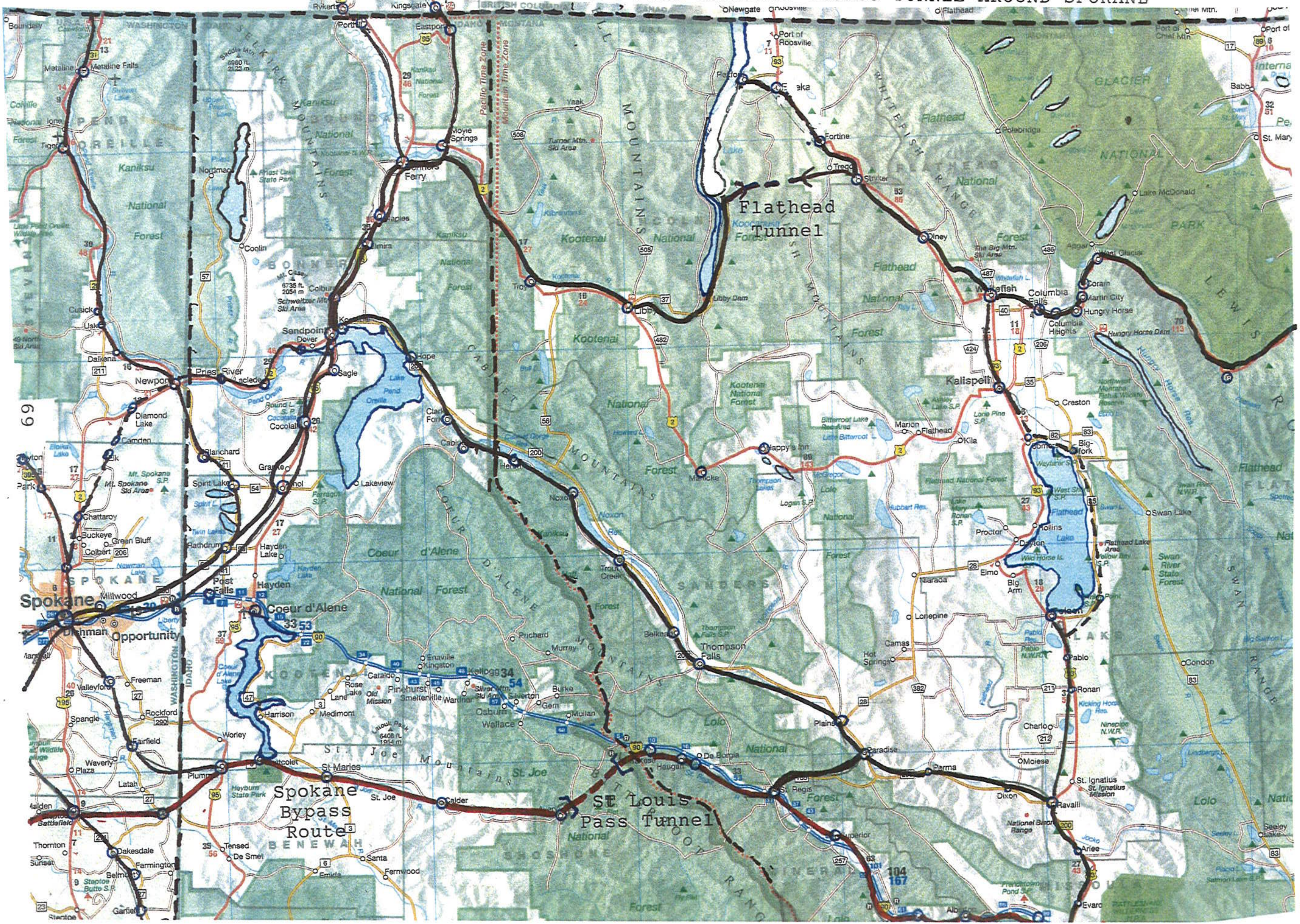
Recent recommendations by the U.S. National Transportation Safety Board and the Canadian Transportation Safety Board incorporate mandatory testing of crude oils for volatility and flammability with particular attention paid to the Bakken Formation light sweet crude oils. An additional recommendation by these two agencies was that alternative routes be found to avoid oil train movements through major urban areas wit h large population centers through existing or new bypasses wherever possible.

The present movement of crude oil trains across the Northern Tier over all or parts of the Great Northwest Corridor generally in parallel to the U.S. 2 highway goes through Spokane for all trains as well as through or near to Portland or Seattle for some of the oil trains. The present route for the crude oil trains goes through Spokane over the same tracks as well as by the Amtrak passenger trains through the Spokane station. The only feasible rail bypass around Spokane for these loaded crude oil trains is to reactivate and rebuild the former Milwaukee Railroad line to the south from Lind, Washington to Avery, Idaho as a double track route. A new double track railroad tunnel would then need to be built in parallel to the previous tunnel under St. Louis Pass between Avery, Idaho and Saltese, Montana.

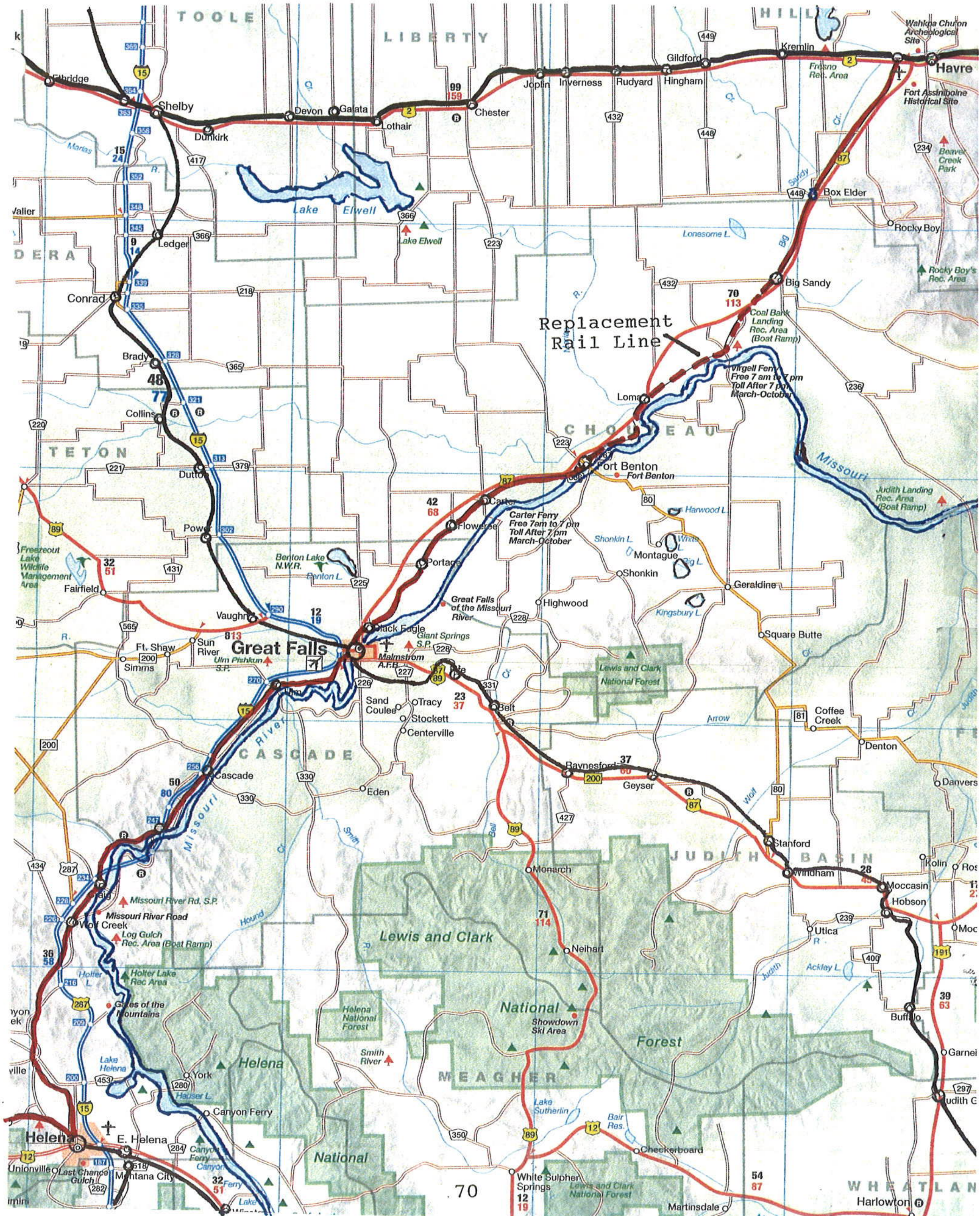
This new railroad line in Montana would follow the previous Milwaukee Railroad line as a double track route over the present existing single track route of the Montana Rail Link to Missoula in parallel to the Interstate 90 freeway along the Clark Fork River. The existing single track line of the Montana Rail Link would then need to be expanded to double track between Missoula and Garrison, Montana. This newly double track line would then be extended over the present Mullan Pass route across the summit of the Rocky Mountains to Helena on the east side. The expanded double track railroad line would then parallel the existing BNSF Railway line between Helena and Great Falls to Fort Benton where the present line ends. This rail line would then have to be reconnected to the previous northern line from Havre to Big Sandy with a new bridge over the Missouri River to join between Fort Benton and Big Sandy to rejoin the existing Great Northern Corridor from Havre to Culbertson and Williston to Minot.

An additional advantage of this alternative route alignment to bypass Spokane by way of the previous Milwaukee Railroad line is that the coal trains from the Powder River Basin in southwestern Montana and northern Wyoming can then be combined with the crude oil trains from North Dakota at Helena. These trains can then proceed to the Washington Coast.

LOCATION OF THE PROPOSED REBUILT ST. LOUIS PASS RAILROAD BYPASS TUNNEL AROUND SPOKANE



ROUTE LOCATION OF THE BNSF RAILWAY BYPASS LINE FROM HELENA TO HAVRE

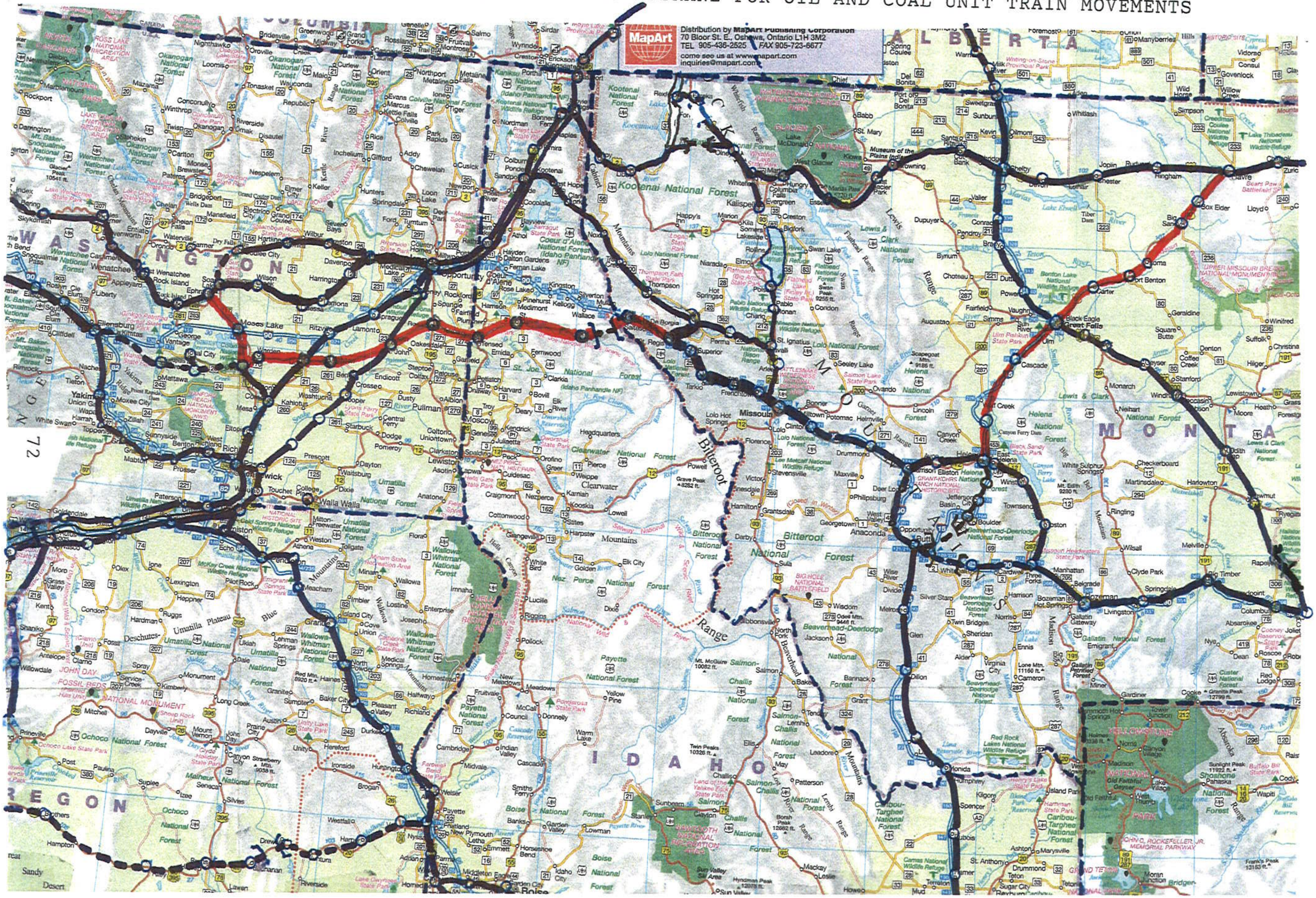


The BNSF Railway has trackage rights over the Montana Rail Link from Huntley, Montana to Sandpoint, Idaho so that the coal and oil trains could go over this existing rail line from Helena to St. Regis, Montana. The coal and oil unit trains could then go over the newly rebuilt former Milwaukee Railroad line from St. Regis, Montana to Avery, Idaho through the St. Louis Pass tunnel and over the rebuilt former Milwaukee Railroad lined through Tekoa and Rosalia to Lind, Washington.

There would then be the route option of following the present short line from Lind to Warden, Washington to the west and then to the north to Wheeler. It would then be necessary to rebuilt the extension of this short line from Wheeler to Ephrata to rejoin the Great Northern Corridor to Wenatchee and through the new Stevens Pass tunnel to Everett to join the coast line. Another option would be to rebuilt the former Milwaukee Railroad line from Othello to Beverly with a new bridge over the Columbia River to the south of Vantage and then go up the long Regress Hill grade to Kittitas and Ellensburg to rejoin the BNSF Railway line over Stampede Pass which would require a new tunnel to be built similar in design to the proposed new Stevens Pass tunnel. The remaining route option would be to follow the existing BNSF Railway main line from Lind to Pasco and then along the north bank of the Columbia River to Plymouth. This present single track line would need to be expanded to double track operation from Plymouth go Wishram where the oil trains would go to the south to California by way of Klamath Falls and Keddie to Marysville and Sacramento to the Bay Area refineries.

The remaining oil and coal unit trains would then go from Wishram to Vancouver, Washington and then either to the north on the main line to Seattle or to the South over the Columbia River to Portland and Clatskanie near Astoria. The difficulty in using the existing heavily used BNSF Railway line along the Columbia River is that it is a combination of single and double track and is built on steep slopes next to the water. In addition to the difficulties in construction of a completely new double track line from Pasco to Vancouver, the oil unit trains must then go to the north over the BNSF Railway main line from Vancouver to Tacoma and Seattle through the largest metropolitan area in the Pacific Northwest with major possible exposures to adjacent populations. The alternative choices are then to build a bypass line around Seattle or else avoid going though Seattle at all by going to the north from the Stevens Pass line.

PROPOSED RAIL BYPASS ROUTE LOCATION AROUND SPOKANE FOR OIL AND COAL UNIT TRAIN MOVEMENTS



## PUGET SOUND

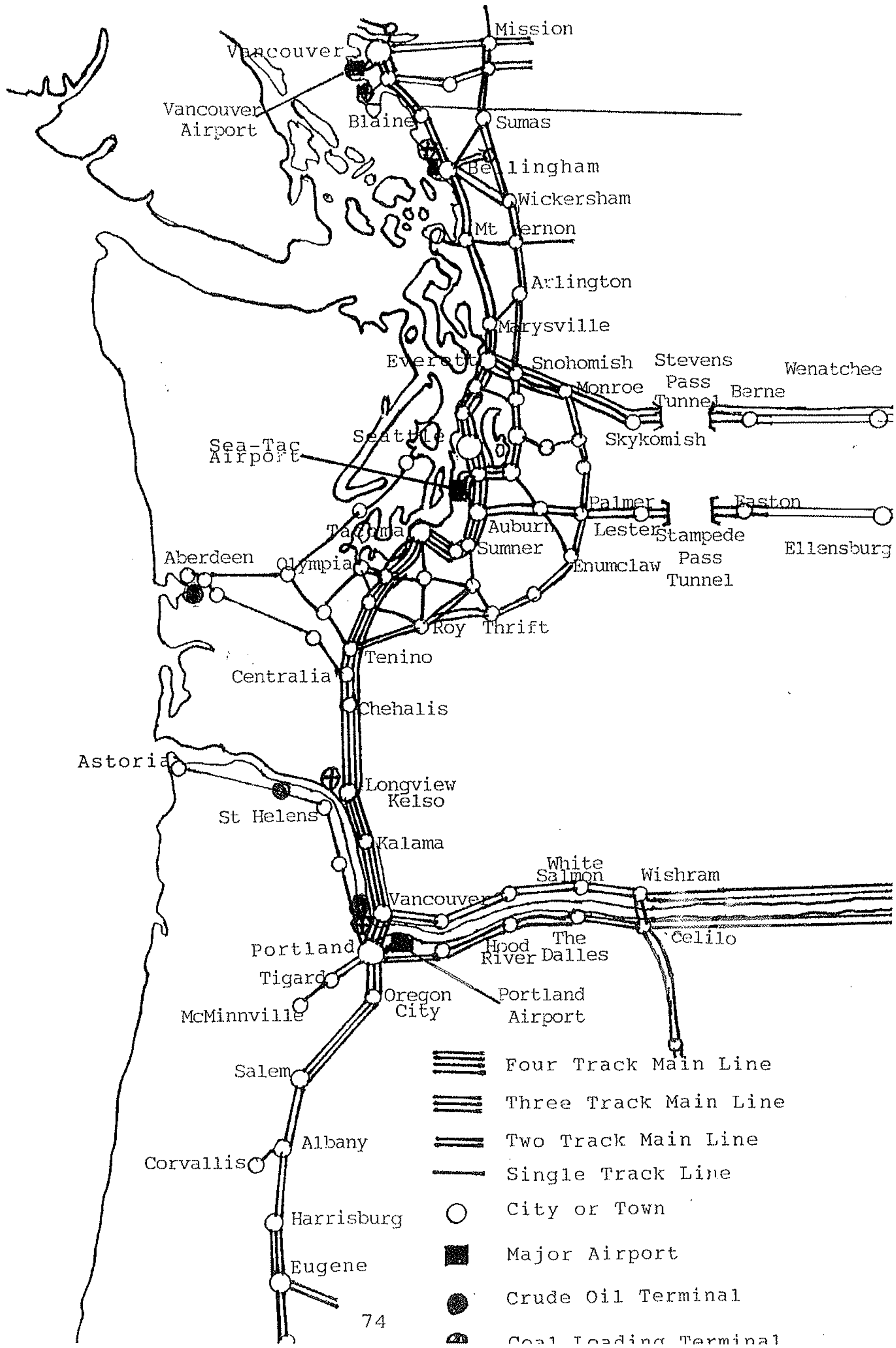
There are three basic choices for dealing with the passage of unit trains carrying crude oil crude oil through the Puget Sound metropolitan area which can also impact coal unit train movements at the same time. One approach is to continue to utilize the present long and circuitous route from North Dakota to Spokane over the BNSF Railway relatively level line or the proposed bypass and then go to Pasco and along the Columbia River route to Wishram, Washington. The oil unit trains going to California will exit and go by way of Klamath Falls and Keddie to Marysville and Sacramento in part over the Union Pacific and then to the Bay Area refineries and to Los Angeles over the Coast Line via Salinas and Ventura.

The oil unit trains going to the refineries in Northwest Washington can then proceed to the west to Vancouver, Washington along the Lower Columbia River. The oil unit trains with crude oil destined for refineries in California can also exit at Vancouver and then cross the Columbia River to Portland, Oregon. These trains can then proceed through St. Helens and Rainier to the port at Clatskanie, Oregon to be loaded onto barges for shipment by marine waterway to the south to refineries in either the Bay Area or Los Angeles. The disadvantages of this route option are that the oil trains must then pass through the northwest part of the Portland urban area and there is also the potential for marine oil spills on the Columbia River.

These crude oil trains, which are destined for delivery to Northwest Washington refineries, can also proceed to a planned marine loading terminal at the Port of Vancouver, Washington. The crude oil can then be offloaded from the tank cars barges which then go down the Columbia River to the mouth of Astoria and then to the north along the Pacific Coast to Cape Flattery at the extreme northwest corner of Washington. The tug-hauled barges then proceed through the Strait of Juan de Fuca to the east into Admiralty Inlet to the refineries located at Cherry Point, Ferndale and Anacortes where the barges are unloaded and then return to Vancouver, Washington for additional oil shipments to the Puget Sound refineries.

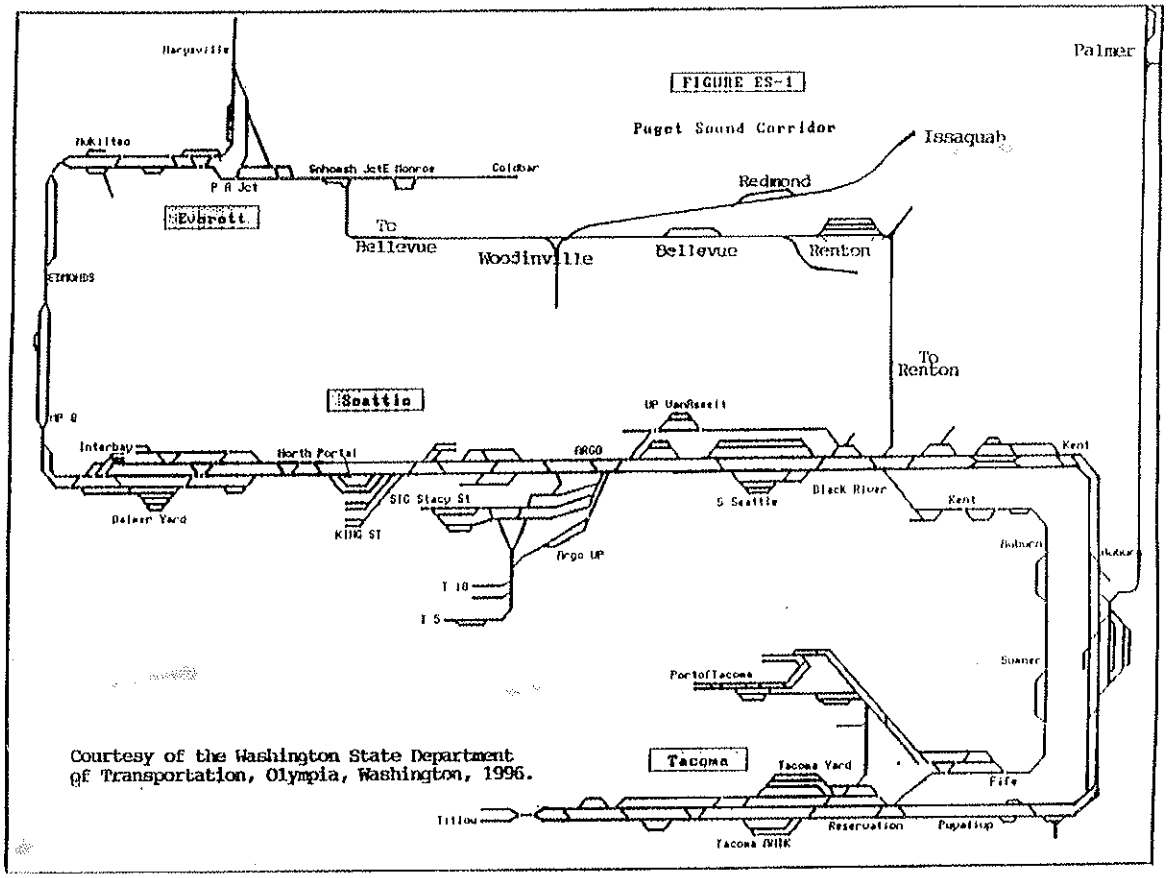
The other alternative is for the oil and coal unit trains to proceed to the north over the existing BNSF Railway double and triple track main line from Vancouver to Longview and Centralia to Tacoma and Seattle through the main metropolitan area. At present, these oil and coal unit trains go through the tunnel under downtown Seattle and then over the line along the Puget Sound from Ballard to Everett where they are highly visible.

TRACK CONFIGURATION REQUIREMENTS FOR THE PACIFIC NORTHWEST RAIL CORRIDOR.

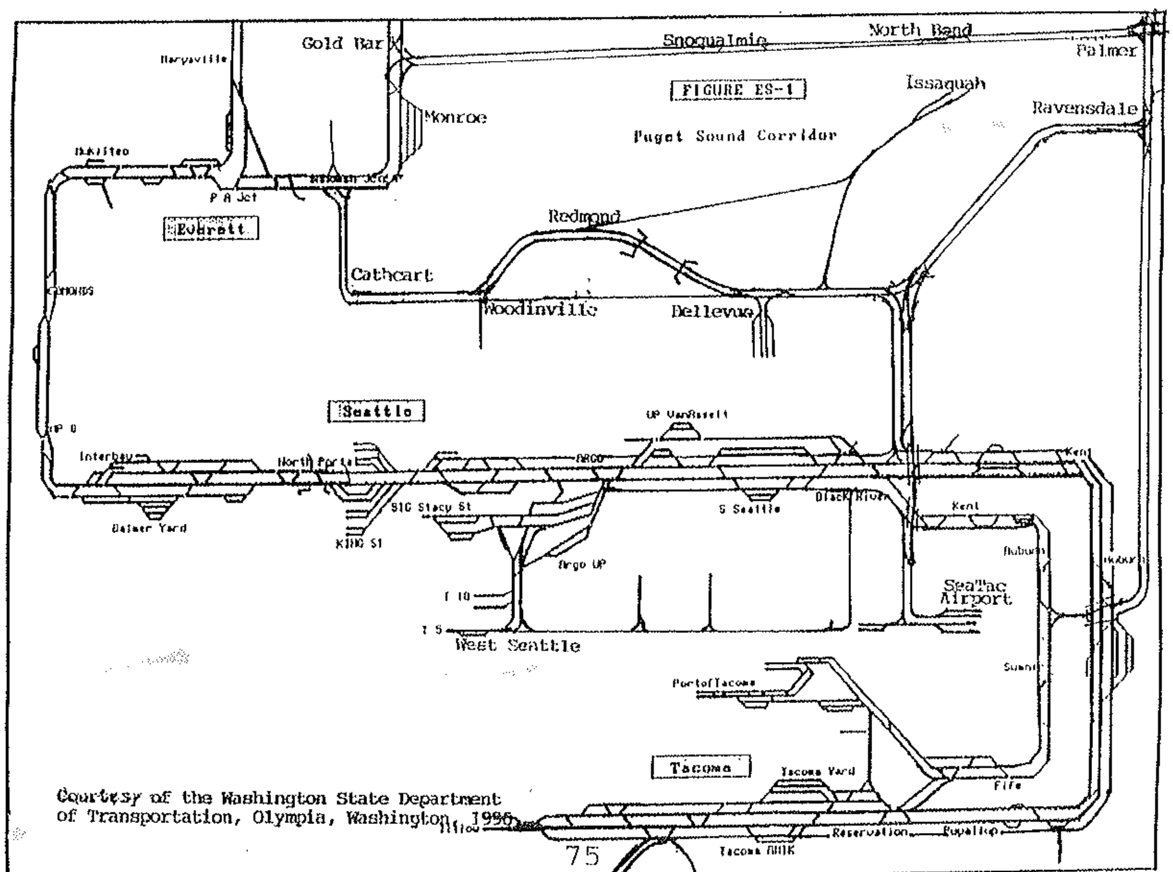


EXISTING AND PROPOSED MAIN RAILROAD TRACK LAYOUTS IN THEEPUGET SOUND AR

EXISTING MAIN RAILROAD LINE TRACK LAYOUT IN THE PUGET SOUND AREA FROM EVERETT TO TACOMA




PROPOSED MAIN RAILROAD LINE TRACK LAYOUT IN THE PUGET SOUND AREA FROM EVERETT TO TACOMA



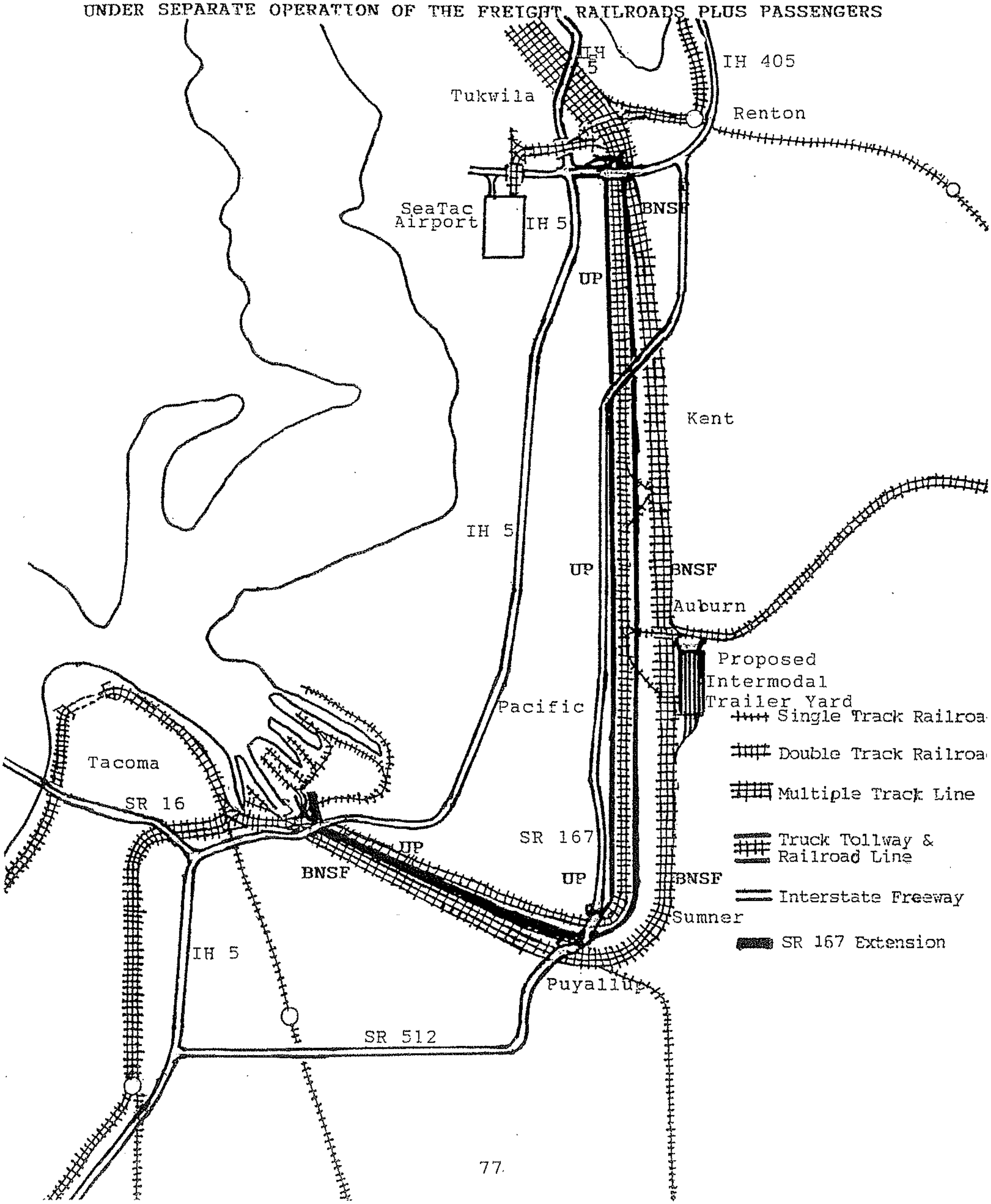
These oil and coal unit trains then go through another short tunnel in Everett and then go to the north to Mount Vernon where the trains to the Anacortes refineries exit. This route goes over relatively flat land and then go along northern Puget Sound in parallel to Chuckanut Drive on a step slope cliff to Bellingham and then through Bellingham harbor area to the refineries at Ferndale and Cherry Point as well as the coal terminal.

It is probably going to be necessary to rebuild this Western Washington main rail line for oil and coal train movements plus for bulk and intermodal cargo trains. The rail line from Vancouver, Washington to Longview will need to be expanded to four tracks with two track for freight and two tracks for passengers. From Longview to Nisqually the oil trains on the former Milwaukee Railroad line will need to be reactivated and then reconstructed as a double track passenger route while the present BNSF Railway double track line will need to be fully used for BNSF and Union Pacific Railroad freight trains between Portland and Seattle.

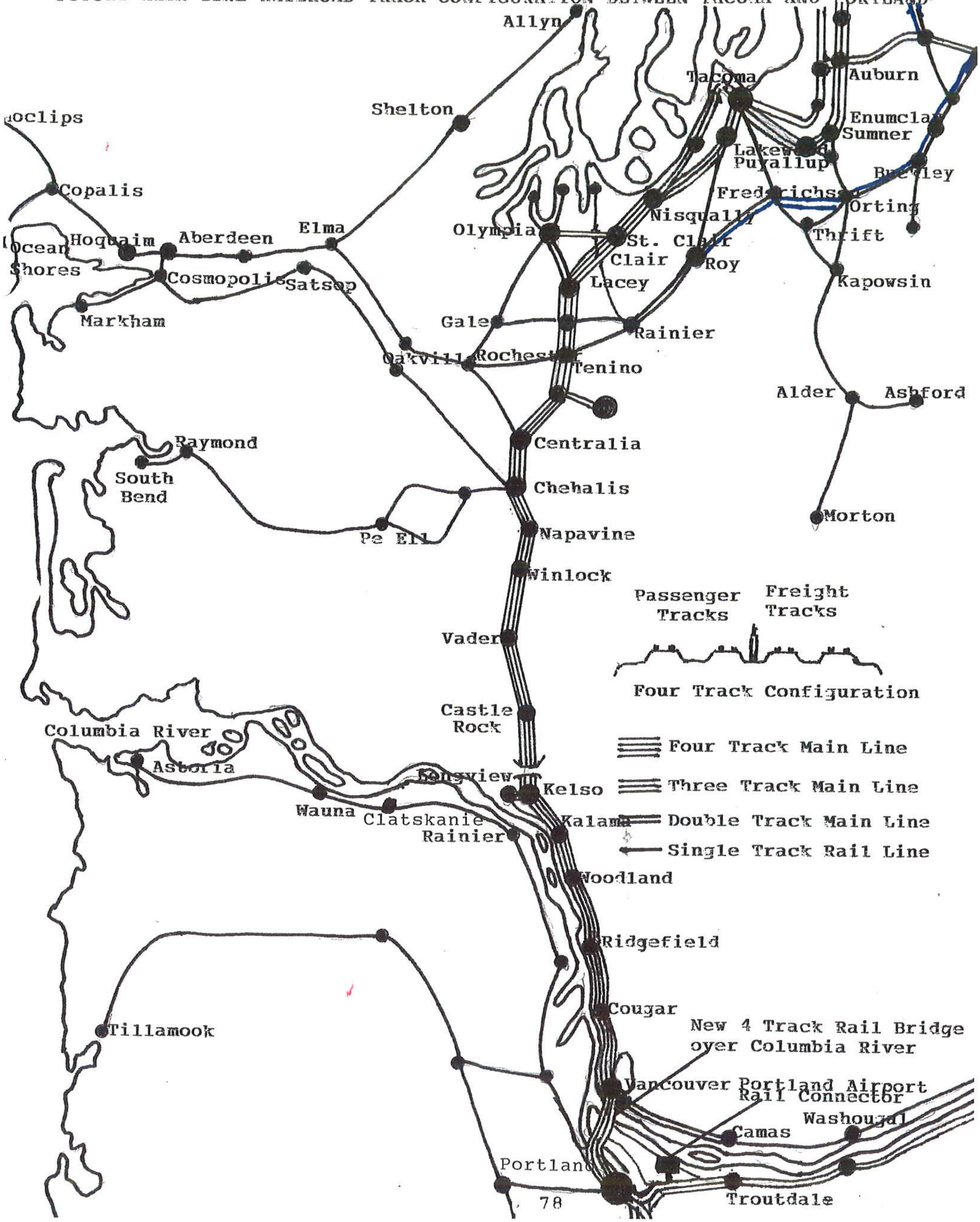
The new passenger railroad line through the Joint Base Lewis McChord will need to be expanded to double track for service between Olympia and Seattle as well as for the local commuter and intercity passenger trains from Nisqually to Tacoma. The freight trains will continue to go from Nisqually to Tacoma over the existing double track Point Defiance line with possible removal of the Ruston tunnel. At Tacoma the present BNSF Railway main line will need to be converted into a double or triple track passenger line with night local freight access to Tukwila. The main rail freight traffic from Tacoma to Seattle will then go over the present Union Pacific Railroad line from Bull Frog Junction to Black River Junction as a new triple track main line for both major freight railroads.

The present six track main railroad line with two BNSF tracks plus two Union Pacific tracks and two passenger tracks from Tukwila to the south of downtown Seattle will remain in place. To the north of Seattle, the present largely double track main line will need to be upgraded and rendered impervious to future landslides by constructing massive retaining walls to Everett. The main rail line to the north from Everett to Mount Vernon will then be expanded to double track operation with primarily passenger service with night time rail freight service. An entirely new double track railroad line will need to be built to the east of the present Chuckanut Drive route in parallel to the Interstate 5 freeway along Lake Samish between Mount Vernon and Bellingham and Blaine with sidings to the refineries at Ferndale and Cherry Point. A double track extension with then need to be expanded into Canada from Blaine to New Westminster.

HORIZONTAL ROUTE CONFIGURATION OF THE TUKWILA-TACOMA RAIL CORRIDOR UNDER SEPARATE OPERATION OF THE FREIGHT RAILROADS PLUS PASSENGERS



# FUTURE MAIN LINE RAILROAD TRACK CONFIGURATION BETWEEN TACOMA AND PORTLAND

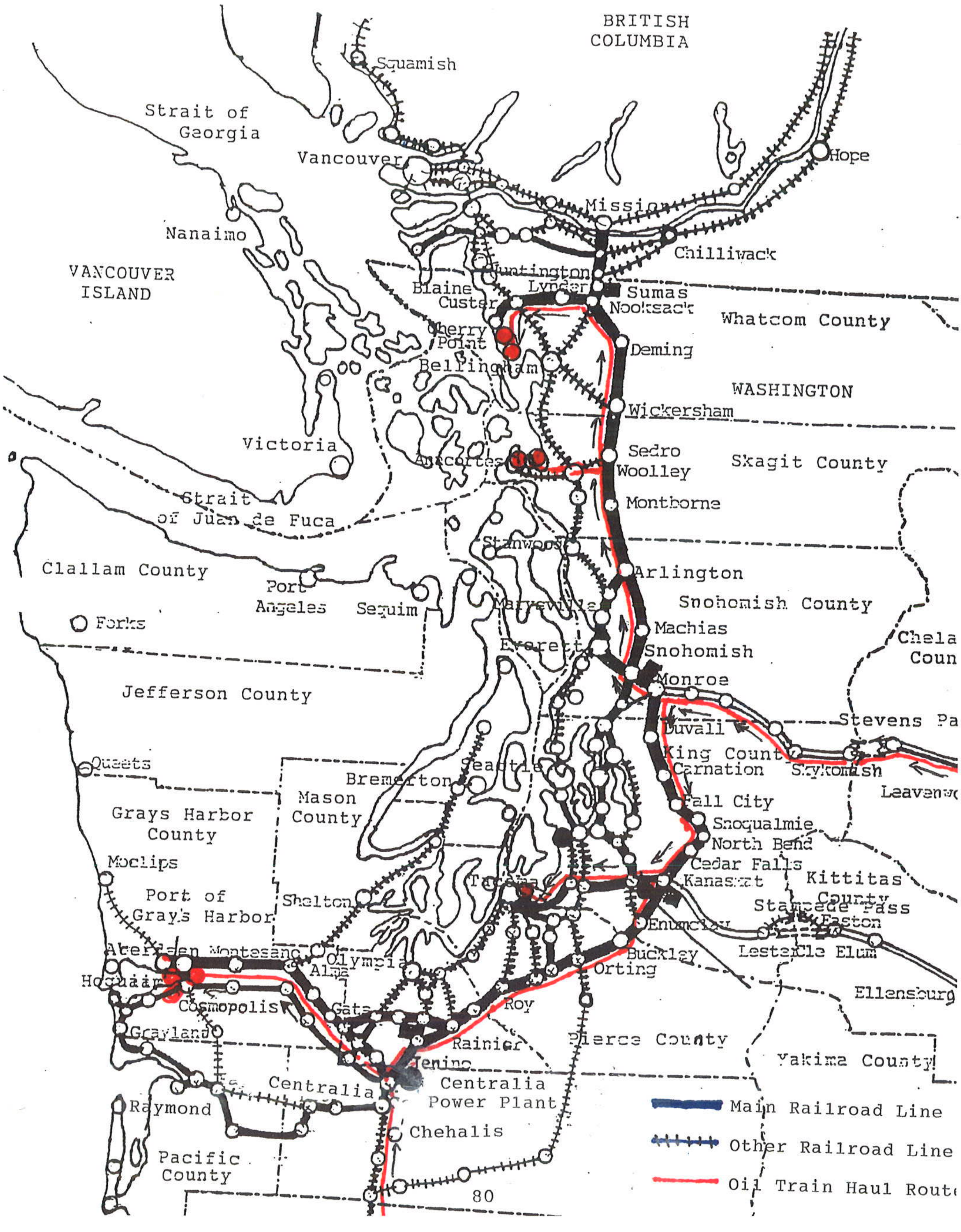


It is going to be necessary to rebuild an entirely new freight rail double track bypass line along the Cascade Foothills Corridor from Tenino to Sumas, Washington and to Mission, British Columbia. This new rail bypass line will then need to go through Orting to Enumclaw and Palmer to the Stampede Pass rail line. The route will then go to North Bend and then to Carnation and Monroe to join the BNSF Railway Stevens Pass line and go to Snohomish and then go to the north to Bellingham and Canada.

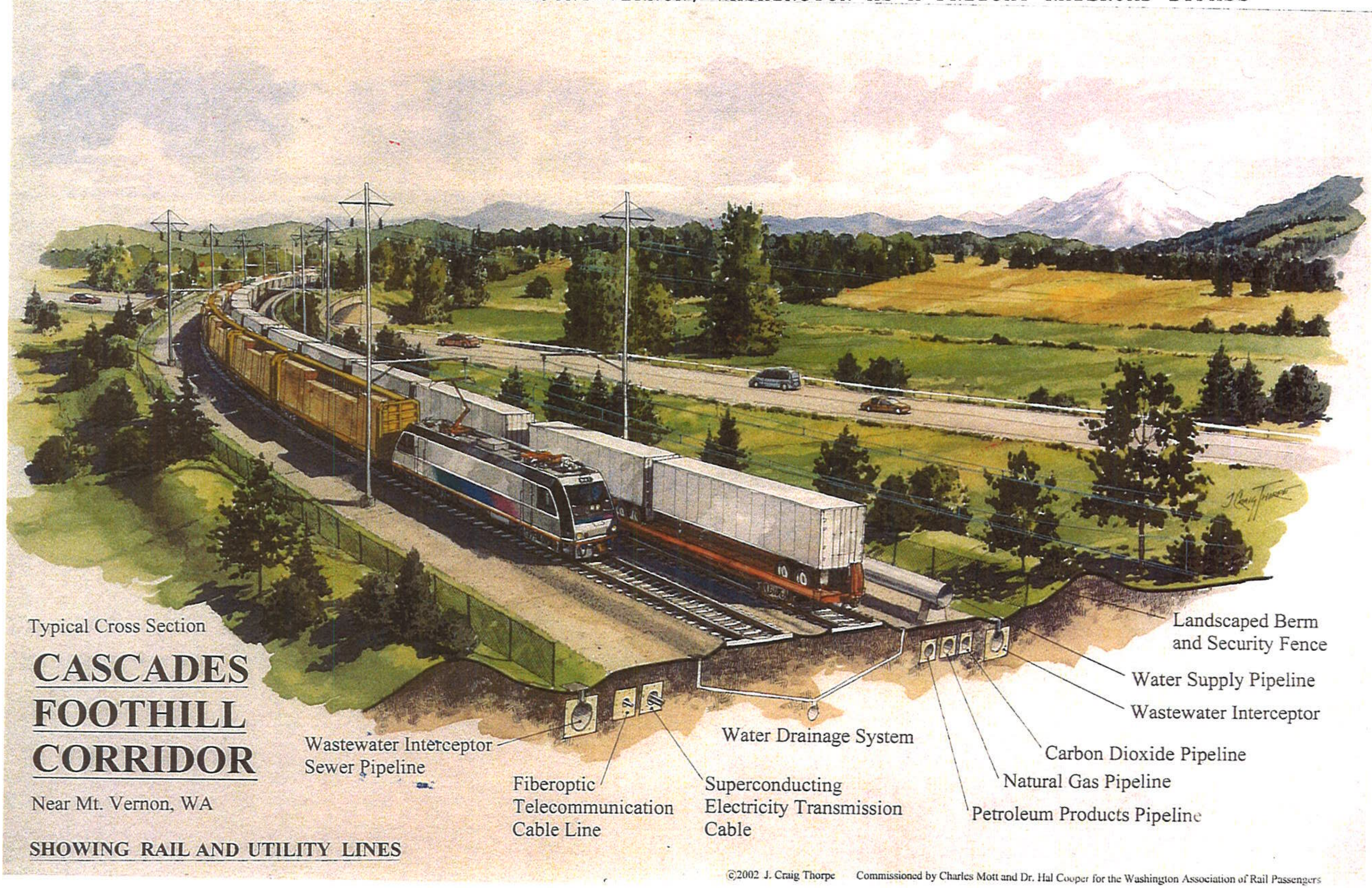
The Cascade Foothills Corridor main rail line will then go to the north over the former Northern Pacific Railroad line from Snohomish to Arlington and Sedro Woolly to Wickersham and Deming to Nooksack and Sumas in Washington at the U.S. – Canada border. The Cascade Foothills railroad line then crosses the border at Huntingdon, British Columbia to connect with the Canadian National Railway at Abbotsford and ends with River on a long bridge the connection at Mission with the Canadian Pacific Railway after crossing the Fraser River to the south.

There are connections to and from the proposed Cascade Foothills Corridor at the southern end at Tenino, Washington to the present BNSF Railway north-south main line. There are connections at the northern end in Canada at Abbotsford and Mission, British Columbia to the respective Canadian National and Canadian Pacific main east-west rail lines in the Lower Mainland to the Fraser River Canyon to the east between Hope and Kamloops, British Columbia. There are also east-west connections of the north-south Cascade Foothills Corridor at Palmer to the Stampede Pass line of BNSF as well as at Monroe and Snohomish to the Stevens Pass line of BNSF, both of which require long tunnels.

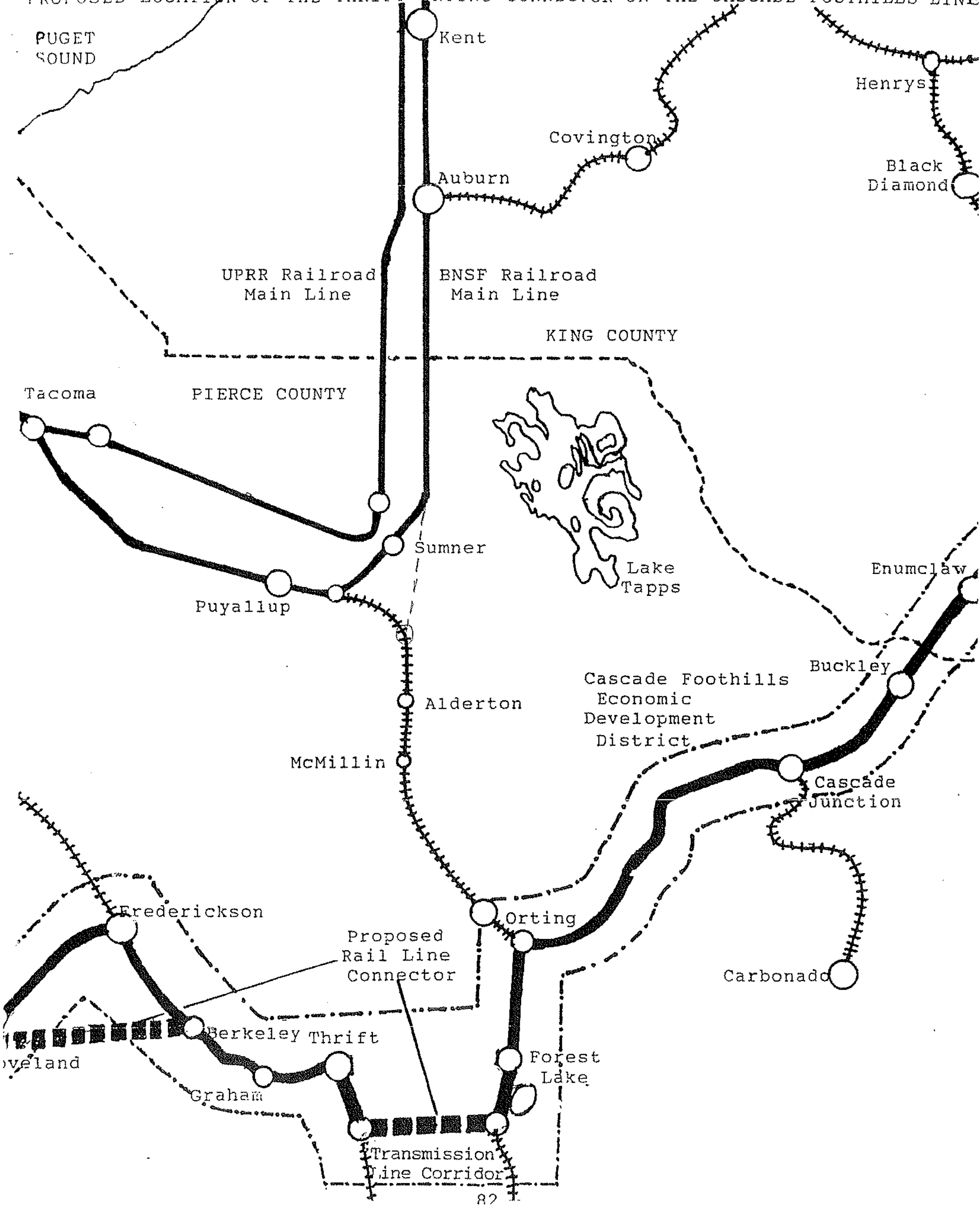
In addition to the Stampede and Stevens Pass lines, there are short diagonal connections between the proposed Cascade Foothills Corridor to the northwest from Wickersham to Bellingham and from Nooksack to the southwest to Bellingham as well as to the main BNSF north-south rail line between Seattle and Vancouver. There are additional connections between the BNSF main rail line from Snohomish to Everett and from Snohomish to Woodinville from the proposed Cascade Foothills Corridor rail line. There is another rail connection between the two rail corridor from Marysville to Arlington as well as from Sedro Woolly to Mount Vernon. There also needs to be an additional rail connection built between Sumner and Puyallup on the north to Orting and Forest Lake to the south so that oil train can also bypass Tacoma through Frederickson.


BRITISH COLUMBIA
Squamish
Strait of Georgia
Vancouver
Hope
Mission
Nanaimo
Chilliwack
VANCOUVER ISLAND
Huntington
Blaine
Lynden
Sumas
Custer
Nooksack
Whatcom County
Cherry Point
Deming
Bellingham
WASHINGTON
Wickersham
Victoria
Sedro Woolley
Skagit County
Anacortes
Montborne
Strait of Juan de Fuca
Stanwood
Clallam County
Arlington
Port Angeles
Sequim
Snohomish County
Marysville
Forks
Machias
Everett
Snohomish
Jefferson County
Monroe
Duvall
Stevens Pa
Queets
King County
Carnation
Skykomish
Seattle
Bremerton
Mason County
Grays Harbor County
Fall City
Snoqualmie
North Bend
Moclips
Cedar Falls
Kittitas County
Port of Gray's Harbor
Tacoma
Kanaskat
Shelton
Stampede Pass
Easton
Enumclaw
Aberdeen
Montesano
Olympia
Lester
Cle Elum
Buckley
Alma
Orting
Hoquiam
Cosmopolis
Gate
Roy
Ellensburg
Grayland
Rainier
Pierce County
Yakima County
Tenino
Centralia
Centralia Power Plant
Raymond
Chehalis
Main Railroad Line
Other Railroad Line
Oil Train Haul Route
Pacific County
80

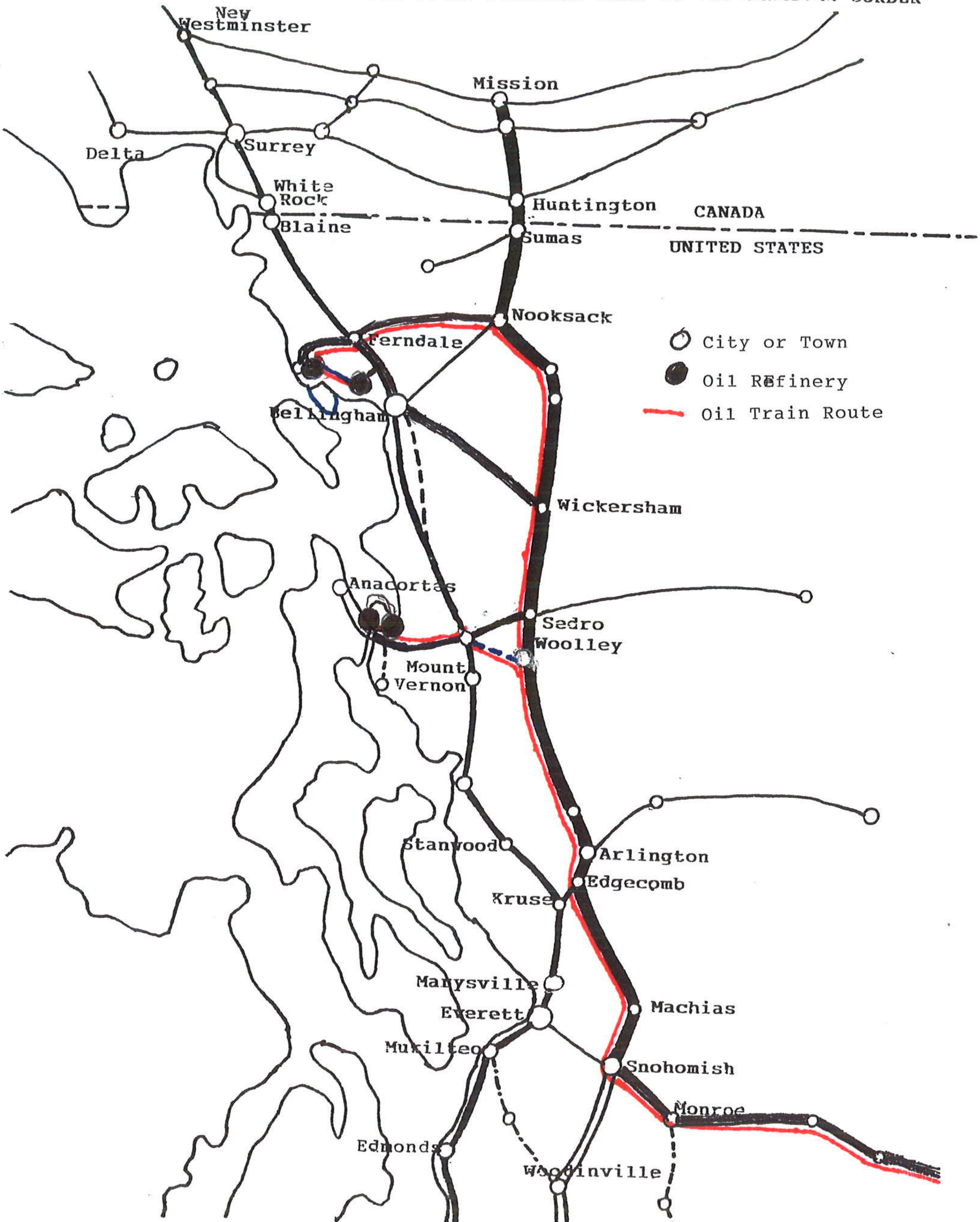
THE CASCADE FOOTHILLS CORRIDOR NEAR MOUNT VERNON, WASHINGTON AS A FREIGHT RAILROAD BYPASS



# PROPOSED LOCATION OF THE THRIFT-ORTING CONNECTOR ON THE CASCADE FOOTHILLS LINE



ROUTE LAYOUT FOR THE SNOHOMISH SUMAS RAILROAD LINE TO THE CANADIAN BORDER



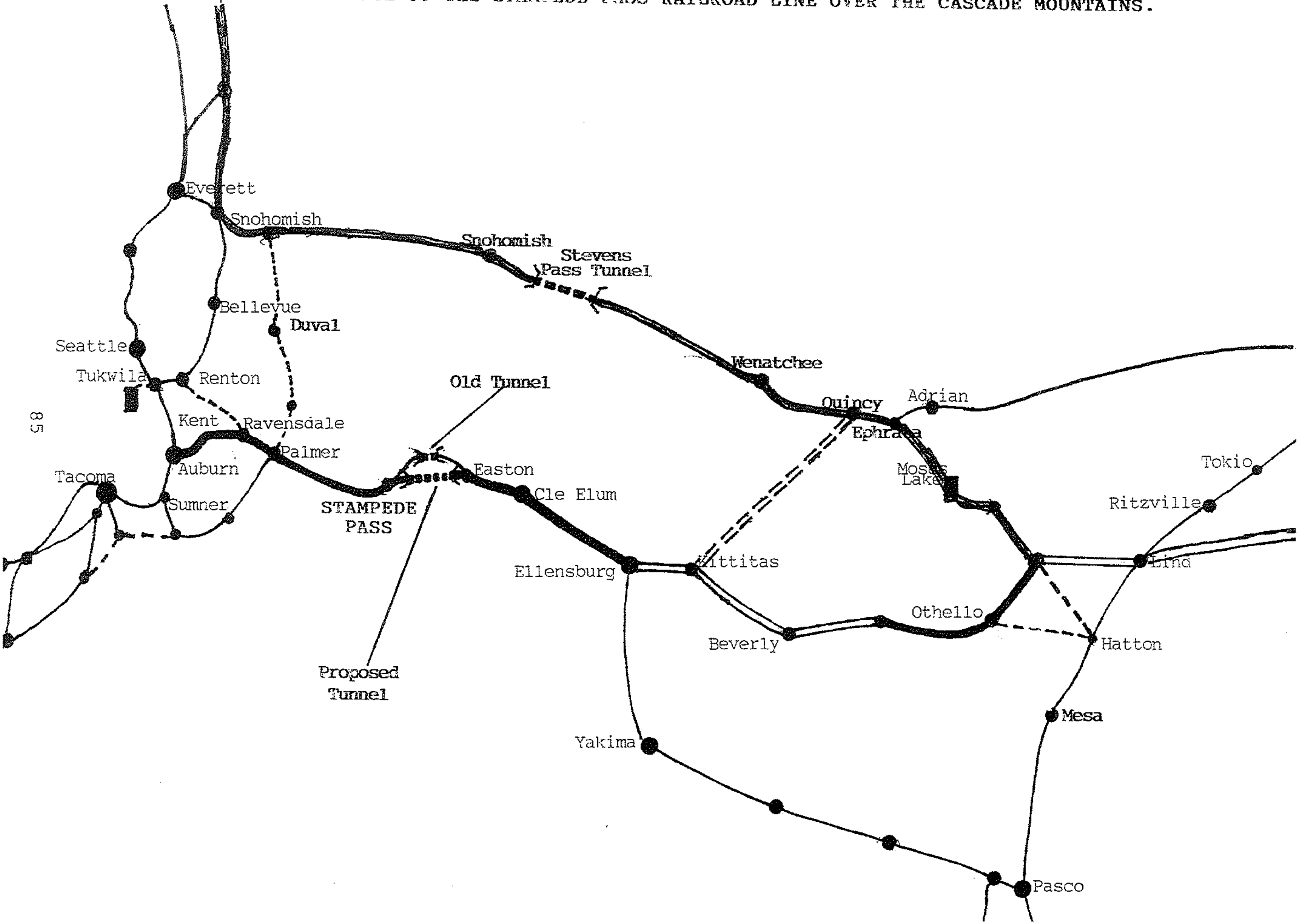
The present rail line from Wickersham to Bellingham will allow for oil unit trains access to the northern refineries at Ferndale and Cherry Point. In addition, the Sedro Woollex to Mount Vernon line allows for access to the two refineries in Anacortes from Mount Vernon on the existing railroad line. The Tacoma refinery can be accessed from the Cascade Foothills Corridor from Palmer to Auburn on the existing BNSF Railway north-south main line between Seattle and Tacoma as well as from Stampede Pass.

Oil and coal unit trains could access the proposed Cascade Foothills Corridor rail line from either the Stevens Pass or Stampede Pass rail lines into the Puget Sound area. The existing and future intermodal container train traffic to and from the Port of Seattle could go out to the Cascade Foothills Corridor by way of a rebuilt Maple Valley rail line from Tukwila to Renton to Maple Valley to Ravensdale. This rebuilt Maple Valley rail line would connect with the existing Stampede Pass rail line at Ravensdale between Auburn and Palmer. These intermodal container trains would then go to the Cascade Foothills Corridor and then either go directly to Lester and through the proposed Stampede Pass turned to Easton and Ellensburg. The train can also go to the north to Monroe to connect with the existing Stevens Pass tunnel rail line to Skykomish and Leavenworth to Wenatchee over the Great Northern Corridor route through Spokane. Intermodal trains do not contain volatile cargoes which constitute a potential danger such as with oil unit trains in going through urban areas.

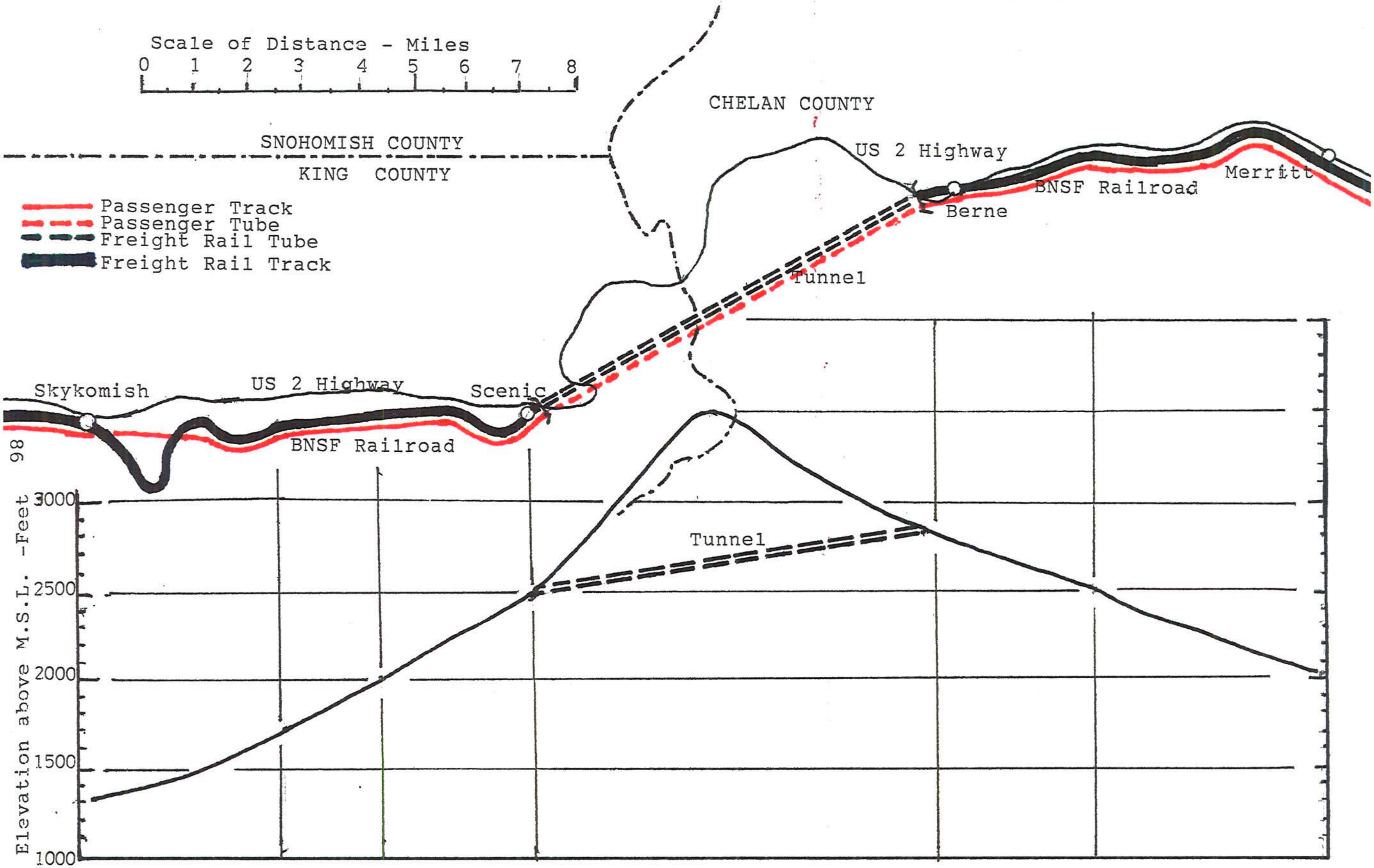
The intermodal container trains which are going to end from the Port of Tacoma would follow the same path as those going to and from the Port of Seattle to the east of Ravensdale. However, these intermodal trains would then go to and from the west over the existing rail line to Auburn. These intermodal container trains would then connect to the south to the existing BNSF Railway main line at present between Tukwila and Tacoma or in the future to the reconstituted and expanded Union Pacific Railroad line between the same two points. The primary future freight corridor with the existing BNSF Railway main line can then be used mainly for intercity and commuter passenger trains in the long term future.

The unit trains carrying crude oil would go over the proposed Cascade Foothills Corridor from either the Stevens Pass or Stampede Pass tunnel rail lines to and from Eastern Washington and would then not enter Seattle at all as a great benefit to public safety and acceptability. The rail line from Ravendale to Auburn with a crossing over the railroad is very important for achieving this result.

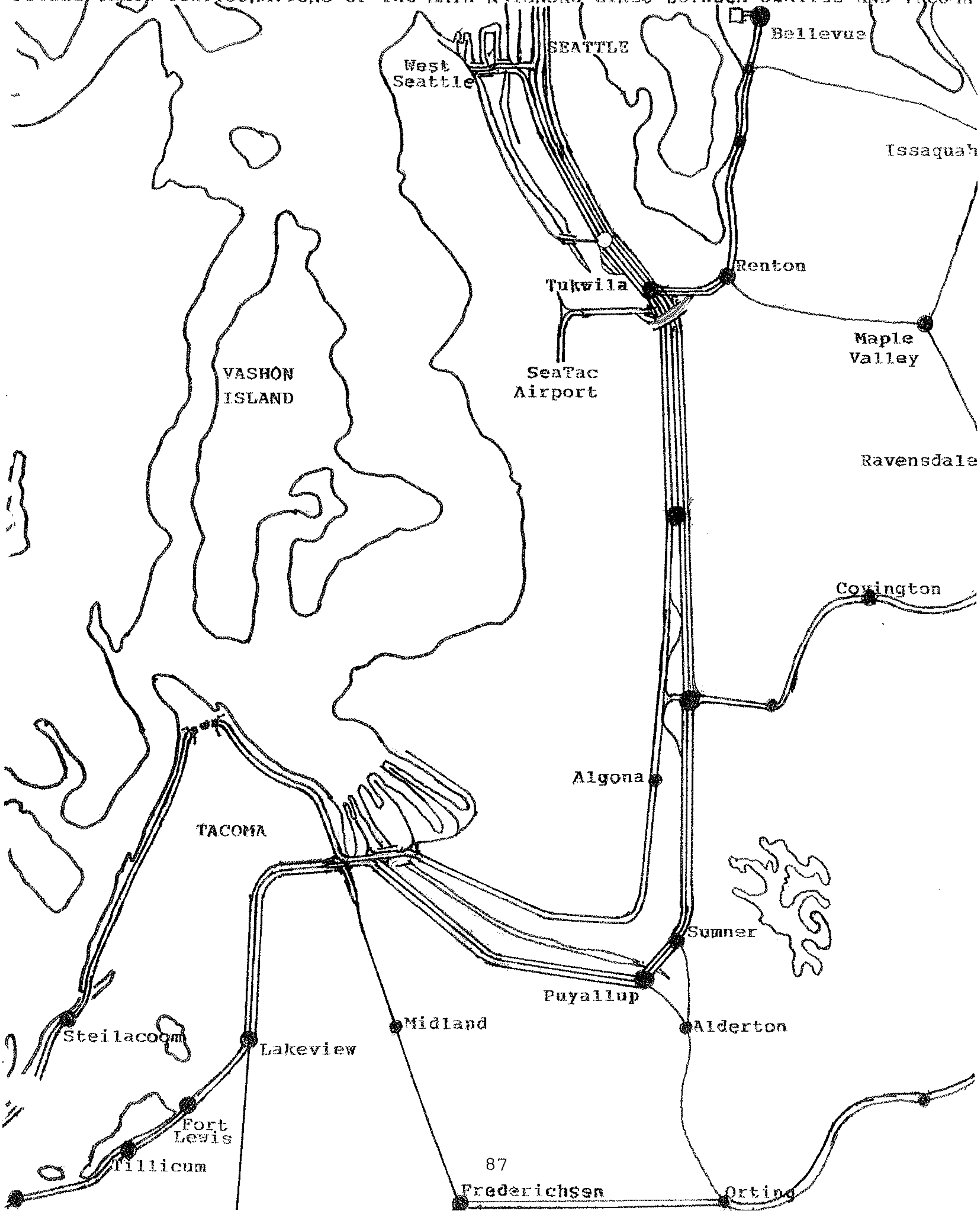
HORIZONTAL LINE PROFILE OF THE STAMPEDE PASS RAILROAD LINE OVER THE CASCADE MOUNTAINS.



VERTICAL AND HORIZONTAL ROUTE CONFIGURATION OF THE STEVENS PASS RAILROAD LINE TUNNEL



FUTURE TRACK CONFIGURATIONS OF THE MAIN RAILROAD LINES BETWEEN SEATTLE AND TACOMA

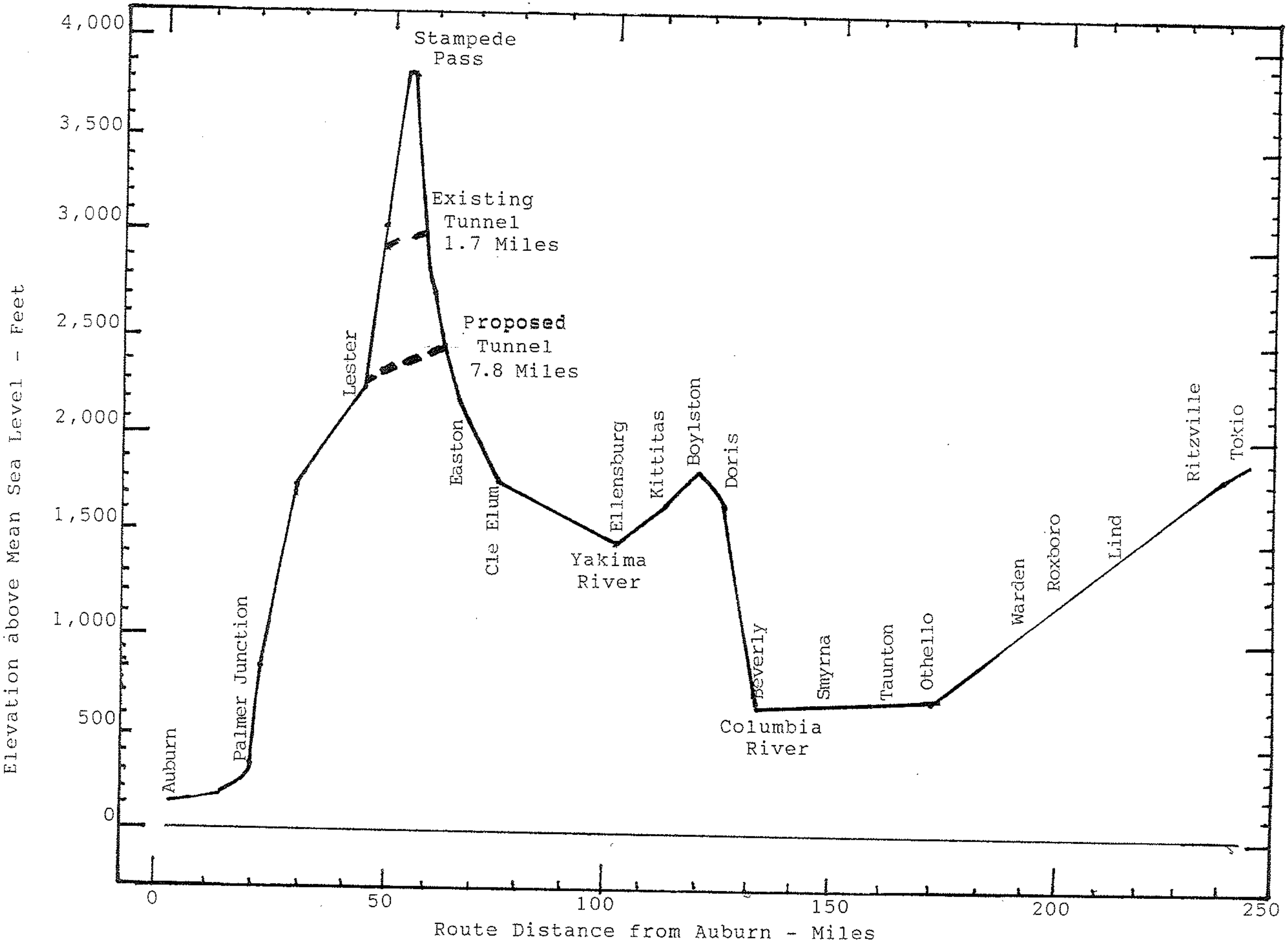


It might be preferable to have the oil and coal unit trains go by way of Stampede Pass because a tunnel could be shorter and more easily built with lesser grades at a lower elevation than at Stevens Pass for the heavy freight load westbound unit trains. A generally downgrade alignment of 150 feet in a westerly direction for this double track tunnel at Stampede Pass would decrease from a 2,500 foot elevation at the eastern portal to a 2,350 foot elevation at the western portal with a similar downgrade at Stevens Pass so that the heavy coal and oil trains go downhill in the tunnel.

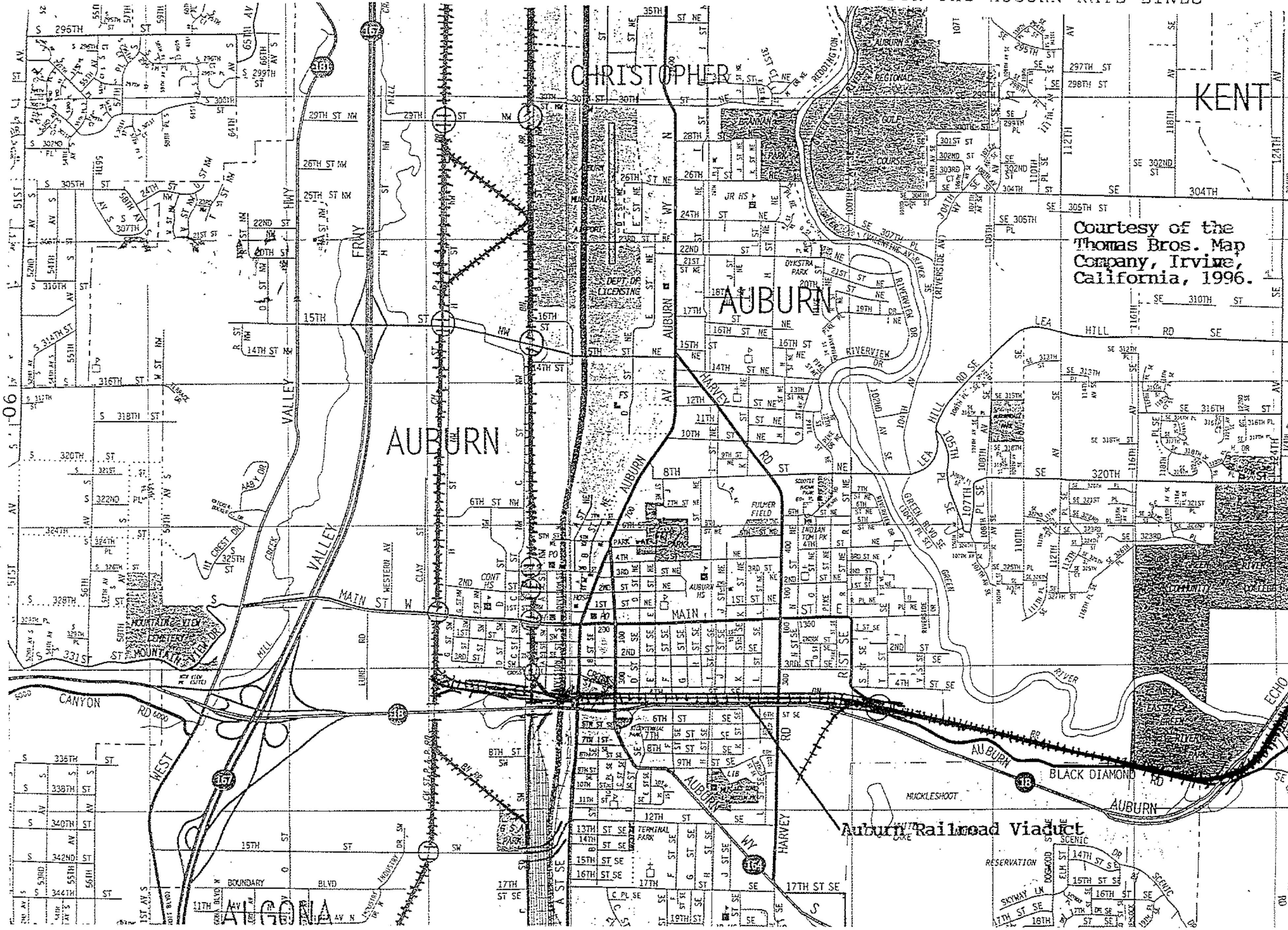
A major operational future advantage over a 7.8 mile tunnel length for heavy westbound oil and coal unit trains could then result with a maximum westbound grade of 1.1 to 1.5 percent. However, there would be a significant grade from Beverly to Boylston on the west side of the Columbia River east of Ellensburg but a relatively level grade on the east side of the Columbia River to Lind. This steep grade could be avoided by going over the existing single track rail line through the Yakima River Canyon between Ellensburg and Yakima, but this line is slow and laden with curves and difficult to double track. The remaining rail line through the Yakima Valley runs through relatively flat farm land to Pasco where it would join the existing BNSF Railway line to Lind and would then connect to the proposed Milwaukee Railroad rebuilding from Lind, Washington to Avery, Idaho and St. Regis, Montana to the Montana Rail Link line to Missoula and Helena to rejoin the BNSF Railway line from Helena to Havre for the oil trains and from Helena to Billings for the coal trains.

The alternative route for the oil trains and the coal trains would be to bypass Spokane by going over the above former Milwaukee Railroad route between Lind and St. Regis. However, this rail line option would go to the west to Warden and then to the north to connect with the BNSF Great Northern Ephrata Corridor line at Ephrata. The oil trains would then go between Ephrata and Havre without going through Spokane in order to reduce the oil volatility hazards in the urban area of Eastern Washington. These oil and coal trains would then go over the existing Stevens Pass and go through the newly double tracked 7.9 mile long tunnel at the same elevation as the existing tube. These heavy coal and oil unit trains would have grades of 1.6 to 1.8 percent or more on the east side and going town hill on 2.2 percent grades on the west side with oil and coal trains operating on the same tracks as intermodal trains.

VERTICAL ELEVATION PROFILE OF THE PROPOSED STAMPEDE PASS RAILROAD TUNNEL FROM LESTER TO EASTON



PROPOSED ROUTE LAYOUT OF GRADE SEPARATIONS AND OVERHEAD VIADUCTS FOR THE AUBURN RAIL LINES



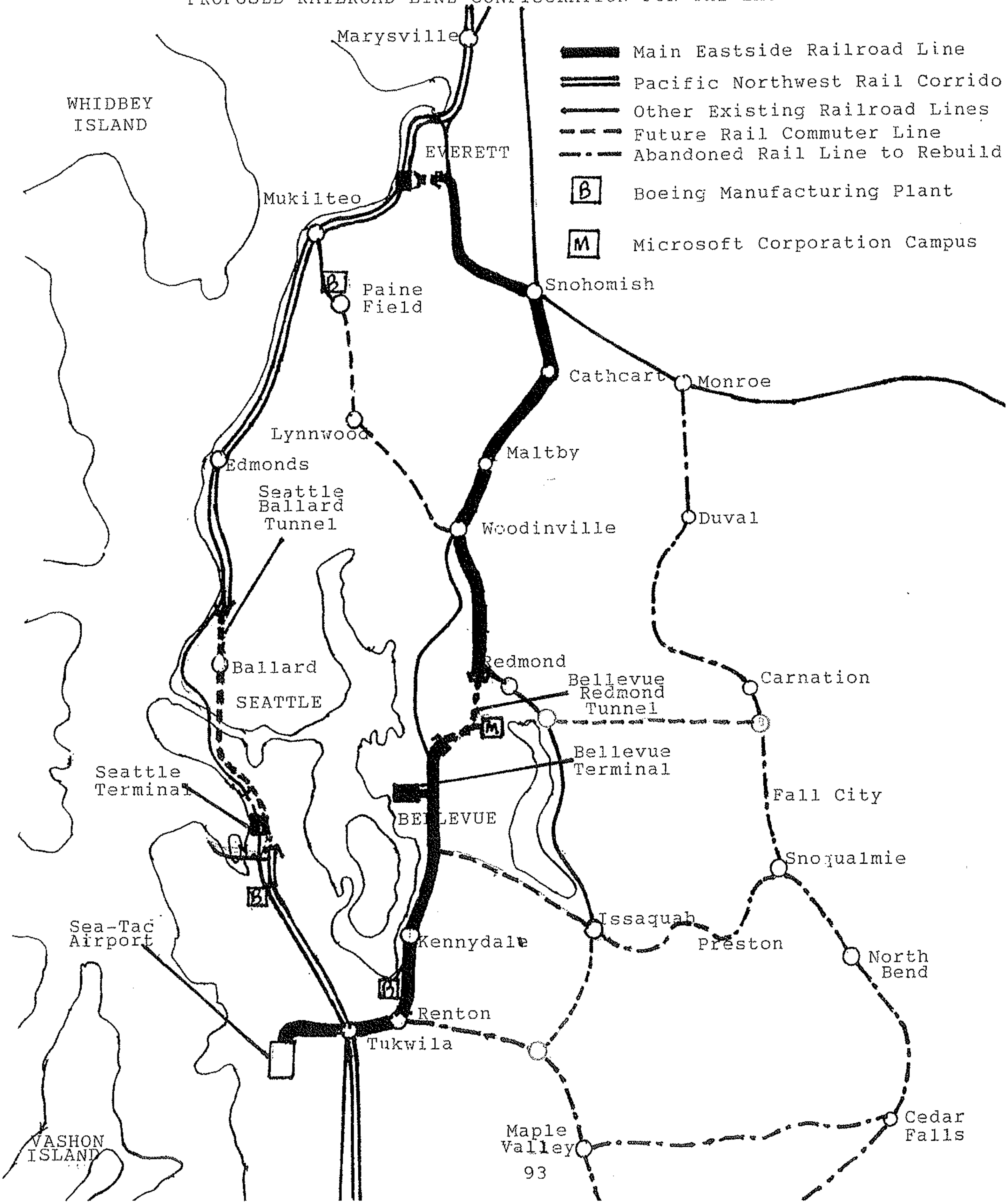
ARTIST CONCEPTION OF A FUTURE RAILROAD TUNNEL ENTRY AT STAMPEDE PASS NEAR LESTER, WASHINGTON

It will involve a tradeoff analysis to decide whether a single new tunnel tube at Stevens Pass or a new double track tunnel at Stampede Pass should both be built for intermodal container trains and oil plus coal unit trains either separately or in combination or that they both may be needed. The Cascade Foothills Corridor would be a necessary means for connecting the oil trains to the refineries at Anacortes, Cherry Point, Ferndale and Tacoma as well as to facilitate access for intermodal container trains to and from the Port of Seattle and Tacoma by way of the Maple Valley and Auburn connecting lines. In addition, the above improvements might just make it possible to provide for a commuter rail passenger connecting rail loop around Lake Washington between Seattle, Tukwila, Renton, Bellevue, Woodinville, Snohomish and Everett back to Seattle as a means of increasing Puget Sound area mobility.

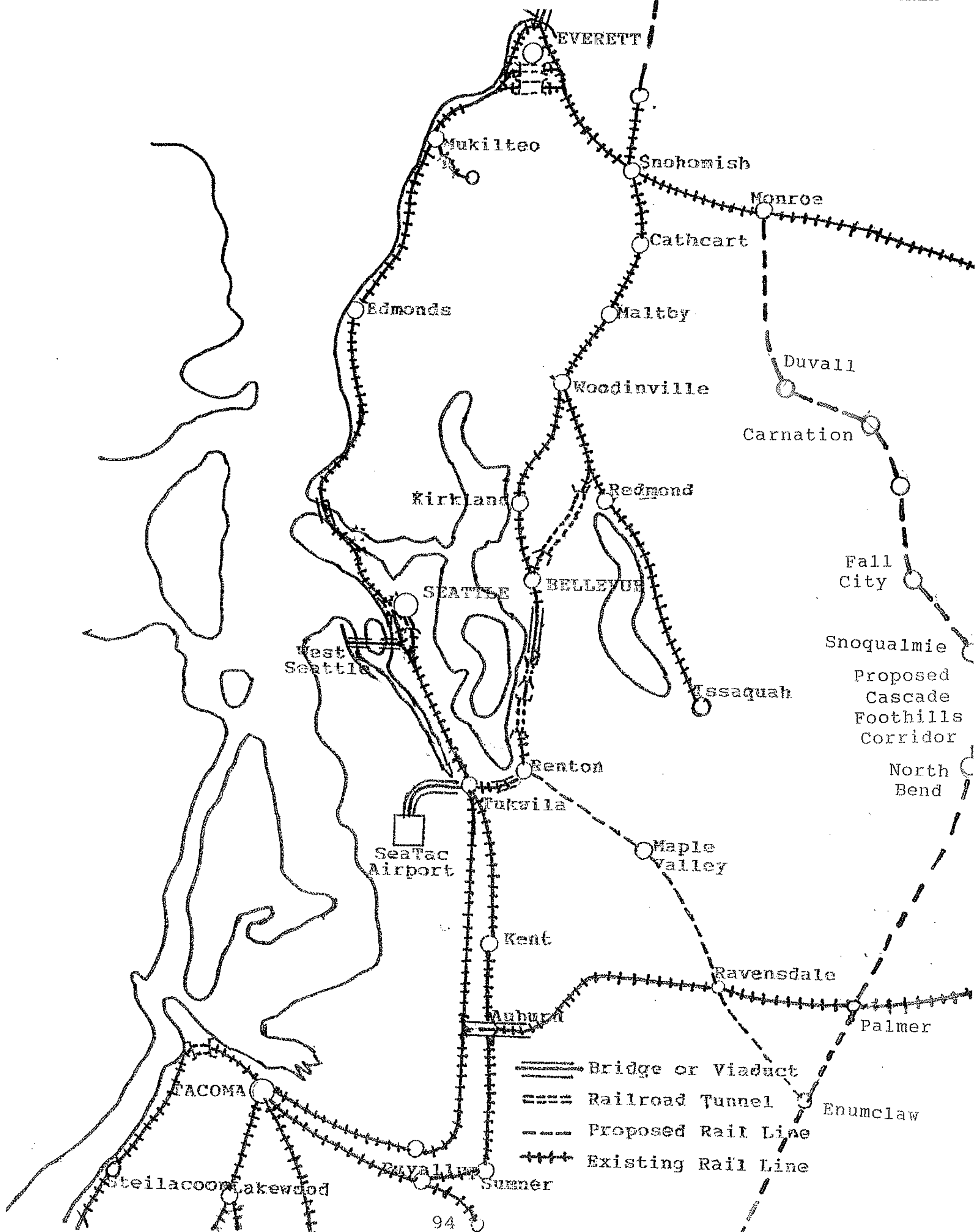
The proposed loop for commuter trains around Lake Washington would make use of the existing BNSF Railway main rail lines between Tukwila and Seattle and Everett as well as from Everett to Snohomish to Monroe. The Eastside rail line from Snohomish to Kenton has now been partially dismantled in Kirkland and Bellevue and would need to be rebuilt in order to renew rail service. The portion of the Eastside rail line from Woodinville to Snohomish has recently been purchased by Snohomish County for continued use as a freight railroad line with a future intermodal terminal at Maltby.

It is proposed that this entire loop around Lake Washington be rebuilt as a route for intercity passenger and urban commuter trains. It is possible that all of the main cities on the Eastside of Lake Washington would then be able to be accessed for both short and long distance passenger travel with major terminals in Seattle (existing) and Bellevue (proposed) with additional service planned to serve Redmond, Kirkland, Woodinville, Renton, Snohomish and Everett plus Tukwila and Shoreline and Mukilteo. Then it would become possible for rapid rail service to be implemented to all of the cities around Lake Washington as well as to have continued rail service.

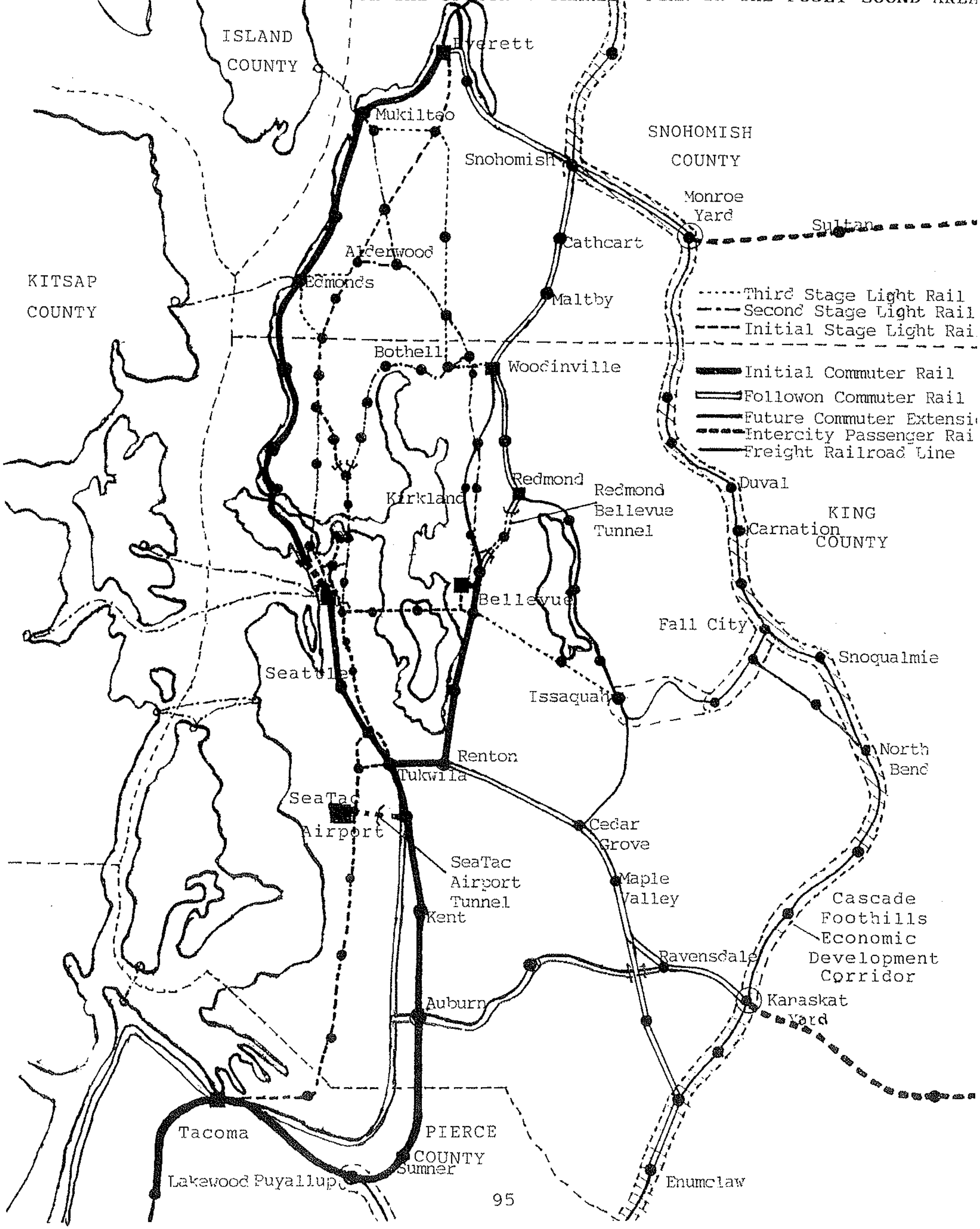
PROPOSED RAILROAD LINE CONFIGURATION FOR THE EASTSIDE



LOCATIONS OF EXISTING AND PROPOSED RAILROAD LINES IN THE PUGET SOUND AREA



THE PROPOSED ROUTE LAYOUT FOR THE OPTION 4 TRANSIT PLAN IN THE PUGET SOUND AREA

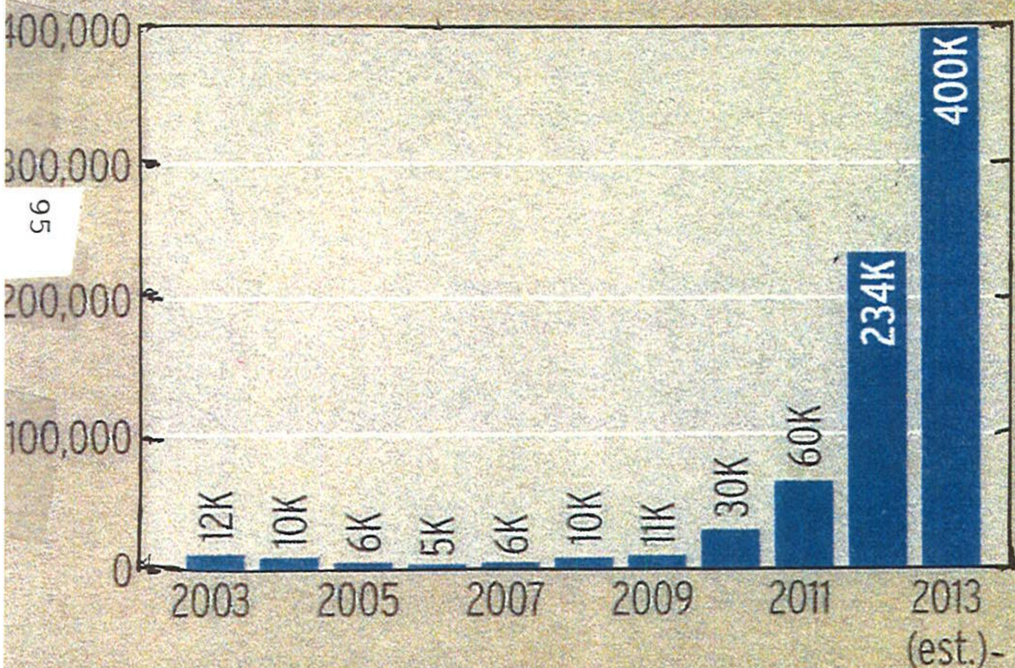


OBSERVED RECENT INCREASES IN CRUDE OIL SHIPMENTS BY RAILROAD IN THE UNITED STATES TO 2013

## OIL BY RAIL'S RAPID RISE

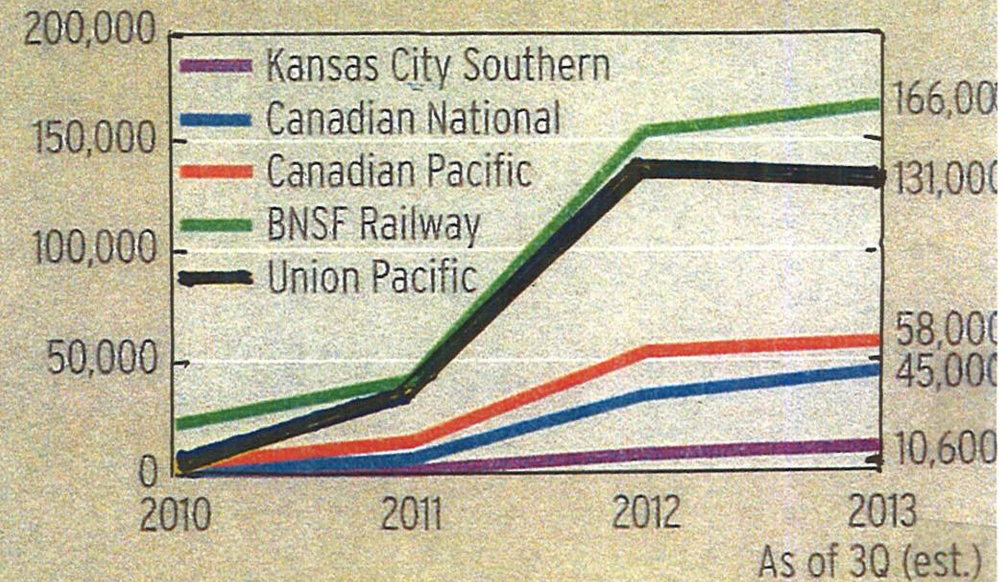


### Originated U.S. rail shipments of crude oil (carloads)



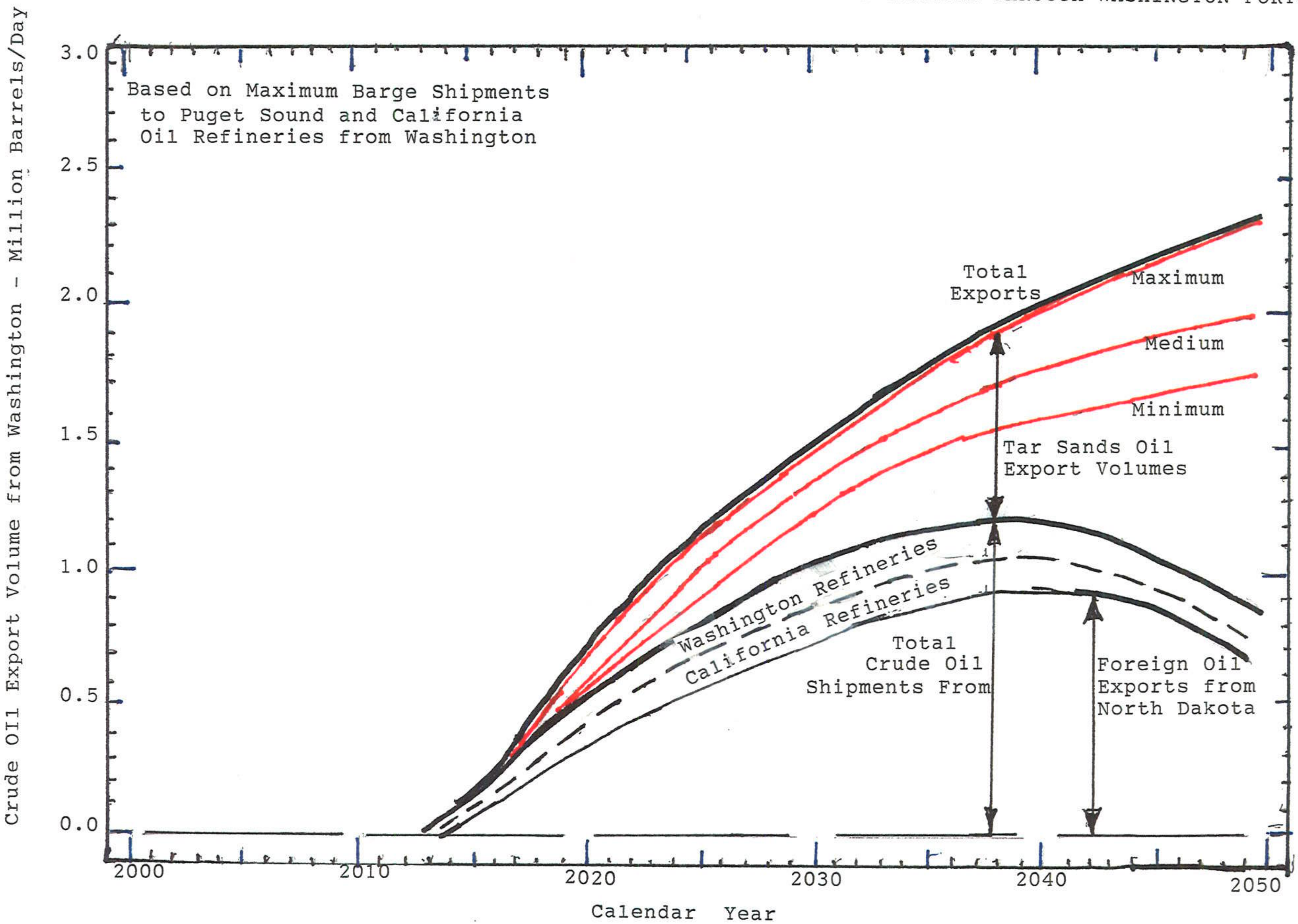

Source: Association of American Railroads

### Class I railroad crude oil shipments (carloads)




Source: Railroad annual reports and investor presentations

EXPECTED TRENDS IN CRUDE OIL EXPORTS FROM NORTH DAKOTA AND ALBERTA THROUGH WASHINGTON PORTS



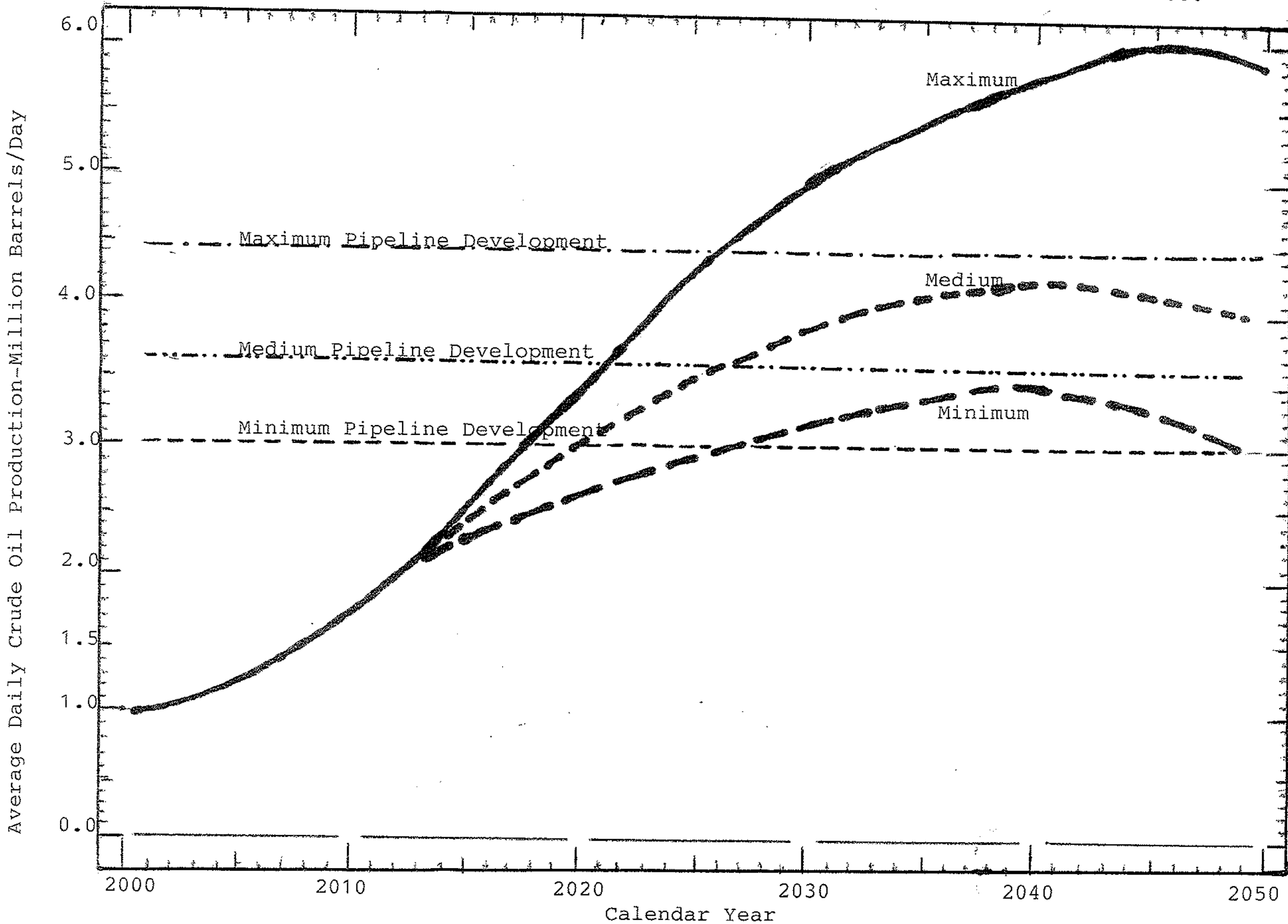
## OIL EXPORTS

It is possible that substantial quantities of crude oil and for petroleum products could be exported out of the State of Washington to other refineries or to other markets in the future. Barge services have already been proposed from the Port of Vancouver and from Grays Harbor to ship Bakken Formation light sweet crude oil delivered by rail from North Dakota to refineries in northwest Washington with at least four oil loading terminal projects in varying stages of regulatory permitting. In addition, there is already a small scale crude oil loading facility located at Clatskanie, Oregon on the Lower Columbia River where Bakken's Formation crude oil from North Dakota delivered by rail is then loaded onto barges and then shipped to refineries in California at a present rate of 15,000 barrels per day. It is very possible that large amounts of crude oil from North Dakota brought by rail would be shipped to overseas location after 2017 which could ultimately total between 1,000,000 to 1,500,000 barrels per day by 2030.

It is also possible that the heavy syncrude oil from the Athabasca tar sands in Alberta could be shipped by the existing or expanded pipeline networks between Edmonton, Alberta and Burnaby, British Columbia for either local use or overseas export from either Vancouver or Cherry Point. It is reported that some of this oil is now being refined at the Cherry Point refinery in Washington and could even be exported by tanker to California or to overseas locations. There is also the possibility that some of this heavy tar sands syncrude oil from Alberta is now or could be in the future hauled by rail from Edmonton to Kingsgate, British Columbia over Canadian Pacific Railway. This tar sands oil could then be hauled over the Union Pacific Railroad from Eastport, Idaho across eastern Washington and central Oregon via California along the interior route of the West Coast Corridor to Klamath Falls, Oregon and to Sacramento, California.

This syncrude oil from Alberta could then be shipped from Sacramento, California over the Union Pacific Railroad lines to the refineries in the Bay Area compatible with its use as well as to refineries in Southern California. Those refineries in California which are already configured to use the already native heavy oil from local fields in the San Joaquin Valley or the Los Angeles Basin are also amenable to utilize the similar grade heavy tar sands syncrude oil from Alberta without major retooling being required. It is estimated that the present local production of heavy oil in California is approximately 650,000 to 800,000 barrels per day which would be assumed to be used entirely by local refineries with no exports out of a total State consumption rate of 1,965,000 barrels per day.

ALTERNATIVE SCENARIOS FOR CRUDE OIL PRODUCTION INCREASES IN ALBERTA: 2000 TO 2050



The remaining 1,165,000 to 1,265,000 barrels per day of crude oil used either came from Alaska or from overseas locations such as from Indonesia or Malaysia.

Information supplied by the California Energy Commission indicates that between 60 and 70 percent of the State's crude oil refined is imported from outside of its borders. With Alaskan crude oil production steadily decreasing, more and more of California's crude oil supply comes fro outside the United States. Previous information supplied in this report indicates that as much as 500,000 barrels per day of Bakken Formation light sweet crude oil would be supplied to California refineries in the future along with up to 600,000 barrels per day to Washington refineries. This crude oil from North Dakota to go to California would follow the previously described route options along the BNSF Railway from Williston to Wishram, Washington on the Columbia River. These trains would then go by rail over the same eastern Oregon route from Celilo and Biggs through Klamath Falls to Sacramento described for the Alberta tar sands oil and then to the local refineries in the Bay Area or Southern California.

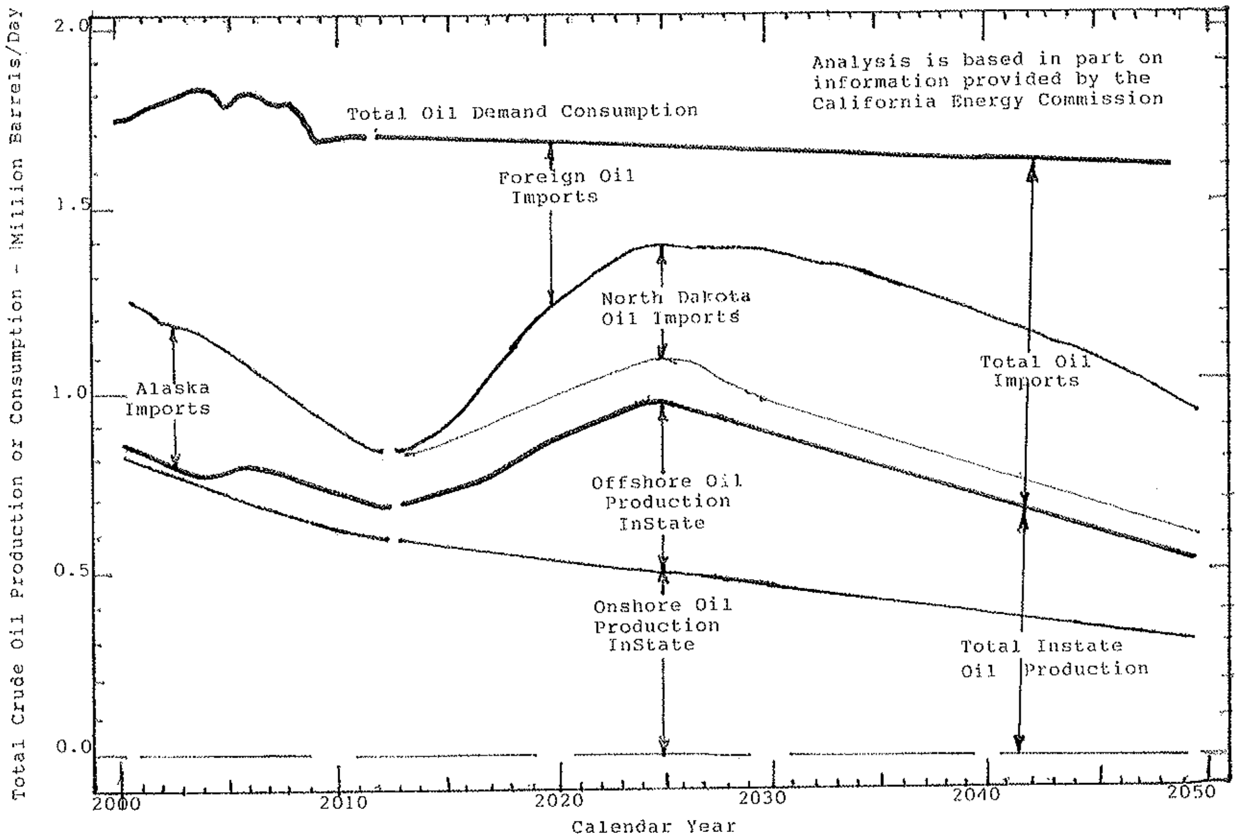
The alternative route for the light sweet crude oil from North Dakota would follow the same route as the other trains but not change routes at Wishram, Washington. These trains would then go to the west to a proposed terminal at Vancouver, Washington to a proposed new oil loading terminal at Grays Harbor after going north from Vancouver to Centralia, Washington over the BNSF Railway line. These crude oil trains would then be transferred to the local short line Puget Sound and Pacific Railway for the short trip to one of three proposal crude oil loading terminals at Grays Harbor near Aberdeen. This crude oil from North Dakota would then either be placed in barges for local refinery deliveries or placed in tankers and then shipped for export to overseas refinery locations. The other shipping option is to haul the trains over the Columbia River Bridge to Portland, Oregon and then go to the west to the present Clatskanie terminal near the mouth of the Columbia River which presently ships 15,000 barrels per day to California on an average daily basis.

The proposed construction of new crude oil loading terminals at Grays Harbor is going to require significant environmental mitigation measures to minimize and to prevent crude oil spills and damage to sensitive aquatic life, including shellfish. There will probably need to be shellfish bed isolation systems placed outside of the navigation channels along the shorelines where shellfish grow in order to separate their growing areas from contamination along with sea water conditioning and treatment.

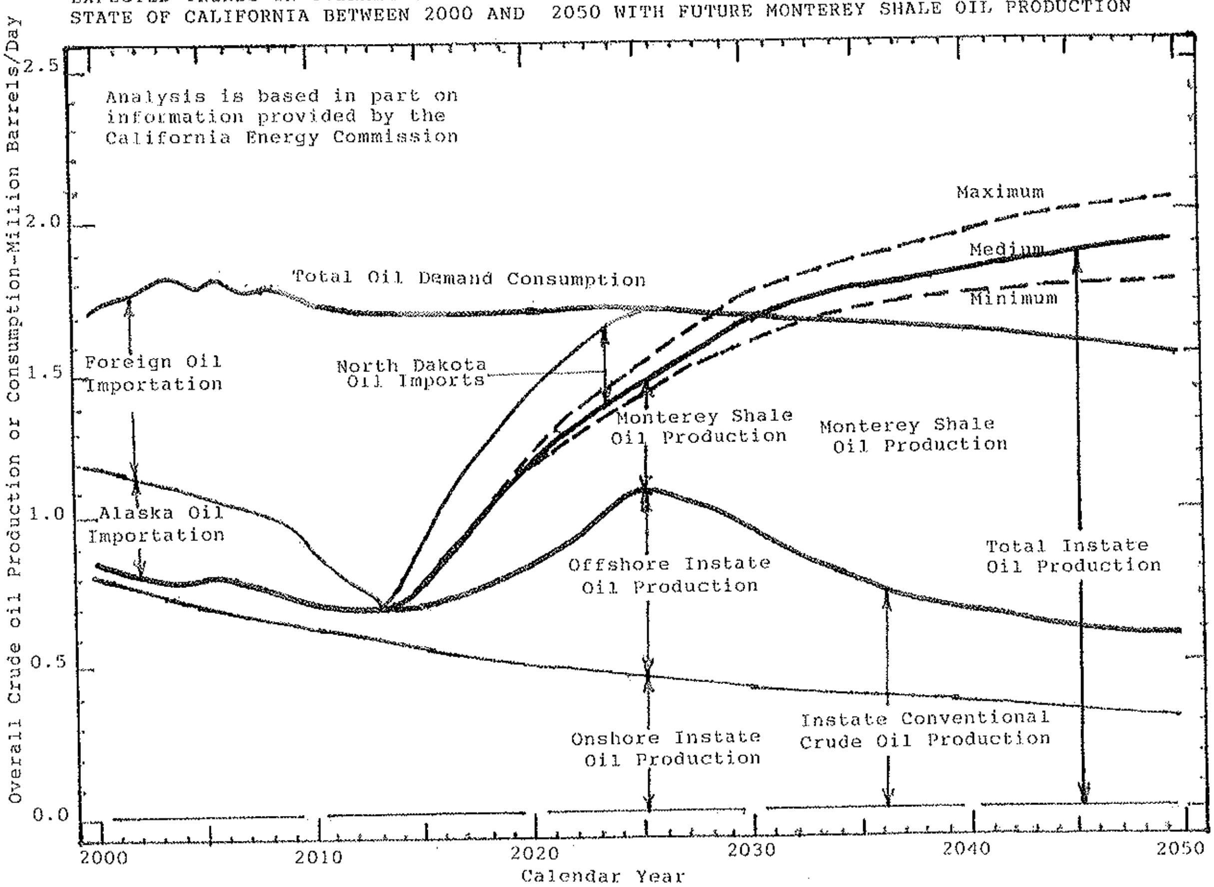
LOCATIONS OF THE BURLINGTON NORTHERN SANTA FE AND UNION PACIFIC RAILROAD LINES IN THE PACIFIC COAST STATES OF CALIFORNIA AND OREGON AND WASHINGTON

EXPECTED IMPACTS OF FUTURE INCREASED CRUDE OIL PRODUCTION FROM THE FUTURE MONTEREY SHALE FORMATION ON OIL PRODUCTION AND CONSUMPTION IN CALIFORNIA

EXPECTED TRENDS IN OVERALL CRUDE OIL PRODUCTION AND CONSUMPTION AND IMPORTS IN THE STATE OF CALIFORNIA BETWEEN 2000 AND 2050 WITHOUT INCREASED MONTEREY SHALE PRODUCTION




EXPECTED TRENDS IN OVERALL CRUDE OIL PRODUCTION AND CONSUMPTION AND IMPORTATION FOR THE STATE OF CALIFORNIA BETWEEN 2000 AND 2050 WITH FUTURE MONTEREY SHALE OIL PRODUCTION



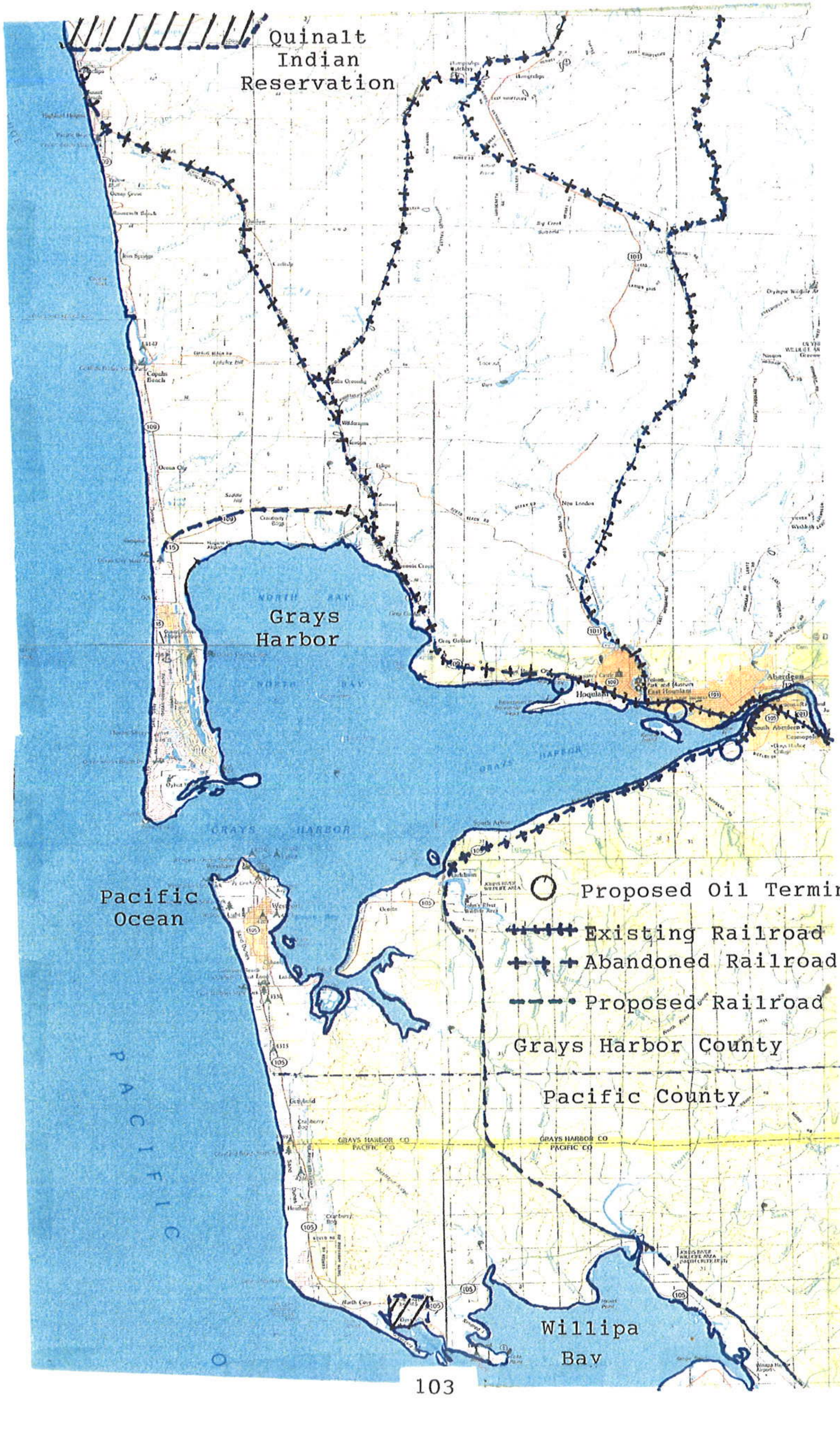
The local Coastal Indian Tribes in the Grays Harbor area rely of shellfish and seafood for their livelihoods and it is especially important to protect their interests. It is suggested that one means for obtaining this goal is to have the Fort Berthold and Quinalt Indian Tribes and others work together on a cooperative basis in terms of oil terminal ownership and operation plus crude oil rail shipment car ownership. It is estimated that crude oil exports of Bakken Formation oils could begin as early as 2017 with as much as 500,000 barrels per day if there are only barge shipments to California or only rail shipments to California.

Then North Dakota crude oil exports out of the Grays Harbor oil loading terminals to foreign countries could increase to as much as 1,000,000 barrels per day by 2020 and to as much as 1,500,000 barrels per day by 2030 and to as much as 2,000,000 barrels per day by 2040 in the extreme case of maximum production. It is also possible that the above value for North Dakota crude oil exports from the proposed Grays Harbor facilities could be as little as 500,000 barrels per day in the long term if there was substantial competition from other users for the light sweet crude oil from the Bakken Formation in North Dakota.

A significant factor which will impact future crude oil production in California and ultimately oil exports from the United States in the Monterey Shale formation. The Monterey Shale formation has a massive presence in the San Joaquin Valley between Taft and Stockton in a north-south direction which encompasses the east-west distance from the edge of the Salinas Valley and Coast Range to near the foothills of the Sierra Nevada. The Monterey Shale is reported to be between 300 and 500 feet thick with typical depths of 5,000 to 7,000 feet with massive crude oil reserves which have been estimated to between 300 to 500 billion barrels or more. The crude oil found in the Monterey Shale is typically of the heavy oils found in California with significant metals and high sulfur contents. The heavy oils found in the Monterey Shale tend to be somewhat similar to the heavy oils from Alberta so that they can be processed interchanges.

The State of California presently consumes approximately 1,650,000 to 1,700,000 barrels per day of oil which is essentially all refined within the State. California presently produces between 650,000 and 700,000 barrels per day of crude oil from onshore and offshore fields and has an import deficit of 1,000,000 to 1,100,000 barrels per day. Crude oil overall imports into California have been steadily increasing in recent years at a rate of 1.2 percent per year while Alaska crude oil use in California has decreased at a rate of 6.2 percent per year.

LOCATION OF THE GRAYS HARBOR CRUDE OIL LOADING TERMINALS AND FISHERIES



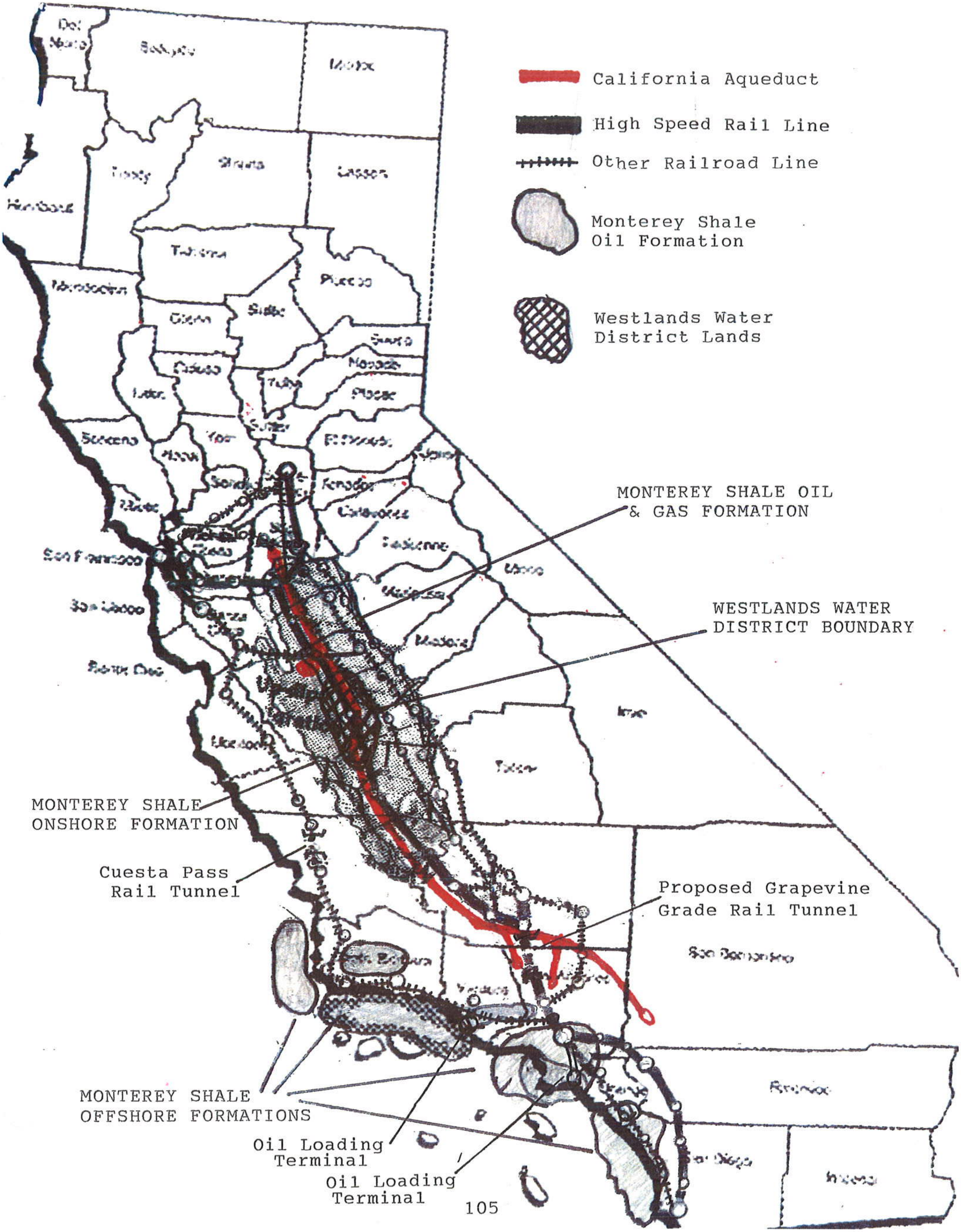
California imported an average of 15,000 barrels per day of crude oil from North Dakota by barge shipped from Clatskanie, Oregon. As a result, foreign oil imports into California have increased in recent years at a rate of 5.5 percent per year. California's overall oil consumption rate is expected to decrease from 1,750,000 barrels per day in 2010 to 1,450,000 barrels per day by 2030. Crude oil production from the existing onshore and offshore fields in California is expected to remain relatively steady at 800,000 to 850,000 barrels per day between 2010 to 2030.

The expected starting of crude oil production from the Monterey Shale is estimated as being as increasing from less than 10,000 barrels per day at present to between 900,000 and 1,400,000 barrels per day by 2050. As a result, California could cease to be a net oil importer by as early as 2025 and as late as 2030 with the expected future crude oil production of 650,000 barrels per day from the Monterey Shale within the State's boundaries. Afterwards, California would become a net crude oil exporter until after 2060 with its exports going primarily to oil refineries in China and India and elsewhere in Asia from the Monterey Shale oil fields.

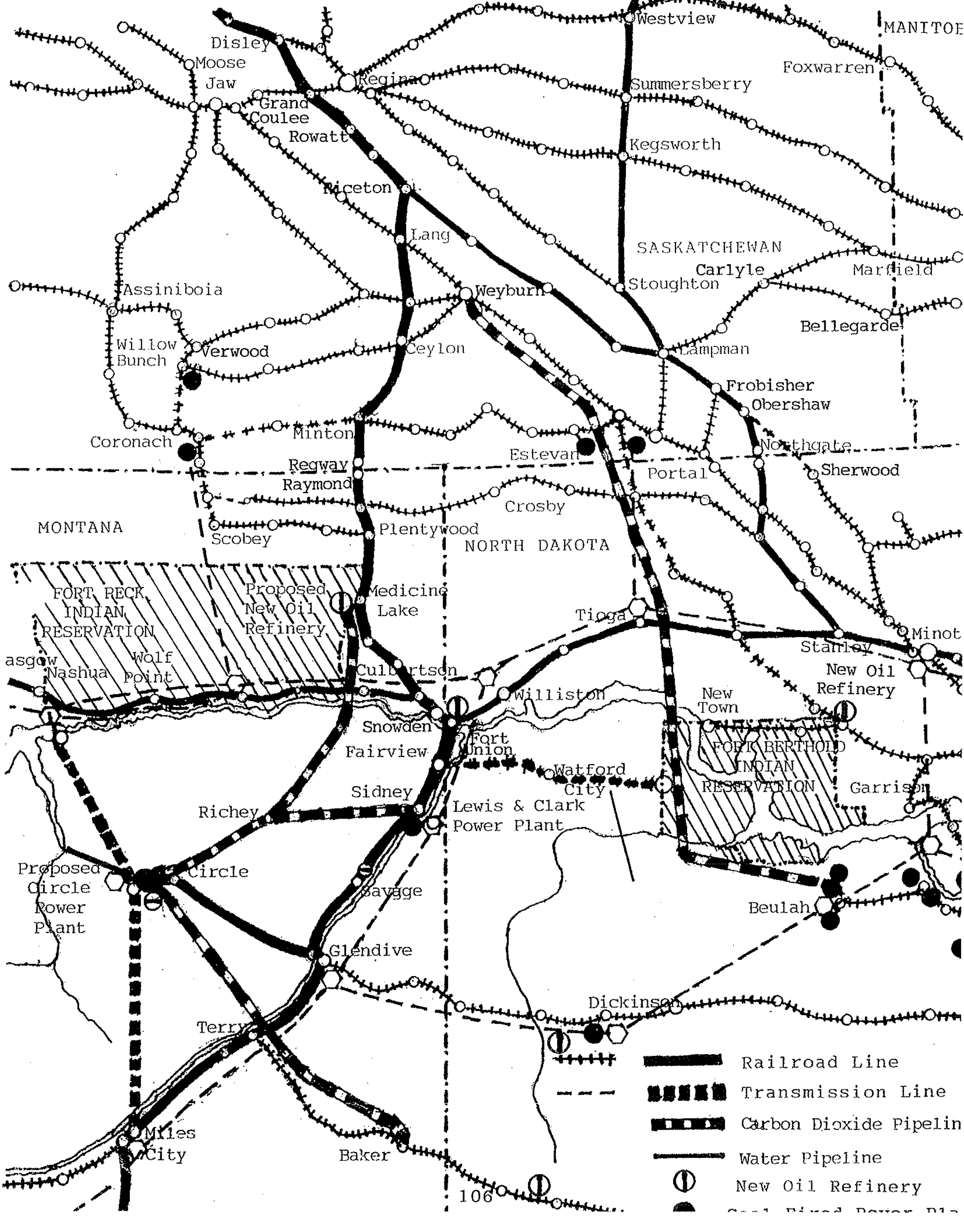
The end result of the development of the Monterey Shale oil formation in California is that it would in all probability not need to import any crude oil from the Bakken Formation in North Dakota by way of the State of Washington. As a result, incremental increases in crude oil exports from the State of Washington of the light sweet crude oil from the Bakken Formation in North Dakota would then occur as a net benefit to the proposed crude oil terminal in the State of Washington with increased through puts and jobs resulting. The State of Washington would then become richly benefited in its future role as the seaport for the State of North Dakota to serve light sweet crude oil exports from the Bakken Formation through the Port of Grays Harbor and elsewhere. New alliances could then be developed between the States of North Dakota and State of Washington as well as between the Interior Resource Indian Tribes and the Coastal Indian Tribes through the BNSF Railway and oil shippers.

It is also possible that additional new refineries could be built in North Dakota, South Dakota and Montana to process the North Dakota crude oil so that petroleum products could then be exported, including through the Port of Grays Harbor. It is even possible that the present oil refinery at Makoti, North Dakota by the Fort Berthold Indian Tribes would be used as a model for other refinery locations, including at Grays Harbor. Such an arrangement might be beneficial if the existing crude oil reserves in the State of Washington were ever to be developed in the future.

LOCATION OF THE CALIFORNIA HIGH SPEED RAIL SYSTEM AND THE MONTEREY SHALE OI



INTERNATIONAL RAILWAY CONNECTOR BETWEEN MONTANA NORTH DAKOTA AND SASKATCHEWAN



## INDIAN RESERVATIONS

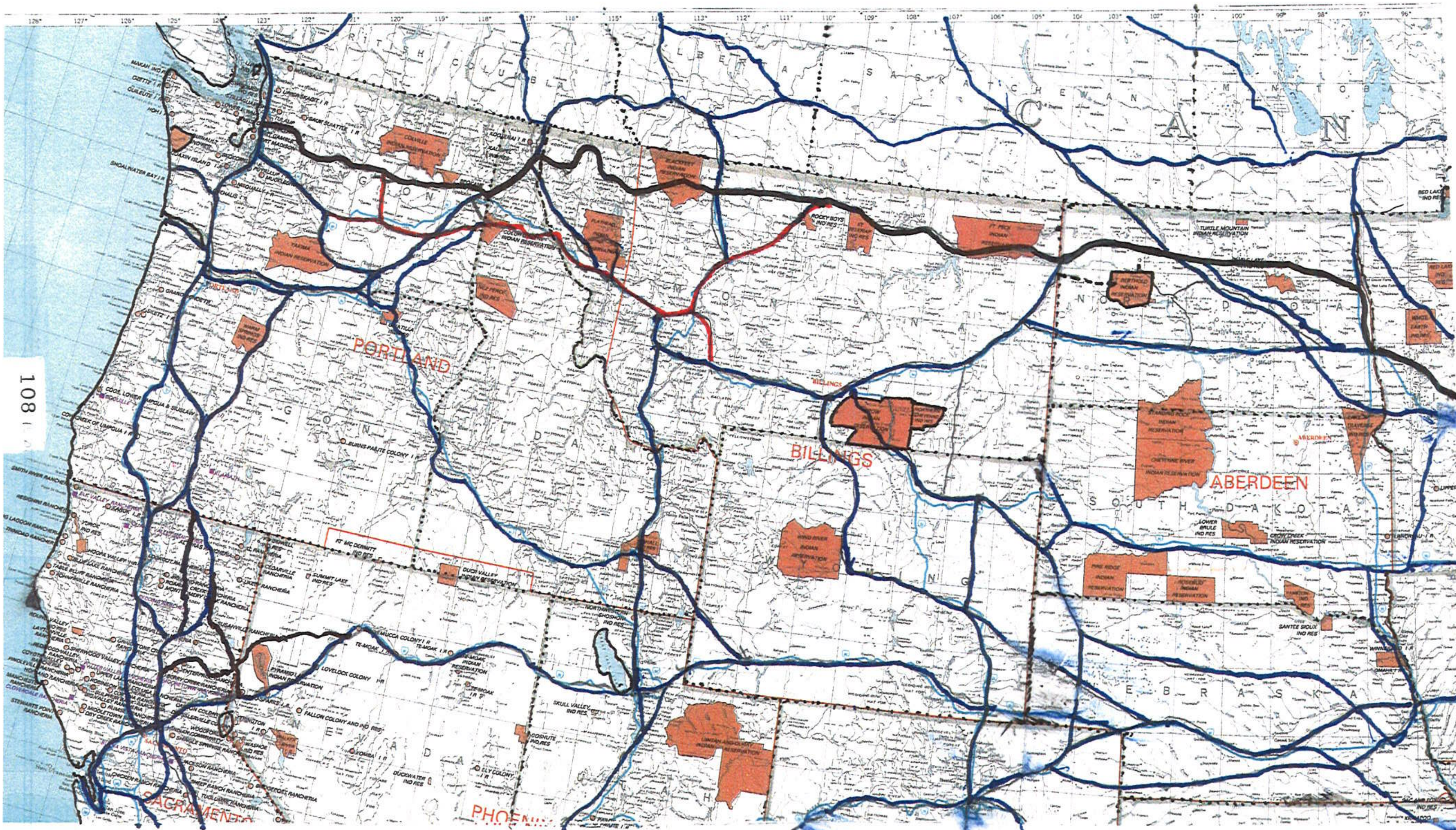
There are a number of Indian Reservations along and adjacent to the Great Northern Corridor across the Northern Tier between the Pacific Coast and Lake Michigan from Seattle and Portland to Milwaukee and Chicago. There are at least 99 Federally registered Indian Tribes located in the ten states along the Northern Tier with at least 15 to 20 Reservations either along or in immediate proximity to the Great Northern Corridor when the southern and northern corridor routes are included. The Indian Tribes can be considered as being Interior Tribes or Coastal Tribes with the Interior Tribes further being categorized as being either Resource or non-Resource Tribes at all Reservations across the Northern Tier over the Great Northern Corridor.

The present primary economic activities of the Interior Indian Tribes are related to forming and ranking with some mining in addition to energy development for the Interior Resource Tribes. The primary economic activities of the Coastal Indian Tribes are involved with fishing and forestry where such resources are available. There is also a generalized economic activity relating to gaming and entertainment on most Indian Reservations along the Northern Tier because most of the Tribes have casinos which normally include hotels and restaurants which include nightclubs.

The tends to be a definite difference between the Interior Resource Tribes and the Coastal Fishing Tribes in terms of their economic interests and cultural views involving economic development in general and energy development in particular. However, all Indian Tribes regard land and water as being sacred and in need of long term environmental protection from the ravages of mankind, especially with regard to the White Non Indian portion. To its credit, the Burlington Northern Santa Fe Railway has always tended to work on a cooperative basis with the Indian Tribes along its routes to the best extent possible. The Burlington Northern Santa Fe Railway has always maintained a favorable policy towards the hiring of Native Americans from the local Reservations along their lines, especially for track and facility maintenance in the field for which they are well-qualified.

From the standpoint of the Interior Resource Tribes, their ability to produce crude oil and natural gas along with the mining of coal makes them important in terms of supplying energy. The Fort Berthold Indian Reservation in western North Dakota with its headquarters at New Town west of Minot is not directly on or along the BNSF Railway Great Northern Corridor, but it is in close proximity to the terminals for truck transport.

LOCATION OF INDIAN RESERVATIONS ALONG THE GREAT NORTHERN CORRIDOR OF THE BNSF RAILWAY



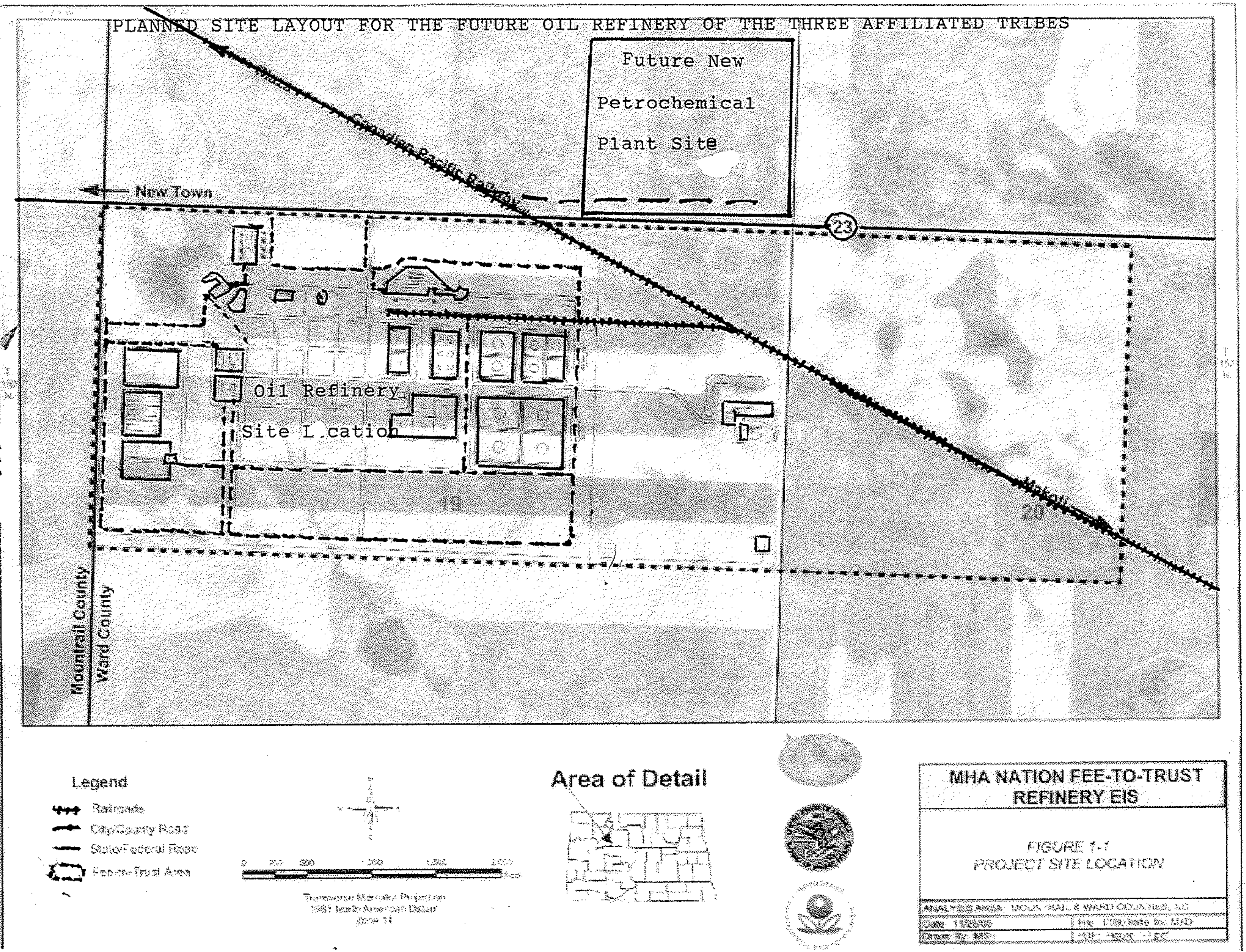

108

However, it is in a central location because of its being located on top of the center of the Bakken Formation oil field in west central with very large crude oil and natural gas reserves under its lands. Fort Berthold serves as the eastern generation point for crude oil shipments to the future crude oil ports to be developed in the Pacific Northwest as the delivery points.

The Fort Berthold Indian Reservation is estimated to hold as much as 25 billion barrels of total oil reserves under its lands, and presently produces 135,000 barrels per day of crude oil from over 1,000 wells. It is possible that there could be as many as 3,000 producing wells within five years and up to 5,000 producing wells within ten years with as much as 300,000 barrels per day of crude oil. The Fort Berthold Indian Reservation presently produces approximately 57 percent of the total crude oil of all of the 596 federally registered Indian Tribes in the United States. Fort Berthold is viewed as the future guidepost for energy and economic development for all of Native America. There will be the new 15,000 barrel per day Black Thunder oil refinery in operation on the Fort Berthold Reservation by the end of 2014 with other future projects also being considered, which may include a parallel petrochemical plant.

The Fort Berthold Indian Reservation is located in west central North Dakota on approximately 1,200,000 acres of land with dimensions of 30 by 50 miles in a generally rectangular configuration. The Fort Berthold Reservation has the Little Missouri River and the main Missouri River flowing through it which is entirely behind Garrison Dam on Lake Sakakawea. The Three Affiliated Tribes on the Fort Berthold Reservation are the Mandan Hidatsa and Arikara Nations where the main towns on the Reservation are at New Town and Mandaree and Parshall. The east side of Lake Sakakawea is primarily level farm land for wheat growing while it is primarily hilly on the west side with oil and gas production plus cattle ranching as the major activities. The Reservation has a large casino and hotel at New Town at the north end. The Tribe combined has approximately 13,000 enrolled members with 10,000 living on the Reservation along with approximately 5,000 non-Tribal members as residents in addition.

The Crow Indian Tribe in southeastern Montana is a Hidatsa Nation with its headquarter at Crow Agency near Hardin in southeastern Montana. The Crow Tribe has a total of seven major towns where 8,000 of the Tribe's 11,000 enrolled members reside with coal mining and cattle ranching as its major economic activities. The Crow Reservation has an estimated 20 billion tons of medium to high grade subbituminous coal sitting under its lands which total 2,300,000 acres as a major resource.


PLANNED SITE LAYOUT FOR THE FUTURE OIL REFINERY OF THE THREE AFFILIATED TRIBES
Future New
Petrochemical
Plant Site
New Town
Canadian Pacific Railway
23
Oil Refinery
Site L.cation
19
20
Mountrail County
Ward County
Legend
Railroads
City/County Road
State/Federal Road
Fee-to-Trust Area
Area of Detail
MHA NATION FEE-TO-TRUST
REFINERY EIS
FIGURE 1-1
PROJECT SITE LOCATION

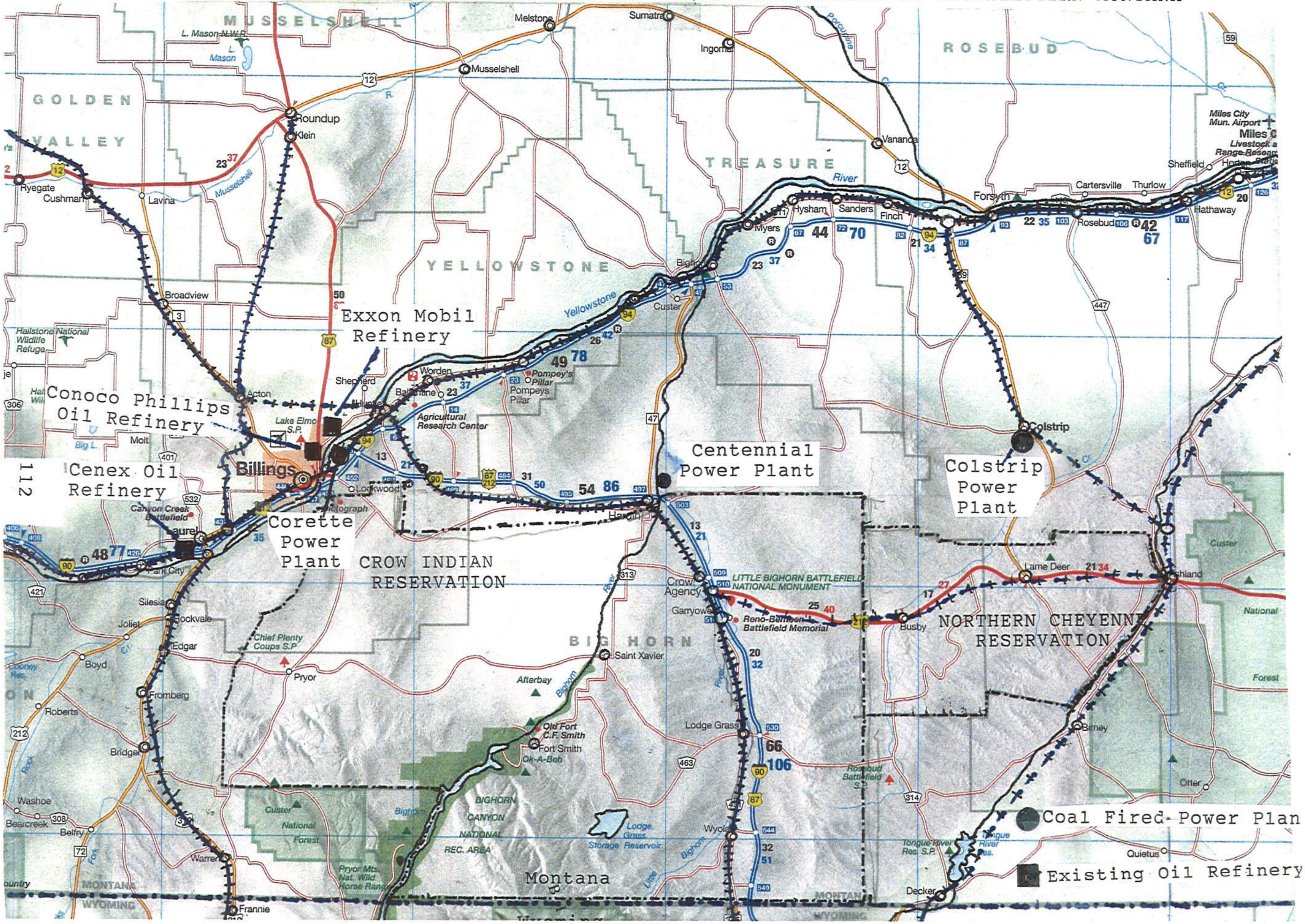
Presently coal mining is going on at the Crow Indian Reservation in southeastern Montana at a rate of approximately two million tons per year by the Westmoreland Coal Company in an exclusive joint venture agreement with the Crow Tribe. The coal from the Crow Tribal lands is presently being shipped by rail over the BNSF Railway line to a variety of electric utility customers as well as being delivered by truck to the adjacent 120 megawatt Centennial power plant located immediately off of the Reservation near Hardin.

Both the Fort Berthold and the Crow Indian Tribes are desirous of having their respective fossil fuel products shipped to offsite customers by rail over the BNSF Railway lines, including to the State of Washington in the Pacific Northwest. The Fort Berthold Indian Reservation houses the Three Affiliated Tribes of the Mandan Hidatsa Arikara Nation in western North Dakota with the very large crude oil reserves. The Three Affiliated Tribes have their oil hauled by rail in tank cars over the BNSF Railway's northern route of the Great Northern Corridor to either the east or to the west to oil refineries. They also have their own refinery at Makoti.

This crude oil first goes through the Tesoro pipeline network or its hauled by truck to one or more of the loading terminals between Minot and Williston along the BNSF Railway main line on the Great Northern Corridor. This crude oil can then be hauled to the Tesoro refinery at Anacortes, Washington or to their refineries in Martinez or Wilmington in California or to other customers over the BNSF Railway. This crude oil can also be hauled by rail to Clatskanie, Oregon over the BNSF Railway and the short line from Portland and is then loaded into barges for shipment to refineries in California over the Pacific Ocean. These oil trains are routed over the BNSF Great Northern Corridor from Williston, North Dakota to Spokane, Washington and then on the Columbia River line to Pasco and Vancouver, Washington and then to the north.

The coal coming from the mines at the Crow Reservation is delivered by truck or conveyor to the loading track along the BNSF Railway line between Billings, Montana and Gillette, Wyoming near Hardin. This coal can then be hauled by unit train to power plants or loading terminals in the Pacific Northwest as at Roberts Bank in southwestern British Columbia near Vancouver. This coal from the Crow Reservation can also be hauled to power plants in the eastern, central or southern United States.

LOCATIONS OF THE CROW AND NORTHERN CHEYENNE INDIAN RESERVATIONS IN SOUTHEASTERN MONTANA



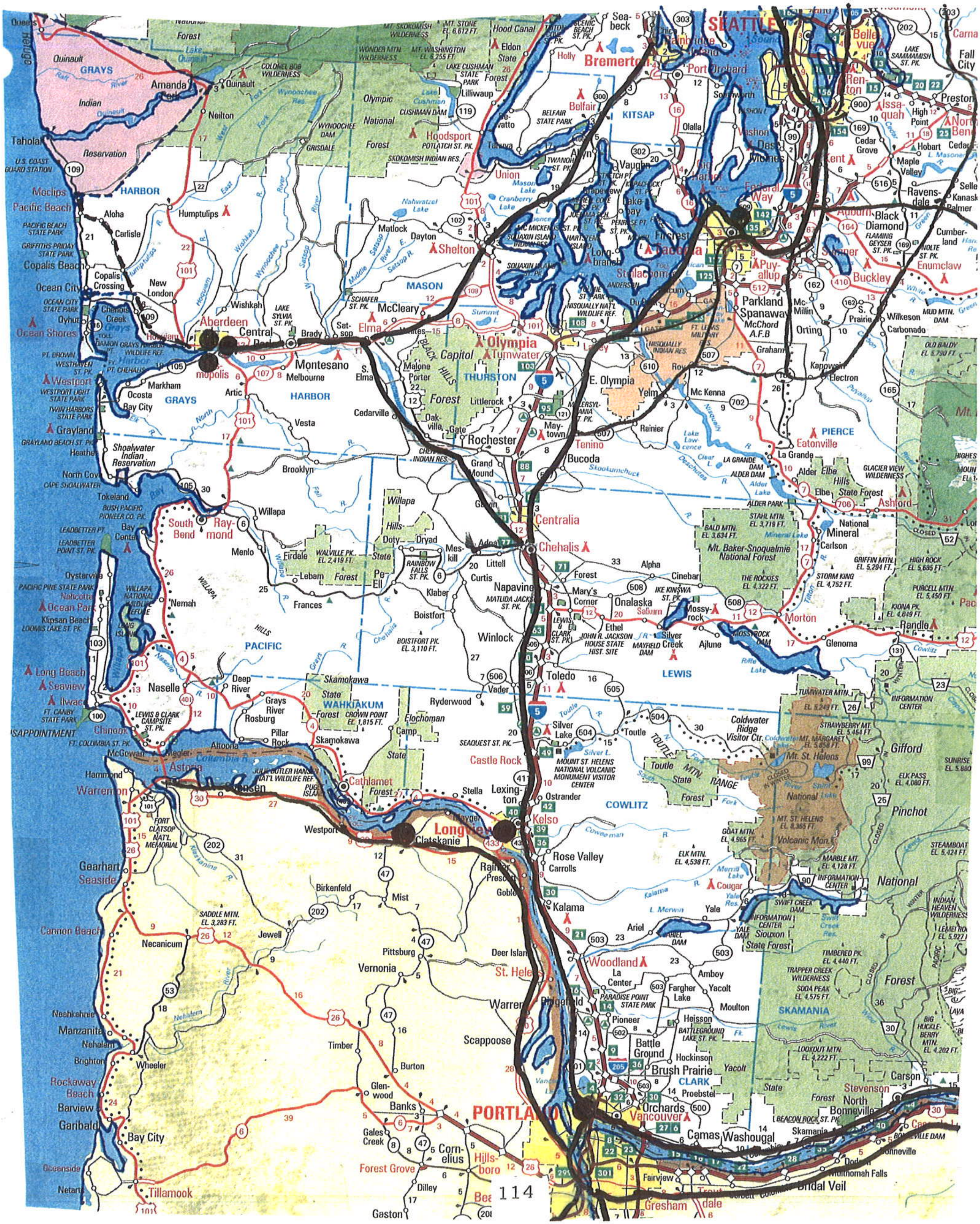
The coal being hauled to the Pacific Northwest would go to either the Centralia or Boardman power plants or to the Roberts Bank terminal at Tsawwassan near Vancouver, British Columbia in Canada at present or to future coal terminals at Vancouver or Longview in southwest Washington or to the Cherry Point terminal near Bellingham in northwest Washington.

The direction of these coal unit trains originating from the Crow Indian Reservation would be routed by way of the Montana Rail Link line across southern Montana from Billings to Sandpoint, Idaho by way of Billings and Helena and Missoula. These coal trains would then go over the BNSF Railway main line from Sandpoint to Spokane and along the Columbia River line through Pasco, Wishram and Vancouver, Washington. These coal unit trains could then be unloaded onto ships at the proposed coal terminal at Vancouver, Washington or then hauled to the north over the BNSF Railway main line to the alternative proposed coal unloading terminal at Longview, Washington. This coal would then be taken from Longview or Astoria down to the mouth of the Columbia River at Astonia and then across the Pacific Ocean to terminals in China or India or Japan or elsewhere. This coal can then burned in power plants to generate electricity or else used for industrial processing as well as to supply their critically needed energy.

The coal not being unloaded at the proposed terminals in Vancouver or Longview, Washington could then be hauled to the north over the BNSF Railway main line through the Puget Sound area. This coal could then be unloaded at the proposed new bulk cargo terminal at Cherry Point for export or else hauled the added short distance across the U.S. – Canada border at Blaine, Washington to the existing Roberts Bank coal terminal at Tsawwassen on the Georgia Strait near Delta, British Columbia in the Lower Mainland. The above described routing presumes that these coal unit trains would be operated over the existing Montana Rail Link and BNSF Railway main lines across southern Montana and northern Idaho. The coal trains can then go to the south along the level but circuitous Columbia River line to Vancouver, Washington and then up the existing BNSF Railway main north south line between Portland, Oregon and Seattle, Washington and Vancouver, British Columbia.

These coal and oil unit trains going along the north side of the Columbia River from Pasco to Vancouver, Washington over the existing largely single track BNSF east-west main line are adding to the already significant freight traffic volumes which exist along this single track line.

LOCATIONS OF THE PROPOSED COAL AND OIL LOADING TERMINALS IN WASHINGTON



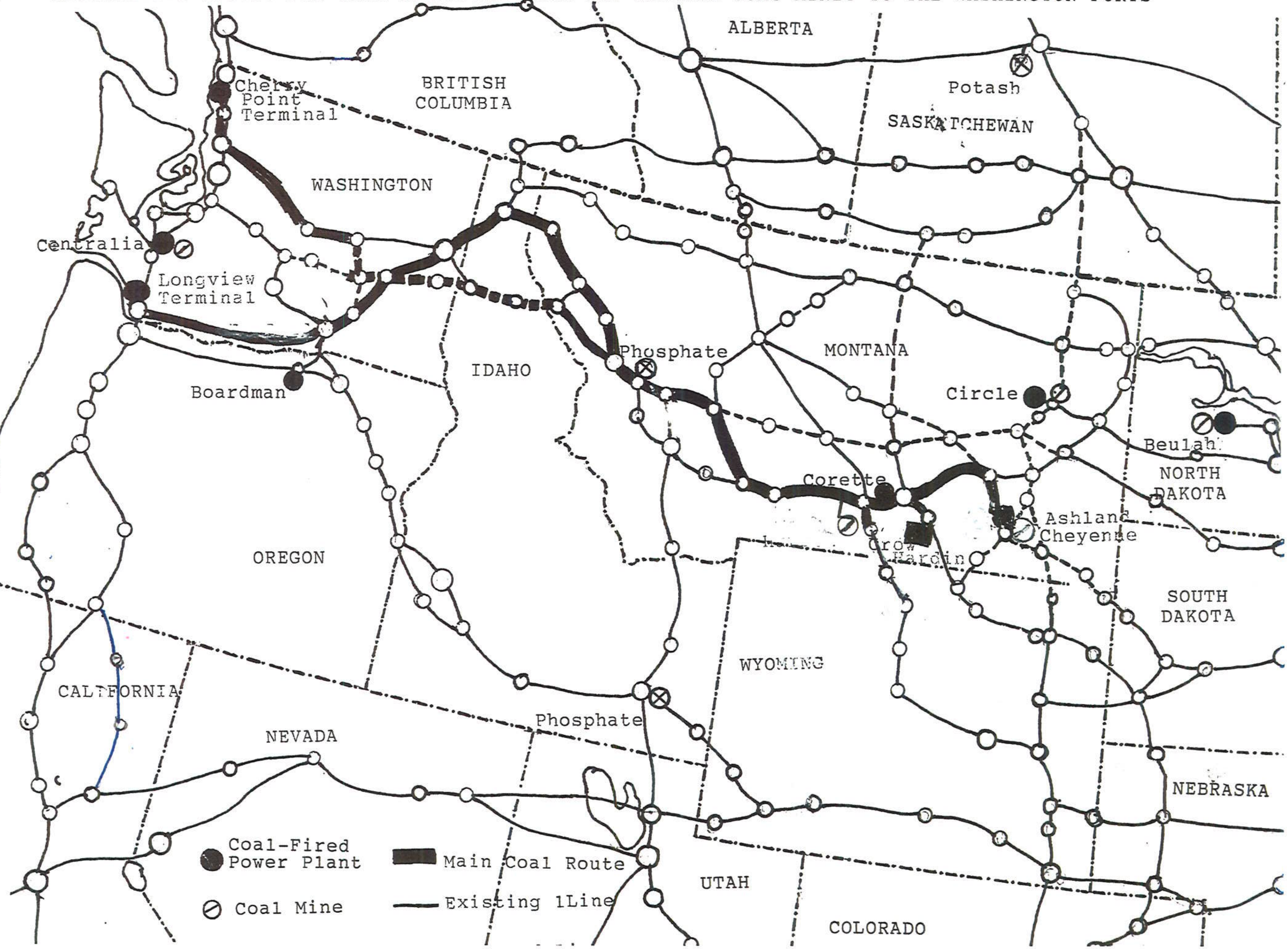
The Columbia River line of the BNSF Railway goes along the north shore of the largely dammed Columbia River with steep sloped where there may be major difficulties in adding a second or third main track. As a result, it may be necessary in the future to consider the alternative routes for these coal and oil unit trains through the Cascade Mountains to the north where new tunnel tubes will likely be required over the Stevens or Stampede Passes.

The other problem with the operation of coal and oil unit trains along the existing BNSF Railway main existing routes is that it will be necessary to go through the Puget Sound metropolitan area and especially through the City of Seattle. This existing routing of unit trains carrying coal and oil through Seattle brings public awareness and complaints from concerned citizens and environmental groups. There is also concern with the potential for oil spills and explosions plus coal dust entrainment along with traffic delays at crossings and the possibility of accidents at grade crossings which might cause injuries or fatalities in transporting coal and oil.

The delivery of coal or oil to the refineries or terminals along the Washington Coast by rail unit trains also create the potential for adverse complaints from affected Indian Tribes along or adjacent to the transit routes to the loading terminals or refineries. The proposed delivery of coal or crude oil to these terminals or refineries has created at all of the potential delivery routes involving noise, dust, vapor releases, plus fires and possible explosions and where direct and indirect environmental impacts may occur on water and air quality and fishing. These concerns have been raised in particular by the Quinault Indian Tribe in the Grays Harbor area near Aberdeen in order to protect fishing rights over the three proposed new crude oil terminals. In addition, there have been complaints by the Lummi Indian Tribe in northwest Washington near Bellingham over the proposed coal and oil loading terminal at Cherry Point near Birch Bay.

The proposed Cascade Foothills Corridor around Puget Sound between Tenino and Sumas makes it possible for coal and oil unit trains to completely avoid going through Seattle. The Cascade Foothills Corridor also makes it possible to provide access from all three of the potential entry routes into the Puget Sound area over or through or around the Cascade Mountains at Stevens Pass, Stampede Pass and the Columbia River. The Cascade Foothills Corridor also makes it possible for the coal and oil unit trains to be able to avoid direct crossing of any Indian Reservations or Indian Lands which now occur anywhere along the existing BNSF Railway main line in western Washington or the Puget Sound Metropolitan area.

ALTERNATIVE ROUTES FOR COAL TRANSPORT FROM THE MONTANA COAL MINES TO THE WASHINGTON PORTS



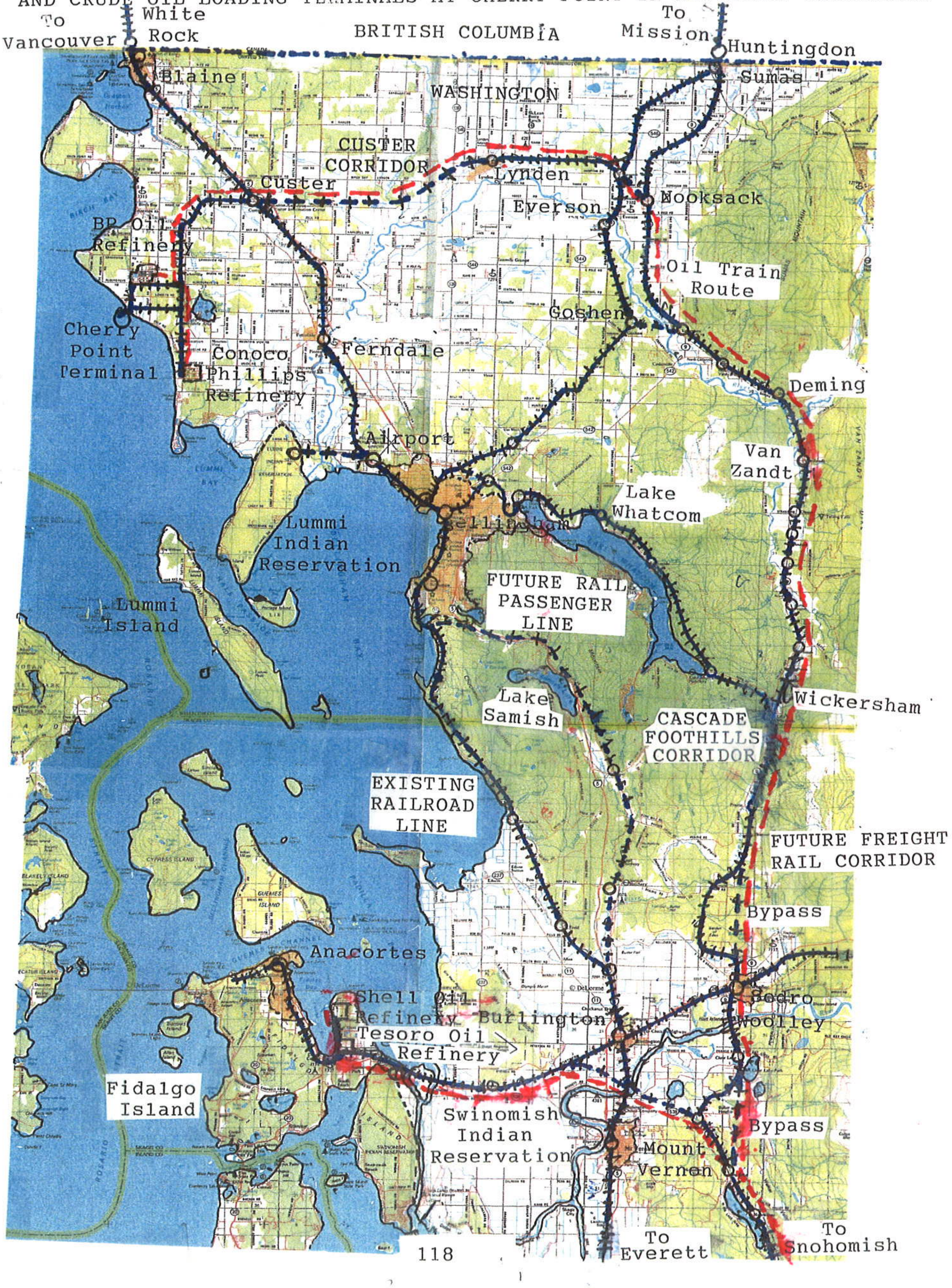
It will be necessary to take extra precautions in order to protect the existing Puget Sound and Pacific short line railroad route from Centralia to Aberdeen to prevent derailments or explosions or accidents with crude oil unit trains going to future terminals at the Port of Grays Harbor. It will also be necessary to take additional measures to prevent marine oil spills at the three proposed crude oil loading terminals at the Port of Grays Harbor which may include enclosing ship loading areas with protective booms and having special waste water treatment facilities to prevent contamination. It may also be necessary to employ separate waste water marine outfalls directly into the Pacific Ocean and not into Grays Harbor as well as to have enclosed fishing and shellfish harvesting areas to prevent any exposure to marine oil spills with separate ocean water access for the ships.

The most directly impacted Indian Tribes near the proposed coal and oil loading-unloading terminals for Pacific regional exports are the Lummi Tribe near Ferndale in northwest Washington and the Quinault Tribe near Grays Harbor in southwest Washington. It is planned to construct large oil and coal unloading terminals at Cherry Point to the west of Ferndale which is approximately seven miles north of the Lummi Indian Reservation on the Georgia Strait. The proposed coal loading terminal at Cherry Point is at the end of a railroad spur which is between the existing British Petroleum (BP) and Conoco Phillips (CP) refineries near Ferndale serving both facilities.

The proposed routing of these coal unit trains over the new Custer Corridor rail line to connect from the Cascade Foothills Corridor between Nooksack and Custer to Cherry Point would eliminate the chose exposure of less than one mile from the present BNSF Railway main line. It is possible that the Cherry Point site could become an additional crude oil loading terminal in the future as well as for coal. However, the crude oil which would then be loaded into tankers for export would more likely be the heavier Athabasca tar sands syncrude oil from Alberta which is much less volatile than the Bakken Formation light crude oil. It is reported that the existing refinery of British Petroleum at Cherry Point already receives some syncrude oil from Alberta via pipeline by way of the Burnaby, British Columbia export terminal at the present time.

The Lummi Indian Reservation relies on fishing and recreation for its primary economic activities as the majority of its members work offsite in the adjacent Bellingham urban area. The Lummi Tribe has an estimated 5,000 enrolled members of which 2,500 live on the Reservation, which has a total of 6,500 residents who are located on the peninsula and island.

LOCATIONS OF THE FERNADLE AND ANACORTES OIL REFINERIES PLUS THE COAL AND CRUDE OIL LOADING TERMINALS AT CHERRY POINT IN NORTHWEST WASHINGTON



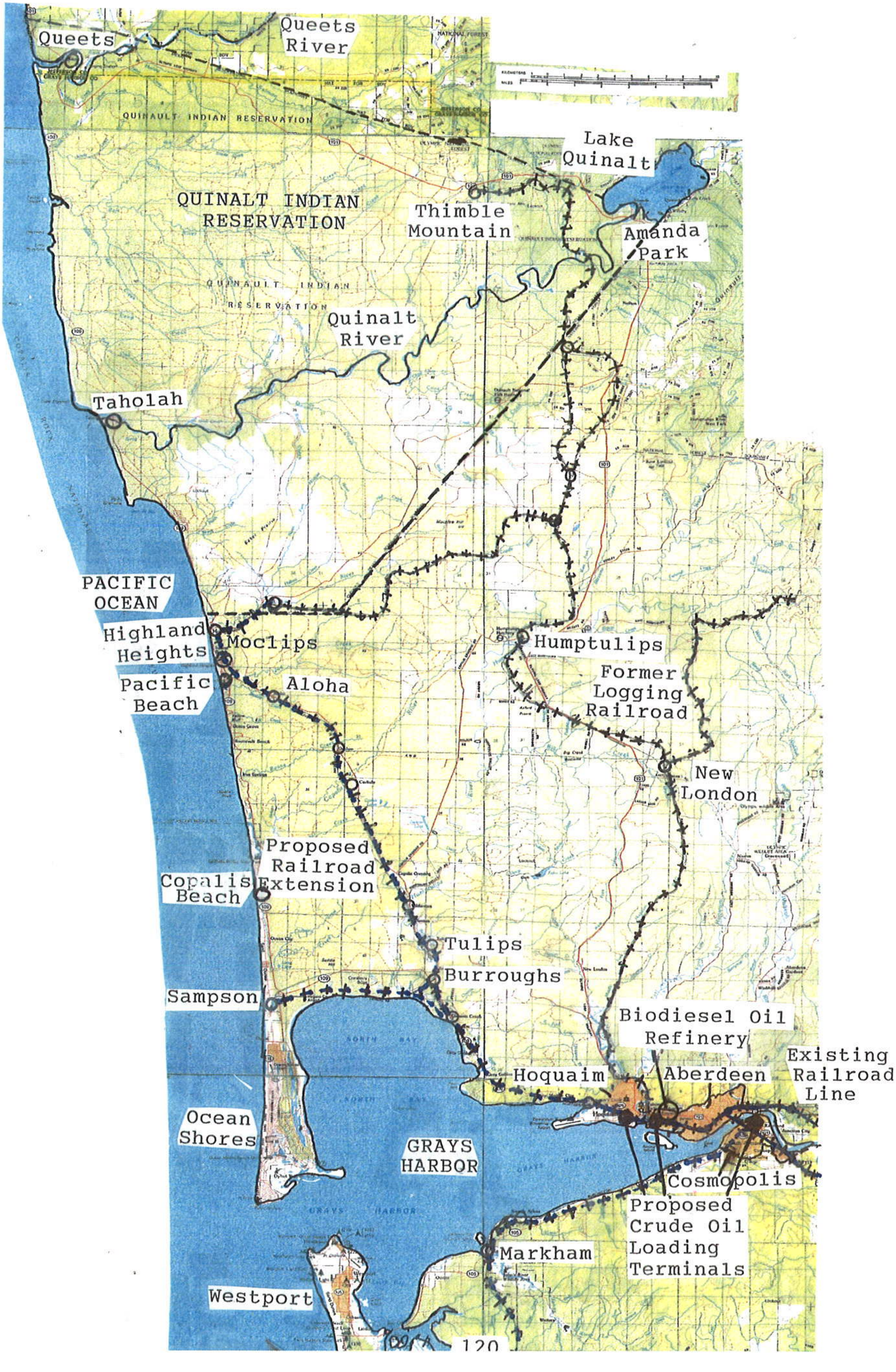
The Lummi Reservation is located a peninsula of the west side of Bellingham Bay with an approximate length of 6 miles and a maximum width of 2 miles on the northwest periphery of the Bellingham urban area. The Lummi Tribes owns or manages up to 13,000 acres of land on its peninsula plus the associated Portage Island which is connected by a bridge connecting to the main part of the Reservation to the southeast which is approximately 2 miles on each side. There is a separate Lummi Island across the Hall Passage which is 9 miles long and one mile wide with a colony which is not a part of the Reservation. The Lummi Indian Tribe is a member of the Salish Nation of Coastal Indians living in the State of Washington and in the southern part of the Province of British Columbia.

The Quinault Indian Reservation is in a very remote location along the Pacific Coast in southwest Washington in an almost opposite rural setting to the urban Lummi Indian Tribe near Bellingham with a large area but a small population. The Quinault Indian Reservation has approximately 225,000 acres of land which borders the Pacific Coast in a generally triangular configuration. The Quinault Indian Tribe has at total of only approximately 1,370 enrolled members of whom nearly 1,200 live on the Reservation where are very few outside residents. The Quinault Indian Tribe has two communities on the Reservation with most of the people living at Taholah where the Tribal Council headquarters is located.

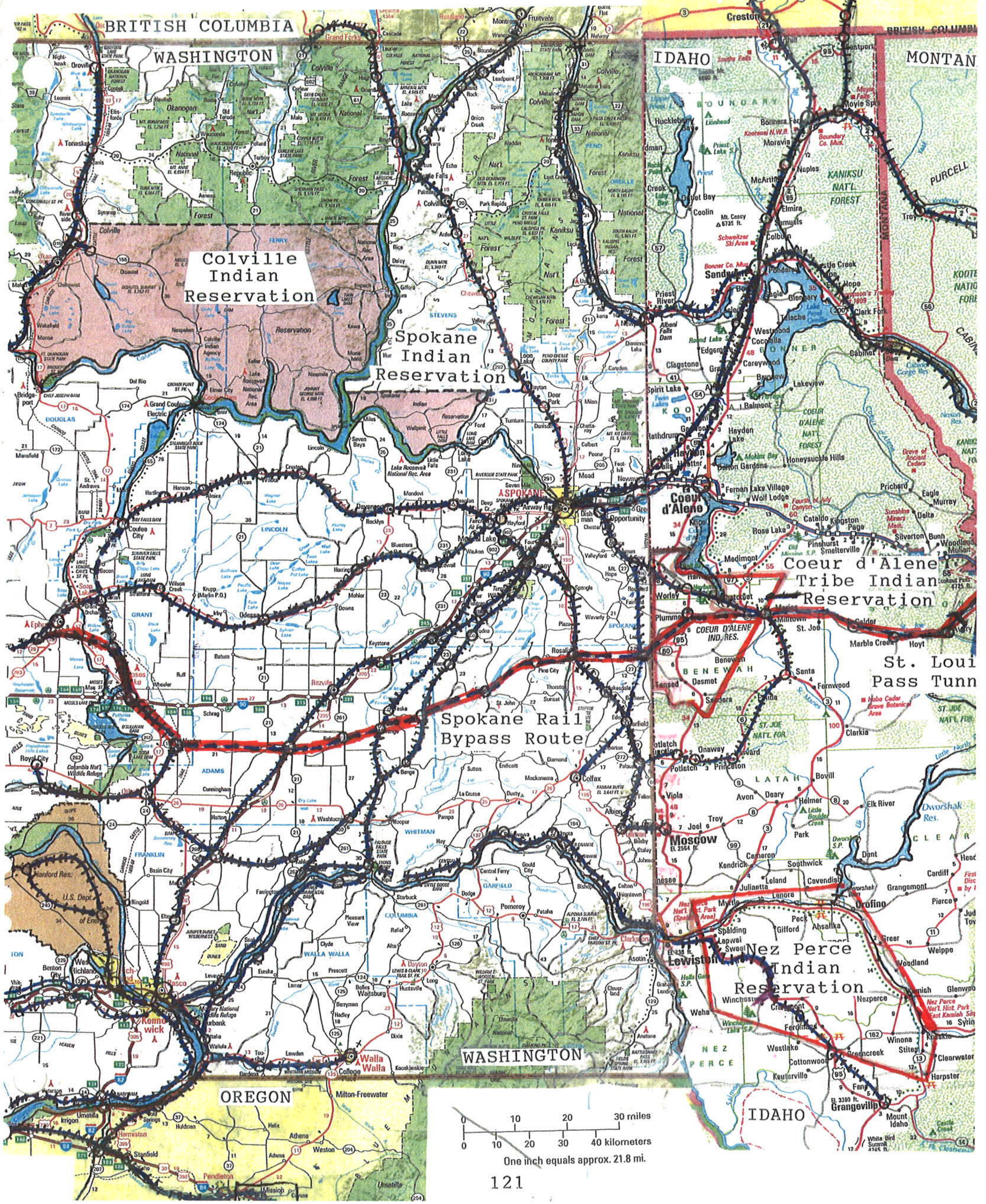
The major economic activity on the Quinault Indian Reservation besides fishing is at the main hotel and restaurant and casino complex at Moclips along the Pacific Ocean at the southwest corner. This hotel and casino complex is the largest single employer in Grays Harbor County as well as being the main source of employment for the Quinault Tribal members. The Quinault Indian Tribe is also heavily involved in raising oysters and clams and mussels as shellfish plus with fishing at Grays Harbor to the south. As a result, the Quinault Tribe has expressed great concern about the potential adverse environmental impact of crude oil loading at Grays Harbor on their shellfish and fishing activities as a major part of their livelihoods so that effective remedial measures are necessary.

There are indications that significant reserves of crude oil and natural gas may lie underneath the Quinault Indian Reservation lands in southwestern Washington as well as significant forest resources above the ground. To date, there has been little actual drilling or seismic analyses of such oil and gas reserves lying under the Quinault Reservation, but there would be a considerable potential for future oil and gas development.

LOCATION OF THE QUINALT INDIAN RESERVATION AND GRAYS HARBOR OIL TERMINA



LOCATIONS OF RAILROAD LINE NETWORKS IN EASTERN WASHINGTON AND NORTHERN IDAHO



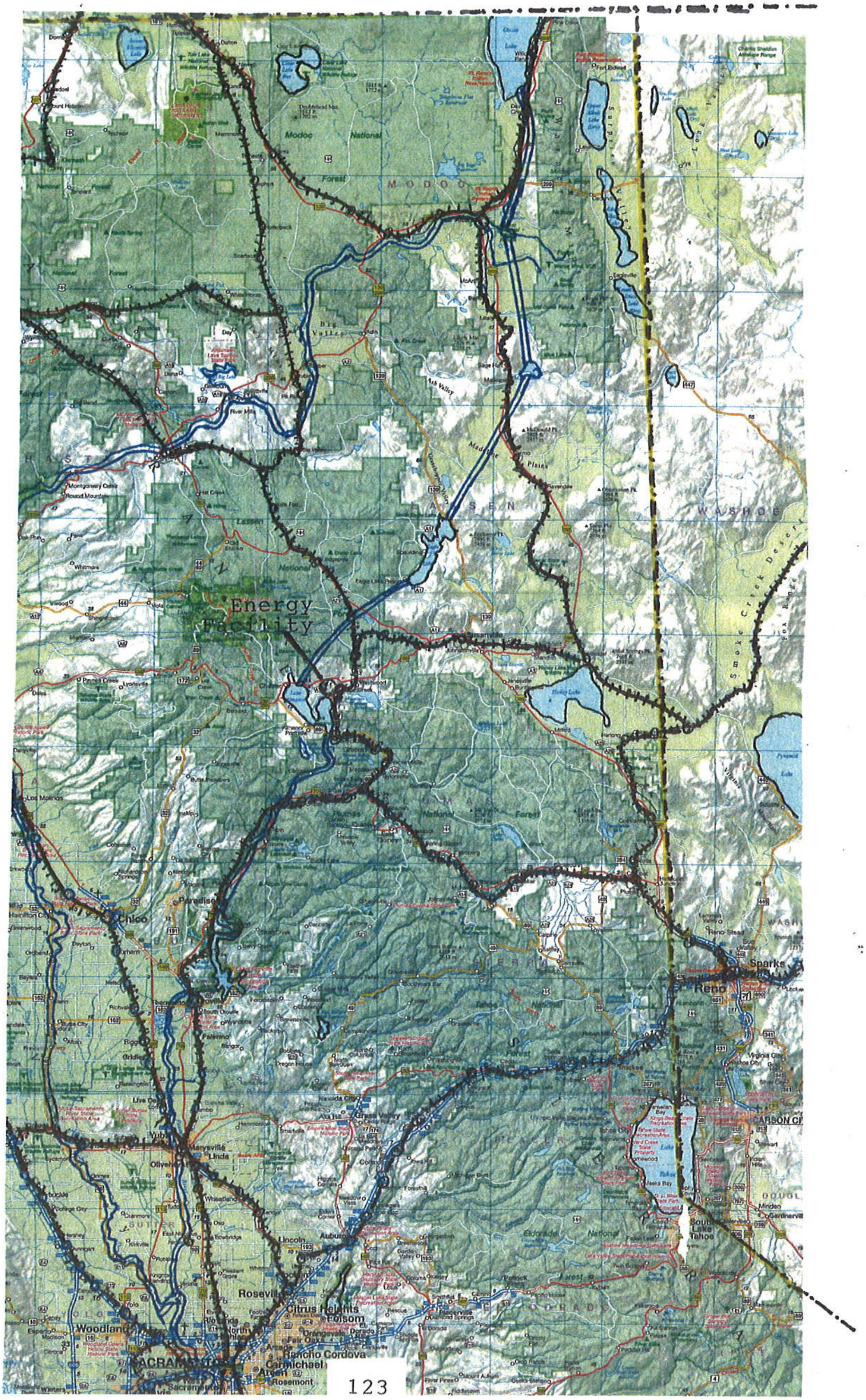
It may be very desirable for the Quinault Indian Tribe in Washington and the Three Affiliated Tribes of the Mandan Hidatsa Arikara Tribes of the Mandan Hidatsa Arikara Nation in North Dakota to meet with each other to discuss joint oil and gas development. These discussions could include a personal visit by the Quinault Tribal Council members to the Fort Berthold Reservation to sea for themselves the potential for working on joint oil and gas development among the Tribes along the Great Northern Corridor.

In summary, there are three separate groups of Indian Tribes who are affected by and potential beneficiaries of the further development of the Great Northern Corridor across the Northern Tier to facilitate oil and coal transport and related economic activities. The Indian Resource Tribes are and will be very much benefited by increased oil and gas production plus coal mining and transport as major present and future customers of the BNSF Railway. The connecting Interior Non-Resource Tribes can also benefit along the Northern Tier Corridor from increased railway access to all Tribal lands from the BNSF Railway as well as the use of the railroad line for shipping of goods and the hauling of people if new rail sidings are provided to serve energy and industrial facilities.

The major uncommitted group are the Coastal Indian Tribes whose major economic activity involves fishing and shellfish raising. It will be essential that maximum environmental protection efforts be made to assure that aquatic life and livehoods are an integral part of any future crude oil or coal transport by rail and at loading terminals onto ships or barges. It is also very likely to be a benefit that all of the involved Interior and Coastal Indian Tribes along the Great Nations Corridor be able to establish some type of advisory or development groups or committee to support the parallel efforts to be made by the involved State Government. Then the Tribal interests and concerns can be addressed in a responsible and constructive way to help foster a positive future development of the Great Northern Corridor across the Northern Tier.

There are also Indian Tribes located along or adjacent to the BNSF Railway line in the north-south direction from Wishram, Washington to Oroville, California in central Oregon and northeastern California. The Warm Springs and Klamath Tribes are located along this rail corridor in Oregon while the Modoc, Maidu and Fort Bidwell Tribes are located in northeastern California along with several small Rancheria Tribes. A new renewable biomass energy facility could be located near Lake Almanor.

LOCATION OF THE WEST COAST FREIGHT RAILROAD CORRIDOR AND THE WATER AQUEDUCT ACROSS NORTHEASTERN CALIFORNIA AND THE ADJACENT INDIAN RESERVATION LANDS



## WEST COAST CORRIDOR

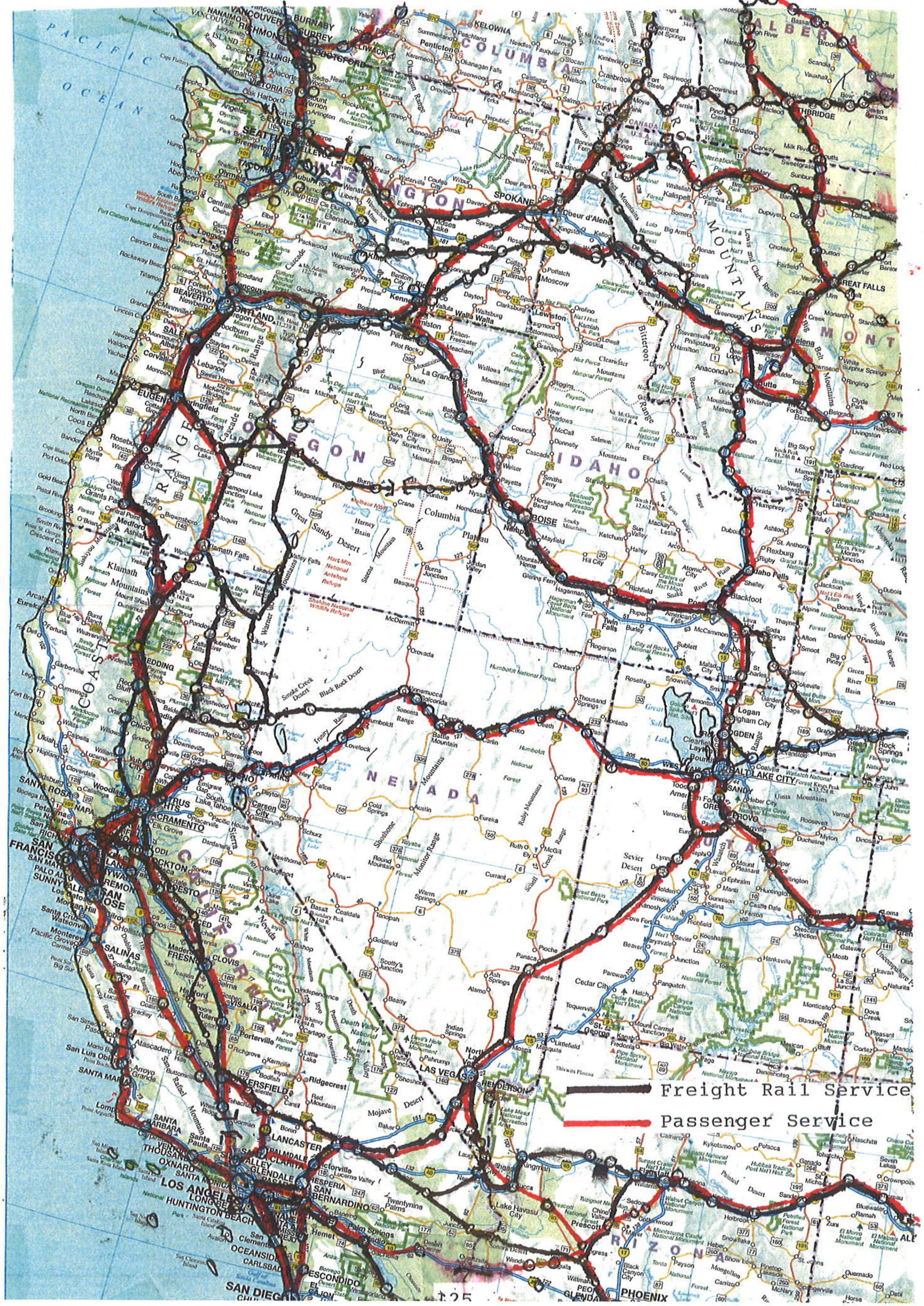
The West Coast Corridor for improved rail passenger and freight service runs through the States of Washington, Oregon and California. The West Coast Corridor also includes the Province of British Columbia in Canada and the State of Baja California Norte in Mexico and in the present case the Province of Alberta in Canada as well. The potential configuration of the West Coast Corridor will ultimately include passenger services between the major cities in a north-south direction plus freight services to serve the major demand centers and commodity transport needs as separate parallel systems. The major commodity of concern to be hauled in the present case from North Dakota or Alberta to Washington or California is oil hauling with the possible future transport of fresh water from northern Canada to California as a secondary concern.

There is already an existing need to haul crude oil from the Bakken Formation in North Dakota to the five oil refineries in the State of Washington by way of the BNSF Railway Great Northern Corridor. There is already a parallel need to haul crude oil by rail from the Bakken Formation in North Dakota to the five oil refineries in both the San Francisco Bay Area as well as those in the Los Angeles Basin of Southern California. Previous projections are that up to 600,000 barrels per day of crude oil can be utilized by the refineries in the State of Washington as well as much as an additional 500,000 barrels per day by the refineries in the State of California in the future for a total of up to 1,100,000 barrels per day.

It is also expected that additional volume of crude oil may also need to be brought by rail from North Dakota to serve additional needs of the refineries in California on at least a temporarily basis. Some of the refineries in California have already built rail unloading terminals for accepting this light sweet crude oil from the Bakken Formation. Also, additional rail oil unloading terminals are being planned or being constructed at other refineries in California who do not presently have them in place already in both the Bay Area and Los Angeles Basin.

Much of the crude oil produced in California is heavy sour oil which is significantly different from the light sweet crude oil in North Dakota. Significantly retooling of refinery processing configurations may be necessary in order to go from using one grade as compared to another grade and source of crude oil for any or all of the existing California refineries.

# ROUTE LOCATION OF THE WEST COAST PASSENGER AND FREIGHT RAILROAD CORRIDOR



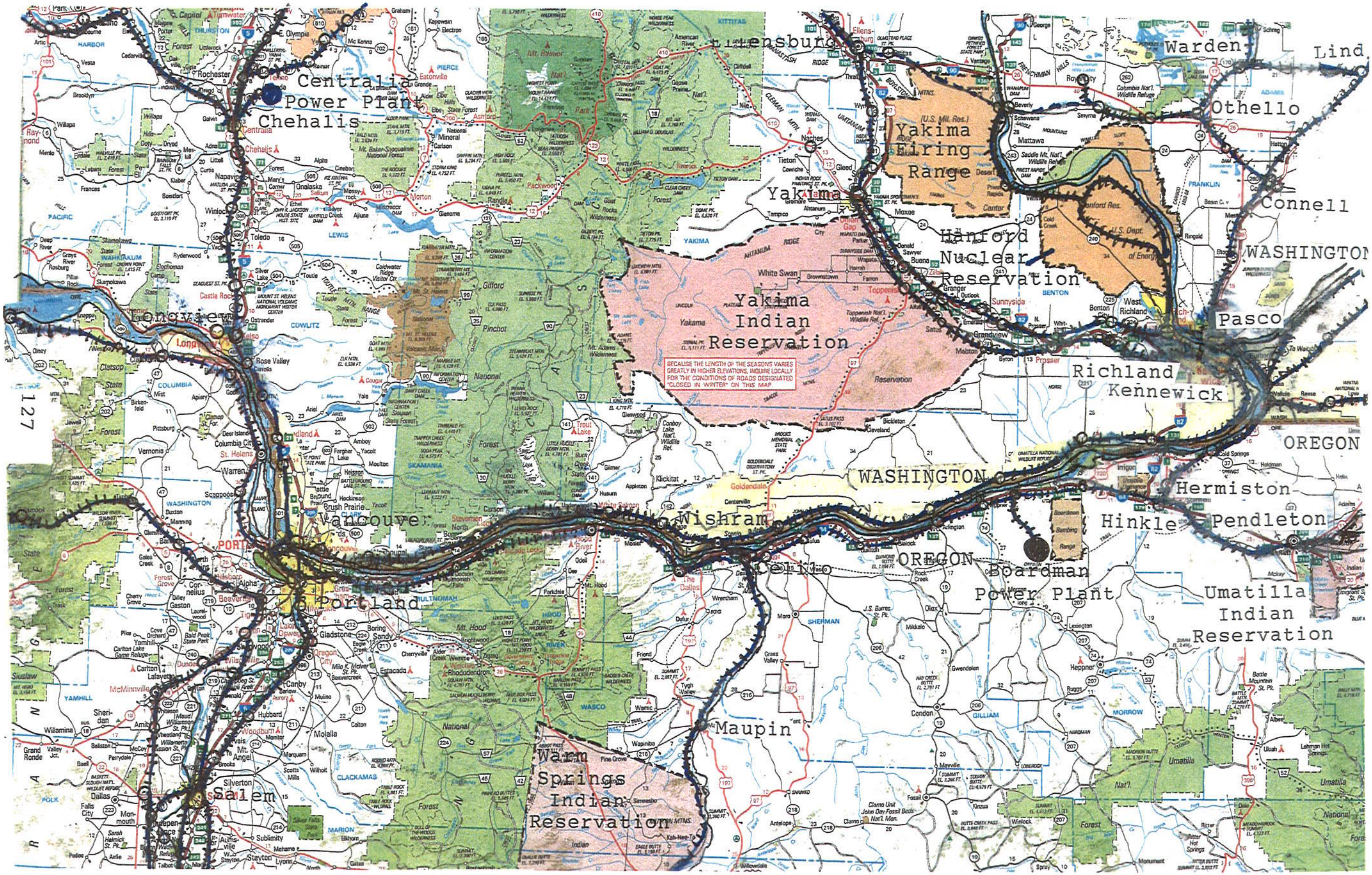
There is presently approximately 700,000 barrels per day of the heavy California crude oil being produced within the State that is used entirely by the local California refineries. The remaining 1,100,000 barrels per day of crude oil used in California has largely been shipped by tanker from Alaska in the past. Increasingly the Alaskan oil has been replaced by imported oil from Indonesia or Malaysia or from other foreign sources which is now being replaced by North Dakota oil from the Bakken Formation.

The exchange point on the BNSF Railway to bring crude oil from North Dakota to California is at Wishram, Washington on the north side of the Columbia River between Pasco and Vancouver. The crude oil unit trains go along the Columbia River main line between Pasco to Vancouver, Washington over a relatively level route to the west, the trains to California go to the south. These crude oil unit trains then go to the south along the steep Deschutes River rail line through Central Oregon to the east of the Cascade Mountains through Bend and Chemult to Klamath Falls in joint service with the Union Pacific Railroad. These crude oil unit trains then go to the southeast through Bieber to Keddie Junction across the northeast quadrant of California to the east of the Sierra Nevada Mountains on the BNSF Railway line. These crude oil unit trains then go by trackage rights over the Union Pacific Railroad Feather River rail line from Keddie through Paradise and Oroville to Marysville and Sacramento to the central receiving point at Stockton and then to the Bay Area or to Southern California.

The crude oil trains being hauled by the BNSF Railway can then be hauled to oil refineries in the Bay Area or Southern California over the same route as follows. These crude oil unit trains can then go over the existing BNSF Railway line from Stockton to Richmond along which the Martinez, Rodeo and Richmond refineries are located. Any crude oil unit trains to be delivered to the Valero refinery at Benecia would need to be transferred to the Union Pacific Railroad in Sacramento and then delivered to the Benecia refinery on the north side of the San Francisco Bay by way of Stockton where significant volumes could be transported.

The crude oil unit trains operated by the BNSF Railway with destinations at oil refineries in Southern California would then go over the Union Pacific Railroad along the Coastal Route from San Jose to Los Angeles by way of Salinas, San Luis Obispo and Santa Barbara. These BNSF Railway crude oil unit trains would parallel the existing online Union Pacific Railroad crude oil haul service from the San Ardo field to the refinery at Wilmington. By way of Cuesta Pass and San Luis Obispo.

ROUTE LOCATION OF THE BURLINGTON NORTHERN SANTA FE COLUMBIA RIVER RAILROAD LINE CORRIDOR



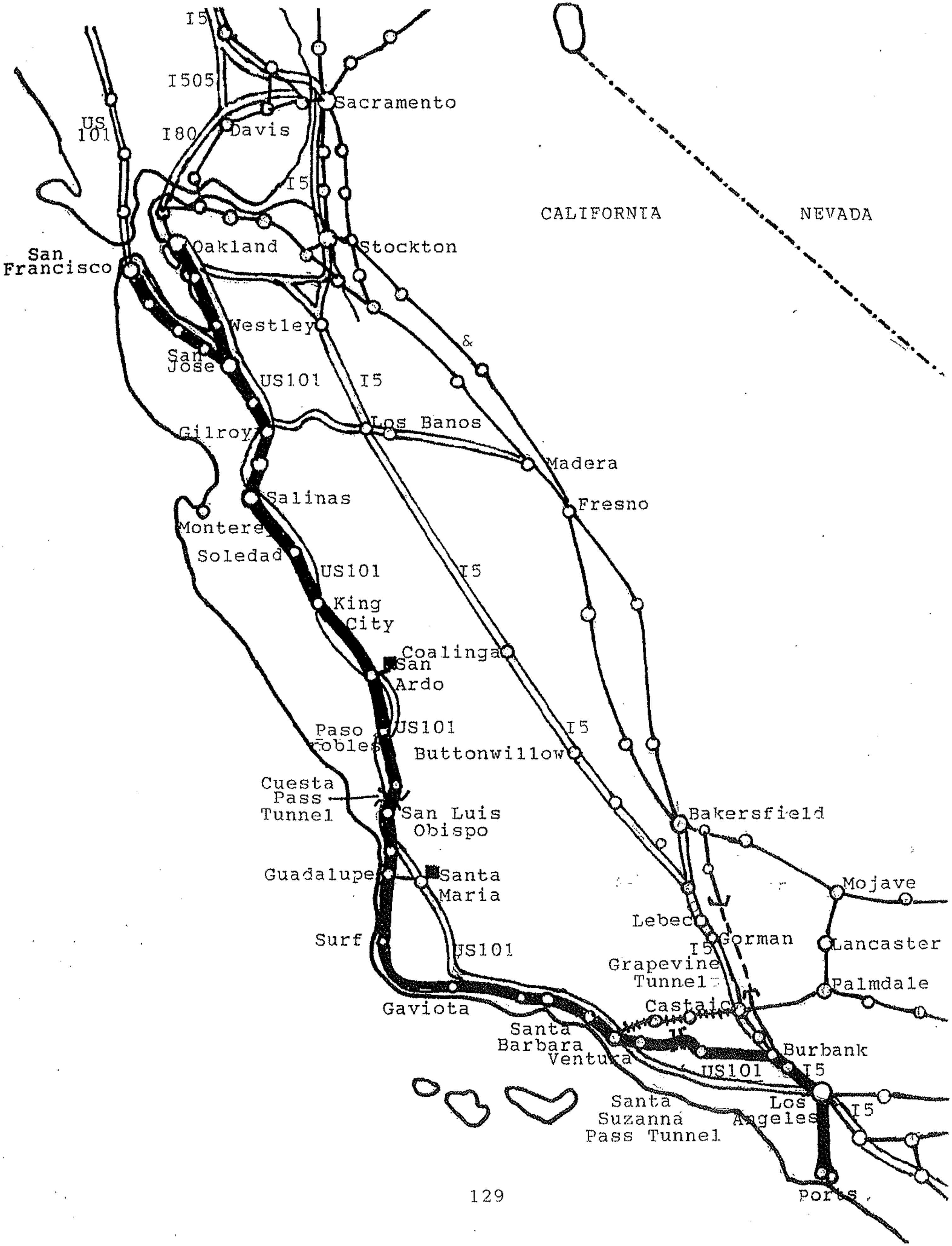
Each oil train would then be delivered from either the BNSF Railway or the Union Pacific Railroad to the applicable Los Angeles refinery. There is an alternative route for these oil trains over the BNSF Railway existing line through the San Joaquin Valley to Bakersfield and Mojave to Barstow and San Bernardino over its own line. However, this route is much longer and slower with a major rail traffic congestion point over Tehachapi Pass from Bakersfield to Mojave which restricts traffic from being able to increase.

There are also crude oil unit trains bringing the heavy syncrude oil from the Athabasca tar sands near Fort McMurray, Alberta to California refineries equipped to process it. These trains originate from a central loading point at Hardisty, Alberta which are now or may be going to California over the existing Canadian Pacific Railway line over the Crowsnest Pass through the southern Rocky Mountains to Kingsgate, British Columbia and Eastport, Idaho to the Union Pacific Railroad.

These oil unit trains on the Union Pacific Railroad then follow the main line along the south shore of Suisun Bay at the western and of the Sacramento – San Joaquin River Delta into the San Francisco Bay area to the refineries at Martinez or Rodeo or Richmond if the heavy oil from Alberta is to be used then. The oil unit trains on the BNSF Railway carrying the North Dakota crude oil run on the parallel main line to the Union Pacific between Stockton and Richmond near the Chevron Refinery where they then join together. The oil unit trains from Alberta on the Union Pacific as well as from North Dakota on the BNSF Railway which will go to the refineries in Southern California are then routed so that they can then go over the existing Union Pacific lines along their Coastal Route through San Jose to Los Angeles or through the San Joaquin Valley by way of Salinas and Santa Barbara. The BNSF oil unit trains are not routed over their long route by way of the San Joaquin and Antelope Valleys and Mojave Desert because of the greater distance as well as the congestion at Tehachapi Pass with the high freight traffic volume.

The West Coast Corridor will need to have a passenger route through Western Washington and Western Oregon to Redding in northern California and then to the south to Sacramento to join the planned California high speed rail system in parallel to the freight system just described so that passenger and intermodal and oil trains can operate.

LOCATION OF THE COAST ROUTE RAILROAD PASSENGER AND FREIGHT SERVICE FROM LOS ANGELES TO SAN FRANCISCO BY WAY OF SANTA BARBARA, SALINAS AND SAN JOSE



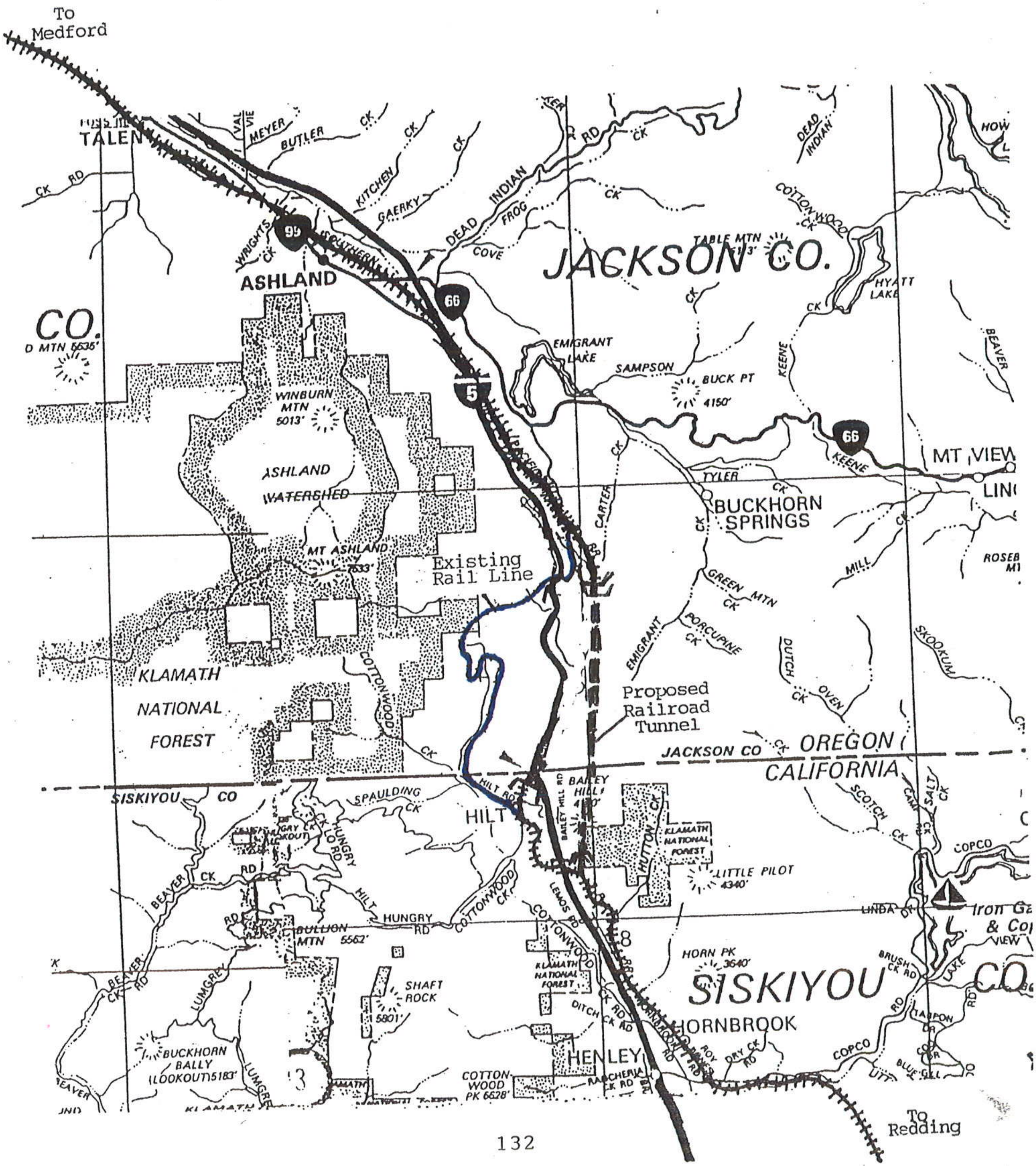
LOCATION OF THE CUESTA PASS RAILROAD TUNNEL ALONG THE COAST ROUTE LINE

It would then be possible to join the existing rail passenger corridor coach services between Vancouver, British Columbia and Seattle to Portland and Eugene sponsored by the States of Washington and Oregon with both the existing conventional speed passenger services for the San Joaquin Valley and Capital Corridor as well as the future high speed rail passenger services. It will be necessary to make a major upgrade of the existing Central Oregon and Pacific Railroad main line from Eugene, Oregon to Black Butte Junction near Weed, California, as well as between Weed and Redding in the Sacramento River Canyon. It will be necessary to dig a new railroad tunnel under the Siskiyou Mountains between Ashland, Oregon and Hilt, California in a manner similar to the need for a similar new railroad tunnel under the Grapevine Grade between Grapevine and Castaic in Southern California refinery near Wilmington.

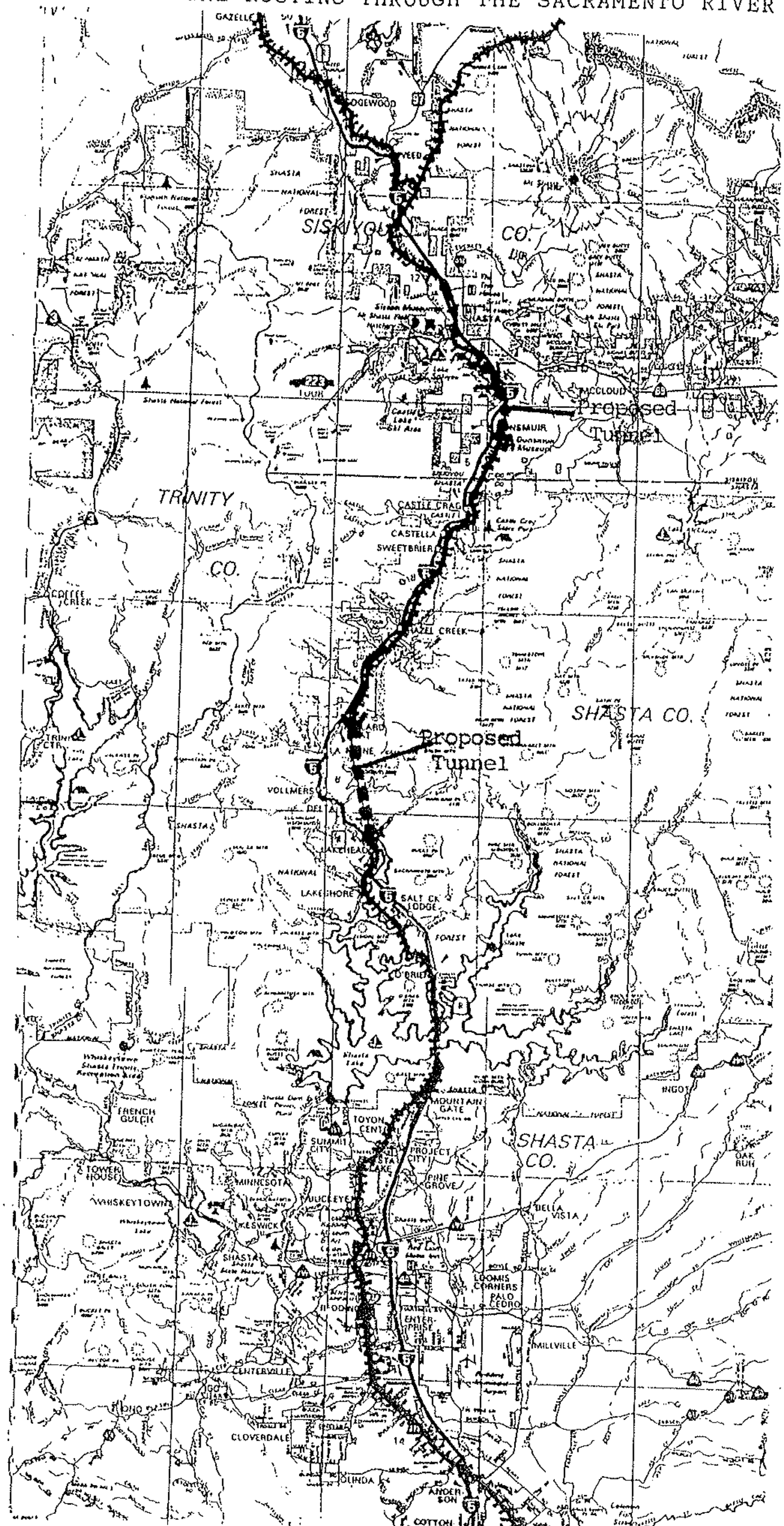
These syncrude oil trains are then transferred to the Union Pacific Railroad across the U.S. – Canada border at Eastport, Idaho and then travel over the Union Pacific Railroad line through Spokane to the main east-west line on the south side of the Columbia River. It might be possible of the Columbia River and it might be possible to reroute these trains to the previously described Spokane bypass route. The Alberta heavy tar sands syncrude oil is much less volatile than the light sweet Bakken Formation crude oil with a much lower explosion hazard during rail transport but has a higher toxicity and corrosion potential and is much more difficult to flow. The Alberta syncrude oil is somewhat similar in properties to the heavy oil from the San Ardofield in central California where it is hauled by rail to an oil refinery near Wilmington with one unit train load per week of 70 cars per train per week with a total amount being hauled of two million barrels per year as the starting point for crude by rail transport.

These oil trains then travel over the Union Pacific Railroad main line on the south side of the Columbia River to Celilo, Oregon where they join the trains from the BNSF Railway crossing the Columbia River from Wishram, Washington. These crude oil unit trains from both North Dakota and Alberta then go over the Deschutes River rail line through Madras and Bend and Chemult to Klamath Falls, Oregon. These rail lines then divide at Klamath Falls with the BNSF Railway trains going to the southeast then to Tulelake and Westwood and then to Keddie Junction. These trains then go to Belden and Paradise to Belden over the interior route and then through the Feather River Canyon to Paradise and Chico to Oroville. These BNSF Railway unit trains carrying Bakken Formation light sweet crude oil from North Dakota then go through the Sacramento Valley to Marysville to Sacramento and then to the south to the main transfer terminal at Stockton.

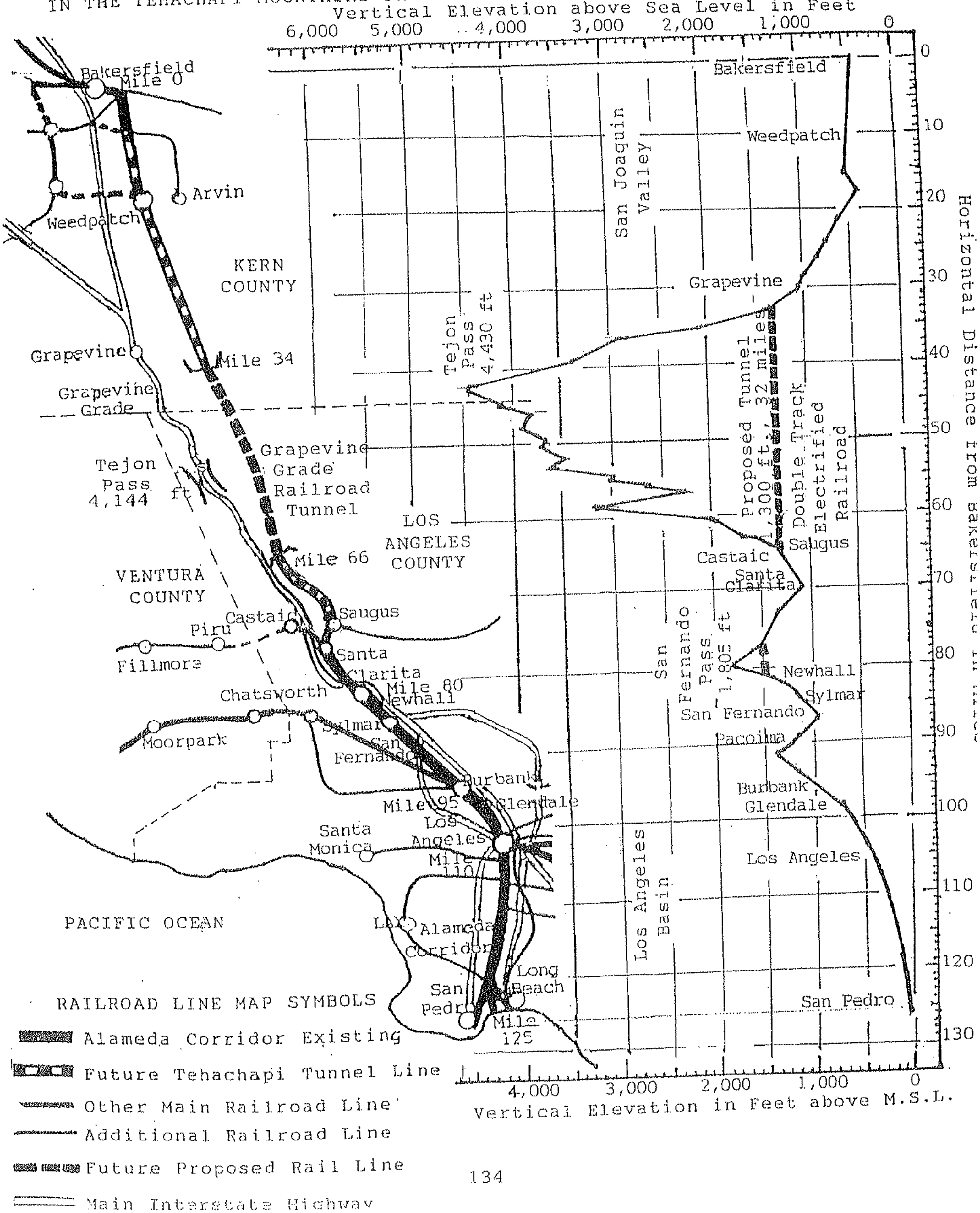
LOCATION OF THE PROPOSED RAILROAD TUNNEL THROUGH THE SISKIYOU MOUNTAINS BETWEEN ASHLAND, OREGON AND HILT, CALIFORNIA



PROPOSED RAILROAD LINE ROUTING THROUGH THE SACRAMENTO RIVER CANYON



HORIZONTAL AND VERTICAL PROFILE OF THE PROPOSED RAILROAD TUNNEL IN THE TEHACHAPI MOUNTAINS FROM GRAPEVINE TO CASTAIC UNDER TEJON PASS



Then crude deliveries are made to the refineries at Richmond and Bakersfield, California of the Bakken Formation crude oil by the BNSF Railway as well as to the existing loading terminal at Clatskanie, Oregon and the planned oil terminal at Cherry Point, Washington.

The unit trains on the Union Pacific Railroad carrying the heavy syncrude oil from Alberta enter the Deschutes River canyon rail line on the south side of the Columbia River at Celilo from the east on the main from Hinkle, Oregon. These oil unit trains on the Union Pacific from Alberta then follow the same route as the BNSF oil trains from North Dakota from Celilo to Madras to Bend and Chemult across central Oregon to the south to Klamath Falls where they divide. These Union Pacific trains then go to the southwest through Dorris and Weed to Black Butte Junction and to Redding.

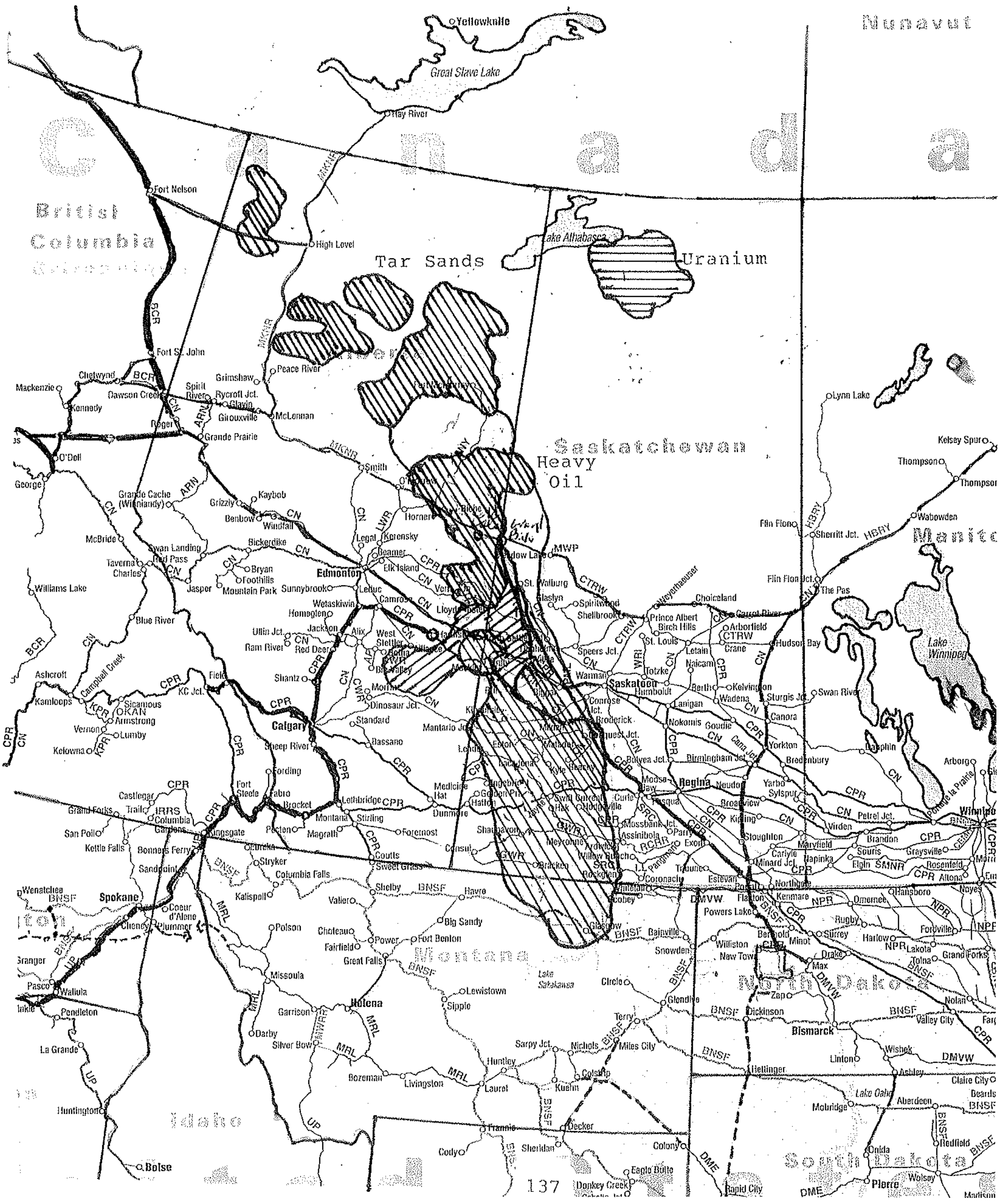
The Union Pacific Railroad oil unit trains go through the Sacramento River Canyon to Redding and then on the east side of the Sacramento Valley through Chico and Marysville to Roseville and Sacramento to the terminal at Stockton. Crude oil deliveries of the heavy Alberta tar sands oil can then be made to the Valero refinery at Benecia, California in the Bay Area by way of Stockton and Pittsburg as well as to refineries in Southern California. It is emphasized that the initial Crude Oil by Rail (CBR) oil hauling service began in California in the 1980's over the Union Pacific Costal Route from the San Ardo heavy oil field in the Salinas Valley to a Southern California oil refinery with one unit train load per week.

An additional commodity may need to be moved between Alberta and California besides syncrude oil because of the persistent drought in California which is fresh water. It may actually also be desirable or necessary to transport water by railroad tank car unit trains using the now obsolete Series DOT 111 cars for crude oil. The fresh clean water could be brought by rail from the Mackenzie or Peace or Liard Rivers in northwestern Canada by rail over the same Canadian Pacific Railroads to California by way of the Kingsgate-Eastport crossing. This water is already badly needed for agricultural and municipal uses and also for hydraulic fracturing in the Monterey Shale Formation in the San Joaquin Valley for oil recovery. In addition, it is also possible that the presently contaminated wastewater from the production of syncrude oil in the Athabasca tar sands of Alberta could be treated and upgraded to remove organic and metallic constituents and then shipped for oil recovery.

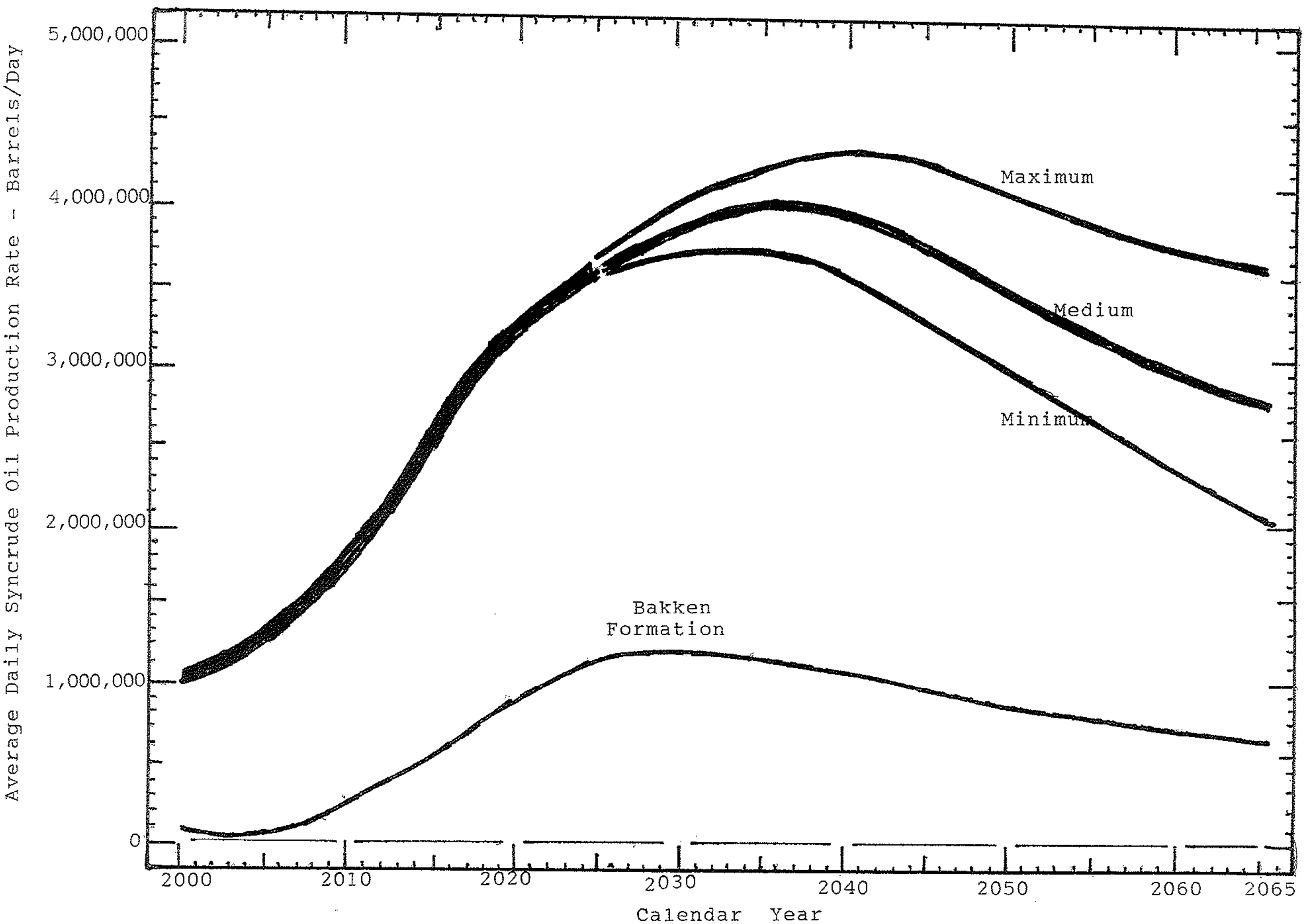
LOCATIONS OF THE UNION PACIFIC RAILROAD LINES IN THE UNITED STATES


136

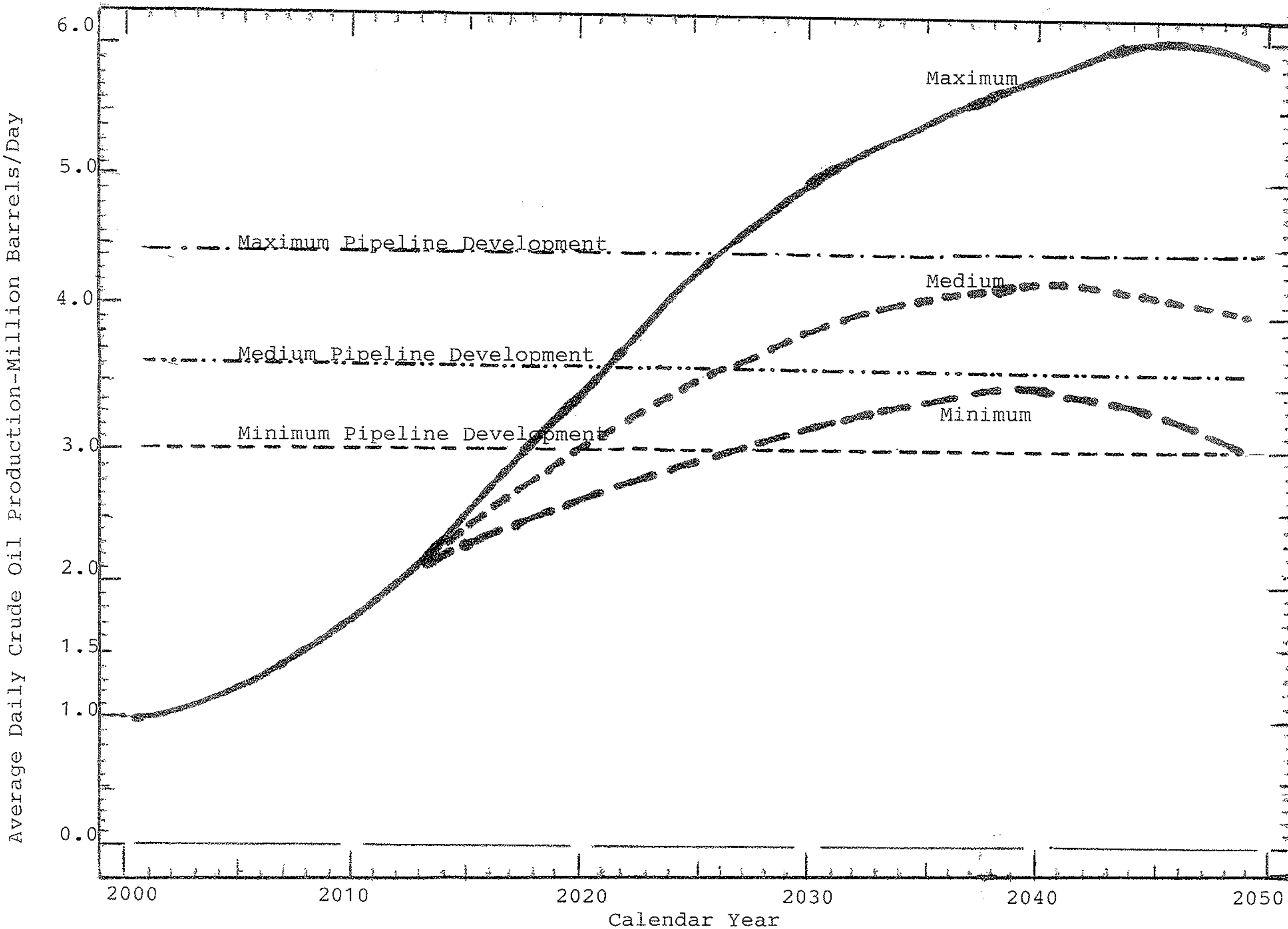
LOCATION OF THE MAIN RAILROAD LINES SERVING THE TAR SANDS AND HEAVY OIL DEPOSITS IN ALBERTA AND SASKATCHEWAN WITH CONNECTIONS TO FORT BERTHOLD



EXPECTED FUTURE TRENDS IN THE ESTIMATED SYNTHETIC CRUDE OIL PRODUCTION LEVELS FOR THE ATHABASCA, PEACE RIVER AND COLD LAKE TAR SANDS FORMATION IN ALBERTA PROVINCE CANADA



ALTERNATIVE SCENARIOS FOR CRUDE OIL PRODUCTION INCREASES IN ALBERTA: 2000 TO 2050



The fresh water from Alberta can be hauled to California by unit train over the same route that the oil would be transported which would go from Brubaker or Hardisty, Alberta to California by way of Kingsgate and Celilo. The water units trains would probably originate at either Hay River or Enterprise in the Northwest Territories on the Mackenzie River or at Watson Lake in the Yukon Territory near the Lind River and then be hauled go Lethbridge, Alberta where they would join the oil trains. These water and oil unit trains would then go to the west over Crowsnest Pass to Kingsgate, British Columbia and Eastport, Washington and then to Spokane and to California. These rail unit trains would be able to go through Spokane without significant danger because water is not explosive and Alberta syncrude oil is not volatile where similar volumes could be transported.

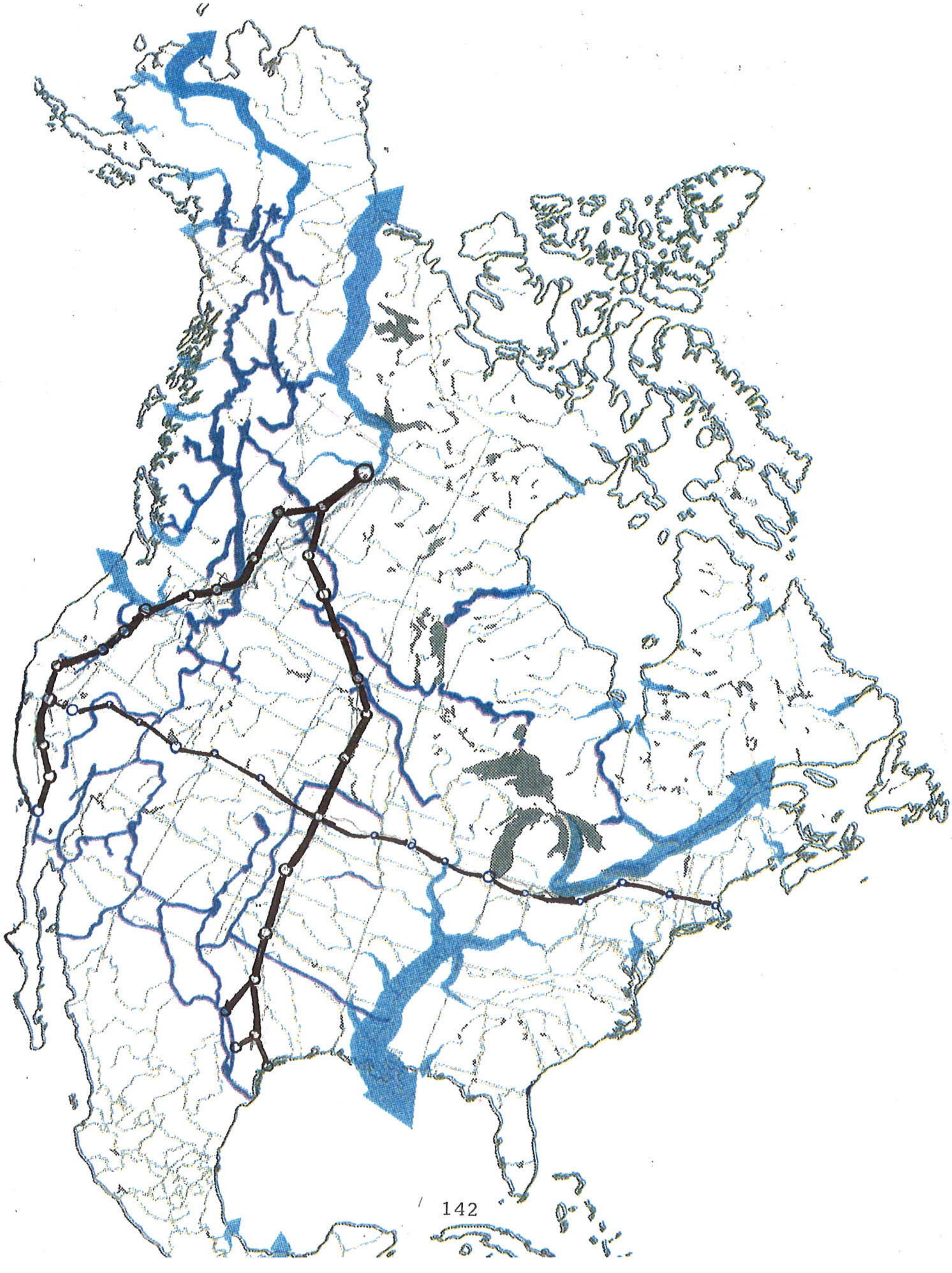
Water could be hauled from other places to California, and water could also be hauled by rail to places other than to California. This water could also then be placed in tank cars and hauled to Texas for hydraulic fracturing in the Eagleford Shale Formation of South Texas where water is also in critically short supply. The Fresh water from the Mackenzie River could also be hauled by brail to communities in South and West Texas where it is also in critically short supply. The North American Water and Rail Alliance (NAWARA) project with railroad transport of water cold then serve as the starting point for implementing the North American Water and Power Alliance (NAWAPA) Project with canals and aqueducts and tunnels as a much larger scale project in order to serve all parts of North America.

The North America Water and Power Alliance Project (NAWAPA) was originally conceived in the early 1960's by the Ralph Parsons Engineering Company of Pasadena, California as a means of supplying fresh water from the wet to the dry regions of all of North America. The original NAWAPA Plan involved building a series of canals, pipelines and aqueducts to move water from the Yukon River in Alaska and the Mackenzie River in northwest Canada to the arid regions of the southwestern United States and northern Mexico in order to enhance water supplies for agriculture, industries and municipalties. The original NAWAPA Plan served as the springload for passage of to California Water Project Initiative in 1962 by the votes of the State of California.

The original NAWAPA Plan involved collecting waters from the Yukon River in Alaska, the Mackenzie River in northwestern Canada and the coastal rivers in British Columbia into a series of large storage lakes in northern British Columbia and then pumping the water to the south.

PROPOSED ROUTE LOCATIONS OF THE RAIL HAUL NETWORK AND THE WATER SUPPLY AQUEDUCT SYSTEMS FOR TRANSPORTING WATER AND SNOW TO CALIFORNIA AND TEXAS

PROPOSED ROUTE LOCATION OF THE NORTH AMERICAN WATER AND RAIL ALLIANCE(NAWA
(NAWARA) WATER BY RAIL TRANSPORT SYSTEM AS A PRECURSOR TO THE PLANNED
NORTH AMERICAN WATER AND POWER ALLIANCE(NAWAPA) WATER AQUEDUCT SYSTEM



These waters were then to be distributed to California, the southwestern United States, to Texas and northern Mexico and to the Great Lakes and eastern Canada. A system was proposed to add water into the upper Columbia River in Canada and then withdraw it from the lower Columbia River across central Oregon into the rivers of northern California to supply the California aqueduct. A second system was intended to pump water from the Mackenzie River in northwestern Canada across the Canadian Prairie to the Great Plains of the United States to Texas and northern Mexico which is intended in part to recharge the Ogallala Aquifer.

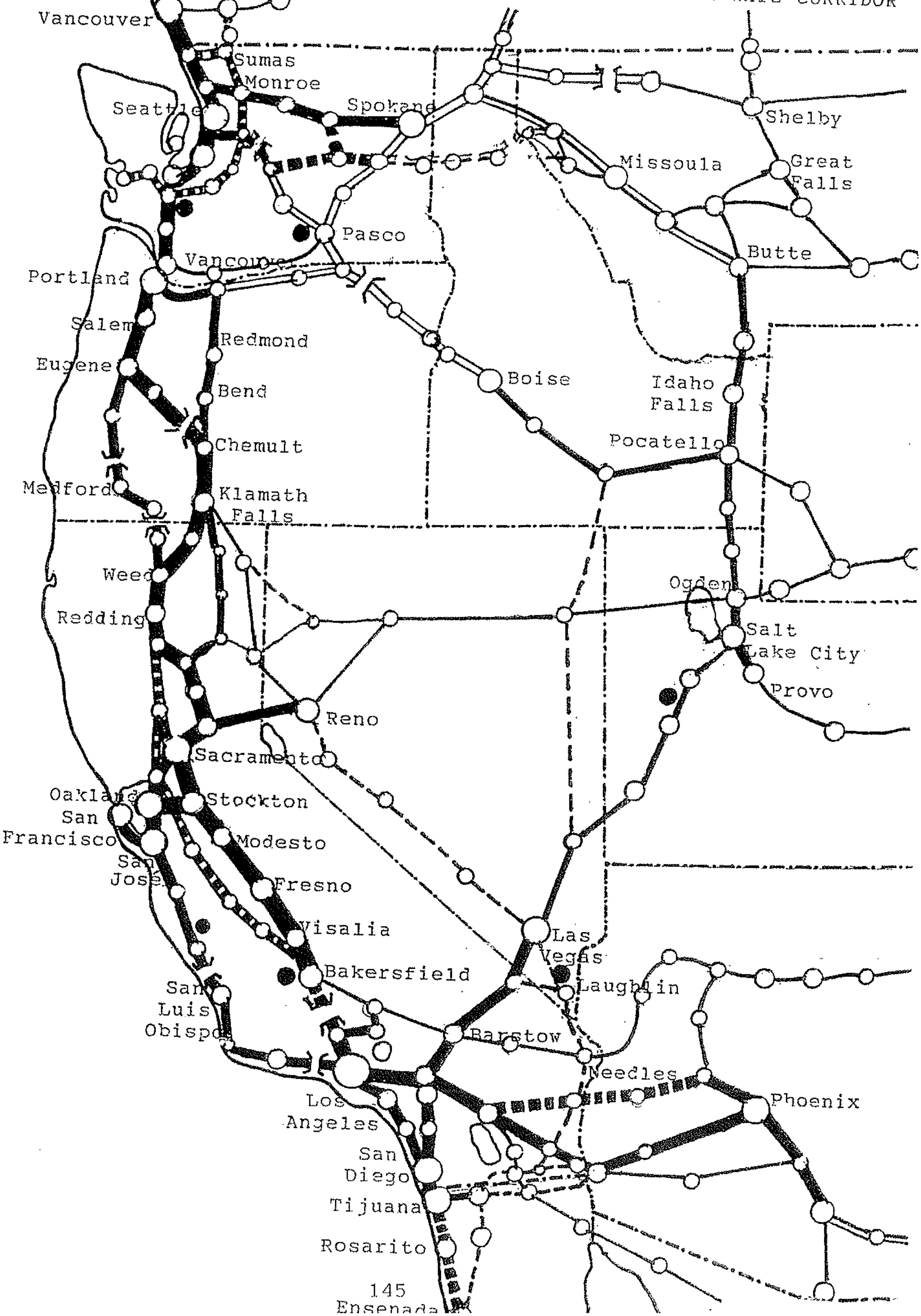
The proposed system to pump water from the Columbia River to California under the NAWAPA Project involves adding water at Mica Dam and letting it flow town the Columbia River from near Revelstoke, British Columbia to the lake behind the Dallas Dam in northern Oregon. The water is pumped out of the Columbia River at Celilo to the east of the Dallas into Lake Billy Chinook on the Deschutes River near Madras, Oregon. This water is then pumped to the southeast to the Prineville Reservoir on the Crooked River near Prineville and then across the southeast Oregon desert to refill Silver Lake and is then pumped into Summer Lake to the south at the eastern edge of the mountains Cascade Mountain range.

The water from Summer Lake is then pumped through the Coglan Buttes into Lake Albert near Paisley. The water from Lake Albert is then pumped uphill past Lakeview into Goose Lake on the California – Oregon border at the highest point in the system. The Goose Lake area is actually at the upper and of the drainage basin for the Sacramento River in California so that the water actually drains out into Davis Creek. The water flowing into the enlarged Davis Creek then flows to the south into the upper eastern and of the Pit River near Alturas. The Pit River flows to the southwest across the southern Cascade Mountains into the eastern end of Lake Shasta behind Shasta Dam on the northeast of Redding.

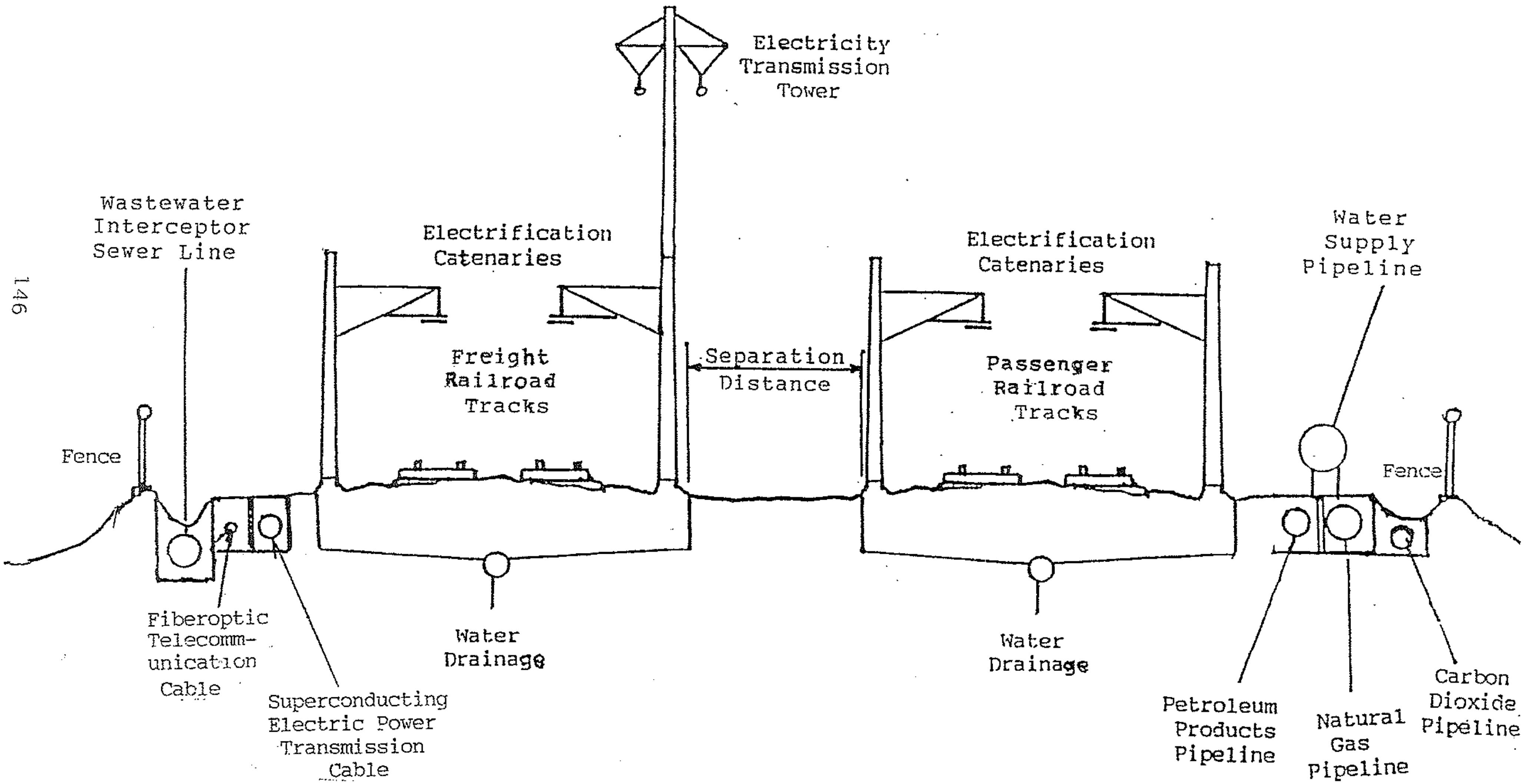
The waste from the Pit River which enters Lake Shasta to the north of Redding then flows through the Sacramento River to the south to Sacramento. The Sacramento River then flows to the southwest into the eastern end of Suisun Bay near Antioch which then becomes part of San Francisco Bay where the tidal water then flows out into the Pacific Ocean at San Francisco through the Golden Gate. There is presently a pumping plant at Bethel Inlet near Tracy on the San Joaquin River in the southern Sacramento – San Joaquin Delta which takes water from the Delta and places it into the California Aqueduct and the Delta Mendota Canal.

PROPOSED ROUTE NETWORK FOR TRANSPORTING WATER BY RAIL AND AQUEDUCT FROM NORTHERN CANADA TO CALIFORNIA AND TEXAS OVER EXISTING RAILROAD LINES

PROPOSED ROUTE NETWORK FOR THE WEST COAST HIGH SPEED PASSENGER RAIL CORRIDOR



CROSS-SECTIONAL VERTICAL PROFILE OF THE COMBINED HIGH SPEED PASSENGER AND FREIGHT RAILROAD LINE ALONG THE INTERSTATE 5 CORRIDOR BETWEEN THE STATES OF WASHINGTON, OREGON AND CALIFORNIA



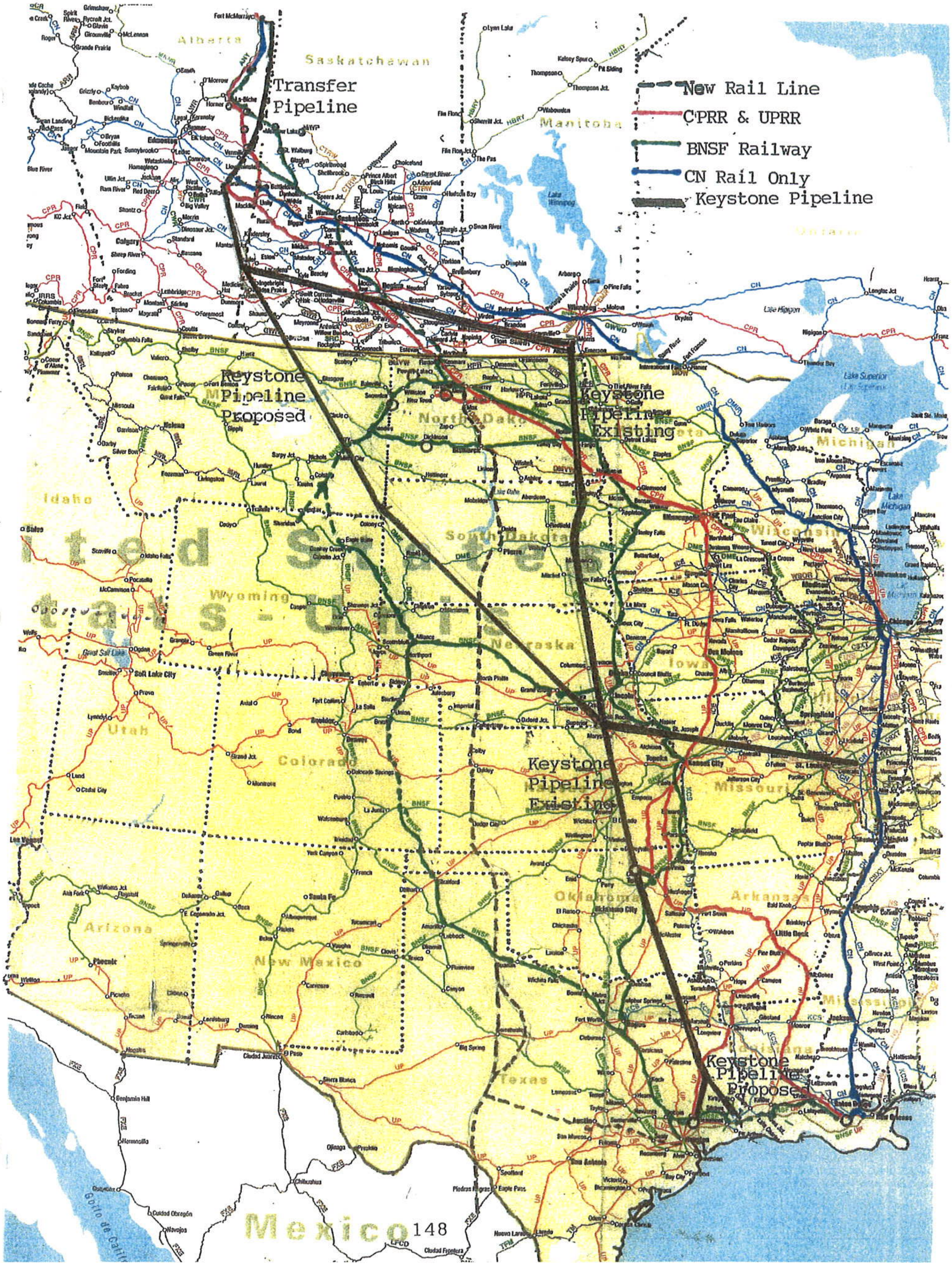
This water is then used by farms and cities in the San Joaquin Valley and is also pumped to Southern California.

It is proposed to develop a railroad version of the proposed NAWAPA aqueduct system to pump waster from Canada to California which will haul water by tank car instead with the NAWARA Project. This proposed rail system to haul water would use the recently banned and now obsolete Series DOT111 tank cars which are no longer usable for oil transport. Water would be hauled from its origin in the form of snow or liquid water in Canada or elsewhere to California. The operating costs would be greater for the rail system to haul water than an aqueduct system to pump water but the capital cost of the rail system is minimal because the railroad actually exists and would involve only the purchase of rank cars and locomotives without the aqueducts and canals.

It is also desired to construct a future high speed rail system along the West Coast between Vancouver, British Columbia and Tijuana, Baja California to connect the United States with Canada and Mexico along the Pacific Ocean. The State of California is planning to build a high speed rail passenger system between Sacramento and San Francisco on the north with Los Angeles and San Diego on the south byway of the cities in the San Joaquin Valley. The State of Oregon is discussing the possibility of building a high speed rail corridor between Portland and Eugene to expand its already existing corridor services along with similar actions by the State of Washington as an integrated rail operating authority.

It will be necessary to construct high speed rail corridor s with parallel but separate high speed passenger and more conventional speed freight rail corridors along common rights-of-way. These corridors will include electric transmission lines, natural gas pipelines, future fiber optic telecommunications cables and in some cases water aqueducts. Such a north-south corridor along the West Coast could also include high speed express cargo as well as high speed passenger service on a partnership basis with the major shipping companies and the host freight railroads which would then be expanded to the eastern United States into a national network. This proposed north-south West Coast Corridor would then parallel a similar north-south Great Plains Corridor from North Dakota to Texas which would incorporated rail lines, electric transmission, water aqueduct as well as the proposed Keystone syncrude oil pipeline.

MAJOR RAIL TRANSPORT ROUTES FOR CRUDE OIL FROM THE NORTHERN TIER TO TEXAS

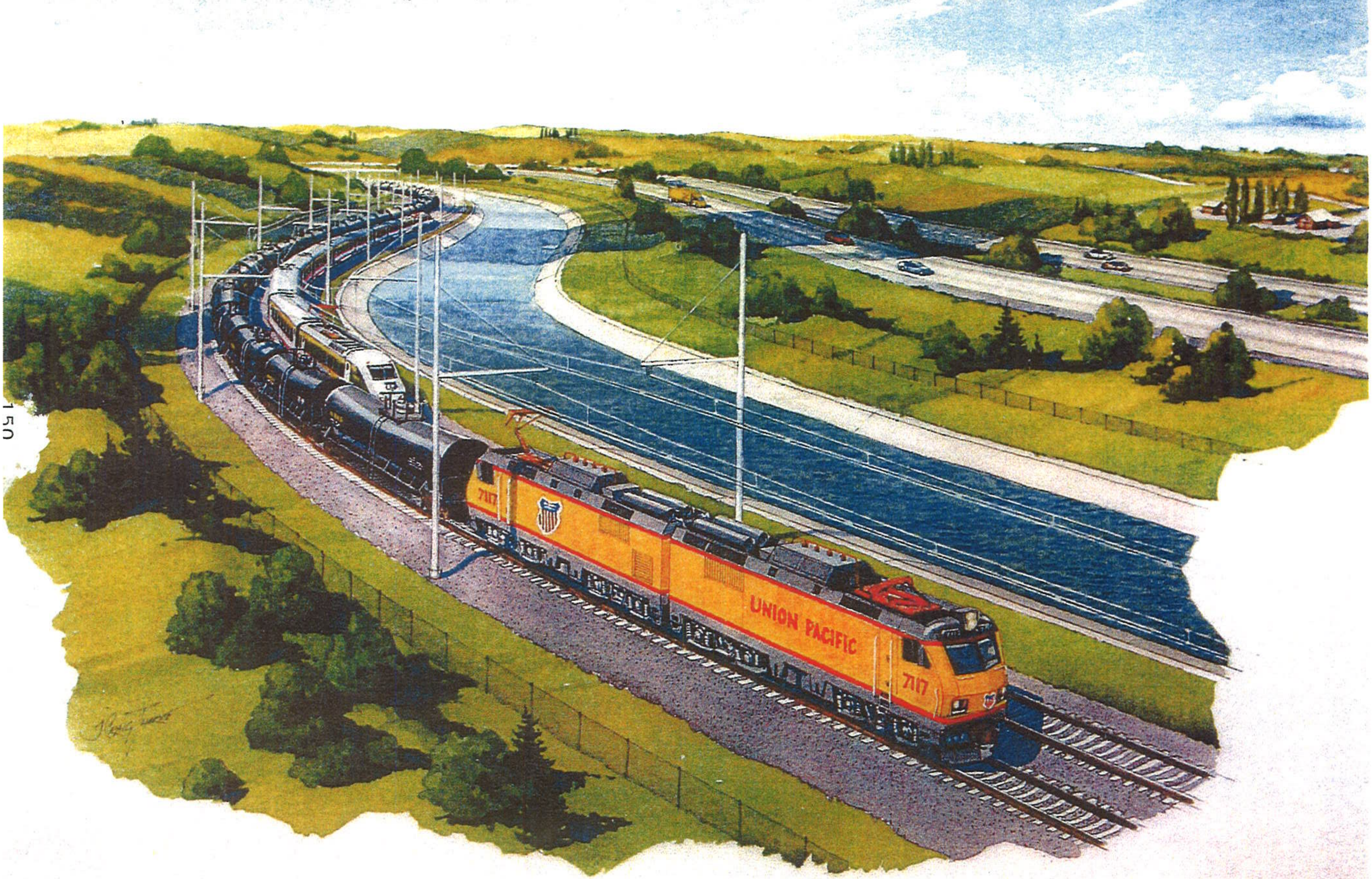


TRACKSIDE VIEW OF THE UNION PACIFIC CRUDE OIL UNIT TRAIN WITH 78 TANK CARS BETWEEN SAN ARDO AND WILMINGTON ON THE COAST ROUTE RAIL LINE AT CASMALIA, CALIFORNIA SOUTH OF SANTA MARIA



**Union Pacific's 78-car oil train rolls north through Casmalia, Calif., on Feb. 23, 2013. The train is headed back to Wunpost, Calif., for reloading.** John Roskoski

PROPOSED ROUTE OF THE SAN JOAQUIN VALLEY WEST SIDE HIGH SPEED RAIL AND OIL TRANSPORT LINE ALONG THE CALIFORNIA AQUEDUCT AND THE INTERSTATE 5 FREEWAY NEAR COALINGA, CALIFORNIA



## ELECTRICITY GENERATION

There is considerable need for additional generation of electric power in the Northern Tier region because of increased oil and gas production in the Williston Basin along with other economic activities. There is an additional need for electric power generation in the State of Washington to serve the growing population in the Puget Sound area as well as the related aircraft manufacturing and high technology industries related to computers and the internet. There are also growing needs for electricity in the other States and regions along the Great Northern Corridor because of population increase and related economic activity throughout the entire Northern Tier regions which are impacted by oil development.

There are a number of electric generation sources available in the different States on the Northern Tier. The use of hydroelectric power is predominant in the Pacific Northwest because of the large number of dams located on the Columbia. The primary electric generation source on the Northern Great Plains is from coal as the result of its relatively low and stable price and large scale availability in the region. There is also a considerable and growing use of natural gas because of its being produced in large amounts as a byproduct of crude oil production in North Dakota. There are also renewable energy resources available at particular locations on the Northern Tier which can be used to generate electricity and make fuels.

The Northern Tier States across the overall Great Northern Corridor have a present population of 26 million people which is expected to grow to 39 million people by 2050 at an average annual rate of 1.1 percent per year. The Northern Tier State with the largest population is Washington at 7.0 million to 11.7 million by 2050. The smallest state in terms of population on the Northern Tier is North Dakota at 700,000 which is expected to increase to 1,300,000 by 2050 largely as the result of the major oil and gas development now ongoing. The States to the west on the northern Tier of Oregon and Washington are expected to experience the greatest total increase in population while the two States to the east of Minnesota and Wisconsin are expected to see the slowest population growth.

The electric generation trends for the Northern Tier States follow a similar pattern to that of the population increase across the region. The overall net electricity generation across the Northern Tier is expected to increase from 364 billion kilowatt-hours per year in 2010 to 476 billion kilowatt-hours per year in 2050 by 31 percent.

## EXPECTED FUTURE POPULATION GROWTH FOR THE NORTHERN TIER STATES ON THE GREAT NORTHERN CORRIDOR

| State | 1990 | 2000 | 2010 | 2011 | 2050 | Increase -% |
|---|---|---|---|---|---|---|
| Idaho | 1,007 | 1,294,000 | 1,568,000 | 1,585,000 | 2,318,000 | 46.2 |
| Minnesota | 4,376,000 | 4,920,000 | 5,304,000 | 5,345,000 | 7,115,000 | 33.1 |
| Montana | 799,000 | 902,000 | 989,000 | 998,000 | 1,406,000 | 40.9 |
| North Dakota | 639,000 | 642,000 | 673,000 | 684,000 | 1,288,000 | 88.3 |
| Oregon | 2,842,000 | 3,422,000 | 3,881,000 | 3,872,000 | 6,384,000 | 64.8 |
| South Dakota | 696,000 | 755,000 | 814,000 | 824,000 | 1,327,000 | 61.0 |
| Washington | 4,867,000 | 5,894,000 | 6,725,000 | 6,830,000 | 11,700,000 | 71.3 |
| Wisconsin | 4,832,000 | 5,364,000 | 5,687,000 | 5,712,000 | 7,054,000 | 23.5 |
| Total | 20,118,000 | 23,193,000 | 25,591,000 | 25,850,000 | 38,592,000 | 49.3 |



## EXPECTED INCREASES IN ELECTRICITY GENERATION AND GENERATION CAPACITY FOR THE NORTHERN TIER STATES

| Specific State | Net Generation – Million Kw-Hr/Year | | | Generating Capacity - Megawatts | | |
|---|---|---|---|---|---|---|
| | 2000 | 2010 | 2050 | 2000 | 2010 | 2050 |
| Idaho | 11,900 | 13,100 | 18,630 | 3,000 | 4,000 | 5,915 |
| Minnesota | 51,400 | 53,700 | 63,990 | 10,300 | 14,700 | 19,510 |
| Montana | 26,500 | 29,800 | 47,650 | 5,200 | 5,900 | 8,385 |
| North Dakota | 31,300 | 34,200 | 49,885 | 4,700 | 6,200 | 11,675 |
| Oregon | 51,800 | 55,000 | 69,960 | 11,300 | 14,300 | 23,830 |
| South Dakota | 9,700 | 10,000 | 11,295 | 2,800 | 3,600 | 5,800 |
| Washington | 108,200 | 103,500 | 127,685 | 26,100 | 30,500 | 53,065 |
| Wisconsin | 59,600 | 64,300 | 87,125 | 13,600 | 17,800 | 22,080 |
| Total | 350,400 | 363,600 | 475,720 | 77,000 | 97,000 | 150,300 |

In the same period the overall electric generating capacity across the Northern Tier states could increase by an estimated 55 percent from 97,000 megawatts in 2010 to 150,000 megawatts in 2050 if it increases at the same general rate as population growth. Perhaps most importantly, substantial increases in electric generating capacity will especially be needed in western North Dakota and in eastern Montana. The reason because of the expected massive increase in oil and gas production from the Bakken Formation and the other layers.

The total number of producing oil and gas wells in North Dakota is expected to increase from 10,000 in 2013 to as many as 90,000 after 2040, which represents up to an 800 percent increase. In the same period, the overall crude oil production in North Dakota is expected to increase from 1,000,000 barrels per day in early 2014 to as much as 3,500,000 barrels per day after 2035 which represents a potential increase of as much as 250 percent over present levels. A recent study by the Kadrmas Lee and Jackson engineering company in Bismarck for the North Dakota Governor's Office reported that this additional crude oil could require an increase in electric generation of 3,000 to 5,000 megawatts within 3 to 5 years. An additional 5,000 and 10,000 megawatts would be needed within 5 to 10 years and up to 10,000 to 15,000 megawatts or more within 15 to 20 years.

It is emphasized that some of the required electricity for increased oil and gas production in western North Dakota could be supplied by electric transmission imports from other States. However, there is a divide in the electric transmission systems between the Midwest Independent System Operator (MISO) to the east and the Western Electric Coordinating Council (WECC) which runs right through the middle of the Bakken Formation oil fields. In addition, there are also expected to be major increases in electric generation requires in the adjacent Provinces of Alberta and Saskatchewan as the result of increased oil and gas production which will be similar to the trends being observed in North Dakota and Montana for the same reasons.

One additional area of increase in electric generating capacity would be if the Great Northern Corridor rail service across the Northern Tier were to be electrified in the future. It is expected that the possible electricity need for electrification of the full Northern Tier railroad line over the full distance between Chicago and Seattle could require as much as 1,000 megawatts for freight service and up to 300 megawatts for passenger service.

LOCATIONS OF THE PROPOSED RAILROAD LINES ACROSS THE NORTHERN TIER WITH POTENTIAL FOR THE ELECTRIFICATION IN PROXIMITY TO THE ELECTRIC TRANSMISSION NETWORK OF THE WESTERN REGION

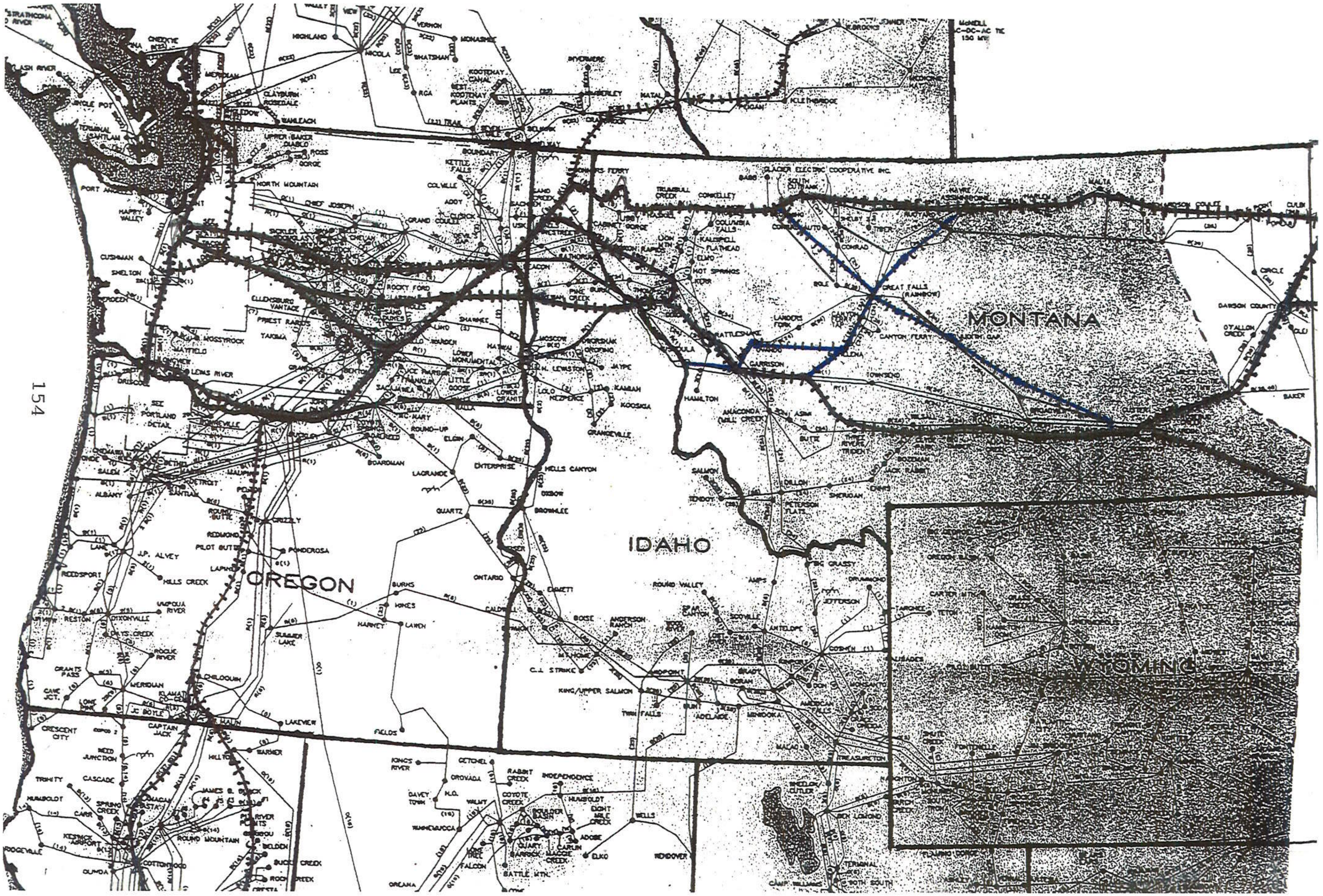
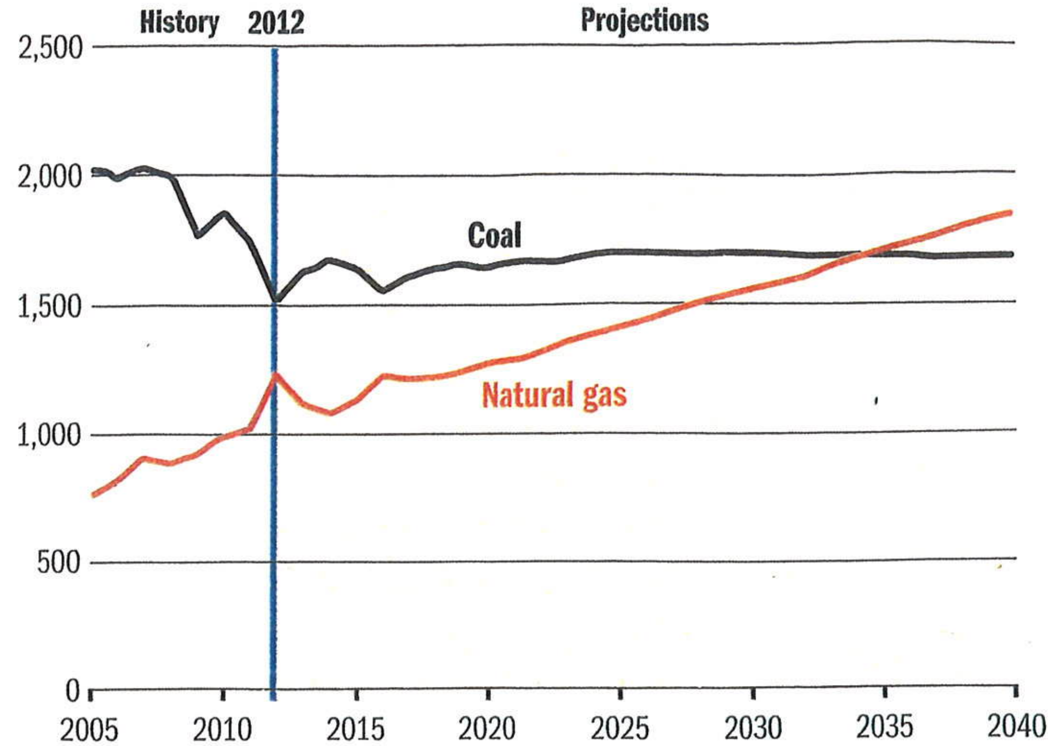
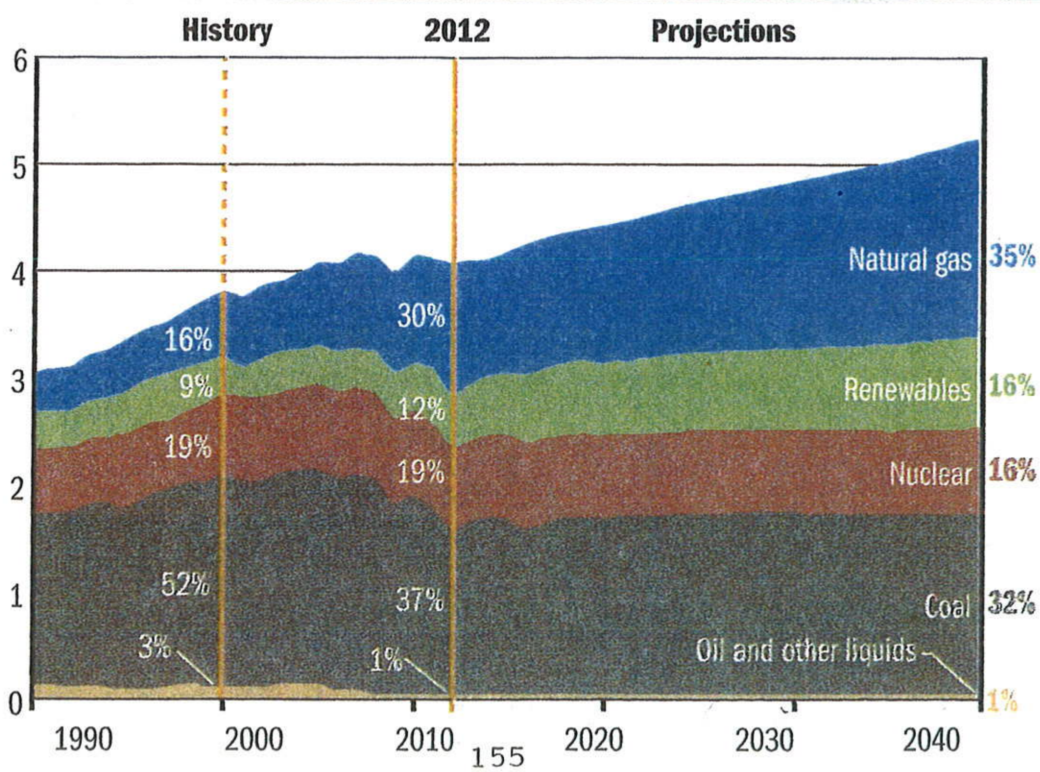


**Figure 2:** Electricity Generation From Natural Gas and Coal, 2005-2040 (Trillion kWh)




*Sources: Energy Information Administration. Annual Energy Outlook 2014 Early Release Overview*

**Figure 3:** Electricity Generation by Fuel, 1990-2040 (Trillion kWh)






*Sources: Energy Information Administration. Annual Energy Outlook 2014 Early Release Overview*

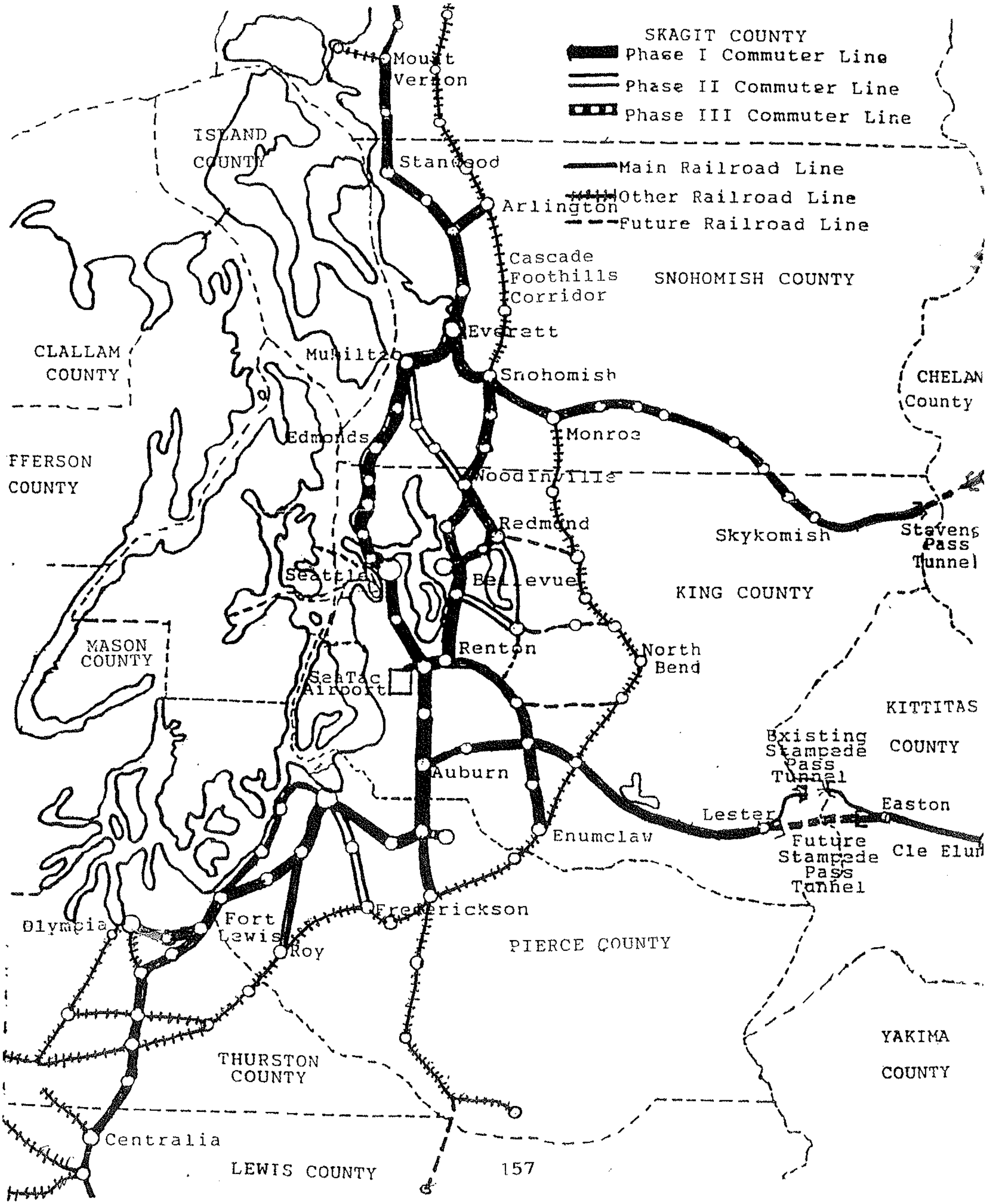
In addition, the possible electrification of the urban rail passenger services in the Puget Sound metropolitan area of western Washington could add up to megawatts of electricity supply with up to 250 megawatts for urban rail electrification in the Chicago and Twin Cities metropolitan areas.

The possible sources of additional electric power for all of the increases in electricity use across the Northern Tier could include coal, natural gas, nuclear, hydroelectric and renewable energy in the form of biomass, solar and wind power. Natural gas is presently being flared off in large volumes from stranded fields because of the relative back of pipelines to export it out of North Dakota and in some cases because the previous low market prices for gas discouraged investments in natural gas pipelines. There are presently three urea fertilizer plant projects in some stage of development in North Dakota which would use at least some of this surplus natural gas now being wasted by flaring.

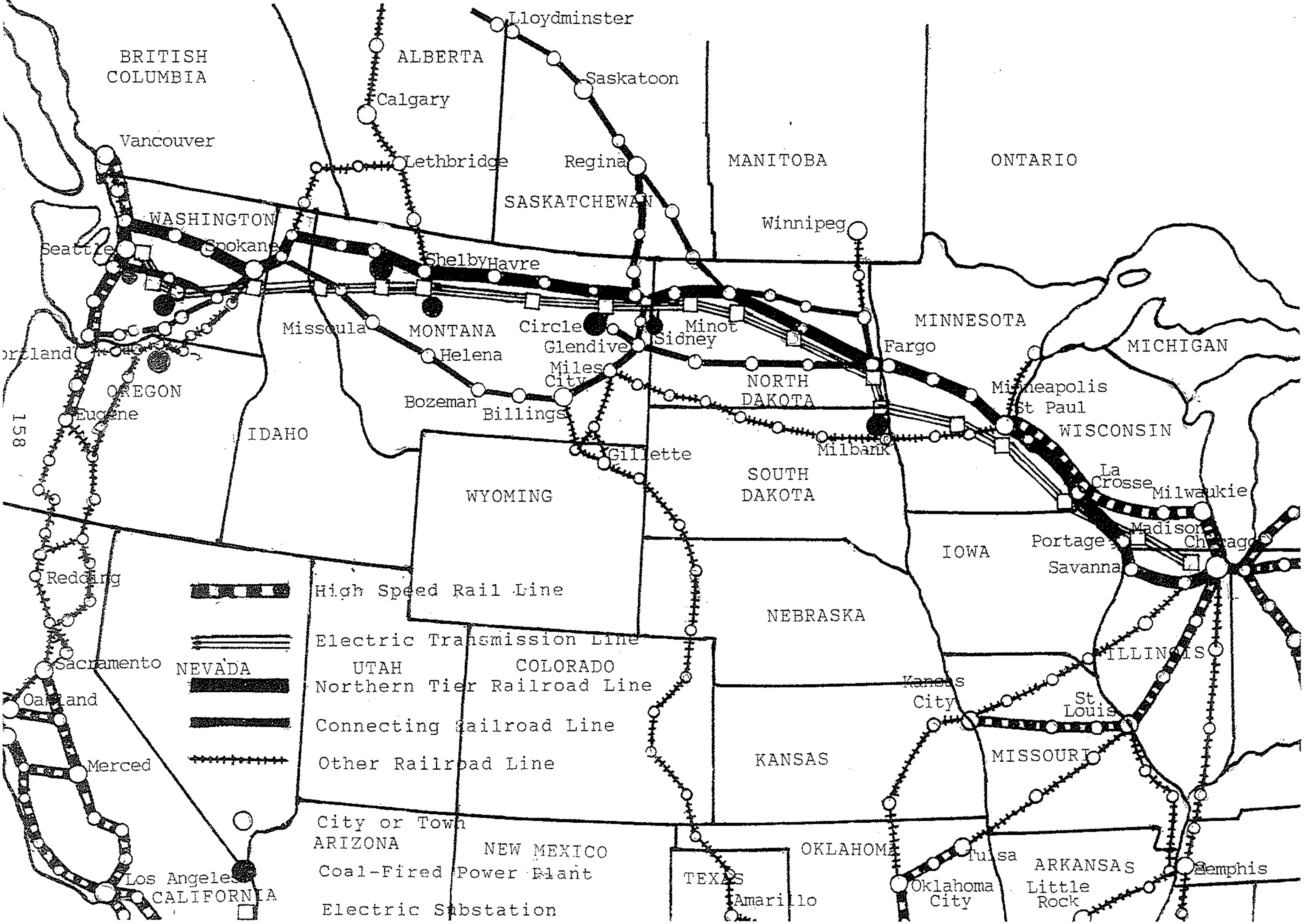
It is possible to generate electricity from natural gas at the wellhead using onsite generators so that it can be used within immediate proximity for pumping oil and related users. It is also possible to collect the natural gas and bring it to a small or medium size power plant using combined cycle gas turbine technology. It is also possible to use the natural gas as a supplemental or replacement fuel for the lignite coal now is being burned at the seven lignite coal – fired power plants in western North Dakota to the immediate east of the Bakken Formation oil fields. Such as step would make it possible to reduce air pollution emission from these power plants, but would also eliminate many of the present lignite coal mining jobs associated with these lignite - fired power plants.

Technologies have been developed to convert natural gas to liquid fuels or to make petrochemical feedstacks. It is necessary to remove the light hydrocarbon liquid constituents from natural gas so that they can be converted into ethylene gas in an ethylene cracking furnace which can then be used as a feedstock to manufacture plastics and tires and to produce petrochemicals. It has been recommended in a separate section of this report to construct an ethylene cracking furnace on property adjacent to the Black Thunder oil refinery with a 15,000 barrel per day capacity by the Mandan Hidatsa Arikara Nation at Makoti on the northeast side of the Fort Berthold Indian Reservation. Then the light hydrocarbon condensate liquids produced as a byproduct of natural gas produced as a part of crude oil production can be fully utilized without generating any waste products.

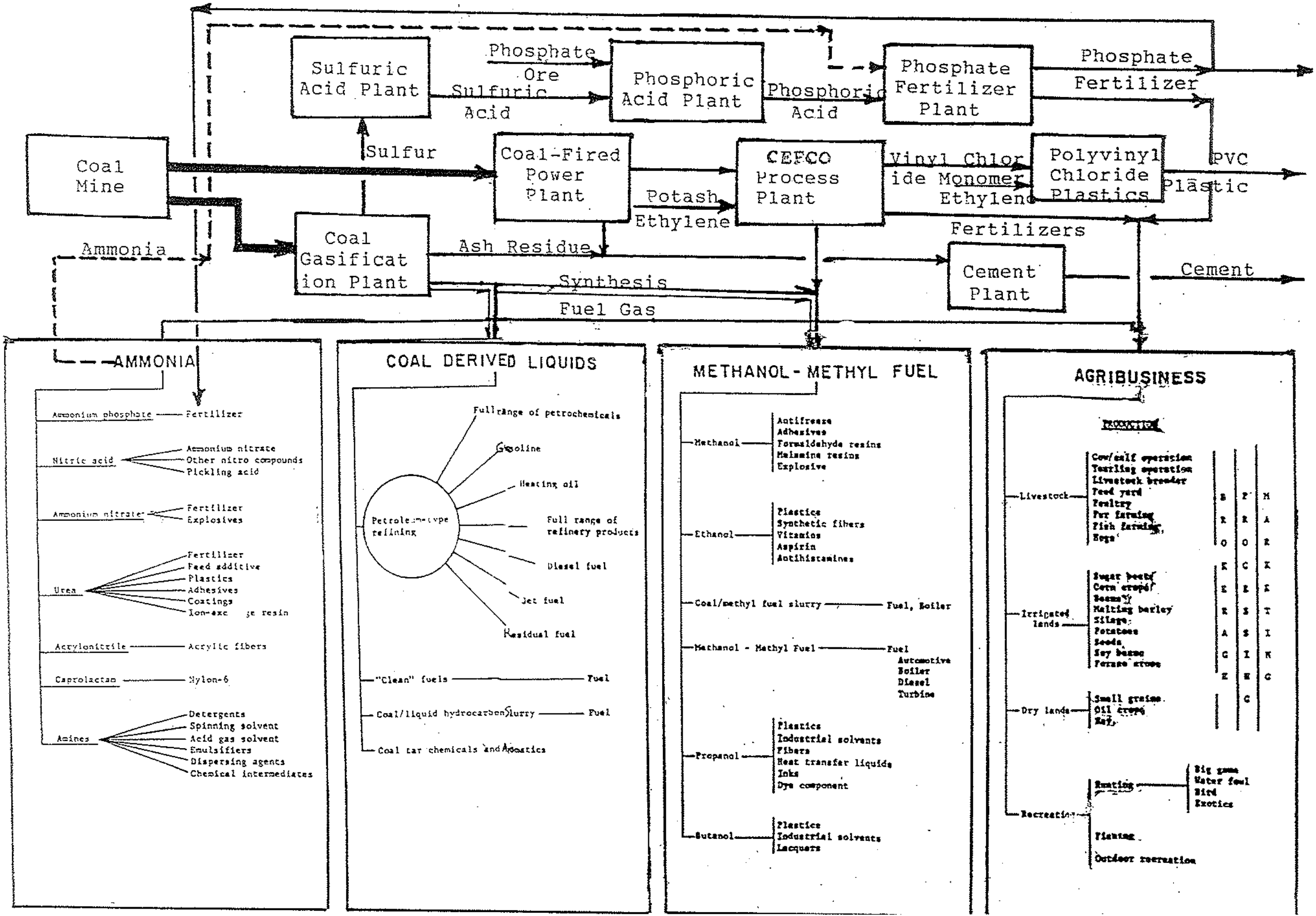
PROPOSED ELECTRIFIED COMMUTER RAILROAD NETWORK IN THE PUGET SOUND AREA



PROPOSED ROUTE LOCATION OF THE NORTHERN TIER ELECTRICAL INTERTIE AND ELECTRIFIED RAILROAD



PROCESS FLOW DIAGRAM OF THE PROPOSED COAL-FIRED POWER PLANT AND COAL GASIFICATION PLANT AT CIRCLE, MONTANA FOR CHEMICAL AND FERTILIZER PRODUCTION FOR AGRICULTURE AND INDUSTRY USAGE




159

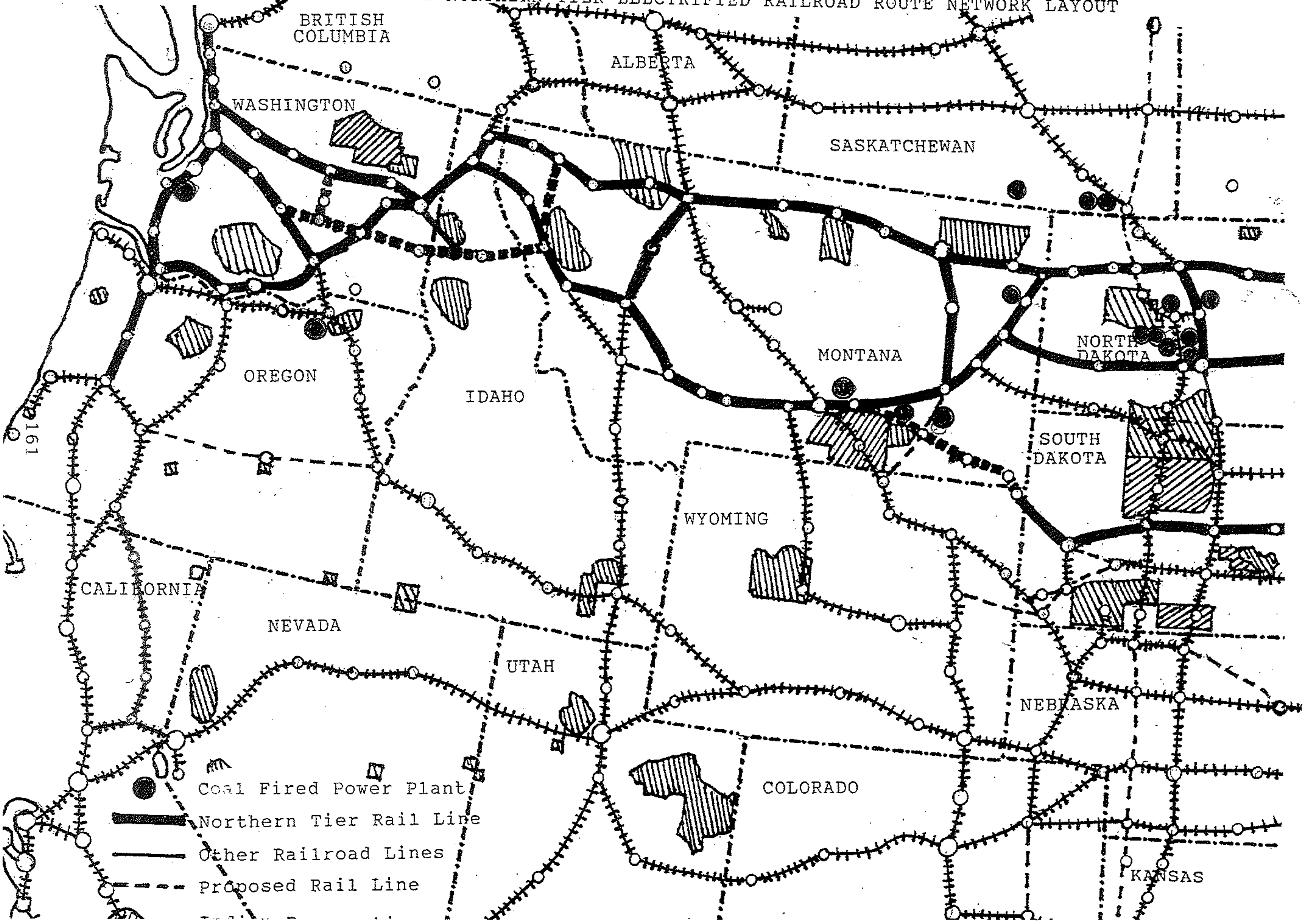
It is also possible to take waste wood or plant residues or municipal solid wastes and to convert them into a synthesis or fuel gas which can then be reacted to produce gasoline fir cars diesel oil for trucks or aviation fuel for planes. An alternative process configuration takes the organic wood or municipal or other waste stream and converts the waste materials into biodiesel fuel which can be added as a supplement to conventional diesel fuel from petroleum to be used in trucks. The new small oil refineries now being developed in North Dakota all rely on producing at least some diesel fuel because of the large numbers of trucks required for the major crude oil production in the Bakken Formation and elsewhere.

It is possible that onsite electric power generating facilities using natural gas or biofuels in conjunction with electricity production and liquid fuels manufacture at Indian Reservation along the Northern Tier. These future electric generating facilities would be small or medium or large in electric generating capacity and could also be used to make liquid fuels as well as to supply the local electricity needs on and adjacent to the respective Indian Reservations. The electricity generated from these facilities could also be used to supply the regional electric grid or the electrification of the BNSF railway line across the Northern Tier while providing jobs and revenues to the affected Indian Tribes.

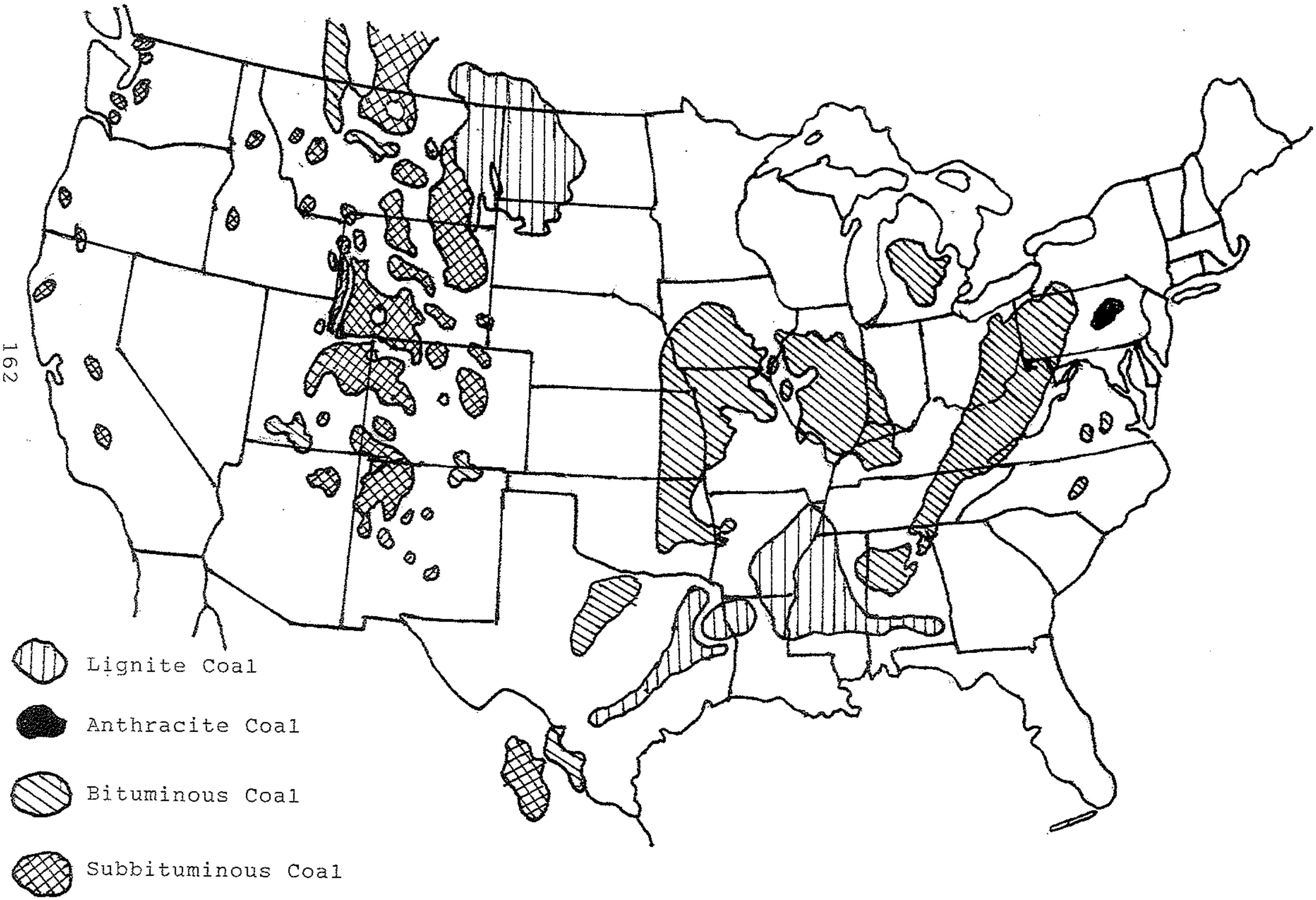
Another possible energy source for electric power generation or for export to foreign countries is coal. The coal can be supplied on one option by the subbituminous or bituminous grade coals such as can be mined on the Crow or adjacent Northern Cheyenne Indian Reservations and then used onsite for electric power generation. The coal can also be shipped offsite to nearby or remote power plants or else hauled to coal terminals in the State of Washington or in British Columbia by the BNSF Railway as previously described. It may also be possible to use the local lignite coal which occurs in both North Dakota and Montana for use in local power plants, including deposits found on the Fort Berthold Indian Reservation along with crude oil. However, it must first be necessary to reduce the air pollution emissions from coal combustions with the CEFCO Process.

The CEFCO Process is an advanced new technology for air pollution emission control on coal – fired power plants which combines a multiple base chemical absorption and recovery system with multiple stage collection sequence to create an efficient and economical means for contaminant removal.

PROPOSED ROUTE LOCATION FOR THE NORTHERN TIER ELECTRIFIED RAILROAD ROUTE NETWORK LAYOUT



GEOGRAPHIC LOCATIONS OF THE MAJOR COAL DEPOSITS BY TYPE IN THE CONTINENTAL UNITED STATES

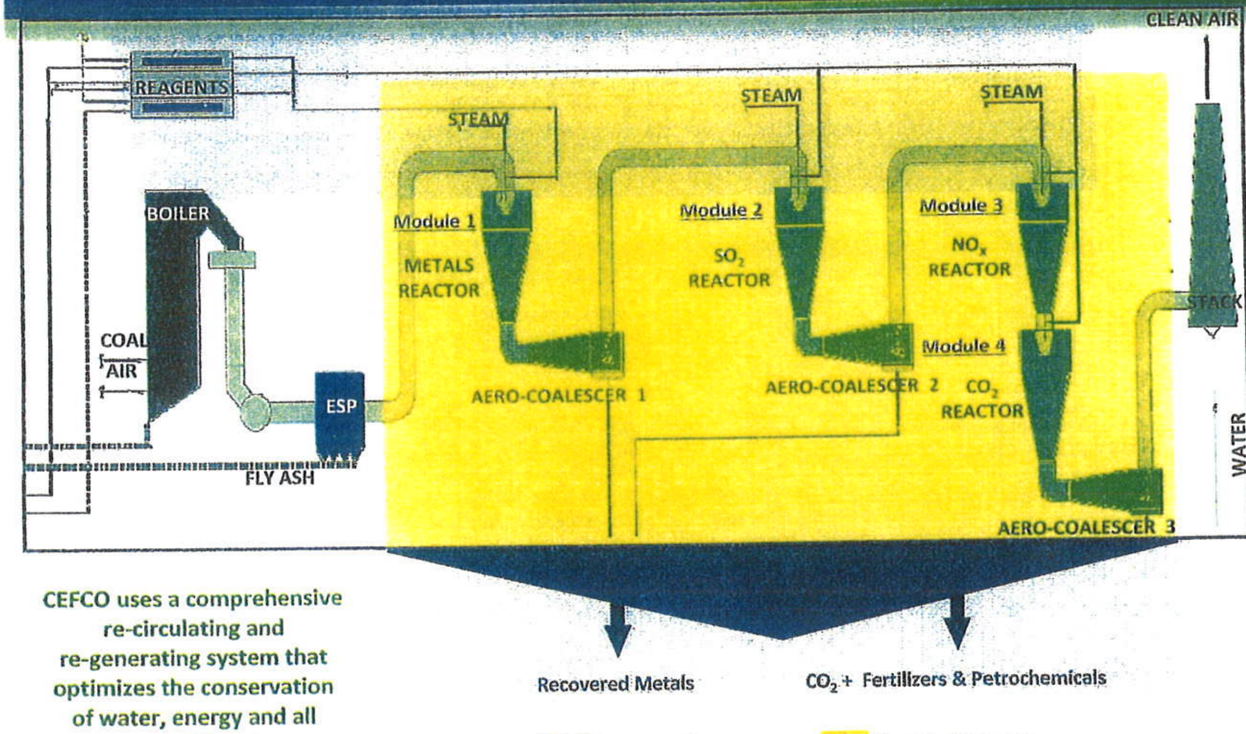


The CEFCO Process employs a multi – stage collection sequence employing multiple removal absorbing solutions to separate mercury vapor, trace metals, sulfur oxides, nitrogen oxides and carbon dioxide from the flue gas stream at very high efficiencies plus conversion of carbon monoxide and trace organics to oxidized products so they can be removed. These air pollutants are then converted into a series of valuable chemical, fertilizer, metal and clean transportation fuel products with a substantial resale value. As a result, the CEFCO Process can actually be operated on a profitable basis while eliminating environmental contamination to the atmosphere as well as water or land as liquid or solid effluents.

The CEFCO Process makes it possible to achieve the complete capture of the air pollutants emitted from coal combustion followed by their complete conversion into usable end products on a profitable basis without any liquid or solid waste streams. The CEFCO Process eliminates the generation of any toxic or hazardous waste solids or sludges because it uses a soluble base chemical absorption and treatment system. The CEFCO Process makes it possible to treat the fly ash and bottom ash solid residuals from coal burning by selective removal with chemical extractants produced from the air pollutants so as to actually reduce the potential toxicity levels of the ash residual waste streams while recovering valuable metals in the purified form so that they can be reclaimed and reused for a variety of purposes.

The CEFCO Process is actually a net generator of water from its operation instead of being a net consumer. The CEFCO Process is able to recover the water present in the coal through condensation from the stack gas as well as to recover the water input in the chemical feed streams through condensation from the liberated carbon dioxide stream during the chemical recovery. The water recovered can then be returned to the chemical feed system through recycling to the plant inlet or else utilized for sanitary water within the plant or used as boiler feed water makeup. It is even possible that the CEFCO Process may make it possible to virtually eliminate input water needs for those coal – fired power plants which employ dry cooling by supplying their other water supply needs. The CEFCO Process can also utilize brackish or saline waste to supply some of its chemical makeup requirements while upgrading their respective quality to distilled water which can be recycled and reused for agricultural, industrial and energy production purposes while reducing contamination.

## CEFCO Modules




CEFCO uses a comprehensive re-circulating and re-generating system that optimizes the conservation of water, energy and all required inputs.

CEFCO

## Recovery & Products

Sequenced modules selectively capture pure products from pollutants.

| | CEFCO Module 1: Metals | CEFCO Module 2: $SO_2$ | CEFCO Module 3: $NO_x$ | CEFCO Module 4: $CO_2$ |
|---|---|---|---|---|
| Final Products | Metal Compounds (Mercury + Trace Metals)<br>Fine Particulates (< 2.0 Microns) | Potassium Sulfate (Fertilizer) | Potassium Nitrate (Fertilizer) | Pure $CO_2$ |
| Potential Revenue Streams | • Metals Market<br>• Alloy-Steel Users<br>• Industrial Market<br>• Trace Metals for Hi-Tech Electronics Users<br>• Catalysts and Additives for Refining & Petrochemical Markets | • Fertilizers & Agricultural Applications<br>• Industrial Market<br>• Feedstock for Petrochemical Market | • Fertilizers & Agricultural Applications<br>• Industrial Market<br>• Feedstock for Petrochemical Market | • Enhanced Oil Recovery<br>• Sequestration Market<br>• Carbon Credit<br>• Ethylene Dichloride, PVC Plastics<br>• Feedstock for Petrochemical Market<br>• Ethanol & Diesel Fuels |



CEFCO

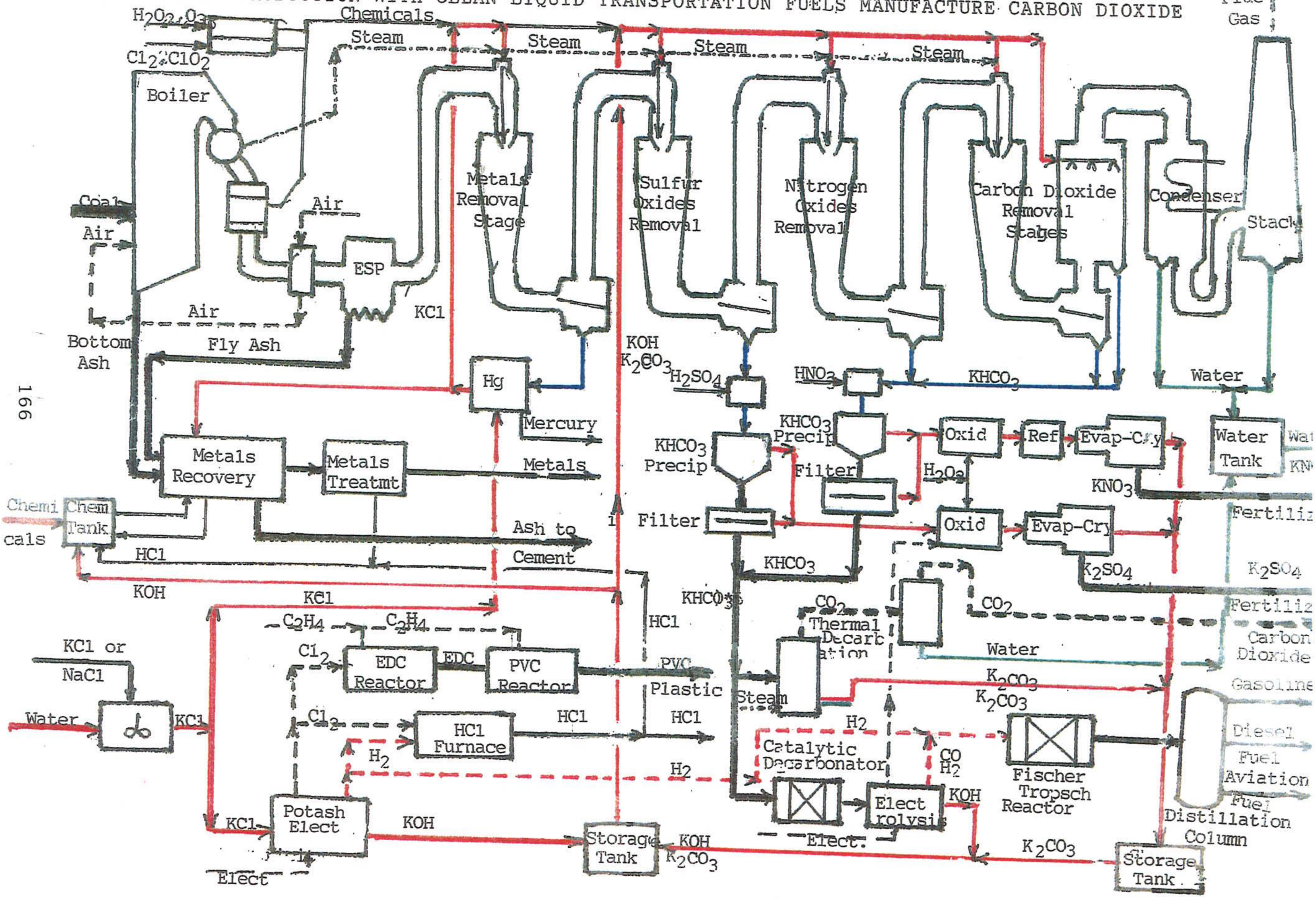
The CEFCO Process can achieve removal efficiencies of 99.9 percent or more for sulfur oxides, 99.0 percent or more for nitrogen oxides and trace metals, up to 90 percent of the carbon dioxide, 80 to 90 percent of the organics and carbon monoxide, and 70 to 80 percent of the water vapor in the flue gases from coal – fired power plants so that the gas stream has the pollutants removed. The CEFCO Process converts the sulfur oxides to valuable potassium sulfate fertilizer and nitrogen oxides in to potassium nitrate fertilizer for soil conditioning and upgrading for agriculture and also produces polyvinyl chloride plastics. It may be possible to recover as many as 40 individual metals from coal with the CEFCO Process by removal from the gas as well as recovery from the ash residues by chemical extraction for subsequent metals refining operations at a separate location.

The CEFCO Process allows for carbon dioxide to be separated from the flue gas stream for subsequent recovery as a purified gas stream through thermal decarbonation. After removal and recovery of the water vapor by condensation, the purified carbon dioxide gas stream can then be injected into oil fields to increase yields through tertiary enhanced oil recovery. The carbon dioxide gas can also be added into greenhouses to enhance plant growth rates for crops such as hothouse vegetables. The carbon dioxide can also be used as a feedstock to produce clean liquid transportation fuels such as ethanol, methanol, gasoline or diesel oil. These fuels can be produced either reaction with hydrogen through catalytic processes, or by production of algae through photosynthesis with either artificial or natural sunlight plus oxygen as a byproduct, or by direct reaction with natural gas.

There are 15 existing coal-fired power plants located in the five western States located along or near the Great Northern Corridor with a total generating capacity of just over 10,000 megawatts. In addition, there are two new coal-fired power plants which could be built near Circle, Montana and Columbus, North Dakota which could be built along with a second generating unit at the existing Boardman power plant in northwestern Oregon. The total capacity of these 17 existing and proposed coal-fired power plants would then have a total aggregate electric generating capacity of 12,360 megawatts if all units were built and in continued operation to place coal on an equal footing with natural gas.

The coal-fired power plants along the Northern Tier burn either low grade lignite coal from the Fort Union Formation in western North Dakota and eastern Montana or medium grade subbitiminous coal from the Powder River Basin in southeastern Montana and northeastern Wyoming.

SCHEMATIC FLOW DIAGRAM OF THE CEFCO PROCESS FOR AIR POLLUTION CONTROL PLUS CHEMICAL AND FERTILIZER PRODUCTION WITH CLEAN LIQUID TRANSPORTATION FUELS MANUFACTURE CARBON DIOXIDE



There are eight of these existing 15 power plants which burn the local medium sulfur lignite coal which are located primarily in North Dakota plus the Lewis and Clark power plant is Sidney, Montana with a total electric generating capacity of 4,190 megawatts. The remaining seven coal- fired power plants burn the low sulfur subbituminous coal from the Powder River Basin in Montana and Wyoming and have a total generating of 5,000 megawatts with lower unit emissions than from lignite coal.

It is planned that if the Great Northern Corridor is ever electrified and high speed rail passenger service across the Northern Tier is actually implemented that a significant portion of the electricity to be supplied to this railroad will be supplied coal. The coal to be burned in the future in these new and existing power plants using the CEFCO Process for air pollution emission control plus chemical and fertilizer recovery with the coal coming from either medium sulfur lignite in the local area or from low sulfur subbituminous coal in the Powder River Basin or from high sulfur bituminous coal to be hauled by rail from the Illinois Basin. The high sulfur Illinois Basin bituminous coal is beneficial from the standpoint of generating the maximum amount of byproduct revenues from the CEFCO Process.

The Great Northern Corridor infrastructure along with Northern Tier States need to have a higher speed double track electrified railroad along its entire length between Chicago and Seattle for freight and passenger transport over long distances. There will also be a four lane highway in parallel to the railroad for truck and automobile transport of freight and passenger generally over the shorter distance trips along the parallel U.S. 2 highway corridor from Everett to Grand Forks. Particular new immediate concerns relate to the need to transport oil field workers between Texas and North Dakota to work in the Williston Basin oil field which will also occur along the Great Northern Corridor railway line as well as for other travel so that eventually a high speed passenger and freight railroad is needed over the entire western United States.

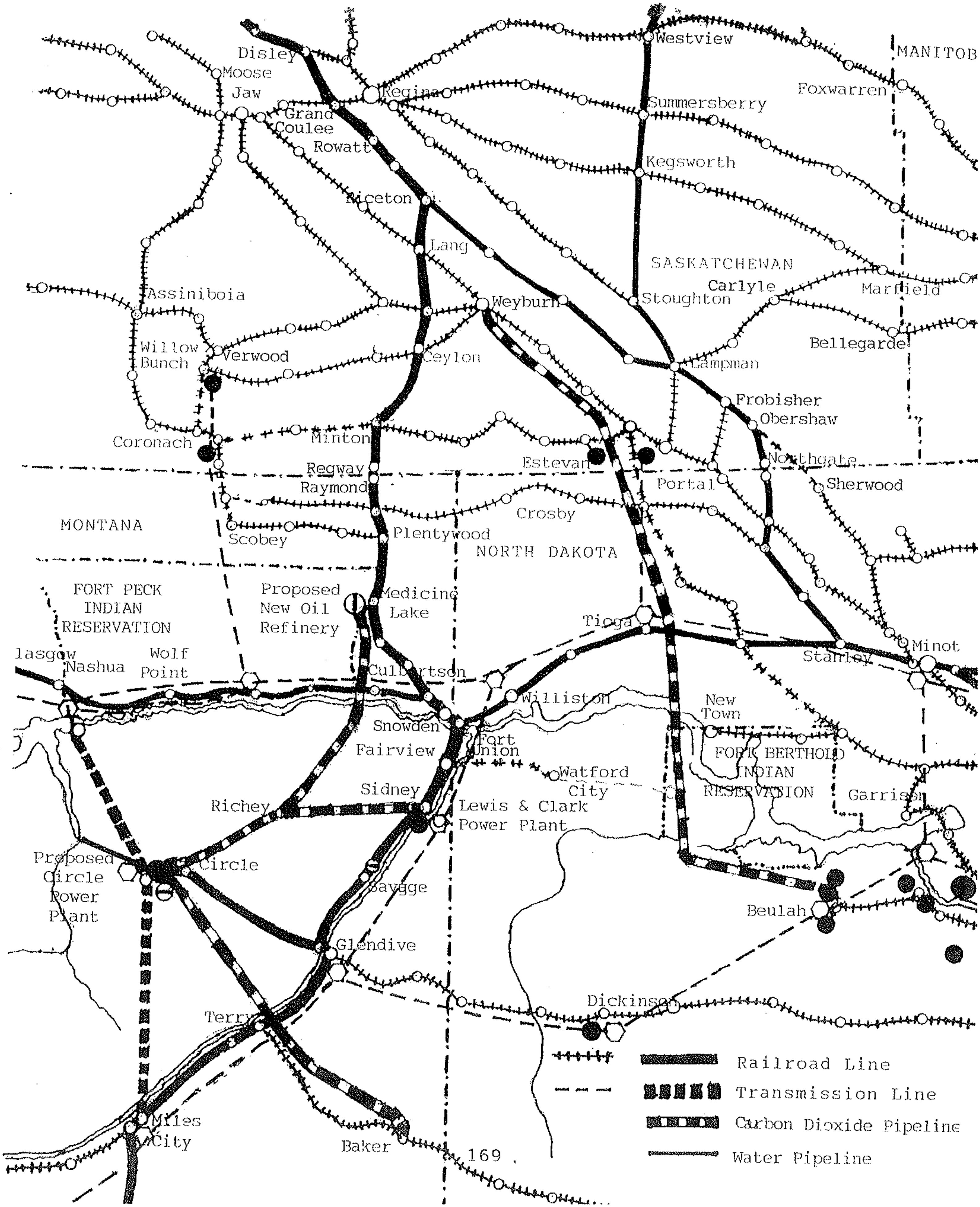
It is planned to construct an electric transmission line along the entire Northern Tier Corridor to be able to transmit large amounts of electricity between the States. This electricity would be transmitted by long distance subsurface high voltage superconducting pipeline cable as well as above ground transmission lines into local communities. There would be expected be considerable increases in the overall electricity consumption along the Great Northern Corridor for farming operations, agricultural irrigation, water supply pumping, mining plus oil and gas production, as well as for industrial manufacturing plants and railroad electrification plus for residential and commercial activities in the Northern Tier states.

## LISTING OF COAL-FIRED POWER PLANTS IN THE WESTERN PART OF THE NORTHERN TIER

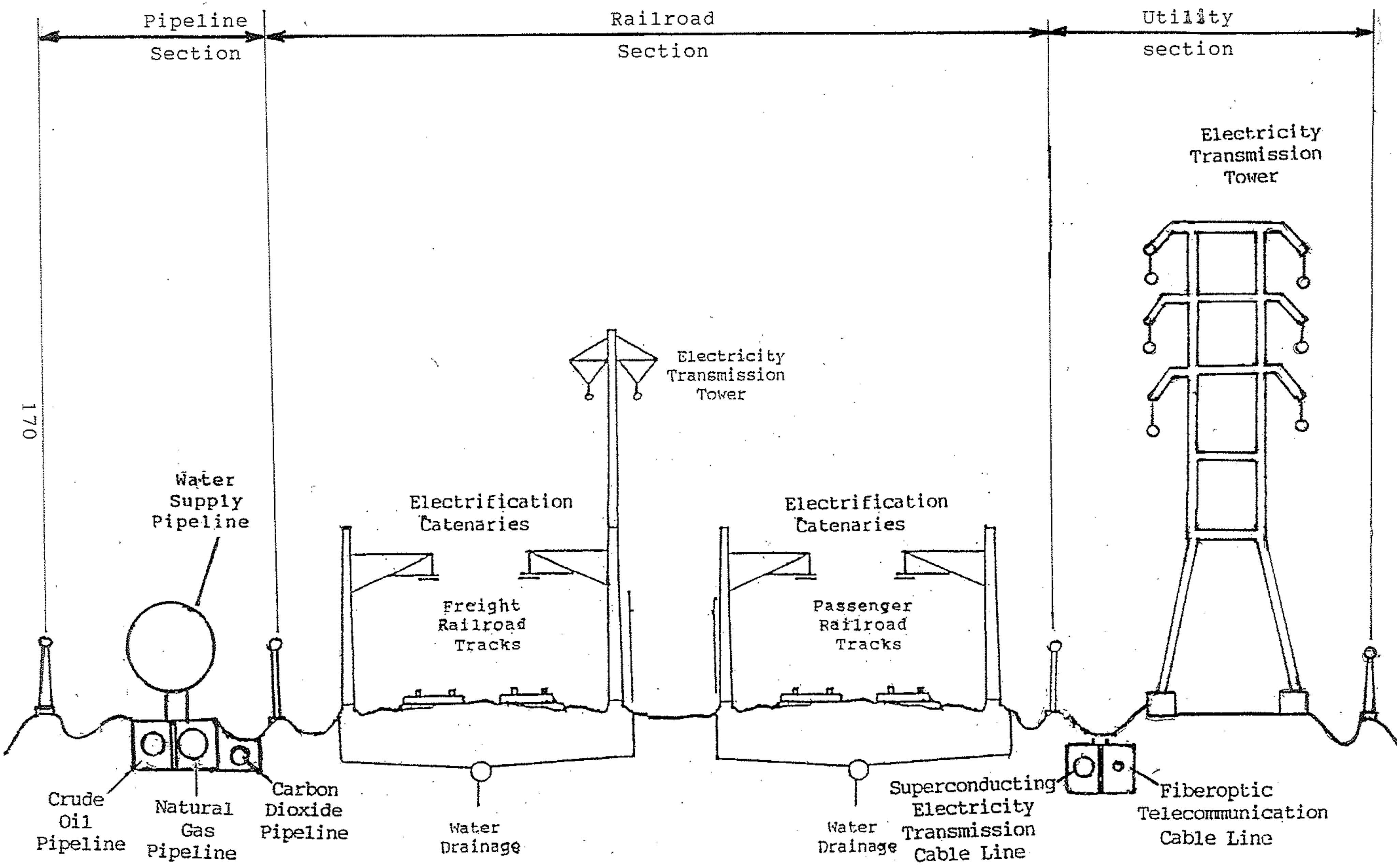
| Specific State | Plant Name | Plant Location | Electric Utility | Capacity Megawatts | Coal Type |
|---|---|---|---|---|---|
| Montana | Centennial | Hardin | MDU | 120 | Subbituminous |
| | Colstrip | Colstrip | PPL – PSE | 2,100 | Subbituminous |
| | Corette | Billings | PPL | 150 | Subbituminous |
| | Lewis & Clark | Sidney | MDU | 120 | Lignite |
| | Circle (P) | Circle | GNP+ | 800 | Lignite |
| | Total: | — | — | 3,290 | — |
| North Dakota | Antelope Valley | Beulah | BEPC | 1,400 | Lignite |
| | Coal Creek | Underwood | GREC | 1,200 | Lignite |
| | Coyote | Beulah | MDU, OTPC | 400 | Lignite |
| | Heskett | Mandan | MDU | 120 | Lignite |
| | Jamestown | Jamestown | GREC | 70 | Lignite |
| | Leland Olds | Stanton | BEPC | 600 | Lignite |
| | MR Young | Center | MEC | 1,100 | Lignite |
| | Stanton | Stanton | GREC | 180 | Subbituminous |
| | Burke County (P) | Columbus | TBD | 1,000 | Lignite |
| | Total: | — | — | 5,070 | — |
| South Dakota | Big Stone | Milbank | OTPC | 500 | Subbituminous |
| Oregon | Boardman | Boardman | PGE | 550 | Subbituminous |
| | Second Unit (P) | Boardman | CEFCO | 550 | Bituminous |
| Washington | Centralia | Centralia | TAGC | 1,400 | Subbituminous |
| Total: | All Plants | — | — | 12,360 | — |

Note: The symbol (P) means a proposed facility.

PROPOSED ROUTING OF THE YELLOWSTONE VALLEY RAILROAD AS AN INTERNATIONAL RAIL CONNECTOR BETWEEN MONTANA AND SASKATCHEWAN TO THE ALASKA CANADA RAILWAY LINE



## COOPER CORRIDOR CONCEPT FOR A COMBINATION RAILROAD PIPELINE UTILITY RIGHT OF WAY NETWORK



## Transportation Corridor Locations

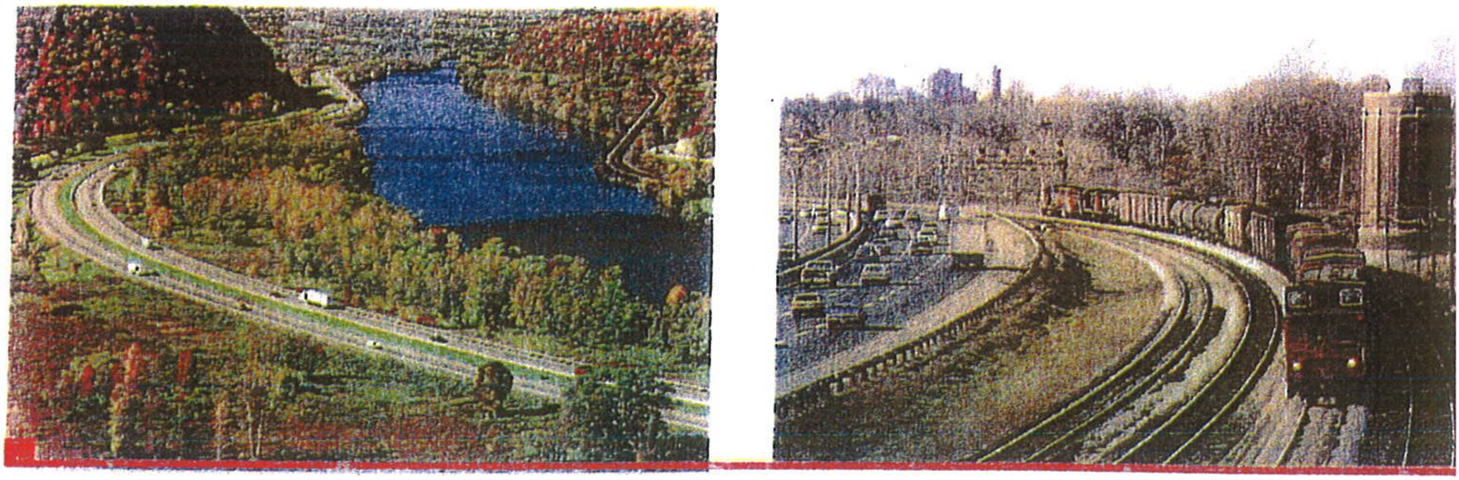


Figure 8: Superconductor Electricity Pipelines can be located along existing transportation rights of way.

## Superconducting Pipeline Comparison

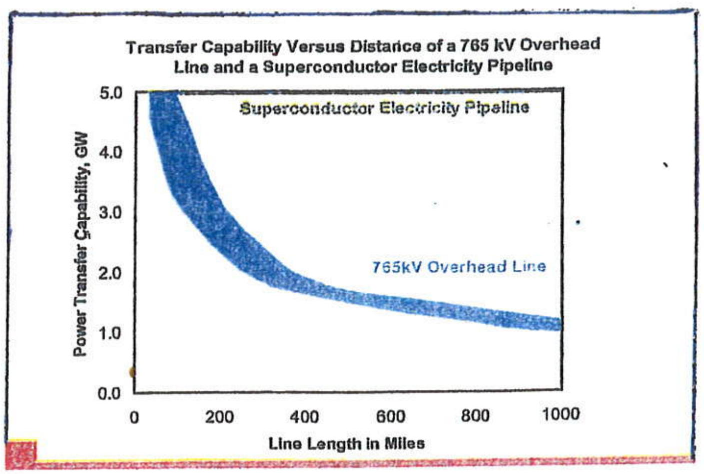



Figure 5: Comparison of power transfer capability versus distance of a single 765 kV AC overhead transmission line to a Superconductor Electricity Pipeline.

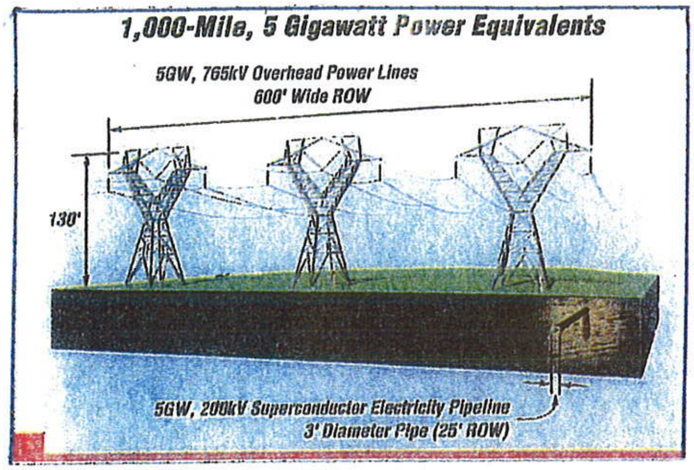



Figure 6: Aggregate right of way comparison to transmit 5 GW (5,000 MW) for 1,000 miles with three overhead AC lines with 8% power losses and DC superconductor cables.

## Comparative Electric Line Losses

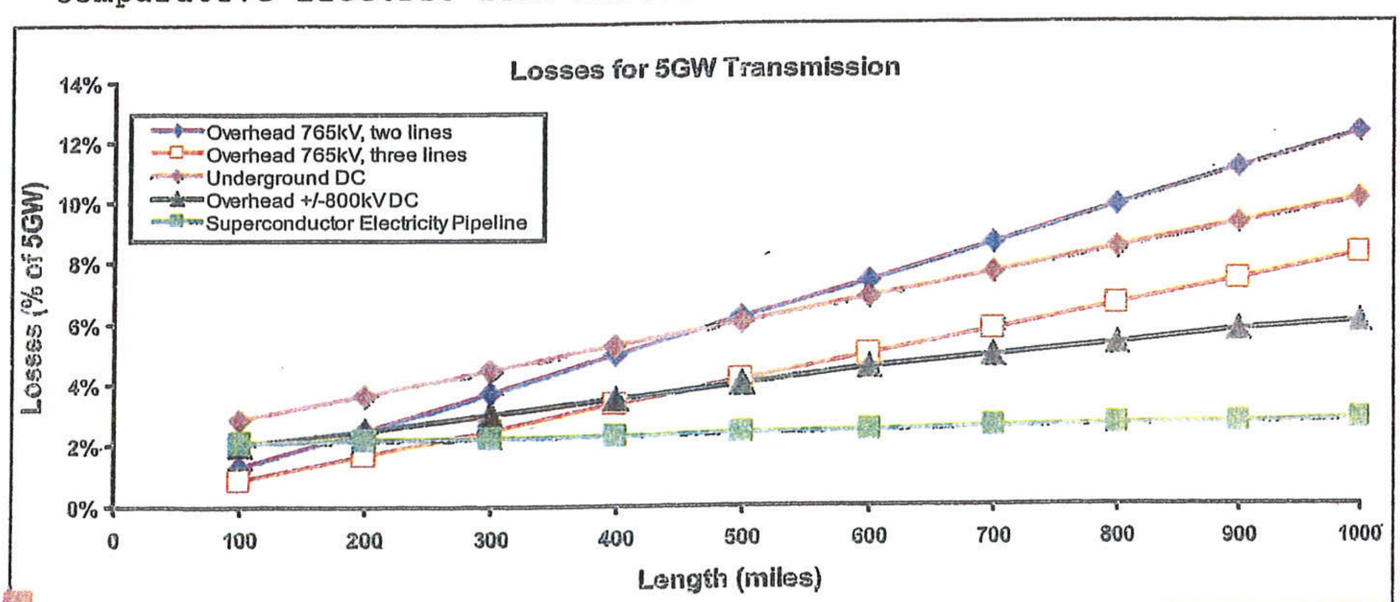



Figure 9: Efficiency of various transmission options.



Courtesy of American Superconductor Corporation, Devers, Massachusetts, 201

## WATER RESOURCES

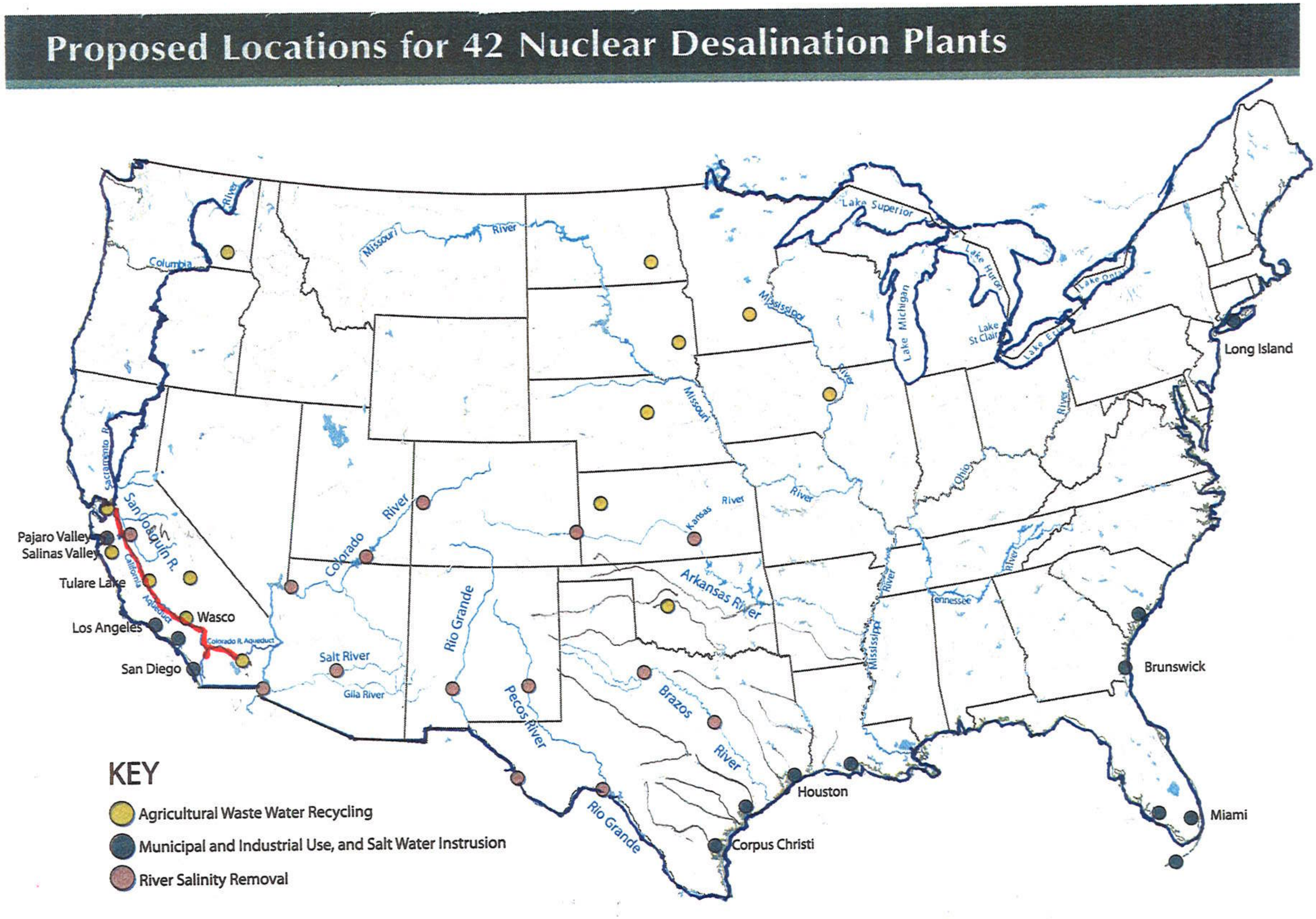
There is great need to supply water to the Great Plains from the available supplies as well as to California. The Ogallala Aquifer has been a primary water source for agriculture in the past, but it is much stressed resource in Texas by a water aqueduct system employing pumped storage for hydroelectric power. Water could be pumped from the Missouri River to a water channel in western its major rivers with water with water recharge from the North American Water and Power Alliance for the Red, Brazos, Colorado and Pecos River basins in a manner similar to that already proposed for the pumping of water from the Columbia River in Oregon to northern and central and southern California. A similar pumped storage reservoirs system to equalize electricity generation could also be implemented along the Columbia and Snake River hydroelectric dam systems along with the required measures to protect salmon fish runs.

It is finally recommended that there be additional measures to enhance irrigation waste water cleanup and reutilization in the San Joaquin Valley of Central California. A series of 42 nuclear reactor – based power plants were previously proposed by the then-existing U.S. Atomic Energy Comission which would incorporate the desalination of brackish and saline waters in the 1950's and 1960's at a series of locations in the United States. This plan eventually led to the proposed by the Ralph M. Parsons engineering company of Pasadena, California in conjunction with the City of Los Angeles Department of Water and Power (LADWP) to build the North American Water and Power Alliance (NAWAPA) project throughout North America. One of the outgrowths of the NAWAPA plan was to construct a nuclear-powered brackish irrigation waste water desalination facility at the proposed Wasco nuclear power plant to be built for the City of Los Angeles Department of Water and Power.

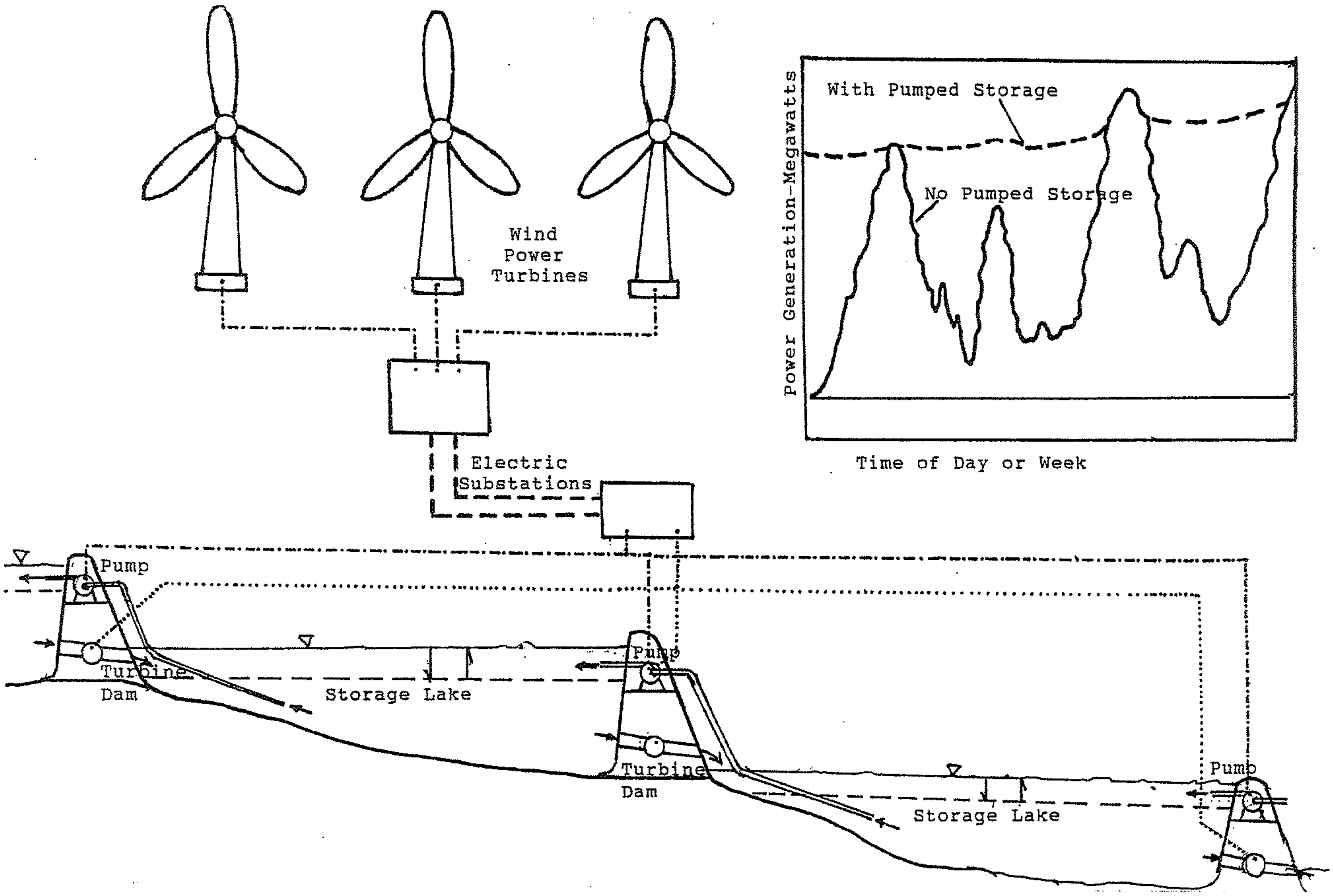
This original plan called for the construction of at least six nuclear power plants along the California Aqueduct in the San Joaquin Valley plus at least six other nuclear power plants in California. These nuclear power plants were to be built in order to generate electricity as well as to desalt irrigation waste waters from the existing farming operations plus from the future farming operations in the southwestern San Joaquin Valley which would afterwards result from the construction of the California Aqueduct project. The California Aqueduct was built following the passage of the Proposition 16 in 1962 to supply water to central and southern California for agriculture, industries and municipalities.

PREVIOUS PLAN FOR 42 NUCLEAR DESALINATION WATER TREATMENT PLANTS OF THE U.S. ATOMIC ENERGY COMMISSION ALONG WITH THE NAWAPA WEST COAST EXTENSION AND THE CALIFORNIA AQUEDUCT ROUTING

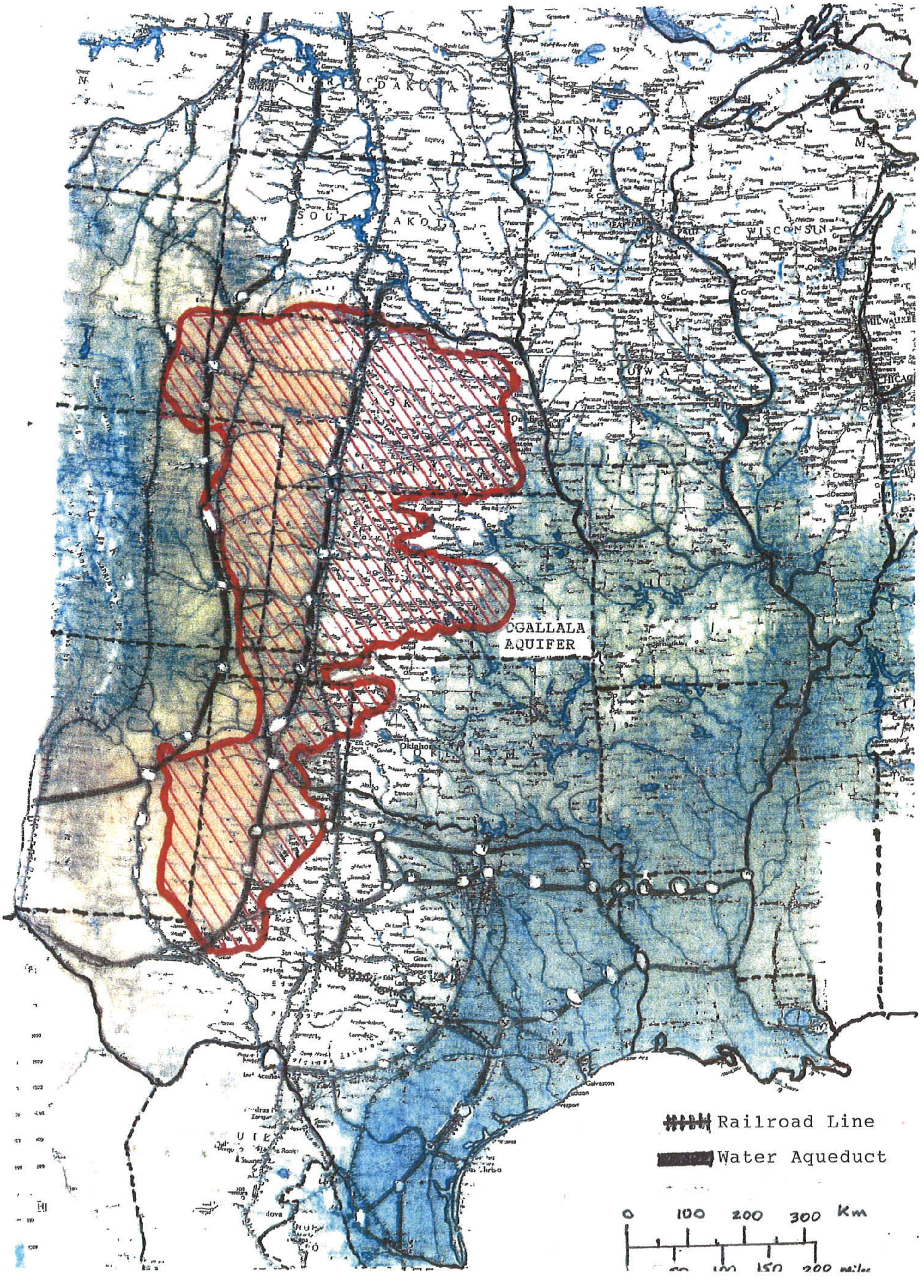




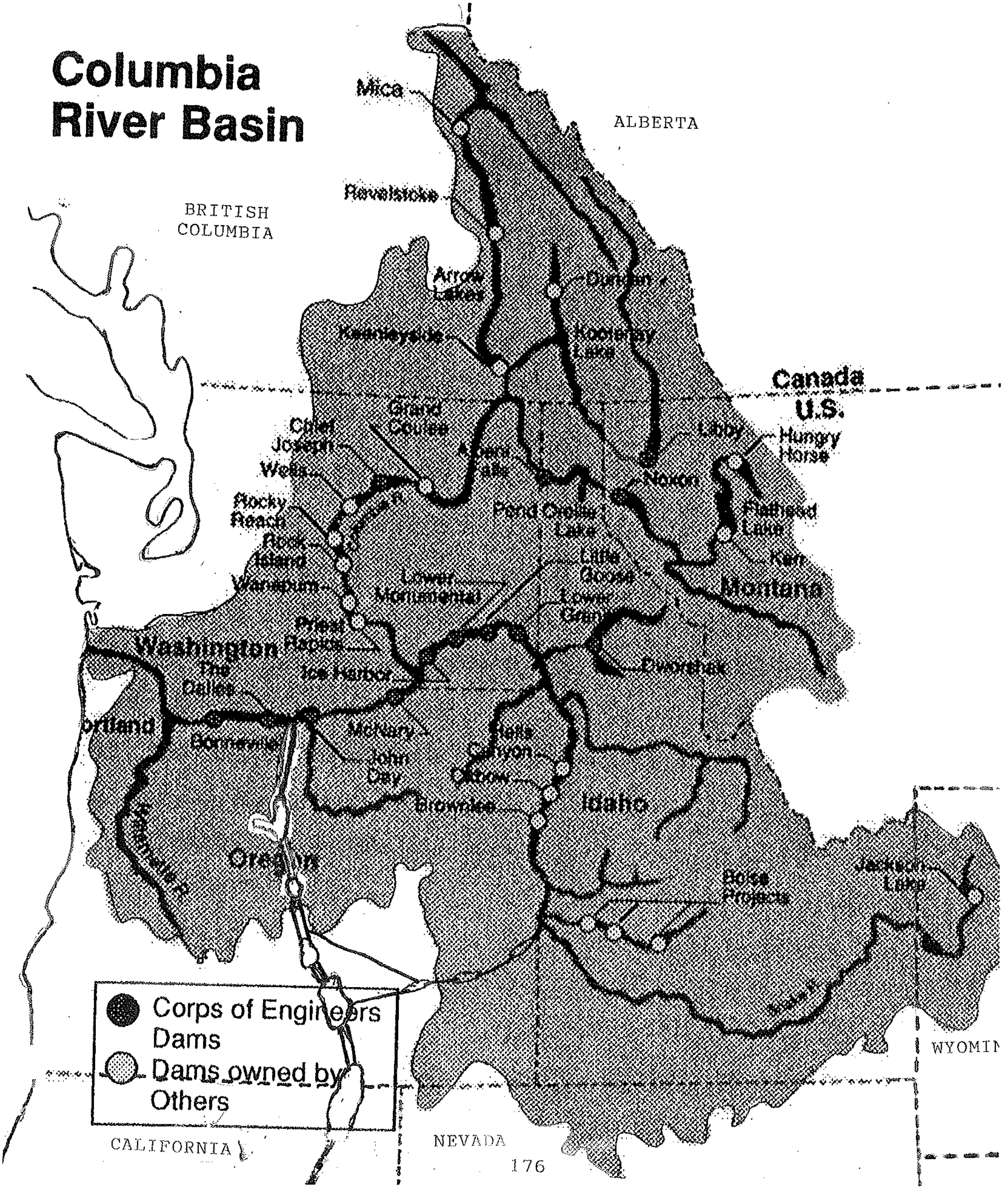
OPERATIONAL CONFIGURATION FOR PUMPED STORAGE HYDROELECTRIC POWER ELECTRICAL ENERGY STORAGE TO SUPPLEMENT WIND POWER ELECTRICAL GENERATION LOAD BALANCING ON



PLAN WATERWAYS AND RAILROAD LINES RELATIVE TO THE OGALLALA AQUIFER



LOCATION OF THE COLUMBIA RIVER BASIN AND THE HYDROELECTRIC DAMS AND RIVERS WITH THE DESCHUTES RIVER DIVERSION TO GOOSE LAKE AND PIT RIVER TO CALIFORNIA



Sadly, the irrigation waste water drainage system along the San Joaquin River and the nuclear power plants incorporating desalting facilities were never built so that irrigation waste water accumulated over time.

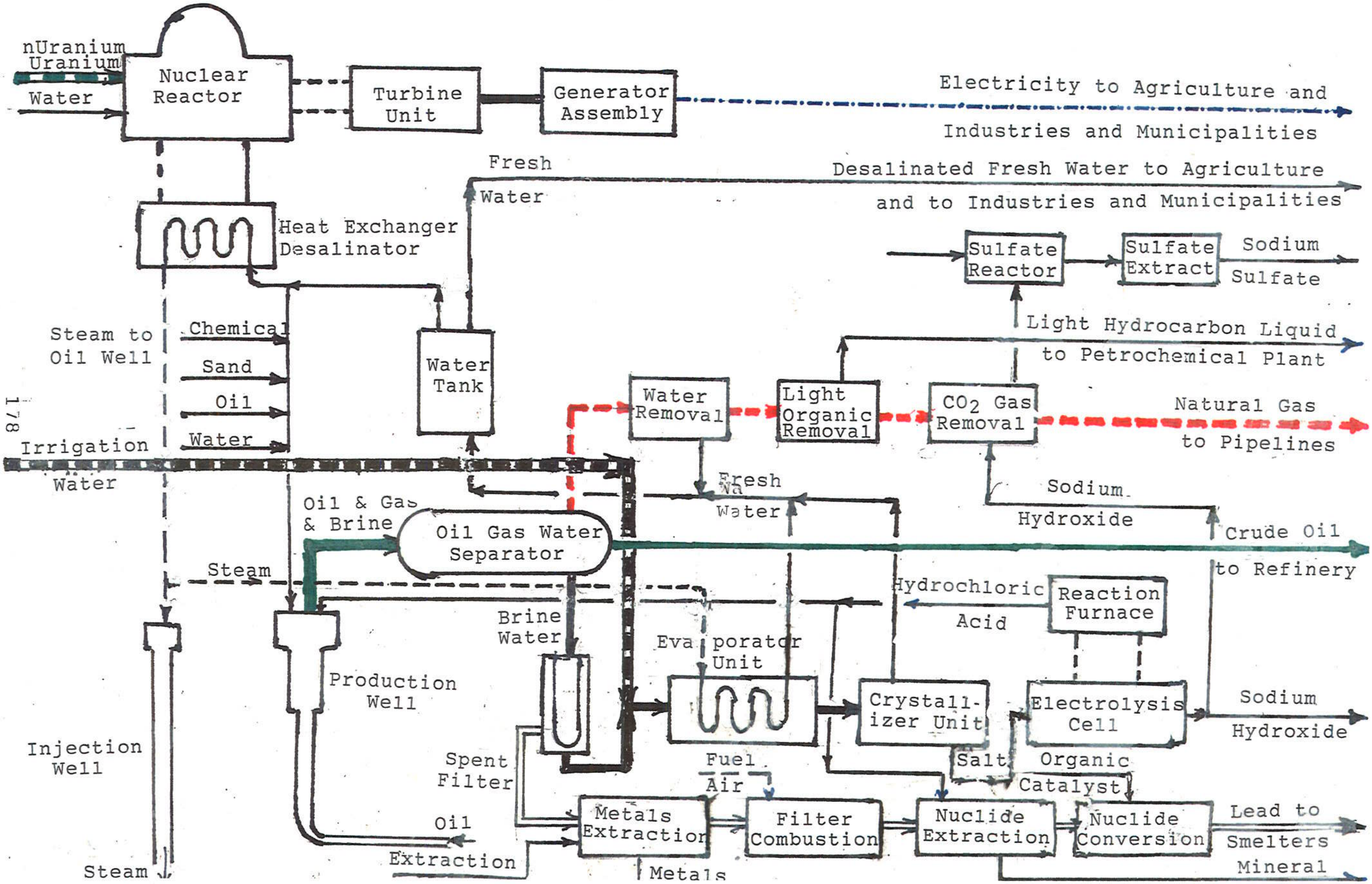
The end results of not building the nuclear desalting plants in the San Joaquin Valley or the San Joaquin River irrigation waste water drainage system were the accumulation of irrigation waste salts in the sails and the eventual poisoning of the crops. Significant areas exceeding 300,000 areas of prime cropland are now unusable for growing crops from the salt water accumulation. Birds have been poisoned from selenium and boron have tried in the Kesterson National Wildlife Refuge at the same time that ground waters have been rendered unusual for irrigation as a water source. There is a definite need to resolve this problem by restoring the original nuclear desalination plan for the San Joaquin Valley to improve water quality.

It is therefore proposed that nuclear power plants incorporating saline and brackish water desalination facilities be built at 6 or more sites on the west side of the San Joaquin Valley at Patterson, Chowchilla, Coalinga, Wasco, Taft and Kern River in order to purify the existing water supplies. Additional electric power is needed in California that can be provided far more efficiently and economically than from the proposed solar renewable power generating farms now being considered. In addition, these nuclear power plants can not only produce fresh water for agriculture and for the municipalities but also the steam required for producing the heavy oils in the Monterey Shale oil formation in the San Joaquin Valley.

The use of nuclear power for the steam generation required for heavy oil recovery in the Monterey Shale and other formations in the San Joaquin Valley also provides a vehicle for treating the recovered brine waters as a byproduct of heavy oil production. The salts recovered from the brine waters by evaporation and crystallization can then be converted to hydrochloric acid and other chemicals which are required to be injected into the heavy oil deposits to facilitate recovery. In addition, the major contributors to increased nitrogen oxides emissions in the San Joaquin Valley resulting from natural gas combustion can then be completely eliminated as a heat source for stream generation with thermal oil recovery.

The air quality in the San Joaquin Valley has become the worst in the United States in terms of photochemical air pollution to cause elevated ozone levels as the result of automobile and truck emissions and agriculture.

PROPOSED IRRIGATION WASTE WATER AND OIL FIELD BRINE WATER TREATMENT SYSTEM WITH NUCLEAR REACTOR DESALINATION IN PARALLEL TO HEAVY CRUDE OIL RECOVERY IN THE SAN JOAQUIN VALLEY




178

PROPOSED LOCATIONS OF THE NUCLEAR DESALINATION PLANTS ALONG THE NORTH AMERICAN WATER AND POWER ALLIANCE WATERWAYS AND THE CALIFORNIA AQUEDUCT

## Oregon-California Distribution System

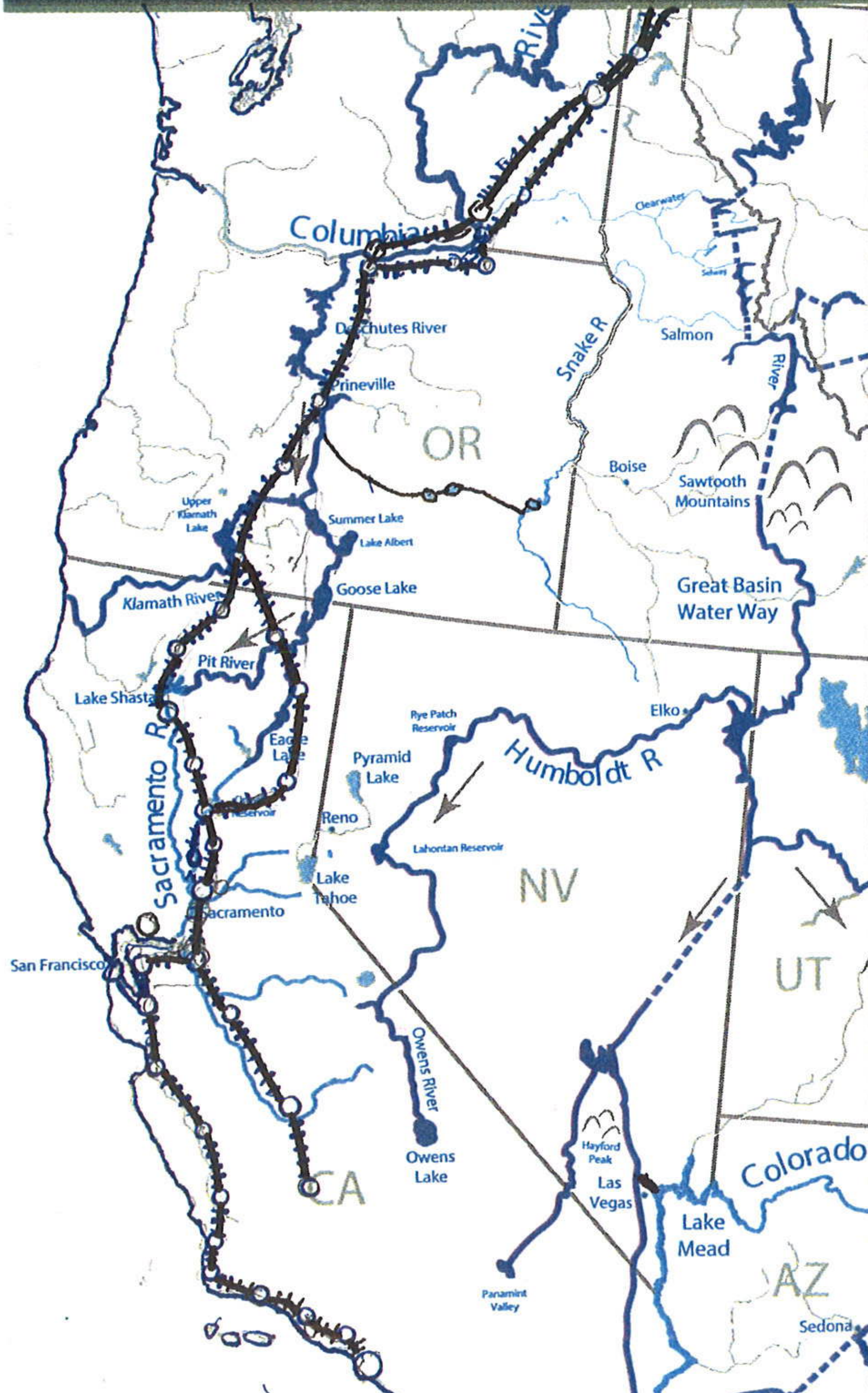

By releasing a portion of the water collected in the Rocky Mountain Trench and adding it to the upper Columbia River into the reservoir formed by Mica Dam, near Revelstoke, British Columbia, additional water would be available to be pumped out of the Columbia River further south, at the Dalles Dam into a reservoir and aqueduct system, beginning with a series of reservoirs on the Deschutes river, before continuing downhill through Central Oregon and Northern California, connecting with the Klamath and Sacramento Rivers.

Connecting with Goose Lake and the Pitts River, increased water supply would flow into Shasta Lake, one of the key storage reservoirs of the Central Valley Project. An additional canal could be added to supply Eagle Lake, and link into Oroville reservoir. These connections will secure the nation's vital agricultural production of the Central Valley, making unsustainable pipeline proposals to bring water from the Sacramento Valley to Southern California unnecessary, and instead, deliver a renewable supply from excess northern precipitation.

A 7-MAF storage reservoir will be created between Murdoch and Bald Eagle Mountains, 50 miles east of Elko, Nevada. By connecting this reservoir with a 30-mile canal to the Humboldt River, water can be distributed across the state, ending at the Humboldt Sink, and from there, can be linked to Lake Lahontan, of the Truckee Carson Irrigation District, serving Northern Nevada, before continuing south and connecting with the Owens River, refilling Owens Lake over time, reviving farmland.

PROPOSED NORTH AMERICAN WATER AND RAIL ALLIANCE ROUTE SYSTEM FOR THE WATER FROM CANADA IN ADDITION TO THE ATHABASCA TAR SANDS OIL SHIPMENTS

# Oregon-California Distribution System




By releasing a portion of the water collected in the Rocky Mountain Trench and adding it to the upper Columbia River into the reservoir formed by Mica Dam, near Revelstoke, British Columbia, additional water would be available to be pumped out of the Columbia River further south, at the Dalles Dam into a reservoir and aqueduct system, beginning with a series of reservoirs on the Deschutes river, before continuing downhill through Central Oregon and Northern California, connecting with the Klamath and Sacramento Rivers.

Connecting with Goose Lake and the Pitts River, increased water supply would flow into Shasta Lake, one of the key storage reservoirs of the Central Valley Project. An additional canal could be added to supply Eagle Lake, and link into Oroville reservoir. These connections will secure the nation's vital agricultural production of the Central Valley, making unsustainable pipeline proposals to bring water from the Sacramento Valley to Southern California unnecessary, and instead, deliver a renewable supply from excess northern precipitation.

A 7-MAF storage reservoir will be created between Murdoch and Bald Eagle Mountains, 50 miles east of Elko, Nevada. By connecting this reservoir with a 30-mile canal to the Humboldt River, water can be distributed across the state, ending at the Humboldt Sink, and from there, can be linked to Lake Lahontan, of the Truckee Carson Irrigation District, serving Northern Nevada, before continuing south and connecting with the Owens River, refilling Owens Lake over time, reviving farmland.

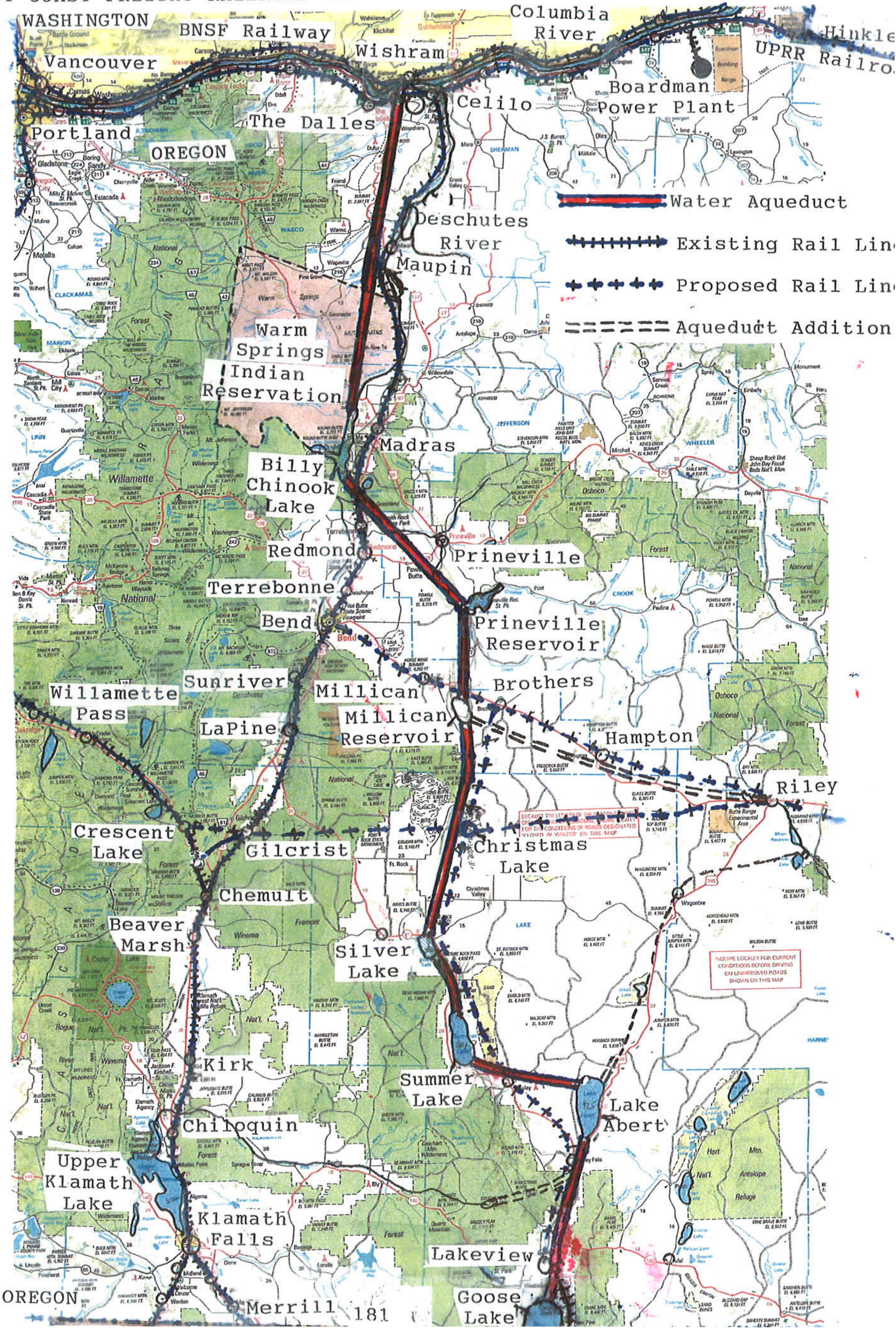
LOCATIONS OF THE NORTH AMERICAN WATER AND POWER ALLIANCE WATERCOURSES INTO NORTHERN CALIFORNIA TO THE CALIFORNIA AQUEDUCT AND NUCLEAR POWER DESALINATION PLANTS IN THE SAN JOAQUIN VALLEY AND THE MONTEREY SHALE

The nitrogen oxides from natural gas combustion reacting with the organic vapor releases from dairies, highways and agriculture combine in the San Joaquin Valley to create a serious photochemical air quality problem. The use of the nuclear desalination facilities results in the production of electricity plus steam and fresh water as a major benefit to the San Joaquin Valley. It is then possible for the farming operations and heavy oil production to coexist in a mutually beneficial fashion so that California can continue to produce the Nation's food supplies. Crude can also be produced oil at the same time and also be self-sufficient in electric generation without adversely impacting air quality throughout the Central Valley of California as well as to preserve many existing jobs while allowing people to be rehired for previously held jobs while new jobs are being created.

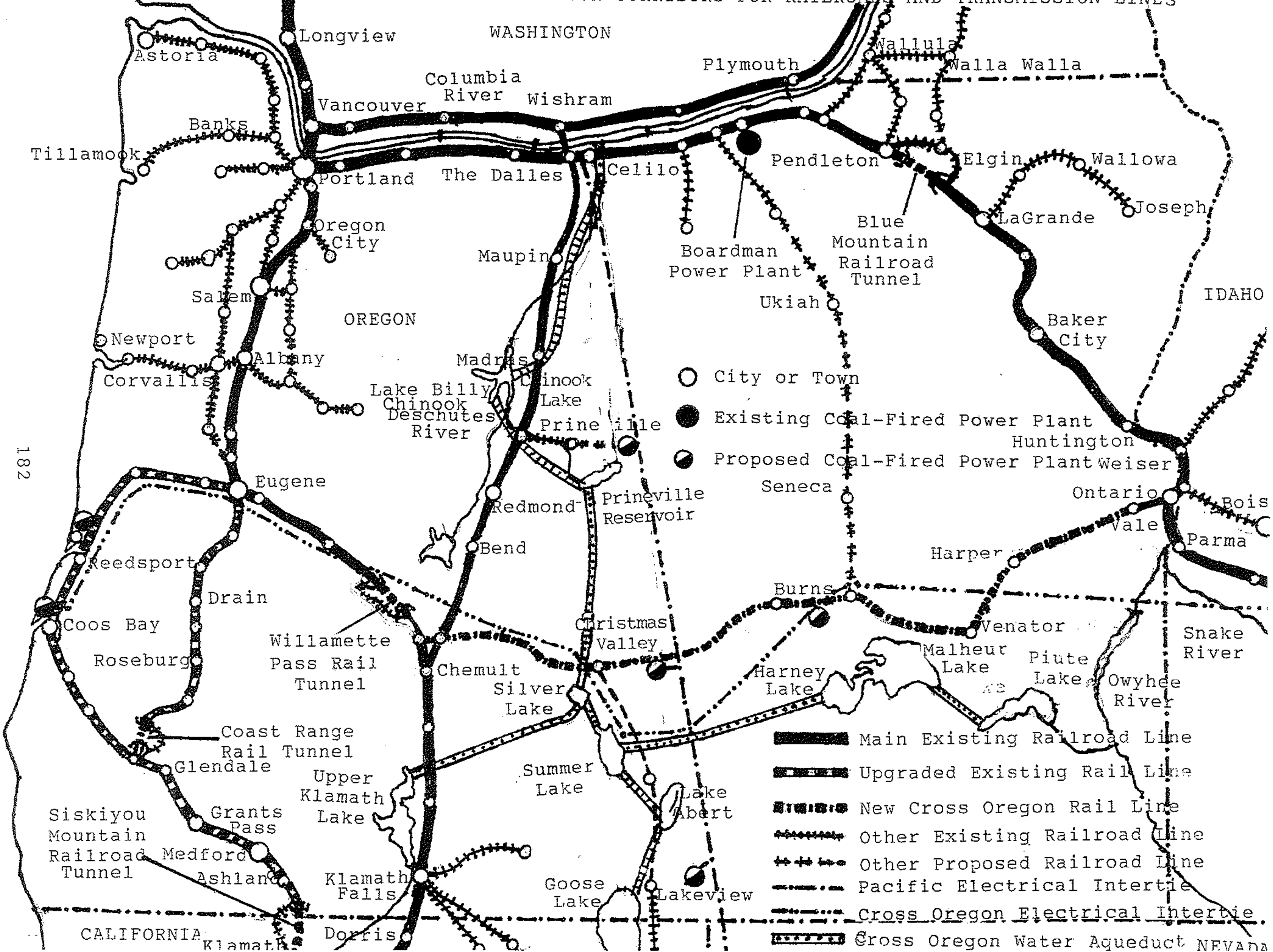
The completion of the North American Water and Power Alliance (NAWARA) project could follow the initial implementation of the North American Water and Rail Alliance (NAWARA) project by developing an initial system for hauling water by rail from Alberta or British Columbia or the Northwest Territories out of the Mackenzie River Basin. The waters pumped from the Columbia River after being added upstream in Canada would then flow to the south through a series of canals and pipelines and aqueducts across central Oregon into Goose Lake at the California – Oregon border. An extensive series of lakes and reservoirs along with dams and water conveyances would then need to be built in central eastern Oregon in order to implement the NAWARA project where as much of the water infrastructure in California either already exists or has already been built or utilized natural watercourses.

The State of Oregon will become the scene of a great deal of infrastructure development and construction with the North American Water and Power Alliance as well as the West Coast Corridor projects. There will be an especially great benefit to the now desert and basically unpopulated southeastern part of Oregon which potentially has rich agricultural land to grow food, but very little water. The completion of the Cross Oregon Corridors railroad line from Ontario to Chemult and Eugene to Coos Bay would open up completely new east-west pathway for economic development across Oregon as well as to open up a new pathway for coal and oil exports to occur on the future. The West Coast Corridor rail project will greatly help economic development between Portland and Ashland in a north-south framework in the same manner.

THE WEST COAST FREIGHT RAILROAD CORRIDOR AND WATER AQUEDUCT ACROSS OREGON



ROUTE LOCATIONS OF THE PROPOSED CROSS OREGON CORRIDORS FOR RAILROADS AND TRANSMISSION LINES




182

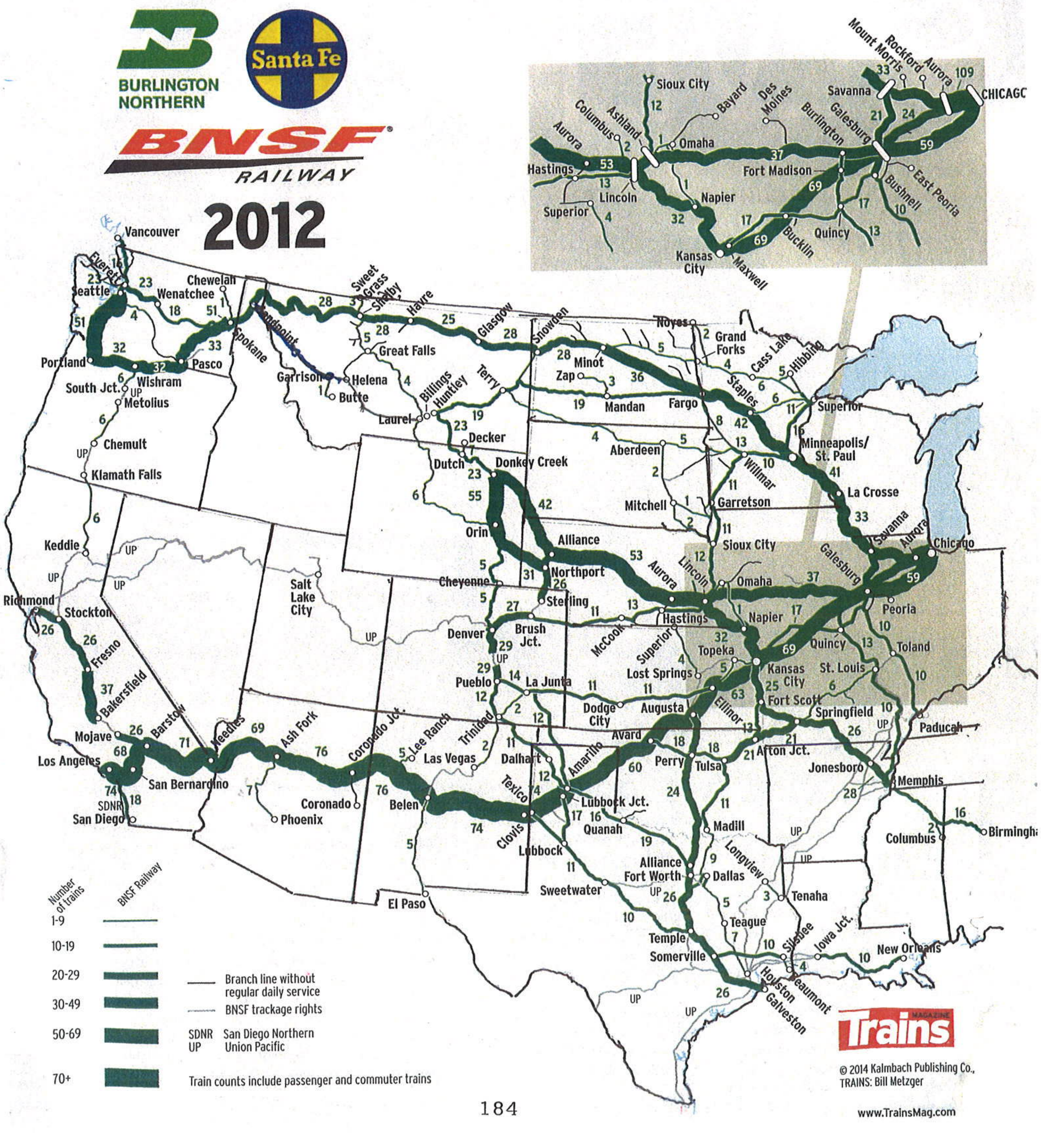
## IMPLEMENTATION PLAN

The present Great Northern Corridor rail line across the Northern Tier between Seattle and Portland along the Pacific Ocean to the west with Milwaukee and Chicago along Lake Michigan to the east is in major need of expansion as the result of the recent major increase in crude oil production and rail traffic from the Bakken Formation in western North Dakota. There has also been a significant increase in agricultural freight traffic as the result of the recent record grain harvests in eastern North Dakota and the neighboring Great Plains States of the Upper Midwest. There is also significant intermodal container and trailer traffic over the Great Northern Corridor between the Ports of Tacoma and Seattle along Puget Sound to the major distribution centers in Chicago and beyond. This intermodal traffic reached an earlier peak in 2006 and then substantially declined until 2010 with the recent downtown in the World economy, but is now again on the increase as the result of increased cross-Pacific trade.

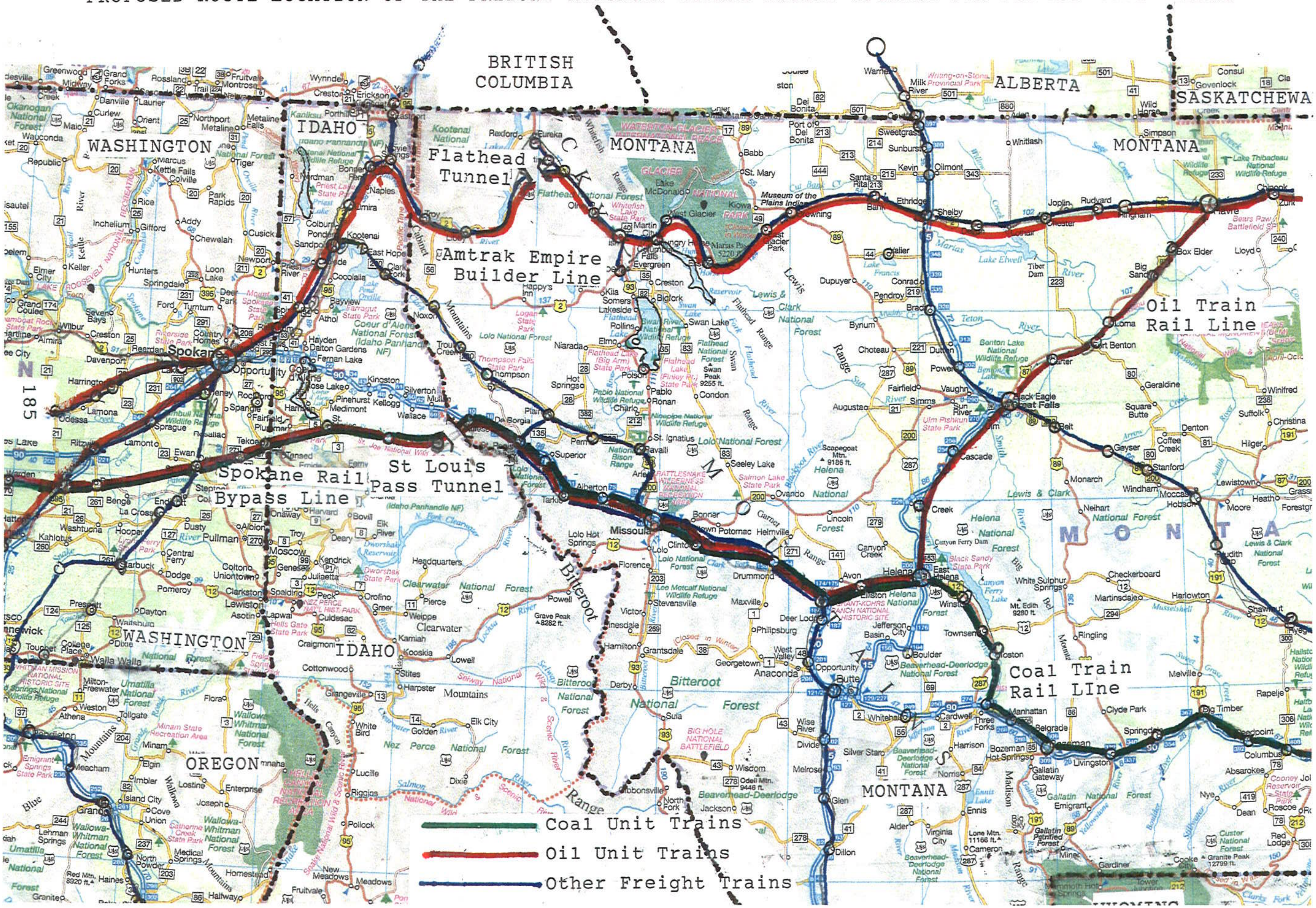
The average daily levels of the overall freight traffic volumes over the Great Northern Corridor line are between 30 and 35 freight trains and two Amtrak passenger trains. There have recently been coal train movements over a part of the Great Northern Corridor from Montana to Washington which go between Sandpoint, Idaho and Spokane over the Great Northern Corridor and along the Columbia River line which ultimately go to the large coal unloading terminal at Roberts Rock near Vancouver, British Columbia. There are also proposals to build additional coal terminals at Vancouver and Longview, Washington as well as at Grays Harbor and at Cherry Point near Bellingham, Washington. These proposed coal terminals would receive coal from the Powder River Basin in northeastern Wyoming and southeastern Montana brought by rail including from an existing mine on the Crow Indian Reservation near Hardin, Montana over the BNSF and Montana Rail Link rail lines through Billings and Helena and Missoula Montana with an expected 26 to 34 unit train loads per day by 2025.

It is then possible that the movements of these coal trains and the oil trains coming from the respective Power River Basin and the Bakken Formation could be joined at Helena, Montana and then go to St. Regis, Montana and then to the rebuilt St. Louis Pass rail bypass line around Spokane. These coal and oil unit trains would then go from Lind in eastern Washington and then either along the existing Columbia River level route or through a new tunnel at Stampede or Stevens Pass in the Cascade Mountains with a new pathway opening up to the Grays Harbor oil terminals with an additional tunnel at the Flathead Tunnel.

AVERAGE DAILY TRAIN MOVEMENTS OVER THE BURLINGTON NORTHERN SANTA FE RAILWAY



PROPOSED ROUTE LOCATION OF THE FREIGHT RAILROAD BYPASS AROUND SPOKANE FOR OIL AND COAL TRAINS

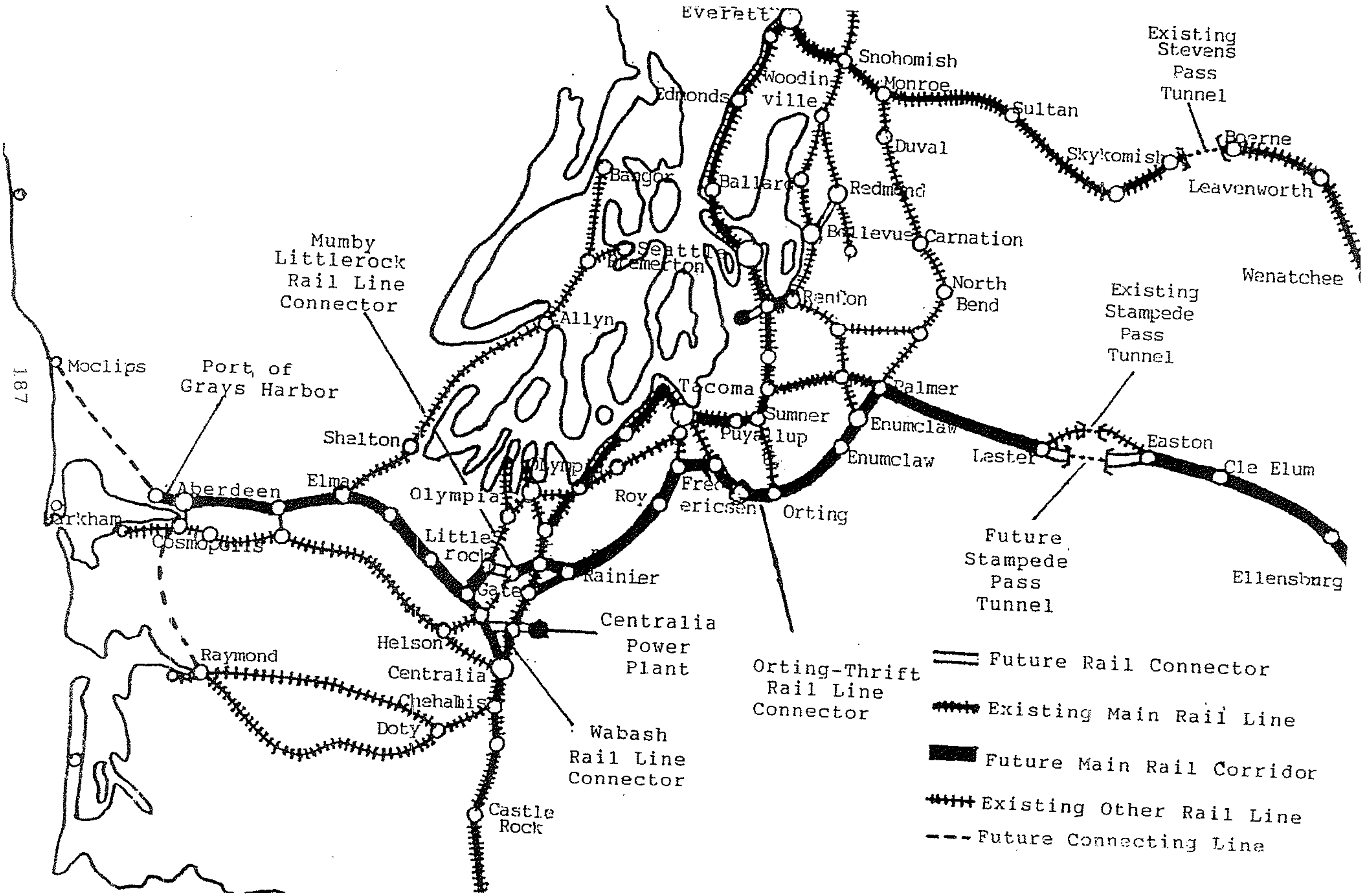


The crude oil trains could then go to either the proposed crude oil terminal out Grays Harbor at Aberdeen or alternatively Vancouver, Washington or Cherry Point near Bellingham, Washington or to Clatskanie, Oregon. The coal trains could then have their contents unloaded onto ships at terminals in Vancouver or Longview, Washington or at Grays Harbor or at Cherry Point. It is suggested that the coal terminals be located at Vancouver and Longview, Washington on the Lower Columbia River with the main crude oil terminal be located at Grays Harbor in southwest Washington with the Cherry Point facility near Bellingham in northwest Washington be developed as a combination coal and oil port.

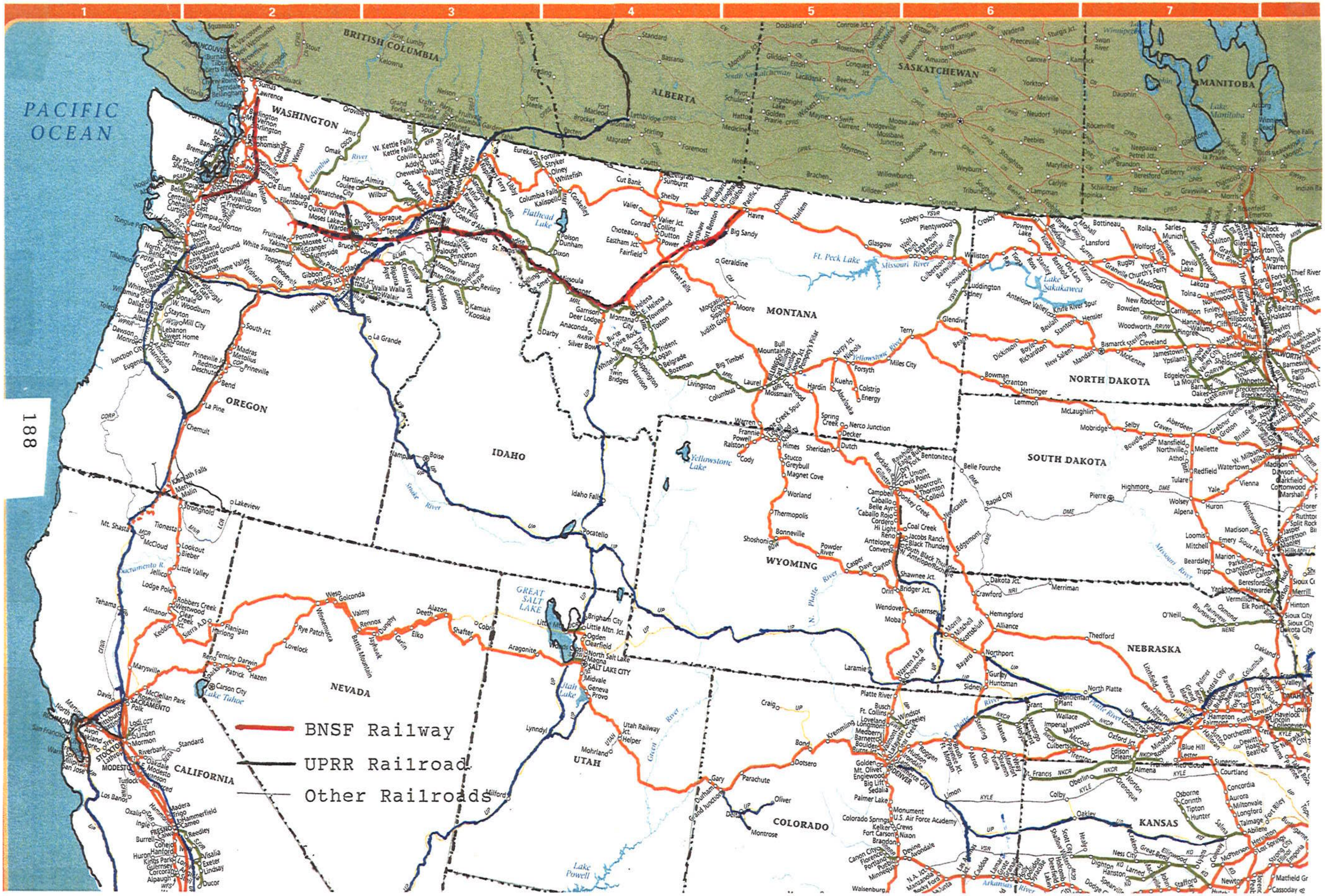
The future role of the State Washington is then prepared to meet its geographic role and destiny of being a major location for the shipments of coal crude oil to China and India and elsewhere in Asia across the Pacific Ocean to serve as the seaport for resource shipments from Montana and North Dakota. This Northern Tier alliance will include not only the eight respective State Governments but the affected Coastal and Interior Indian Tribes as partners instead of being opponents. Considerable coordination between all of these governmental and native and private entities will be necessary to achieve success, of which the first step is the recently commissioned Strengths, Weaknesses, Opportunities and Threats (SWOT) study of the Great Northern Corridor by the Montana Department of Transportation. It is emphasized that the connecting link between all of these locations, organizations and entities is the Burlington Northern Santa Fe Railway (BNSF) on the Great Northern Corridor across the Northern Tier.

In addition to the substantial freight movements over the Great Northern Corridor, there are also a large number of people who are being brought into western North Dakota to work in the Bakken Formation oil fields who do not live in North Dakota who come from as far away as Seattle and Portland to the west and from Chicago, Milwaukee and the Twin Cities to the east. One of the ways that these workers come to work at the oil fields in western North Dakota is on the present Amtrak Empire Builder, which operates on the basis of one passenger train eastbound and one passenger train westbound between Seattle and Portland on the west to Chicago on the east. The route of the Amtrak Empire Builder is along the Great Northern Corridor along the so-called BNSF Railway "High Line" across the Northern Tier through Washington and Oregon to Idaho and Montana into North Dakota to Minnesota and Wisconsin to Chicago.

EXISTING RAILROAD LINE NETWORK BETWEEN THE PORT OF GRAYS HARBOR AND THE CASCADE FOOTHILLS



EXISTING ROUTE NETWORK OF THE BURLINGTON NORTHERN SANTA FE RAILWAY ON THE NORTHERN TIER

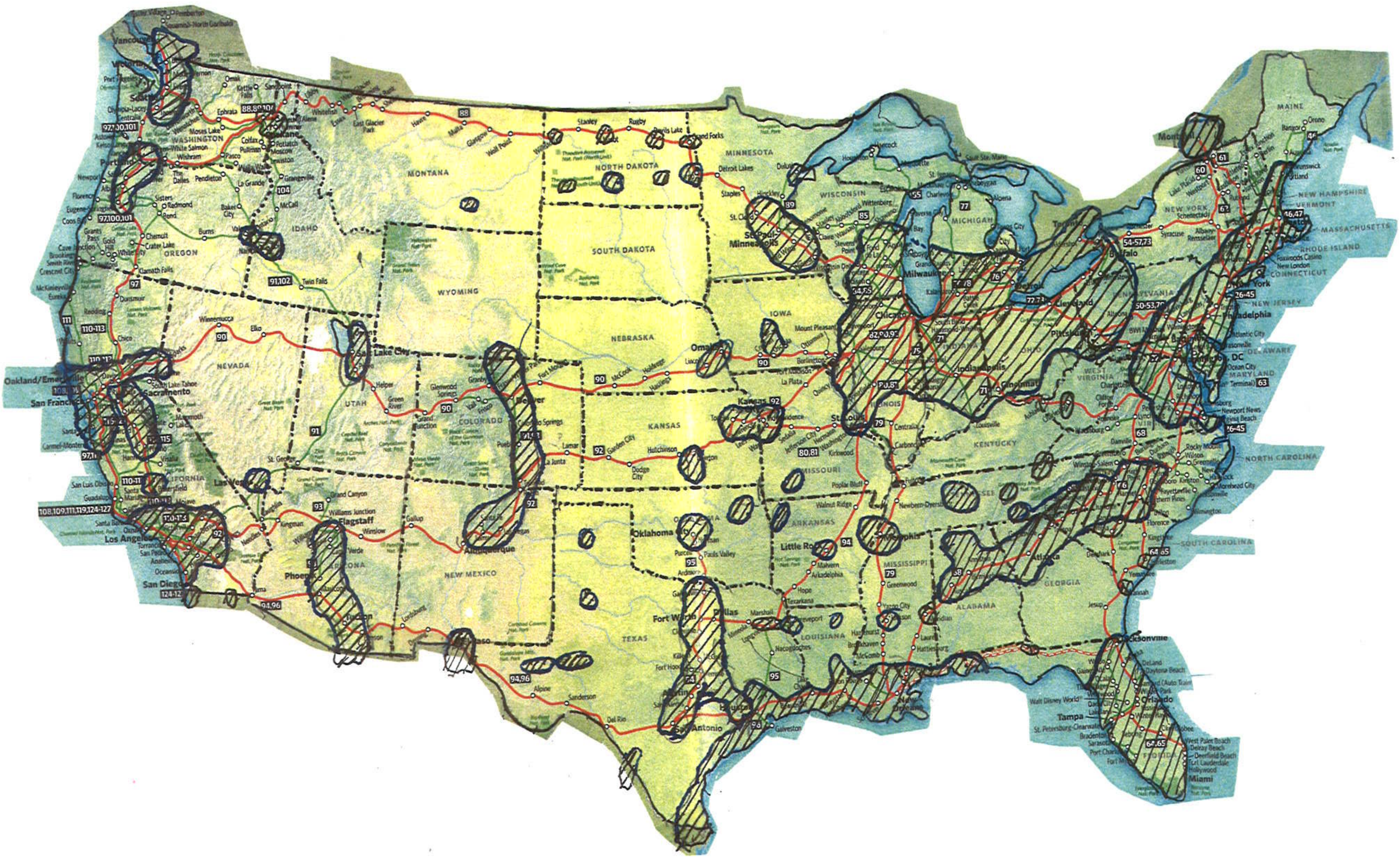


The trip is approximately 2,200 miles in length and presently takes between 42 and 44 hours if the trains are on time. In the recent time, the Amtrak trains have been increasingly unable to meet their schedule. The reason is because of the massive rail traffic congestion across much of North Dakota because of the major oil-related activity and to a lesser intent the increases in grain traffic movements. The BNSF Railway is making major capital investment in western North Dakota to correct these problems which include double tracking the line between Minot and Williston. They are also making other local improvements to increase capacities and to reduce traffic delays along the entire extent of the Great Northern Corridor from Seattle and Portland on the west to Milwaukee and Chicago on the east through the affected Northern Tier States.

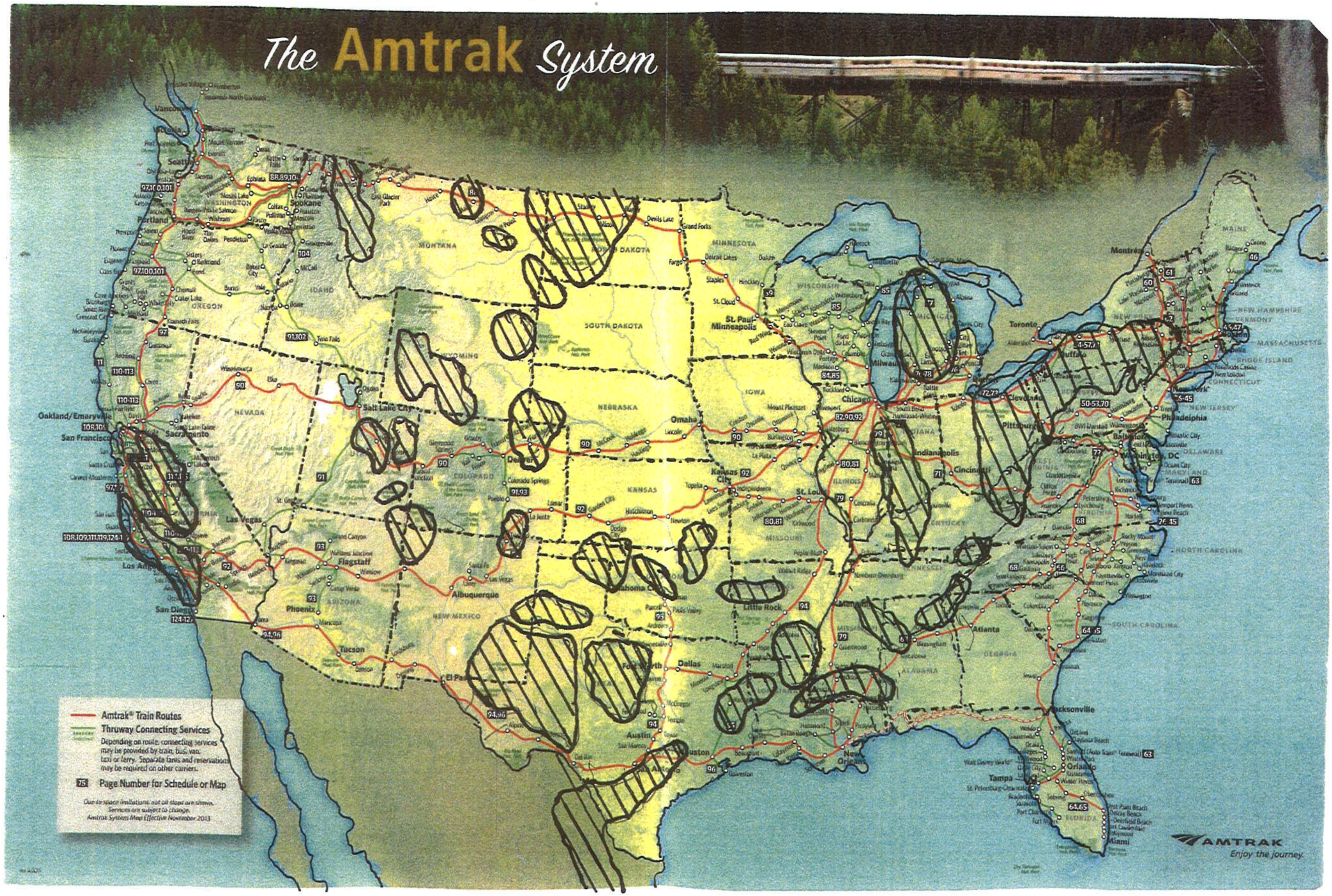
The result of the above developments is that the massive recent increase in crude oil development in western North Dakota and to some extent in eastern Montana have resulted in not only oil train traffic out of the region in tank cars but also a considerable expansion of materials, sand, equipment and supplies being brought into the oil producing regions in western North Dakota. These increasing material supplies being brought into the oil field region between Minot and Williston now and Culbertson in the future include sand and chemicals for hydraulic fracturing plus pipes and other steel for wells and construction along with large amounts of equipment for oil field use along with food and other supplies for up to 100,000 workers in the region. It is estimated that there are between 10,000 and 20,000 people or more who work in North Dakota who do not live in North Dakota on a regular basis. Many of these people are frequent candidates to ride the trains from their homes to their work in North Dakota on a regular basis because they typically work for two to three weeks and then go home for one to two weeks and then return to their jobs as a regular schedule in western North Dakota from across the Northern Tier.

The present Amtrak Empire Builder as it is now is not adequate to serve the existing ridership market for oil workers to and from their jobs in western North Dakota. The trip takes too long and the service is not frequent or reliable enough to meet the market needs of the oil field workers and others who are their potential ridership market. In addition, the already massive freight traffic volumes over the Great Northern Corridor which now exist that result from crude oil as well as from grain, coal and intermodal traffic add in a major way to the overall traffic volumes which can no longer be accommodated by a presently single track railroad line alone with expected future traffic volumes of over 100 trains per day.

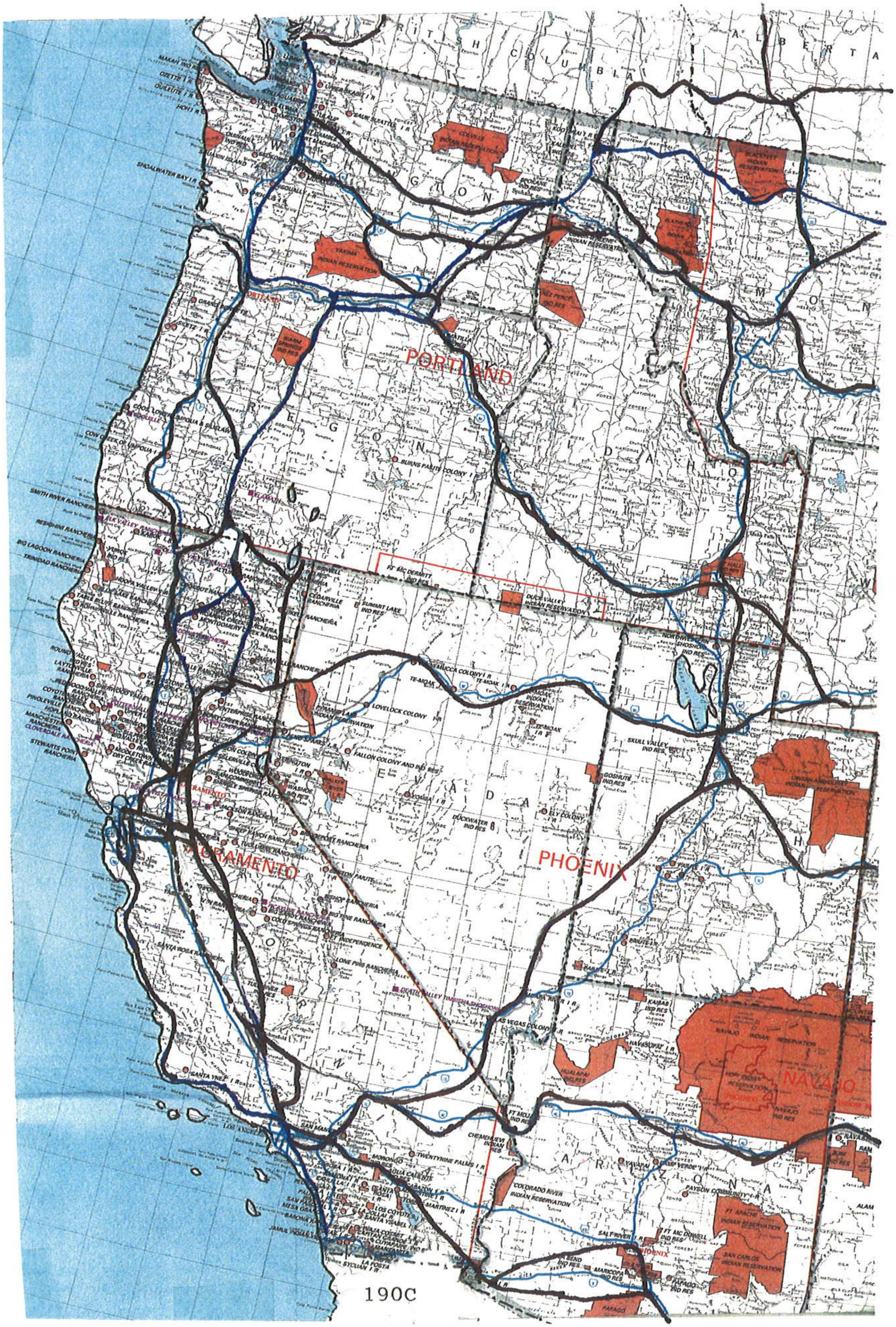
EXISTING AMTRAK RAILROAD PASSENGER ROUTE NETWORK AND THE EMERGING MEGAREGION URBAN CENTERS



LOCATION OF THE AMTRAK RAIL PASSENGER ROUTE NETWORK ADJACENT TO SHALE OIL AND GAS FIELDS



LOCATION OF THE WEST COAST RAIL CORRIDOR AND THE ADJACENT INDIAN RESERVATIONS

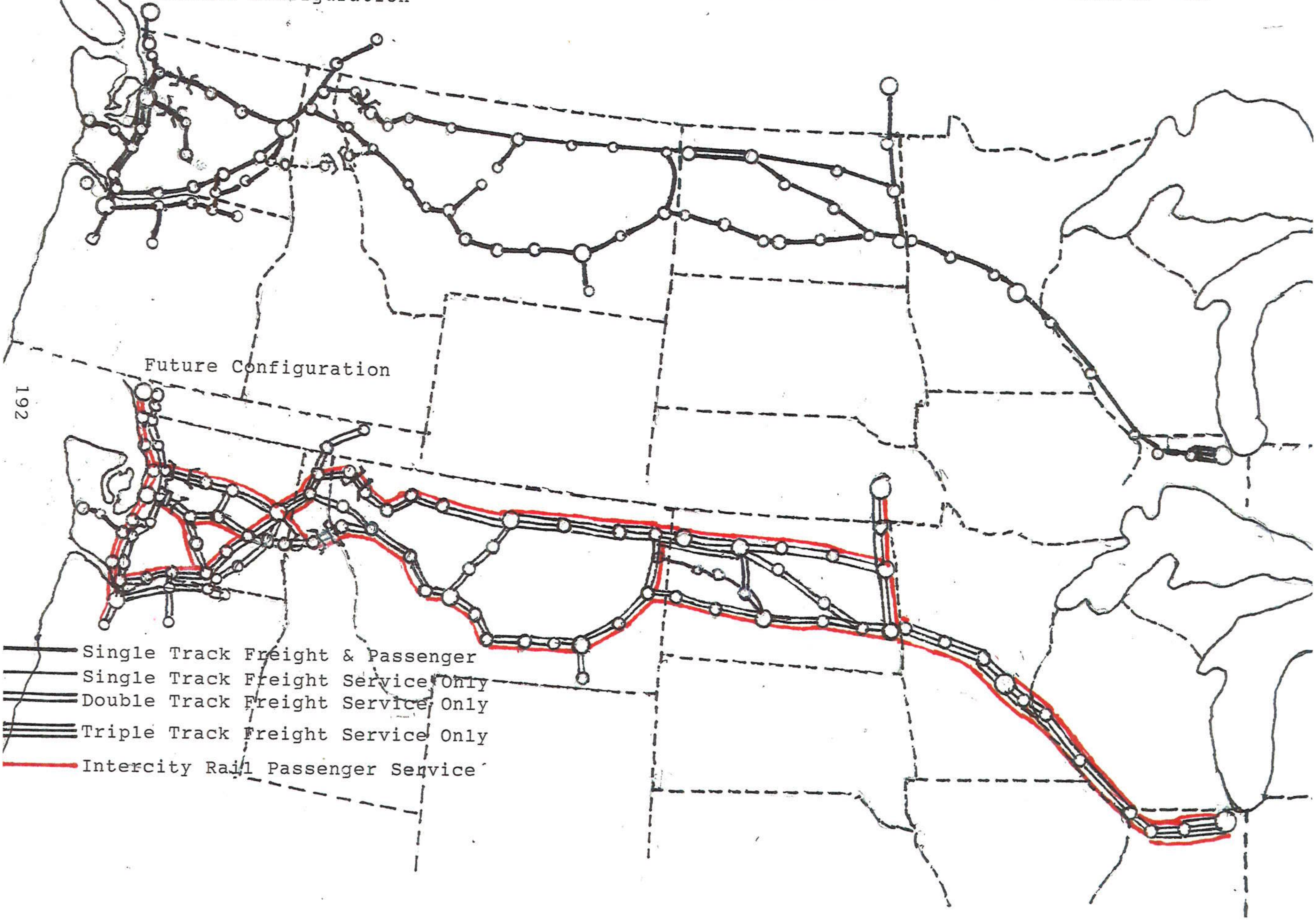


The result is that there are going to need to be major capacity expansions and facility upgrades to increase train speeds along the existing Great Northern Corridor in order to handle future freight and passenger traffic volumes over the existing rail line of up to 120 trains per day.

It is proposed that the present BNSF Railway line across Northern Tier over the Great Northern Corridor between the Pacific Ocean and Lake Michigan be reconfigured as a multiple track route between Seattle and Portland on the west to Milwaukee and Chicago on the east. It is intended that parallel but separate tracks be constructed for the freight and passenger trains with two tracks for freight service and one track with periodic passing sidings for passenger service between Spokane and the Twin Cities. It is possible that there could be two separate passenger tracks could be located between Minneapolis and Chicago which as the basis for the high speed passenger system through Madison and Milwaukee as a component of the proposed Midwest High Speed Rail Network by the Midwest High Speed Rail Association. There would be separate double track rail lines between Fargo and Bismarck, Fargo and Minot and between Fargo and Grand Forks with an extension to Minot to serve the main cities in North Dakota. The present BNSF line between Minot and Williston now being double tracked will also need to have a third track added for freight along with a separate track for passenger trains in the future.

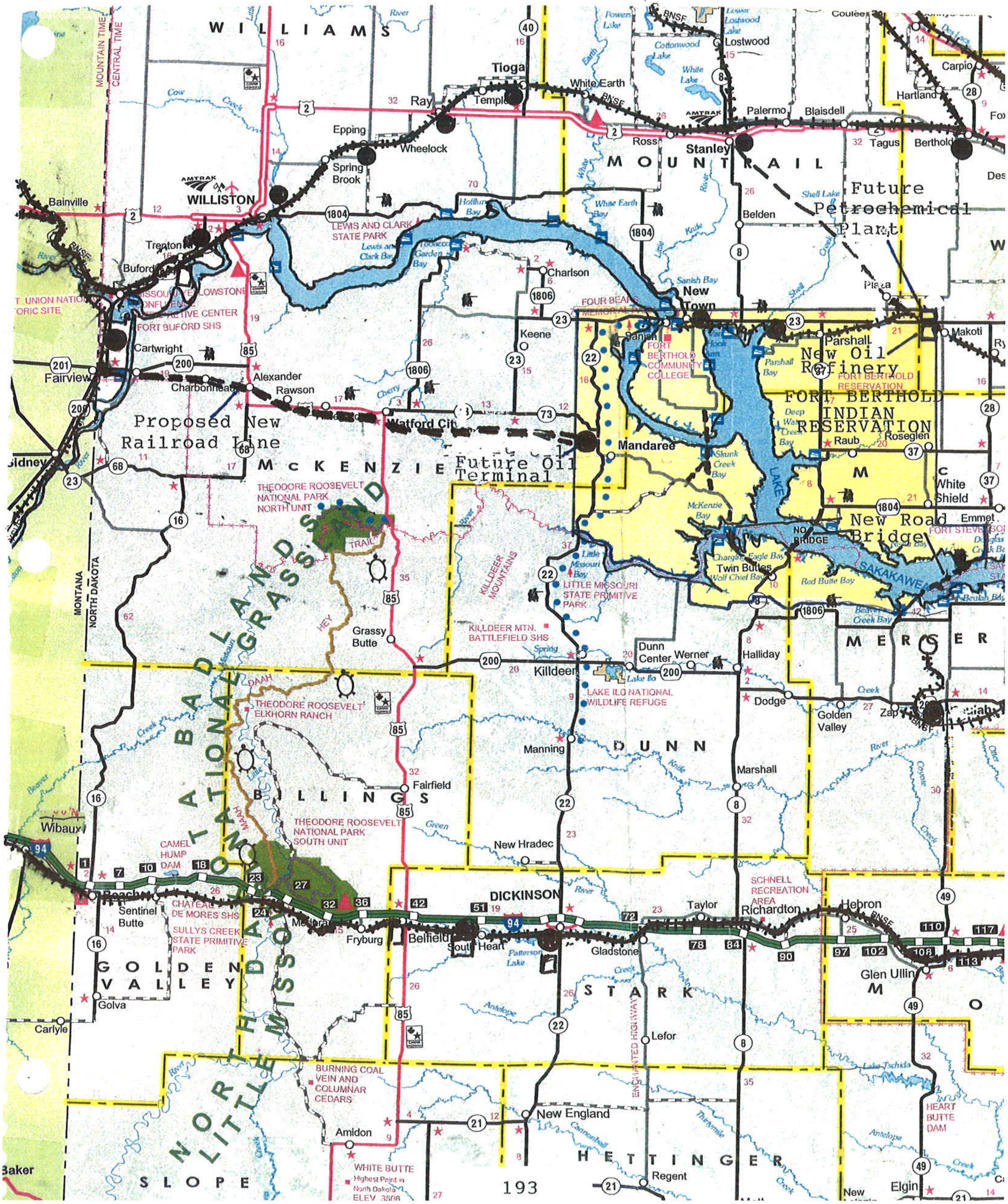
Further to the west, the rail lines separate from the BNSF Railway Great Northern Corridor will need to have a second main track added between Bismarck and Dickinson to Glendive, Montana for the coal route which should then be extended to Hantley, Montana near Billings. The Yellowstone Valley Railroad short line from Glendive to Snowden, Montana should also have a second track added for reasons which should include new and increased freight service for coal and grain and oil and other commodities. There should be a parallel tracks as well as to support future passenger service between Billings, Montana and Dickinson, North Dakota through Glendive on the southern route as well as from Glendive, Montana to Williston, North Dakota for the oil workers to ride. The Yellowstone Valley Railroad should then rebuild and restart the abandoned branch line from Fairview, Montana to Watford City, North Dakota. This line can be extended to Mandaree on the western side of the Fort Berthold Indian Reservation where a future crude oil loading terminal can be built to ship oil from the Fort Berthold Reservation to the future Quinault Tribe owned unloading terminal to be built at Grays Harbor near Aberdeen, Washington.

PRESENT AND FUTURE TRACK CONFIGURATIONS FOR THE BNSF RAILWAY GREAT NORTHERN CORRIDOR LINE




192

PROPOSED DEVELOPMENT OF NEW RAILROAD AND ROADWAY INFRASTRUCTURE ON THE FORT BERTHOLD INDIAN RESERVATION PLUS NEW OIL TERMINALS AND FACILITIES

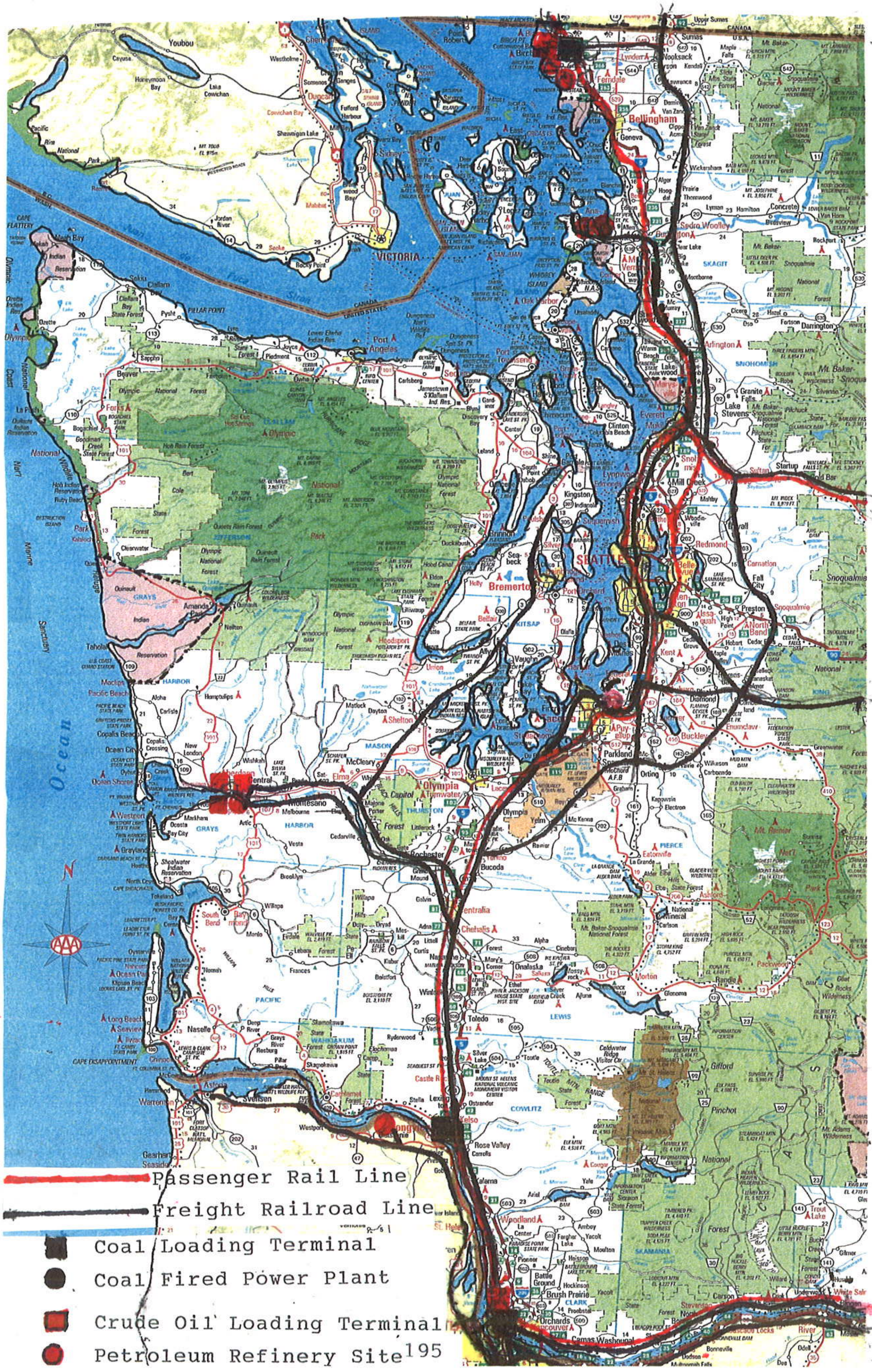


Then the double track rail bypass line needs to be built from Havre to Helena, Montana over the BNSF Railroad line along the Missouri River. The present Montana Rail Link single track main rail line from Huntley to Billings and Helena to Garrison and Missoula, Montana needs to have a second track added to as far as St. Regis, Montana over the existing line with a possible third track for passenger service in the future. The former Milwaukee Railroad line from St. Regis to Saltese, Montana needs to be rebuilt as a new double track railroad line through a new double track tunnel under St. Louis Pass to Avery, Idaho. This line then goes to the west through St. Maries, Idaho to Rosalia and then Lind, Washington to the existing BNSF main line to Pasco, and Vancouver, Washington. This BNSF Railway main line at level grades along the Columbia River will need to be expanded to double track for freight service plus a passenger track throughout over the route from Pasco to Vancouver and perhaps a third track along part or add all of the affected route.

The proposed Milwaukee Railroad rebuilt line at Lind, Washington needs to be extended to Othello, Washington and then to the north to Moses Lake over the existing route run by a short line railroad. This line will be a three track operation with two freight and one passenger track from Lind to Othello and a double track freight line from Othello to Ephrata to rejoin the Great Northern Corridor between Seattle and Spokane. The rail line at Othello can then be extended to Beverly and up the grade to Ellensburg to join the Yakima Valley line to Pasco and then go over the existing Stampede Pass line as a double track route through the new double track tunnel from Easton to Lester. This rail line can then join proposed Cascade Foothills Corridor route at Palmer so that the oil trains can then go to the southwest to the Grays Harbor oil loading terminal or to Auburn to join the main freight line. The passenger trains running over the line could then go to either Seattle or Tacoma. There would also be a separate three track railroad tunnel through Stevens Pass on the main Great Northern Corridor route between Seattle and Spokane to the north.

It is proposed that the Great Northern Corridor rail expansion project between the Pacific Ocean and Lake Michigan from Seattle and Portland to Milwaukee and Chicago be basically supported as a private sector effort. The capital cost of the freight rail portion with the upgrading of the existing track and the construction of the second main freight track would be the responsibility of the Burlington Northern Santa Fe Railway. There would also need for some additional investment by the Montana Rail Link and the connecting short line railroads in the State of Washington as well as by BNSF.

LOCATIONS OF THE COAL AND OIL LOADING TERMINALS AND OIL REFINERIES IN THE WESTERN WASHINGTON AND WESTERN OREGON ON THE COLUMBIA RIVER & PUGET SOUND



The entire capital cost of the passenger rail single or double track systems would be the responsibility of a new private sector entity to be created which could also create a long term low interest financing mechanism not only for its own needs but for the freight rail improvements as well. It would be the intention that the entire capital cost of the proposed major bypass route from Havre, Montana to Ephrata, Washington and the non-BNSF proposed would be the responsibility of this new private sector company.

The proposed overall project financing mechanisms for the overall Great Northern Corridor railroad development across the Northern Tier between Chicago and Seattle along the BNSF Railway line would be divided into freight, railroad, passenger railroad, grade separations and major tunnels plus related infrastructure. The construction and operation of the freight rail would be financed by the Burlington Northern Santa Fe Railway while the parallel passenger railroad would be financed by the new private sector passenger railroad company. The construction of the required grade separations plus related safety facilities would be financed by the respective State Governments with the assistance of the Federal Government. Major tunnels would be financed by the BNSF Railway and the private passenger railroad with the assistance of the Federal Government where necessary. The passenger stations in the cities and towns would be financed by the local city and county governments in association with private real estate interests.

The estimated capital cost of the above rail infrastructure improvements would be in the range of $25 to 45 billion and could be implemented over an extended period of time. It is suggested that the new private sector entity to be created for planning, implementing and operating the proposed passenger service along the Great Northern Corridor be able to purchase the existing franchise for the Amtrak Empire Builder between Seattle and Portland to Chicago from the Federal Government. Government agencies could also provide financial support for the project. The specific oil loading and unloading terminals in North Dakota and Washington would be developed and financed by the affected Three Affiliated Tribes at Fort Berthold and by the Quinault Indian Tribe plus others where applicable. A single arrangement could be made for the proposed coal loading and unloading terminals by the Crow Indian Tribe in Montana plus the local Indian Tribes either at Vancouver, Longview or Grays Harbor as well as at Cherry Point. Electrification of the railroad lines should also be considered as a part of the project.

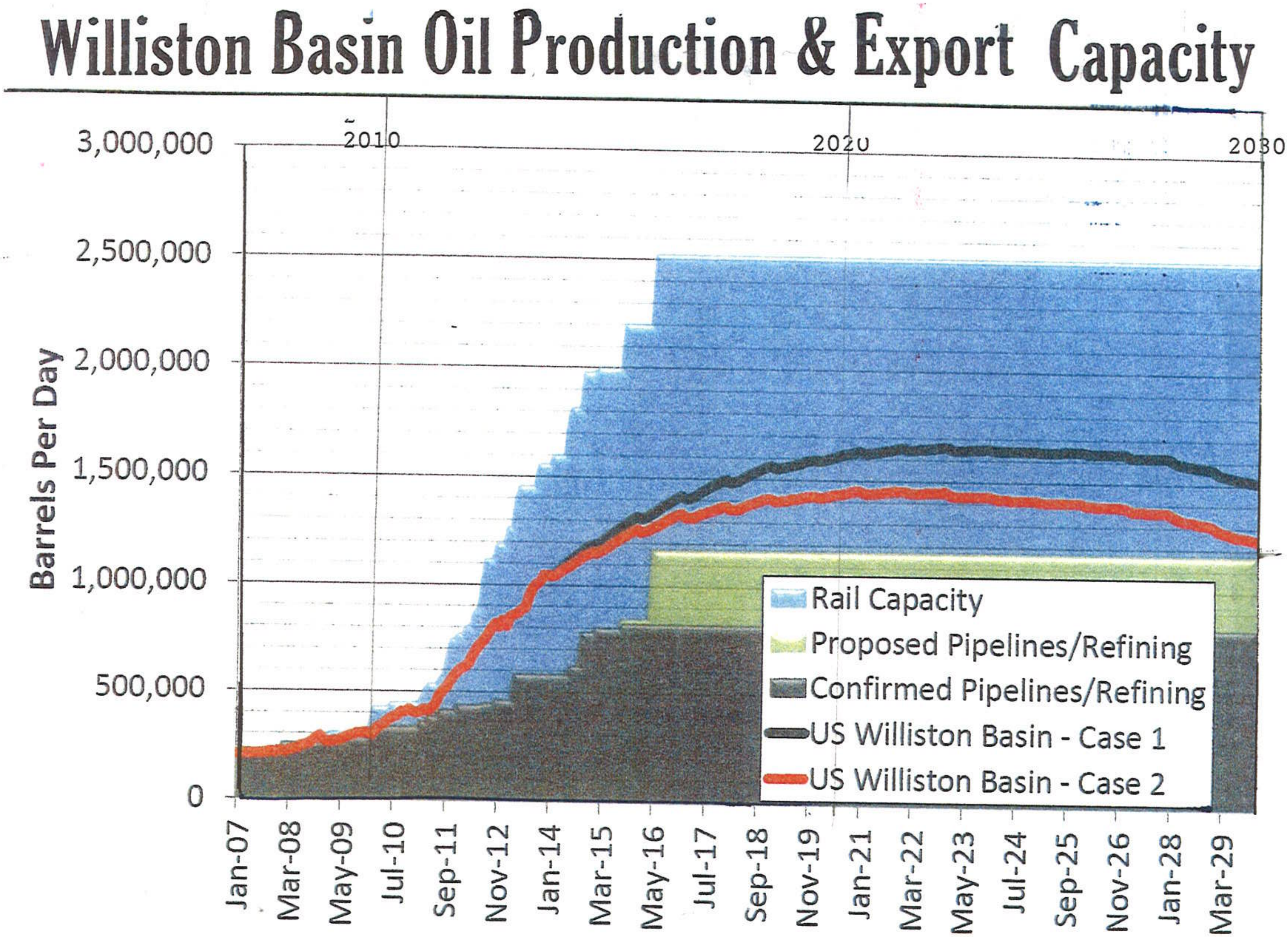
## PROPOSED MAJOR RAILROAD TUNNEL INFRASTRUCTURE PROJECTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE RAILWAY BETWEEN CHICAGO AND SEATTLE

| Tunnel Name | Tunnel Location | Distance In Miles | Number Of Tracks |
|---|---|---|---|
| Stevens Pass | Skykomish, Washington<br>Leavenworth, Washington | 7.9 | 3 |
| Stampede Pass | Lester, Washington<br>Easton, Washington | 8.5 | 2 |
| Flathead Tunnel | Stryker, Montana<br>Libby, Montana | 7.78 | 2 |
| St. Louis Pass | Avery, Idaho<br>Saltese, Montana | 10.5 | 2 |

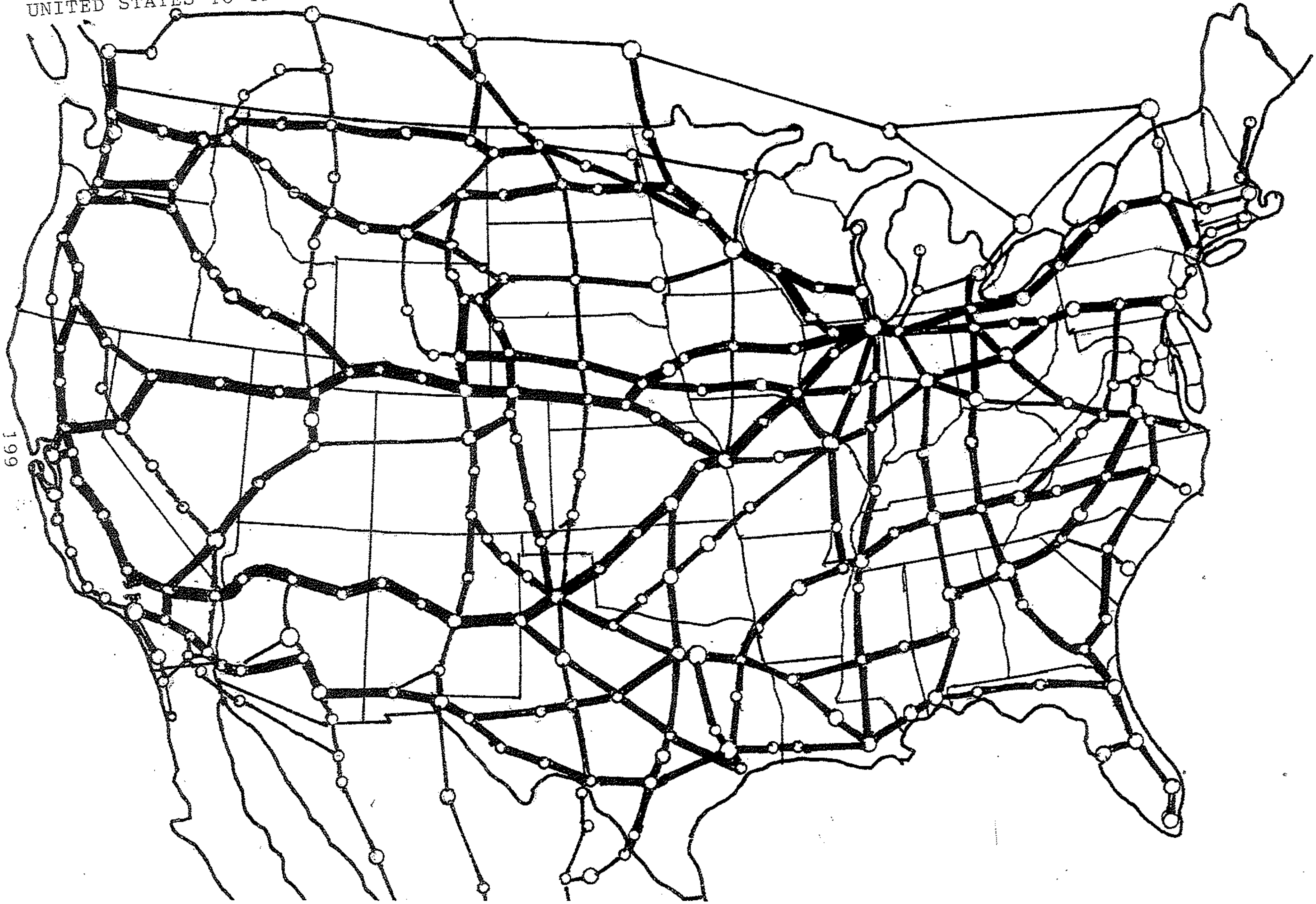
## PROPOSED FINANCIAL MECHANISMS FOR RAILROAD INFRASTRUCTURE IMPROVEMENTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE

| Infrastructure Category | Number of Tracks | Financing Mechanism | Financing Source |
|---|---|---|---|
| Freight Railroad | 2 to 3 | Low Interest<br>Loans Equity & Bond | Private Sector |
| Passenger Railroad | 1 to 2 | Low Interest<br>Equity Funds & Loans | Private Sector |
| Stations and Terminals | 4 to 12 | Public Investment<br>Equity & Loans | Private Sector<br>Private Sector |
| Grade Separations | 2 to 4 Tracks<br>2 to 4 Lanes | Governmental<br>Appropriations | Public Sector |
| Major Tunnels | 2 to 3 | Private Low Interest<br>+ Governmental Support | Private Funds<br>+ Public Sector |

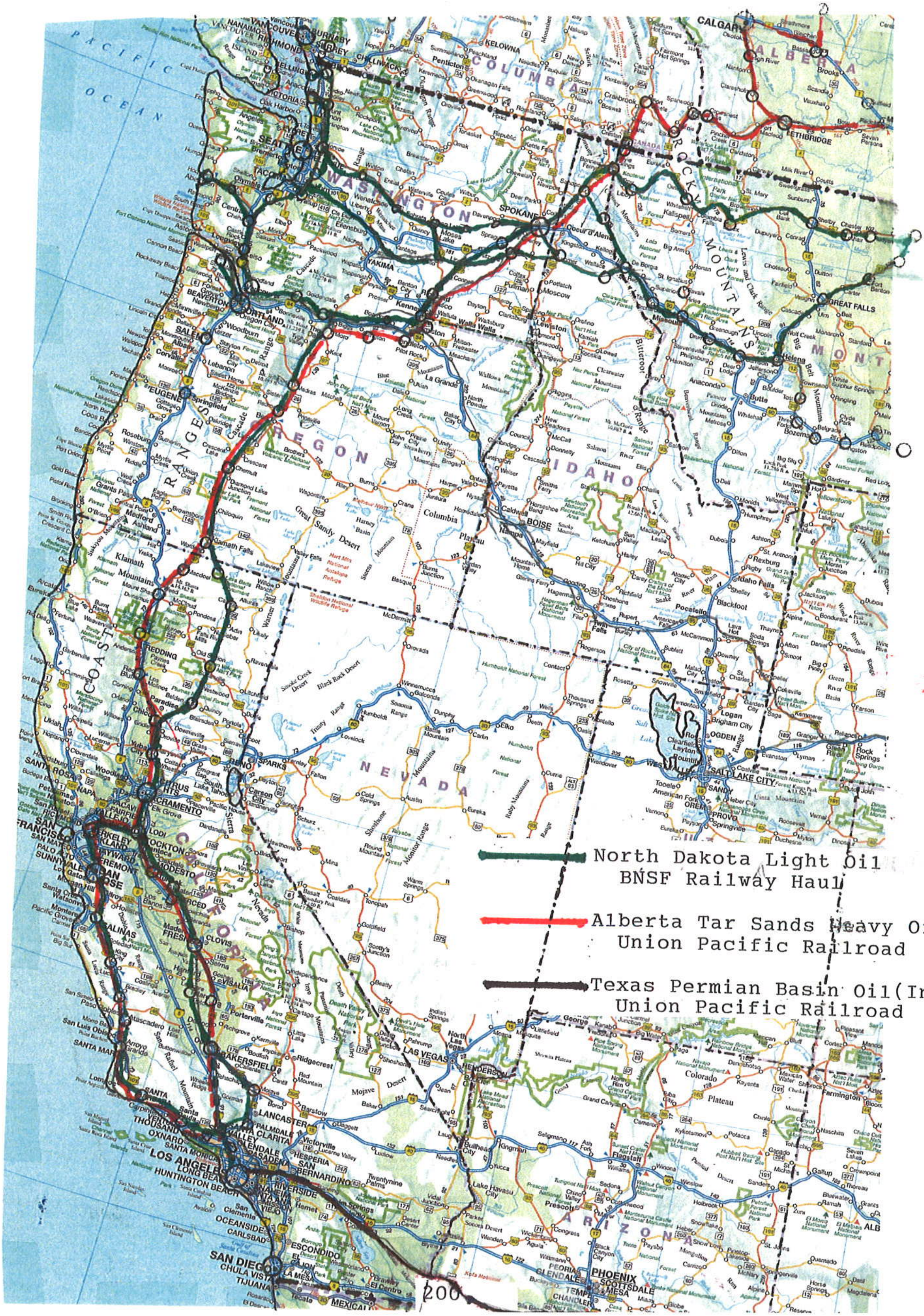
PROJECTIONS OF CRUDE OIL PRODUCTION AND TRANSPORT BY PIPELINE AND RAILROAD IN NORTH DAKOTA FROM 2007 TO 2030 IN THE WILLISTON BASIN BY THE NORTH DAKOTA PIPELINE AUTHORITY



PROPOSED ROUTE LAYOUT FOR THE 42,000 MILE NATIONAL RAILROAD ELECTRIFICATION SYSTEM FOR THE UNITED STATES TO TRANSPORT FREIGHT AND PASSENGERS BETWEEN CITIES OVER EXISTING RAIL LINES



ROUTE LOCATION OF THE WEST COAST RAILROAD CORRIDOR ROUTE NETWORK
FOR CRUDE OIL AND FRESH WATER TRANSPORT FROM ALBERTA TO CALIFORNIA



# CONCLUSIONS

An analysis of future oil train traffic flows into the State of Washington from the Bakken Formation oil fields in North Dakota could be as much as 1,100,000 barrels per day by 2020. This oil train traffic would necessitate increases of up to 37 train movements on a daily basis over the Great Northern Corridor from North Dakota to Washington. This increased freight train traffic resulting from oil shipments would essentially double the existing freight traffic volumes over the Great Northern Corridor and would necessitate double tracking the entire line from Everett, Washington to Williston, North Dakota. These crude oil shipments to Washington refineries of 600,000 barrels per day and 500,000 barrels per day to California refineries would essentially consume essentially all of the expected crude oil available for export from North Dakota by 2020 in the estimated amount of 1,100,000 barrels per day.

The light sweet crude oil being shipped from the Bakken Formation in North Dakota should be considered as being potentially hazardous in terms of flammability and volatility and should be tested before shipment by rail. This light sweet crude oil from the Bakken Formation in North Dakota should be subjected to either or both vacuum distillation and /or nitrogen desorption to remove the volatile light molecular weight aliphatic hydrocarbons as well as benzene and other aromatic organic hydrocarbons from the crude oil. The devolatilized crude oil can then be placed in tank cars for rail shipment to refineries in Washington and California. As an additional precaution, there should be a bypass of these oil until trains around Spokane between Havre, Montana and Ephrata, Washington over the former Milwaukee Railroad line with a new tunnel under St. Louis Pass at the Idaho-Montana border to the south of the Great Northern Corridor.

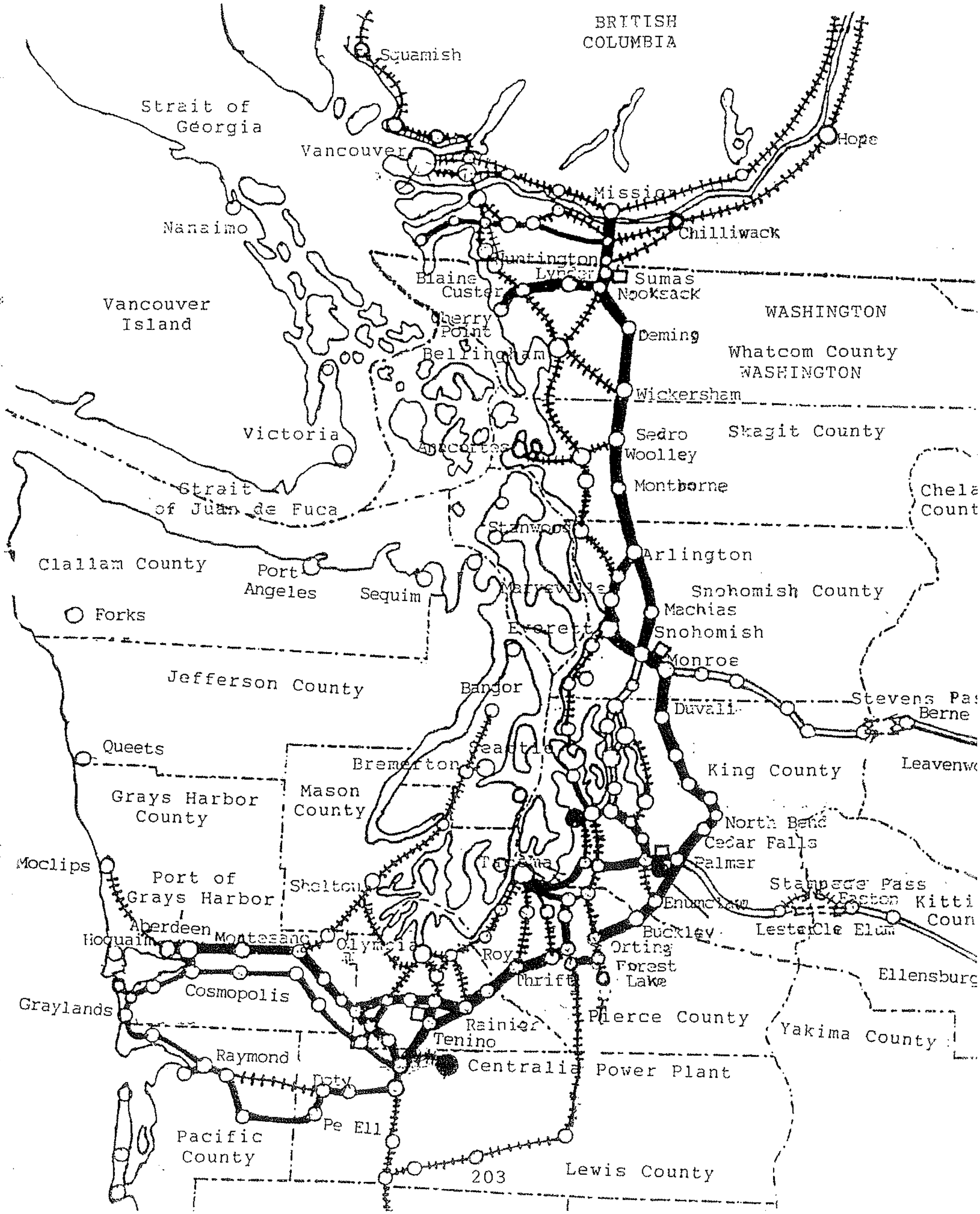
It is suggested that there be a new tunnel built at Stevens Pass between Skykomish and Leavenworrth with a second tube in parallel to the existing tube in a similar pattern with a west side downslope favorable to heavy unit trains. A combination railroad tunnel at Stevens Pass could then handle both intermodal container trains to and from the Ports of Seattle and Tacoma as well as coal and oil unit trains. It is also possible that a second new double track railroad tunnel could be built at Stampede Pass as well as at Stevens Pass but its eastside gradient requirements would be more sever and more new rail line would need to be constituted, In addition, it would also be necessary to double track the existing BNSF Railway Columbia River Line from Pasco to Vancouver with additional expansion of the Wisham to Sacramento roads sections in Oregon and California.

The proposed Cascade Foothill Corridor would need to be built between Tenino, Washington and Mission, British Columbia as the future main rail freight route for north-south traffic through the Puget Sound metropolitan area. The oil unit trains entering the Puget Sound region would then come from Stampede Pass or Stevens Pass to the north from Palmer or Snohomish to Sedro Woolley to the Anacortes refineries or to Wickersham and Bellingham to the Ferndale and Cherry Point refineries. The container trains going to and from the Port of Seattle would go from Monroe to Palmer over the Cascade Foothill Corridor and to Ravensdale on the Auburn line and then over a new Maple Valley line from Ravensdale to Renton and Tukwila or alternatively to Auburn. The container trains going to and from the Port of Tacoma would go from Palmer to Ravensdale and Auburn to the freight line on the Union Pacific rail corridor with passenger trains on the BNSF line.

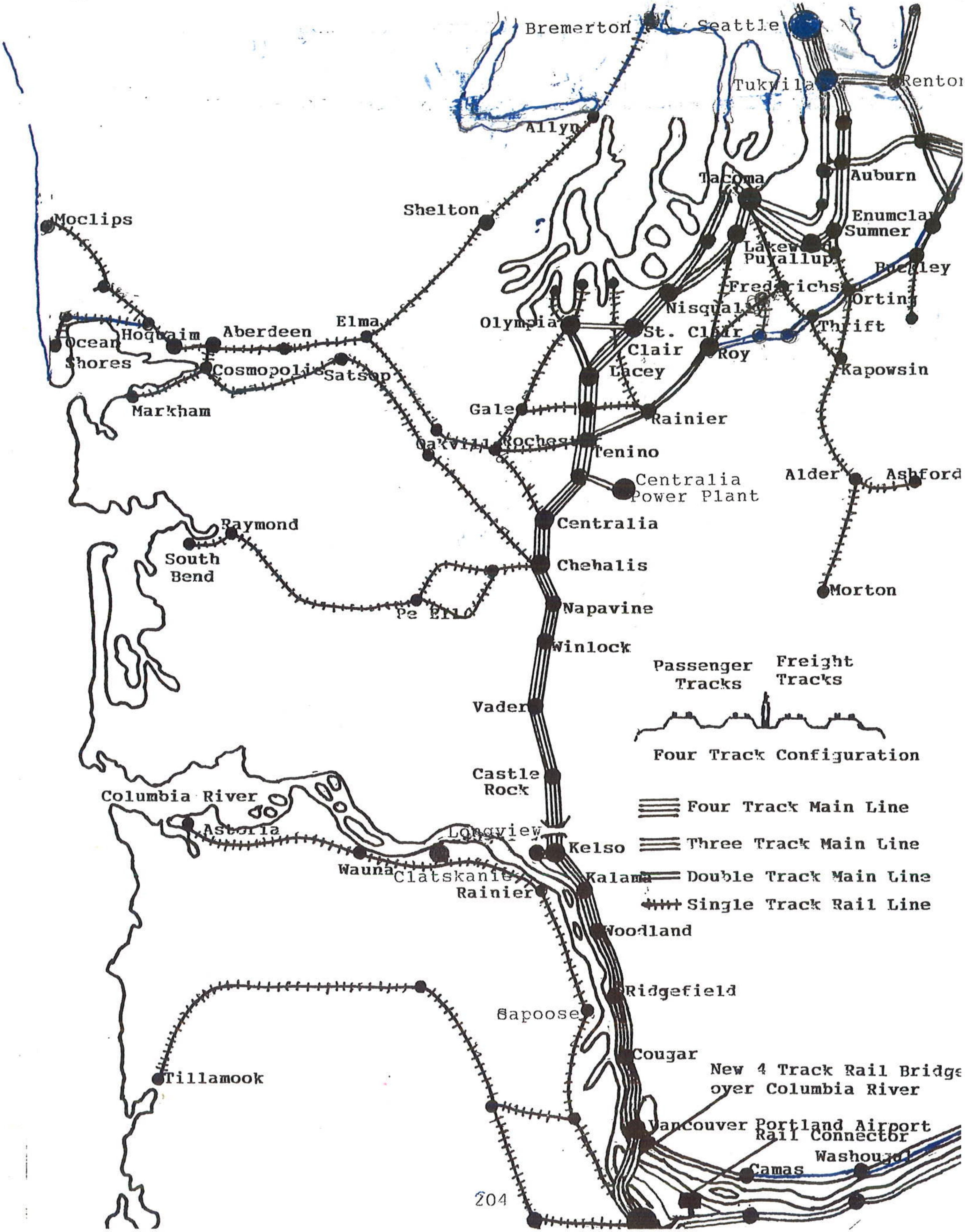
It is suggested that there be a basic rebuilding of the BNSF Railway line south of Tacoma into separate freight and passenger lines to Portland. The freight trains would then go by way of the BNSF existing line while then passenger trains would go by way of the rebuilt former Milwaukee Railroad line to Longview and then to Vancouver, Washington. Crude oil could also be offloaded at the Port of Vancouver, Washington and shipped by barge to the Northwest Washington refineries by way but marine oil spills could be a concern in the rough waters of the Pacific Ocean. The existing BNSF Railway main line from Seattle to Everett and Bellingham should become a primarily passenger corridor to the north with the main freight carried by the Cascade Foothills Corridor to the east. In addition, a passenger commuter loop railroad line could then be built around Lake Washington between Seattle, Tukwila, Bellevue and Everett.

It will become desirable for purposes of economic growth and development to construct a large marine oil loading terminal near Grays Harbor at Aberdeen in order to ship crude oil by barge to refineries in Northwest Washington as well as in the Bay Area and Southern California along the Pacific Coast. It will be even more important to develop the Grays Harbor oil loading terminal for the future export of crude oil from North Dakota as well as for finished refined products. It will be essential to develop and implement methods for preventing future oil spills in Grays Harbor for the purpose of protecting fish and shellfish from potential oil spill contamination. The development of a future alliance between the Interior resource Indian Tribes in North Dakota and Montana shipping crude oil with the Coastal fishing Indian Tribes through joining owned transportation facilities will be essential to promote this effort.

PROPOSED ROUTE LOCATION OF THE CASCADE FOOTHILLS RAILROAD FREIGHT CORRIDOR



TRACK CONFIGURATION OF THE MAIN LINE BETWEEN PORTLAND AND SEATTLE RAIL LINES

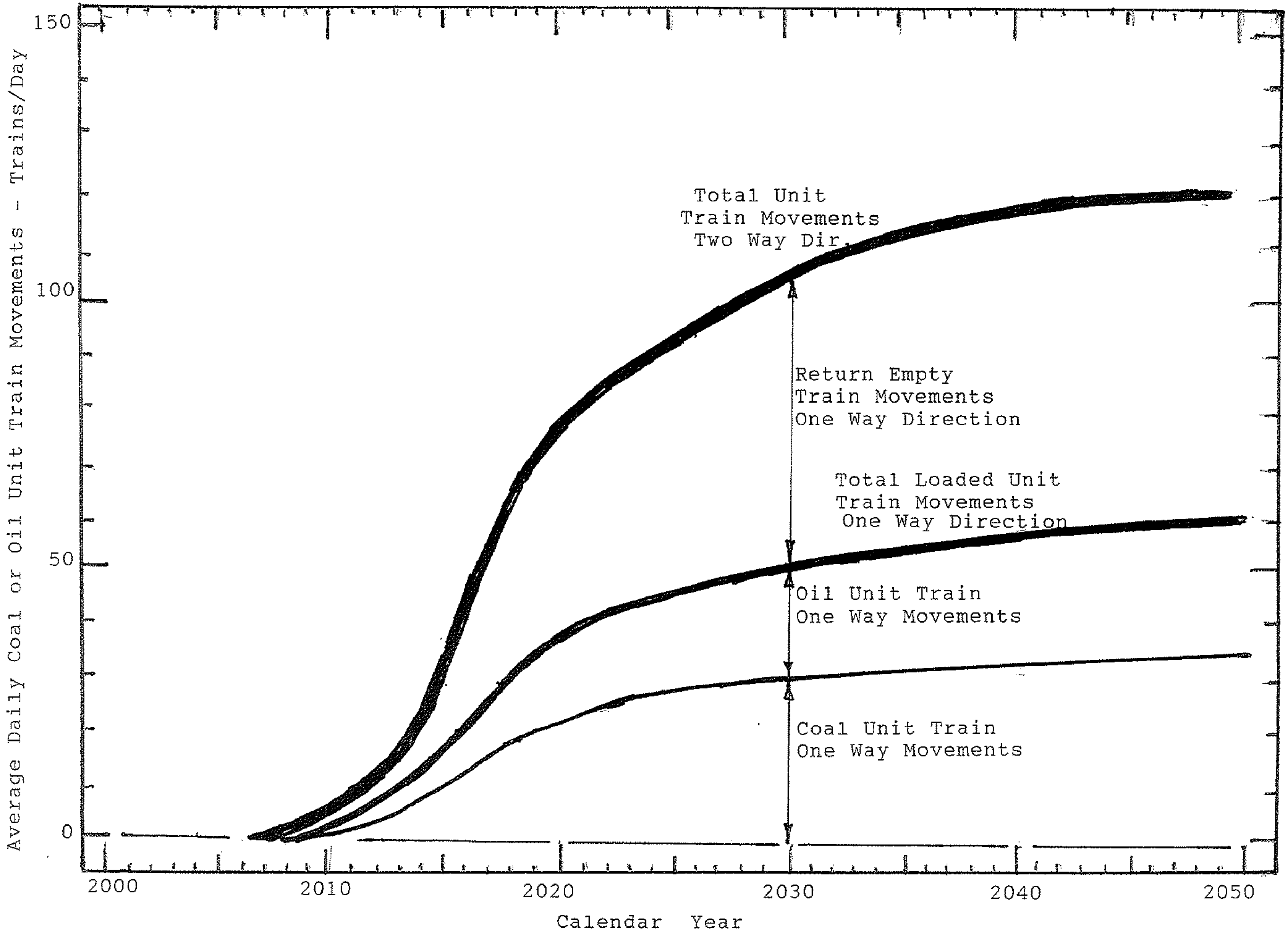


It is recommended that there be oversight bodies for the proposed Great Northern Corridor across the Northern Tier representing the specific State Governments as well as of the Indian Tribes. It is anticipated that the new private sector company would purchase the operating rights to the Amtrak Empire Builder and then initiate service over separate tracks on the BNSF rights-of-way. This future passenger service would begin with two to four round trips per day to haul oil workers to and from North Dakota at train speeds initially of 90 to 110 miles per hour as well as to an from other locations as well. This service would have an initial single track operation with passing sidings at 10 to 15 mile intervals. This initial passenger service on a single separate track with periodic passing sidings would later be expanded to between four and eight round trips per day on both the northern and southern routes across Montana and North Dakota along the Great Northern Corridor between Chicago and Seattle at train speeds of 125 to 150 to miles per hour with heavy freight traffic volumes.

The proposed rail passenger service between Chicago and Seattle over the Great Northern Corridor would intend to be supplemental by the hauling of express cargoes and packages through private third party carriers such as Federal Express, United Parcel Service, the U.S. Postal Service and others in the future. This express cargo service on the passenger tracks would be operated separately from the existing BNSF Railway intermodal freight service for both trailers and containers and would be administered as a joint venture between the passenger operating company and the BNSF Railway. This express cargo service along the passenger tracks would be intended to operate at speeds of 110 to 150 miles per hour would be in tandem with passenger trains operating in the same speed range. Maximum train speeds could ultimately be increased to real high speed operation with further line improvements to speeds of between 175 and 200 miles per hour as perhaps the first long distance cross country high speed rail service that could later be expanded into a national network.

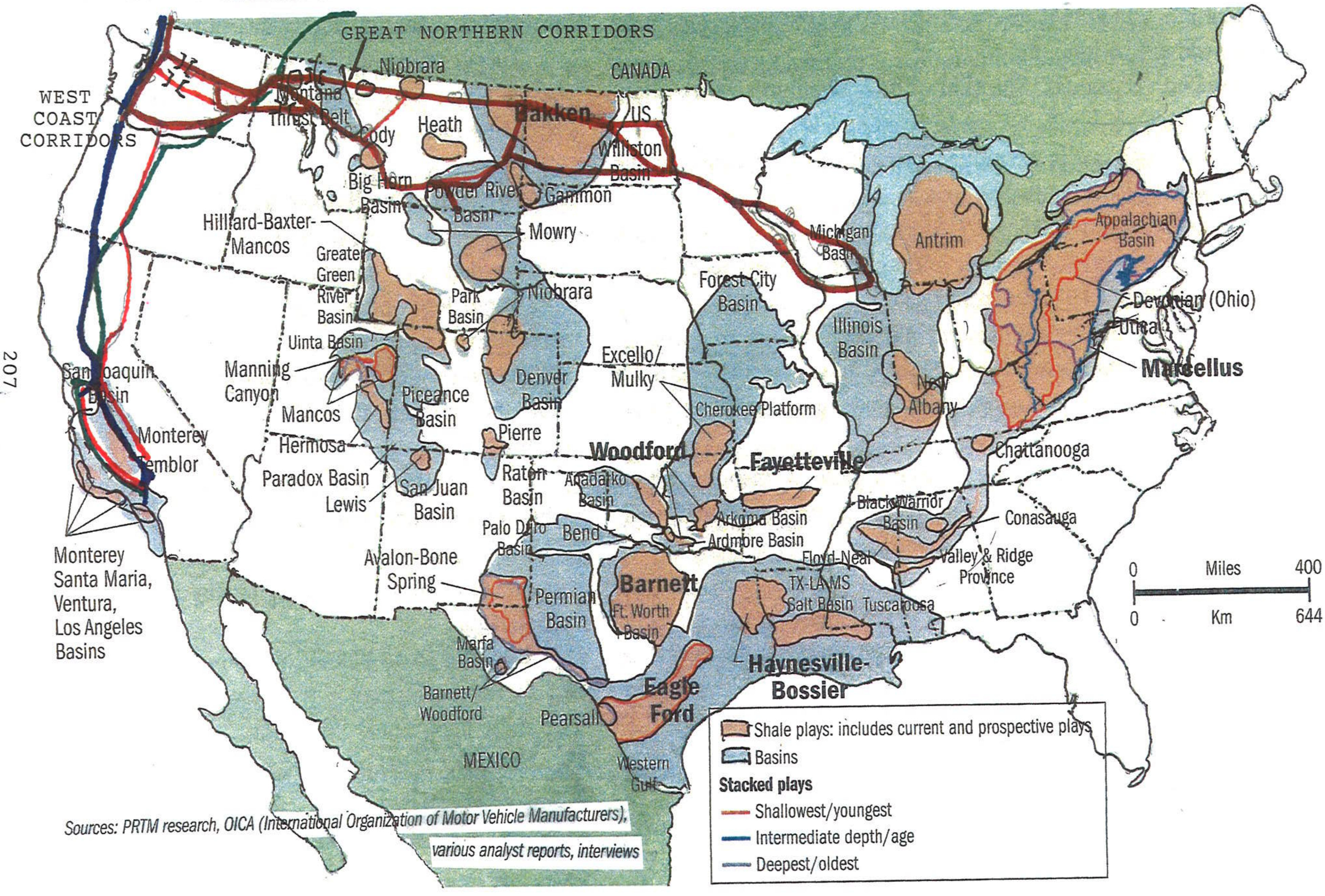
It may become possible to electrify the Great Northern Corridor for rail passenger and freight service on separate parallel tracks of common railroad rights-of-way between Chicago and Seattle if the future. The existing power plants and hydroelectric dams and wind power farms alone the route can then be used to supply the electricity requirements the electrified railway for freight and passenger service along with new power plants. The provision of the additional electricity required for the passenger and freight trains propulsion will need to be added on to the future electric power demands for oil and gas production plus population growth along the Northern Tier with along with additional transmission line capacity.

EXPECTED INCREASES IN COAL AND CRUDE OIL UNIT TRAIN MOVEMENTS OVER THE GREAT NORTHERN RAILROAD CORRIDOR ACROSS THE NORTHERN TIER FROM NORTH DAKOTA TO WASHINGTON: 2000-2050



LOCATIONS OF THE MAJOR CRUDE OIL AND NATURAL GAS SHALE FORMATIONS IN THE UNITED STATES

**Figure 1:** Lower 48 States Shale Plays




*Sources: PRTM research, OICA (International Organization of Motor Vehicle Manufacturers), various analyst reports, interviews*

207

Lastly, the major crude oil shipment potential by rail from North Dakota to Washington should merit not just a Strength Weaknesses Opportunity and Threats (SWOT) analyses of the Great Northern Corridor by the Montana Department of Transportation in conjunction with the respective ports and the States of Washington, Oregon, Idaho, Montana, Minnesota and Wisconsin. It would also be beneficial for Governor Dalrymple of North Dakota and Governor Inslee of Washington to take the lead in conjunction with the Governor Kitzhaber of Oregon, Otter of Idaho, Bullock of Montana, Dayton of Minnesota and Walker of Wisconsin to work together to formulate formal arrangements to facilitate the safe and efficient transport of crude oil and coal plus intermodal containers and grain and other commodities across the Northern Tier. All of this effort is part of a plan to wean the United States off of foreign oil imports so that it can become energy self-sufficient as well as a future net oil exporter.

The implementation plan for the proposed new freight and passenger rail system across the Northern Tier will go over the Great Northern Corridor between Portland and Seattle on the west end to Milwaukee and Chicago on the east over the existing Burlington Northern Santa Fe Railway line. It is proposed that this corridor be expanded from its present largely single track configuration with mixed traffic to a separate parallel double track freight line and a single track passenger line over the entire route along common rights-of-way. It is further proposed that here be a major new freight double track rail bypass around Spokane over the former Milwaukee Railroad line from Havre, Montana to Ephrata, Washington along with the Cascade Foothills Corridor around the Puget Sound area. A new double track tunnel at St. Louis Pass in eastern Idaho as well as a new double track railroad tunnel at Stampede Pass and a triple track tunnel at Stevens Pass will be needed in order to handle the increased traffic.

It is proposed that there be a new rail oil loading terminal at Mandaree on the Fort Berthold Indian Reservation in western North Dakota built in conjunction with a major marine oil terminal complex to be built at Grays Harbor with the Quinault Indian Tribe in southwest Washington as a joint Tribal venture with tank car oil transport. A similar proposal exists for the Crow Indian Tribe in Montana for coal transport by rail to new coal terminals in Washington operated with Indian Tribal participation. It is intended that the proposed project be financed and built through the private sector by the BNSF Railway for the freight portion and by a new private sector company for the passenger portion at a total estimated capital cost of $25 to 45 billion through long term low interest financing instruments.

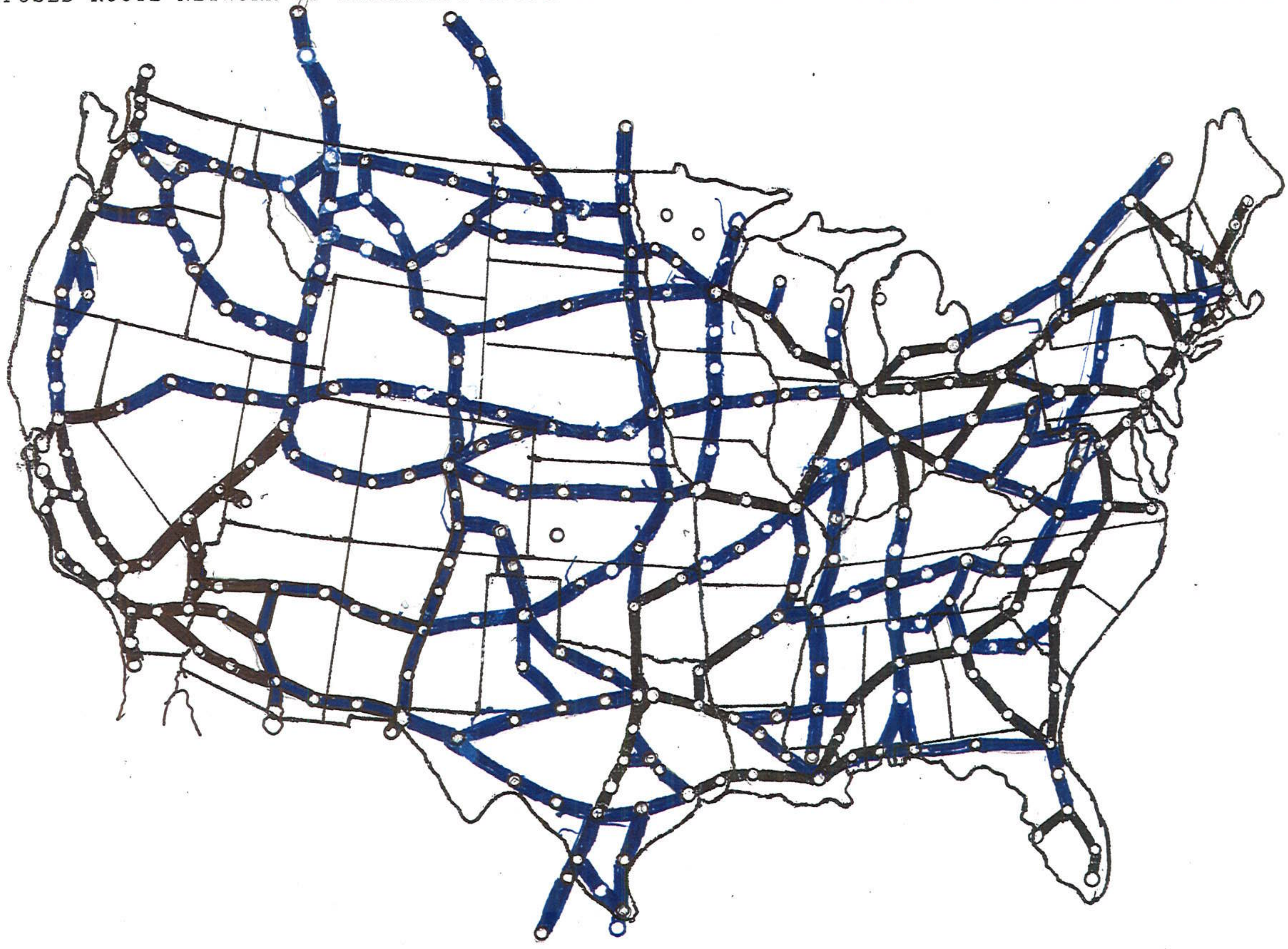
## PROPOSED MAJOR RAILROAD TUNNEL INFRASTRUCTURE PROJECTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE RAILWAY BETWEEN CHICAGO AND SEATTLE

| Tunnel Name | Tunnel Location | Distance In Miles | Number Of Tracks |
|---|---|---|---|
| Stevens Pass | Skykomish, Washington<br>Leavenworth, Washington | 7.9 | 3 |
| Stampede Pass | Lester, Washington<br>Easton, Washington | 8.5 | 2 |
| Flathead Tunnel | Stryker, Montana<br>Libby, Montana | 7.78 | 2 |
| St. Louis Pass | Avery, Idaho<br>Saltese, Montana | 10.5 | 2 |

## PROPOSED FINANCIAL MECHANISMS FOR RAILROAD INFRASTRUCTURE IMPROVEMENTS ALONG THE GREAT NORTHERN CORRIDOR OF THE BURLINGTON NORTHERN SANTA FE

| Infrastructure Category | Number of Tracks | Financing Mechanism | Financing Source |
|---|---|---|---|
| Freight Railroad | 2 to 3 | Low Interest<br>Loans Equity & Bond | Private Sector |
| Passenger Railroad | 1 to 2 | Low Interest<br>Equity Funds & Loans | Private Sector |
| Stations and Terminals | 4 to 12 | Public Investment<br>Equity & Loans | Private Sector<br>Private Sector |
| Grade Separations | 2 to 4 Tracks<br>2 to 4 Lanes | Governmental<br>Appropriations | Public Sector |
| Major Tunnels | 2 to 3 | Private Low Interest<br>+ Governmental Support | Private Funds<br>+ Public Sector |

NATIONAL NETWORK OF HIGH SPEED PASSENGER AND EXPRESS CARGO RAILROAD INTERCITY CORRIDORS IN PARALLEL TO EXISTING FREIGHT RAILROAD MAIN LINES ON SEPARATE TRACKS OF COMMON ROUTES ON A PROPOSED ROUTE NETWORK OF FEDERALLY DESIGNATED HIGH SPEED RAILROAD TRANSPORTATION CORRIDORS



# Pre-processing Light Crudes for Safer Transport and Improved Marketability

A New Process Created bv

CATALYTIC RESOURCES

TERRENUS RESOURCES

CPT HOLDINGS, LLC

INDUSTRIAL COMMISSION
STATE OF NORTH DAKOTA
DATE 9-23-14 CASE NO. 23084
Introduced By Terrenus
Exhibit A
Identified By Ramer

# Who We Are

CATALYTIC RESOURCES

- CR specializes in R&D and commercialization of new ways to refine and process crude oil into safer, more valuable products
- Based in Seattle, WA
- Presentation Team:
  - Jon Ramer
  - John Lotzgesell
  - Mike Lindberg
  - Jim Jory
- Over 50 years combined experience in the petroleum industry

# The Problem

CATALYTIC RESOURCES

- US is moving towards energy security

- HOWEVER:
  - US has a lack of light refining capacity
  - 60% of US production is light crude
  - Regulatory restrictions on crude export

- **Public perception is that light crudes demonstrate a higher volatility than expected for CBR transport**

# A Safer Way

CATALYTIC RESOURCES

- **It is possible to reduce the volatile content of light crude via a proprietary catalytic process and create a more stable crude oil**
- Bakken crude has been processed through a methane-catalyzing reactor to create a Refined Bakken crude with:
  - Improved flash point
  - Decreased vapor pressure
  - Increased initial boiling point
  - Improved API gravity

- **A simple process that is modular, scalable, designed for zero emissions, and can be quickly incorporated into existing infrastructure**

# Our Process

CATALYTIC RESOURCES

- Creates no new compounds in resulting refined crude
- No additives are used
- Operating parameters are easily reached and maintained
  - 150-170° F
  - Less than 10 psi
  - Continuous flow
- Catalyst has expected lifecycle of at least 10 years
- Process creates a stream of safer, higher value crude oil plus a secondary stream of high value, naphtha / diluent
- Operates at LOW TEMP and LOW PRESSURE
- Uses proven technologies in a different way

# Process Results

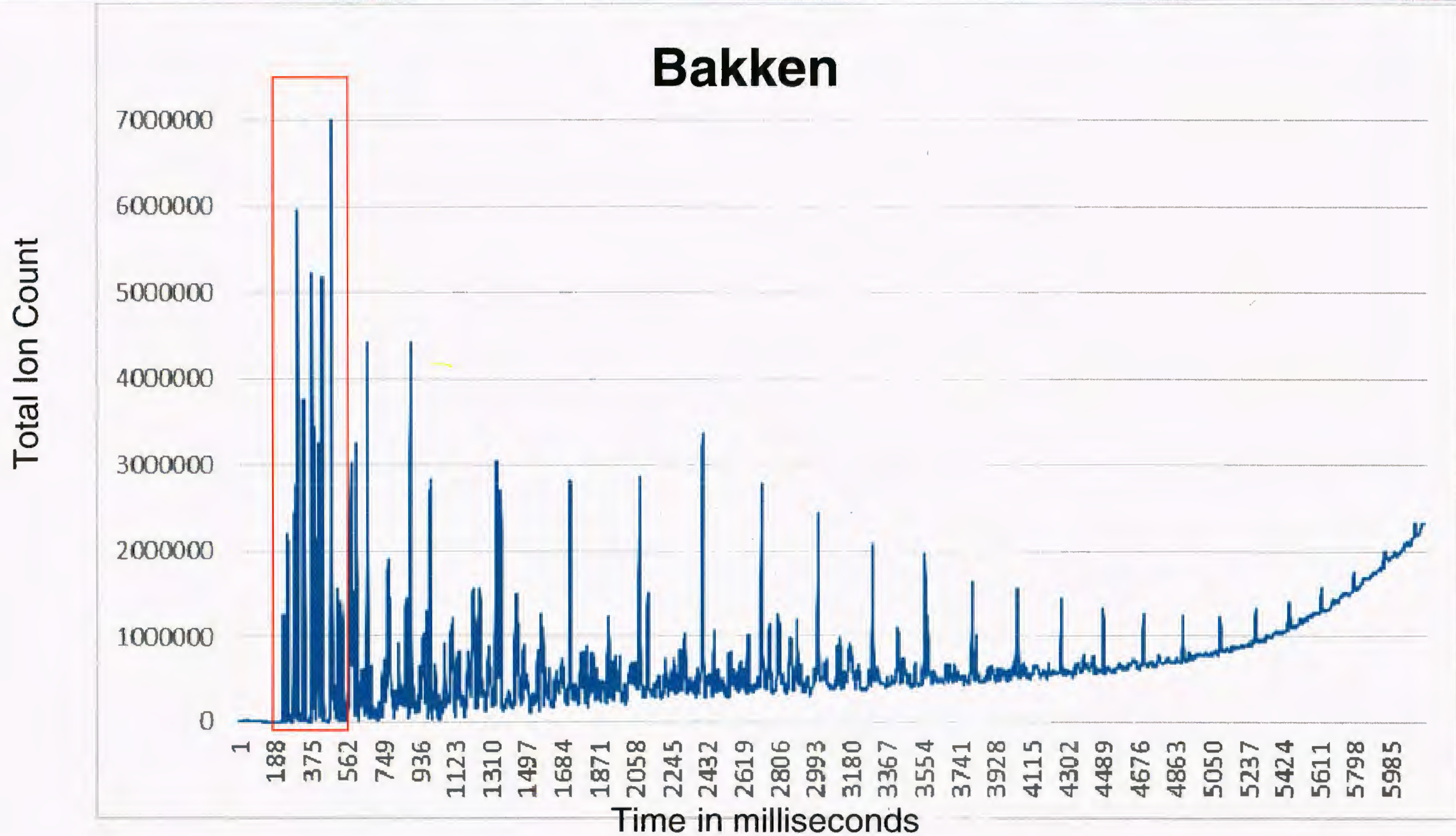
CATALYTIC RESOURCES

| Test | Bakken Crude Feedstock | Refined Bakken Product |
|---|---|---|
| API (D1298) | 43 | 37.2 |
| Flash point (D93) | 20°C (68°F) | 30°C (86°F) |
| Vapor Pressure (D6377) | 58.5 kPa (8.5 psi) | 8.3 kPa (1.2 psi) |
| D86 IBP | 38°C (100°F) | 92°C (198°F) |
| D86 T50 | 241°C (466°F) | 274.5°C (526°F) |
| D86 T90 | <300° C (65%) | <300° C (60%) |
| BS&W (D4007) | 0 | 0 |
| Corrosion (TM-0172) | E | A |
| Sulfur ppm (D4294) | 632 | 733 |

Third party independent laboratory test results

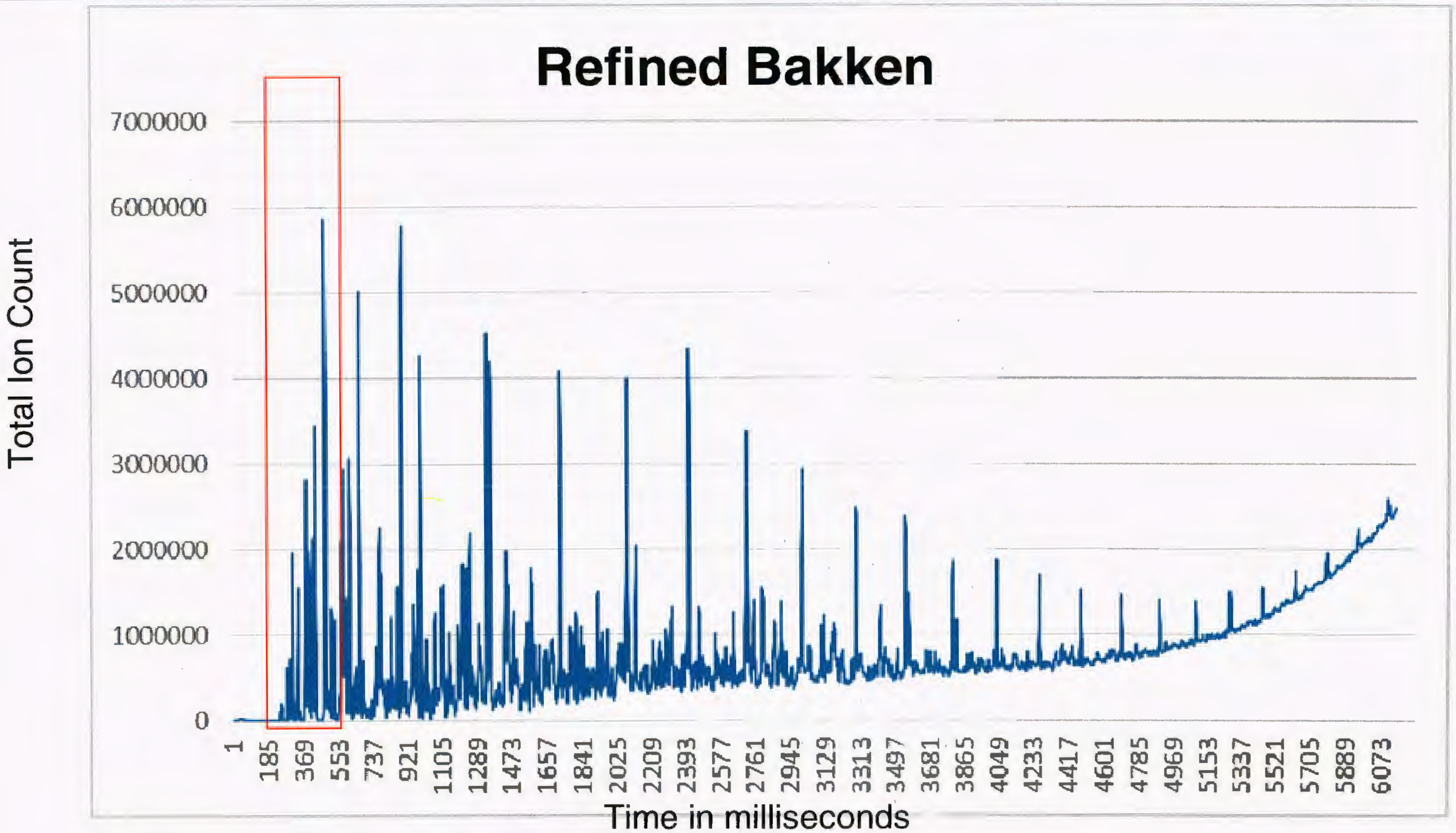
# Process Analysis - GCG

CATALYTIC RESOURCES



# Process Analysis - GCG

CATALYTIC RESOURCES



# A Safer, More Marketable Crude

CATALYTIC RESOURCES

- Refined Bakken is safer
  - We remove and convert majority of the volatile light end components
  - Reduced corrosiveness
- Refined Bakken is more marketable
  - Increase in high value constituency of crude
  - Near identical characteristics to WTI crude
  - Safer product may open new markets
  - Refined Bakken meets Federal requirements to allow export to foreign markets

# A Safer Transportation Solution

CATALYTIC RESOURCES

- Reduce the transportation cost and risk for moving Bakken crude

- **Refined Bakken has a flash of 30° C (86° F) and an initial boiling point of 92° C (196° F) making it qualify as a PG 3 liquid per CFR 173.120 instead of PG 1 or 2**
  - Packing Group II liquids
    - Flash ≤ 23° C (73° F) and a boiling point < 35° C (95° F)
  - Packing Group III liquids
    - Flash < 23° C (73° F) but ≤ 60.5° C (141° F) and a boiling point of < 35° C (95° F)

- Published costs to use PG 3 liquid rail cars are lower
- Rail units carrying PG 3 cars can move at higher speeds
- More PG 3 cars available for transport

# A New Paradigm

CATALYTIC RESOURCES

## The solution to The Problem is not to change the infrastructure, but to change the process.

Not only can our system do this, but we can increase the value of the feedstock crude, improve safety, and reduce risk for rail transport at the same time.

# Thank You for Your Time

CATALYTIC RESOURCES

## Any Questions?

| | |
|---|---|
| **From:** | Kari Cutting |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | FW: Message sent on behalf of Kari Cutting: Testimony for NDIC hearing on Tuesday, Sept 23, 2014, 3:30 p.m. Central |
| **Date:** | Monday, September 22, 2014 4:58:50 PM |
| **Attachments:** | 2014 0923 NDIC Task Force Response to Case 23084 - JBH v1.docx<br>bakken crude and conditioning fact sheet.pdf<br>Hearing_Oasis.pptx<br>DEPA North Dakota Crude Conditioning Issues 9-23-14 2.docx |
| **Importance:** | High |

Good afternoon,

I am submitting the attached from Jeff Hume, chairman of the BKN task force, Oasis and DEPA for tomorrow's hearing.

In addition, I have attached a fact sheet that was assembled by NDPC.

Sincerely,
Kari Cutting

**North Dakota Petroleum Council**
**Bakken Crude Characterization Task Force**

**DMR Oil & Gas Division Hearing**
**Case 23084 – Oil Conditioning**
**September 23, 2014**

Good morning. I am Jeff Hume, Chairman of the NDPC Bakken Crude Oil Characterization Task Force. Thank you for the opportunity to address the Commission on this important topic.

The Bakken Crude Oil Characterization Task Force (Task Force) was created to address allegations that Bakken crude oil (BKN) does not meet DOT standards for a Class 3, Packing Group I or II Flammable Liquid for rail transportation in DOT 111 tank cars, and further, that Bakken crude is more volatile than other domestic light sweet crude oils that may be shipped by rail. Due to the complex and scientific nature of the allegations, the Task Force engaged Turner Mason & Company (TM&C) to make recommendations for the testing and analysis to address these issues.

TM&C proposed a scientific testing program to analyze multiple samples from numerous wells and rail loading terminals located across all geographic areas of the Bakken field within the US Williston Basin. The plan was approved by the Committee and TM&C was contracted to manage all phases of the study.

A team of experts in the field of crude oil testing and characterization was assembled by TM&C and SGS Laboratories, an internationally recognized testing laboratory, was contracted to perform the sample and field data collection, and to conduct the prescribed testing. Strict sample procurement and chain of custody protocol was established, along with comprehensive field operating data collection. Each sample was subjected to a specific slate of testing to provide data for characterization analysis. The results of the study were presented to the NDIC on September 15, 2014 by TM&C. The study findings and conclusions made by TM&C indicate that BKN crude oil is similar to other light sweet crude oils and meets specifications outlined in Title 49 CFR 171-180 for safe transport by rail or truck.

The TM&C report included a list of recommend best practices for field operations to insure the established quality specifications will be continually met or improved upon. These recommendations should be reviewed as part of this hearing and include:

- General operating conditions for lease treating equipment;
- Periodic testing to insure expected property specifications identified in the study are maintained;

- Acknowledgement that legacy production from various producing formations located within the proximity of the Bakken field is part of the production stream and permissible;
- Continued prohibition of plant NGLs being added to the crude oil stream;
- Elimination of any non-stabilized liquids recovered from wet-gas gathering pipelines being commingled with the BKN; and
- Insure blending of crudes from outside the US Williston Basin does not occur to prevent sulfur and other contaminants that may degrade the low corrosivity of the BKN.

The study recognized that various types of lease processing equipment are being utilized to condition crude oil for market across the basin. However, the sample testing indicated fairly tight distribution of physical properties, especially at the rail terminals where crude oil from many wells operated by a variety of companies is aggregated in large storage tanks for shipping. This tight distribution indicates that the various equipment designs and configurations are performing their function with very similar results.

Another observation of the study data is that only minor changes to light end composition can be made by optimizing the operating conditions of the production equipment, specifically temperature and pressure. A comparison of temperature and pressure to percent ethane and propane for wells with fired equipment showed only slight reduction with increased temperature and even slighter improvement with lower operating pressure. However, this data indicates that equipment specific optimization could potentially reduce the amount of ethane and propane remaining in the conditioned crude oil.

Today you will hear testimony from several operators on how they approach production operations to optimize conditioning of both oil and gas for market. The variety of equipment deployed and the operational limitations provide fairly tight variation for optimization. However, optimization can be achieved on a lease-by-lease basis if properly addressed.

Thank you for the opportunity to share this information and answer any questions that you may have regarding the study conducted by the Task Force.

NORTH DAKOTA PETROLEUM COUNCIL

# Bakken Crude and Conditioning

## Light Crude vs. Condensate

The U.S. Energy Information Administration and industry uses API gravity to define crude oil as heavy, light or, in some cases, condensate. Heavy crudes, such as the oil produced in Canada's Tar Sands, have an API gravity of less than 35 degrees, while light crudes, such as Bakken crude, have a gravity of between 35 and 49. Condensate is a class of light crude oil containing a high concentration of natural gas liquids and having an API gravity greater than 50 degrees.

Bakken crude has an average weight of 42 degrees, which is comparable to West Texas Intermediate – a common benchmark crude used to price oil – with an API gravity of 41 degrees. Similarly, Brent crude - a crude produced in the North Sea and used as a major benchmark price for purchases of oil worldwide - is 38 degrees. These crudes are classified as light crudes and do not require stabilization for storage and transport. Conversely, some crudes, such as Eagle Ford crude oil with an API gravity of 58 degrees, is classified as condensate and requires stabilization to meet federal regulations for storage and transport.

## Stabilization

Many have stated that stabilization of Bakken crude is needed to enhance safety, but what is stabilization and is it necessary?

Crude oil produced at the well head contains "light ends," which are dissolved hydrocarbons that have a lower boiling point such as butane, ethane and propane. "Stabilization" is the process of removing light ends from crude oil.

There is a lot of confusion about the term stabilization. Part of this confusion is due to the fact that industry has used the term to describe two different processes: stabilization at the well site, or well-site conditioning, and post-well site stabilization.

Stabilization at the well site is often called *well site conditioning*, while post-well site stabilization occurs at offsite commercial stabilization units that separate condensate to market to petrochemical plants. These plants produce the chemicals needed to manufacture plastics, fertilizers and other important products we use every day.

Stabilization offsite will lower the vapor pressure of crude oil down to 9 to 12 pounds per square inch (psi).

## Well Site Conditioning

In North Dakota, crude oil is conditioned or *stabilized* at the well head. All wells are required to have conditioning equipment such as separators, heater treaters or equivalent devices, and stock tanks to *condition* (or "stabilize") crude oil at the well site. This conditioning equipment is installed at a cost between $200,00 and $400,000 per well. After well site conditioning, Bakken vapor pressure is in the range of 8 – 12 pounds per square inch (psi) - the same range of vapor pressure as stabilized condensate. This characteristic of Bakken crude is uniform throughout the Bakken and does not change in transportation.

## Conclusion

North Dakota has the proper regulations in place to properly treat and condition Bakken crude to meet federal specifications of the product by rail. Because Bakken crude is not condensate and can be considered a stabilized crude, not needing additional offsite conditioning. In fact, additional offsite conditioning would be a redundant process that would not yield any additional safety benefits. Rather, the result could be separate set of flammable liquids or flammable gases being transported by truck or rail because North Dakota does not have a petrochemical market to process those light ends here, nor does it have the pipeline infrastructure in place to transport it to a market out of state.

# OASIS FACILITY OPERATIONS

September 23, 2014

# Agenda

- Oasis Overview
- Single Well Facilities
- Central Tank Batteries
- Surface Equipment

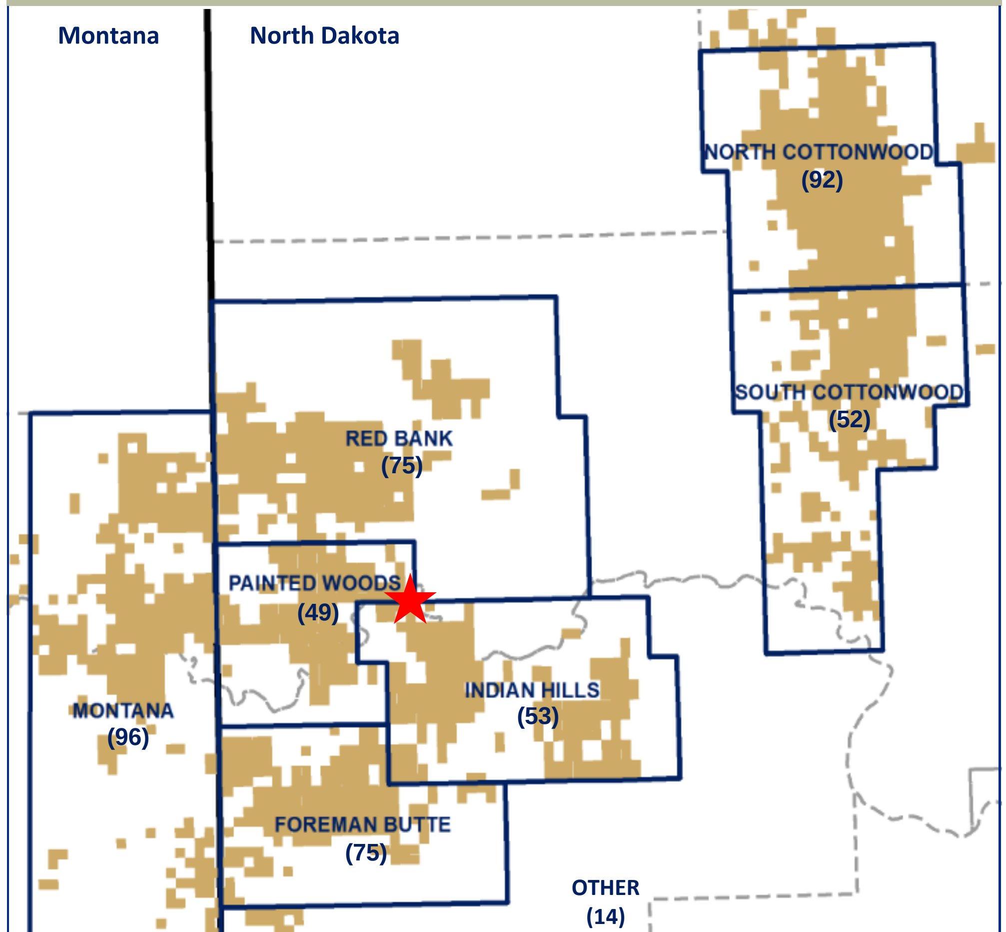

OASIS PETROLEUM

# Oasis Petroleum – Overview(1)

## Highlights

- Significant position in Williston Basin: 507k net acres
  - West Williston: 362K net acres
  - East Nesson: 145K net acres
- Wide areal acreage distribution leads to multiple facility configurations
  - Well Performance
  - Infrastructure Capacity
  - Asset Life-cycle
- Variable facilities yield consistent product

## West Williston | East Nesson

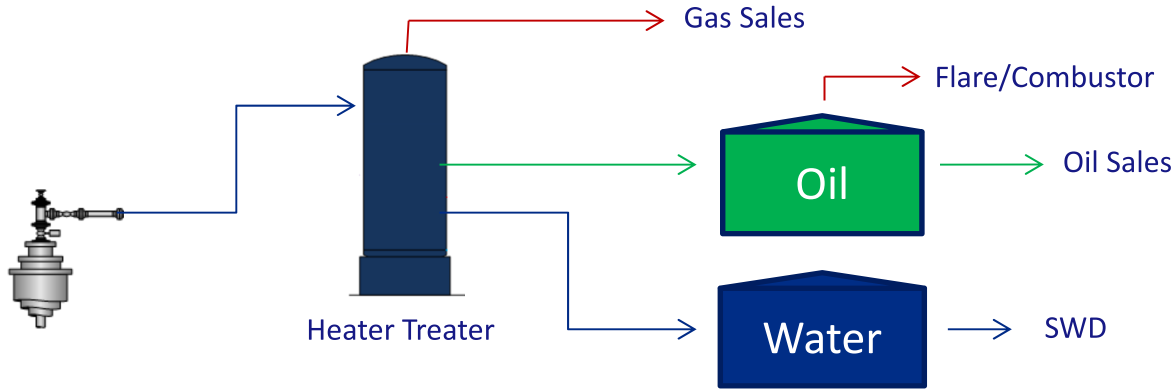


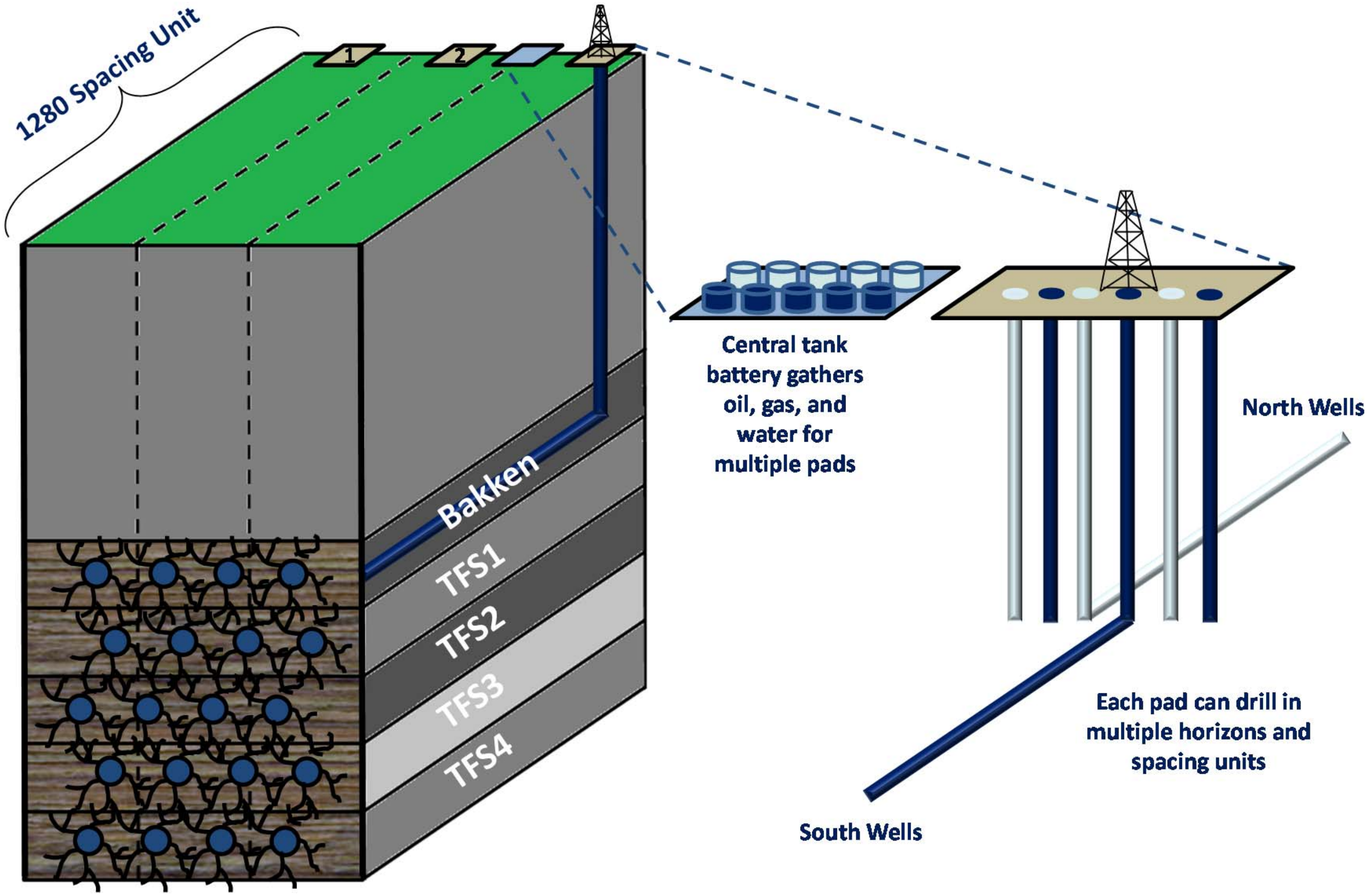

*Acreage in 000s in parenthesis

★ - WILLISTON

(1) As of 12/31/13 and does not include acreage associated with Sanish that was divested in March 2014

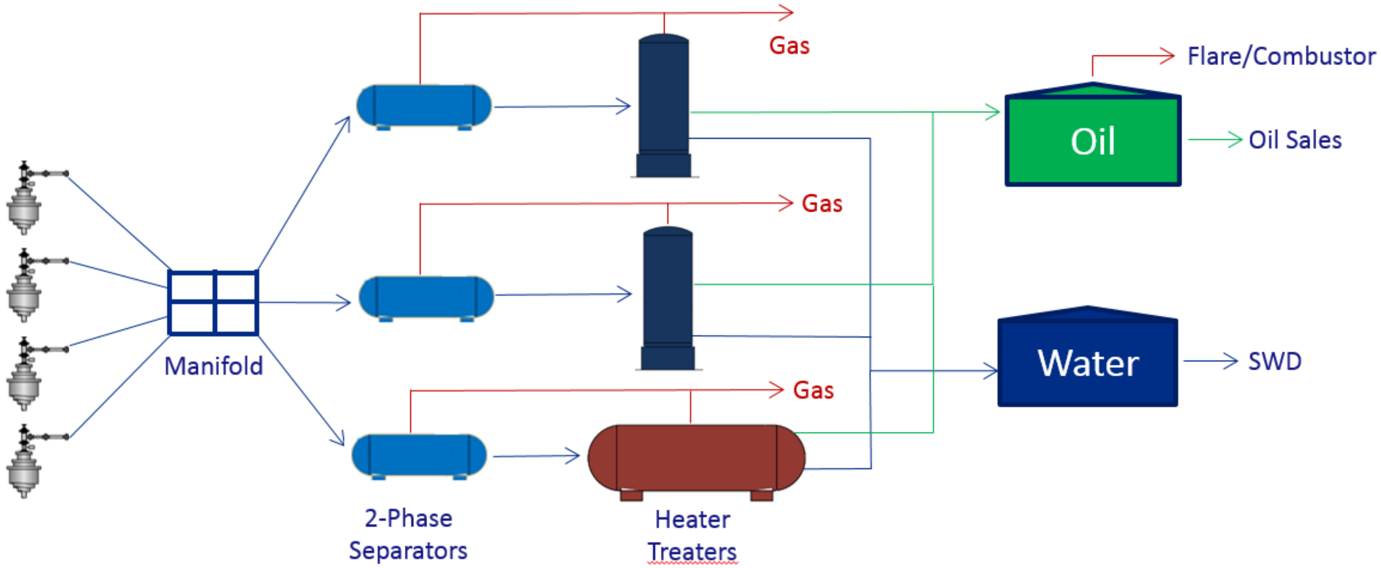
# Single Well Facilities

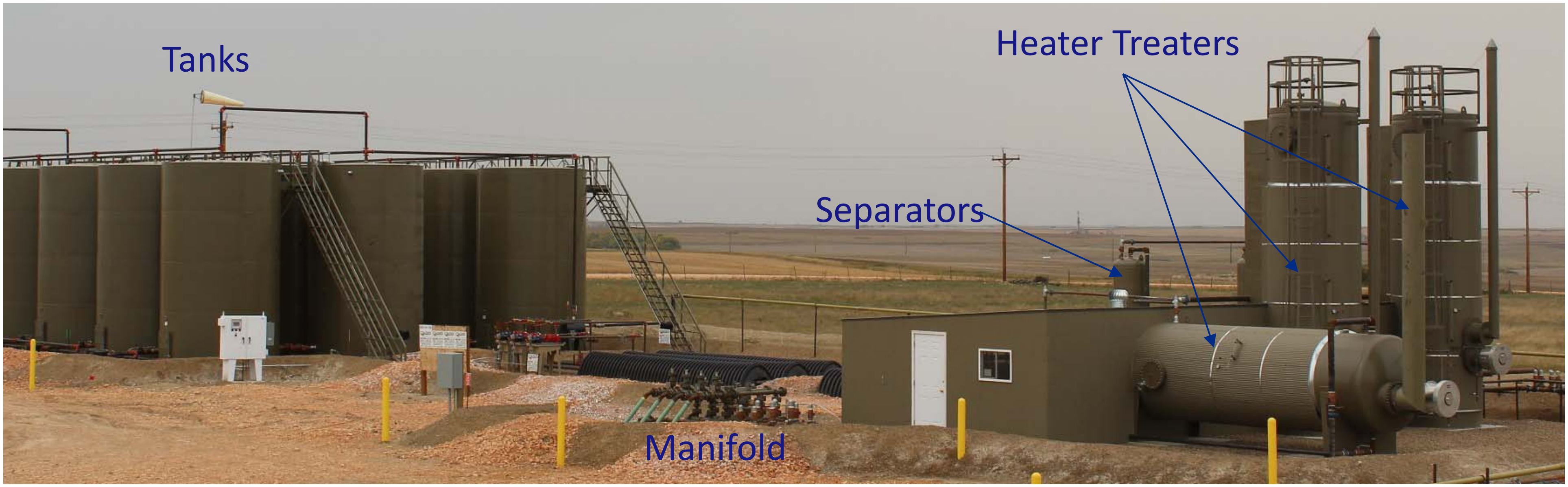



## Minimizes equipment and simplifies infrastructure construction

# Central Tank Batteries






OASIS PETROLEUM

# Surface Separation Equipment

## 2-Phase Separator

- Pressure: 75 - 150 psig
- Temperature: 60° - 150°F
- Retention: 30 – 150 min as per spec

## Heater Treaters

- Pressure: 40 – 70 psig
- Temperature: 90° - 150°F
- Retention: 30 – 150 min as per spec



OASIS PETROLEUM

# Summary

- Facility variation dependent primarily on infrastructure needs and DSU development cycle
- Separator/Treater operating temperature driven by flow rate, BHT, and added heat
- Operating pressure typically minimum required to move fluid and maximize gas sales
- Variable facilities yield consistent product

Testimony presented to the North Dakota Industrial Commission on behalf of the
Domestic Energy Producers Alliance (DEPA)
Well Site Conditioning
Tuesday, 23 September 2014

On behalf of the Domestic Energy Producers Alliance ("DEPA"), I offer these comments pertaining to the topic of well site conditioning of light sweet crude in North Dakota.

DEPA is a unique organization with a grassroots approach to domestic onshore energy advocacy and education. We are an alliance of producers, royalty owners, and oilfield service companies, as well as state and national independent oil and gas associations, representing the small businessmen and women of the energy industry. Our members are devoted to the survival of U.S. domestic crude oil and natural gas exploration and production. The Domestic Energy Producers Alliance is a nationwide collaboration of 15 coalition associations – from California to West Virginia, Texas to Montana and North Dakota – representing about 10,000 individuals and companies engaged in domestic onshore oil and natural gas exploration and production (E&P). We believe in seeking common ground, and in common sense solutions to the challenges that we face in our businesses, including our relationship with the federal legislative and executive branches of government. In only its fifth year, DEPA now represents a majority of the individuals and companies responsible for the current renaissance in American oil and natural gas production. On behalf of the members of DEPA, we thank The North Dakota Industrial Commission for the opportunity to comment on this very critical issue.

DEPA members' collectively represent literally hundreds of years of experience in the exploration, production and marketing of crude oil. The development of the light tight shale crudes has created a renaissance of energy production, which renaissance has brought this country to a level of energy security that is vital to our nation's future. Over half of the crude oil in the U.S. is produced in Texas, Oklahoma and North Dakota and a large percentage of that volume is light crude extracted from tighter shale formations. In some areas, infrastructure has been sufficient to facilitate transportation of these crudes to market via truck and pipeline with some rail shipment. In the case of the North Dakota Bakken fields, this same infrastructure is not yet available, such that rail shipment has played a much larger transportation role. Reportedly, 60% of Bakken crude was transported by rail in the month of July.

There have been a relatively small number of major railway mishaps involving Bakken crude oil which have raised questions regarding the chemical composition and physical characteristics of light sweet crude and the ability of Bakken crude to be transported safely under the current regulatory environment as administered by the Pipeline and Hazardous Materials Safety Administration (PHMSA).

Independent studies[1] commissioned by the American Fuel and Petrochemical Manufacturers, the North Dakota Petroleum Council and the Pipeline and Hazardous Materials Safety

---

[1] *A Survey of Bakken Crude Oil Characteristics Assembles For the U.S. Department of Transportation*, 14 May 2014 o *Submitted* by American Fuel & Petrochemical Manufacturers, Prepared by Dangerous Goods Transport Consulting, Inc.

*The Turner Mason & Company Study on Bakken Crude Properties*, 16 July 2014 o Submitted by the Bakken Crude Characterization Task Force, Prepared by Turner, Mason & Co. Consulting Engineers

*Operation Safe Delivery*, July 2014, including *Operation Classification*, August 2013, as pertaining to Bakken Crude *o* Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation

Administration (PHMSA), U.S. Department of Transportation have now shown that Bakken crude is not unique, but is in fact very similar in composition and physical parameters to other North American light, sweet crude oils produced not only from the tighter shale formations, but also from conventional formations in Texas and Oklahoma. All of these light, sweet crudes fall under the classification of a Class 3 flammable liquid.

The preamble to the recent rule proposed by PHMSA – "Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains", stated that:

> *"…the number of mainline train accidents involving crude oil has increased from zero in 2010 to five in 2013 and thus far five in 2014."*

During this same time frame, the volume of Bakken crude shipped by rail had increased tremendously. This preamble continued however by stating that:

> *"...across the entire rail network, the number of train accidents and hazardous materials releases are decreasing; while total shipment volume has increased, the total number of train accidents has declined by 43 percent since 2003, and accidents involving a hazardous materials release has declined by 16 percent since 2003."*

It should follow that the number of rail accidents involving crude oil should assume the same declining trend as the other Class 3 flammable shipments have experienced as described in this preamble. One would not expect that a train carrying crude or any other Class 3 flammable substance would tend to experience more accidents attributed solely to the substance being carried.

The NDPC has commissioned Turner Mason and Company, engineering consultants with extensive crude oil expertise, to conduct a study of the physical characteristics of the North Dakota Bakken crude.    John Auers, executive vice president of Turner Mason called this study "the most comprehensive and thorough study of a crude oil and shale oil basin in the United States, to date." The Turner Mason study found that the vapor pressure of Bakken crude oil is not the highest or the lowest of crude oils transported in the United States but is 4 times less than the regulatory limit and 10 times less than the design capability of railcars. This study also showed that Bakken crude oil has the same composition throughout the Williston Basin and maintains this composition during transport.

Light sweet crude oils across the U.S. now make up 60% of the domestic crude oil produced and continue to dominate the market s new discoveries are made. Just as a matter of comparison, the Eagle Ford crude produced in south Texas has an API gravity of up to 58° and is classified as a condensate.  Condensate is a class of light crude oil containing natural gas liquids, often referred to as natural gasoline, which has an API gravity of over 50°.   Bakken crude has an average API gravity of 42°.  WTI has an average API gravity is 41°, and Brent crude - 38°.  The U.S. Energy Information Administration lists crude oils with API gravity of greater than 35° as light crude oils. Therefore, neither Bakken nor most other Texas or Oklahoma light sweet crudes are to be considered condensate.

This hearing has been called to address the need and possible process for stabilization or conditioning of crude at the well site or the associated oil handling facility.  The purpose of conditioning as we understand it is to lower the vapor pressure of the crude oil by driving off the light ends. The current separation equipment employed at the oil handling facilities prior to lease custody transfer has proven successful in reducing the vapor pressure of Bakken crude to a range of 8-12 psi, variable by season. The same type equipment that has been used for years to separate the oil from the gas and from the produced water effectively accomplishes this goal, when operated properly. The separation equipment is designed on the parameters of temperature, pressure and residence time required to effectively and most efficiently separate these three phases of the produced stream. Various designs have evolved through technological research over the many years of oil and gas production and have been modified and improved to accomplish this separation with the greatest efficiency. Our members either design, manufacture or use this separation equipment.

The heated separator, referred to as the "heater treater" has as its main purpose to break out oil/water emulsions to augment the crude for market quality specifications. The other types of separation equipment employed at these facilities also serves to modify the oil and gas streams to market quality specs. As the produced stream is routed through each separation vessel, it experiences a drop in pressure drop in pressure which allows for evolution of lower chain volatile fractions. These tanks used to store the crude oil are operated at or near near ambient pressure and temperature, or if a vapor recovery unit is used to control VOC emissions, a slight vacuum is imposed on the tank contents. The lighter fractions of the crude column flash at the lower pressures to evolve the methane/ethane fraction to the gas stream. In fact, the EPA considers the crude tank overhead gases to be 100% volatile organic liquids (i.e. C3+) unless otherwise sampled and analyzed.

The actions taken by North Dakota have the potential to affect the treatment and transportation of light crudes all across the United States. DEPA feels that the operators in North Dakota and across the U.S. have developed extensive experience in oil/gas/water separation, driven primarily by market quality specifications for their products. And we believe that the record will show that the same separation equipment that has been employed for these purposes has also produced the vapor pressures and other physical criteria that PHMSA considers safe for transportation of these light tight crudes, which are bringing this country energy security.

Thank you very much on behalf of the Domestic Energy Producers' Alliance and its members.

| | |
|---|---|
| **From:** | Kari Cutting |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | FW: 2 of 2 Messages sent on behalf of Kari Cutting: Testimony for NDIC hearing on Tuesday, Sept 23, 2014, 3:30 p.m. Central |
| **Date:** | Monday, September 22, 2014 4:55:06 PM |
| **Attachments:** | Hess-API NDIC Testimony 09 23 14.pdf<br>Whiting testimony 9-23-14.pdf |

Good afternoon, I am submitted the following on behalf of API and Whiting Petroleum for tomorrow's hearing.

Sincerely, Kari Cutting

**North Dakota Industrial Commission**
Hearing – Case No. 23084
September 23, 2014

Good morning, my name is Brent Lohnes and I am the Director for Field & Plant Operations for Hess Corporation. I want to thank the State, and the North Dakota Industrial Commission, for giving Hess the opportunity to participate in this important hearing today.

Safety has always been a core value of both Hess and the oil and natural gas industry, and we are committed to working with regulators and all stakeholders to ensure public safety in the handling, packaging and transportation of crude oil. Any new proposals for operator requirements must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations.

Today I am testifying on behalf of Hess Corporation as well as the American Petroleum Institute, the national trade association representing America's oil and natural gas industry. API has more than 600 members, including integrated companies, as well as exploration and production, refining, marketing, pipeline, marine businesses, and service and supply firms.

Hess has a long history of operating in North Dakota – we have been here since 1951 when our company drilled the first production oil well in the state. We are proud to say that generations of Hess employees have called, and will continue to call, North Dakota home. Today, Hess is one of the largest producers in the entire region, with a 17 rig program and over 800 wells of which Hess is the primary operator. In the Bakken, we are expecting to produce approximately 80,000 barrels of oil equivalent per day on a net basis, with plans to reach 125,000 barrels of oil equivalent per day by 2016.

With the substantial increase in production of Bakken crude from North Dakota, the industry is experiencing constraints on pipeline capacity for transporting the product, which has resulted in a larger amount of Bakken crude to be shipped out of the state via rail. Several high profile rail incidents involving transport of Bakken crude have caused greater speculation and scrutiny around the chemical characteristics of the product, causing federal regulators and others to question whether or not transportation of crude by rail is safe. As the debate continues on the potential changes to rail regulations at the federal level, we are here today to discuss the practices of oil conditioning processes in the field – which we believe are sufficient in preparing Bakken crude for transport by rail, pipeline, or truck.

The North Dakota Petroleum Council, in conjunction with Turner, Mason & Co., has conducted Bakken quality assurance tests that studied the range and variability of Bakken crude oil qualities. The Turner Mason study was based on original data collected from both well sites and rail sites, and was representative of the entire Bakken field by using samples from older wells, newer wells, areas of different geography, and from different operators. The results of this study have shown that Bakken crude oil is very similar to other light crude oils. All samples were typical of light crude oil and classified as flammable liquids according to federal regulations. The study found no meaningful change in transit,

little geographical variation, and no evidence of corrosiveness – showing that Bakken crude is extremely consistent across the entire basin, and from load to delivery point.

The results of the study support our position that there is no practical difference in the characteristics of Bakken crude and other light crudes, and that it is suitable for shipment in current rail tank cars. Hess currently operates CPC-1232 tank cars, which exceed today's required specifications for safe transport of flammable liquids as prescribed by the Department of Transportation. Hess also incorporates strict safety protocols into our day-to-day management of crude shipments, and will continue to do so. As such, the transportation safety of crude oil should be considered holistically by evaluating the product, the package, and the operations. Turner Mason's study and API's work on a standard for classification address the characteristics of the product and the proper classification and loading of crude oil in rail tank cars.

In fact, the NDPC testified recently before Congress that three independent studies have now shown that Bakken crude is similar to other North American light, sweet crude oils in gravity, vapor pressure, flash point and initial boiling point – the key parameters in proper classification. According to these studies, Bakken crude oil chemical properties attest to its proper classification as a Class 3 flammable liquid.

An across-the-board requirement to stabilize crude oil beyond the current practices taking place would still likely result in a product that remains a flammable liquid, as defined by the Department of Transportation. To date, no evidence has been presented to suggest that measureable safety improvements would result from processes beyond current oil conditioning. Furthermore, additional oil conditioning would create two separate product streams of flammable liquids for transport. Because of the lack of existing infrastructure in North Dakota, this would be even more flammable liquids that would still have to be transported by rail. We believe Bakken crude oil is sufficiently prepared for transport in the field using conventional separation equipment already in place at well sites – for example, separators and heater-treaters, as Hess employs in our operations. Furthermore, oil conditioning at the well site is conducted to prepare the oil for market by separating the oil, water, and gas components. While practices will differ between operators – due to equipment or infrastructure constraints – we are confident that current oil conditioning practices by industry, including Hess, already meet transportation requirements.

It is important to note that all operating conditions must be carefully optimized to stay within equipment design limits, as well as product quality and general operability constraints. For example, increasing heater-treater temperature to the upper end of the design limits can have the undesirable and unacceptable consequence of increasing internal tube failures and driving excessive amounts of crude oil range material ($C_4^+$) into the gas stream.

Hess feels there is merit in assuring a standard level of conditioning being employed at all well sites. However, as stated before, we believe that any new safety solutions – at any level of government – must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations. Doing anything else could cause unintended consequences to the safety and production of Bakken crude, while potentially putting economic constraints on business decisions in the state.

API and the oil and gas industry remain committed to the safe production and transportation of crude oil. When evaluating potential standards or provisions, API encourages this committee to consider actions that will make a measurable improvement to safety.

Thank you, again, for allowing us to participate today.

# Whiting well site Oil Equipment

Wells and Pumping units

Heater Treaters

Tanks

LACT

# Whiting well site Gas Equipment

Heater Treaters

Gas Sales Meter Building

Tanks

VRU

Combustor

# Whiting Heater Treater experience

One individual Treater works best for large wells
Two wells per Treater is sufficient for most wells
Vertical Treaters preferred in Sanish, Hidden Bench and Tarpon

Oil vapor pressure and NGL content is much more dependent on Treater Pressure than Temperature

Treater temperatures above 120F are counter productive

- -Minimal difference on oil vapor pressure and NGL content
- -Salt precipitation leads to plugged/failed equipment

| | |
|---|---|
| **From:** | Kari Cutting |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | DMR Kari Testimony-oral |
| **Date:** | Monday, September 22, 2014 4:53:10 PM |
| **Attachments:** | DMR Kari Testimony-oral.docx<br>DMR slides.pptx |

Good afternoon,

I am submitting the following testimony from the North Dakota Petroleum Council for tomorrow's hearing on well site conditioning.

Sincerely, Kari Cutting

Kari Cutting
Vice President
North Dakota Petroleum Council
701-557-7741

**North Dakota Petroleum Council**

**DMR hearing on well site conditioning**

**September 23, 2014**

Good morning, my name is Kari Cutting, Vice President of the North Dakota Petroleum Council. Thank you for the opportunity to comment on transportation safety and marketability of Bakken crude oil.

The North Dakota Petroleum Council (NDPC) represents more than 550 companies engaged in all aspects of oil and gas activities in North Dakota, South Dakota, and the Rocky Mountain region. NDPC members produce 98% of all oil and gas in North Dakota.

North Dakota is now the second largest oil-producing state in the nation and reached 1 million barrels of daily production in May 2014, up from 100,000 barrels per day in 2007. Although North Dakota's oil and gas production has grown substantially in recent years, pipeline capacity to key markets has not, requiring 60 percent of Bakken crude to be hauled via rail in July.

In the last eighteen months, there have been ten railway incidents involving crude oil. Four of the trains contained Bakken crude oil. Six incidents involved fire. Nine of the incidents involved derailment and the remaining incident was a leaky valve. The root cause of at least of two of the accidents was significant human error, and another was due to washout of the tracks from heavy rails. Some are still under investigation. The material contained in these railcars was not the cause of the accident.

As a result, questions have been raised regarding the chemical composition and physical characteristics of Bakken crude, how it compares with other flammable liquids under U.S. Department of Transportation regulations, and whether it can be safely transported across North America under the current regulatory environment as enforced by the Pipeline and Hazardous Materials Safety Administration (PHMSA).

**Three independent studies[1] have now shown that "Bakken crude is not a unique flammable liquid",** and that it is properly classified as a Class 3 Flammable Liquid. The flammable liquids category contains common fuels including ethanol, gasoline, diesel fuel, jet fuel, and other fuel and petrochemical feed stocks offered for transportation in the United States.

One of the referenced studies was commissioned by the NDPC. The study included a comprehensive sampling and analysis plan and was conducted by Turner Mason & Company, an internationally known and recognized group of engineering consultants with extensive crude oil expertise. John Auers,

---

[1] *A Survey of Bakken Crude Oil Characteristics Assembles For the U.S. Department of Transportation*, 14 May 2014 o *Submitted* by American Fuel & Petrochemical Manufacturers, Prepared by Dangerous Goods Transport Consulting, Inc.

*The Turner Mason & Company Study on Bakken Crude Properties*, 16 July 2014 o Submitted by the Bakken Crude Characterization Task Force, Prepared by Turner, Mason & Co. Consulting Engineers

*Operation Safe Delivery*, July 2014, including *Operation Classification*, August 2013, as pertaining to Bakken Crude *o* Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation

executive vice president of Turner Mason stated that this study was **"the most comprehensive and thorough study of a crude oil and shale oil basin in the United States, to date."**

**Turner Mason Study Conclusions:**

1. **Bakken crude oil as a light sweet crude oil, is low in sulfur content but rich in valuable gasoline, diesel fuel, and jet fuel components, making it extremely desirable to the refining community.**

2. **The vapor pressure of Bakken crude oil is not the highest or the lowest of crude oils transported in the United States but its vapor pressure is four times less than the regulatory limit and 10 times less than the design capability of railcars.**

3. **Bakken crude oil has the same composition throughout the Williston Basin and maintains this composition during transport.**

**Stabilization:**

When Bakken was first called volatile, there were many in the petrochemical industry who assumed that Bakken must be condensate and therefore, required stabilization. The U.S. Energy Information Administration and industry uses API gravity, or the measure of how heavy or light a crude oil is, to determine what crude oils are considered condensate. Condensate is a class of light crude oil containing a high concentration of natural gas liquids and having an API gravity greater than 50 degrees, while crudes having an API gravity of 35 to 49 are considered light crudes. Other light crudes are West Texas intermediate with an API gravity of 41 degrees and Brent crude with 38 degrees. Eagle Ford condensate has an average API gravity of 58 degrees.

There is a lot of confusion about the term stabilization. Part of this confusion is due to the fact that industry has used the term to describe two different processes: treatment or conditioning at the well site and post-well site stabilization.

Post well site stabilization units are commonly used to remove valuable and saleable natural gas liquids from condensate and to reduce its vapor pressure to meet EPA requirement for storage in floating roofed tanks or for the commercial purpose of selling some its component to produce fuels or petrochemicals. Many have stated that stabilization of Bakken crude is needed to enhance safety, but that is neither necessary nor is it an effective safety measure.

North Dakota has frequently been compared to Texas, but like comparing Bakken crude to Eagle Ford condensate, this is an unfair comparison. The state of Texas has infrastructure in place to support the movement of the products separated from the condensate stream during stabilization. The state has ample pipeline infrastructure for transport and petrochemical plants as a ready market for those feedstocks. North Dakota does not have the petrochemical markets that Texas already has in place. Commercial stabilization at centralized locations in North Dakota could necessitate another layer of pipeline infrastructure..

It is important to note that since North Dakota lacks a market for products separated in the stabilization process, these products would be hauled by rail by truck to a market out of state. Furthermore, stabilization of Bakken crude oil would still yield a Class 3 flammable liquid, Packing Group I or II for transportation.

**Well –Site Conditioning:**
NDPC applauds the Department of Mineral Resources for using the terminology ***well site conditioning*** to distinguish the use of equipment on the well site from a commercially driven stabilization unit.

Currently, all wells in North Dakota are required to have conditioning equipment such as separators, heater treaters or equivalent devices, and stock tanks which are sufficient to condition (or "stabilize") crude oil at the well site. This conditioning equipment was installed at a cost of between $200,000 and $400,000 per well. With more than 11,280 wells producing in North Dakota, this means an investment of anywhere between $2.26 and $4.51 billion in crude oil conditioning equipment.

Well site conditioning is stabilization. After well site conditioning, Bakken vapor pressure is in the range of 8 to 12 pounds per square inch (psi), which is in the same range of vapor pressure as stabilized condensate. Again, this vapor pressure is four times below the 43.5 psi regulatory threshold to be properly transported by truck or rail and is 10 times below the railcar design pressure.

Taking all of this information into consideration, requiring stabilization beyond current conditioning practices would be a costly, redundant process that would not yield any additional safety benefits. Rather, the result could be separate set of flammable liquids or flammable gases being transported by truck or rail.

**Safety:**

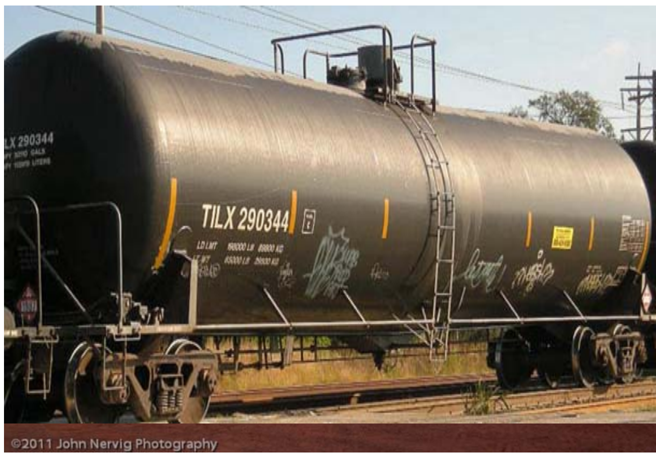
Safety is a core value of the oil and gas industry and we remain committed to ensuring we are doing all we can to produce and transport this important natural resource as safely as possible. Using the scientific evidence gathered from the Turner Mason study (as well as comparable data pulled from other studies), the NDPC has recommended a set of best practices to ensure Bakken crude is being treated the same by all producers and ensure uniformity in crude quality and handling. Additionally, NDPC members are developing a set of typical specifications based on the Turner Mason study that along with well site conditioning, will ensure that emergency responders have sufficient information to effectively respond to an incident involving Bakken crude oil or other flammable liquids transported by rail in Packing Group I or II.

The oil and gas industry, in partnership with the railroads, is working to develop a common educational tool to be distributed broadly to fire departments either through web portal or DVDs. This information will also be available for companies to use in continued interaction with fire departments and other EMS personnel. Rail and oil industries in many states have worked collaboratively on drills and exercises, development of additional response resources, and periodic meetings to keep the lines of communication open in order to maximize information sharing of the latest data on emergency response for crude incidences.

The NDPC and its members believe rail safety improvements must be developed using a holistic, comprehensive, and systematic approach that examines prevention, mitigation, and response. PHMSA recently issued a Notice of Potential Rulemaking that addresses the durability of the railcar and infrastructure as well as training for emergency response personnel. These components are necessary to affect rail safety improvement for the transportation of all flammable liquids in the United States.

NDPC encourages the U.S. Department of Energy to utilize the national laboratories to study all domestic crudes. We believe it is important that the testing of crude oils continues to provide comparative scientific data and enhance information and training provided to emergency responders. The oil and gas industry in North Dakota supports further testing of Bakken crude oil and monitoring to guarantee Bakken quality and consistency.

We look forward to continuing our work with state leaders to enhance safety by taking science-based steps to ensure Bakken crude oil maintains its consistent characteristics from the well site and rail loading facility, so that we may always bring this product to market safely and ensure our state can continue to improve our energy security by providing a reliable energy resource for our nation.




# CRUDE BY RAIL

Table 1: Ten Major Accidents Involving Crude-by-Rail in USA and Canada, 2013-2014

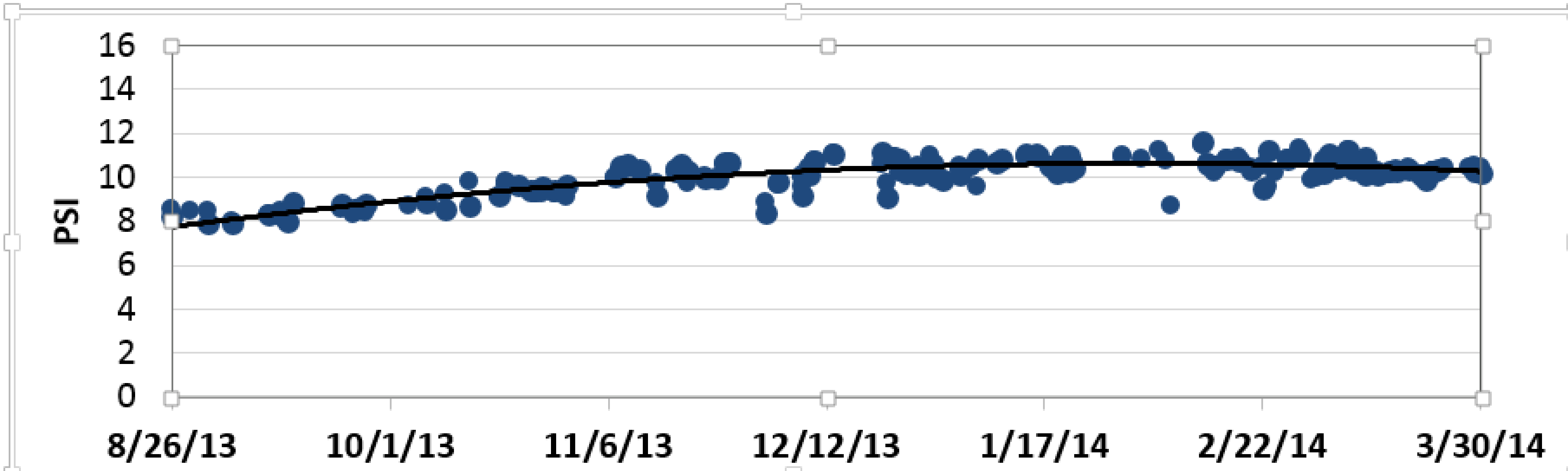
| Date | Location | Railroad | Crude Source | Fire? | Spill Volume (U.S. Gallons) | Type of Incident |
|---|---|---|---|---|---|---|
| Mar. 27, 2013 | Parkers Prairie, Minnesota | Canadian Pacific | Canada, possibly tar sands | No | 10,000-15,000 | Derailment |
| Jul. 5, 2013 | Lac-Mégantic, Quebec, Canada | Montreal, Maine & Atlantic Railway | Bakken, North Dakota | Yes | >26,500 | Derailment |
| Oct. 19, 2013 | Gainford, Alberta, Canada | Canadian National | Unknown | Yes | Unknown | Derailment |
| Nov. 8, 2013 | Aliceville, Alabama | Genesee & Wyoming | Bakken, North Dakota | Yes | <748,400 | Derailment |
| Dec. 30, 2013 | Casselton, North Dakota | BNSF | Bakken, North Dakota | Yes | >400,000 | Derailment |
| Jan. 7, 2014 | Plaster Rock, New Brunswick, Canada | Canadian National | Unknown, Western Canada | Yes | Unknown | Derailment |
| Feb. 3, 2014 | Wisconsin/Minnesota | Canadian Pacific | Unknown | No | <12,000 | Leak from tank car over 70 miles of track |
| Feb. 13, 2014 | Vandergrift, Pennsylvania | Norfolk Southern | Tar Sands Bitumen, Alberta, Canada | No | 4,550 | Derailment |
| Apr. 30, 2014 | Lynchburg, Virginia | CSX | Bakken, North Dakota | Yes | <50,000 | Derailment |
| May 9, 2014 | LaSalle, Colorado | Union Pacific | Niobrara, Colorado | No | 6,500 | Derailment |

# API number

| CRUDE NAME | ORIGIN | API |
|---|---|---|
| Eagle Ford Light | Texas | 58 |
| Arabian Super Light | Saudi Arabia | 51 |
| Eagle Ford | Texas | 48 |
| Agbami | Nigeria | 48 |
| DJ Basin | Colorado | 45 |
| Sarahan Blend | Algeria | 43 |
| Bakken | North Dakota | 42 |
| West Texas Intermediate | Tex/New Mexico | 41 |
| Brent | United Kingdom | 38 |
| LLS | Louisiana | 36 |
| Alvheim Blend | Norway | 35 |
| Arabian Heavy | Saudi Arabia | 28 |
| Alberta Dilbit | Alberta | 21 |

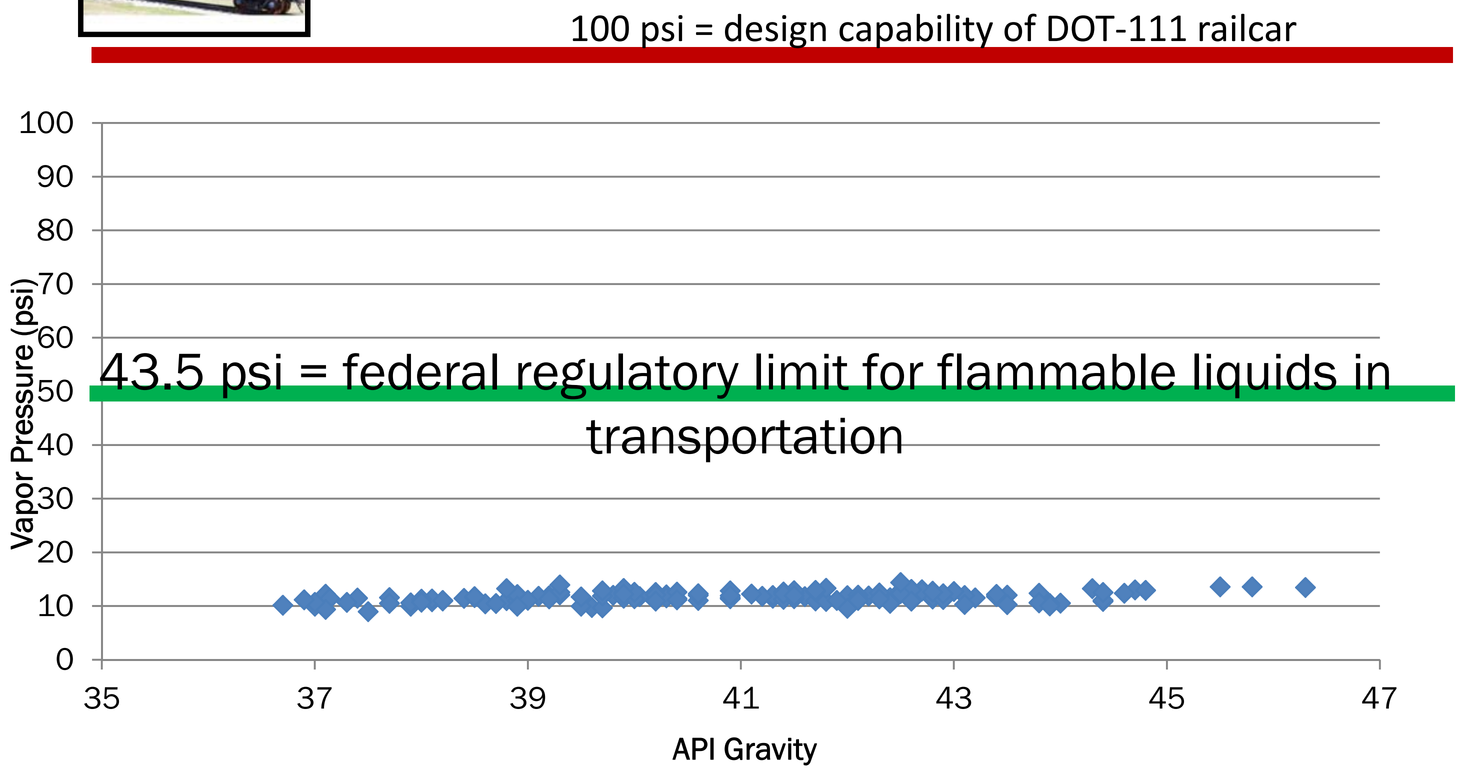
# Vapor Pressure

- BKN Average Vapor pressure 11.5-11.8 psi (Mar-Apr—Turner Mason report)
  - 61% below regulatory threshold
- Seasonal Variation: summer 8-10 psi, winter 10-12 psi
- Measurements are True Vapor Pressure not Reid Vapor Pressure
- Similar to vapor pressures for centralized stabilization designs



# API gravity vs. Vapor Pressure

- DOT regulations allow transport of vapor pressure to 43.5 psi; Railcars designed to 100 psi or greater



# Recommended Testing Procedures

- Well Site Operators/Purchasers – Prior to each custody transfer or LACT EOM
  - API gravity corrected to 60° F using hydrometer
  - Basic Sediment & Water (BS&W) by field centrifugal grind-out
  - Spot test vapor pressure pending available field testing equipment
- Rail/Pipeline Terminal Operators
  - Test each unit train loading or tank shipment batch
    - API gravity corrected to 60° F using hydrometer
    - BS&W by field centrifugal grind-out
  - Test at least midmonth and EOM
    - ASTM D6377 @100° F vapor pressure using certified laboratory

# Other recommended practices

– DO NOT deliver fluid recovered from gas pipe lines (a.k.a. “pigging operations”) to crude oil sales system unless processed by stabilization unit capable of lowering vapor pressure below 10 psi at 100° F.

– DO NOT blend non-Williston Basin crude oils into the BKN common stream.

– DO NOT blend plant liquids (plant condensates, pentanes, butanes or propane) into the BKN common stream.

# Bakken typical specification ranges

| | Range | Typical |
|---|---|---|
| API Gravity (hydrometer at 60°F) | 35° to 45° | 42° |
| Vapor Pressure (ASTM D6377 @ 100°F) | 8 to 15 psi | 11.5 psi |
| Initial Boiling Point (ASTM D86) | 90°F to 105°F | 95°F |
| Sulfur | <0.3% | 0.15% |
| $H_2S$ | <10 ppm | <1 ppm |
| Light Ends (C2 – C4s) | 3% to 9% | 5% |

# BKN specifications

- Define BKN specifications
- Value:
  - Producers will follow specific field standards to meet BKN specs
  - Ensure proper BKN oil characterization, now and future
  - Create reference point for buyers and sellers

NORTH DAKOTA PETROLEUM COUNCIL

*We keep North Dakota going strong*

# Questions?

| | |
|---|---|
| **From:** | Day, Ronald W. |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Tesoro Comments for Oil Conditioning Practices |
| **Date:** | Monday, September 22, 2014 4:51:41 PM |
| **Attachments:** | Tesoro NDIC Comments Sept 22 2014.pdf |

Please find attached Tesoro's comments associated with tomorrow's North Dakota Industrial Commission "Hearing Set on Oil Conditioning Practices.

If you need any additional information please feel free to contact me via e-mail or by phone at (701) 667-2416.

Sincerely,

Ron Day
Director, Mid-Continent Government & Public Affairs
Tesoro Refining & Marketing Company LLC

TESORO

Tesoro Refining & Marketing Company LLC
900 Old Red Trail N.E.
Mandan, ND 58554-1589

September 22, 2014

North Dakota Industrial Commission
600 E. Blvd. Ave., Dept. 405
Bismarck, ND 58505-0840

Dear Commissioners:

The Tesoro Refining & Marketing Company LLC ("Tesoro") appreciates the opportunity to submit written comments in connection with the North Dakota Industrial Commission hearing on the establishment of oil conditioning standards appropriate for the improvement of transportation safety and marketability of Bakken-sourced petroleum.

Tesoro commends Governor John Dalrymple and the Commission for holding this hearing and for their ongoing attention to the entire suite of issues relative to the safe and efficient transportation of Bakken-based crude within North Dakota and throughout the United States.

Tesoro Refining & Marketing Company LLC, a Fortune 100 company, is an independent refiner and marketer of petroleum products. Tesoro, through its subsidiaries, operates six refineries in the western United States with a combined capacity of over 850,000 barrels per day and ownership in a logistics business which include a 35% interest in Tesoro Logistics LP (NYSE:TLLP) and ownership of its general partner. Tesoro's retail-marketing system includes over 2,200 retail stations under the ARCO, Shell, Exxon, Mobil, USA Gasoline(TM) and Tesoro brands. Tesoro is proud to have a long-time and significant presence in North Dakota, and we are honored to be a vital member of this community. Relative to the issue at hand, Tesoro also brings a unique as well as comprehensive perspective as we are, in North Dakota, simultaneously a pipeline operator, a rail shipper, rail car lessee, and refiner. It is from this perspective that we will direct our comments to the issue of stabilization of Bakken crude.

Tesoro is currently aware of three studies that have independently reached the same conclusion that Bakken crude is similar to other North American light sweet crude oils in gravity, vapor pressure, and initial boiling point, which are the primary components of volatility. Those studies are "A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transportation," dated May 14, 2014, submitted by the

American Fuel and Petrochemical Manufacturers (AFPM); "The Turner Mason and Company Study on Bakken Crude Properties," dated July 16, 2014, submitted by the Bakken Crude Characterization Task Force; and "Operation Safe Delivery," dated July 2014 (incorporating "Operation Classification," dated August 2013), submitted by the U.S. Department of Transportation. Further, and again based on the conclusions of all three studies, the chemical properties of Bakken crude oil confirm its proper classification as a Class 3 flammable liquid under current federal regulations governing the shipment of hazardous materials.

Tesoro is not currently aware of any study that has reached an opposite conclusion on Bakken volatility and neither, apparently, is the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA). Indeed, recent congressional testimony on September 9, 2014, by PHMSA's Associate Administrator, Tim Butters, before the U.S. House Committee on Science and Technology, Subcommittees on Energy and Oversight, explicitly agreed with the conclusions of the May 14 AFPM study and stated that PHMSA had independently reached the same conclusion as AFPM based on data collected by the agency during Operation Safe Classification. Presumably, if PHMSA were aware of a study reaching an opposite conclusion, they would have stated as much. In fact, the September 9 hearing was called to explore the state of research on the issue of Bakken crude characteristics and at no time did any of the witnesses testifying point to the existence of any study that reached an opposite conclusion on Bakken volatility.

Setting aside the absence of any credible data in support of higher Bakken volatility compared to other domestic light sweet crudes, there are several operational realities present in North Dakota that have discouraged stabilization activities to date. These include a lack of infrastructure for transporting the light ends produced by stabilization, namely collection piping systems from wellhead to gas processing facilities, investment and operating costs associated with stabilization equipment, and the need for additional storage capacity to hold the light end product. All of these realities would need to be factored into any decision on Bakken stabilization moving forward.

Finally, Tesoro urges the Commission to carefully consider several questions as it proceeds with making a determination on the issue presented. One, would requiring stabilization to ostensibly reduce Bakken volatility only create a scenario by which the resulting and volatile light ends would then have to be transported elsewhere, thus increasing safety concerns? Second, would stabilization result in a re-classification of Bakken crude as a combustible liquid under existing regulations governing the transport of hazardous materials? Third, would the stabilization of Bakken crude reduce the relative refining value of the commodity, as the stabilization process would cut deep into the gasoline valued fraction of the Bakken crude? Fourth, would the stabilization of Bakken crude truly address the safety concerns presented by a derailment scenario in which multiple ignition sources would be present as the burning of either stabilized or unstabilized crude is unlikely to materially differ?

Tesoro remains strongly committed to the safe transportation of Bakken crude by rail as evidenced by our Company being the industry leader in voluntarily divesting our fleet of legacy DOT-111 tank cars earlier this year and by supporting the increased shell thickness of new tank cars as part of the ongoing U.S. Department of Transportation rulemaking. At this point; however, and based on known data to date, Tesoro is unable to conclude that the stabilization of Bakken crude is warranted.

Ronald W. Day
Director, Mid-Continent Government and Public Affairs
Tesoro Refining & Marketing Company LLC

| | |
|---|---|
| **From:** | John Zellitti |
| **To:** | Kadrmas, Bethany R.; kroth@ndoil.org |
| **Cc:** | Dominic Spencer; Daniel Lockley; Greg Salveson |
| **Subject:** | RE: News Release: Hearing Set on Oil Conditioning Practices |
| **Date:** | Monday, September 22, 2014 4:51:40 PM |
| **Attachments:** | image001.png<br>Triangle USA SHRC Tank Concept 9-19-14.pptx<br>Triangle Haggen SHRC Tank Off 7-29-14.mp4<br>Triangle Haggen SHRC Tank On 7-29-14.mp4<br>Triangle Moose SHRC Tank Off 7-31-14.mp4<br>Triangle Moose SHRC Tank On 7-31-14.mp4<br>Triangle Stone SHRC Tank Off 7-29-14.mp4<br>Triangle Stone Shrc Tank On 7-29-14.mp4 |

Please see attached a power point presentation describing an alternate method of producing and gathering oil and gas that is being applied by Triangle USA to Bakken oil production in McKenzie County, ND. We refer to this system as a SHRC Tank (Safe Hydrocarbon Recovery Containment). Historic methods utilize a single separator and oil storage tanks for each well, oil production was dumped from the separator to atmospheric oil storage tanks allowing liquid rich gas to flash off to the flare system. The SHRC tank system allows the oil production to remain pressurized from the oil separator into the pressurized SHRC tank which is then pumped straight into the oil gathering pipeline using a LACT pump. This eliminates flashing the oil into atmospheric production tanks where the gas is either flared or has to be captured by expensive vapor recovery compressors, the gathered oil and vapor composition can then be stabilized at a central facility. I have also attached some videos of tank vapors that are being omitted from oil storage tanks before and after the SHRC tanks are utilized. The video of the vapors coming from the oil storage tank while the SHRC tanks are "On" is gas vapors that are still flashing from the crude oil. These vapors will reduce with time as long as the SHRC tank is running and not producing into the oil storage tank. The videos demonstrate the significant reduction in tank vapor gas using the SHRC tank system.

***John Zellitti***
***Triangle USA – Production Manager***
***1200 17th Street, Suite 2600***
***Denver, CO 80202***
***303-260-7125 Main***
***303-260-1766 Office***
***jzellitti@trianglepetroleum.com***

TUSA

The attached video files are available upon request.

## KEY ADVANTAGES OF THE SHRC TANK

*The SHRC (Safe Hydrocarbon Recovery Containment) System provides economic incentives, environmental solutions and operational benefits*

| | |
|---|---|
| **INCREASED REVENUE** | ▲ The SHRC Tank allows an operator to capture the NGL rich tank vapors and realize revenue that would otherwise be vented to atmosphere<br>▲ Tank vapors can account for more than 2% of the gross well revenue. |
| **DECREASED COST** | ▲ Significantly reduces field staffing requirements to monitor pads<br>▲ Combined with quad pack separators, the SHRC System requires only 6-10 tanks per pad, as compared to 6 tanks per well (36 tanks for a six well pad)<br>▲ Reduces maintenance costs |
| **INCREASED RELIABILITY** | ▲ The SHRC Tank has no moving parts, allowing it to be more reliable and simpler to maintain than conventional vapor recovery methods<br>▲ Vapor recovery units can have downtime anywhere from 20-50% in North Dakota cold weather |
| **IMPROVED SAFETY AND ENVIRONMENTAL CONTROL** | ▲ The SHRC Tank keeps the entire production system in a pressurized state, preventing the release of any gas emission through oil storage tanks<br>▲ Reduces risk of oil spills by ~50%<br>▲ Delivers crude to pipe or rail at 9.5 Reid Vapor Pressure |

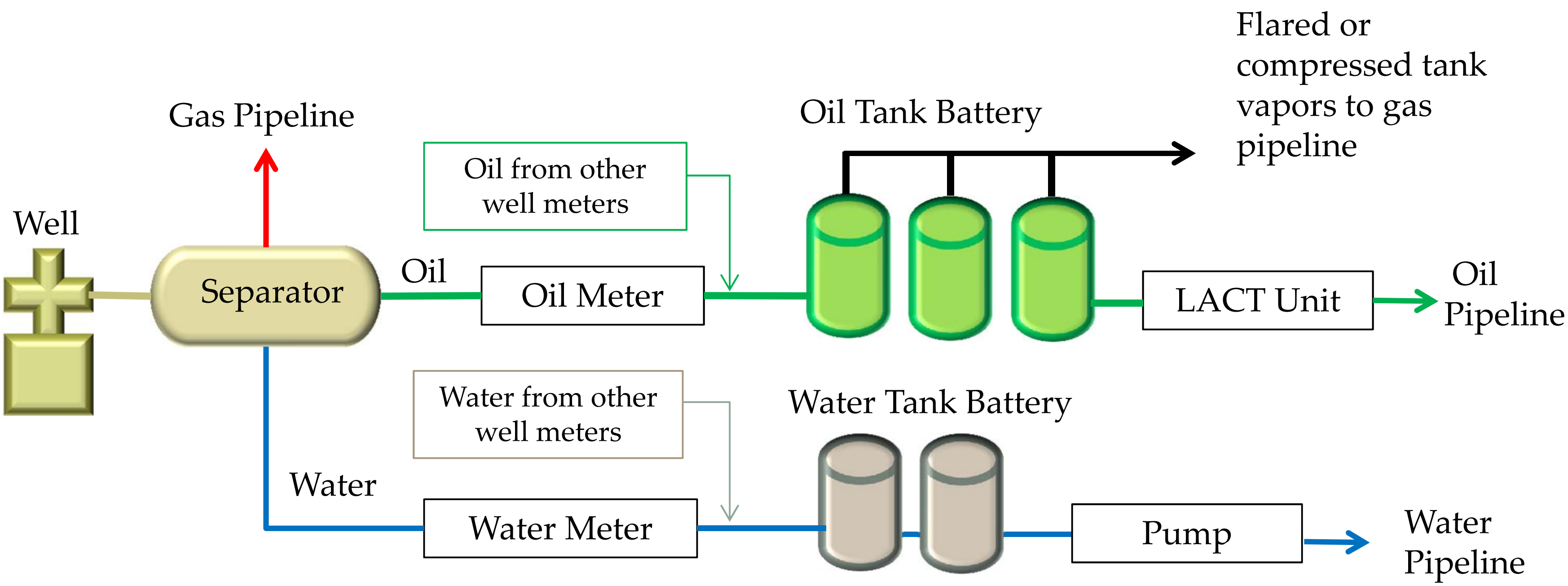




TRIANGLE
PETROLEUM CORPORATION

## OLD METHOD

- Production separator dumps oil to atmospheric oil storage tanks allowing liquid rich gas to flash off to the flare system.
- Tank vapor calculation flashing from separator operating at 100 psig & 88 degrees F to atmospheric tanks is approximately 100 scf/bbl oil
- Capturing this tank vapor gas requires expensive vapor recovery compressors which are difficult to operate.



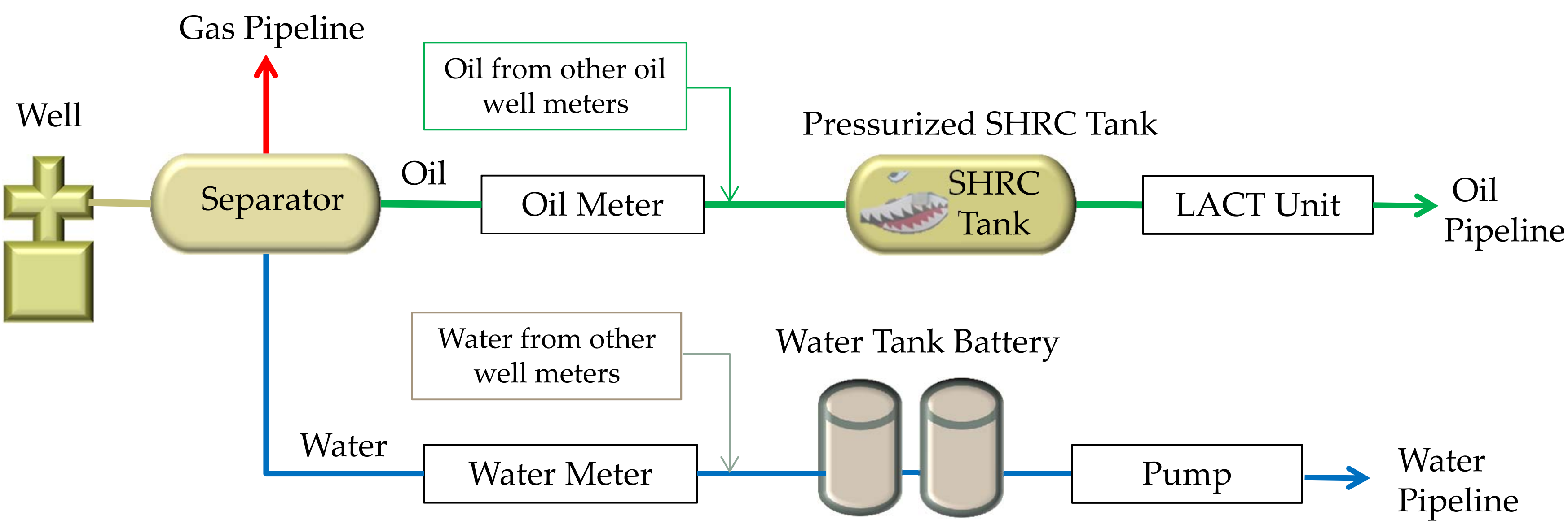



TRIANGLE PETROLEUM CORPORATION

## NEW SHRC TANK METHOD

- **<u>S</u>**afe **<u>H</u>**ydrocarbon **<u>R</u>**ecovery **<u>C</u>**ontainment System keeps vapor gas in solution sending down the oil pipeline to the central oil stabilization facility

- Eliminates use of oil storage tanks during normal operation
- Oil level is maintained in SHRC tank from separator allowing LACT to pump oil to oil pipeline
- Pressurized SHRC tank keeps liquid rich vapor gas in solution
- Oil is piped to oil stabilization facility where solution gas is removed, liquids stripped and gas sold to gas pipeline.



| | |
|---|---|
| **From:** | Timothy Lane |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Letter for comment for the NDIC, Oil and Gas Division meeting |
| **Date:** | Monday, September 22, 2014 4:46:10 PM |
| **Attachments:** | NDIC LETTER OF COMMENT.pdf |

Attached please find a letter of comment.

Thank you very much,

Timothy A. Lane
Menands, New York

# Timothy A. Lane

**7 Sage Court**
**Menands, NY 12204**
**518-429-8550/Timothy.lane7@gmail.com**


September 22, 2014

Governor Jack Dalrymple, Chair
North Dakota Industrial Commission, Oil and Gas Division
1000 East Calgary Avenue
Bismarck, North Dakota 58503

Dear Governor Dalrymple,

I am writing to you in regard to tomorrow's hearing of the North Dakota Industrial Commission to consider amending field rules relating to the Bakken, Three Forks, and Sanish Pools that would improve the transportation safety of crude oil.

When I purchased my beautiful home in 2011, my wife was expecting and I knew we needed a bigger home. My home prior was on busy thru street and did not have a front yard, so I searched for a home on a dead-end street with ample room for my children to play and not be in fear of being hit by a car. However, it turns out that speeding cars are now the least of my worries. Little did I know that when I purchased my home in 2011, that a short 3 years later I would reside in a blast zone. I live in my home in the lovely Village of Menands, NY with my wife and 3 year-old twins, Timothy and Campbell Rose. We can count the Bakken crude oil-filled tanker cars from our deck. It is quite a sight knowing that they present a significant danger to the lives of my family and my community daily. I am concerned for the property value of my home due to the transport of this highly unstable and explosive product on the CP Rail line. This is the community that I grew up in and my parents still reside in their home just one-half mile away. Their property abuts the rail property as does that of dozens of neighbors. Living near a rail line has never been a cause for concern in our village. Now that it is we are not only concerned for our property values but our lives.

I am imploring you: please require that the companies producing the crude oil that passes my home every day be stabilized. That you are allowing these companies to ship this explosive product pass my home and endangering the lives of my wife and children on a daily basis is ethically, morally and governmentally irresponsible.

The safety of millions of people, including my own family, lies with your commission. You can require this product to be stabilized before it leaves the Bakken Shale Field and I asking that you do exactly that.

I thank you for accepting my letter of comment for consideration at your meeting tomorrow morning at 9AM.

Sincerely,

*Timothy A. Lane, V*

| | |
|---|---|
| **From:** | Don Morrison |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Comments: Case No. 23084 Improving oil transportation safety - Dakota Resource Council |
| **Date:** | Monday, September 22, 2014 3:59:13 PM |
| **Attachments:** | DRC Comments- Bakken crude stabilization Sept 22.pdf |

Please find attached written comments from Dakota Resource Council for the hearing on transportation safety and marketability of crude oil (Case No. 23084).

Please let me know if you have any questions or would like further information. Thank you.

Sincerely,
Don Morrison

--
Don Morrison, Executive Director
**Dakota Resource Council**
1200 Missouri Ave, Suite 102
Bismarck ND 58501
(o) 701-224-8587
don@drcinfo.com

**Dakota Resource Council Comments Regarding Case No. 23084 (Oil Stabilization)**

## Introduction

The nation is waiting and watching North Dakota as it decides how to make Bakken crude safer to transport by rail. As trains throughout the US continue to carry explosive Bakken crude through communities across North America, people are expressing legitimate concerns. Fiery derailments involving Bakken crude are responsible for taking the lives of 47 people in Quebec as well as untold amounts of property and environmental damage in cities across the United States[1].

The debate is no longer whether or not Bakken crude is volatile; the debate now hinges on what can be done to make Bakken crude less volatile. Numerous industry-funded studies used faulty science in attempts to lead people to believe Bakken crude was not volatile. But such studies are akin to a fox guarding the henhouse and as a result need to be dismissed. Despite the science showing the relationship between vapor pressure, lights ends and volatility, a study funded by North Dakota Petroleum Council, an industry advocacy group, contains a disclaimer stating that they did not thoroughly investigate the possibility of vapor pressure or light ends as metrics impacting volatility[2].

Only studies regarding Bakken crude volatility completed by parties with no interest in profiting from Bakken crude should be considered. In contrast to the limited study funded by NDPC, the study completed by PHMSA (Pipeline and Hazardous Materials Safety Administration) found Bakken crude to be meet all metrics (including vapor pressure and lights ends) pointing towards Bakken having increased volatility[3]. This study should be considered over any industry-funded study

It must also be noted that North Dakota oil regulators have an excessively close relationship with the oil industry. North Dakota oil regulators often promote the oil industry and regulate only when it is an absolute last resort. This close-knit relationship between the oil industry and North Dakota oil regulators must be noted because it is has

---

[1] Justin Giovannetti, Grant Robertson And Jacquie Mcnish (2013-07-11). "As Lac-Mégantic death toll reaches 47, safety board calls for immediate rail-safety changes". The Globe and Mail. Retrieved 2014-09-10.

[2] Mikulka, Justin. "Oil Industry Study Claiming Bakken Crude Safe Contains Whopper of a Disclaimer." *DeSmogBlog*. DeSmogBlog, 5 Aug. 2014. Web. 14 Sept. 2014. <http://www.desmogblog.com/2014/08/13/oil-industry-study-claiming-bakken-crude-safe-contains-whopper-disclaimer>.

[3] Nowatzki, Mike. "ND Oil Regulators, Executives Say Bakken Crude's Volatility Unfairly Singled out." *Prairie Business Magazine*. Forum Communications, 7 Aug. 2014. Web. 15 Sept. 2014. <http://www.prairiebizmag.com/event/article/id/20306/>.

clouded past regulatory decisions and regulatory response regarding oil and gas activity in North Dakota.

At this time, there appear to be two potential solutions to make Bakken crude less volatile, which in turn would allow it to be safely shipped via rail: 1) Conditioning and 2) Stabilization. Both methods have their pros and cons. Regardless of which method is chosen, the safety of people along the rail lines must be the number one consideration.

In our comments we will cover the following topics:

1. Close relationship with oil industry impacts regulatory environment
2. Importance of stabilizing crude and timeline of accidents involving Bakken
3. Oil Stabilization: It works in Texas
4. Oil Conditioning: Short Term Solution?
5. The case for slowing down oil permitting

## I. Close relationship with oil industry impacts regulatory environment

North Dakota oil regulators have an excessively close, almost exclusionary, relationship with oil and gas operators and oil advocacy groups such as the North Dakota Petroleum Council (NDPC). These cozy relationships often compromise regulation of the oil industry in North Dakota.

The cozy relationship between the oil industry and current state oil regulators stems from two major reasons: first, the chief oil and gas regulator, the director of the Department of Mineral Resources, is tasked with the conflicted job requirement of both promoting and regulating the oil industry per the North Dakota Century Code[4], and second, oil industry money via campaign contributions and other means dominates politics in the Capitol making it difficult for regulators to do anything negative from a regulatory standpoint to the oil industry without fear that they will be fired or reprimanded by their elected superiors who sit on the North Dakota Industrial Commission[5].

One need not look any further than the background of the current director of the Department of Mineral Resources Lynn Helms to see an apparent conflict of interest as a regulator. Prior to becoming North Dakota's chief oil and gas regulator, Lynn Helms spent over 20 years working for oil companies, such as Hess[6]. Helms consistently is in

---

[4] ND Century Code 38-08-01

[5] Kusnetz, Nicholas. "How Oil and Gas Firms Gained Influence and Transformed North Dakota." *Center for Public Integrity*. Center for Public Integrity, 21 July 2014. Web. 11 Sept. 2014. <http://www.publicintegrity.org/2014/07/21/15107/how-oil-and-gas-firms-gained-influence-and-transformed-north-dakota>.

[6] Dalrymple, Amy. "Lynn Helms Goes from Oil Industry to Oil Regulator |." *Oil Dispatch*. Forum Communications, 1 Apr. 2013. Web. 17 Sept. 2014. <http://oilpatchdispatch.areavoices.com/2013/04/01/lynn-helms-goes-from-oil-industry-to-oil-regulator/>.

lock step with the oil industry despite the fact that his role is to be a check and balance against the heavy-handed nature of the oil industry.

Another outcome of having a chief oil regulator whose past career was as an oil industry employee combined with money influencing elected officials tasked with codifying regulatory decisions is the creation of an environment where regulation only occurs in reaction to public outcry or a catastrophic event. Two very clear instances in which oil industry money combined with close relationships to the oil industry dominated the way regulators do their job are the 2013 Tioga oil spill and the regulation of flaring.

The Tioga oil spill, and the associated response by current North Dakota state government officials, is a great example of how oil industry influence dominates public disclosure and regulation. The Tioga oil spill occurred in October 2013 when a pipeline burst and spewed over 20,000 barrels of oil onto Steve and Patricia Jensen's farm[7]. The Tioga pipeline spill is one of the largest on-land oil spills in United States history[8]. Prior to the Tioga pipeline spill thousands of oil and wastewater spills occurred throughout the Bakken region with no public notification. Although groups asked for spill notification in the 2011 legislature, it fell on deaf ears with lawmakers when the oil industry opposed it[9]. In fact, from January 2012 until the Fall of 2013, over 750 oil field incidents and 300 oil spills were recorded without notice to the public[10]. Although it is commonplace for oil producing states to publicize oil spills, North Dakota regulators and elected officials found doing so to be unnecessary. Only after the Tioga spill and the bad public relations associated with the notification procedures and state government officials not even informing the public until 10 days after the Tioga spill did state officials have an inclination to start doing something as basic as notifying the public about spills[11].

Following the public outcry and investigations done by reporters, it was determined that state regulators in working on the Tioga spill response were complicit in working with the oil industry. For example, an open records request by Greenpeace contained evidence of efforts by Department of Health staff to help cover up the spill for Tesoro[12]. Following the public uproar, North Dakota officials decided to require spill reporting on a website at

---

[7] Gerken, James. "North Dakota Oil Spill: Tesoro Corp. Pipeline Breaks Near Tioga; Dumps More Than 20,000 Barrels Of Crude." *The Huffington Post*. TheHuffingtonPost.com, 10 Oct. 2013. Web. 17 Sept. 2014. <http://www.huffingtonpost.com/2013/10/10/north-dakota-oil-spill-tesoro_n_4079323.html>.

[8] Id.

[9] McPherson, James. "Hundreds of North Dakota Spills Went Unreported." *Fuel Fix*. Associated Press, 26 Oct. 2013. Web. 17 Sept. 2014. <http://fuelfix.com/blog/2013/10/26/north-dakota-spills-went-unreported/>.

[10] Id**.**

[11] Gilberson, Lydia. "North Dakota's Oil Spill Website Now Live | Bakken.com." *Bakken.com*. Shale Play Media, 5 Dec. 2013. Web. 12 Sept. 2014. <http://bakken.com/news/id/53704/north-dakotas-spill-website-now-live/>.

[12] Horn, Steve. "Revealed: Never Before Seen Photos of Tesoro Fracked Oil Spill in North Dakota, Pipeline Restarted Today." *DeSmogBlog*. DeSmogBlog.com, 1 Nov. 2013. Web. 17 Sept. 2014. <http://www.desmogblog.com/2013/11/01/revealed-never-seen-photos-nd-fracked-oil-spill>.

the Department of Health[13]. If no public uproar would have been present in the case of the Tesoro spill, it is likely that regulators would have chalked the spill up as just another incident in the Bakken.

The regulation of flaring is another example where current North Dakota regulators' excessively close relationship to the oil industry combined with the influence of oil money in Bismarck idominated simple regulation. Despite the fact that North Dakota Century Code explicitly states that oil and gas must be developed while not wasting oil or gas, oil and gas regulators until very recently continually rubber stamped requests from companies asking to get an exemption to flare off valuable natural gas[14]. The result of the North Dakota Industrial Commission (NDIC) policy to hand out seemingly endless flaring exemptions was that by 2012 the level of flaring in North Dakota had become a national disgrace. Due to consistent exemptions given by the NDIC, flaring was so widespread in the Bakken that the North Dakota oil field was visible from space[15]. In addition, the lack of regulation by the NDIC resulted in lost taxable revenues for the state and lost royalty payments to mineral owners. The taxable revenues lost because of flaring amounted to approximately 100 million dollars of wasted natural gas according to investor group CERES[16].

In addition, several pieces of legislation were introduced during the 2013 Legislative Assembly only to be killed by oil industry lobbyists and oil regulators working in tandem and claiming the bills were too harsh on the oil industry. Most notable of these bills was Senate Bill 2315, which if passed would only have ended flaring exemptions beyond the first year[17].

Despite the shame involved with North Dakota officials allowing flaring at the same rate as in Third World countries such as Nigeria, North Dakota regulators did not move to curb flaring until they were approached by the North Dakota Petroleum Council (NDPC), the industry lobby group, with a proposal to address the flaring situation[18].

---

[13] Gilberson, Lydia. "North Dakota's Oil Spill Website Now Live | Bakken.com." *Bakken.com*. Shale Play Media, 5 Dec. 2013. Web. 12 Sept. 2014. <http://bakken.com/news/id/53704/north-dakotas-spill-website-now-live/>.

[14] Krauss, Clifford. "Oil Companies Are Sued for Waste of Natural Gas." *The New York Times*. The New York Times, 17 Oct. 2013. Web. 17 Sept. 2014. <http://www.nytimes.com/2013/10/18/business/energy-environment/oil-companies-are-sued-over-natural-gas-flaring-in-north-dakota.html?_r=0>.

[15] Sklar, Julia. "Gas Flares from Bakken Fracking Are Visible from Space."*New Scientist.com*. New Scientist, 28 Jan. 2013. Web. 17 Sept. 2014. <http://www.newscientist.com/blogs/shortsharpscience/2013/01/julia-sklar-reporter.html>.

[16] "Flaring Up: North Dakota Natural Gas Flaring More Than Doubles in Two Years." *Ceres*. Ceres, July 2013. Web. 17 Sept. 2014. <http://www.ceres.org/resources/reports/flaring-up-north-dakota-natural-gas-flaring-more-than-doubles-in-two-years/view>.

[17] Smith, Nick. "Bill Bans Flaring after 1 Year : Energy News." *Bismarck Tribune*. 26 Jan. 2013. Web. 17 Sept. 2014. <http://bismarcktribune.com/bakken/bill-bans-flaring-after-year/article_7f83e23a-673f-11e2-bbe0-001a4bcf887a.html>.

[18] Krauss, Clifford. "Industry in North Dakota to Cut Flared Natural Gas." *The New York Times*. The New York Times, 29 Jan. 2014. Web. 17 Sept. 2014. <http://www.nytimes.com/2014/01/30/business/energy-environment/industry-in-north-dakota-promises-to-reduce-flared-natural-gas.html?_r=0>.

It should be noted that the NDPC is the same group that worked to defeat legislation aimed at curbing flaring in the 2013 Legislature because it would supposedly be too expensive for the industry. The fact that only when the NDPC came forward with a proposal to curb flaring did North Dakota regulators move to curb flaring exemplifies how North Dakota's regulatory environment is dominated by oil industry influence.

Both the Tioga spill and the inaction by regulators to curb flaring (until approached by the North Dakota Petroleum Council) highlight how the regulatory landscape in North Dakota has been dominated by the oil industry and its associated money. We hope in the case of stripping volatile gases and vapors from Bakken crude, that the decisions to be made by North Dakota regulators have not already been determined by oil industry power and influence. Solutions in this case must be made in the name of public safety for millions of people across North America, not in the name of preserving the profits and power of the oil industry.

## II. Importance of Bakken stabilizing crude and timeline of accidents involving Bakken crude

The importance of the decision to be made by North Dakota regulators regarding how best to stabilize our oil (render crude not explosive) cannot be downplayed. Federal agencies such as the U.S. Department of Transportation are currently working on regulating the rail cars carrying Bakken crude as well as how Bakken is classified for shipment[19].

Though the efforts of the Federal Department of Transportation are important, such efforts do not get to the root of the problem. The root of the problem in the case of moving Bakken crude via rail lines is that it contains explosive elements and, in the case of an accident, can potentially explode[20]. North Dakota regulators have the authority to do what the Federal Government does not have the authority to do at this point to address the root of the problem regarding North Dakota crude. Whatever decision North Dakota regulators make regarding how to make Bakken crude safer for transportation, they first need consider the events involving Bakken crude over the past 15 months.

On July 6, 2013 a fiery derailment occurred in the Quebec resort town of Lac-Megantic[21]. 47 people died as a result of the derailment and the associated explosion[22]. The environmental damage resulting from the derailment included 26,000 gallons of oil

[19] Snow, Nick. "DOT Emergency Order Covers Bakken Crude Transportation by Rail." *Oil & Gas Journal*. Oil & Gas Journal, 10 Mar. 2014. Web. 18 Sept. 2014. <http://www.ogj.com/articles/print/volume-112/issue-3a/general-interest/dot-emergency-order-covers-bakken-crude-transportation-by-rail.html>.
[20] Gold, Russell, and Chester Dawson. "North Dakota Fracking: Behind the Oil Train Explosions." *The Wall Street Journal*. Dow Jones & Company, 7 July 2014. Web. 16 Sept. 2014. <http://online.wsj.com/articles/north-dakota-fracking-behind-the-oil-train-explosions-1404761720>.
[21] "Timeline: Lac Megantic Train Derailment - CBCNews.ca." *CBCnews*. CBC/Radio Canada, 02 Oct. 2013. Web. 18 Sept. 2014. <http://www.cbc.ca/news2/interactives/timeline-lac-megantic/>.
[22] Id.

spilling into the Chaudière River. Overall the cost of cleaning up Lac-Megantic disaster is estimated at 7.6 billion dollars.

On November 8, 2013 an explosive derailment involving Bakken crude occurred in Aliceville, Alabama[23]. Of the 90 cars traveling through Aliceville 25 oil cars derailed. The result was a nearby river contaminated by oil. Workers recovered more than 200,000 gallons of Bakken crude from a swampy marsh, which was contaminated by crude[24]. Despite the diligent cleanup efforts, oil still can be seen in the wetlands in the area of the spill[25].

On December 30, 2013 a train carrying Bakken crude crashed into a derailed grain train near North Dakota Governor Jack Dalyrmple's hometown of Casselton, North Dakota[26]. The derailment spilled over 400,000 gallons of crude near Casselton and the associated fires required that residents living in the area to be voluntarily evacuated[27]. The irony of the Casselton Derailment is that North Dakota's chief oil and gas regulator, Lynn Helms, was quoted two weeks earlier on December 13 stating, "we need to create a whitepaper to dispel this myth that it [Bakken crude] is somehow an explosive, really dangerous thing to have moving up and down our rail lines"[28]. This quote by Helms again shows his preference to protect and promote the oil and gas industry rather than serve as a regulator who would be concerned about public safety.

On April 30, 2014, 15 railcars traveling through Lynchburg, Virginia derailed causing another explosive event. Three railcars involved in the derailment ended up in the historic James River[29]. Smoke and fire was also highly visible from the Lynchburg city limits, causing heath concerns among residents[30].

The events over the past 15 months involving the explosive derailments of trains carrying Bakken crude should serve as reminder to North Dakota regulators that whatever regulatory decision they make regarding how to treat Bakken crude prior to transport will

---

[23] Gates, Verna, and Edward McAllister. "Crude Oil Tank Cars Ablaze after Train Derails in Alabama." *Reuters*. Thomson Reuters, 08 Nov. 2013. Web. 18 Sept. 2014. <http://www.reuters.com/article/2013/11/09/us-crude-train-explosion-idUSBRE9A70Q920131109>.

[24] "Oil Mars West Alabama Swamp Months after Train Crash near Aliceville (photos)." *AL.com/Associated Press*. Associated Press, 15 Mar. 2014. Web. 15 Sept. 2014.

[25] Id.

[26] Shaffer, David, and Evan Ramstad. "NTSB: 400,000 Gallons of Crude Spilled in N.D. Train Wreck." *StarTribune.com: News, Weather, Sports from Minneapolis, St. Paul and Minnesota*. Star Tribune, 13 Jan. 2014. Web. 18 Sept. 2014. <http://www.startribune.com/business/239948631.html>.

[27] Id.

[28] Federman, Adam. "Hazardous Cargo: Shipping Highly Flammable Bakken Crude Oil by Rail." *Earth Island Institute*. Earth Island Journal, n.d. Web. 15 Sept. 2014. <http://www.earthisland.org/journal/index.php/eij/article/warning_highly_flammable/>.

[29] Nunez, Christina. "Oil Train Derails in Lynchburg, Virginia." *National Geographic*. National Geographic Society, 30 Apr. 2014. Web. 15 Sept. 2014. <http://news.nationalgeographic.com/news/energy/2014/04/140430-oil-train-derails-in-lynchburg-virginia/>.

[30] Id.

have huge ramifications on the safety and wellness of communities across the North American continent. This is a chance for North Dakota regulators to put safety first.

## III. Oil Stabilization: It works in Texas

Oil stabilization is one solution that could potentially rid Bakken crude of its explosive elements. Stabilization is currently used in the Eagle Ford shale of Texas[31]. In layman's terms oil stabilization involves piping crude containing volatiles (raw crude) in a system of pipelines or trucks to "stabilizers." "Stabilizers" are micro-refineries which process between 10,000 to 200,000 barrels of oil per day and strip crude oil of its volatile elements prior to oil being shipped to refineries[32].

Requiring oil stabilization via the use of stabilizers will require a robust investment on behalf of the oil industry. Pipeline infrastructure and micro-refineries will have to be constructed for stabilization to work[33]. Currently North Dakota has over 11,000 active producing oil wells and it is apparent that pipeline and refinery infrastructure would need to be built. Only one micro-refinery, named the Dakota Prairie refinery, is in the works and is currently being constructed near Dickinson[34]. With several experts claiming that there will be more than 50,000 wells in North Dakota by the end of the boom, it can be argued that now is a better time than later to start investing in new infrastructure before the oil industry increases the number of wells by five-fold.

Although many oil producers in the Bakken will argue against stabilizers due to construction costs, one need not look any further than Texas' Eagle Ford shale to see how a rapid investment in stabilizers occurred almost overnight with little complaint from industry. For example, in 2012 Texas had almost no stabilizers, and after discovering a good market for the propane produced in association with Eagle Ford oil, combined with regulations from the Texas Rail Road Commission requiring the treatment of oil prior to shipment, Texas now has several stabilizers that are able to sustainably process its crude making it safer to transport[35].

---

[31] Shaffer, David, and Evan Ramstad. "NTSB: 400,000 Gallons of Crude Spilled in N.D. Train Wreck." *StarTribune.com: News, Weather, Sports from Minneapolis, St. Paul and Minnesota*. Star Tribune, 13 Jan. 2014. Web. 15 Sept. 2014. <http://www.startribune.com/business/239948631.html>.

[32] Hays, Kristen. "Safety Debate Eyes Taming Bakken Crude before It Hits Rails." *Reuters*. Thomson Reuters, 12 May 2014. Web. 10 Sept. 2014. <http://www.reuters.com/article/2014/05/12/us-davegrailways-safety-crude-idUSBREA4B0JD20140512>.

[33] Id.

[34] Faulx, Nadya. "Refining the Final Touches: Dakota Prairie Refinery on Track to Open Later This Year." *The Dickinson Press*. Forum Communications, 27 Aug. 2014. Web. 18 Sept. 2014. <http://www.thedickinsonpress.com/content/refining-final-touches-dakota-prairie-refinery-track-open-later-year>.

[35] Gold, Russell, and Chester Dawson. "North Dakota Fracking: Behind the Oil Train Explosions." *The Wall Street Journal*. Dow Jones & Company, 7 July 2014. Web. 16 Sept. 2014. <http://online.wsj.com/articles/north-dakota-fracking-behind-the-oil-train-explosions-1404761720>.

If “stabilizers” or micro-refineries are the preferred method in North Dakota to remove explosive volatile elements prior to shipping North Dakota crude via rail, the footprint of the necessary infrastructure must be minimized as much as possible. A process of bringing together stakeholders including landowners, local government officials, state government officials, tribal officials, and oil companies must be employed in the planning of new pipelines and refineries. Pipelines should follow corridors that impact the least number of landowners and do not impact large swaths of land. In addition, new micro-refineries must be placed in a manner as to not impact the agricultural land uses that are common and necessary throughout western North Dakota.

There are several companies that build and operate stabilizers. Myron Goford heads one company, which leases oil stabilizers in Texas. When asked this past May by Reuters to explain the difference between North Dakota and Texas when it comes to rules regarding stabilization of crude, Goford responded by stating, “It's a little like the wild west up in the Bakken, where everybody gets to do what they want to do. In the Eagle Ford, you've got to play by the rules, which forces the oil companies to treat it differently.” Goford added that companies are not going to invest in “stabilizers” unless they are required to incorporate it into their business plans via regulation [36].

It is time that North Dakota not be known by the nation as the Wild West, but rather as a modern safe oil development. Requiring that our oil be stripped of volatiles, while planning and investing in infrastructure that does no further burden to our residents’ use and enjoyment of the land seems like a logical step in the right direction for North Dakota.

## IV. Oil Conditioning: The Short Term Solution

Oil conditioning, unlike stabilization, does not require robust infrastructure. Oil conditioning typically can be completed with existing equipment and minor modifications to existing equipment at the well site[37]. Once the volatiles are separated from the oil, then the gases that were separated must be shipped via pipeline or flared[38]. By comparison to stabilization, conditioning is far less mechanized. As a result, if conditioning is chosen as the preferred method to strip volatile constituents out of Bakken crude, regulators must have uniform regulatory requirements on how each company conditions Bakken crude prior to being put in rail cars.

Conditioning in simple terms means using a variety of changes in temperature and pressure to separate volatile constituents from the crude[39]. It should only be used in the short run until stabilizers can be fully utilized. Due to the large changes in temperature in western North Dakota throughout the seasons, there is high likelihood for operator error in conditioning the crude. As a result, a uniform process must be required across operators so that conditioning can be effectively completed in all four seasons. In

[36] Id.
[37] Carney, S.c. Crude Oil Conditioning and Separation Process. Patent US 2303609 A. 1 Dec. 1942.
[38] Id.
[39] Id.

addition, “conditioned” crude should be tested prior to being put in rail cars so that it can be verified that trains will not be carrying potentially volatile crude that could explode in the case of a rail accident. When a test proves that a company did not condition the crude, it must result in a large fine and a suspension of drilling permits until they can prove to a regulator their competency in conditioning crude. Large fines for those who either are technically unable to stabilize their crude via oil conditioning, or simply refuse to do so to save money, would make companies think before they cut corners in conditioning Bakken crude.

In summary, oil conditioning could be used as a short-term solution with the caveat that the method must ensure public safety. If the NDIC chooses to require conditioning, the requirements must be of sound science and the nature of North Dakota temperature fluctuations must be taken in to account. Also flaring should be prohibited. Flaring is already a problem in North Dakota and any additional flaring would fly in the face of the recent effort by the NDIC to curb flaring[40]. New technologies, including remote capture technology, should be required if there is no gas capture infrastructure to send the separated gases/volatiles. Lastly, long-term solutions like “stabilizers” must also be considered for the future if conditioning becomes the preferred method through this current rule making.

## V. The case for slowing down permitting

There are currently more than 11,000 active oil wells in the Bakken, and many experts predict that North Dakota will have over 50,000 active wells by the end of the boom[41]. It is clear that the pace of the boom is not congruent with safety. The rush to get oil out of ground at a breakneck pace combined with lack of oversight by North Dakota regulators regarding the composition of our oil has put North Dakota in this predicament. We propose that North Dakota drilling permits be temporarily suspended until the state can hire experts to oversee quality control for whatever method is chosen to stabilize the crude. There are three scenarios which we believe could potentially be implemented by North Dakota to make Bakken crude safe for transport: 1.Conditioning is required, 2. Stabilization is required, or 3. Phased approach, which allows conditioning to be employed until stabilization infrastructure is built.

<u>Scenario one: conditioning required:</u> If conditioning is chosen, we propose that the state not allow an operator to get any new drilling permits until they can prove to a third party expert that they have competency in their ability strip volatiles out of the oil. To pay a third party, companies would pay North Dakota a permit fee for the services. Once a

---

40 Smith, Nick. "Questions Remain over Flaring Policy : Energy News."*Bismarck Tribune*. Bismarck Tribune, 13 July 2014. Web. Sept. 2014. <http://bismarcktribune.com/bakken/questions-remain-over-flaring-policy/article_4a43d67a-0937-11e4-9254-001a4bcf887a.html>.

41 "MillionDollarWay (All Bakken All The Time)." *Million Dollar Way Blog*. N.p., 18 June 2013. Web. 18 Sept. 2014. <http://willistonbasin.blogspot.com/2013/06/forty-eight-48-wells-per-spacing-unit.html>.

company proves its proficiency in stripping volatiles from its oil, then the company can apply for new drilling permits.

Scenario two: stabilization is required: If stabilizers are chosen, permitting must be slowed until the necessary infrastructure is built so that oil can be stabilized. In addition, a third party expert must certify that the installed stabilizers are sufficiently stripping volatiles out of the crude. In this scenario conditioning would be prohibited.

Scenario three: phased/blended approach: If a phased/blended approach is chosen, where conditioning is used until stabilization infrastructure can be built out, then permitting should be suspended for operators until they can prove to a third party expert proficiency in stripping out volatiles. In addition, companies that are in close proximity to stabilizers will be required to utilize stabilizers over doing conditioning regardless of economics. Companies that make use of stabilizers will not have to pay permit fees for their oil to be inspected and will not have to worry about having to prove competency in conditioning in order to get new drilling permits. This is the preferred route because it will allow our crude to be rendered safe, while also giving operators an incentive to build out new infrastructure. Under this scenario the emphasis will be on getting the stabilization infrastructure constructed.

It should be noted that a third party expert can be defined as either a government agency employee that is an expert on petroleum engineering or a third party consultant with expertise in petroleum engineering to be hired by North Dakota State Government.

Because this is a matter of safety, quality control will be paramount. Slowing down permitting until a company can prove proficiency in rendering oil stable will force companies to make their oil safe if they want to operate in the North Dakota. Further slowing down production means less oil cars on the rails, thus relieving congestion for North Dakota farmers trying to get their grain on the rail lines[42]. Lastly, slowing down permitting will also provide time for the Department of Transportation to phase out the dangerous DOT-111 cars and put safer oil cars on the rail[43].

## Conclusion/Recommendations

1. Stripping volatile elements out of Bakken crude is a safety issue. Accidents from the United States and Canada highlight the dangers of Bakken crude containing volatile elements. Therefore, the volatility of Bakken crude needs to be addressed swiftly and pragmatically by North Dakota officials.
2. The excessively close-knit relationships between the oil industry and North Dakota officials are obvious. For this issue though, North Dakota officials need to

[42] Nixon, Ron. "Grain Piles Up, Waiting for a Ride, as Trains Move North Dakota Oil." *The New York Times*. The New York Times, 25 Aug. 2014. Web. 18 Sept. 2014.
[43] Gerken, James. "DOT-111 Oil Tank Cars, Like Those In Lac-Megantic, Quebec Disaster, Long Seen As Flawed." *The Huffington Post*. TheHuffingtonPost.com, 9 July 2013. Web. 18 Sept. 2014.

disregard their friends in the oil industry and make their decision based on public safety rather than making another effort to preserve oil industry profits.

3. Oil-permitting needs to be slowed so that a viable solution for stripping Bakken crude of its volatiles can be developed, implemented, and tested among all oil and gas operators in North Dakota.
4. Companies that refuse or cannot meet oil conditioning/stabilization standards set by North Dakota should be fined and barred from applying for new ADPs or drilling any new wells until they can prove competency in stripping light-ends or volatiles from Bakken crude.
5. The preferred regulatory route is to employ a phased/blended approach in which conditioning may be used until stabilization infrastructure is fully constructed. Under this regulatory route companies must prove competency in stripping volatiles out of the crude prior to being able to apply for new drilling permits. Emphasis must be on getting stabilizers constructed throughout the oil patch.

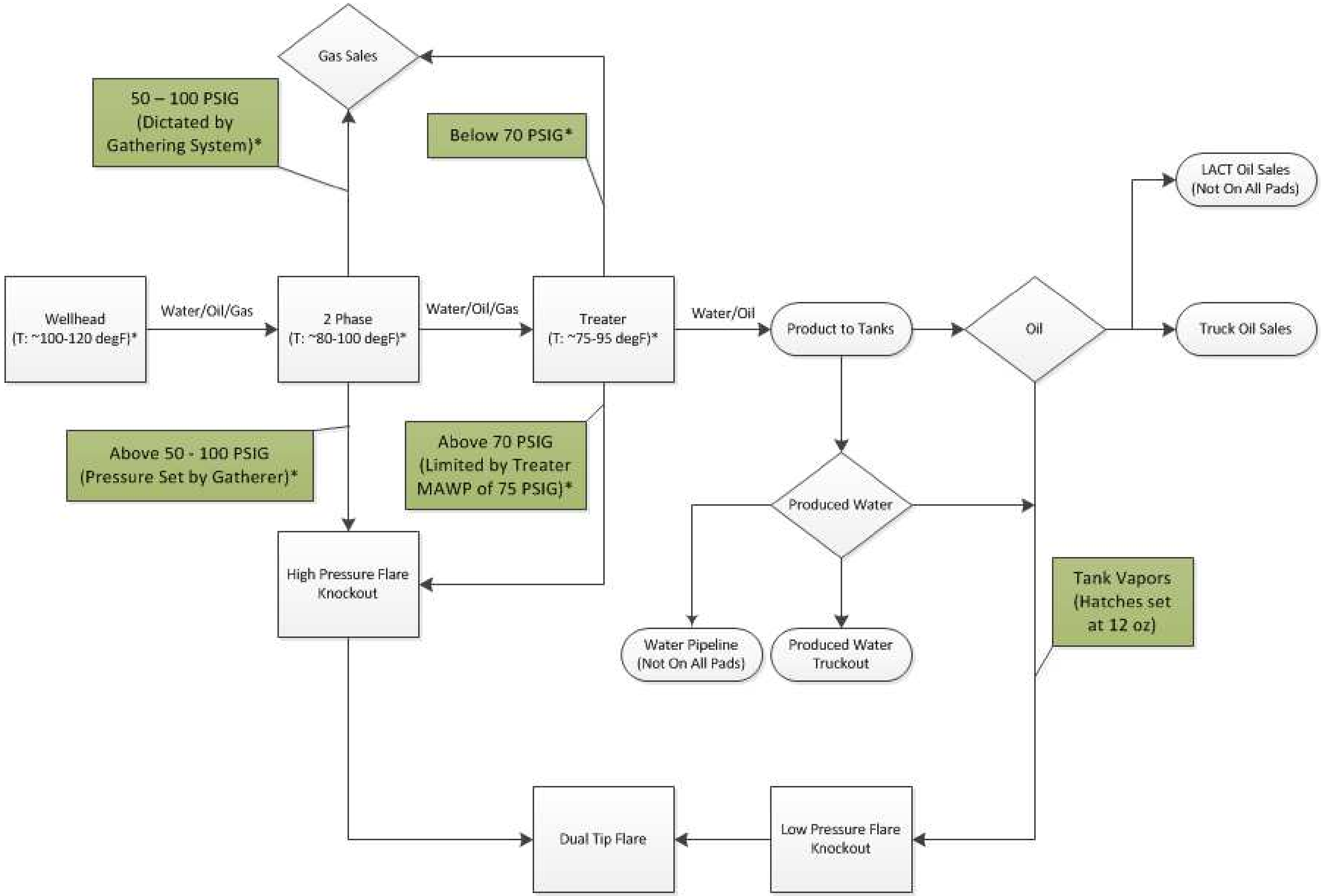
| | |
|---|---|
| **From:** | Tony Lucero |
| **To:** | Kadrmas, Bethany R. |
| **Cc:** | Kari Cutting |
| **Subject:** | Enerplus Handout for 9/23/14 Hearing |
| **Date:** | Monday, September 22, 2014 3:57:03 PM |
| **Attachments:** | Enerplus Wellflow Slide.pdf |

Please find attached a handout (process flow diagram) that Enerplus will use during its testimony tomorrow (Case 23084) regarding oil conditioning. I will bring 12 copies to hand out for the hearing. Thank you.

Tony

**Tony Lucero**
Lead, Regulatory Programs
US Operations
**Enerplus**
950-17th Street, Suite 2200
US Bank Tower
Denver, CO 80202-2805
T. 720-279-5542 | C. 303-905-4405
www.enerplus.com

# WELL FLOW DIAGRAM




*Note: Process conditions vary from well to well based on ambient conditions and position of well on gathering system.

enerPLUS

| | |
|---|---|
| **From:** | Alison Lane |
| **To:** | Kadrmas, Bethany R. |
| **Cc:** | Phillip Steck |
| **Subject:** | Letter on behalf of NYS Assemblymember Steck |
| **Date:** | Monday, September 22, 2014 3:54:25 PM |
| **Attachments:** | NDIC letter 9.22.14.pdf<br>NDIC letter P 2.pdf |

---

Dear North Dakota Industrial Commission, Oil and Gas Division:

Attached please find a letter of testimony at the September 23, 2014 meeting.

I thank you in advance for your kind consideration of my letter.

Sincerely,


Phillip G. Steck
New York State Member of Assembly, 110th A.D.

New York State Assembly
Legislative Office Building Rm. 819
Albany, NY 12248
518-455-5931
518-377-0902

THE ASSEMBLY
STATE OF NEW YORK
ALBANY

COMMITTEES
Children and Families
Health
Insurance
Judiciary
Transportation

Phillip G. Steck
Member of Assembly, 110th District

September 22, 2014

Governor Jack Dalrymple, Chair
North Dakota Industrial Commission, Oil and Gas Division
1000 East Calgary Avenue
Bismarck, North Dakota 58503

Dear Governor Dalrymple,

I am writing to you in regard to the September 23, 2014 hearing at the request of the North Dakota Industrial Commission to consider amending field rules relating to the Bakken, Three Forks, and Sanish Pools that would improve the transportation safety and marketability of crude oil. This oil is transported daily through the 110th Assembly District in New York, which I represent.

The crude oil hydro-fractured from the Bakken field contains highly volatile Natural Gas Liquids (NGLs). As you are aware, there has been a series of explosions of this oil, resulting in significant losses of both property and life. This crude oil has been tested for its volatility by the federal government, so there is no question as to it being more volatile than other crude.

The CP Rail and CSX rail lines that run from the Bakken, North to Canada and East to Minnesota, both ultimately reach the State of New York, where it is then stored and transported from the Port of Albany to points North and South. Once this oil leaves the Bakken field by rail, the State of New York, and all the other states it travels through to get here, has little or no control as to the volatility of this oil and its explosive potential; however, the North Dakota Industrial Commission does.

As this oil travels from state to state, communities and municipalities along these rail lines are spending untold numbers of dollars in an attempt to prepare for and mitigate the potential disaster this oil could create. Sadly, cleanup of many oil spills and disasters have been borne by taxpayers, and not the private companies responsible for it. New York State taxpayers should not have to bear both these costs, which amounts to an unfunded mandate to the taxpayers of New York State.

The commission has a critical opportunity to institute changes that will dramatically impact public safety and, therefore, we strongly urge you to require the companies producing this crude oil to stabilize it before it is transported by rail beyond your border. The stabilizer technology that shaves off the NGLs has been available for years and is commonplace infrastructure in other oil producing regions such as the Eagle Ford Shale in Texas.

The outcry from the oil producers in the Bakken is that it will cost them money to put the stabilizer infrastructure in place. However, the costs of mitigation, emergency planning, drills by local police and fire, evacuation routing, etc. is already being borne by the local taxpayers of the states this oil travels through. For local municipalities along these rail lines to subsidize these oil companies is unfair and stronger field rules would help stop it. In other words, the companies should simply bear the costs of the product they are producing.

To that end, I am requesting that this letter be considered testimony and considered at the September 23, 2014 hearing of the North Dakota Industrial Commission. I have the support of numerous other state, county and local elected officials who have signed on in support of this letter; their names and titles are provided on an accompanying separate page.

Thank you.

Sincerely,

Phil Steck

Phillip G. Steck
Member of Assembly, 110th A.D.

Hon. Karim Camara
Member of Assembly, 43rd A.D.

Hon. James Brennan
Member of Assembly, 44th A.D.

Hon. David Buchwald
Member of Assembly, 93rd A.D.

Hon. Sandy Galef
Member of Assembly, 95th A.D.

Hon. Richard N. Gottfried
Member of Assembly, 75th A.D.

Hon. John T. McDonald III
Member of Assembly, 108th A.D.

Hon. Patricia Fahy
Member of Assembly, 109th A.D.

Hon. Anthony Brindisi
Member of Assembly, 119th A.D.

Hon. Daniel P. McCoy
County Executive, County of Albany, NY

Hon. Craig D. Apple, Sr.
Sheriff, County of Albany, NY

Hon. Michael F. Conners, II
Comptroller, County of Albany, NY

Hon. Shawn Morse
*Chair of the Legislature*
Albany County Legislator, 17th L.D.

Hon. Lucille McKnight
Albany County Legislator, 1st L.D.

Hon. Douglas A. Bullock
*Chair Mass Transit Committee*
Albany County Legislator, 7th L.D.

Hon. Raymond F. Joyce
Albany County Legislator, 13th L.D.

Hon. Alison McLean Lane
Albany County Legislator, 14th L.D.

Hon. Sean E. Ward
Albany County Legislator, 16th L.D.

Hon. Gilbert F. Ethier
Albany County Legislator, 18th L.D.

Hon. Timothy D. Nichols
Albany County Legislator, 19th L.D.

Hon. Joseph E. O'Brien
Albany County Legislator, 25th L.D.

Hon. Dennis Feeney
Albany County Legislator, 28th L.D.

Hon. Bryan M. Clenahan
Albany County Legislator, 30th L.D.

Hon. Charles S. Dawson, Jr.
Albany County Legislator, 35th L.D.

Hon. Kathy M. Sheehan
Mayor, City of Albany, NY

Hon. Paula A. Mahan
Supervisor, Town of Colonie, NY

Hon. David C. Rowley
Town of Colonie Board Member

Hon. Richard Conti
City of Albany Common Council Member, 6th Ward

Hon. Catherine Fahey
City of Albany Common Council Member, 7th Ward

Hon. Judy Doesschate
City of Albany Common Council Member, 9th Ward

Hon. Judd Krasher
City of Albany Common Council Member, 11th Ward

Hon. Meg Grenier
Mayor, Village of Menands, NY

Hon. Seth Harris
Mayor, Village of Menands, NY

Hon. Mike Mackay
Trustee, Village of Menands, NY

Hon. Aileen Nichol
Trustee, Village of Menands, NY

People of Albany United for Safe Energy – Pause
(A Citizens' advocacy organization with a membership of over 120 Capital Region members)

| | |
|---|---|
| **From:** | nancy.casler.27@gmail.com on behalf of Nancy Casler |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Letter to Governor Dalrymple and the NDIC Regarding Field Rules |
| **Date:** | Monday, September 22, 2014 2:28:59 PM |
| **Attachments:** | NDIC_letter_092214.pdf |

Greetings,

I am writing in regard to the hearing on oil conditioning practices scheduled for tomorrow. My written comments are attached. Thank you for your consideration.

Sincerely,

Nancy Casler

Nancy Casler
36 Tillinghast Avenue
Menands, NY 12204
nancy@nancycasler.com

September 22, 2014

Governor Jack Dalrymple, Chair
North Dakota Industrial Commission, Oil and Gas Division
1000 E. Calgary Ave.
Bismarck, ND 58503

Dear Governor Dalrymple:

I am writing to you in regard to the September 23, 2014 hearing at the request of the North Dakota Industrial Commission to consider amending field rules relating to the Bakken, Three Forks, and Sanish Pools. My hope is those rules will be changed to significantly reduce the risks associated with rail transportation of crude oil, and that the hearing is not a mechanism to simply maintain the status quo in order to protect record profits in what I consider to be essentially a big, dangerous experiment.

I have very good reasons to care about this hearing. I live in Albany County, NY, in the quaint and vibrant village of Menands. It's a beautiful, close-knit community adjacent to the City of Albany that features wide, tree-lined streets and numerous examples of old Arts & Crafts bungalows. My home, which I bought as a single parent 12 years ago, is situated approximately 30 feet from the tracks. I was willing to put up with the rail traffic at the time in order to live in this wonderful place and send my children to its high-performing school. Our village park, also trackside, is truly the heart of this community. Every spring dozens of youth baseball games are played at our park just steps from the tracks, and the modern, safe playground at its center is visited daily by many children and their parents. On any given day you will find any number of activities underway: in the summer months, a game of pickup basketball on the well-used court or kids gathering for an impromptu game of kickball; in the winter months, sledding on the hill or a raucous snowball fight. My 11-year-old son regularly rides his bicycle around the neighborhood with his little friends, and they cross back and forth across the tracks regularly. The tracks cut right through the middle of the village, so crossing the tracks for daily activities is completely unavoidable. We all teach our children from a very early age to regard the tracks and the cars traveling on them with caution. Those of us living in the evacuation zone would appreciate it if the oil producers would afford us that same cautious treatment.

Proximity to the tracks used to be a tolerable part of life here until oil shipments increased upon the NYS Department of Environmental Conservation's expansion of Global Partners' and Buckeye Partners' permits, allowing them to handle a combined 2.8 billion gallons of crude oil. This expansion was pushed through without an environmental impact study. Now these tracks carry shipments that average 3.5 million gallons of Bakken crude oil per train daily through Menands and other parts of this heavily populated area on their way to the Port of Albany. And we're just one little stop on the huge network of tracks handling Bakken crude across this country. There are many decent, college-educated, hard-working families just like me living along the tracks; a conservative estimate by Forest Ethics (based on U.S. Census data) puts the total number of American men, women and children living, working and attending schools within the rail evacuation zone at 25,000,000. That's a lot of people to be putting at risk every day through a lack of caution and irresponsible disregard for public safety.

In many industries, it's considered good for business to put public safety at the top of the list of the costs of doing business. As a marketing professional, I can tell you that this kind of money is usually well spent in the end. This whole crude-by-rail operation would be getting a lot less negative publicity if it was clear that the oil producers were actively seeking to make the product safer for rail shipment by stabilizing it at the source. Instead of pointing fingers at the rail companies, expecting THEM to take all the responsibility for safety (who have no choice but to ship the product), oil producers could actually look like the GOOD guys here. I'm not saying that the trend toward putting only one person in charge of a train's operation is not part of the problem; I shudder to think what would happen if the train operator had a heart attack or stroke. I'm saying that all the players need to be doing what they can to keep people in the path of this stuff safe. Morally and ethically, it's the right thing to do. It should also be the legally mandated thing to do.

As I read through the list of discussion topics for this hearing, I was struck by one cost that did not make it onto the agenda: the human cost. Since 2008, there have been at least 10 significant derailments in the U.S. and Canada in which crude oil has spilled from ruptured tank cars, often resulting in huge fireballs. At the same time, rail shipments of crude oil have increased by 4,000 percent with no significant upgrades to any part of the infrastructure that handles this hazardous material. And the number of shipments continues to rise week by week. The players in this oil-by-rail game are lying to the public when they claim that the current setup is acceptably safe and that another accident where humans die is not going to happen. Do we have to wait until some of our citizenry burns to a crisp here in the United States before we act to ensure the safety of human beings? I would like the members of the Commission to ask themselves these questions: "How would I feel about safety if I personally lived next to the tracks like these 25 million people do? Would I really feel comfortable about the current arrangement of shipping unstabilized oil if my close family members and friends lived at risk of a derailment and possible explosion? Should I be able to rest comfortably knowing that innocent people live next to moving shipments of the same material that killed 47 people in Quebec last year if I haven't done what I could to make sure they're as protected as possible from something they never invited into their backyards?" We have no control over what we have to live in the path of. The North Dakota Industrial Commission, however, does.

The official position of the oil industry is that Bakken crude is no more dangerous than any other crude oil. The facts surrounding recent crude oil accidents tell a completely different story. Call it an explosion, call it a fireball…it's still a dangerous and highly combustible material that the oil producers could make a lot less hazardous if they were willing to shoulder their share of the responsibility for the safety of the crude-by-rail operation in this country. I urge you and the other Commission members to think about the human beings affected by this surge in oil production and rail shipping as you consider any changes you may make to the current field rules.

Sincerely,

Nancy A. Casler

| | |
|---|---|
| **From:** | Noyes, Joel |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Testimony for NDIC Case No. 23084 |
| **Date:** | Monday, September 22, 2014 11:54:22 AM |
| **Attachments:** | Hess-API NDIC Testimony 09.23.14.pdf |

Please see attached for testimony that Hess intends to deliver at tomorrow morning's hearing. If you need anything further from me, please let me know.

Thank you,
Joel


Joel Noyes
*Senior Manager, Government Affairs & Public Policy*
**HESS CORPORATION**
1501 McKinney Street | Houston, TX 77010
(713) 496-6048 Office
(202) 263-1027 Office
(512) 520-6019 Cell
jnoyes@hess.com




.

**North Dakota Industrial Commission**
Hearing – Case No. 23084
September 23, 2014

Good morning, my name is Brent Lohnes and I am the Director for Field & Plant Operations for Hess Corporation. I want to thank the State, and the North Dakota Industrial Commission, for giving Hess the opportunity to participate in this important hearing today.

Safety has always been a core value of both Hess and the oil and natural gas industry, and we are committed to working with regulators and all stakeholders to ensure public safety in the handling, packaging and transportation of crude oil. Any new proposals for operator requirements must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations.

Today I am testifying on behalf of Hess Corporation as well as the American Petroleum Institute, the national trade association representing America's oil and natural gas industry. API has more than 600 members, including integrated companies, as well as exploration and production, refining, marketing, pipeline, marine businesses, and service and supply firms.

Hess has a long history of operating in North Dakota – we have been here since 1951 when our company drilled the first production oil well in the state. We are proud to say that generations of Hess employees have called, and will continue to call, North Dakota home. Today, Hess is one of the largest producers in the entire region, with a 17 rig program and over 800 wells of which Hess is the primary operator. In the Bakken, we are expecting to produce approximately 80,000 barrels of oil equivalent per day on a net basis, with plans to reach 125,000 barrels of oil equivalent per day by 2016.

With the substantial increase in production of Bakken crude from North Dakota, the industry is experiencing constraints on pipeline capacity for transporting the product, which has resulted in a larger amount of Bakken crude to be shipped out of the state via rail. Several high profile rail incidents involving transport of Bakken crude have caused greater speculation and scrutiny around the chemical characteristics of the product, causing federal regulators and others to question whether or not transportation of crude by rail is safe. As the debate continues on the potential changes to rail regulations at the federal level, we are here today to discuss the practices of oil conditioning processes in the field – which we believe are sufficient in preparing Bakken crude for transport by rail, pipeline, or truck.

The North Dakota Petroleum Council, in conjunction with Turner, Mason & Co., has conducted Bakken quality assurance tests that studied the range and variability of Bakken crude oil qualities. The Turner Mason study was based on original data collected from both well sites and rail sites, and was representative of the entire Bakken field by using samples from older wells, newer wells, areas of different geography, and from different operators. The results of this study have shown that Bakken crude oil is very similar to other light crude oils. All samples were typical of light crude oil and classified as flammable liquids according to federal regulations. The study found no meaningful change in transit,

little geographical variation, and no evidence of corrosiveness – showing that Bakken crude is extremely consistent across the entire basin, and from load to delivery point.

The results of the study support our position that there is no practical difference in the characteristics of Bakken crude and other light crudes, and that it is suitable for shipment in current rail tank cars. Hess currently operates CPC-1232 tank cars, which exceed today's required specifications for safe transport of flammable liquids as prescribed by the Department of Transportation. Hess also incorporates strict safety protocols into our day-to-day management of crude shipments, and will continue to do so. As such, the transportation safety of crude oil should be considered holistically by evaluating the product, the package, and the operations. Turner Mason's study and API's work on a standard for classification address the characteristics of the product and the proper classification and loading of crude oil in rail tank cars.

In fact, the NDPC testified recently before Congress that three independent studies have now shown that Bakken crude is similar to other North American light, sweet crude oils in gravity, vapor pressure, flash point and initial boiling point – the key parameters in proper classification. According to these studies, Bakken crude oil chemical properties attest to its proper classification as a Class 3 flammable liquid.

An across-the-board requirement to stabilize crude oil beyond the current practices taking place would still likely result in a product that remains a flammable liquid, as defined by the Department of Transportation. To date, no evidence has been presented to suggest that measureable safety improvements would result from processes beyond current oil conditioning. Furthermore, additional oil conditioning would create two separate product streams of flammable liquids for transport. Because of the lack of existing infrastructure in North Dakota, this would be even more flammable liquids that would still have to be transported by rail. We believe Bakken crude oil is sufficiently prepared for transport in the field using conventional separation equipment already in place at well sites – for example, separators and heater-treaters, as Hess employs in our operations. Furthermore, oil conditioning at the well site is conducted to prepare the oil for market by separating the oil, water, and gas components. While practices will differ between operators – due to equipment or infrastructure constraints – we are confident that current oil conditioning practices by industry, including Hess, already meet transportation requirements.

It is important to note that all operating conditions must be carefully optimized to stay within equipment design limits, as well as product quality and general operability constraints. For example, increasing heater-treater temperature to the upper end of the design limits can have the undesirable and unacceptable consequence of increasing internal tube failures and driving excessive amounts of crude oil range material ($C_4^+$) into the gas stream.

Hess feels there is merit in assuring a standard level of conditioning being employed at all well sites. However, as stated before, we believe that any new safety solutions – at any level of government – must be data-driven and produce measurable improvements to safety without creating new risks or inadvertently shifting the risks to other businesses or operations. Doing anything else could cause unintended consequences to the safety and production of Bakken crude, while potentially putting economic constraints on business decisions in the state.

API and the oil and gas industry remain committed to the safe production and transportation of crude oil. When evaluating potential standards or provisions, API encourages this committee to consider actions that will make a measurable improvement to safety.

Thank you, again, for allowing us to participate today.

| | |
|---|---|
| **From:** | Hogan, Hope L. |
| **To:** | Helms, Lynn D.; Hicks, Bruce E.; Kadrmas, Bethany R. |
| **Subject:** | FW: AFPM Request for Additional time To File Comments for September 23, 2014 Oil Conditioning Hearing |
| **Date:** | Monday, September 22, 2014 7:54:08 AM |


Hope L. Hogan
--------------------------------------------
Assistant Attorney General
ND Office of the Attorney General
Division of Natural Resources and Indian Affairs
500 N 9th Street
Bismarck, ND 58501
(701) 328-3640


**From:** David Friedman [mailto:DFriedman@afpm.org]
**Sent:** Friday, September 19, 2014 3:30 PM
**To:** Hogan, Hope L.
**Subject:** AFPM Request for Additional time To File Comments for September 23, 2014 Oil Conditioning Hearing

Dear Ms Hogan,

The American Fuel & Petrochemical Manufacturers (AFPM) requests an extension of time to file written comments to be included as part of the Oil Conditioning Hearing on September 23, 2014. The docket for the hearing states that written comments must be submitted no later than 5:00 CDT on September 22, 2014. AFPM is in the process of completing a white paper on crude stabilization issues and will be unable to submit comments by the September 22, 2014 deadline. We therefore request an extension until October 1, 2014 in order to file complete comments on the issues raised at the hearing. We thank you in advance for consideration of this request and can be reached at the number listed below if you have any further questions.


**David N. Friedman**
Vice President
Regulatory Affairs

**American**
**Fuel & Petrochemical**
**Manufacturers**
1667 K Street NW
Suite 700
Washington, DC 20006
202.457.0480 office
202.552.8461 direct
202.457.0486 fax

dfriedman@afpm.org

| | |
|---|---|
| **From:** | Ron Schalow |
| **To:** | Kadrmas, Bethany R. |
| **Cc:** | A DRC Scott Skokos; A Lynn C Wolff; 1 Alison Lane; 1 NJ Firefighters; 1 F Elizabeth Harman International Association of Fire Fighters; 1 Maio, Linda; 1 Moss, Toshia; G1 Governor; G Vancouver Mayor; G MN LEG; G1 Governor Jay Inslee; G1 Mayor Aurora; G1 Mayor Barrington, IL; G1 US Senate; G1 US Senate; G1 MN Mayor; G1 Mayor |
| **Subject:** | Comments: ND Industrial Commission Hearing on Oil Conditioning Practices |
| **Date:** | Sunday, September 21, 2014 4:52:46 PM |

Ms. Kadrmas -

"It took **"more than 1,000 firefighters from 80 different municipalities in Quebec, and from six counties in the state of Maine"** to help with evacuations and fire-fighting efforts in the small town (Lac-Megantic) of only a few thousand people, according to a Transportation Safety Board of Canada report."--Bellingham Herald

*Lac-Megantic was just one of six massive explosions involving Bakken oil trains. The first was in 2008. There have been five more incidents since July 2013.*

**The Science:**

**Crude Oil:** Mostly carbon, some hydrogen, and small amounts of nitrogen, oxygen, and various metals.

**NOT Crude Oil:** Methane, hextane, pentane, propane, heptane, ethane, butane, isobutane...

Do **NOT** put the **"NOT Crude Oil"** in the same railroad tanker cars as the **"Crude Oil,"** as the Bakken producers have been doing, and the trains won't explode. *Is that too much to ask?*

**"If I threw a match into Bakken crude oil it would not ignite it."** --John Auers; Executive Vice President at Turner Mason & Company. Turner, Mason is an energy consulting firm that wrote "The North Dakota Petroleum Council Study on Bakken Crude Properties" report for the North Dakota Petroleum Council (NDPC), the lobbying entity for the Bakken oil producers.

If Mr. Auers speaks the truth, and why would you doubt a lobbyist, then **Bakken producers must be squeezing a ton of NGL's into the tanker cars, because they sure have IGNITED!**

To remove the explosive element from Bakken crude, the **North Dakota Industrial Commission MUST mandate the "STABILIZATION" of the**

**oil**, with ACTUAL stabilizers, before shipping by rail. Nothing less. The explosions must stop. The North Dakota Industrial Commission has full and complete authority to fix this problem. Now, after 10 years...FINALLY, it needs to be done right.

Ron Schalow
Fargo, North Dakota
The Coalition for Bakken Crude Oil Stabilization

# NEWS RELEASE

For Immediate Release:
August 20, 2014
Contact: Alison Ritter, 701-328-8036
amritter@nd.gov

## Hearing Set on Oil Conditioning Practices

BISMARCK– The Oil and Gas Division of the Department of Mineral Resources has scheduled a special hearing to address the transportation safety and marketability of crude oil.

The hearing will be held at 9 a.m., Tuesday, September 23, at the department's offices, 1000 E. Calgary Ave. in Bismarck.

The commission will consider amending field rules relating to the Bakken, Three Forks and Sanish pools.

Persons interested in testifying should be prepared to supply testimony of a technical nature.

The commission is seeking input on the following:

- Typical operating temperature, pressure, and retention time of gas/liquid separators.
- Optimum operating gas/liquid separator temperature, pressure, and retention time to effectively remove light hydrocarbons.
- Typical operating temperature, pressure, and retention time of treaters.
- Optimum operating treater temperature, pressure, and retention time to effectively remove light hydrocarbons.
- Optimum oil stock tank pressure to effectively operate vapor collection equipment.
- Optimum oil tank settling time prior to shipment.

- Capital costs of typical gas/liquid separator and treating equipment.
- Operating costs of typical gas/liquid separator and treating equipment.
- Other field operation methods to effectively reduce the light hydrocarbons in crude oil.
- Crude oil quality and safety studies including but not limited to those conducted by American Fuel & Petrochemical Manufacturers, PHMSA & FRA Operation Classification, Transportation Safety Board of Canada, and Turner Mason & Company.

Submit written comments to brkadrmas@nd.gov before 5 p.m. CDT, Monday, September 22.

## Hearing Testimony Procedure

- No telephonic testimony will be accepted.
- Sign up will begin at 8 a.m. in the hearing room—parties will be called in order signed up and must appear or be moved to end of list (at the discretion of the Hearing Officer).
- 15-minute limit on testimony.
- Parties will be asked not to repeat testimony of others.

-30-

Alison Ritter

Public Information Officer
Department of Mineral Resources
Phone: 701-328-8036
Fax: 701-328-8022
amritter@nd.gov
www.dmr.nd.gov/oilgas

| | |
|---|---|
| **From:** | Paul Hanson |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Testimony for Cas # 23084 |
| **Date:** | Tuesday, September 16, 2014 1:28:16 PM |
| **Attachments:** | The North Dakota Petroleum Council Study on Bakken Crude Properties.doc |

To whom it may concern:

Attached is my testimony regarding the Industrial Commission's hearing on safe transport of Bakken Crude Oil.

Respectfully,

Paul R. Hanson
phanson_58257@yahoo.com

The North Dakota Petroleum Council Study on Bakken Crude Properties

Bakken Crude Characterization Task Force

A Critique

Paul R. Hanson, B.S
477 154th Ave NE
Mayville, N. Dak. 58257
Phanson_58257@yahoo.com

Abstract

Bakken crude oil from deposits in North Dakota has been scrutinized for its volatility during transport. An explosion in Lac-Mégantic, Quebec which caused the deaths of 47 people as well as explosions in Casselton North Dakota and Lynchburg Virginia which caused citizen evacuation has highlighted the need to understand the chemical characterization of the crude oil. The North Dakota Petroleum Council has enlisted Turner, Mason and Company to study the oil. Turner, Mason and Company is a consultant for several domestic oil companies. Their report, dated August 4, 2014, is being studied; 2 scopes of their investigation are being analyzed. Of particular concern are the report's conclusions over the volatility of the crude compared with that of the Pipeline and Hazardous Materials Safety (PHMSA) analysis,

Introduction

Oil production in North Dakota has rapidly evolved within the last few years. The importance to the industry, the state and to the nation for energy independence should not be understated. Simultaneously, numerous situations have developed that question the safe handling procedures of the oil shipments. The development of the oil industry and safe handling conditions must co-exist; a harmonious blend is necessary in a sophisticated society. The report by Turner, Mason and Company does little to merge the two factions. On one hand the well publicized Bakken oil explosions tells one tale, while the study's analyses tells another tale . Hence, there is a significant discrepancy.

References to the study are being accessed through the website: www.ndoil.org/resources/bkn. where the pdf link to the full report can be found.

I. Verification

While the report design format is for readership by policy makers and isn't necessarily destined for a scientific literature publication, an issue of this magnitude should warrant inclusion of the generally accepted scientific document principles.

Specifically:

1. The authors' names are provided but their contact information and level of expertise is not. "The TM & C team included engineers with extensive refining and crude characterization/ evaluation experience and a chemist with over 40 years of laboratory experience….." (page 2) is an example of loose references.
2. "….SGS, a global leader in testing and inspection with over 135 years in the business." (page 2) does little to establish their expertise. Further, their contact information is missing.
3. Table 1 ( page 2) lists the comparison of crude properties from several locations. The locations are named, but not identified. Their sources are listed, but there isn't an address or an identifier.
4. In Table 9: Round-Robin D86 IBP(page 23), a undisclosed "Lab M" was used to compare results with other SGS laboratories. Lab M was not identified as to location or ownership. Thus, those results should be completely discounted.

The context of the entire study is conversational, anecdotal and without sufficient reference. Concisely written reports with adequate verification are more convincing than loosely constructed documentation. Therefore, the results are misleading and should be considered to be incomplete.

## II. Laboratory Analyses, Protocols and Analytical Methods

On page 38/39 the report deals with sampling protocols and methods. It indicates ASTM Standard methods were used by SGS (the consulting laboratory). As often is the case with industry laboratory analyses, industry sanctioned methods and analytical instrumentation are used to measure components and possible contaminants of the finished product. While this allows conversation and transparency within industry players, it does little to satisfy pertinent questions.

An internet search of ASTM standards, e.g. analytical instrumentation and standardization, revealed little of those techniques. The astm.org website offered a copy of their standard methods, albeit for a price. The literature is copyrighted and is not readily available to independent researchers. Those that are familiar with analytical instrumentation would wonder if rudimentary techniques (the report has frequent references to hydrometers for density measurement – a relatively unsophisticated instrument) were used or if more in depth measurers were employed. For example, chemistry laboratories typically rely on High Performance Liquid Chromatography, Gas Chromatography, Mass Spectrometry or Fourier Transform Infrared Spectroscopy for studies. These instruments are the heart and soul of sophisticated chemistry laboratories.

The report used 7 general categories of the Bakken Crude. They are:

1. Flash Point (F)

2. D86 IBP (F)
3. VPCR 4 @ 100 F (psia)
4. Ethane (Liq Vol %)
5. Propane (Liq Vol %)
6. Butane (Liq Vol %)
7. C2 –C4s*

* These are the Carbon chains with lengths of 2, 3 and 4 Carbons.

Conspicuously absent in the study is a analysis components of highly organized carbon ring structures, conjugated dienes (of which plastics are made), inorganic substances and radioisotope emitters. Thus, to exclude a majority of the components of the crude is to oversimplify safe transportation aspects.

For a quick overview of petroleum's complex composition, visit http://chemistry.about.com/od/geochemistry/a/Chemical-Composition-Of-Petroleum.htm

When determining Packing Group designation which is the core of this issue, two of the above parameters are considered. They are Flash point and initial boiling point. The table (taken from law.cornell.edu) below separates the packing group on those parameters. It is the shipper's responsibility to identify and correctly determine the appropriate packing group.

| Packing Group | Flash Point | Initial boiling Point |
|---|---|---|
| I | | <= 95 F |
| II | < 73 F | >95 F |
| III | >=73 F <=140 F | > 95 F |

On page 31 of the NDPC report, the range of initial boiling point is listed between 91.5 F to 106.8 F with an average of 99.5 F. Clearly, some of the samples met the criteria for Packing Group I. How many of the samples met that definition remains unclear. There is no data to support either way.

Also on page 31, the PHMSA's Flash Point results show it do be less than 50 F which meets Packing group I's definition. This clearly answers PHMSA's claim of the unusual volatility of the oil. Furthermore, the evaporation of dissolved organic gasses (methane) prior to analysis would alter the results; a generic methodology must take great care to minimize this loss. As a personal observation, a bottle of Bakken crude evolved gasses at significant rates. Tim Butters, Deputy Administrator of the PHMSA, in his testimony on Septermber 9, 2014 indicates the presence of the more ignitable fluids while using the more sophisticated methods. His testimony may be found at:

http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_D3B52787331158CFA844EE1F78E24A74DCC30300/filename/Written_Statement_of_Timothy_Butters_for_House_Science_Tech_Comm_Hearing.pdf

## III. Summary, Conclusions and Suggestions

The NDPC report does not corroborate with the physical evidence of massive releases of energy from rail car accidents. Further, federal regulators (PHMSA) have the final responsibility of oversight for the nation's public safety; **it should not be disregarded**.

Despite the simplified view of Bakken crude, the NDPC study suggests that very little change in the composition occurs from the time of drilling to transport to final destination which has significant implications. Additionally, the report offers best operating practice measures which may be useful as an industry standard.

As law and policy makers in North Dakota, it would seem natural to engage chemistry departments in North Dakota universities. Those laboratories are well equipped to analyze the components of Bakken crude. For example, as separation and quantification by compounds become evident, their physical data (boiling point, heat of combustion are a few) can easily be referenced which would resolve any ambiguities.

While not within the scope of this document, conversations in the media and elsewhere indicate dissatisfaction with the amount of flaring of natural gas, AKA the light ends. To use this energy source to power individual turbine generators for the generation of electricity for use either locally or supply the grid is a distinct possibility. A transport of electrons is safer and easier to control then a fluid transport of ignitable compounds. Further study into this is encouraged.

## Kadrmas, Bethany R.

**From:** Ron Schalow <rschalow56@gmail.com>
**Sent:** Thursday, September 11, 2014 3:12 PM
**Subject:** Safety of Citizens in Bomb Train Blast Zones in Hands of North Dakota Politicians

Fri, 2014-09-05 13:30 by JUSTIN MIKULKA

# Safety of Citizens in Bomb Train Blast Zones in Hands of North Dakota Politicians

When North Dakota Congressman Kevin Cramer was asked recently if it was scientifically possible to make Bakken crude oil safer by stripping out the explosive natural gas liquids with a process like oil stabilization, his response was quite telling.
"So scientifically can you do it? Sure, but you have to look at it holistically and consider all of the other elements including economics, and is the benefit of doing something like that does that trump other things like speed of trains, and what kind of cars," he said.

This is very similar to the comments made by Lynn Helms of the North Dakota Department of Mineral Resources according to the July 29 meeting minutes provided to DeSmogBlog by the Industrial Commission of North Dakota.

> "In response to a question regarding other mechanisms besides oil conditioning in the field, Mr. Helms stated there are other mechanisms — none of them without a significant downside….It makes sense to do the conditioning in the field. There are other options to do it downstream somewhere in a very large and very expensive operation."

In a June 24 e-mail obtained by DeSmogBlog through a freedom of information request, Helms identified himself as "the primary contact for Governor Dalrymple's team on the crude safety issue" in response to an inquiry from the Department of Energy about who would be working on the issue of Bakken crude oil safety.

As the point person on this issue for North Dakota, Helms' opinions carry significant weight. **And just like Congressman Cramer, Helms is pointing out the "significant downside" of stabilization, which is that it is an expensive operation.**

**It is well established that stabilization works and would make oil trains much safer.** Not even North Dakota politicians are arguing that point anymore. **But the industry doesn't want to pay for it.** And right now, the only ones who could mandate them to stabilize the oil via new regulations are the three members of the Industrial Commission of North Dakota.

## What About The Feds' Oil-By-Rail Regulations?

The reason North Dakota politicians are discussing this issue at all is because the federal government has essentially punted the question.

In the 200 pages of new proposed oil-by-rail regulations released in July, there is not a single line about requiring the oil or rail companies to stabilize the oil prior to shipping.
Stabilization is a process that removes the explosive natural gas liquids from the oil and is required by pipeline companies. **This process would turn the current Bakken "bomb trains" into simple oil trains.** They would still pose a threat of oil spills, but would no longer threaten to kill people in massive explosions like the one in Lac-Megantic, Quebec, or be a target for terrorism.
While the proposed regulations don't require stabilization, they do include three questions that indicate lawmakers are aware that stabilizing or "degassifying" the crude makes it safer and that producers have the ability to reduce the volatility of crude oil prior to shipping it by rail.

> Is the current exception for combustible liquids sufficient to incentivize producers to reduce the volatility of crude oil for continued use of existing tank cars?
>
> Would an exception for all PG III flammable liquids further incentivize producers to reduce the volatility of crude oil prior to transportation?
> What are the impacts on the costs and safety benefits of degasifying to these levels?

As previously reported by DeSmogBlog, **the regulators in charge of finalizing the new proposed oil-by-rail regulations are big believers in cost-benefit analysis. And looking at their questions, it is clear they know the oil can be made less volatile. But they want to hear more from the industry about the costs of doing this before doing anything. And instead of requiring stabilization, they are looking for ways to "incentivize" the producers to do it.**

## Oil Conditioning vs. Oil Stabilization

The North Dakota Industrial Commission is holding a hearing on September 23rd during which it is requesting input on how to make the Bakken crude oil safer for transport. **The headline of its press release, "Hearing set on oil conditioning practices," almost ensures that oil stabilization will never be required in North Dakota.**
**Oil conditioning is not the same as oil stabilization.** Oil conditioning can be done with all of the existing equipment already in the field in North Dakota and thus the cost is minimal. However, in situations where the industry needs to ensure it strips out all the volatile natural gas liquids from the oil, as in the Eagle Ford formation in Texas, they use a different process called stabilization.

Helms and the members of the Industrial Commission like to cite the North Dakota Petroleum Council Study on Bakken Crude Properties when claiming that Bakken crude is no different than other crude oils and thus doesn't require stabilization. **However, that very report makes it clear that conditioning, done with the equipment currently available, is insufficient and was never designed to achieve the type of results expected from stabilization.**
**From the report, prepared by industry consultant Turner and Mason:**

> The data consistency [sic] indicates that **field equipment is limited in its ability** to significantly impact vapor pressure and light ends content.
>
> This is consistent with the expected capabilities of the equipment.

> The field equipment is designed to separate gas, remove water and break emulsions to prepare crude for transport, and not remove significant levels of dissolved light ends from the crude.

Meanwhile, at the August 26 meeting of the North Dakota Industrial Commission, Helms once again acknowledged the effectiveness of stabilization, as reported by Petroleum News: "This is very routinely done with high gravity condensate — oil that condenses out of a gas well as it is produced," Helms said. "That has to be stabilized before it can move through the system."
Helms word choice is telling. Oil that "has to be stabilized before it can move through the system." Oil that is moved by pipeline has to be stabilized before it can be moved because pipeline companies require it. The rail companies do not.

Despite his acknowledgement of how stabilization is routine in the pipeline business, at the August meeting, **Helms was also sure to point out that in North Dakota they expected to choose conditioning as their solution, as reported by Petroleum News.**

> Helms agreed, saying conditioning is likely more suitable for North Dakota since the equipment is already in place on well sites but he'd like to hear from others at the upcoming hearing.
>
> "We haven't closed the door to (stabilization)," Helms said. "We want to hear what people have to say."

However, if the North Dakota Industrial Commission actually wanted to hear what people have to say about stabilization, the press release about the September 23rd hearing probably **should have actually mentioned stabilization. It doesn't.**

## The North Dakota Industrial Commission

If there is going to be any regulation requiring stabilization of the Bakken crude it will require the three members of the North Dakota Industrial Commission to make it happen.

Governor Jack Dalrymple is one member of the commission. And his point man on this issue, Helms, has already made it clear he supports conditioning over stabilization.

North Dakota Attorney General Wayne Stenehjem is another member. When a report by the Pipeline and Hazardous Safety Materials Administration recently concluded that Bakken oil was more flammable than most other crude oils, Stenehjem responded to the science by saying, "It seems like they are picking on us."
The third member of the commission is Agricultural Commissioner Doug Goehring. At the August 26th meeting of the commission, Petroleum News reported that Goehring opposed stabilization for an unlikely reason for someone who helped oversee the massive expansion of the Bakken oil production.

> Agriculture Commissioner Doug Goehring voiced his concern with dotting the landscape with stabilizer units.

> “We’ve been trying hard to shrink that footprint out there on the landscape, and that’s going to make that awfully difficult.”

So in all likelihood, stabilization is off the table and conditioning will be the new regulation. Helms and others often say conditioning is already being done because the equipment is already in the field. Yet, according to the minutes from the July meeting of the Industrial Commission, Governor Dalrymple said: “Right now we are assuming producers are doing conditioning but we do not have a mechanism to verify that.”

**So, let’s get this straight. It is more than a year after the explosion of a Bakken crude train in Lac-Megantic that killed 47 people. And it’s been more than eight months since a train of Bakken crude exploded in Casselton, ND. And the best the regulators can do is hold a hearing to talk about how to do regulate a practice that’s inadequate and they already assume is being done?**

http://www.desmogblog.com/2014/09/05/safety-citizens-bomb-train-blast-zones-hands-north-dakota-politicians

https://www.facebook.com/BombTrainBuckStopsWithNorthDakota

**From:** Ron Schalow
**Subject:** Safety of Citizens in Bomb Train Blast Zones in Hands of North Dakota Politicians
**Date:** Friday, September 05, 2014 5:45:30 PM

---

Fri, 2014-09-05 13:30 by JUSTIN MIKULKA

# Safety of Citizens in Bomb Train Blast Zones in Hands of North Dakota Politicians

When North Dakota Congressman Kevin Cramer was asked recently if it was scientifically possible to make Bakken crude oil safer by stripping out the explosive natural gas liquids with a process like oil stabilization, his response was quite telling.

"So scientifically can you do it? Sure, but you have to look at it holistically and consider all of the other elements including economics, and is the benefit of doing something like that does that trump other things like speed of trains, and what kind of cars," he said.

This is very similar to the comments made by Lynn Helms of the North Dakota Department of Mineral Resources according to the July 29 meeting minutes provided to DeSmogBlog by the Industrial Commission of North Dakota.

> "In response to a question regarding other mechanisms besides oil conditioning in the field, Mr. Helms stated there are other mechanisms — none of them without a significant downside....It makes sense to do the conditioning in the field. There are other options to do it downstream somewhere in a very large and very expensive operation."

In a June 24 e-mail obtained by DeSmogBlog through a freedom of information request, Helms identified himself as "the primary contact for Governor Dalrymple's team on the crude safety issue" in response to an inquiry from the Department of Energy about who would be working on the issue of Bakken crude oil safety.

As the point person on this issue for North Dakota, Helms' opinions carry significant weight. **And just like Congressman Cramer, Helms is pointing out the "significant downside" of stabilization, which is that it is an expensive operation.**

**It is well established that stabilization works and would make oil trains much safer.** Not even North Dakota politicians are arguing that point anymore. **But the industry doesn't want to pay for it.** And right now, the only ones who could mandate them to stabilize the oil via new regulations are the three members of the Industrial Commission of North Dakota.

## What About The Feds' Oil-By-Rail Regulations?

The reason North Dakota politicians are discussing this issue at all is because the federal government has essentially punted the question.

In the 200 pages of new proposed oil-by-rail regulations released in July, there is not a single line about requiring the oil or rail companies to stabilize the oil prior to shipping.

Stabilization is a process that removes the explosive natural gas liquids from the oil and is required by pipeline companies. **This process would turn the current Bakken "bomb trains" into simple oil trains.** They would still pose a threat of oil spills, but would no longer threaten to kill people in massive explosions like the one in Lac-Megantic, Quebec, or be a target for terrorism.

While the proposed regulations don't require stabilization, they do include three questions that indicate lawmakers are aware that stabilizing or "degassifying" the crude makes it safer and that producers have the ability to reduce the volatility of crude oil prior to shipping it by rail.

> Is the current exception for combustible liquids sufficient to incentivize producers to reduce the volatility of crude oil for continued use of existing tank cars?
>
> Would an exception for all PG III flammable liquids further incentivize producers to reduce the volatility of crude oil prior to transportation?
>
> What are the impacts on the costs and safety benefits of degasifying to these levels?

As previously reported by DeSmogBlog, **the regulators in charge of finalizing the new proposed oil-by-rail regulations are big believers in cost-benefit analysis. And looking at their questions, it is clear they know the oil can be made less volatile. But they want to hear more from the industry about the costs of doing this before doing anything. And instead of requiring stabilization, they are looking for ways to "incentivize" the producers to do it.**

## Oil Conditioning vs. Oil Stabilization

The North Dakota Industrial Commission is holding a hearing on September 23rd during which it is requesting input on how to make the Bakken crude oil safer for transport. **The headline of its press release, "Hearing set on oil conditioning practices," almost ensures that oil stabilization will never be required in North Dakota.**

**Oil conditioning is not the same as oil stabilization.** Oil conditioning can be done with all of the existing equipment already in the field in North Dakota and thus the cost is minimal. However, in situations where the industry needs to ensure it strips out all the volatile natural gas liquids from the oil, as in the Eagle Ford formation in Texas, they use a different process called stabilization.

Helms and the members of the Industrial Commission like to cite the North Dakota Petroleum Council Study on Bakken Crude Properties when claiming that Bakken crude is no different than other crude oils and thus doesn't require stabilization. **However, that very report makes it clear that conditioning, done with the equipment currently available, is insufficient and was never designed to achieve the type of results expected from stabilization.**

**From the report, prepared by industry consultant Turner and Mason:**

> The data consistency [sic] indicates that **field equipment is limited in its ability** to significantly impact vapor pressure and light ends content.
>
> This is consistent with the expected capabilities of the equipment.
>
> The field equipment is designed to separate gas, remove water and break emulsions to prepare crude for transport, and not remove significant levels of dissolved light ends from the crude.

Meanwhile, at the August 26 meeting of the North Dakota Industrial Commission, Helms once again acknowledged the effectiveness of stabilization, as reported by Petroleum News: "This is very routinely done with high gravity condensate — oil that condenses out of a gas well as it is produced," Helms said. "That has to be stabilized before it can move through the system."

Helms word choice is telling. Oil that "has to be stabilized before it can move through the system." Oil that is moved by pipeline has to be stabilized before it can be moved because pipeline companies require it. The rail companies do not.

Despite his acknowledgement of how stabilization is routine in the pipeline business, at the August meeting, **Helms was also sure to point out that in North Dakota they expected to choose conditioning as their solution, as reported by Petroleum News.**

> Helms agreed, saying conditioning is likely more suitable for North Dakota since the equipment is already in place on well sites but he'd like to hear from others at the upcoming hearing.
>
> "We haven't closed the door to (stabilization)," Helms said. "We want to hear what people have to say."

However, if the North Dakota Industrial Commission actually wanted to hear what people have to say about stabilization, the press release about the September 23rd hearing probably **should have actually mentioned stabilization. It doesn't.**

## The North Dakota Industrial Commission

If there is going to be any regulation requiring stabilization of the Bakken crude it will require the three members of the North Dakota Industrial Commission to make it happen.

Governor Jack Dalrymple is one member of the commission. And his point man on this issue, Helms, has already made it clear he supports conditioning over stabilization.

North Dakota Attorney General Wayne Stenehjem is another member. When a report by the Pipeline and Hazardous Safety Materials Administration recently concluded that Bakken oil was more flammable than most other crude oils, Stenehjem responded to the science by saying, "It seems like they are picking on us."

The third member of the commission is Agricultural Commissioner Doug Goehring. At the August 26th meeting of the commission, Petroleum News reported that Goehring opposed stabilization for an unlikely reason for someone who helped oversee the massive expansion of the Bakken oil production.

> Agriculture Commissioner Doug Goehring voiced his concern with dotting the landscape with stabilizer units.
>
> "We've been trying hard to shrink that footprint out there on the landscape, and that's going to make that awfully difficult."

So in all likelihood, stabilization is off the table and conditioning will be the new regulation. Helms and others often say conditioning is already being done because the equipment is already in the field. Yet, according to the minutes from the July meeting of the Industrial Commission, Governor Dalrymple said: "Right now we are assuming producers are doing conditioning but we do not have a mechanism to verify that."

**So, let's get this straight. It is more than a year after the explosion of a Bakken crude train in Lac-Megantic that killed 47 people. And it's been more than eight months since a train of Bakken crude exploded in Casselton, ND. And the best the regulators can do is hold a hearing to talk about how to do regulate a practice that's inadequate and they already assume is being done?**

---

**Tags:** North Dakota oil by rail Kevin Cramer Bakken crude Bakken Natural Gas Liquids NGLs oil stabilization oil conditioning Industrial Commission of North Dakota Lynn Helms Governor Dalrymple Bomb Trains Lac-Megantic Eagle Ford Turner and Mason Petroleum News Attorney General Wayne Stenehjem Doug Goehring casselton

http://www.desmogblog.com/2014/09/05/safety-citizens-bomb-train-blast-zones-hands-north-dakota-politicians

https://www.facebook.com/BombTrainBuckStopsWithNorthDakota

**From:** saego@ndsupernet.com
**To:** Kadrmas, Bethany R.
**Subject:** ND crude oil before transport
**Date:** Thursday, September 04, 2014 10:42:41 AM

---

To: Department of Mineral Resources, Oil and Gas Division

After reading this letter I Hope this Help clear the problem
#1 With a derailment a car can be sideways on a track and with a million tons in the cars behind that will hit it, the pressure inside that car will be enough to spontaneous ignite even the crude oil in the tank much less the gas vapors.

#2 They are making the cars thicker which will only make the explosion more violent.

#3 To prevent a fire or explosion, You have to only remove 1 of 3 items, Fuel, Oxygen, Fire

Can't remove fuel because the car is full of it.
Can't remove fire because in a derailment there will be sparks from steel
So The only 1 left is oxygen

If you purge all the air out of the rail car and fill with crude to about 90% and added 2 to 4 pounds of vapor propane to fill the other 10% of the car. There will be no oxygen for explosions to occur, fire will l still be possible after a car ruptures or leaks, but fire departments would be able to treat the other cars on the track as propane tanks allowing them get close enough to fight the fire.
When the crude is removed from the car they can 100% fill with 2 to 4 pounds of vapor propane, and when car is filling with crude remove 90% of the propane. There is no oxygen inside the tank so if there is gas vapors cummings out of the crude it will only join the propane.
This will remove most of the risk of explosions and squirting crude oil on fire from tank.

Something to think about, The automobile gas tank has an electric fuel pump with brushes throwing sparks while it is running but the brushes are surrounded with liquid gasoline, They do not explode because no oxygen is present at that point.

Removing oxygen from rail cars will make safer crude transportation.
Any Questions Contact
Thank You
Edward Decker
701-483-4396
Auto Mechanic by trade

| | |
|---|---|
| **From:** | RJ Larsen |
| **To:** | Kadrmas, Bethany R. |
| **Subject:** | Does ND crude need to be stabilized? |
| **Date:** | Thursday, August 28, 2014 9:26:46 AM |

I'm wondering why the focus is being put on the oil and not on the rail carriers, this seems to be some kind of spin from the media, oil does not cause rail accidents its the people operating these trains that should be the main focus. How come so many accidents in a short period of time? These are the questions that should be being asked. The oil has been transported by rail for many years now, i know it was being done back in 2007 , so all these years later its a problem? I 've messaged this Ron Schalow fellow and called him out on this and havent received a response, and asked him who does he really represent, and that he should stop wasting the people of North Dakotas time with what seems to be some anti oil witch hunt. The rail carrier needs to be the focus, how are their employees being trained and why the increase in accidents, Thanks for your time.

"Common sense *doesn't* seem to be so common anymore"

| | |
|---|---|
| **From:** | Ritter, Alison M. |
| **To:** | "Ron Schalow"; Kadrmas, Bethany R. |
| **Subject:** | RE: Hearing Set on Oil Conditioning Practices |
| **Date:** | Friday, August 29, 2014 8:39:34 AM |

Mr. Schalow-

Yes, the email is functional. However, due to the pending nature of this case we are unable to answer your questions due to the statue below.

**28-32-37. Ex parte communications.**

1. Except as provided in subsections 2 and 4 or unless required for the disposition of ex parte matters specifically authorized by another statute, an agency head or hearing officer in an adjudicative proceeding may not communicate, directly or indirectly, regarding any issue in the proceeding, while the proceeding is pending, with any party, with any person who has a direct or indirect interest in the outcome of the proceeding, with any other person allowed to participate in the proceeding, or with any person who presided at a previous stage of the proceeding, without notice and opportunity for all parties to participate in the communication.

2. When more than one person is the hearing officer in an adjudicative proceeding, those persons may communicate with each other regarding a matter pending before the panel. An agency head or hearing officer may communicate with or receive aid from staff assistants if the assistants do not furnish, augment, diminish, or modify the evidence in the record.

3. Except as provided in subsection 4 or unless required for the disposition of ex parte matters specifically authorized by statute, no party to an adjudicative proceeding, no person who has a direct or indirect interest in the outcome of the proceeding, no person allowed to participate in the proceeding, and no person who presided at a previous stage in the proceeding may communicate directly or indirectly in connection with any issue in that proceeding, while the proceeding is pending, with any agency head or hearing officer in the proceeding without notice and opportunity for all parties to participate in the communication.

4. In an adjudicative proceeding conducted by a hearing officer other than the agency head, counsel for the administrative agency and the agency head, without notice and opportunity for all parties to participate, may communicate and consult regarding the status of the adjudicative proceeding, discovery, settlement, litigation decisions, and other matters commonly communicated between attorney and client, to permit the agency head to make informed decisions. This subsection does not apply after recommended findings of fact, conclusions of law, and orders have been issued, except counsel for the administrative agency and the agency head may communicate regarding settlement and negotiation after recommended findings of fact, conclusions of law, and orders have been issued.

5. If, before being assigned, designated, or appointed to preside in an adjudicative proceeding, a person receives an ex parte communication of a type that could not properly be received while presiding, the person, promptly after being assigned, designated, or appointed, shall disclose the communication in the manner prescribed in subsection 6.

6. An agency head or hearing officer in an adjudicative proceeding who receives an ex parte communication in violation of this section shall place on the record of the pending matter all written communications received, all written responses to the communications, or a memorandum stating the substance of all oral communications received, all responses made, and the identity of each person from whom the person received an ex parte oral communication, and shall advise all parties, interested persons, and other persons allowed to participate that these matters have been placed on the record. Any person desiring to rebut the ex parte communication must be allowed to do so, upon requesting the opportunity for rebuttal. A request for rebuttal must be made within ten days after notice of the communication.

7. If necessary to eliminate the effect of an ex parte communication received in violation of this section, an agency head or hearing officer in an adjudicative proceeding who receives the communication may be disqualified, upon good cause being shown in writing to the hearing officer or to the agency. The portions of the record pertaining to the communication may be sealed by protective order issued by the agency.

8. The agency shall, and any party may, report any willful violation of this section to the appropriate authorities for any disciplinary proceedings provided by law. In addition, an administrative agency may, by rule, provide for appropriate sanctions, including default, for any violations of this section.

9. Nothing in this section prohibits a member of the general public, not acting on behalf or at the request of any party, from communicating with an agency in cases of general interest. The agency shall disclose such written communications in adjudicative proceedings.

Alison Ritter

Public Information Officer
Department of Mineral Resources
Phone: 701-328-8036
Fax: 701-328-8022
amritter@nd.gov
www.dmr.nd.gov/oilgas

**From:** Ron Schalow [mailto:rschalow56@gmail.com]
**Sent:** Thursday, August 28, 2014 12:01 PM
**To:** Kadrmas, Bethany R.
**Cc:** Ritter, Alison M.
**Subject:** Fwd: Hearing Set on Oil Conditioning Practices

Hi...is the email address on the news release functional? Could someone kindly answer the questions I sent last week?

Ron Schalow
Fargo

---------- Forwarded message ----------
From: **Ron Schalow** <rschalow56@gmail.com>
Date: Thu, Aug 21, 2014 at 12:14 PM
Subject: Hearing Set on Oil Conditioning Practices
To: brkadrmas@nd.gov

Good afternoon -

Can you point me to the current "field rules" on your website, please? Also; which ND agency is charged with enforcing these rules? And, how many years has this agency had the jurisdiction?

Is the "gas/liquid separator" referred to, a piece of equipment that is currently in use by Bakken oil producers?

Are the installation of "stabilizers" under consideration?

Will tanker cars still explode during derailments?

Thanks for your help.

Ron Schalow
Fargo

**From:** Ron Schalow
**To:** Kadrmas, Bethany R.
**Subject:** Hearing Set on Oil Conditioning Practices
**Date:** Thursday, August 21, 2014 12:15:11 PM

---

Good afternoon -

Can you point me to the current "field rules" on your website, please? Also; which ND agency is charged with enforcing these rules? And, how many years has this agency had the jurisdiction?

Is the "gas/liquid separator" referred to, a piece of equipment that is currently in use by Bakken oil producers?

Are the installation of "stabilizers" under consideration?

Will tanker cars still explode during derailments?

Thanks for your help.

Ron Schalow
Fargo

# A Survey of Bakken Crude Oil Characteristics Assembled For the U.S. Department of Transportation

**Submitted by**

**American Fuel & Petrochemical Manufacturers**

**Prepared by**

**Dangerous Goods Transport Consulting, Inc.**

**May 14, 2014**

# Table of Contents

**About the Author**: This report has been prepared for AFPM by Frits Wybenga of Dangerous Goods Transport Consulting, Inc. Mr. Wybenga has more than forty years' experience in the field of hazardous materials transportation. In 1971, he became the first U.S. Coast Guard officer with formal training related to hazardous materials in the Port of Houston, Texas. In succeeding years, he worked for the USCG in Washington, DC on matters dealing with technical and regulatory issues on safety and environmental protection relating to transportation of hazardous materials in bulk in tank barges, petroleum tank ships, chemical tankers, and liquefied gas carriers. Based on extensive technical and international experience, in 1989, he assumed responsibility for leading international activities on the transport of hazardous materials for the DOT Research and Special Programs Administration (subsequently renamed the Pipeline and Hazardous Materials Safety Administration). He served as the head of U.S. delegations to the United Nations Subcommittee of Experts on the Transport of Dangerous Goods (UNSCETDG) from 1989 to 2004 and served as the UN Subcommittee vice Chairman for 8 years. In 2000, he became the Deputy Associate Administrator for Hazardous Materials Safety and remained in this position until retiring from DOT in 2005. Among other recognitions, his contributions to safety and environmental protection were recognized by two separate DOT Secretary Silver Metal Awards and two Hammer Awards signed by Vice President Gore. Since retiring from his DOT position, he continues to participate in the UNSCETDG, representing a range of non-governmental organizations. He has degrees in chemical engineering, environmental engineering and business administration. He qualified as a registered professional engineer (chemical engineering) in the District of Columbia in 1974. He may be contacted at fwybenga@dg-transportation.com.

## Executive Summary

Recent incidents in the U.S. and Canada involving the transport of Bakken crude oil originating in North Dakota has focused considerable attention on the transportation of Bakken crude oil by rail. Questions have been raised as to whether Bakken crude oils pose substantially different risks than crude oils that have traditionally been transported. At the request of the Department of Transportation (DOT), the American Fuel & Petrochemical Manufacturers (AFPM) conducted a survey of its members to address questions posed by DOT and developed this report of its findings. In addition to obtaining responses to the questions DOT raised, as part of its survey, AFPM also collected data stemming from analysis of approximately 1400 samples of Bakken crude oil in order to better understand its properties.

This report assembles AFPM member responses to questions posed by DOT and provides summary data on Bakken crude oil characteristics and hazards based on the sample information collected. The results show that Bakken crude oil may appropriately be classified as a flammable liquid based on DOT and international transportation requirements.[1] Comparison of assay data on Bakken crude oil with data from non-Bakken crude oils indicates that Bakken crude oil is within the norm with respect to the hazard characteristics of a light crude oil. While Bakken crude (and other light crudes) may contain higher amounts of dissolved flammable gases compared to some heavy crude oils, the percentage of dissolved gases would not cause Bakken crude to be transported under a DOT hazard class other than Class 3 Flammable Liquid and does not support the need to create a new DOT classification for rail transportation. Flammable gas content correlates with vapor pressure. The maximum vapor pressure observed based on data collected was 61% below the vapor pressure threshold limit for liquids under the HMR; demonstrating that Bakken crude oil is properly classified as a flammable liquid. With one exception, hydrogen sulfide concentrations were found to be extremely low – below the Short Term Exposure Limits for workers established by OSHA regulations. In the exceptional case, concentrations were substantially higher. Where they exist, high hydrogen sulfide concentrations are addressed under existing transportation and workplace safety regulatory provisions without affect to rail tank car authorizations. Data and experience indicate there to be no basis for classifying Bakken crude oil as having a corrosivity risk as defined by DOT Hazardous Materials Regulations.[2]

The information provided confirms that Bakken crude oil does not pose risks significantly different than other crude oils or other flammable liquids authorized for rail transport. Bakken and other crude oils have been classified as flammable liquids. As noted, Bakken crude poses a lower risk than other flammable liquids authorized for transport by rail in the same specification tank cars. Measured tank car pressures show that even the older DOT 111's authorized to

[1] The United Nations Recommendations on the Transport of Dangerous Goods form the basis for DOT regulations and regulations used widely throughout the world.
[2] Title 49 of the Code of Federal Regulations Parts 105 to 180.

transport Bakken crude oil are built with a wide margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.

Survey results are summarized below. Bakken crude oil currently is transported in compliance with the HMR as a Class 3 flammable Liquid in either Packing Group I, II, or III. In conclusion, there is no identifiable basis for regulating Bakken crude differently than other flammable liquids regulated by the DOT Hazardous Materials Regulations.

**Summary Table on Bakken Crude Oil Characteristics Evaluated in AFPM's Survey**

| Characteristic | Reported Values | Hazmat Transportation Regulatory Implications |
|---|---|---|
| Flashpoint | Range: -59°C to 50°C | Bakken crude oils meet the criteria for Packing Group I, II, or III flammable liquids or as combustible liquids[3] |
| Initial Boiling Point | Range: 2.2°C to 66.9°C | Bakken crude oils with an initial boiling point of 35 °C or less meet criteria for Packing Group I flammable liquids; others for Packing Group II or III flammable liquids or combustible liquids according to flashpoint |
| Vapor Pressure at 50°C | Maximum: 16.72 psia | All Bakken crude oils have a vapor pressure below 43 psia at 50°C and must be transported as liquids |
| Reid Vapor Pressure at 38°C | Maximum:15.4 psia | Not used by the regulations; confirm the vapor pressure at 50°C is well below the above 43psia limit and Bakken crude oils must be transported as liquids. |
| Rail tank car pressures on delivery | Maximum:11.3 psig | Demonstrates that Bakken crude may be safely transported in DOT specification 111 tank cars [4] |
| Flammable gas content | Maximum:12.0 liquid volume % | None; with the vapor pressures of all Bakken crudes oils examined not exceeding a vapor pressure of 43 psia at 50°C, all Bakken crude oils examined must be transported as liquids |
| Hydrogen sulfide content in the vapor space | Most reported $H_2S$ concentrations were below the OSHA STEL; one reported a maximum level of 23000 ppm | None when low values are experienced; additional hazard communication to warn of the presence of $H_2S$ when inhalation hazard levels are encountered[5] |
| Corrosivity | NACE B+ or B++ | Data and experience indicate that Bakken crude oil does not corrode steel at a rate of ¼ inch per year or more so that Bakken crude oil is not a corrosive liquid |

[3] *Note* the Bakken crude data submitted included only one sample that qualified as a combustible liquid, which has a lower risk than other flammable liquids.

[4] §179.201-1 provides summary specifications for DOT-111 rail tank cars. Earlier DOT 111's were designed to a 240 psig burst pressure whereas later designs are designed to a minimum burst pressure of 500 psig. Based on §179.15(b)(2)(ii) the minimum pressure relief valve settings for tank cars with a minimum burst pressure of 240 psig is 35 psig and for 500 psig designs the minimum setting is 75 psig.

[5] See §172.327.

# I. Introduction

The American Fuel & Petrochemical Manufacturers (AFPM) is an industry association representing virtually all of the petroleum refiners and petrochemical manufacturers throughout the United States. The fuel and petrochemical manufacturing industries have a strong commitment to safety as well as environmental protection, and strive for opportunities to enhance safety and environmental protection. AFPM members depend upon a plentiful, affordable supply of crude oil as a feedstock for the transportation fuels and petrochemicals that they manufacture. Approximately 11 percent of the crude oil processed by AFPM members is transported by rail.

As manufacturers, AFPM members acquire crude oils from multiple sources, including crude oil produced from the Bakken formation. Based on concerns expressed by the U.S. Department of Transportation (DOT) over the properties of Bakken crude oil being transported by rail, AFPM, at DOT's request, conducted a survey of its members in an effort to characterize various hazard characteristics that could be relevant to the transportation of Bakken crude oils. For comparison purposes, the properties of crude oils from other fields were also considered.

Bakken crude oil is derived primarily from northwestern North Dakota and to a lesser extent northeastern Montana, and the bordering Canadian provinces of Manitoba and Saskatchewan. Due to the lack of pipeline infrastructure, Bakken crude oil is transported extensively by rail. The data submitted in response to the survey demonstrates that Bakken crude oil is properly transported in accordance with the DOT Hazardous Materials Regulations (HMR) as UN1267 Petroleum Crude Oil, or NA1993 Combustible Liquid, NOS.

**Survey Scope**

The initial questions posed to AFPM by DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) on January 29 are attached in Appendix 1 to this report. PHMSA personnel in a regional office posed additional questions to AFPM members and these are attached in Appendix 2. These two sets of questions formed the basis for the survey conducted by AFPM. More recently, the experts from Canada and the United States to the United Nations Subcommittee of Experts on the Transport of Dangerous Goods submitted a formal document noting recent rail transport incidents involving Bakken crude oil and soliciting the input of the Subcommittee as to whether crude oil such as Bakken crude oil derived from fracking operations posed a different degree of risk than other crude oils.[6] To the extent possible this report also responds to questions raised in the UN paper.

This report compiles information provided by 17 AFPM members who participated in the survey. Data analysis focused on Bakken crude oil as transported. Bakken data stems from sampling at loading points at well head locations, intermediate collection facilities (distribution

[6] A copy of the UN Paper is reprinted in Appendix 3.

centers) at which crude oil may be loaded into rail tank cars and at refinery locations taking receipt of crude oil after a rail journey. Data on approximately 1400 samples of Bakken crude oil was taken into account.

## II. Discussions on Transportation Considerations – Regulatory, Practice and Hazard Characteristics

While PHMSA's Bakken Blitz data collection is ongoing, PHMSA staff has suggested that Bakken crude oil is different from other crudes oils that have traditionally been transported by rail in the United States. The Canada/U.S. UN paper reiterates this opinion concerning Bakken crude oil stating, "[t]his mostly 'younger' crude is being found to contain significantly higher 'light ends' than what has been traditionally transported as UN 1267." Again referring to crude oils like Bakken crude oil, the UN paper goes on to suggest, "lighter crude oil with a higher quantity of dissolved flammable gases pose a significantly different risk than heavier crude oils that do not have such a high constituency of more volatile components." Against this background, it may be instructive to first examine some relevant regulatory requirements, related crude oil hazard characteristics, and transport practices, particularly as they relate to Bakken crude oil.

**Definitions of gas and liquid.**[7] The HMR base the definition of a gas on whether a substance is a gas at 20°C (68°F). Substances with a vapor pressure of more than 300 kPa (43.5 psia) at 50°C (122°F) are also considered as gases irrespective of whether any liquid is still present at that temperature. Substances that have a vapor pressure of not more 300 kPa (43.5 psia) at 50°C (122°F) and with a melting point at or below 20°C (68°F) are generally considered liquids. Crude oil, including Bakken crude oil, is properly classified as a liquid – irrespective of light end concentration – provided its vapor pressure is not more than 300 kPa (43.5 psia) at 50°C (122°F). The AFPM survey confirms that vapor pressures of Bakken crude oil are well below the 300 kPa at 50°C (122°F) limit and are properly transported as liquids under the HMR.

**Reid Vapor Pressure (RVP).** Reid vapor pressure is a common measure of a substance's vapor pressure at 100°F (38°C). The RVP of crude oil increases with the increasing presence of flammable gases and other volatile flammable liquid components (e.g., pentanes).

Up until 1990, prior to harmonization of the HMR with international regulations, the HMR used RVP in place of the 300 kPa at 50°C (122°F) criterion for differentiating between a liquid and a gas.[8] A substance with an RVP of 40 psia or less was regarded as a liquid. In addition, earlier editions used flashpoint and RVP as a basis for identifying authorized packagings, including authorized rail tank cars, for various flammable liquids. Then, §173.119 differentiated substances with an RVP of 16 psia or less from more hazardous substances with RVP's between

[7] *See* 49 CFR § 171.8.
[8] 49 CFR §173.119 (1990 ed.).

16 and 27 psia and 27 and 40 psia; and used an RVP of 40 psia as the threshold for use of DOT specification 111 tank cars. It is noteworthy that Bakken crude oil RVP values obtained in this survey were all less than 16 psia so that the corresponding crude oils would all have been subject to earlier HMR packaging requirements appropriate for the two prior lowest hazard flammable liquid categories.

RVP continues to be used by other regulatory agencies and the petroleum industry. For example, U.S Coast Guard (USCG) regulations for tank ships and tank barges still use a 40 psia RVP criterion for differentiating between liquids and gases in the case of petroleum products, including crude oils. The USCG regulations permit substances to be transported in integral tanks (i.e., gravity tanks not designed for any appreciable pressure) when regarded as liquids (i.e., RVP of 40 psia or less).[9]

Though no longer used in the HMR, the considerable information on the RVP of Bakken crudes serves to provide insight into the characteristics of crude oils derived from the Bakken formation. The current regulatory limit of 300 kPa at 50°C is only marginally different from RVP in the case of crude oils so that RVP values may be deemed a close approximation of the vapor pressure at 50°C (122°F).

**Degree of hazard.** The HMR vary the stringency of requirements according to the degree of risk various substances pose in transportation. Many hazards, including the flammability hazard of liquids, are subdivided into three risk levels:

Packing Group I – encompasses substances regarded as posing a high hazard level;
Packing Group II – encompasses substances regarded as posing a medium hazard level; and
Packing Group III – encompasses substances regarded as posing a low hazard level.

**Packing Group as it pertains to rail transport.** While Packing Group is commonly used in the HMR for purposes of tiering the severity of regulatory requirements, in the case of rail transport of crude oil, it should be noted that DOT 111 rail tank cars are authorized for transporting Packing Group I, II and III crude oils under UN1267.[10] DOT 111's are widely used for transporting Bakken crude oil. While the HMR also authorize AAR Class 206 rail tank cars for Packing Groups II and III crude oil, these are legacy tank cars with few remaining in service. As such, Packing Group, in practice, has little to no impact on the integrity of rail tank cars used in transporting Bakken crude oil since DOT specification 111 tank cars are in common usage.[11]

DOT regulations and publications suggest that Packing Group is a secondary consideration in the case of emergency response. HMR placarding and rail tank car markings requirements, which are intended to communicate essential emergency response information, to emergency responders in the event of an accident or incident, do not communicate the Packing Group of the

[9] *See* 46 CFR §§ 30.10-22 (definition of a flammable liquid) and 30.10-39 (definition of a liquefied flammable gas).
[10] *See* 49 CFR §§ 173.242 and 173.243.
[11] For combustible liquids AAR 203W (less than 100) and 211W (less than 1100) tanks are also authorized.

hazmat involved. Further, the 2012 Emergency Response Guidebook (ERG)[12] does not take Packing Group into account when advising emergency responders on immediate first response measures.

The HMR require shippers to include the Packing Groups of hazardous materials on shipping papers and for rail transport this second level information for crude oil and other hazardous materials is available to emergency responders by accessing the train consist.[13] Bakken crude is described on shipping papers (or the train consist) depending on Packing Group in the following concise well recognized format:

- UN1267, Petroleum crude oil, 3, I;
- UN1267, Petroleum crude oil, 3, II; or
- UN1267, Petroleum crude oil, 3, III.

When Bakken crude oil is transported in DOT 111 rail tank cars, as is common practice, the difference in shipping paper descriptions is the only regulatory difference distinguishing Packing Group I, II or III Bakken crude oils as they are transported by rail.

**Flammability.** Flammable gases and vapors will ignite when they are mixed with air in certain concentration ranges. The lowest temperature at which flammable liquids produce vapor in sufficient amounts to support combustion is termed the liquid's *flashpoint*.

Under DOT and international regulations, a flammable liquid is a liquid that has a flashpoint of less than or equal to 60°C (140°F). Flammable liquids with a flashpoint of 23°C (73°F) or less are assigned to either Packing Group I or II. In essence, the flashpoint limits of 23°C (73°F) and 60°C (140°F) for flammable liquids indicate whether a substance has:

- Potential of producing a flammable vapor under moderate ambient temperature conditions – i.e., 23°C (73°F); or
- Potential of producing a flammable vapor under the most extreme ambient temperature conditions – i.e., 60°C (140°F).

Under the HMR, a flammable liquid with a flashpoint in the range of 38°C (100°F) and 60°C (140°F) may also be regarded as a combustible liquid, reflecting that such substances have a lower risk of igniting. Combustible liquids also include liquids with a flashpoint up to 93°C (200°F).

Except for classification under the HMR, flashpoint is not commonly used to characterize crude oil. Testing for flashpoint is an inherently dangerous test to conduct even under controlled laboratory conditions. Given the specific threshold values in the HMR, measurement of an exact

[12] The ERG is periodically prepared and published jointly by DOT and the governments of Canada and Mexico. Registration fees collected from hazmat shippers and carriers in accordance with 49 CFR Subpart G support its wide distribution to emergency responders in the U.S.
[13] *See* 49 CFR §§ 172.202(a) and 174.26.

flashpoint value is not required. For compliance with the HMR, it is important to know what range of values the flashpoint of a particular crude oil falls into (e.g.; 23°C or less) – not the specific flashpoint value. For this purpose, approximation methods may be used (e.g.; chromatography or calculation methods). This may be common practice in the case of routine screening of crude oil shipments. Test methods identified by the HMR are typically not valid for substances below -30°C (-22°F); and approximation methods may have been used in producing some of the flashpoint data discussed in this report.

While there is no regulatory limit on how low the flashpoint of a flammable liquid may be, diethyl ether, a Packing Group I flammable liquid transported as a pure substance, has a flashpoint of -45°C (-49°F).

**Initial boiling point.** The HMR and international regulations use initial boiling point as a classification criteria. Boiling point is considered indicative of a substance's volatility or its propensity to form flammable vapor plumes in air. Plume formation could occur after a spill of a flammable liquid when a fire is not involved. Increasing volatility leads to the formation of larger flammable vapor plumes. A lower boiling point generally implies increased volatility. As such, boiling point is used to evaluate the degree of risk a flammable liquid poses. The larger the flammable vapor plume a flammable liquid is capable of forming when spilled, the more dangerous it is considered to be, since the size of the plume affects the probability that flammable vapors will reach an ignition source and ignite. Predicting the size of a plume a particular liquid produces involves complex calculations accounting for ambient conditions and many other properties of a substance. Since boiling point is widely available, it is used as an approximation for gauging a substance's volatility. The HMR use *initial boiling point* as the basis for a differentiating between substances that have a Packing Group I high hazard risk (i.e., an initial boiling point of less than 35°C (95°F)) or a Packing Group II medium hazard risk.

Pure substances have a single boiling point and boil off completely at one temperature. Mixtures of flammable liquids made up of various components, like crude oil, boil over a temperature range. The more volatile components (e.g., dissolved gases in the case of crude oils) will boil off at the initial boiling point leaving less volatile components with higher boiling points in the liquid. Increasingly higher temperatures are required to boil off remaining components. Subsequent less volatile and less dangerous (from a flammability perspective) fractions of a liquid mixture may not boil off until significantly higher temperatures are reached. An assay of a Bakken crude oil indicates a boiling point range spanning approximately 500°C. From a flammability/volatility perspective, in comparing a pure substance with a flammable liquid mixture with the same initial boiling point, the pure substance is more volatile and more dangerous.

**DOT flammable liquid classification criteria.** The HMR and international regulations classify flammable liquids into three Packing Groups as follows:

| Packing Group | Flash point (closed-cup) | Initial boiling point |
|---|---|---|
| I | | ≤35 °C (95 °F) |
| II | <23 °C (73 °F) | >35 °C (95 °F) |
| III | ≥23 °C, ≤60 °C (≥73 °F, ≤140 °F) | >35 °C (95 °F) |

**Emergency Response.** An important function of the HMR is to provide hazard information to emergency responders in the event of an accident or incident involving a hazardous material in transportation. The HMR hazard classification requirements result in the assignment a hazard class (e.g., flammable liquid), assignment of a UN number and proper shipping name and assignment of Packing Group. These determinations in turn lead to requirements for labeling and placarding to pictorially communicate the various HMR hazards, package markings to convey the UN number and proper shipping name, and shipping paper requirements providing additional information on the details of a hazardous material shipment.

The 2012 Emergency Response Guidebook (ERG) is intended to supplement hazard communication information provided on packages and shipping papers. It is intended for use by emergency responders first arriving on the scene of an accident or incident. First responders include law enforcement personnel and fire department personnel – both professionals and volunteers. DOT distributes the ERG widely throughout the United States with the objective of making it available to every potential first responder. The frequency of hazardous materials accidents and incidents is rare so that on average a first responder is expected to encounter less than one incident in a career. As such information must be basic and understandable to those who have a low probability of encountering a hazardous materials accident or incident.

The ERG serves this purpose. Through the UN number or proper shipping name of a substance, a first responder is able to access instructions on what steps to take upon arrival at the scene of an accident or incident. For crude oil assigned to UN 1267 Petroleum crude oil, irrespective of Packing Group, or crude oil meeting combustible liquid criteria and transported under NA 1993 Combustible liquid, NOS, guide page 128 of the ERG provides a first responder with the appropriate information (see Appendix 5). In this respect, it is important to note that the range of crude oils subject to the HMR (i.e., crude oils of Packing Groups I, II and III and combustible liquid crude oils) are addressed by one set of instructions made available to first responders. The same guide page is applicable to many other flammable liquids independent of the degree of hazard.

**Flammable gases dissolved in liquids.** Gases typically dissolve to some degree in liquids. For a given temperature, the amount of gas that dissolves in a liquid is directly proportional to the partial pressure of the gas in equilibrium with the liquid. The amount of gas that can dissolve in a liquid increases with pressure and decreasing temperature. For this reason, soda in a bottle bubbles when the top is removed as carbon dioxide held in the liquid is released as a gas because the bottle pressure no longer holds the carbon dioxide in the liquid. The same happens with crude oil where flammable gases such as methane, ethane, propane and butane, held in solution under high pressure underground, are released as the pressure is decreased when it is brought to the surface and stored. If stored at a low temperature, crude oil will retain more gas than if stored at a higher temperature.

Crude oil taken from the wellhead and placed in a stabilization tank continues to release dissolved gases until an equilibrium concentration between the gas dissolved in the crude oil and the concentration of the gas in the tank vapor space is reached.

The DOT definition of a gas places a regulatory limit on the amount of flammable gas that may be held in crude oil in transportation. If a crude oil had a vapor pressure in excess of 300 kPa at 50°C (122°F) due to a high dissolved gas concentration, it would be regarded as a gas and not as a liquid.

In some cases the HMR explicitly permit some quantities of certain gases to be transported in liquids. For example, up to 30% ethylene oxide (a toxic and flammable gas) may be transported in propylene oxide (a liquid) under UN 2983 Ethylene oxide and propylene oxide mixtures.

**Hydrogen sulfide.** In a pure form hydrogen sulfide is a gas and is regulated as a toxic and flammable gas under the HMR and OSHA regulations. Crude oil commonly contains some amount of sulfur. It may be present in hydrocarbon molecules (e.g., mercaptans) or as hydrogen sulfide dissolved in the liquid. The chemical/thermal and biological breakdown of the sulfur bearing hydrocarbon molecules in crude oil, as it is brought to the surface and is stored, may lead to increased evolution of hydrogen sulfide gas in crude oil liquid and vapor.

When a crude oil contains concentrations of hydrogen sulfide at levels that may present an inhalation hazard, the HMR require communication of its presence. Bakken crude oil is generally considered a sweet crude and the survey data confirm that sulfur and hydrogen sulfide concentrations are normally low. However, exceptions were noted in the case of one respondent.

**Light crude oils.** Light crude oils are generally regarded as those crude oils with an API gravity of 37 degrees or more. API gravity varies inversely with specific gravity so that increasing API gravity values reflect decreasing specific gravity or density. Light crudes tend to have higher concentrations of light ends (i.e., methane, ethane, propane, butanes and pentanes). The presence of increasing amounts of dissolved gases and other light ends (i.e., pentanes) has the effect of increasing the crude oil's vapor pressure, lowering its flashpoint and lowering its initial boiling point. Light crude oils may qualify as Packing Group I, II or III flammable liquids under the

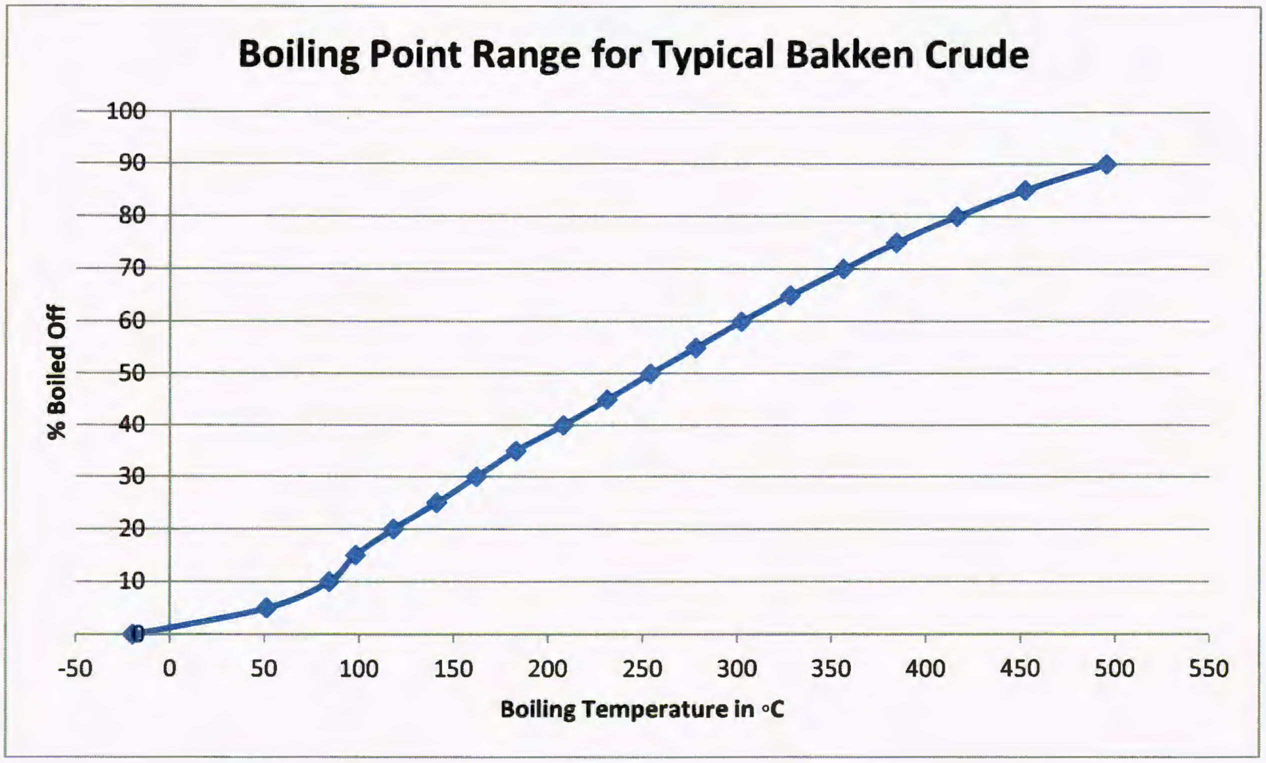
HMR depending on properties of the specific crude oil. Some may be transported as combustible liquids. Light crude oils are common throughout the world. Bakken crude oil is regarded as a light crude oil.

**Bakken crude oil.** Bakken crude oil, like other crude oils, consists of a range of primarily hydrocarbon gases and liquids. The table below illustrates the composition of a Bakken crude oil sampled at a distribution center prior to loading for rail transportation. The table also provides the HMR classification for each component. Division 2.1 refers to the HMR flammable gas classification and Class 3 refers to the HMR flammable liquid classification. The particular Bakken crude oil sample depicted in the sample below had an RVP of 7.6 psia.[14]

| Hydrocarbon gas | Concentration in Liquid Volume % | DOT Classification |
|---|---|---|
| Methane | <0.01 | Div. 2.1 Gas |
| Ethane | 0.05 | Div. 2.1 Gas |
| Propane | 0.80 | Div. 2.1 Gas |
| Iso-Butane | 0.46 | Div. 2.1 Gas |
| N- Butane | 2.36 | Div. 2.1 Gas |
| Total Gas | 3.67 | |
| Neopentane | <0.01 | Class3; PG I |
| Iso-Pentane | 1.33 | Class 3; PG I |
| N-Pentane | 2.36 | Class 3; PG II |
| Hexanes | 4.10 | Class 3; PG II |
| Heptanes Plus | 88.56 | Varies Class 3; PG II to combustible liquid to non-regulated |
| Benzenes | 0.08 | Class 3; PG II |

For the same crude oil, the figure below provides the boiling point range. Note that the boiling point temperature progressively increases after the more volatile components are boiled off.

[14] Among assays of Bakken crude oil, 7.6 psia is a normal RVP value.




15

Consideration of flashpoint and boiling point data for hydrocarbons suggests that, for the crude oil illustrated, when 40% of the crude oil is boiled off, the remainder would not be regulated as a flammable liquid.[16] As boiling continues beyond the 40% level, the remaining liquid would transition from a combustible liquid to a non-regulated substance. All else being equal, a pure flammable liquid with a boiling point comparable to the initial boiling point of the example crude oil would produce a flammable vapor plume 2.5 times larger than the example crude.[17] While a rough comparison, it illustrates that pure substances may be considerably more volatile than flammable liquid mixtures with identical initial boiling points.

The range of boiling points also suggests that in accident conditions where a tank is engulfed in flames, considerably more heat would be required to boil off the example crude oil than would be required of a pure substance with the same IBP. Consequently, based this and other factors, pressure buildup within a tank containing the example crude oil would be expected to be more gradual than that for a pure substance.

[15] IBP values in this chart where based on ASTM 5307, a capillary chromatography method, producing lower values as compared to IBP data from samples provided which were based largely on ASTM D 86 – a method referenced in the HMR.

[16] Estimated based on the properties of n-dodecane, a C-12 hydrocarbon with a flashpoint of 71°C and a boiling point of 216°C, which is not subject to the DOT HMR as a flammable liquid. Crude oil compositions with a boiling point of 216°C or higher were assumed to not qualify as flammable liquids with a flashpoint less than 60°C.

[17] Some examples of other Class 3 Flammable Liquids that are transported in DOT 111's with a higher risk profile than Bakken crude would include: diethyl ether, acrylonitrile, and ethyl mercaptan.

**Crude oil processing.** When crude oil is extracted, it is typically processed to remove water and entrained gases, and stored in a tank prior to transportation. Processing, settling time in storage tanks and ambient temperature conditions all influence the extent to which light ends including gases are released from crude oil before it is transported.

## III. Survey Results

### A. Testing Used to Evaluate Bakken Crude Oils

As a Class 3 flammable liquid or a combustible liquid under the HMR, Bakken crude oil is subject to evaluation of its flashpoint and initial boiling point for classification purposes in accordance with the HMR. Other tests evaluating vapor pressure, flammable gas content, hydrogen sulfide content and corrosivity are also employed by industry and provide additional information relative to the hazards of crude oil.

Tests are carried out on crude oil samples taken at multiple locations along the distribution chain as it moves from the production point at a well to a refinery destination. Samples may be taken and evaluated at the well head, at gathering stations, at rail loading facilities, at pipeline facilities and when it is received at the refinery. Survey responses include data resulting from testing by AFPM members or independent laboratories (e.g. assays).[18] Data considered relevant for purposes of this survey was limited to data characterizing crude oil "in transportation," – ranging from data on samples taken at the well head location at the point of loading for transportation to data from samples taken where transportation ended at the refinery gate.

Members generally found variations in properties of specific crude oils to be minimal as these crude oils moved through the distribution chain. Summary data provided in the survey aggregates data obtained for samples taken along the distribution chain. A number of members noted seasonal variations in some properties of Bakken crude oils. The variations may be attributable to higher retention of flammable gases in crude oils in winter owing to lower ambient temperatures.

### B. Test Methods Used to Characterize the Hazards of Crude Oil

PHMSA requested information on test methods used to characterize crude oil. The test methods used to evaluate selected characteristics are provided in Appendix 4.

[18] Crude oil assays are detailed evaluations of crude oils that are commonly performed for commercial non-regulatory purposes. They may be used to define crude oil purchased by a refiner from a producer. The values reported in an assay reflect the properties of a specific sample. They are intended to represent characteristics of crude oils to be purchased and do not normally account for variations that may be identified among multiple samples. For example, higher RVP values for Bakken crude oil are noted in this survey for other samples. In addition, data from more than one assay was used in this report. Even though the data in assays are not normally used for regulatory compliance purposes, consideration of assay data was instructive for purposes of this survey given the detailed information they provide.

## C. Reported Information and Test Results - Discussion and Range

The following information on Bakken crude oil is based on responses from AFPM members and data provided on approximately 1400 samples of Bakken crude oils.[19] The data included data points on specific characteristics as follows:

Flash Point: 77 data points;
Initial Boiling Point: 275 data points;
RVP: 807 data points;
Rail Tank Car Pressure (PSIG): 387 data points;
Total C1-C4: 18 data points;
$H_2S$ in Liquid: 37 data points;
$H_2S$ in Vapor: 535 data points; and
Corrosivity to metal: 7 data points.[20]

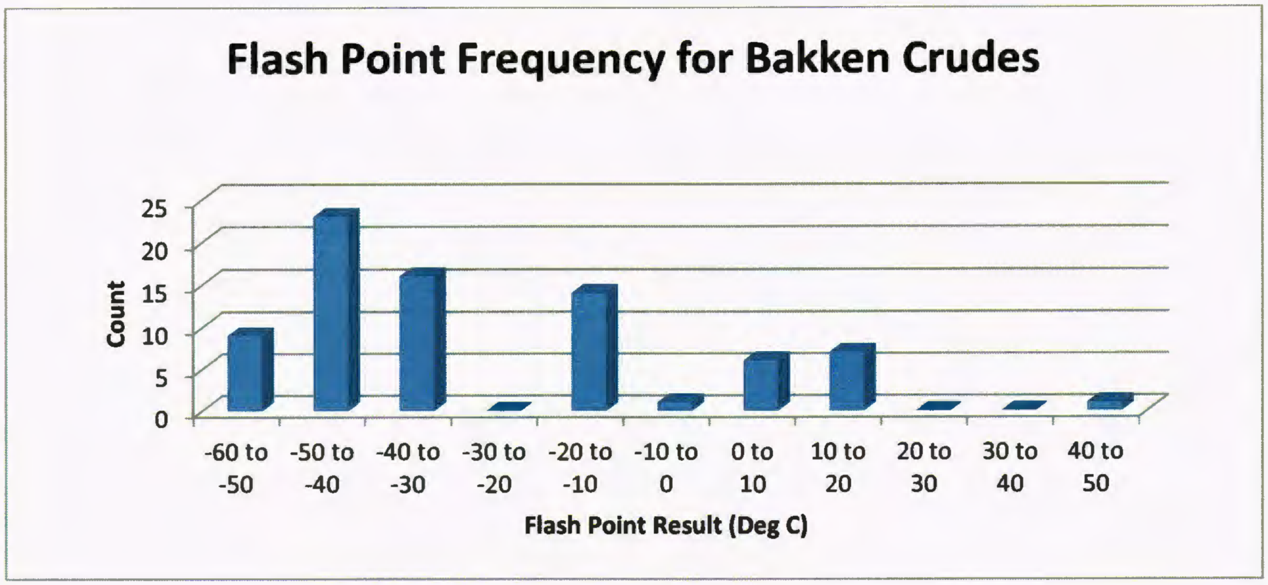
For comparison purposes data from samples of non-Bakken crude oil was also considered.

### 1. Flashpoint

*Reported Bakken flashpoint range.* Survey respondents reported flashpoints ranging from -59°C (-74°F) to 110°C (230°F). On the basis of this flashpoint information, Bakken crude oil in transportation ranges from being subject to regulation as flammable liquids (in all 3 Packing Groups), combustible liquids or not regulated as hazardous materials under the HMR.

The chart below shows the distribution of flashpoints among all Bakken crudes for which data was provided as part of this survey.

[19] Many of the samples were collected in February/March 2014 in North Dakota. Given the prevailing ambient temperature, these samples are expected to represent "worst case" conditions that contribute to higher flashpoint, vapor pressure and dissolved gasses.
[20] Data provided was initially acquired for a range of purposes and not necessarily for compliance with the HMR. As such data on samples did not always include data points on all of the characteristics considered in the survey.



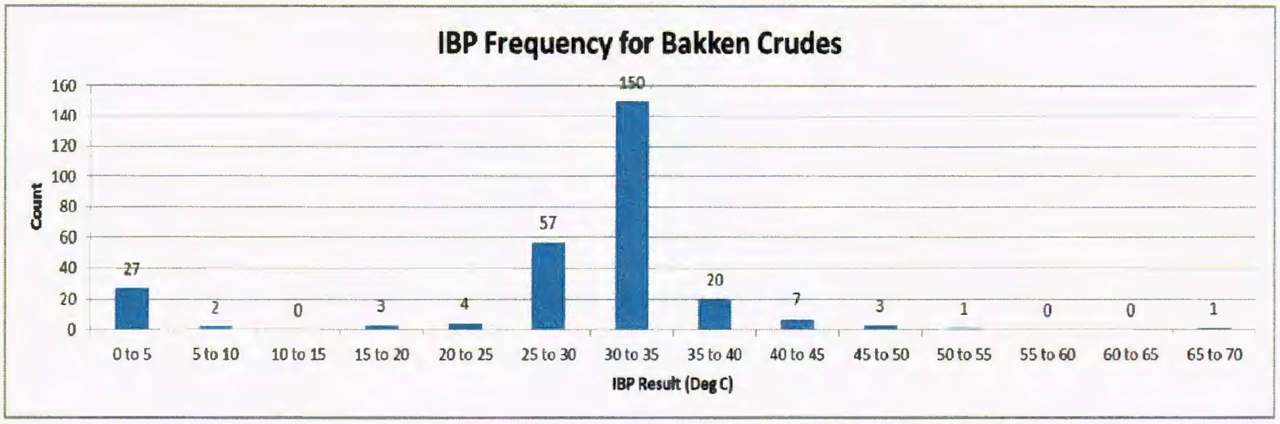

| | |
|---|---|
| Mean | -27.1°C (-16.8°F) |
| Median | -36° C (-32.8°F) |
| Mode | -15.0 °C (5 °F) |
| Minimum | -59°C (-74.2°F) |
| Maximum | 50°C (122°F) |

*Discussion on flashpoint data.* Survey data indicate that 76 of the 77 crude oil samples meet the classification criteria for Packing Group I or II. One crude oil sample for which data was provided could be classified either as Packing Group III or as a combustible liquid.

As already noted, flashpoint data may be based on estimation methods with the objective of determining the HMR flashpoint range a particular crude oil falls into (e.g., 23°C or less). While these methods suffice for HMR classification purposes in that they assign a substance to the appropriate flashpoint range they may not accurately reflect the precise flashpoint value that would be obtained using a method identified as suitable under the HMR. As such caution is advised when considering specific values.

## 2. <u>Initial boiling point</u>

*Reported Initial Boiling Points.* The chart below describes the range of initial boiling point data that was provided on Bakken samples from crude oil in transportation.




| | |
|---|---|
| Mean | 29.0°C (69.6°F) |
| Median | 30.7° C (87.3°F) |
| Mode | 30.2 °C (86.4 °F) |
| Minimum | 2.2°C (36.0°F) |
| Maximum | 66.9°C (152.4°F) |

*Discussion on Initial Boiling Point information.* Based on the data provided in the survey, the majority of Bakken crude oils in transportation have an initial boiling point ranging from 15°C to 50°C. The low values shown in the lower left hand side of the chart stem from samples taken upon arrival at a refinery in the months of February to April suggesting that IBP is influenced by seasonal conditions.

The HMR utilize an IBP threshold criterion of 35°C to delineate between Packing Group I and II. Among Bakken crude oils, IBP values are clustered around the regulatory threshold. Respondents to the survey noted problems with the variability and repeatability of IBP tests. While no misclassification is implied, the clustering of IBP values around the 35°C threshold value combined with repeatability problems associated with IBP testing could present practical challenges with respect to the assignment to Packing Group I or II.

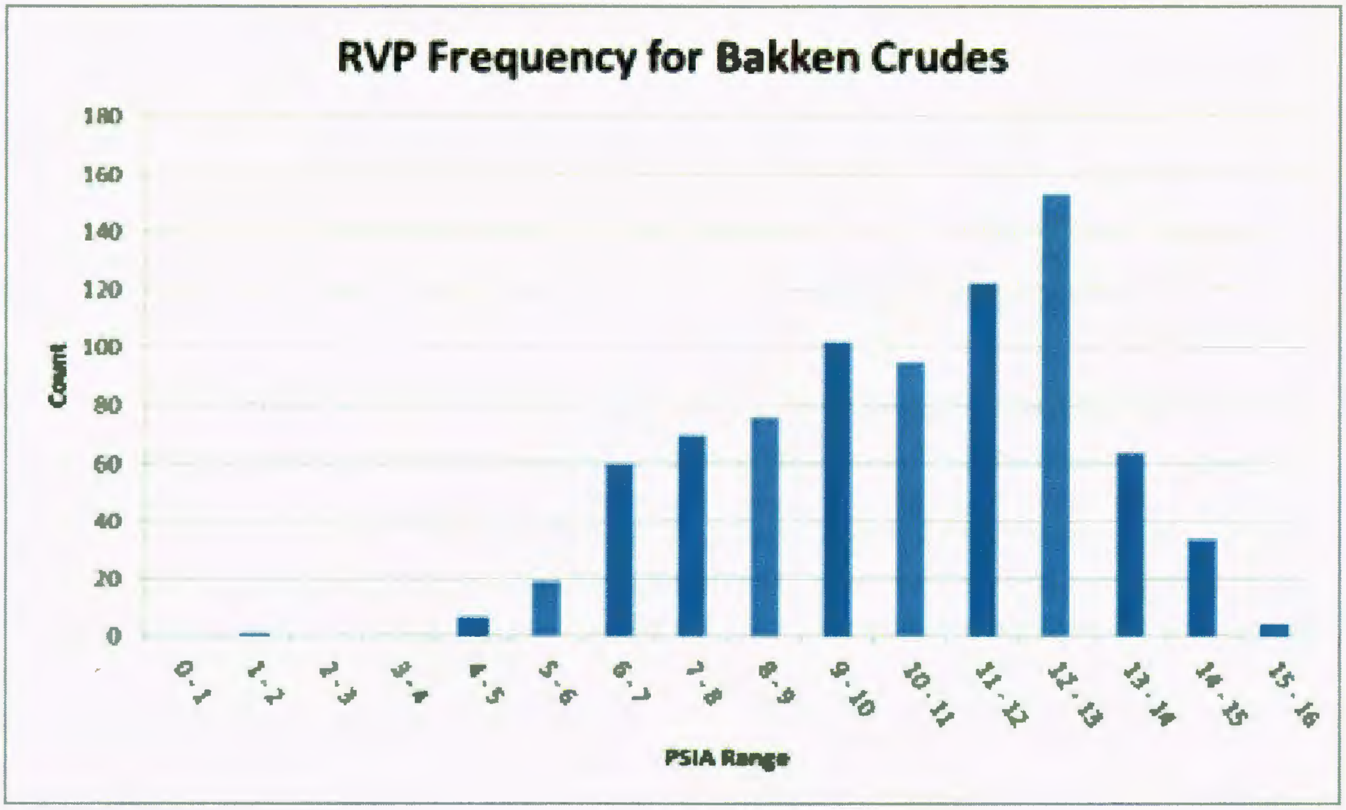
## 3. <u>Vapor pressure of crude oil in transportation, tank car pressures</u>

*Reported vapor pressure at 50°C.* Vapor pressure values were reported in data on nine Bakken samples. The vapor pressure values ranged from a low of 13.89 psia to 16.72 psia. Based on RVP data these values appear to be in the high range of what would normally be expected for Bakken crude oil – although well below the vapor pressure threshold for a flammable gas. All but two samples were taken at the rail loading point in North Dakota. These values were from samples taken in February and March 2014. Lower vapor pressure values would be anticipated at other times during the year when ambient temperatures are higher.[21] The data confirm that Bakken crude oils fall within the definition of a liquid under the HMR in that they are well below the 300 kPa (43 psia) threshold value delineating between a gas and a liquid.

Note that the vapor pressure at 50 °C will normally correlate closely with the far more widely reported RVP which is measured at 38 °C (100 °F) as discussed below.

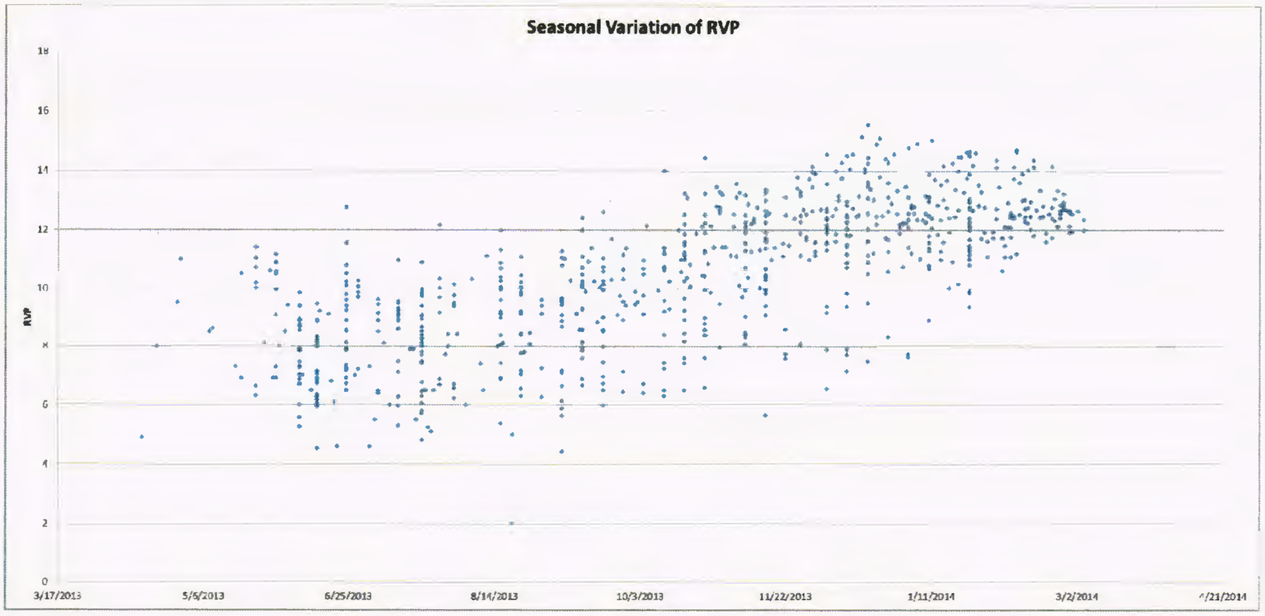
*Reported Reid Vapor Pressure values (vapor pressure at 38 °C (100 °F)).* Among the survey respondents and based on the data submitted, Bakken crude oil offered for transportation was found to have RVP values ranging from 0.8 to 15.54 psia.

The chart below shows the distribution of RVPs among all Bakken crudes for which data was obtained as part of this survey.




[21] The seasonal variation of RVP is discussed below.

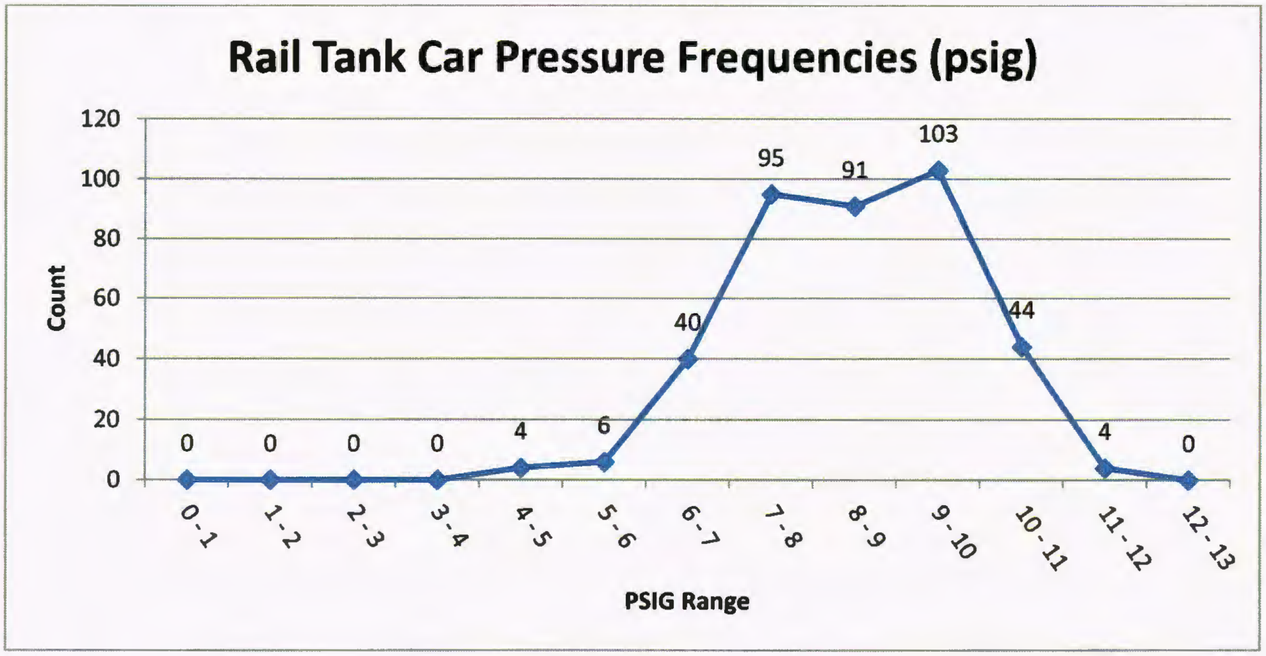
*Seasonal variations of RVP.* Seasonal variations of RVP are demonstrated in the following chart.




The chart shows that RVP values average 8 psia for warmer times of the year and average 12.5 psia during colder periods. RVP and other parameters are interrelated. As such, similar seasonal variations in other parameters such as flashpoint, initial boiling point, and flammable gas content are likely.

*Operational limits on crude oil RVP.* Respondents noted that, outside of the HMR, there are operational limits on the RVP of crude oil. First of all, it is common to store crude oil in floating roof tanks. Environmental regulations governing the release of volatile organic compounds (VOCs) restrict the RVP (or a variant known as TVP measured at ambient temperature) of crude oil in floating roof tanks to 10-11 psia. The floating roof tank pressure limits impose practical RVP limits on the crude oil transported by rail to refiners and petrochemical facilities. Recipients monitor crude oil for RVP to ensure compliance with these environmental regulations. One respondent noted that they test the RVP of every rail shipment at the time of loading and upon receipt. In their experience RVP values varied according to the time of year with RVP values as high as 15 psia in the winter and with lower RVP values typical in the summer. The second operational restriction on the transportation of high RVP value crude oils is due to increased potential for pump cavitation. A limiting RVP of 10 psia was reported as typical for crude oils transported by pipeline where pumping is required. Pipelines are a destination for some Bakken crude oils transported by rail. Finally, lower RVPs are also more desirable from a refinery operational perspective. One refinery respondent noted a contractual RVP limit of 9.5 psia.

*Reported rail tank car pressure measurements.* The chart below indicates pressures measured in rail tank cars upon arrival at a refinery. The highest value reported was 11.3 psig. This value is lower than the 35 psig minimum relief valve setting for older DOT 111 rail tanks cars and their required 240 psig minimum design burst pressure. This suggests that DOT 111's are built with an ample margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.




| | |
|---|---|
| Mean | 8.5 psig |
| Median | 8.5 psig |
| Mode | 9.0 psig |
| Minimum | 4.2 psig |
| Maximum | 11.3 psig |

## 4. **Flammable Gas Content**

*Reported flammable gas concentrations.* In response to the PHMSA question on ranges of flammable gas content of Bakken crude oil, respondents reported the following ranges:[22]

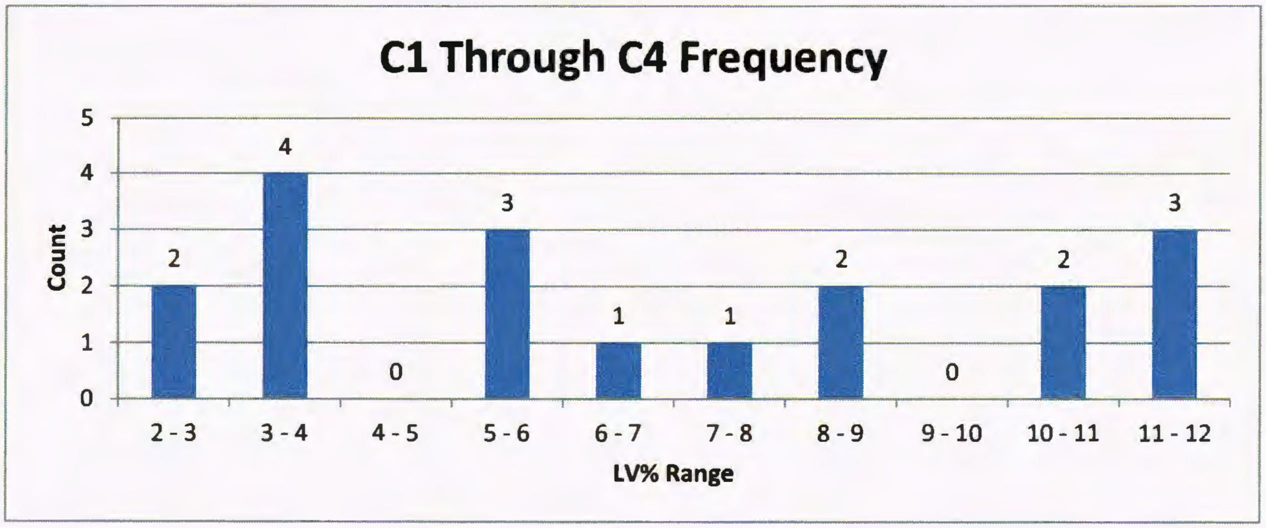
| Hydrocarbon gas | Concentration in Liquid Volume % |
|---|---|

[22] In data collected, some samples were found to have higher values than indicated in the range of values reported. Maximum values were 0.77 LV % for ethane, 3.4 LV % for propane, and 8.0 LV % for butane. As reflected in the bar chart below, based on sample data, the maximum total flammable gas content for all samples was 11.9 LV %. Samples were obtained in February and March.

| | |
|---|---|
| Methane | <0.01 |
| Ethane | 0.50 |
| Propane | <1-2% |
| Iso-, N-Butane | 3-4% |

Eighteen samples included measurements of flammable gas content. The information differs from light end content in that pentane, which is not a gas under the HMR, is commonly included in light end data. Data from three respondents indicated a maximum total flammable gas content (C1 to C4) of 3.5% Liquid Volume %.

Information provided by a fourth respondent, included data from 12 samples taken in a one month period beginning in early February and ending in early March. In the case of the latter samples, total flammable gas content ranged from 5.9% to 11.9%. Ambient temperatures affect these gas concentration values. The data obtained from all respondents is illustrated in the chart below.



*Comparison with other crude oils.* To determine whether Bakken crude oil's "light end" content is markedly different from other crude oils, data (primarily from assays) for other non-Bakken crude oils were examined.[23] The table below illustrates that some selected other crude oils have comparable gas contents and in addition illustrates some of the variations in characteristics that exist among crude oils with a range of API gravities. (Note that "light ends" as the term is used in the petroleum industry includes pentanes which are deemed flammable liquids under the HMR.) Based on assay data for Bakken and non-Bakken crude oils[24], the following table summarizes data obtained:

| **Crude Name** | **Origin** | **API** | **RVP (psia)** | **Vol % of Light Ends (C2 – C5)** |
|---|---|---|---|---|
| Arabian Super Light | Saudi Arabia | 51 | 20.7 | 12.53 wt %[25] (C1-C4 only) |
| Eagle Ford | Texas | 48 | 7.95 | 8.3 |
| Agbami | Nigeria | 48 | 2.2 | 5.61 wt % |
| DJ Basin | Colorado | 45 | 7.82 | 8.0 |
| Sarahan Blend | Algeria | 43 | 7.46 | 8.1 |
| Bakken | North Dakota | 42 | 7.83 | 7.2 |
| WTI | Texas / New Mexico | 41 | 5.90 | 6.1 |
| Brent[26] | United Kingdom | 37.5 | 9.33 | 5.28 wt % |
| API gravity of 37 or more defines light crude oil | | 37 | | |
| LLS | Louisiana | 36 | 4.18 | 3.0 |
| Alvheim blend | Norway | 34.9 | 3.9 | 1.86 wt % |
| Arabian Heavy | Saudi Arabia | 28.4 | 18.3 | 5.13 wt % (C1-C4) |
| Alberta Dilbit[27] | Alberta | 21.1 | 7.18 | 7.30 wt % |
| Alba | United Kingdom | 19.6 | 1.6 | 0.14 wt % |

[23] *Note* "light ends" as the term is used in the petroleum industry includes pentanes which are deemed flammable liquids under the HMR.
[24] Sources included data collected as part of the survey as well as online data at http://www.oil-transport.info/crudedata/crudeoildata/crudeoildata.html and data at http://www.statoil.com/en/ouroperations/tradingproducts/crudeoil/crudeoilassays/pages/default.aspx
[25] Because the specific gravities of gases and pentanes in the liquid state are lower than that of other components, "wt %" is lower than "LV %". Conversion from wt % to LV% requires the concentrations of each individual component.
[26] Data from a sample taken at the loading point.
[27] Data from a sample taken at the loading point.

Using assay data allows for evaluating oils on a consistent basis. While survey data on specific samples of Bakken crude oils (like other light crude oils) showed higher gas content than assay data, it may be expected that similar variations arise in the case of non-Bakken crude oils. The data suggests that Bakken crude oil is within the norm for what might be expected in the case of light end content in light crude oils. Light crudes oils are not unique to new drilling practices and have been common since the advent of petroleum extraction.

*Operational limits on flammable gas content.* Since flammable gas content and vapor pressure are closely linked, operational limitations identified relative to RVP (i.e., floating roof tank limits, pipeline pumping limits and refinery operational considerations) also apply in the case of flammable gas concentrations.

## 5. <u>Hydrogen sulfide content</u>

*Reported hydrogen sulfide concentrations.* Respondents indicated hydrogen sulfide vapor space concentrations were less than 10 ppm.

Data reviewed was for either hydrogen sulfide concentration in the liquid or hydrogen sulfide concentration in the vapor.

*Data on $H_2S$ in liquid.* For samples, hydrogen sulfide concentrations (in ppm) in the liquid were reported as follows:

| H2S in liquid | Count |
|---|---|
| x< 0.2 | 4 |
| x<1.0 | 2 |
| x< 2 | 22 |
| x<5.0 | 1 |
| x< 10 | 8 |
| **Total** | **37** |

These would suggest very low hydrogen sulfide vapor concentrations.

*Data on $H_2S$ in vapors.* Reports of hydrogen sulfide (in ppm) in the vapor were reported as follows:

| H2S in Vapor | Count |
|---|---|
| x<1 | 390 |
| x<2.0 | 9 |
| x>2000 | 6 |
| **Total** | **535** |

The above six values indicating "x>2000" stemmed from one of four respondents providing $H_2S$ vapor data. In addition, the same respondent reported 129 measured $H_2S$ values (in ppm) that are summarized as follows:

| H2S in Vapor | |
|---|---|
| Mean | 3580 |
| Median | 2000 |
| Min | 1 |
| Max | 23000 |

The data was based on samples taken at a gathering location where crude oil was being collected for transportation. For crude oils with $H_2S$ concentrations posing an inhalation hazard, additional HMR hazard communication requirements apply, including warnings on rail tanks cars.[28]

*Operational limits on hydrogen sulfide.* With an OSHA short term exposure limit (STEL) of 15 ppm for 15 minutes exposure, occupational limits are far below those warranting communication of the toxic hazard under the HMR. Where there is potential for exposure, employees are fitted with monitors and ambient air is subject to gas sampling. Testing for hydrogen sulfide is common for rail unloading operations and one respondent noted that hydrogen sulfide levels greater than 15 ppm were not allowed at company rail unloading facilities. Another respondent noted that where high hydrogen sulfide crude oils are encountered, the crude oil is typically not transported before first being subjected to treatment using amine scavengers.

When appropriate, based on potential high levels of hydrogen sulfide which pose a health risk to workers, the risks of hydrogen sulfide are delineated on Safety Data Sheets.

### 6. Corrosivity to metals

*Discussion.* Under the HMR, in addition to criteria for corrosivity to skin, a substance is regarded as corrosive if it corrodes steel or aluminum at a rate of 6.25 mm (0.25 inches) per year. A substance with this degree of corrosivity would penetrate steel used in crude oil rail tank cars in a period of approximately two years. There is no evidence that Bakken crude corrodes steel or aluminum at this rate.

*Reported corrosivity data.* Data reported using NACE TM 172 indicates that Bakken crude oil scores as either B+ or B++ using this method. Generally, a NACE value of B+ or better is

[28] *See* 49 CFR §172.327.

required for transportation via pipeline. While crude oil does not meet the HMR corrosivity criteria, water, solids and H2S contaminants in crude may cause corrosion at rates less than that specified in the HMR for classification purposes. Industry deals with this lower level of corrosion from an asset management perspective.

**D. What safety information is provided to carriers?**

The HMR require that a considerable amount of information be provided to carriers, including:

1. UN number of the crude oil;
2. Proper shipping name under which it is transported;
3. Hazard class (Class 3);
4. Packing Group of the crude oil;
5. Total quantity being offered or the number of packagings (i.e., rail tank cars) involved;
6. Emergency response information that includes immediate hazards to health; risks of fire or explosion; intermediate methods to be taken for handling fires; initial methods for handling spills or leaks in the absence of a fire; and preliminary first aid measures; and
7. A 24-hour emergency telephone number where more detailed information may be obtained.

Upon request, carriers may also be provided material safety data sheets.

## IV. Summary Remarks

Survey results obtained by AFPM members provide a considerable amount of information on which to assess the hazard characteristics of Bakken crude oil. The data obtained appears to be of good quality. From the data, it is clear that parameters such as vapor pressures, initial boiling points, flashpoints and dissolved gas content were influenced by seasonal variations. Yet even when considering data obtained during periods of cold weather, Bakken crude oil was found to be well within the limits for what is acceptable for transportation as a flammable liquid. Bakken crude oil was compared with other light crude oils and determined to be within the norm in the case of light hydrocarbon content, including dissolved flammable gases.

Measured tank car pressures show that even the older DOT 111's authorized to transport Bakken crude oil are built with a wide margin of safety relative to the pressures that rail tanks may experience when transporting Bakken crude oil.

Other factors influence the properties of crude that is transported. As manufacturers, AFPM members have an interest in limiting the RVP for purposes of operational efficiency and adherence to Clean Air Act requirements. RVP values correlate with values for flammable gas content, initial boiling point and flashpoint. Levels of all these parameters, consistent with an RVP of approximately 10 psia or lower are in the best interests of AFPM members. Compliance with OSHA requirements related to exposure to $H_2S$ also plays a role in reducing the hydrogen sulfide content of crude oil in transportation.

AFPM and its members appreciate the concerns raised in relation to rail transport of Bakken crude oil and stand ready to work cooperatively with DOT and other governmental organizations to ensure the safe transportation of Bakken crude oil. This survey shows that Bakken crude oil does not pose risks that are significantly different than other crude oils and other flammable liquids authorized for transportation as flammable liquids. In some respects Bakken crude oil may be regarded as posing a lower degree of risk than other flammable liquids transported in accordance with the HMR, particularly pure substances.[29]

[29] Some examples of other Class 3 Flammable Liquids that are transported in DOT 111's with a higher risk profile than Bakken crude would include: diethyl ether, acrylonitrile, and ethyl mercaptan.

# Appendix 1

U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

Administrator

1200 New Jersey Ave., S.E.
Washington, DC 20590

January 29, 2014

Mr. Charles Drevna
American Fuel and Petrochemical Manufacturers
1667 K Street, NW
Suite 700
Washington, DC 20006

Dear Mr. Drevna:

The recent railroad derailments and resulting fires in North Dakota, Alabama, New Brunswick, Ontario, and Lac-Megantic, Quebec have raised my concerns about the safety risks associated with the transportation of crude oil, specifically the crude oil originating from the Bakken region. One concern is whether this product has inherent properties and characteristics different from traditional crude oils historically transported and whether these characteristics pose additional transportation risks. In order to address my concerns, I invite you to meet with me in Washington, DC on Wednesday, February 5, 2014, from 10 a.m. to 11:30 a.m. at Department of Transportation headquarters to discuss potential safety issues related to truck and rail transportation of crude oil. I am specifically concerned about the methods and processes you use to meet your responsibilities in the Hazardous Material Regulations to properly test, characterize, and classify the crude oil for transportation by truck and rail.

Based upon preliminary information obtained from investigations into the derailments noted above, PHMSA issued a safety alert to the industry reiterating the requirement to properly test, characterize, and classify hazardous materials prior to transportation. Title 49 Code of Federal Regulations §172.204 requires offerors of hazardous materials to properly classify and describe the hazardous materials being offered for transportation. As part of this process, offerors must ensure that all potential hazards are properly characterized and communicated on shipping papers. Proper characterization identifies those properties that could affect the integrity of the packaging or present additional hazards, such as corrosivity, sulfur content, and dissolved gas content, in addition to how the product is classified for transportation. Proper classification, packing group assignment, and communication of all the hazards of product shipments are required and fundamental to the safe transportation of these materials, regardless of the mode of transportation.

In order to have meaningful discussions during your visit, please consider and be prepared to answer the following questions:

- What tests or methods do you use to determine the properties of the crude oil to include its vapor pressure, flammable gas content, flash point, boiling point, hydrogen sulfide content and corrosive properties prior to offering it in transportation?
- Who performs these tests and how frequently are they completed?
- When you find high levels of gases in crude, what actions do you require of your oilfield personnel before loading into a transport vehicle? What information about the crude oil properties, if any, is provided by the producers to you prior to transportation? How is this information communicated?
- What information do you share with truck and rail carriers about the crude oil properties?
- Are there any prescribed limits involving vapor pressure, flammable gas concentration or hydrogen sulfide content above which the crude oil is not placed into transportation? If so, what are these limits and how are they determined?

I welcome your insights to these questions and any other information that you may have about the chemical and hazardous properties of Bakken crude oil. I look forward to meeting you and working together on this critical transportation safety issue.

We are also extending this invitation to anyone else that you believe would benefit from attending or further contribute to this meeting. My executive assistant, Sabrina Morris, will contact your office to schedule the meeting. If you have any questions, please feel free to call me at (202) 366-4433.

Regards,

Cynthia L. Quarterman

**Appendix 2**

## PHMSA Field Office Questionnaire

**Company:** ______________________ **Contact Name:** ______________________

**Address:** ______________________ **Title:** ______________________

**City, State:** ______________________ **Phone:** ______________________

**Type:** Refinery ☐ Transfer Terminal ☐ **Email:** ______________________

- What tests, if any, are performed on the crude oil upon receipt?
  - How frequently are they completed?
  - Are you willing to share the results with us?
- When you find high levels of gases in crude, what actions do you require of your personnel before unloading?
  - What information about the crude oil properties, if any, is provided by the offerors or carriers prior to receipt?
  - How is this information communicated?
- Have you had to add any special safety measures or make any procedural changes in the unloading process to protect workers or modify the flow to the facility?
- Are there any prescribed limits involving vapor pressure, flammable gas concentration or hydrogen sulfide content above which the crude oil is not accepted at terminal or refinery?
  - If so, what are these limits and how are they determined? (*Note: We have heard that one of the larger refineries in Canada placed gauges on top of rail cars to measure pressure before unloading and in turn rejected some 400 rail cars.*)

United Nations ST/SG/AC.10/C.3/2014/49

Secretariat

Distr.: General

2 April 2014

Original: English

**Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labeling of Chemicals**

**Sub-Committee of Experts on the Transport of Dangerous Goods**

**Forty-fifth session**

Geneva, 23 June – 2 July 2014

Item 4 (c) of the provisional agenda
**Listing, classification and packing: miscellaneous**

# Classification and hazard communication provisions for crude oil

## Transmitted by the experts from Canada and the United States of America[30]

## Background

1. North America is experiencing a significant increase in crude oil supply, bolstered both by growing production in the Canadian oil sands and the recent expansion of shale oil and natural gas production in the United States of America and Canada.

2. North American shale oil and natural gas extraction has been mostly in geographic areas not linked to traditional crude oil or natural gas pipelines, resulting in an increase in surface transport. Surface transport has also enabled crude transport to different refinery capacities situated across North America. This mostly "younger" crude is being found to contain significantly higher "light ends" than what has been traditionally transported as UN 1267.

[30] In accordance with the programme of work of the Sub-Committee for 2013-2014 approved by the Committee at its sixth session (refer to ST/SG/AC.10/C.3/84, para. 86 and ST/SG/AC.10/40, para. 14).

3. This significant and exponential increased in surface movement of crude oil has led authorities within Canada and the United States of America to carefully consider transport safety impacts as well as potential impacts to the environment. These efforts have been prioritized based on a series of major accidents across North America involving crude oil transport by rail - including a catastrophic incident brought to the attention of the Sub-Committee at its previous session that caused numerous fatalities and destroyed much of Lac Mégantic, Quebec, in July 2013.

4. The increased production and experience has led to a renewed focus within North America on assessing the adequacy of the current provisions governing crude oil transport. While an assessment of relevant rail operational conditions have been major components of this effort, a significant portion of the experience gained is relevant to all modes and would benefit from broader review and discussion within the Sub-Committee. The purpose of this paper is to initiate discussions relevant to the experience recently gained, to raise important questions regarding the proper classification of - and transport provisions for – crude oil, and to invite the Sub-Committee to consider whether a review of the existing UN entries, assigned classifications, and transport provisions is warranted. This discussion may also eventually encumber other petroleum products such as natural gas condensates.

5. In particular, the Sub-Committee is invited to consider whether the current entries for crude oil in the Dangerous Goods List adequately distinguish between what can be significant variations in the flammable gas content of crude oils from different sources (see discussion below relevant to classification).

## Discussion

6. This document contains no proposals. The Sub-Committee is invited to provide feedback as a first step towards evaluating the efficacy of the current provisions of the Model Regulations based on an evolving understanding of the risks inherent in the transport of crude oil. Specifically, based on the information available on various types of crude oils in global transport today, the Sub-Committee is requested to provide feedback with respect to the classification and hazard communication elements of the Model Regulations currently applicable to crude oil.

(a) Classification

Unlike other Class 3 manufactured goods, organic materials from oil and gas production represent a unique challenge in regards to classification. Differences in the chemical makeup of the raw material can vary day-to-day and from well head-to-well head. Unprocessed crude oil may present unique hazards based on the specific dissolved gas content, posing different hazards in transport. Would further distinctions beyond merely identifying the Packing Group relevant to the flammable liquid hazard or the flammable gas content of the crude be appropriate to account for the differing hazards posed by what can be significant quantities of dissolved flammable gases? What is the most appropriate measure of this volatility – boiling point or vapour pressure? Is the proposed measurement method a calculation based on the properties of the material or an observed value? What are the most appropriate sampling and testing procedures? And finally, at what threshold should revisions to the regulatory requirements be considered?

(b) Hazard communication

The current flammable liquid entries in the Dangerous Goods List provide for a distinction in hazard by the assignment of Packing Groups based on the liquid's boiling and flash points. However, lighter crude oil with a higher quantity of dissolved flammable gases pose a significantly different risk than heavier crude oils that do not have such a high constituency of more volatile components. Would enhanced hazard communication distinguishing more volatile crude oils be beneficial for transport workers and emergency response personnel? If so, would a new table entry for such a material be sufficient?

## Conclusion

7. The Sub-Committee is invited to consider appropriate next steps to ensure that the provisions of the Model Regulations adequately address the risks posed by the transport of crude oil. Based on the feedback received at this session, the experts from Canada and the United States of America would be willing to prepare specific proposals for consideration at a future session.

**Appendix 4**

## Test methods used to evaluate selected Bakken Crude Oil Characteristics

1. Flashpoint *(Note: Some reported using the methods referenced in §173.120(c).)*
   - ASTM D56 Standard Test Method for Flash Point by Tag Closed Cup Tester
   - ASTM D93 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
   - ASTM D3278 Standard Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus

2. Initial boiling point *(Note: Some reported using the methods referenced in §173.121(a)(2).)*
   - ASTM D86 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure
   - ASTM D1160 Standard Test Method for Distillation of Petroleum Products at Reduced Pressure
   - ASTM D2887 Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
   - ASTM D5134 Standard Test Method for Detailed Analysis of Petroleum Naphthas through n-Nonane by Capillary Gas Chromatography
   - ASTM D7169 Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography

3. Vapor pressure
   - ASTM D2879 Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
   - ASTM D5191 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)

4. Flammable gas content
   - ASTM D-5134 Standard Test Method for Detailed Analysis of Petroleum Naphthas through n-Nonane by Capillary Gas Chromatography
   - ITM 6008 Light ends analysis by Gas Chromatography
   - IP 344 Determination of light hydrocarbons in stabilized crude oils - Gas chromatography method

5. Hydrogen sulfide content
   - ASTM D5705 Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils

- IP 507: Determination of boiling range distribution by gas chromatography method - Part 2: Heavy distillates and residual fuels
- UOP163 Hydrogen Sulfide and Mercaptan Sulfur in Liquid Hydrocarbons by Potentiometric Titration

6. Corrosivity to metal
    - NACE TM172 Standard Test Method - Determining Corrosive Properties of Cargoes in Petroleum Product Pipelines

## Appendix 5

Guide 128 from the 2012 ERG

# GUIDE 128 Flammable Liquids (Non-Polar/Water-Immiscible)

### FIRE OR EXPLOSION

- **HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**
- Vapors may form explosive mixtures with air.
- Vapors may travel to source of ignition and flash back.
- Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Vapor explosion hazard indoors, outdoors or in sewers.
- Those substances designated with a **(P)** may polymerize explosively when heated or involved in a fire.
- Runoff to sewer may create fire or explosion hazard.
- Containers may explode when heated.
- Many liquids are lighter than water.
- Substance may be transported hot.
- For UN3166, if Lithium ion batteries are involved, also consult GUIDE 147.
- **If molten aluminum is involved, refer to GUIDE 169.**

### HEALTH

- Inhalation or contact with material may irritate or burn skin and eyes.
- Fire may produce irritating, corrosive and/or toxic gases.
- Vapors may cause dizziness or suffocation.
- Runoff from fire control or dilution water may cause pollution.

- **CALL EMERGENCY RESPONSE Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind.
- Keep out of low areas.
- Ventilate closed spaces before entering.

### PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Structural firefighters' protective clothing will only provide limited protection.

### EVACUATION

**Large Spill**

- Consider initial downwind evacuation for at least 300 meters (1000 feet).

**Fire**

- If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions.

### FIRE

**CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.**

**CAUTION: For mixtures containing alcohol or polar solvent, alcohol-resistant foam may be more effective.**

**Small Fire**

- Dry chemical, $CO_2$, water spray or regular foam.

**Large Fire**

- Water spray, fog or regular foam.
- **Do not use straight streams**.
- Move containers from fire area if you can do it without risk.

**Fire involving Tanks or Car/Trailer Loads**

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from

area and let fire burn.

## SPILL OR LEAK

- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Prevent entry into waterways, sewers, basements or confined areas.
- A vapor suppressing foam may be used to reduce vapors.
- Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.
- Use clean non-sparking tools to collect absorbed material.

**Large Spill**

- Dike far ahead of liquid spill for later disposal.
- Water spray may reduce vapor; but may not prevent ignition in closed spaces.

## FIRST AID

- Move victim to fresh air.
- Call 911 or emergency medical service.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Remove and isolate contaminated clothing and shoes.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- Wash skin with soap and water.
- In case of burns, immediately cool affected skin for as long as possible with cold water. Do not remove clothing if adhering to skin.
- Keep victim warm and quiet.
- Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves

**Appendix 6**

Glossary of Terms and Acronyms

*AFPM* means the American Fuel & Petrochemical Manufacturers.

*DOT* means U.S. Department of Transportation.

*ERG* means the Emergency Response Guidebook produced by PHMSA in cooperation with the governments of Canada and Mexico and used throughout North America as the basis for the initial response to a hazardous materials emergency.

*Flashpoint* means the lowest temperature at which a liquid or gas produces a concentration of vapor in air that may be ignited.

$H_2S$ means hydrogen sulfide.

*HMR* the Hazardous Materials Regulations in 49 CFR Parts 105 to 180.

*IBP* means initial boiling point.

*OSHA* means the Occupational Safety and Health Administration.

*PHMSA* means the DOT Pipeline and Hazardous Materials Administration.

*Packing Group* means the degree of hazard assigned to materials subject to the DOT HMR according to specified criteria. Hazard levels of Packing Group I (high), II (medium) and III (low) are possible.

*RVP* means Reid Vapor Pressure.

STEL means short term exposure limit for a specific substance in air. The value is commonly based on 15 minutes exposure.

*TVP* means True Vapor Pressure.

# Operation Safe Delivery Update

## Executive Summary

Oil and gas production is at an historic high in the United States – a positive development for our economy and our energy independence – but the responsibilities that come along with that production are serious. More crude oil is being shipped by rail than ever before, and it is the U.S. Department of Transportation's responsibility to ensure these crude shipments travel safely.

USDOT is focused on ensuring the United States is the world leader in safely transporting energy, and we have taken more than two dozen steps to strengthen all the ways we deliver this oil, from issuing emergency orders to advancing new rail safety and tank car regulations.

On July 6, 2013, a train carrying 72 tank cars, each filled with 30,000 gallons of crude oil from the Bakken Shale Formation, derailed in a small resort village outside Quebec. A large part of the town, known as Lac-Megantic, was destroyed, and forty-seven of its people perished.

There were oil train derailments in North America before Lac-Megantic. There have been derailments since. And yet no event, as much as that one, has warned us to the dangers of transporting the continent's newfound bounty of energy.

The Lac-Megantic tragedy, along with other crude oil train derailments, made clear that we need to take steps to understand the risks associated with the transport of crude oil in growing volumes and better understand the characteristics of the product being shipped.

In August 2013, the Department embarked on Operation Classification in the Bakken Shale Formation, in the Williston Basin of North Dakota, where crude oil production has skyrocketed. Operation Classification is focused on ensuring shippers are properly classifying crude oil for transportation in accordance with federal regulations, and on better understanding the unique characteristics of mined gases and oils from this region.

We were particularly focused on the Bakken region because there was some question of whether the crude being produced there is more flammable, or more volatile, than most of the other types of crude being produced or shipped in this country. After months of unannounced inspections, testing, and analysis, Operation Classification has determined that the current classification applied to Bakken crude is accurate under the current classification system, but that the crude has a higher gas content, higher vapor pressure, lower flash point and boiling point and thus a higher degree of volatility than most other crudes in the U.S., which correlates to increased ignitability and flammability.

Importantly, our review of crude oil transportation data also confirmed that large volumes of this crude are moving at long distances across the country. At any given time, shipments of more than two million gallons are often traveling distances of more than one thousand miles. Put simply, Operation Classification determined that the U.S. is currently shipping a crude oil product with a higher gas content, lower flash point, lower boiling point and higher vapor pressure than other crude oils in large amounts and for long distances.

This report provides the Pipeline and Hazardous Materials Safety Administration's (PHMSA) and the Federal Railroad Administration's (FRA) testing results of Bakken crude oil as of May 2014.

## Background

The United States is in the midst of a historic increase in energy production. One significant area of domestic oil production is in Bakken Shale Formation, which covers approximately 200,000 square miles in Montana, North Dakota and Saskatchewan, Canada. Crude oil is the primary product being mined from the Bakken region, where oil production there has nearly tripled from 2010 to 2013.

Crude oil is being transported throughout North American and Canada through various modes of transportation, including pipelines, truck, barge and, increasingly, by rail.
In the vast majority of cases, these shipments reach their final destination without incident. Rail incidents have declined by 47 percent over the past decade and incidents involving the transportation of hazardous materials have declined by 16 percent.

Despite this progress, over the last year, a number of significant incidents involving Bakken crude have demonstrated the potential devastating consequences of a crude oil train derailment:

- Lac-Megantic, Quebec involving 63 tank cars out of 72;
- Aliceville, Alabama involving 26 tank cars out of 88;
- Casselton, North Dakota involving 20 tank cars out of 106;
- Lynchburg, Virginia involving 17 tank cars out of 105.

As the nation's regulator of hazardous materials by all modes, PHMSA requires the proper classification of hazardous materials. Proper classification of hazardous materials helps ensure the proper packaging is selected to safely transport the material. It also communicates the risks associated with the material to emergency responders and others who are likely to come in contact with the product as it moves through the transportation network, and in case of an incident.

Operation Classification activities include unannounced inspections, data collection and sampling at strategic terminal and loading locations for crude oil. PHMSA investigators continue to test samples from various points along the crude oil transportation chain: from cargo tanks that deliver crude oil to rail loading facilities, from storage tanks at the facilities, and from pipelines connecting storage tanks to rail cars that would move the crude across the country.

Operation Classification is part of DOT's broader effort called Operation Safe Delivery. Launched in 2013, Operation Safe Delivery is examining the entire system of crude oil delivery, from the well head to its final destination, and applying a comprehensive approach to ensure the safe transportation of crude oil moving by rail.

Additional DOT efforts to improve the safe transport of crude oil include:

- **Safety Communications and Alerts**—Concurrent with enforcement and rulemaking actions, the Department, FRA and PHMSA continue to address safety concerns by issuing emergency orders, safety advisories, safety alerts and other announcements. On May 7, 2014, for example, DOT required railroad carriers to inform first responders about crude oil being transported through their towns.
- **Regulatory Actions**—As recent derailments have proven, the current tank car most frequently used to transport crude oil – the DOT 111 – is not an adequate container for flammable crude oil involved in an incident or derailment. PHMSA and FRA have worked to update rail safety regulations, including those that address rail tank car standards as well as operating practices that would enhance rail safety.
- **A Call to Action**— On January 16, 2014, Secretary Foxx issued a Call to Action, to the rail and petroleum industries, to identify immediate actions to improve safety in the transportation of crude oil by rail. Following the Call to Action, railroad companies agreed to a series of significant safety measures, including speed reductions, increased inspections, the implementation of new brake technology, new routing protocols, and investments in first responder training.
- **Safety Education and Awareness**—PHMSA and FRA continue to provide resources to educate industry, the public, and emergency responders about safe transportation of hazardous materials.
- **Field Inspections, Testing and Enforcement Actions**—PHMSA and FRA continue to conduct hazardous materials field inspections, crude oil testing and, when necessary, issue enforcement penalties.

## The Classification of Petroleum Crude Oil

PHMSA issues the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) that prescribe requirements for the safe transportation of hazardous materials by all modes. The proper classification of any hazardous material is required prior to offering it into transportation. Packaging selection, marking, labeling, shipping papers and placarding are all dependent upon this first, critical step.

Each entity that offers hazardous materials for transportation is considered a shipper (i.e., both initial offerors and subsequent downstream offerors). It is the shipper's responsibility to properly classify and describe a hazardous material, including determining the constituents present and any multiple hazard classes present.

Each shipment of hazardous materials must be accompanied by a shipping paper that must include a statement certifying that the material is in compliance with all appropriate regulations, including classification and packaging. In summary, anyone offering a hazardous material for shipment must:

1. Properly identify all the **hazards** of the material.
2. Determine which of the **nine hazard classes** characterizes the hazards associated with the material.
3. Assign each material to a **packing group**, if applicable.

***Hazard Classes:*** The HMR has nine hazard classes that define the type of risk a hazardous material poses. Some materials meet the definition of more than one hazard class with primary risks and subsidiary risks. Some hazard classes contain divisions in order to further group materials with similar risks and designate higher degrees of a particular hazard. [See Hazardous Materials Hazard Class/Division Table 49 CFR § 173.2]

***Packing Group (PG):*** Once classified, some hazardous materials are assigned to one of three packing groups based upon their degree of hazard, from a great hazard (PG I) to a minor hazard (PG III) material. The quality, damage resistance, and performance standards of the package authorized in each packing group are designed for the hazards of the material transported.

The hazard class and packing group for a material meeting more than one of these hazard classes shall be determined using the precedence table in 49 CFR § 173.2a(b).

The following list illustrates the hazard classes and sub-divisions that need to be considered, at a minimum, for mined gases and liquids based on knowledge of the material.

(1) Class 2, Division 2.3 (poisonous gases) [49 CFR § 173.115]

(2) Class 2, Division 2.1 (flammable gases) [49 CFR § 173.115]

(3) Class 2, Division 2.2 (nonflammable gases) [49 CFR § 173.115]

(4) Class 6, Division 6.1 (poisonous liquids), PG I, poisonous-by-inhalation only [49 CFR § 173.132]

(5) Class 3 (flammable liquids) [49 CFR § 173.120]

(6) Class 8 (corrosive materials) [49 CFR § 173.136] or Division 6.1 (poisonous liquids or solids other than PG I, poisonous-by-inhalation) [49 CFR § 173.132]

(7) Class 3 (combustible liquids) [49 CFR § 173.120]

Provided a particular crude oil does not meet the definition of a gas or poisonous-by-inhalation liquid, and it meets the definition of a flammable liquid, it would be classified and transported as a flammable liquid.

***Flammable Liquid Hazard Class:*** A flammable liquid (Class 3) means a liquid having a flash point of not more than 140 °F, or any material in a liquid phase with a flash point at or above 100 °F that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging. There are five exceptions, see (HMR §173.120 (a) (1-5)). Flash point is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

For flammable liquids (Class 3), the packing groups are defined below.

**Hazardous Materials Packing Groups Table**

| Packing Group | Flash Point | Initial Boiling Point |
|---|---|---|
| **I** (Great Danger) | | ≤ 95 °F |
| **II** (Medium Danger) | < 73 °F | > (95 °F |
| **III** (Minor Danger) | ≥ 23 °C, ≤ 60 °C (140 °F) | > (95 °F |

On March 6, 2014, DOT issued an amended Emergency Order (EO) requiring all rail shippers to test product from the Bakken region. That way, they can ensure the proper classification of crude oil in accordance with the HMR before it's transported by rail.

The Emergency Order also requires those who ship bulk quantities of petroleum crude oil – and do so by rail with tank cars – to treat petroleum crude oil as a Class 3 PG I or PG II hazardous material only, even if it tests as PG III.

## Analysis and Classification

The intent of Operation Safe Delivery's sampling and analysis component is to determine if shippers are properly classifying crude oil for transportation. The intent is also to quantify the range of physical and chemical properties of crude oil.

Prior to the launch of our sampling and analysis, FRA identified that most crude oil loading facilities were basing classification solely on a generic Safety Data Sheet (SDS), formerly known as Material Safety Data Sheets (MSDS). This data can provide a wide range of material properties. SDSs provide workers and emergency personnel with procedures for handling or working with a substance in a safe manner, and include information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures. PHMSA observed that SDSs for crude oil were out-of-date with unverified information and provide ranges of chemical and physical property values instead of specific measured values. Further, these ranges may cross the threshold between PG I, II and III making it difficult to assign the proper packing group. Given the potential variability of crude oil, PHMSA and FRA believed that operators' reliance on generic information was a safety concern.

Based on the initial findings and shippers' reliance on SDS, the operation was expanded to take more samples and test for additional chemical composition and properties including vapor pressure, corrosivity and chemical components of the materials. PHMSA performed the following series of sampling and testing activities.

**Legend**

FP – Flash Point
BP – Initial Boiling Point
API – American Petroleum Institute Specific Gravity
ASTM – American Society for Testing of Materials
RVP – Reid Vapor Pressure
TVP – True Vapor Pressure
BTEX – Benzene/Toluene/Ethylbenzene/Xylene content
Comp – Gas/Liquid composition
W&S – Water & Sediment content
Sulfur – Sulfur content
H2S – Hydrogen Sulfide content
Corrosion – Steel/Aluminum

**PHMSA Sampling and Testing Activities Summary**

| # Samples Tested | Period | Tests Completed | Test Lab | Mean Ambient Temps |
|---|---|---|---|---|
| 14 | August, 2013 | FP | Minnesota Valley Test Lab | 78 °F |
| 21 | September – October, 2013 | FP, BP | Intertek | 44 °F - 66 °F |
| 12 | November, 2013 | FP, BP, API, RVP, Comp, W&S, Sulfur, H2S, BTEX | Intertek | 24 °F |
| 88 | February-May, 2014 | FP, BP, RVP, TVP, Comp, H2S, BTEX, Corrosion | Intertek | 10 °F - 55 °F |
| Total Samples Tested: 135 | | | | |

Below is a table summarizing the two phases of testing and sampling performed pursuant to Operation Safe Delivery.

| Date | August – November | February - May |
|---|---|---|
| **Summary** | The initial efforts of this phase were focused on determining and verifying hazard classes and packaging group selection. Tests focused on flash point and boiling point and then expanded to address other chemical characteristics of crude oil. | The goal of Phase 2 was to gain a more complete understanding (beyond flash and boiling points) of the properties of crude oil and collect a more representative sample of the transportation population. A continuous rotation of investigators was present in the Bakken region during this phase. These investigators collected more samples from various points in the transportation stream. |

| | | |
|---|---|---|
| **Samples Taken** | 47 Total Samples from rail loading facilities and cargo tanks, storage tanks, pipelines used to load rail cars and several were collected from cargo tanks. All samples were collected in accordance with ASTM 4057, "Standard Practice for Manual Sampling of Petroleum and Petroleum Products. | 88 Total Samples from rail loading facilities and cargo tanks, storage tanks, pipelines used to load rail cars and several were collected from cargo tanks. Samples were collected via a syringe-style cylinder in accordance with ASTM 4057, "Standard Practice for Manual Sampling of Petroleum and Petroleum Products. |
| **ASTM Tests Conducted** | Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method) (ASTM D323).<br><br>Standard Test Method for Determination of Individual Components of Crude Oil (ASTM D6730 MOD).<br><br>Standard Test Method for Water and Sediment in Crude Oil (ASTM D4007).<br><br>Standard Test Method for Sulfur in Petroleum and Petroleum Products (ASTM D4294).<br><br>Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils Hydrogen Sulfide Content (ASTM D5705).<br><br>Standard Test Method for Density and Relative Density for Crude Oil (ASTM D5002).<br><br>Standard Test Method for Flash Point by Tag Closed Cup Tester (ASTM D56).<br><br>Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure (ASTM D86). | Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method) (ASTM D323).<br><br>Standard Test Method for Determination of Individual Components of Crude Oil (ASTM D6730 MOD).<br><br>Standard Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils Hydrogen Sulfide Content (ASTM D5705).<br><br>Standard Test Method for Flash Point (FP) by Tag Closed Cup Tester (ASTM D56).<br><br>Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure, Initial Boiling Point (IBP) (ASTM D86).<br><br>Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method) for both Vapor/Liquid ratios of 0.02 (at 122 °F) and 4 (at 100 °$^{0}$F).<br><br>U.N. Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Chapter 37 (corrosion to aluminum and carbon steel). |

## Summary and Test Results

**Total Samples Taken: 47 total samples (August – November, 2013)**

The first set of testing began with taking samples from several locations, and with limited analysis that included flash point and boiling point to determine if petroleum crude oil was being properly classified and packaged. The effort continued through the fall of 2013 based upon observations from investigators and testing results.

During the week of August 26-30, 2013, PHMSA and FRA investigators conducted joint activities at 14 crude oil transfer locations in North Dakota. The summary of the results from these samples are provided in Table A.

Investigators observed that facility analyses only determined viscosity, solid content, and sulfur content. PHMSA acquired a total of 14 samples at these locations. Analytical results indicated that the materials had a flash point less than 73°F, indicating that, at a minimum, PG II must be assigned to the material.

Boiling point information was not determined because the lab conducting the testing did not have adequate equipment to test for boiling point. So, final determination of a packing group was not possible. The results are provided in Table A.

**Table A**
**Crude Oil Samples (August 26-30, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| #1 | New Town, ND | <73 | Not Analyzed | I or II |
| #2 | New Town, ND | <73 | Not Analyzed | I or II |
| #3 | Berthold, ND | <73 | Not Analyzed | I or II |
| #4 | Stanley, ND | <73 | Not Analyzed | I or II |
| #5 | Fairview, ND | <73 | Not Analyzed | I or II |
| #6 | Trenton, ND | <73 | Not Analyzed | I or II |
| #7 | Dore, ND | <73 | Not Analyzed | I or II |
| #8 | Epping, ND | <73 | Not Analyzed | I or II |
| #9 | Tioga, ND | <73 | Not Analyzed | I or II |
| #10 | Ross, ND | <73 | Not Analyzed | I or II |
| #11 | Dickinson, ND | <73 | Not Analyzed | I or II |
| #12 | Dickinson, ND | <73 | Not Analyzed | I or II |
| #13 | Belfield, ND | <73 | Not Analyzed | I or II |
| #14 | Scranton, ND | <73 | Not Analyzed | I or II |

The week of September 9, 2013, PHMSA and FRA investigators collected samples at three additional rail loading facilities. The samples were analyzed for flash point and boiling point. Two of the samples met criteria as a PG II and one sample met criteria as a PG I. The results are provided in Table B.

**Table B**
**Crude Oil Samples (September 9, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| #1 | Epping, ND | <40 | 96.5 | II |
| #2 | Ross, ND | <40 | 96.2 | II |
| #3 | Tioga, ND | <40 | 81 | I |

From October 8-10, 2013, PHMSA and Federal Motor Carrier Safety Administration (FMCSA) investigators collected 18 samples from cargo tank motor vehicles at roadside inspections or at loading/unloading terminals. Of the 18 samples tested, 10 samples met criteria as PG I and eight samples met criteria related to this testing as PG II. The results from these tests are provided in Table C.

**Table C**
**Crude Oil Samples (October 8-10, 2013)**

| Sample | Location | Flash Point (°F) | Boiling Point (°F) | Packing Group |
|---|---|---|---|---|
| #1 | Portal, ND | < 50 | 102.7 | II |
| #2 | Portal, ND | < 50 | 123.8 | II |
| #3 | Docado--SWSW 11-162N-98W (Divide Cty, ND) | < 50 | 108.1 | II |
| #4 | Zimmerman 3-13H | < 50 | 96.8 | II |
| #5 | Plano 1-28H | < 50 | 103.7 | II |
| #6 | SW/SW sec.12-7151N- Rigaw (Mckenzie Cty, ND) | < 50 | 118.3 | II |
| #7 | Cora Martin Battery 12345 Tank #2380 | < 50 | 96.7 | II |
| #8 | Cora Martin Battery 12345 Tank #2395 | < 50 | 89 | I |
| #9 | BB- State H3 (McKenzie Cty, ND) | < 50 | 92.1 | I |
| #10 | SW-SE Section 34 Township 152 Dir N | < 50 | 92.6 | I |
| #11 | HA Nelson A Facility 152-95-3427 | < 50 | 91.9 | I |
| #12 | SW-SE Section 2 Township Dir N Tank Lact L8515 | < 50 | 89 | I |
| #13 | AV-Wrigley-163-94-0607H-1 (Burke Cty, ND) | < 50 | 96.2 | II |
| #14 | SESW-8-154-93 (Mountrail, ND) | < 50 | 88.9 | I |
| #15 | SE-SE Section 9 Township 156 Dir N Range 93 Dir W (Mountrax Cty, ND) | < 50 | 87.6 | I |
| #16 | SC Ellingsberg 32-29 H-2 25697 (Williams Cty, ND) | < 50 | 90.9 | I |
| #17 | Cora Martin Battery 12345 Tank #2377 | < 50 | 91.6 | I |
| #18 | Cora Martin Battery 12345 Tank #2388 | < 50 | 92.1 | I |

During the week of November 5, 2013, PHMSA investigators collected 12 samples, including eight samples from the discharge of cargo tanks into bulk storage tanks at rail loading facilities. The remaining four samples were taken from bulk storage tanks at a rail loading facility. The scope of testing was expanded to determine vapor pressure, gas and liquid composition, corrosivity, and toxicity, density, flash point and boiling point.

The results from these analyses are provided in Table D.

**Table D**
**Crude Oil Samples (Week of November 5, 2013)**

| Sample | Location | Reid Vapor Pressure (psia) | Methane (% Vol) | Ethane (% Vol) | Propane (% Vol) | Butane (incl. isomers) (% Vol) | Water & Sediment Content (% Vol) | Sulfur Content (% Wt) | Hydrogen Sulfide Content (ppm) | API Gravity @60°F | Flash Point (°F) | Initial Boiling Point (°F) | Packing Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #1 | Killdeer, ND | 10.4 | <0.01 | 0.12 | 1.17 | 2.94 | 0.05 | 0.123 | <5 | 39.9 | < 32 | 88.2 | I |
| #2 | Beulah, ND | 10.05 | <0.01 | 0.13 | 1.17 | 2.89 | 0.05 | 0.121 | <5 | 40.0 | < 32 | 104.2 | II |
| #3 | Killdeer, ND | 8.70 | <0.01 | 0.05 | 0.81 | 2.70 | 0.10 | 0.117 | < 5 | 41.4 | < 32 | 89.1 | I |
| #4 | Beulah, ND | 8.80 | < 0.01 | 0.05 | 0.86 | 2.80 | 0.10 | 0.128 | < 5 | 41.5 | < 32 | 92.6 | I |
| #5 | Killdeer, ND | 11.45 | < 0.01 | 0.06 | 1.00 | 3.19 | 0.05 | 0.112 | < 5 | 42.0 | < 32 | 91.1 | I |
| #6 | Beulah, ND | 11.75 | < 0.01 | 0.07 | 1.14 | 2.21 | 0.10 | 0.111 | < 5 | 42.4 | < 32 | 84.6 | I |
| #7 | Killdeer, ND | 9.20 | < 0.01 | 0.06 | 0.96 | 2.91 | 0.05 | 0.117 | < 5 | 41.1 | < 32 | 95.6 | II |
| #8 | Tioga, ND | 10.80 | < 0.01 | 0.08 | 1.08 | 3.06 | 0.05 | 0.116 | < 5 | 41.4 | < 32 | 85.9 | I |
| #9 | New Town, ND | 9.50 | < 0.01 | 0.04 | 0.76 | 2.72 | 0.05 | 0.148 | < 5 | 41.2 | < 32 | 93.7 | I |
| #10 | New Town, ND | 10.90 | < 0.01 | 0.12 | 1.21 | 2.41 | 0.05 | 0.0844 | < 5 | 43.8 | < 32 | 85.5 | I |
| #11 | Epping, ND | 7.70 | < 0.01 | 0.03 | 0.61 | 2.42 | 0.10 | 0.114 | < 5 | 42.0 | < 32 | 95.6 | II |
| #12 | Dickinson, ND | 8.75 | < 0.01 | 0.06 | 0.82 | 2.68 | 0.10 | 0.0856 | < 5 | 42.8 | < 32 | 91.7 | I |

## Summary and Test Results

**Total Samples Taken: 88 total samples (February – May, 2014)**

The second phase of testing involved additional inspectors on a continual rotation in the Bakken region to collect samples. The majority of the samples were collected at rail loading facilities from storage tanks and pipelines that were used to load rail cars. Several were collected from cargo tanks. Four of the samples collected were drawn using a closed syringe-style cylinder connected to loading pipeline to determine if there were differences from previous samples collected using the open container sampling method. The results are provided as Table E. The following tests were conducted:

**Table E**

**Crude Oil Samples (February – May, 2014)**

| Company Name | City | State | Sample Date | Test Date | Flash Point (deg. F) | Initial Boiling Point (deg. F) | VPCR 0.02 @122 deg. F (psia) | VPCR 4 @ 100 deg. F (psia) | Methane (%Vol) | Ethane (% Vol) | Propane (% Vol) | Butane (% Vol) | Hydrogen Sulfide (ppm) | Corrosivity (% Weight Loss) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bakken Oil Express LLC | Dickinson | ND | 02/24/14 | 03/03/14 | < 50 | 88.1 | 27.0 | 11.1 | 0 | 0.2079 | 1.2461 | 3.1643 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 89.3 | 27.8 | 11.4 | 0 | 0.2256 | 1.2991 | 3.2295 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 97.5 | 25.7 | 11.1 | 0 | 0.2015 | 1.2461 | 3.1735 | <1 | |
| | | | 02/24/14 | 03/03/14 | < 50 | 93.1 | 27.7 | 12.2 | 0 | 0.2586 | 1.4587 | 3.4972 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 89.0 | 29.8 | 12.5 | 0 | 0.2206 | 1.3773 | 3.423 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 93.6 | 28.3 | 12.7 | 0 | 0.2574 | 1.4409 | 3.3963 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.1 | 26.9 | 10.8 | 0 | 0.1746 | 1.0088 | 2.8672 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 89.4 | 26.7 | 10.7 | 0 | 0.1735 | 1.0093 | 2.8324 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.3 | 23.4 | 10.5 | 0 | 0.184 | 1.0543 | 2.9483 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 83.8 | 24.3 | 11.6 | 0 | 0.2233 | 1.3951 | 3.4341 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 86.2 | 28.2 | 12.4 | 0 | 0.2347 | 1.384 | 3.3272 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 87.2 | 30.2 | 12.5 | 0 | 0.2251 | 1.4192 | 3.4896 | <1 | |
| Dakota Plains/Strobel Starostka | New Town | ND | 02/25/14 | 03/03/14 | <50 | 90.5 | 31.2 | 13.1 | 0 | 0.2192 | 1.5254 | 3.735 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 92.8 | 28.6 | 11.8 | 0 | 0.1379 | 1.279 | 3.521 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02/25/14 | 03/02/14 | < 50 | 86.4 | 27.7 | 12.2 | 0 | 0.1359 | 1.2462 | 3.4476 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC | Beuthold | ND | 02/26/14 | 03/03/14 | < 50 | 93.5 | 26.7 | 11.2 | 0 | 0.1945 | 1.2662 | 3.2127 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 89 | 26.4 | 11.1 | 0 | 0.1975 | 1.2624 | 3.1692 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 92.5 | 26.8 | 11.2 | 0 | 0.2182 | 1.3064 | 3.2112 | <1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 02/25/14 | 03/03/14 | < 50 | 88.4 | 29.3 | 13.3 | 0 | 0.1194 | 1.1389 | 3.3152 | <1 | 0** |
| | | | 02/25/14 | 03/03/14 | < 50 | 85.7 | 28.5 | 13.3 | 0 | 0.2099 | 1.5419 | 3.7439 | <1 | |
| | | | 02/25/14 | 03/03/14 | < 50 | 86.8 | 29.4 | 13.4 | 0 | 0.2112 | 1.5539 | 3.7434 | <1 | |
| | | | | | | | | | | | | | | |
| Plains Marketing, LP | Ross | ND | 02/26/14 | 03/02/14 | < 50 | 81.8 | 28.7 | 14.2 | 0 | 0.2005 | 1.7301 | 4.1952 | <1 | |
| | | | 02/26/14 | 03/02/14 | < 50 | 80.6 | 29.0 | 15.1 | 0 | 0.2858 | 1.9851 | 4.4043 | <1 | |
| | | | 02/26/14 | 03/02/14 | < 50 | 83.8 | 29.0 | 13.3 | 0 | 0.3158 | 2.0843 | 4.48 | <1 | |
| | | | | | | | | | | | | | | |
| Inergy Crude Logistics, LP | Epping | ND | 02/26/14 | 03/03/14 | < 50 | 85.5 | 28.3 | 13.5 | 0 | 0.3064 | 1.5878 | 3.5817 | <1 | 0** |
| | | | 02/26/14 | 03/03/14 | < 50 | 84.9 | 28.7 | 13.6 | 0 | 0.2963 | 1.5604 | 3.5526 | <1 | |
| | | | 02/26/14 | 03/03/14 | < 50 | 84.7 | 29.8 | 13.6 | 0 | 0.2965 | 1.606 | 3.6625 | <1 | |
| | | | | | | | | | | | | | | |
| Great Northern Gathering & Marketing | Fryburg | ND | 02/26/14 | 03/10/14 | < 50 | 86.7 | 26.2 | 11.5 | 0 | 0.2635 | 1.399 | 3.3975 | <1 | |
| | | | 02/26/14 | 03/10/14 | < 50 | 87.0 | 27.1 | 11.3 | 0 | 0.3138 | 1.617 | 3.8413 | <1 | |
| | | | 02/26/14 | 03/10/14 | < 50 | 90.8 | 26.4 | 11.1 | 0 | 0.3204 | 1.5856 | 3.7071 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Stampede | Stampede | ND | 02/27/14 | 03/10/14 | <50 | 88.0 | 28.2 | 12.4 | 0 | 0.1719 | 1.2974 | 3.3689 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 88.1 | 25.5 | 12.5 | 0 | 0.2685 | 1.7044 | 3.8848 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 87.7 | 29.5 | 12.9 | 0 | 0.3153 | 1.9675 | 4.4686 | <1 | |
| | | | | | | | | | | | | | | |
| Musket Corp. | Dickinson | ND | 02/27/14 | 03/10/14 | <50 | 86.7 | 28.5 | 13.4 | 0 | 0.2329 | 1.5192 | 3.6576 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02/27/14 | 03/10/14 | <50 | 84.5 | 28.7 | 13.4 | 0 | 0.241 | 1.5076 | 3.6036 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 88.0 | 28.1 | 13.3 | 0 | 0.2711 | 1.6539 | 3.9135 | <1 | |
| | | | | | | | | | | | | | | |
| Red River Supply | Williston | ND | 02/27/14 | 03/10/14 | <50 | 88.7 | 28.4 | 13.0 | 0 | 0.2631 | 1.3361 | 3.0534 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 89.0 | 29.1 | 13.3 | 0 | 0.3444 | 1.7621 | 4.0086 | <1 | |
| | | | 02/27/14 | 03/10/14 | <50 | 87.5 | 28.6 | 12.9 | 0 | 0.3953 | 1.9241 | 4.3453 | <1 | |
| | | | | | | | | | | | | | | |
| Great Northern Gathering & Marketing | Fryburg | ND | 02/27/14 | 03/10/14 | <50 | 91.7 | 26.8 | 11.2 | 0 | 0.2265 | 1.4366 | 3.7671 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Beulah | Beulah | ND | 02/28/14 | 03/10/14 | <50 | 83.3 | 30.0 | 11.8 | 0 | 0.227 | 1.3635 | 3.5145 | <1 | |
| | | | 02/28/14 | 03/10/14 | <50 | 87.3 | 26.3 | 10.6 | 0 | 0.1877 | 1.3101 | 3.566 | <1 | |
| | | | 02/28/14 | 03/10/14 | <50 | 88.1 | 25.2 | 11.2 | 0 | 0.2195 | 1.4373 | 3.9621 | <1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 03/04/14 | 03/07/14 | < 50 | 87.9 | 26.6 | 12.1 | 0 | 0.2312 | 1.5577 | 3.7271 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 89.3 | 28.3 | 12.6 | 0 | 0.2393 | 1.5617 | 3.6901 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC | Berthold | ND | 03/04/14 | 03/07/14 | <50 | 93.6 | 26.4 | 11.4 | 0 | 0.1743 | 1.1727 | 3.062 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 88.9 | 26.1 | 11.3 | 0 | 0.1645 | 1.1517 | 3.0522 | <1 | |
| | | | | | | | | | | | | | | |
| Savage | Trenton | ND | 03/04/14 | 03/07/14 | <50 | 84.4 | 27.5 | 12.7 | 0 | 0.2583 | 1.5151 | 3.5849 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 87.1 | 28.7 | 13.1 | 0 | 0.248 | 1.4652 | 3.5252 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 88.8 | 30.0 | 13.1 | 0 | 0.2667 | 1.5277 | 3.5926 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 84.1 | 29.2 | 13.2 | 0 | 0.2743 | 1.5579 | 3.6289 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 85.0 | 26.1 | 13.1 | 0 | 0.2364 | 1.4313 | 3.4846 | <1 | |
| | | | 03/04/14 | 03/07/14 | <50 | 86.6 | 29.5 | 13.0 | 0 | 0.2251 | 1.4072 | 3.4837 | <1 | |
| | | | | | | | | | | | | | | |
| Plains All | New Town | ND | 03/04/14 | 03/11/14 | <50 | 83.7 | 31.2 | 13.3 | 0 | 0.2538 | 1.6544 | 3.9182 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American | | | | | | | | | | | | | | |
| | | | 03/04/14 | 03/11/14 | <50 | 82.7 | 28.1 | 13.4 | 0 | 0.2456 | 1.6288 | 3.8824 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 87.3 | 30.1 | 13.6 | 0 | 0.2062 | 1.5219 | 3.7927 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 87.3 | 29.7 | 13.4 | 0 | 0.2602 | 1.6871 | 3.9719 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 86.9 | 29.0 | 13.5 | 0 | 0.2584 | 1.6681 | 3.9274 | <1 | |
| | | | 03/04/14 | 03/11/14 | <50 | 86.7 | 32.1 | 14.1 | 0 | 0.2649 | 1.6666 | 3.8536 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Stampede | Stampede | ND | 03/10/14 | 03/17/14 | <50 | 88.5 | 28.6 | 12.8 | 0 | 0.2709 | 1.5797 | 3.7126 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 90.8 | 29.2 | 13.2 | 0 | 0.2988 | 1.6097 | 3.6708 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 86.7 | 28.0 | N/A | 0 | 0.259 | 1.5127 | 3.6046 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 89.2 | 27.8 | 13.0 | 0 | 0.2869 | 1.6188 | 3.7266 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 89.8 | 29.1 | 13.3 | 0 | 0.2495 | 1.4623 | 3.5335 | <1 | |
| | | | 03/10/14 | 03/17/14 | <50 | 91.3 | 27.2 | 13.2 | 0 | 0.294 | 1.6143 | 3.712 | <1 | |
| | | | | | | | | | | | | | | |
| Basin Transload/Global Beulah | Beulah | ND | 03/11/14 | 03/17/14 | <50 | 92.3 | 24.9 | 10.1 | 0 | 0.1556 | 0.9818 | 2.7378 | <1 | |
| | | | | | | | | | | | | | | |
| Bakken Oil Express LLC | Dickinson | ND | 03/12/14 | 03/17/14 | <50 | 88.0 | 26.1 | 12.2 | 0 | 0.2476 | 1.3834 | 3.3223 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 87.7 | 26.3 | 11.7 | 0 | 0.232 | 1.3385 | 3.2275 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 88.9 | 20.3 | 11.6 | 0 | 0.2368 | 1.333 | 3.2269 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.9 | 26.8 | 11.7 | 0 | 0.2235 | 1.3089 | 3.2207 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 87.1 | 27.2 | 11.9 | 0 | 0.2034 | 1.241 | 3.1276 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.1 | 27.0 | 11.8 | 0 | 0.233 | 1.3208 | 3.2072 | < 1 | |
| | | | 03/12/14 | 03/17/14 | <50 | 92.3 | 27.4 | 11.7 | 0 | 0.2211 | 1.2849 | 3.1663 | < 1 | |
| | | | | | | | | | | | | | | |
| EOG Resources | Stanley | ND | 03/13/14 | 03/18/14 | <50 | 89.6 | 27.20 | 12.24 | 0 | 0.1845 | 1.4065 | 3.5213 | <1 | |
| | | | 03/13/14 | 03/18/14 | <50 | 86.6 | 27.02 | 12.03 | 0 | 0.1849 | 1.3732 | 3.4601 | <1 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 03/13/14 | 03/18/14 | <50 | 94.0 | 26.80 | 12.24 | 0 | 0.1913 | 1.4155 | 3.5186 | <1 | |
| | | | | | | | | | | | | | | |
| Hess Corporation | Tioga | ND | 03/11/14 | 03/15/14 | <50 | 85.8 | 27.12 | 14.38 | 0 | 0.23 | 1.8 | 4.02 | <1 | |
| | | | | | | | | | | | | | | |
| Inergy Crude Logistics, LP | Epping | ND | 03/18/14 | 03/21/14 | <50 | 86.6 | 28.89 | 13.29 | 0 | 0.1961 | 1.3918 | 3.5 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 94.4 | 28.34 | 13.7 | 0 | 0.2251 | 1.51 | 3.626 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 88.4 | 29.84 | 13.82 | 0 | 0.2484 | 1.5539 | 3.649 | <1 | |
| | | | 03/18/14 | 03/21/14 | <50 | 92.3 | 23.04 | 10.22 | 0 | 0.0571 | 0.8493 | 3.0056 | <1 | |
| | | | | | | | | | | | | | | |
| Hess Corporation | Tioga | ND | 03/17/14 | 03/20/14 | <50 | 79.1 | 25.26 | 13.64 | 0 | 0.217 | 1.7327 | 4.1573 | <1 | |
| | | | | | | | | | | | | | | |
| Enbridge Rail, LLC* | Berthold | ND | 04/28/14 | 05/01/14 | <50 | 88.5 | 39.36 | 11.31 | <0.01 | 0.19 | 1.2 | 3.07 | <1 | |
| | | | 04/26/14 | 05/01/14 | <50 | 87.2 | 24.71 | 10.97 | <0.01 | 0.21 | 1.32 | 3.31 | N/A | |
| | | | 04/26/14 | 05/01/14 | <50 | 85.9 | 26.35 | 11.29 | <0.01 | 0.21 | 1.29 | 3.24 | N/A | |
| | | | | | | | | | | | | | | |
| Plains Marketing, LP* | Ross | ND | 04/30/14 | 05/02/14 | <50 | 84.2 | 36.73 (0.05) | 14.28 | <0.01 | 0.29 | 1.95 | 4.44 | N/A | |
| Great Northern Gathering & Marketing* | Fryburg | ND | 05/01/14 | 05/05/14 | <50 | 86.7 | 37.21 | 11.12 | <0.01 | 0.2 | 1.16 | 3.05 | N/A | |
| Dakota Plains/Strobel Starostka* | Newtown | ND | 05/02/14 | 05/05/14 | <50 | 84.1 | 31.12 | 11.47 | <0.01 | 0.15 | 1.24 | 3.32 | N/A | |

## Conclusion

Based upon the results obtained from sampling and testing of the 135 samples from August 2013 to May 2014, the majority of crude oil analyzed from the Bakken region displayed characteristics consistent with those of a Class 3 flammable liquid, PG I or II, with a predominance to PG I, the most dangerous class of Class 3 flammable liquids. Based on our findings, we conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude– which correlates to increased ignitability and flammability.

Bakken crude's high volatility level – a relative measure of a specific material's tendency to vaporize – is indicated by tests concluding that it is a "light" crude oil with a high gas content, a low flash point, a low boiling point and high vapor pressure. The high volatility of Bakken crude oil, and its identification as a "light" crude oil, is attributable to its higher concentrations of light end hydrocarbons. This distinguishes it from "heavy" crude oil mined in other parts of the United States,

Given Bakken crude oil's volatility, there is an increased risk of a significant incident involving this material due to the significant volume that is transported, the routes and the extremely long distances it is moving by rail. Trains transporting this material, referred to as unit trains, routinely contain more than 100 tank cars, constituting at least 2.5 million gallons within a single train. Unit trains only carry a single type of product, in this case flammable crude oil. These trains often travel over a thousand miles from the Bakken region to refinery locations along the coasts.

PHMSA and FRA plan to continue the sampling and analysis activities of Operation Safe Delivery through the summer and fall of 2014 and to work with the regulated community to ensure the safe transportation of crude oil across the nation. The Department will continue to keep the public, regulated entities and emergency responders informed about our efforts.

###

Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

# RAILWAY INVESTIGATION REPORT R13D0054

## RUNAWAY AND MAIN-TRACK DERAILMENT

## MONTREAL, MAINE & ATLANTIC RAILWAY FREIGHT TRAIN MMA-002 MILE 0.23, SHERBROOKE SUBDIVISION LAC-MÉGANTIC, QUEBEC 06 JULY 2013

Canada

Transportation Safety Board of Canada
Place du Centre
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741
1-800-387-3557
www.tsb.gc.ca
communications@bst-tsb.gc.ca


Cat. No. TU3-6/13-0054E
ISBN 978-1-100-24860-8

# Railway Investigation Report R13D0054

# Runaway and main-track derailment

# Montreal, Maine & Atlantic Railway
# Freight train MMA-002
# Mile 0.23, Sherbrooke Subdivision
# Lac-Mégantic, Quebec
# 06 July 2013

## *Summary*

On 06 July 2013, shortly before 0100 Eastern Daylight Time, eastward Montreal, Maine & Atlantic Railway freight train MMA-002, which was parked unattended for the night at Nantes, Quebec, started to roll. The train travelled approximately 7.2 miles, reaching a speed of 65 mph. At around 0115, when MMA-002 approached the centre of the town of Lac-Mégantic, Quebec, 63 tank cars carrying petroleum crude oil (UN 1267) and 2 box cars derailed. About 6 million litres of petroleum crude oil spilled. There were fires and explosions, which destroyed 40 buildings, 53 vehicles, and the railway tracks at the west end of Megantic Yard. Forty-seven people were fatally injured. There was environmental contamination of the downtown area and of the adjacent river and lake.

*Ce rapport est également disponible en français.*

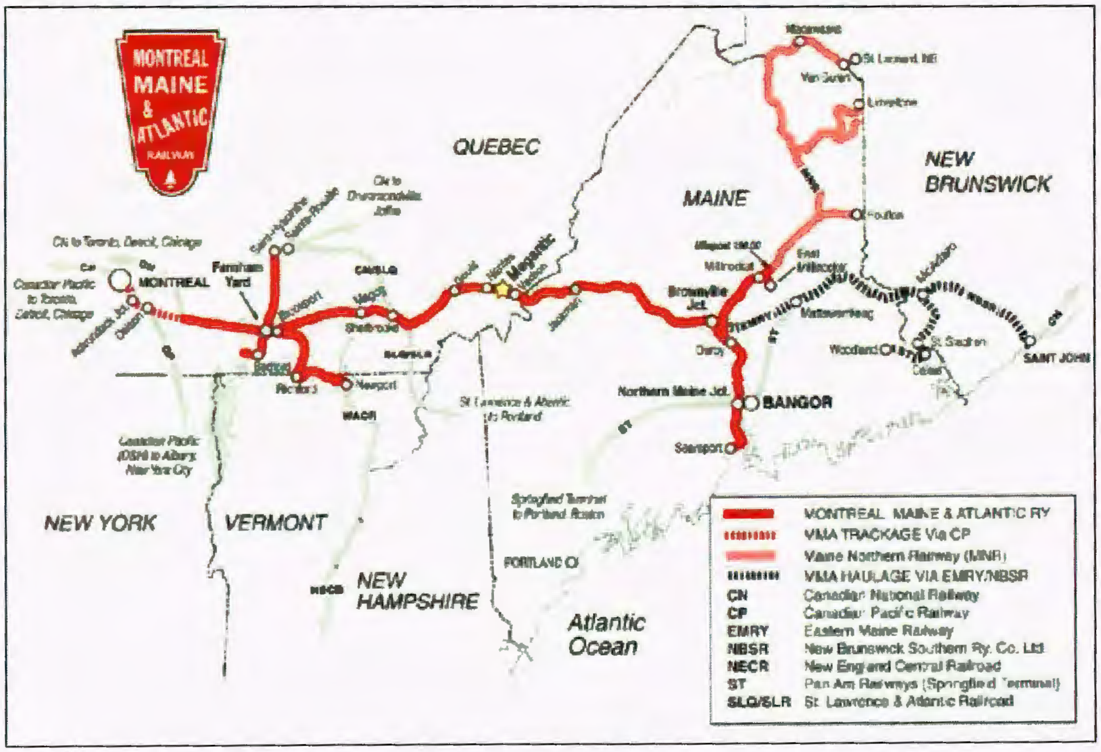
# *Table of contents*

# 1.0 *Factual information*

## 1.1 *The accident*

On 05 July 2013, at about 1355,[1] eastward Montreal, Maine & Atlantic Railway (MMA)[2] freight train MMA-002 (the train) departed Farnham (near Brookport, Mile 125.60 of the Sherbrooke Subdivision), Quebec, destined for Nantes (Mile 7.40 of the Sherbrooke Subdivision), Quebec, where it was to be re-crewed and was to continue on to Brownville Junction, Maine. The train's final destination was Saint John, New Brunswick (Figure 1). The train consisted of 72 tank cars loaded with approximately 7.7 million litres of petroleum crude oil (UN 1267), 1 box car (buffer car[3]), and the locomotive consist (5 head-end locomotives and 1 VB car[4]). The train was controlled by a locomotive engineer (LE) who was operating alone and was positioned in the lead locomotive, MMA 5017. During the trip, the LE reported mechanical difficulties with the lead locomotive, which affected the train's ability to maintain speed.

**Figure 1. Montreal, Maine & Atlantic Railway (MMA) map (source: MMA, with TSB annotations)**




At around 2250, the train arrived at Nantes, was brought to a stop using the automatic brakes, and was parked for the night on a descending grade on the main track. The LE

1 All times are Eastern Daylight Time.

2 See Appendix L for abbreviations and acronyms.

3 A non-placarded car of any type used to separate the locomotive consist from dangerous goods cars in order to enhance the safety of the crew members in the locomotive consist.

4 A special-purpose caboose equipped to remotely control the locomotives.

applied the independent brakes to the locomotive consist. He then began to apply the hand brakes on the locomotive consist and the buffer car (7 cars in total), and shut down the 4 trailing locomotives. Subsequently, the LE released the automatic brakes and conducted a hand brake effectiveness test without releasing the locomotive independent brakes. The LE then contacted the rail traffic controller (RTC) responsible for train movements between Farnham and Megantic Station (Megantic), who was located in MMA's yard office in Farnham, to indicate that the train was secured.

The LE then contacted the RTC in Bangor, Maine, who controlled movements of United States crews east of Megantic. During this conversation, the LE indicated that the lead locomotive had continued to experience mechanical difficulties throughout the trip and that excessive black and white smoke was now coming from its smoke stack. The LE expected that the condition would settle on its own. It was mutually agreed to leave the train as it was and that performance issues would be dealt with in the morning.

A taxi was called to transport the LE to a local hotel. When the taxi arrived to pick up the LE at about 2330, the taxi driver noted the smoke and mentioned that oil droplets from the locomotive were landing on the taxi's windshield. The driver questioned whether the locomotive should be left in this condition. The LE indicated that he had informed MMA about the locomotive's condition, and it had been agreed upon to leave it that way. The LE was then taken to the hotel in Lac-Mégantic and reported off-duty.

At 2340, a call was made to a 911 operator to report a fire on a train at Nantes. The Nantes Fire Department responded to the call and arrived on site, and the Sûreté du Quebec (SQ) called the Farnham RTC to inform the company of the fire. After MMA unsuccessfully attempted to contact an employee with LE and mechanical experience, an MMA track foreman was sent to meet with the fire department at Nantes. When the track foreman arrived on site, the firefighters indicated that the emergency fuel cut-off switch had been used to shut down the lead locomotive. This shutdown put out the fire by removing the fuel source. Firefighters also moved the electrical breakers inside the locomotive cab to the off position to eliminate a potential ignition source. These actions were in keeping with railway instructions.

Both the firefighters and the track foreman were in discussion with the Farnham RTC to report on the condition of the train. Subsequently, the fire department and the MMA track foreman left the scene.

With no locomotive running, the air in the train's brake system slowly began to be depleted, resulting in a reduction in the retarding force holding the train. At about 0100 (July 06), the train started to roll downhill toward Lac-Mégantic, 7.2 miles away. At about 0115, the train derailed near the centre of town, releasing about 6 million litres of petroleum crude oil, which resulted in a large fire and multiple explosions.

The locomotive consist did not derail; rather, it separated from the rest of the train and then further separated into 2 sections. Data downloaded from the de la Gare Street crossing (located by Megantic Station) showed that the 2 sections were separated by 104 feet. Both continued travelling eastward onto the Moosehead Subdivision, coming to rest on an ascending grade in the eastern part of town and stopping approximately 475 feet apart. During the course of this entire sequence, the train passed through 13 level crossings.

After approximately 1.5 hours, while emergency and evacuation efforts were under way, the leading section of the locomotive consist rolled backwards toward downtown and contacted the trailing section; both sections travelled backwards an additional 106 feet. At approximately 0330, MMA officials secured the locomotive consist on the grade by re-tightening the hand brakes.

See Appendix A for more detailed information about the sequence of events.

Photo 1. The Lac-Mégantic derailment site following the accident

## 1.2 *Aftermath*

As a result of the derailment and the ensuing fires and explosions, 47 people died, and about 2000 people were evacuated. Forty buildings and 53 vehicles were destroyed (Photo 1).

The derailed tank cars contained about 6.7 million litres of petroleum crude oil, about 6 million litres of which were released, contaminating approximately 31 hectares of land. Crude oil migrated into the town's sanitary and storm sewer systems by way of manholes. An estimated 100 000 litres of crude oil ended up in Mégantic Lake and the Chaudière River by way of surface flow, underground infiltration, and sewer systems. About 740 000 litres were recovered from the derailed tank cars.

The hydrocarbon recovery and cleanup operation began as soon as the fire was extinguished and the site was stabilized, approximately 2 days after the derailment. The assessment and remediation of the environment were performed using a combination of monitoring wells and exploratory trenches serviced by vacuum trucks under the guidance of a specialized engineering firm.

## 1.3 Weather

At 2300 on 05 July 2013, the temperature at the weather station in Sherbrooke, Quebec, approximately 95 km west of Lac-Mégantic, was 21.7 °C. The dew point was 20.5 °C, and wind speed was 5 km/h from the south. At 0100 on 06 July 2013, the temperature was 21.2 °C, with a dew point of 20.4 °C and wind speed of 0 km/h.

## 1.4 Subdivision information

The Sherbrooke and Moosehead Subdivisions were owned and operated by MMA. These subdivisions were previously owned by Quebec Southern Railway (QSR) and, prior to that, by Canadian Pacific Railway (CPR).

### 1.4.1 Sherbrooke Subdivision

The MMA Sherbrooke Subdivision was a single main track extending west from Megantic (Mile 0.00) to Brookport (Mile 125.60), Quebec, where it connected with the Adirondack and Newport Subdivisions, near Farnham. Train movements were controlled by the Occupancy Control System (OCS), as authorized by the *Canadian Rail Operating Rules* (CROR), and supervised by an RTC located in Farnham. Traffic on the Sherbrooke Subdivision consisted of 2 freight trains per day, for an annual tonnage of 4.5 million gross tons. The track was classified as Class 3[5] according to the Transport Canada–approved *Track Safety Rules* (TSR). The maximum allowable speed for freight trains was 40 mph. However, due to track conditions, the speed on the entire subdivision had been reduced with temporary slow orders, including:

- 25 mph between Mile 0.82 and Mile 93 (with 11 locations further reduced to 10 mph),
- 10 mph between Mile 93 and Mile 103.87, and
- 25 mph between Mile 103.87 and Mile 125.60 (with 2 locations further reduced to 10 mph).

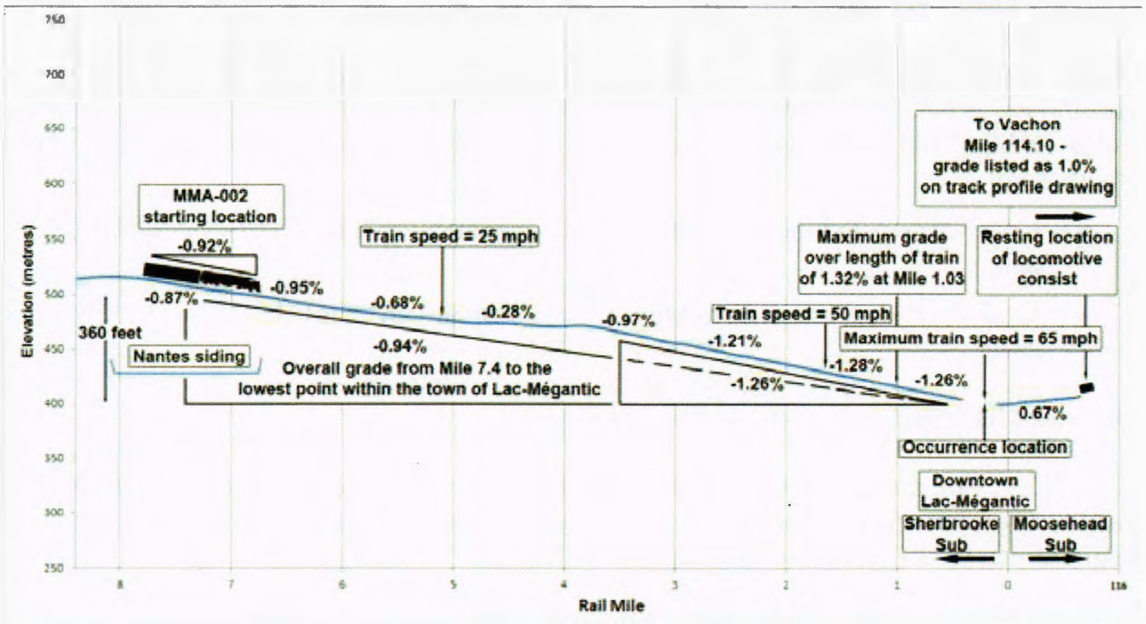
The subdivision was equipped with 6 hot box detectors, the last one located at Mile 13.30. MMA-002 did not receive any alarms from these detectors.

Between Nantes and Megantic (Mile 7.40 to the lowest point near Mile 0.00), the average descending grade was 0.94%, and the steepest grade over the length of the train was 1.32% at Mile 1.03 (Figure 2). The elevation dropped approximately 360 feet between Nantes and Megantic. For the last 2 miles before the point of derailment, the track descended at a grade of approximately 1.30%. The maximum horizontal curvature of the track was 4.25°, which was at the derailment location (Engineering Laboratory Report LP167/2013).

---

[5] The *Track Safety Rules* (TSR) define 5 classes of track. The maintenance requirements, as well as the maximum speed for both freight and passenger trains, are dictated for each class.

**Figure 2. Grade and elevation between Nantes and Megantic**




Cautionary limits[6] were in effect between Mile 0.82 and Mile 0.00, due to the presence of the yard at Megantic. Movements were to be made in accordance with CROR 94 and 105(c).[7] There was a permanent speed restriction of 10 mph over Frontenac Street (Mile 0.28) until the crossing was fully occupied.

### *1.4.2 Moosehead Subdivision*

The Moosehead Subdivision was a single main track that extended east from Megantic (Mile 117.14) to Brownville Junction (Mile 0.00), where it connected with the Millinocket Subdivision. The track was classified as Class 3 according to the TSR. Movements departing Megantic and heading eastward on this subdivision encountered an ascending grade of approximately 1%. Further east at Vachon (Mile 114.10), Quebec, the closest siding to Lac-Mégantic, there was a 6470-foot passing track.

## *1.5 Rail traffic control*

MMA had 2 RTCs on duty at all times (1 in Bangor and the other in Farnham), with duty periods of 12 hours, starting at 0600 and 1800. The Farnham RTC controlled movements west of Megantic, and the Bangor RTC controlled movements east of Megantic. The Farnham RTC on duty at the time of the accident was a qualified LE with previous experience securing trains at Nantes.

---

6 Cautionary limits, as defined in the *Canadian Rail Operating Rules* (CROR), are essentially an extension of the main track through yards and terminals where there is need for caution due to the likelihood of encountering other equipment or unlined switches.

7 This rule requires a movement to operate at a speed that will allow it to stop within ½ of the range of vision of equipment or a track unit.

## 1.6 Personnel information

From Farnham to Nantes, MMA-002 was operated by 1 LE positioned in the lead locomotive as per single-person train operations (SPTO) special instructions. The LE was rules-qualified and met fitness and work/rest regulatory requirements. The LE's 2 previous shifts were:

- MMA-002 (eastbound from Farnham to Megantic) on 02 July 2013 from 1230 to 0030, and
- MMA-001 (westbound from Megantic to Farnham) on 03 July 2013 from 0830 to 2030.

Both trips had been performed with a conductor.

On 05 July 2013, the LE awoke at approximately 0530 and reported for duty at 1330 for MMA-002. When the LE was at home in Farnham, he normally slept about 8 hours per night. When the LE laid over, he usually slept between 5 and 6 hours per night.

The LE was hired by CPR in January 1980, and qualified as an LE in 1986. In September 1996, he transferred to QSR when that company acquired the trackage from CPR. In January 2003, the LE transferred to MMA when QSR was purchased by Rail World, Inc. (RWI), MMA's parent company. During this time, he completed hundreds of trips between Farnham and Lac-Mégantic and was familiar with the territory.

In the 12 months before the accident, the LE completed about 60 eastbound trips on MMA-002. About 20 of these trips were completed as a single-person train operator.

## 1.7 Train information

The tank cars originated in New Town, North Dakota, where they were picked up by CPR. At origin, the train consisted of 1 box car (the buffer) and 78 tank cars loaded with petroleum crude oil (UN 1267), a Class 3 flammable liquid. On 30 June 2013, when the train was in Harvey, North Dakota, 1 tank car was removed for a mechanical defect after the train received a safety inspection and a Class I air brake test.[8] This air brake test verifies the integrity and continuity of the brake pipe, as well as the brake rigging, the application, and the release of air brakes on each car.

The petroleum crude oil had been purchased by Irving Oil Commercial G.P. from World Fuel Services, Inc. (WFSI). The shipping documents indicated that the shipper was Western Petroleum Company (a subsidiary of WFSI) and the consignee was Irving Oil Ltd. (Irving).

The cars operated through Minneapolis, Minnesota, Milwaukee, Wisconsin, Chicago, Illinois, and Detroit, Michigan, and arrived in Canada through Windsor, Ontario. The cars travelled to Toronto, Ontario, and underwent a No. 1 air brake test by a certified car inspector on 04 July 2013. The cars departed Toronto as part of a mixed freight train, consisting of 2 locomotives and 120 cars, destined for Montréal. When the train arrived in Montréal, it underwent a routine safety and mechanical inspection in Saint-Luc Yard on

---

[8] In Canada, this type of test is called a No. 1 air brake test.

05 July 2013. Mechanical defects were identified on 5 tank cars, which were removed from the train. The remaining tank cars were then interchanged to MMA.

On the morning of 05 July 2013, the cars were taken to Farnham, where they received a brake continuity test and a mechanical inspection by Transport Canada (TC). Minor defects were noted on 2 cars, and these were corrected. Departing Farnham, the train was approximately 4700 feet long, weighed about 10 290 tons (Appendix B) and consisted of the following (Photo 2):

1. lead locomotive MMA 5017, General Electric Company (GE) C30-7;
2. special-purpose caboose (VB car) VB 1;
3. locomotive MMA 5026, GE C30-7;
4. locomotive CITX 3053, General Motors (GM) SD-40;
5. locomotive MMA 5023, GE C30-7;
6. locomotive CEFX 3166, GM SD-40;
7. buffer car CIBX 172032; and
8. 72 tank cars.

**Photo 2. MMA-002 at Brookport on 05 July 2013 (photo: Richard Deuso, with TSB annotations)**


## 1.8 *Accident site information*

The investigation focused on 3 locations (Figure 3):

- Nantes, where the train was parked;
- downtown Lac-Mégantic, where the train derailed; and
- the ascending grade, east of Megantic, where the locomotive consist came to its final stop (Mile 116.41 of the Moosehead Subdivision).

Figure 3. The 3 locations that were the focal points of the investigation: Nantes, downtown Lac-Mégantic, and the location where the locomotives came to a stop (Mile 116.41 of the Moosehead Subdivision) (source: Google Earth, with TSB annotations).


### *1.8.1 Nantes*

Railway lines at Nantes are located in a rural area where the main track and a siding run parallel and immediately adjacent to public highway 161. The average descending grade on the main track where the train was parked is 0.92%.[9] During site examination, a black oily residue was found on the surrounding vegetation and on the rails where the lead locomotive was parked (Photo 3).

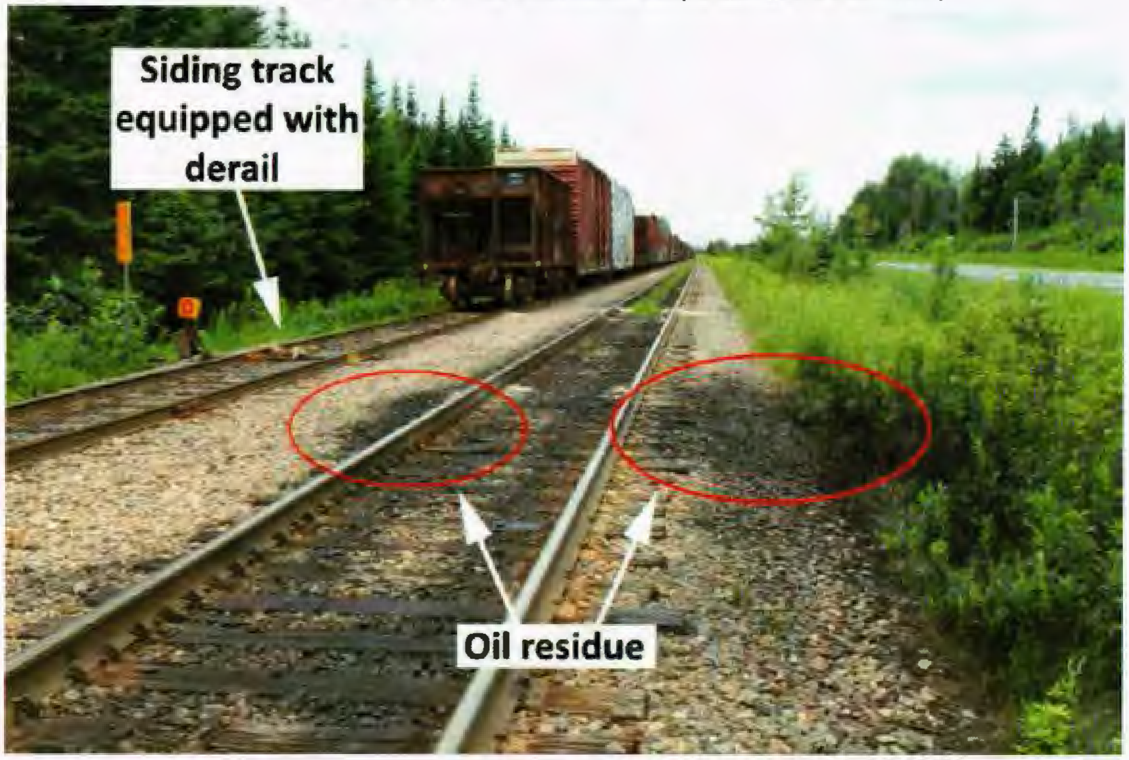
The east siding switch was located at Mile 6.67, and the siding was 7160 feet long. At the time of the accident, several rail cars were being stored there. The siding was equipped with a special derail,[10] located approximately 230 feet west of the switch (Photo 3). A derail is a mechanical safety device that sits on top of the rail and is used to derail runaway equipment. This derail was locked in the derailing position to protect the main track from unintended movements out of the siding.

---

9 Grades of approximately 1.00% are considered steep for railway purposes (see section 1.12.4 for more information).

10 A special derail is a derail that may be left in non-derailing position when equipment is not present. (Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* [CROR] 104.5: Derails.)

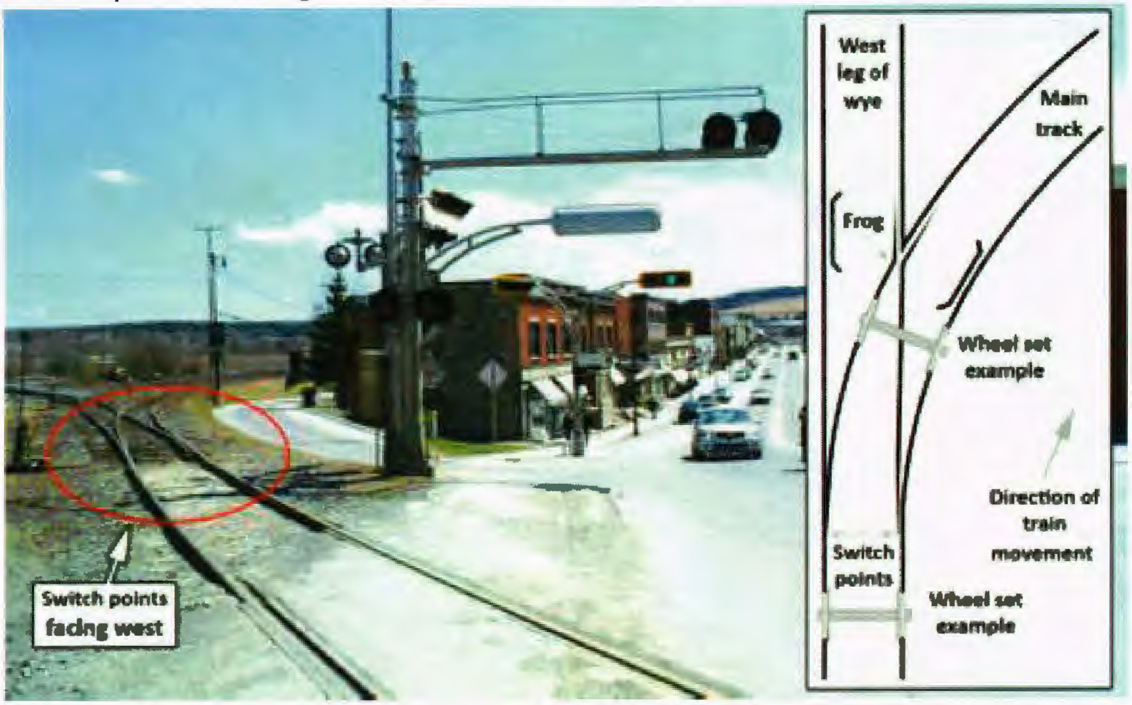
Photo 3. Oil residue on the ground and vegetation at Nantes. Note derail on adjacent siding track on left (view westward from the location where the lead locomotive was parked on the main track).




### 1.8.2 *Lac-Mégantic derailment site*

The MMA Megantic Station was located in a commercial district of Lac-Mégantic, where the Sherbrooke and Moosehead Subdivisions met. Frontenac Street, a main thoroughfare, ran through the centre of the town. The main track intersected with Frontenac Street just west of the Megantic West turnout and was maintained for a maximum speed of 15 mph. The turnout was located at Mile 0.23, with the switch points facing west (Photo 4).

Photo 4. Frontenac Street public grade crossing, looking eastward. The circled area denotes the location of the switch points and the frog for the Megantic West turnout (photo: Pierre Blondin, with TSB annotations).




The derailed equipment covered the main track, 3 adjacent yard tracks, and the west leg of the wye, which is a triangular arrangement of tracks that can be used for turning rail equipment (Photo 5).[11] At the time of the accident, there were box cars parked in yard tracks 1 and 2.

11 At Lac-Mégantic, the wye track also served as an access location to an industry serviced by MMA.

**Photo 5. Eastward view of the location of the tracks in relation to the first derailed cars: main track (A), yard track 1 (B), yard track 2 (C), yard track 3 (D), and the west and east legs of the wye tracks (E and F)**


The track and crossing infrastructure was damaged as follows:

- The damage to the main track started approximately 20 feet east of Frontenac Street.
- The main-track turnout, approximately 400 feet of main track, and an additional 2000 feet of yard and wye tracks, including 3 turnouts, were destroyed.
- Approximately 500 feet from the crossing, the main track was shifted about 4 feet to the north.
- Yard tracks 1 and 2 were demolished from the west-end turnout for about 600 and 500 feet, respectively.
- Rails were curled and twisted, unsettled from tie plates, and moved randomly. Due to the severity of the fire, most track components were badly damaged.
- The Frontenac Street southeast public-crossing cantilever mast and the control box were shattered. Road traffic lights, electrical wires, lighting posts, and other appliances were also damaged.

The derailed equipment at the Lac-Mégantic site consisted of 2 box cars and 63 loaded tank cars.

The derailed equipment came to rest as follows:

- The buffer box car, which had a broken knuckle from a torsional overstress on the leading end (Engineering Laboratory Report LP184/2013), and the first 3 derailed tank cars were on their sides, jackknifed, and partially coupled. They came to rest close to each other and came in contact with the 7 box cars in yard track 2, derailing 1 of the standing box cars.

- The fourth and fifth derailed tank cars were also on their sides, jackknifed, and resting between yard tracks 2 and 3, about 50 feet north of the main track. They were separated by 125 feet from the preceding cars and had struck a pile of rails stored in the yard.
- The sixth and seventh derailed tank cars, still coupled together, came to rest near yard track 3, about 150 feet north of the main track.
- The eighth derailed tank car was uncoupled and came to rest in a wooded area between yard track 3 and the west leg of the wye.
- All of the remaining derailed tank cars came to rest in a large pileup toward the west leg of the wye, with the last derailed car coming to rest on the Frontenac Street crossing. The ninth and tenth cars stayed coupled and aligned with the roadbed. The next 53 cars came off their trucks, jackknifed, and were severely damaged. The debris from the derailed equipment was confined to the derailment site. Most of the wheel sets and trucks were found on the south side of the pileup, within approximately 400 feet from the Frontenac Street crossing. There were no reports of any pieces of tank cars being projected away from the downtown area.

The last 9 tank cars on the train were still coupled to the last derailed car, but did not derail.

Examination of the derailed equipment determined that a hand brake had been applied on the buffer car. No hand brakes were found to have been applied on any of the tank cars.

### 1.8.3 *Location of the locomotive consist*

The locomotive consist came to rest approximately 4400 feet east of the Lac-Mégantic derailment site, at Mile 116.41 of the Moosehead Subdivision (Photo 6).

**Photo 6. Location of the locomotive consist (Mile 116.41 of the Moosehead Subdivision) in relation to the derailment site. The white arrows denote the route of the locomotive consist, which followed the main track.**

At this location, the track ran parallel to d'Orsennens Street. During site examination, the following was noted:

- There was no damage to the track between the derailment site and the location of the locomotives.
- There was a black oily residue, similar to the residue observed at Nantes, on the ground adjacent to the lead locomotive (MMA 5017), as well as about 600 feet east of where the locomotives came to rest.
- Hand brakes were applied on all 5 locomotives and the VB car.
- There was severe wear on some of the brake shoes and various degrees of blueing[12] on most of the wheels.
- One of the knuckles connecting the second locomotive (MMA 5026) and the third locomotive (CITX 3053) was broken, and a locomotive connector cable had been pinched between the knuckles (Photo 7), indicating that a separation had occurred and the consist had rejoined.
- A broken piece of the knuckle was found under the second locomotive, approximately 15 feet from the coupling (Photo 8). The locomotive knuckle and pin failed in tensile overstress mode, initiating at pre-existing fatigue cracks (Engineering Laboratory Report LP184/2013).

12 Blueing is a blue discolouration of steel surfaces that is indicative of exposure to heat. On railway wheels, tread blueing is caused by the frictional heat generated during a heavy or extended brake application.

**Photo 7. Pinched connector cable between couplers of second and third locomotives (occurring after the accident)**

**Photo 8. Broken locomotive knuckle segment found under the second locomotive**

## *1.9 Train air brakes*

Trains are equipped with 2 air brake systems: automatic and independent. The automatic brake system applies the brakes to each car and locomotive on the train, and is normally used during train operations to slow and stop the train. Each locomotive is equipped with an independent brake system, which only applies brakes on the locomotives. Independent brakes are not normally used during train operations, but are primarily used as a parking brake.

### *1.9.1 Automatic brakes*

A train's automatic braking system is supplied with air from compressors located on each operating locomotive. The air is stored in the locomotive's main reservoir. This reservoir supplies approximately 90 pounds per square inch (psi) of air to a brake pipe that runs along the length of the entire train, connecting to each locomotive and individual car. Air pressure changes within this brake pipe activate the brakes on the entire train.

When an automatic brake application is required, the LE moves the automatic brake handle to the desired position. This action removes air from the brake pipe. As each car's air brake valve senses a sufficient difference in pressure, air flows from a reservoir located on each car into that car's brake cylinder, applying the brake shoes to the wheels.

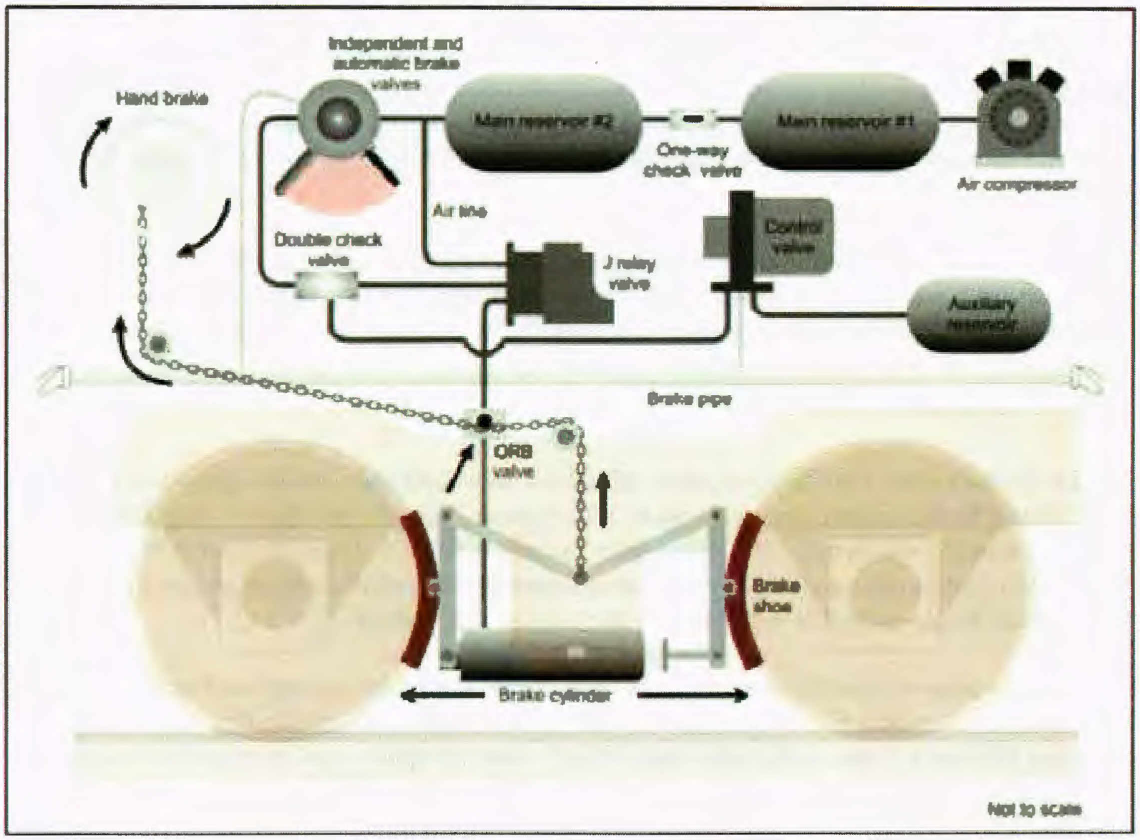
In order to release the brakes, the LE moves the automatic brake handle to the release position. This action causes air to flow from the main reservoir on the locomotive into the brake pipe, restoring pressure to 90 psi. Sensing this, each car's brake valve allows air to be released from its brake cylinder, and the shoes are removed from the wheels.

### *1.9.2 Independent brakes*

The independent brakes are also supplied with air from the main reservoir. When an independent brake application is required, the LE moves the independent brake handle, which in turn injects up to 75 psi of air pressure directly from the main reservoir into the brake cylinders of the locomotive. This causes the brake shoes to apply to the wheels (Figure 4).

To release the independent brakes, the LE moves the independent brake handle to the release position. This causes air to be released from the locomotive's brake cylinders, and the shoes are removed from the wheels.

**Figure 4. Schematic of the locomotive air brake and hand brake**




## 1.9.3 *Penalty brake application*

A penalty brake application is similar to a full automatic brake application. However, this type of braking further reduces the brake pipe pressure to zero, requiring a moving train to stop and recharge the brake pipe. This type of braking occurs as a result of a "penalty" applied by the system, such as when the reset safety control (RSC) is not reset. This application occurs at a rate that does not deplete all of the air in each car's reservoir.

## 1.9.4 *Emergency brake application*

An emergency brake application is the maximum application of a train's air brakes, during which the brake pipe pressure is rapidly reduced to zero, either from a separation of the brake pipe or operator-initiated action. Following an emergency brake application, a train's entire air system is depleted.

Brake pipe pressure below 40 psi cannot be relied upon to initiate an emergency brake application.

### *1.9.5 Leakage*

When locomotives are shut down, the air compressors are also shut down and no longer supply air to the train. Given that the system has many connections, which are prone to air leaks, the main reservoir pressure will slowly begin to drop soon afterward.

Because the main reservoir supplies air to the entire system, when its pressure falls to the level of that in the brake pipe, the pressure in both components will thereafter diminish at the same rate. This sequence also occurs when the main reservoir and brake pipe reach the same pressure as that in the brake cylinder, at which point all 3 will lose pressure at the same rate.

As the air in the brake cylinder decreases, the amount of force being applied to the locomotive wheels by the independent brakes is reduced. If the system is not recharged with air, the brakes on the locomotives will eventually become completely ineffective.

## *1.10 Train hand brakes*

In addition to a train's air brake system, all locomotives and rail cars are equipped with at least 1 hand brake, which is a mechanical device that applies brake shoes to the wheels to prevent them from moving or to retard their motion (Photo 9). Typically, hand brakes consist of a hand brake assembly, which designates the B-end of each car. When the wheel on the hand brake assembly is tightened, the brakes are applied.

The effectiveness of hand brakes depends on several factors, including hand brake gearing system lubrication and lever adjustment. Also critical is the force exerted by the person applying the hand brake, which can vary widely from one person to another. For example, railway standards are based on an application of 125 pounds of force on the outside rim of the hand brake wheel. However, previous TSB investigations have noted that, on average, employees apply 80 to 100 foot-pounds of force.

Photo 9. Hand brake assembly and wheel at the B-end of a tank car


### 1.10.1 *Hand brake requirements*

#### 1.10.1.1 *Locomotives*

There are no requirements for a locomotive to hold any other equipment when the hand brake is applied. On many locomotives, including the ones in this accident, when the hand brake is applied, only 2 of as many as 12 brake shoes are applied to the locomotive wheels.

For locomotives placed in service after 04 January 2004, the Federal Railroad Administration (FRA) in the United States requires that the hand brake(s) alone be capable of holding a locomotive on a 3% grade. This equates to a net braking ratio[13] of approximately 10%. Although there were no such requirements prior to 2004, locomotive manufacturers generally designed locomotive hand brakes to meet the 3% holding capacity.

13 The brake ratio reflects the amount of brake shoe force being applied on a rail car or locomotive relative to its gross loaded weight. For example, a total of 26 000 pounds of brake shoe force applied to the wheels of a rail car weighing 260 000 pounds equates to a braking ratio of 10%.

#### *1.10.1.2 Cars*

According to Standard S-401 (Brake Design Requirements) of the Association of American Railroads' (AAR) *Manual of Standards and Recommended Practices* (MSRP), the force applied to the wheels by the brake shoes must be equal to about 10% of the car's gross load weight, with 125 pounds of force applied to the outside rim of the hand brake wheel.

Unlike hand brakes on many locomotives, hand brakes on cars normally apply all brake shoes (typically 8) to the wheels.

## *1.11 Hand brake effectiveness test*

In order to verify that the hand brakes applied are sufficient to secure the train, crews were required to perform a hand brake effectiveness test, in accordance with CROR 112 (b), to ensure that the equipment will not move. After applying the hand brakes, the test is performed by releasing all of the air brakes and allowing the slack to adjust under gravity, or by attempting to move the equipment slightly with reasonable locomotive force.

If the hand brakes prevent the equipment from moving, then they are determined to be sufficient. If not, additional hand brakes must be applied and the process repeated until a successful effectiveness test has been completed.

Special instructions of some Canadian railway companies, including MMA, permitted the hand brakes on the locomotive consist to be included in the minimum required number of hand brakes. For example, if a company's special instructions required at least 10 hand brakes to be applied, and the train were operating with 4 locomotives, then only 6 hand brakes were required to be applied on the cars in addition to those on the locomotives. During an effectiveness test performed with hand brakes applied on the locomotive consist, the LE has to overcome the braking force on the locomotives before moving the rest of the train.

## *1.12 Rules and instructions on securing equipment*

### *1.12.1 Rule 112 of the Canadian Rail Operating Rules*

The CROR are the rules by which Canadian railways under federal jurisdiction operate, which include MMA's Canadian operations. At the time of the accident, CROR 112 stated the following, in part:

> (a) When equipment is left at any point a sufficient number of hand brakes must be applied to prevent it from moving. Special instructions will indicate the minimum hand brake requirements for all locations where equipment is left. If equipment is left on a siding, it must be coupled to other equipment if any on such track unless it is necessary to provide separation at a public crossing at grade or elsewhere.[14]

---

[14] Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR), 112: Securing Equipment, (a).

To ensure that there was sufficient retarding force to prevent a train or cars from moving unintentionally, CROR 112 required the effectiveness to be tested when hand brakes were used to secure the equipment. The rule stated:

> (b) Before relying on the retarding force of the hand brake(s), whether leaving equipment or riding equipment to rest, the effectiveness of the hand brake(s) must be tested by fully applying the hand brake(s) and moving the cut of cars slightly to ensure sufficient retarding force is present to prevent the equipment from moving [. . .][15]

In addition to CROR 112, MMA employees were governed by the special instructions in MMA's *General Special Instructions* (GSIs) and *Safety Rules*.

Since MMA operated in former CPR territory, it adopted CPR's General Operating Instructions (GOIs).[16]

### *1.12.2 Montreal, Maine & Atlantic Railway's General Special Instructions on Rule 112*

Section 112-1 (Hand Brakes) in MMA's GSIs provided instructions on the minimum number of hand brakes required, and stated in part:

> Crew members are responsible for securing standing equipment with hand brakes to prevent undesired movement. The air brake system must not be depended upon to prevent an undesired movement.
>
> [...]

| Cars | Handbrakes | Cars | Handbrakes |
|---|---|---|---|
| 1 - 2 | 1 Hand Brake | 50 - 59 | 7 Hand Brakes |
| 3 - 9 | 2 Hand Brakes | 60 - 69 | 8 Hand Brakes |
| 10 - 19 | 3 Hand Brakes | 70 - 79 | 9 Hand Brakes |
| 20 - 29 | 4 Hand Brakes | 80 - 89 | 10 Hand Brakes |
| 30 - 39 | 5 Hand Brakes | 90 - 99 | 11 Hand Brakes |
| 40 - 49 | 6 Hand Brakes | 100 - 109 | 12 Hand Brakes |

> Note: [...] If conditions require, additional hand brakes must be applied to prevent undesirable movement.[17]

The numbers in the table are commonly referred to by MMA employees as the "10% + 2" instruction.

Section 112-2 (Hand Brakes: Reduced Minimum Number, Designated Specific Locations) provided specific locations where the minimum number of hand brakes had been reduced.

---

15 Ibid., 112(b).

16 Montreal, Maine & Atlantic Railway (MMA) decided to use Canadian Pacific Railway's (CPR) General Operating Instructions (GOIs), and decided how to apply and interpret any instruction.

17 Montreal, Maine & Atlantic Railway (MMA), *General Special Instructions* (First Edition, 01 March 2012), Section 112-1: Hand Brakes.

For example, at Sherbrooke, between cautionary limit signs, including the main track and sidings, and at Farnham, the minimum number of hand brakes equated to approximately 10%. For Megantic Yard, the required number was less than 10%.

### 1.12.3 *Montreal, Maine & Atlantic Railway's Safety Rules on Rule 112*

MMA's Safety Rule 9200 (Sufficient Number – Operating Hand Brakes) stated in part:

> Employees must:
>
> a. Know how to operate the types of hand brakes with which various types of cars are equipped.
>
> [...]
>
> c. Before attempting to operate handbrake, make visual inspection of brake wheel, lever, ratchet and chain.
>
> [...]
>
> f. **Be aware of and work within the limits of your physical capabilities and do not use excessive force to accomplish tasks. Past practices that do not conform to the rules are unacceptable.**[18]

MMA's Safety Rule 9210 stated in part:

> h. All hand brakes shall be fully applied on all locomotives in the lead consist of an unattended train.
>
> i. When leaving railway equipment, the minimum number of hand brakes must be applied as indicated in the following chart.[19] Additional hand brakes may be required; factors which must be considered are:
>
> Total Number of Cars
>
> Empties or Loads
>
> Weather Conditions
>
> Grade of Track
>
> [...]
>
> k. In reference to the minimum number of hand brakes in the preceding chart,[19] it is acceptable to include the hand brakes applied on locomotives.

---

[18] Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Sufficient Number – Operating Hand Brakes, 9200. (Bold text in original.)

[19] The chart was not included in the *Safety Rules*.

[...]

m. There may be situations where all hand brakes should be applied.

[...]

o. To ensure an adequate number of hand brakes are applied, release all air brakes and allow or cause the slack to adjust. It must be apparent when slack runs in or out, that the hand brakes are sufficient to prevent that cut of cars from moving. This must be done before uncoupling or before leaving equipment unattended.[20]

### *1.12.4 Instructions of Class 1 railways regarding Rule 112 of the Canadian Rail Operating Rules*

#### *1.12.4.1 Canadian Pacific Railway*

Prior to early 2013, CPR's instructions for determining the minimum number of hand brakes were to divide the number of cars to be left unattended by 10, and then add 2. The instructions also included the requirement to secure each locomotive left unattended with its hand brake. When a train was to be left unattended with the locomotive(s) attached, it was acceptable to include the locomotive hand brakes as part of the minimum required number of hand brakes.

Prior to the accident, CPR modified its hand brake instructions, no longer specifying the minimum number of hand brakes. Crews were responsible for evaluating their train and other operating conditions to determine the sufficient number of hand brakes and for testing their effectiveness before the equipment was left unattended.

In addition, section 2.0 of CPR's GOIs still stated that on light, heavy, and mountain grades,[21] a specific number of hand brakes (higher than the minimum) was required when a hand brake effectiveness test could not be performed. For example, on grades between 1.0% and 1.29%, hand brakes were required on 25% of the train. Additionally, in some territories, an increased number of hand brakes had to be applied when a movement was stopped on a grade.

#### *1.12.4.2 Canadian National*

At Canadian National (CN), the hand brake instructions in effect at the time of the accident for rail cars left unattended were:

- Divide the number of cars on the train by 10 and add 1 additional hand brake, up to a maximum of 5 hand brakes.
- If the hand brake effectiveness test is not successful, more hand brakes are required to ensure that the movement remains immobilized.

---

20 Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Sufficient Number - Operating Hand Brakes, 9210.

21 Light grades are below 1.0%, heavy grades are between 1.0% and 1.8%, and mountain grades are above 1.8%.

- Certain locations outlined in CN's timetable required double (up to a maximum of 10) the number of hand brakes, depending on the track characteristics.
- Trains with locomotives attached with at least 1 locomotive running can be left on the main track with only 1 locomotive hand brake applied, provided that there is brake continuity throughout the train, the automatic air brakes are fully applied and the independent brakes are applied.[22]

In addition to the above instructions, CN special instructions for leaving trains or transfers unattended on mountain grade territory were as follows:

- Every effort must be made, including RTC pre-planning, to avoid leaving trains or transfers in steep grades in excess of 0.75%.
- When absolutely necessary, a sufficient number of hand brakes must be applied to prevent any unintended movement caused from possible brake cylinder leak-off.
- The automatic air brakes must not be solely relied upon to secure equipment against undesired movement.
- Stop with the least amount of air brake application possible.
- Leave locomotives attached with brake pipe continuity throughout the train, and do not bleed off cars before applying hand brakes.
- Apply 25% of the train hand brakes on grades between 0.75% and 0.9%, and apply 40% of the train hand brakes on grades up to 1.4%.[23]

Crew members were required to communicate and confirm that they had left the train in accordance with these instructions, and the RTC was to be advised of the number of hand brakes applied.

## *1.13 Recorded information*

### *1.13.1 Locomotive event recorder*

A train's locomotive event recorder (LER) is analogous to a "black box" on an aircraft. The LER monitors and records a number of parameters, including throttle position, time, speed, and distance, as well as pressure within the brake pipe and locomotive brake cylinder. Changes in the brake pipe pressure cause each car to apply (or release) its air brake. In this accident, because the train was unattended, the LER was instrumental in providing key pieces of data.

Table 1 summarizes some important information obtained from the download of the LER on the lead locomotive. Brake pipe pressure is at its maximum at 95 psi (brakes fully released), and locomotive brake cylinder pressure is maximized at 70 psi (full independent brake application). Any drop in brake cylinder pressure indicates a reduction in retarding force.

---

[22] Canadian National (CN), General Operating Instruction (GOI) 7.12.

[23] Canadian National (CN), Regional Special Instructions: Time Table 20, Rule 112 – Leaving Trains or Transfers Unattended, Mountain Grade Territory (effective 01 August 2012).

**Table 1. Locomotive event recorder information**

| Time | mph | Brake pipe pressure (psi) | Locomotive brake cylinder pressure (psi) | Event |
|---|---|---|---|---|
| 05 July 2013 2249:37 | 0 | 82 | 69 | MMA-002 was stopped at Nantes using a 13-psi automatic brake application, and the independent brakes were fully applied. |
| 2303:48 | 0 | 94 | 69 | The automatic brakes were released. The locomotive independent brakes remained fully applied. |
| 2358:42 | 0 | 95 | 69 | Lead locomotive MMA 5017 was shut down. |
| 06 July 2013 0005:55 | 0 | 94 | 70 | Brake pipe pressure began to decrease, and continued to decrease at an average rate of 1 psi per minute. |
| 0013:55 | 0 | 79 | 69 | Independent brake cylinder pressure began to decrease at the same rate as the brake pipe pressure. |
| 0058:21 | 1 | 32 | 27 | MMA-002 began to run away. |
| 0115:30 | 65 | 16 | 14 | The highest recorded speed of 65 mph was attained. |
| 0115:31 | 65 | 0 | 14 | Brake pipe pressure dropped to 0 psi as the cars began to derail. The locomotive consist separated into 2 sections. |
| 0117:12 | 0 | 0 | 6 | The first section stopped 5016 feet east of the point of derailment, at Mile 116.30 of the Moosehead Subdivision, on a 1% ascending grade. |
| 0245:06 | 1 | 0 | 0 | The first section of the locomotive consist began to move backwards (west) down the grade toward downtown Lac-Mégantic. |
| 0246:23 | 8 | 0 | 0 | The first section of the locomotive consist travelled 475 feet west and struck the stationary second section of the consist. |
| 0246:42 | 0 | 0 | 0 | The 2 sections rejoined and moved an additional 106 feet west before coming to a final stop. |

### *1.13.2 Sense and braking unit*

The sense and braking unit (SBU) is a device placed on the rear of the train and is connected to the train brake pipe. The SBU senses train movement, monitors brake pipe pressure, and sends the information to the locomotive, where it is displayed in the cab. The SBU can also be used to initiate an emergency brake application from the end of the train.

The SBU data from MMA-002 were downloaded (Engineering Laboratory Report LP132/2013). The SBU data and crossing download data were used to corroborate the LER data. An analysis of the SBU data determined that when the SBU first recorded movement (start-to-move) at Nantes, brake pipe pressure at the rear of the train was 29 psi.

Approximately 16 minutes and 40 seconds after the train began to move, the brake pipe pressure at the rear of the train had diminished to 0 psi.

## *1.14 Brake testing conducted by the Transportation Safety Board*

### *1.14.1 Air brake and hand brake tests using similar locomotives and tank cars*

A train similar to MMA-002 was assembled to test braking system performance. The train consisted of 5 locomotives (2 GE C30-7s, 2 GE C39-8s, and 1 GM SD-40), 1 VB car, and 80 Class 111 tank cars. The first test was conducted to determine the time required to manually shut down the 4 trailing locomotives and apply hand brakes. The test results are summarized in Table 2.

**Table 2. Time required to shut down the 4 trailing locomotives and apply hand brakes**

| Number of locomotives shut down | Number of hand brakes applied | Time |
|---|---|---|
| 4 | 7 | 9 minutes and 20 seconds |
| 4 | 9 | 10 minutes and 55 seconds |
| 4 | 18 | 17 minutes and 20 seconds |

With the locomotives shut down, the brake pipe fully charged with air, the automatic brakes released, and the independent brakes applied, a second test was conducted to understand the effects of a normal loss of air on the brake system. The train brake pipe pressure as well as the locomotive brake cylinder pressure were monitored at different locations on the train. The test results were as follows:

- After 30 minutes, the brake pipe pressure began to drop, and continued to drop at an average rate of approximately 1 psi per minute.
- After 50 minutes, the locomotive brake cylinder pressure began to decrease at the same rate as the brake pipe pressure.
- After 1 hour and 35 minutes, the brake cylinder pressure dropped to 27 psi, the point at which MMA-002 first began to roll.
- Due to the slow decrease in brake pipe pressure, no automatic brake application occurred.

Also, when the electrical breakers were put in the off position, no penalty brake application occurred.

### *1.14.2 Air brake and hand brake tests on the occurrence locomotives*

The locomotives from MMA-002 were moved to the siding at Vachon for examination and testing of the air brakes and hand brakes. This testing included a brake leakage test of the entire consist, a full brake system evaluation for each locomotive, and brake shoe force testing.

The first test determined that, starting from a fully charged brake system, the brake cylinder pressure dropped to 27 psi in 1 hour and 6 minutes due to air leakage.

The second test evaluated the braking performance of each locomotive and its components. Appendix C identifies the sources of measurable air leakage for each locomotive.

Locomotives are expected to leak air from their systems once they are shut down, yet the amount of time it takes for the independent brakes to leak off is highly variable. While leakage was noted, and was sometimes excessive on several components, it did not exceed the pressure-maintaining capabilities of the locomotives, and the combined leakage was within industry norms. Nevertheless, as a result of the above tests, 5 valves, including the quick release brake (QRB) valve, were removed for further analysis. The majority of the defects with the valves were related to the age and condition of their internal components (rubber seals, O-rings, return springs, etc.). See Engineering Laboratory Report LP185/2013 for complete details on the condition of the valves.

### *1.14.2.1 Quick release brake valve*

On GE C30-7 locomotives, the brake cylinder for the brake shoes applied by the hand brake is equipped with a QRB valve. The QRB valve is normally tripped during the application of the hand brake by the brake chain. When tripped, the QRB valve removes air from the brake cylinder so that an effective hand brake can be applied (Photo 10 and Photo 11).

**Photo 10. QRB valve used to exhaust brake cylinder air during hand brake application**

**Photo 11. As the hand brake is tightened, the upward movement is intended to activate the release mechanism on the QRB valve.**

The QRB valve on the second locomotive (MMA 5026) did not trip to exhaust brake cylinder air when tested. An examination of the valve showed wear and damage to the QRB valve's lifter and inside surface of the retaining disc. In addition, the examination showed that non-standard repairs had been applied to the valve's release mechanism in an attempt to keep the valve working.

If the QRB valve does not trip, the hand brakes will not provide any braking effort. To ensure that the hand brakes remain operational on these locomotives, MMA issued *Summary Operating Bulletin* 2-276, which stated in part:

> The hand brake will not tighten if the air from the R#2 brake cylinder is not exhausted. The handbrake chain will tighten and it may appear that the handbrake is set however if the R#2 brake cylinder is in the "out" position, the handbrake is not applied. On C-30-7 locomotives if an air exhaust is not heard while tightening the handbrake the QRB valve may be malfunctioning or out of adjustment.
>
> It is possible to manually operate the valve from the ground on the right side of the locomotive. The QRB valve and handle is located directly adjacent to the handbrake chain, mounted on the top of the front truck between axles 2 and 3. A crew member can manually trip the valve by use of the lever located on the valve. After tripping the QRB valve the handbrake must immediately be re-tightened.[24]

The LE was not aware of this instruction.

#### *1.14.2.2 Examination of the wheels and brake shoes on the locomotive consist*

The wheels and brake shoes on the locomotives were examined. The brake shoes were measured to analyze the wear that had occurred during the runaway and to determine the amount of braking force that was being applied (Engineering Laboratory Report LP182/2013). The following was determined:

- Some of the brake shoes had worn through the lining to the backing plate.
- The pattern of wheel blueing (Photo 12) and brake shoe lining wear indicated that the independent brakes had been providing most of the retarding brake force for the train.
- Not all of the wheels subjected to hand brake force (2 per locomotive) showed full tread blueing or excessive brake shoe lining wear. This pattern indicated that these hand brakes had not been, or could not be, applied securely.

24 Montreal, Maine & Atlantic Railway (MMA), Summary Operating Bulletin No. 2-276 (Effective 01 July 2013), (U) Six Axle C-30-7.

**Photo 12. Blueing of locomotive wheel due to heat**

### 1.14.2.3 *Brake shoe force testing on the locomotive consist*

An examination of the brake shoe force generated by the locomotive consist was performed with both air brakes and hand brakes (Engineering Laboratory Report 187/2013). Using a coefficient of friction of 0.38 and 100 foot-pounds of torque,[25] the following was determined:

- The total retarding brake force required to hold the train on the grade where it was parked at Nantes was calculated to be approximately 146 700 pounds.
- Before applying the hand brakes, the total retarding brake force generated by the independent brakes was approximately 249 760 pounds.
- After applying the hand brakes (and activating the QRB valves on those locomotives so equipped), the total retarding brake force generated by the independent brakes was approximately 215 500 pounds.
- The total retarding brake force generated by the 7 hand brakes on the train (taking into consideration that the QRB valve did not trip on MMA 5026) was approximately 48 600 pounds. Had the QRB valve been operative, the total retarding brake force would have increased by 4830 pounds.
- At a brake cylinder pressure of 27 psi, when the train first began to move, the retarding brake force of the independent brakes was reduced to approximately 97 400 pounds.
- The average brake ratio of the locomotive hand brakes was approximately 3.8% (range of 3.0% to 4.7%). The average retarding brake force generated by the locomotive hand brakes was approximately 5590 pounds per locomotive. (When 80

[25] Previous investigations have determined that hand brakes are typically applied with approximately 65 foot-pounds to 80 foot-pounds of torque. During field testing, it was determined that, with reasonable force, hand brakes on these locomotives could be applied with approximately 100 foot-pounds of torque.

foot-pounds of torque were applied, the average retarding brake force was 4360 pounds per locomotive.)

- The brake ratio of the VB car was 19.2%.

### 1.14.3 *Hand brake and air brake testing on tank cars*

The air brakes and hand brakes of the 9 tank cars that did not derail were tested and met AAR requirements. The average retarding brake force generated by the hand brakes at 80 foot-pounds of torque was approximately 6920 pounds per car. At 100 foot-pounds of torque, the brake force was approximately 8650 pounds per car.

### 1.14.4 *Testing of the sense and braking unit*

Testing was conducted on a rail car to evaluate how the rate of brake pipe leakage affected the car's air brake system. Following simulated brake pipe leakage, the car's brake pipe pressure dropped 5 psi (to 85 psi) in 7 minutes. The car's air brakes did not engage. The car was then recharged to 90 psi, and the test was repeated. In this test, the brake pipe was reduced by 80 psi (to 10 psi) in 75 minutes. The car's air brakes again did not engage.

A turbine-equipped SBU,[26] similar to the one used on MMA-002, was then tested to determine what effect the brake pipe air lost through the SBU would have on the car's air brake system. The venting of air through the SBU caused the air brakes on a single car to engage almost immediately.

Testing was then conducted with a turbine-equipped SBU on a train with 2 locomotives and 71 cars. The test showed that a similar rate of brake pipe air loss through the SBU would initiate a brake application on a train that was 5 cars or fewer, but not on a train longer than 5 cars. Similar to the single-car test, this test demonstrated that brake pipe air pressure on an entire train can be reduced to 0 psi at a slow rate and result in no brake application on the cars.

### 1.14.5 *Additional hand brake testing on tank cars*

Railways require that air brakes be fully released on cars prior to the application of hand brakes. However, in some instances, such as when a train is stopped on a grade, it is not possible to release the air brakes before applying the hand brakes. Testing was conducted on a cut of tank cars to determine the effect on the hand brakes from the 13-psi automatic brake application on MMA-002 at Nantes. It was determined that when the hand brakes were applied after an air brake application, more brake force was applied to the wheels. The extent of the additional force was relative to the extent of the brake application. Through this testing, it was also determined that an air brake application of 13 psi would result in hand brake forces approximately 40% higher than the same application without air brakes applied.

---

[26] A turbine-equipped sense and braking unit (SBU) uses brake pipe air to drive a small electrical generator to power the SBU. The air that is used is vented to the atmosphere, and brake pipe air is replaced by the pressure-maintaining feature of the locomotives.

### *1.14.6 Previous brake testing for other occurrences*

The TSB investigated other runaway train occurrences where extensive hand brake tests were conducted (TSB Rail Investigations R95C0282, R96C0172, and R11Q0056). It was determined that an average of 65 foot-pounds to 80 foot-pounds of torque had been applied on the hand brakes. In one occurrence, the air brakes leaked off and released after approximately 7 hours due to weather conditions. In another occurrence, the majority of the brake cylinders of the cars leaked off after approximately 1 hour following an emergency brake application due to their poor condition. See Appendix D for more information on previous brake testing for other occurrences.

### *1.14.7 Wiring of the locomotive reset safety control*

New locomotives manufactured since 1986 must be equipped with a reset safety control (RSC). The RSC is a vigilance system that activates alarms and then applies a penalty brake application if it is not reset by the LE, or the controls are not being manipulated within a predetermined time interval. There are no standards for the installation of RSCs. Usually, when the electrical breaker on an RSC is opened or the main electrical power is shut off on a locomotive, a penalty brake application will result. However, when the electrical power was shut off on MMA 5017 at Nantes, the RSC did not create a penalty brake application.

The 3 GE locomotives on MMA-002 were built before 1986 and were retrofitted with an RSC by a previous owner. The locomotives were examined by the TSB (Engineering Laboratory Report LP233/2013), and the following was determined:

- The wiring modifications on the 3 locomotives were not consistent, and the penalty brake performance for all 3 locomotives was different.
- Locomotive MMA 5017 did not produce a penalty brake application under any of the power loss conditions tested. The RSC had been connected directly to the battery. Therefore, the RSC would remain powered even when the main electrical cut-off switch was opened.

Testing of 5 other GE locomotives owned by MMA showed similar variations. In total, no penalty brake application occurred when the electrical breakers were opened on 5 of the 8 locomotives tested. Since there is no requirement for the RSC to initiate a penalty brake application in the event that the power to the device is cut, there is no requirement for this function to be verified during shop inspections.

## *1.15 Lead locomotive MMA 5017*

Lead locomotive MMA 5017 was a GE model C30-7 that had been placed in service in 1979. It was equipped with a 16-cylinder, turbocharged 4-stroke diesel engine, and generated 3000 horsepower. The locomotive had 2 three-axle trucks and a 26 L-type air brake system. The overall weight of MMA 5017 was approximately 195 tons.

### *1.15.1 Engine repair and fire on locomotive MMA 5017*

On 07 October 2012, MMA 5017 entered the shop in Derby, Maine, after an engine failure. It was determined that several power assemblies as well as cam segments had been damaged as a result of an articulated rod failure on one of its power assemblies. The engine block had also been damaged at the same cam bearing. On 15 March 2013, the locomotive was returned to the shop, where an oil leak was found at the same cam bearing bore. To repair the leak, the cam bearing mounting bolt at the cam bearing bore was tightened.

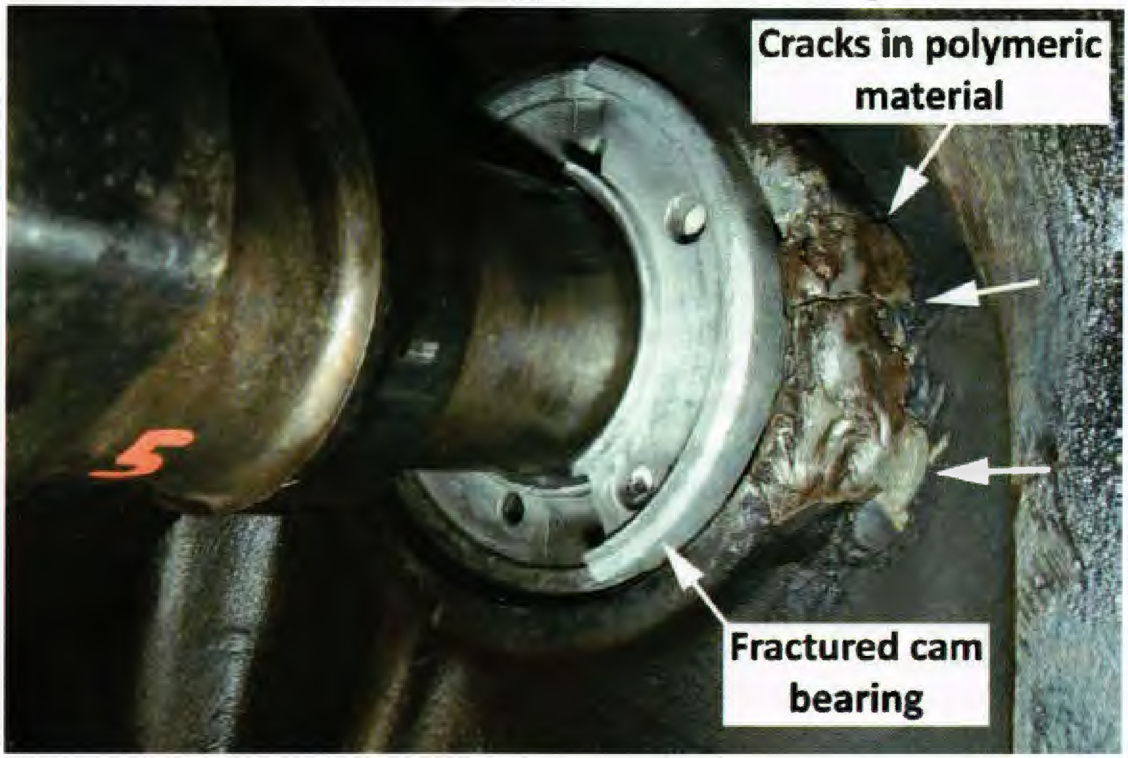
On 04 July 2013, MMA 5017 was in the lead position of MMA-001, being operated by another LE. On the trip from Nantes to Farnham, MMA 5017 was having engine problems. The engine was surging, which was reported by fax to the shop in Derby that day, and verbally to Farnham management the next morning. No action was taken, and MMA 5017 remained in service.

On 05 July 2013, with MMA 5017 in the lead position of MMA-002, the LE reported to the RTC upon departure that there were problems with the engine surging when the throttle was at full. During the trip to Nantes, the engine continued to surge, affecting the LE's ability to maintain a consistent speed. Upon arrival, heavy black and white smoke, as well as oil droplets, were observed coming from the lead locomotive. At 2340, shortly after the LE's departure, a fire ignited in the locomotive smoke stack (Photo 13).

**Photo 13. Locomotive fire at Nantes (photo: Nancy Cameron)**

Following the accident, the locomotive consist was moved from Lac-Mégantic to a maintenance facility in Saint John for examination. A partial engine teardown of MMA 5017 was conducted (see Engineering Laboratory Report LP181/2013 for complete details). It was determined that the cam bearing had fractured when the mounting bolt was over-tightened after the cam bearing had been installed as part of a non-standard repair to the engine block. This temporary repair had been performed using a polymeric material, which did not have the strength and durability required for this use (Photo 14). Failure of the cam bearing reduced the engine oil supply to the valve train at the top of the associated power assembly. The decreased lubrication led to valve damage and eventually to a punctured piston crown. The damaged valves and piston crown allowed engine oil to flow into the cylinder and the intake and exhaust manifolds. Some of the engine oil collected in the body of the turbocharger. The engine fire later occurred in the exhaust stack due to the build-up and ignition of engine oil in the body of the turbocharger.

Photo 14. Polymeric material applied to cam bearing bore and fractured cam bearing




### 1.15.2 *Abnormal engine conditions*

MMA's Safety Rule 9126 stated:

> When there is an abnormal condition such as noise, smoke or odor coming from engine, the engine should be shut down. Employees must immediately leave the engine room and shut down the engine by emergency "shut down" button at the control stand, control panel or fueling location on either side of the locomotive.[27]

## 1.16 *Defences to prevent runaway trains*

Runaways can best be avoided by selecting a location that would limit the distance travelled by an uncontrolled movement (bowl-shaped tracks for switching) or by ensuring that trains are not left unattended by performance of crew-to-crew exchanges. Due to many factors, such as mechanical breakdowns and severe weather conditions, railways have developed rules regarding the safe securement of equipment. In addition, there are physical defences that provide additional levels of safety, such as:

- Derails—These are usually placed on secondary tracks, and in some cases in sidings, and set in the derailing position to protect the main track from cars that may be rolling uncontrolled. In locations such as the main track, where there are no permanent derails, portable derails weighing about 40 pounds can be carried in a

---

[27] Montreal, Maine & Atlantic Railway (MMA), *Safety Rules* (Second Edition, 31 October 2010), Working with Locomotives, 9126.

locomotive cab. They can be easily applied by an LE and can provide a physical defence to prevent uncontrolled movements. Portable derails are not commonly used when securing trains on the main track.

- Chocking devices—These portable devices weigh as little as 20 pounds, and can be applied to the rail, directly against the leading wheels of a train. They provide temporary blocking of that equipment. Chocking devices are more commonly used when securing trains on other than main track.
- Mechanical emergency device—This device activates the braking system of a stopped train in the case of an undesired movement. It consists of a clamp that attaches to the rail and to the lead locomotive air brake hose. If the train begins to move, the hose detaches from the locomotive, the brake pipe air is vented, and the emergency brakes are activated.
- Electronically controlled pneumatic (ECP) brakes—This braking system is an alternative to conventional air brakes. The system sends electrical signals to the cars, instantaneously applying the brakes (quick response braking); it does not rely on the flow of air from the locomotive to each car to activate the brakes. Information is also exchanged between the locomotives and each car. When the system senses that the brake pipe pressure has dropped below 50 psi, a "low brake pressure condition" message is initiated. This message results in all of the ECP-equipped cars and the ECP-equipped locomotives automatically applying their brakes in emergency.

Auto-start systems (also known as hot starts) can be installed on locomotives to automatically shut down and restart locomotives for fuel conservation and to protect critical systems. Locomotives equipped with auto-start will automatically shut down when they are idling for a set time and will automatically restart when certain parameters are met, such as when locomotive brake cylinder pressure falls below a prescribed level and when main reservoir pressure falls below 100 psi. However, the auto-start feature would be nullified if the locomotive is set to isolate, or if it has been shut down manually.

Some of the locomotives used by MMA were equipped with an auto-start system, including locomotives CITX 3053 and CEFX 3166. MMA's Summary Operating Bulletin 2-276 states:

> (L) Hot Starts/Locomotive Shut Down: Unless equipped with a working Hot Start, when temperature is above 45 degrees, Engineers must shut down locomotives that will be idling for periods in excess of 15 minutes [....][28]

When MMA crews were leaving trains at Nantes, most would leave the lead locomotive running and shut down all others, including those equipped with the auto-start system. On the night of the accident, the LE manually shut down locomotives CITX 3053 and CEFX 3166.

Operating instructions adopted by MMA on locomotive auto-start systems highlight the importance of ensuring that trains are properly secured and tested, as it is expected that main reservoir, brake pipe, and brake cylinder pressures will eventually leak off.

---

[28] Montreal, Maine & Atlantic Railway (MMA), Summary Operating Bulletin No. 2-276 (effective 01 July 2013), (L) Hot Starts/Locomotive Shut Down.

The RSC can be upgraded to include a built-in runaway protection feature that initiates an alarm as soon as it detects a movement of 0.5 mph. If the RSC is not reset, a penalty brake application is initiated.

As the SBU, along with the input and display unit (IDU) in the locomotive, serves as a monitor for the air pressure, manufacturers indicated that, with a software update, SBUs could be set up to apply a penalty or emergency brake application before the brake pressure becomes too low to provide effective braking.

## *1.17 Track information*

### *1.17.1 Particulars of the track*

In the vicinity of the derailment, the track was continuous welded rail (CWR). The rail was secured with 2 spikes per tie plate in tangent track, and 3 spikes per tie plate in the curves. Most of the rail was Algoma Steel 115-pound RE rolled between 1966 and 1971, except in some curves, where the high rail was rolled and installed in 2003. The rail was laid on 14-inch double-shouldered tie plates. There were approximately 3200 hardwood ties per mile. Every second tie was box-anchored. The ballast consisted mainly of crushed rock and was generally in good condition. There was insufficient ballast, or ballast fouling, noted at 10 locations over a 10-mile distance.

### *1.17.2 In-train forces, vehicle dynamics, and derailment speed*

MMA-002 ran away eastward and, when approaching Megantic Station, encountered a reverse curve configuration beginning with a 1.5°, left-hand, 670-foot curve with a maximum superelevation[29] of 1 inch, followed by a 60-foot tangent section of track, then a 4.25° right-hand, 1200-foot curve. This curve had a 230-foot-long entry spiral, starting approximately 100 feet west of the Frontenac Street public grade crossing. After the crossing, the turnout at Megantic West provided access to Megantic Yard and its wye tracks. The turnout was a No. 11, 115-pound, left-hand-operated turnout[30] at the end of the entry spiral.

For the right-hand curve section in the vicinity of the derailment, the superelevation (1 inch to 1 ½ inches) corresponded to a balanced speed[31] of between 18 mph and 22 mph. An analysis of the derailment speeds estimated that 10 cars derailed below 40 mph, 5 of which derailed below 30 mph (Engineering Laboratory Report LP039/2014) (Figure 5). Recorded data showed that the derailment took approximately 1 minute (Engineering Laboratory Report LP136/2013).

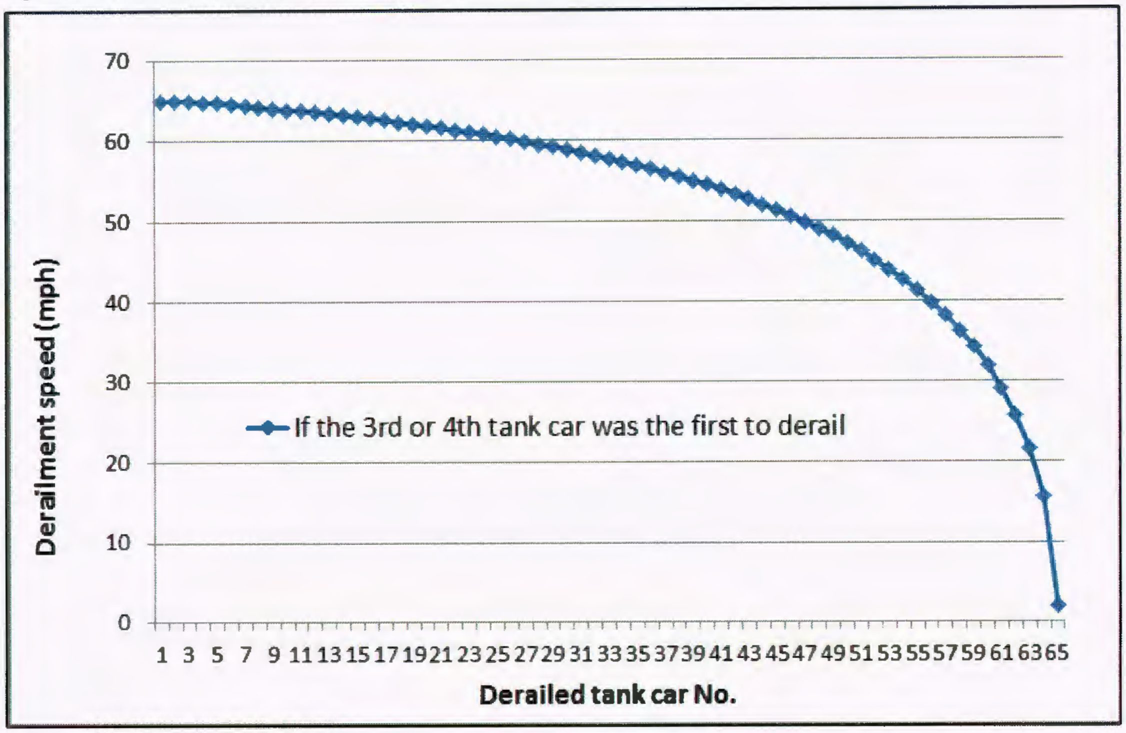
---

29 Superelevation is the difference in elevation (height) between the 2 rails. For the right-hand curve, most of the superelevation varied between 1 inch and 1 ½ inches, except for a 60-foot section where the superelevation reached 3 5/8 inches.

30 A No. 11 turnout turns with a 5°40'44" of curvature.

31 Balanced speed is defined as the speed at which the combination of curvature and superelevation exactly balance the centrifugal acceleration.

Figure 5. Estimated speed at which each car derailed if the third or fourth car was the first to derail[32]




At the time of the derailment, the train was near the Megantic West turnout. The train was analyzed to assess the in-train forces as it transitioned from the downhill grade of 1.26% to the relatively flat terrain of 0.2% at Megantic. A vehicle dynamics simulation of a Class 111 tank car negotiating the curve at Megantic Station was also conducted (see Engineering Laboratory Report LP188/2013 for complete details). It was determined that a combination of the centrifugal force and the dynamic forces generated by the track geometry conditions at a speed of 65 mph was sufficient to cause the derailment. With extremely high lateral forces on the high rail, gauge widening could occur. Furthermore, with complete unloading on the low rail, wheel lift could occur. Either of these conditions or a combination could cause track damage and a derailment.

### *1.17.3 Track inspections by Montreal, Maine & Atlantic Railway*

The main track was regularly inspected as per the TSR. Prior to the accident, MMA performed these track inspections:

- Visual inspection by a track maintenance employee in a hi-rail vehicle was performed on 05 July 2013. During this inspection, no exceptions were noted in the vicinity of the derailment.
- Monthly turnout inspections were performed as required. The most recent turnout inspection was performed on 21 June 2013, and no defects were noted.

---

32 The derailment speeds of both scenarios are nearly identical. For the last 5 derailed tank cars, there is less than 4% difference in derailment speeds if the third car was the first to derail, versus if the fourth car was the first to derail.

- The track was tested annually for internal rail defects using an automated rail flaw detection system. The most recent rail flaw testing was on 19 September 2012, and no defects were noted in the vicinity of the derailment.
- The track geometry was last tested by a track geometry car on 21 August 2012 (Appendix E).

In the immediate area of the rail joints located between the Frontenac Street public grade crossing and the Megantic West turnout, the track geometry readings for surface, cross-level, gauge, and alignment were measured.

The track geometry readings met the maximum allowable limits for 15 mph. According to the TSR, to operate as Class 2 track, the track had to be improved to meet the 25-mph criteria (within 72 hours after the passage of the track geometry car). Consequently, following the August 2012 track geometry test, the rail joints were lifted to correct the geometry irregularities and restore the track to Class 2 criteria. The fouled ballast was not replaced, and was not compacted with heavy machinery.

### *1.17.4 Post-accident track examination*

The TSB examined sections of track over approximately 30 miles on each side of the town of Lac-Mégantic (that is, between Mile 106.00 of the Moosehead Subdivision and Mile 18.00 of the Sherbrooke Subdivision). The following was observed:

- The rail surface had microcracks, corrugation, and multiple signs of wheel slippage and crushed rail head.
- The rail head on the low rail (that is, inside of the curve) of many curves was flattened and worn.
- The vertical rail wear exceeded the acceptable wear limits at Miles 106.60, 107.50, 110.40, 115.56, and 116.25 of the Moosehead Subdivision, and at Miles 3.00, 16.15, 17.50, and 17.60 of the Sherbrooke Subdivision. The vertical wear was as much as 25 mm (1 inch) in some areas.
- Lateral rail wear could not be accurately measured because of crushed rail head and loss of rail profile condition. At Mile 110.55 of the Moosehead Subdivision, the lateral part of the rail head on the field side was completely worn.
- In the curve at Mile 17.60 of the Sherbrooke Subdivision, the rail showed signs of track buckling (for example, the rail undulated laterally, and the ties had shifted sideways).
- At rail joints with significant vertical rail wear, there was damage to the joint bars due to wheel load impacts (that is, contact with wheel flanges). Wheel flange contacts were observed in the area of the derailment (Photo 15).

**Photo 15. Damaged rail joint bar due to contact with wheel flanges**

### *1.17.5 Rail wear standards at Montreal, Maine & Atlantic Railway*

MMA's track standards were based on standards previously developed by the Bangor & Aroostook Railroad[33] (that is, System Track Standards, Part I, for track maintenance limits, and Part II for construction and maintenance practices).

For rail wear, System Track Standards, Part I, Section 113.5 (b), specifies in part:

> (1) VERTICAL HEAD WEAR
> 115 RE ¾"- Then limit track speed to 25 mph
> [...]
> (2) GAGE WEAR (is measured five-eighths of an inch below the top of the rail head)
> 115 RE ¾"- Then limit track speed to 25 mph[34]

At MMA, when the vertical rail wear exceeded the limits set out in its Rail Wear Standard, a temporary slow order of 25 mph was placed on the track. This track section would also be identified for its rail replacement program. MMA did not have a vertical head wear limit specific to jointed rail.

In comparison, the rail wear standards for Canadian Class 1 railways are:

- CN's track standards are summarized in Engineering Track Standard (ETS) TS 1.0 - General 13 and 14, June 2011 edition. Based on these standards, the vertical wear

---

33 In 1995, Iron Road Railways acquired Bangor & Aroostook Railroad. In 2003, its lines were sold to RWI, who initially incorporated them into MMA. In 2010, the tracks from Millinocket north to the Canadian border were sold to the State of Maine to be operated by Irving's Maine Northern Railway.

34 Montreal, Maine & Atlantic Railway (MMA), Montreal, Maine & Atlantic Rail Wear Standard, Section 113.5 (b).

limit for 115-pound rail is 16 mm (5/8 inch) for CWR, and 8 mm for jointed rails. For jointed track, high-clearance joint bars must be used to avoid any contact between the wheel flange and joint bar. Rail wear standards do not require replacement of the rail, as long as the wear limit has not been reached. However, the sum of the vertical and flange wear shall not exceed 21 mm (13/16 inch). A speed restriction may be placed and additional inspection frequency specified if rail is worn beyond the limits and is to be left in the track. The condition of rail (for example, shells, spalls, corrugation) must also be taken into consideration if the rail is left in the track.[35]

- CPR's track standards are summarized in the *Red Book of Track Requirements*. These standards specify that the vertical wear limit of 115-pound RE rail is 17 mm (11/16 inch). A varying amount of combined vertical and flange wear is allowed, up to a maximum of 23 mm (7/8 inch). Where rail wear has resulted in joint bars being heavily affected by wheel flanges, the joint must be welded, or a high-clearance bar or compatible worn bar must be applied. Train speed must be restricted to a speed as near as possible to equilibrium speed until the joint is welded or a high-clearance bar is applied.[36]

### 1.17.6 *Laboratory examination of track components*

A No. 11 rail-bound manganese frog and other track components were recovered and sent to the TSB Laboratory for examination (Engineering Laboratory Report LP151/2013). It was determined that the wing rails and other components were damaged due to overstress fractures. It was also determined that the vertical rail wear was within allowable limits, and that there were no pre-existing defects or fatigue cracks on the fracture surfaces.

## 1.18 *Class 111 tank cars*

In 2013, there were approximately 228 000 Class 111 tank cars in service in North America, of which over 141 000 were being used to transport dangerous goods (DGs). Of those, 98 000 were used to carry Class 3 DGs (flammable liquids). The majority of these tank cars were general-service cars (Figure 6). The specifications applicable to these cars are listed in TC safety standard CAN/CGSB-43.147[37] and the U.S. *Code of Federal Regulations* Title 49 (49 CFR), paragraph 179.200,[38] for Canada and the United States, respectively.

---

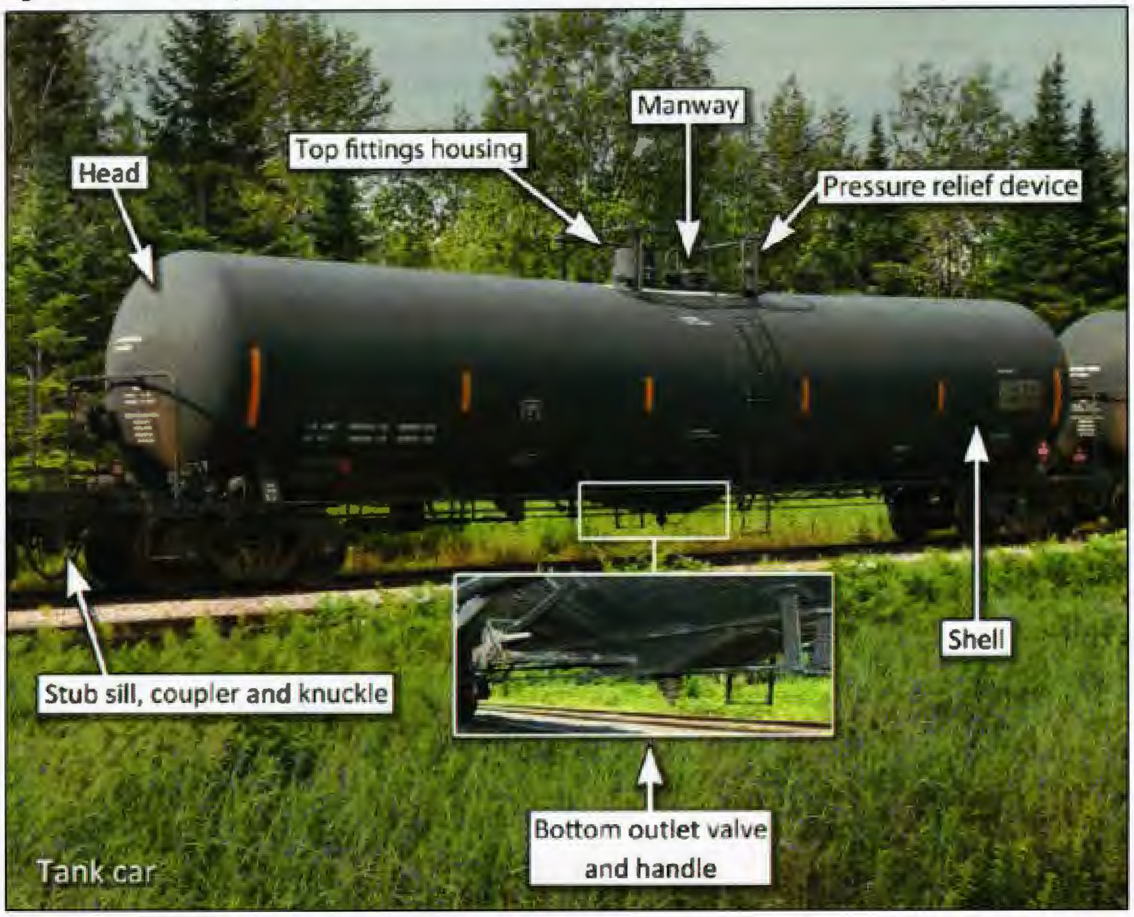
35 Canadian National Railway (CN), Engineering Track Standard (ETS) (June 2011 edition), TS 1.0 – General 13 and 14.

36 Canadian Pacific Railway (CPR), *Red Book of Track Requirements* (2012), sections 6.1.3 and 17, Appendix 6.

37 Section 5.14 of the *Transportation of Dangerous Goods (TDG) Regulations* specifies that a means of containment manufactured, selected, and used in accordance with safety standard CAN/CGSB-43.147, last amended July 2008, is a permitted means of containment for the transportation of Class 3, 4, 5, 6.1, 8, or 9 DGs by rail or by ship.

38 United States *Code of Federal Regulations*, Title 49, Part 179, Specifications for Tank Cars.

Figure 6. Tank car components




### *1.18.1 Examination of the derailed tank cars*

The 63 derailed tank cars were examined in the field (Engineering Laboratory Report LP149/2013), and the following was determined:

- All tank cars were manufactured to United States Department of Transportation (DOT) specification 111A100W1 between 1980 and 2012, and 78% were built in the 5 years prior to the accident.
- All tank cars had been ordered before 01 October 2011.
- None of the tank cars were equipped with head shields, jackets, or thermal protection.
- The shells of 52 tank cars and the heads of 44 tank cars were made of non-normalized steel.[39]
- The shells of 11 tank cars and the heads of 19 tank cars were made of normalized steel.

---

[39] Normalization is a type of process used to improve ductility and toughness properties. The steel is heated slightly above its upper critical temperature and then is air cooled. This results in a fine pearlitic structure, and a more uniform structure.

All 63 derailed tank cars were in compliance with the specification requirement that was in effect at the time of their approval and construction.

The stencilling or stamped markings on some of the tank cars was not legible due to fire and impact damage. Furthermore, some tank car identification plates had been affixed with low-melting-point fasteners and had separated from the tank during the post-derailment fire.

### *1.18.2 Tank car damage assessment*

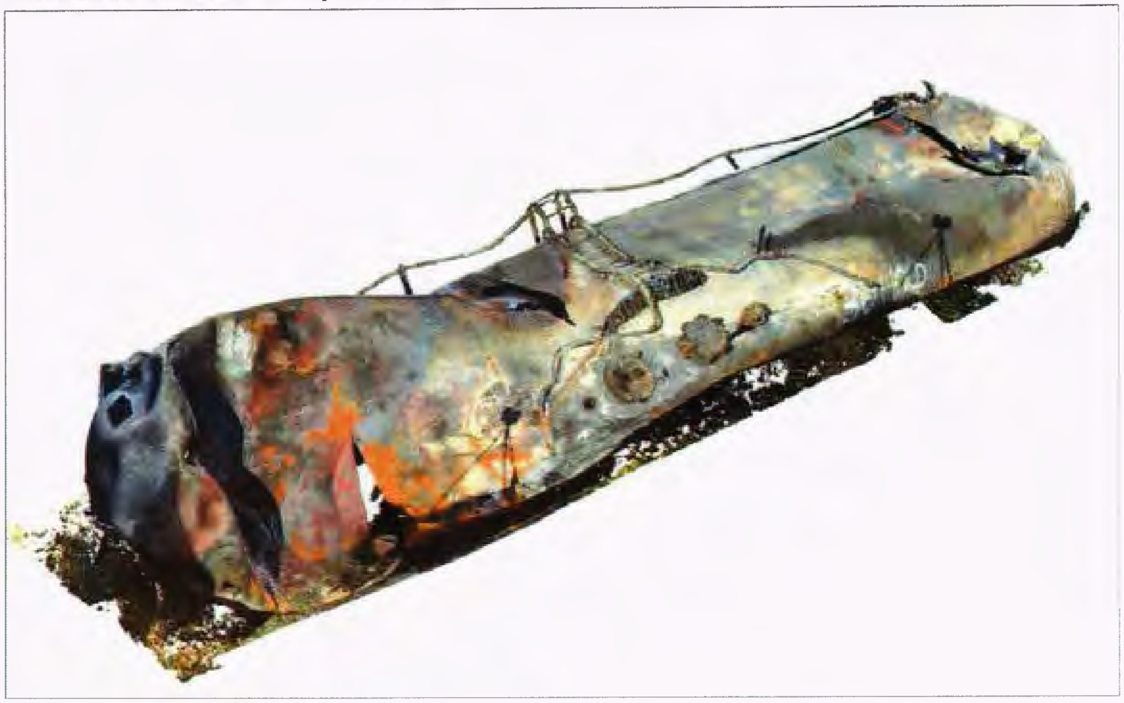
An assessment of the damage sustained by the 63 derailed tank cars revealed that 59 (94%) were breached and released crude oil due to tank damage. The location and extent of the damage varied, depending on the orientation and speed of the cars during the derailment. Many cars sustained damage in multiple locations (Table 3).

**Table 3. Distribution of damage on derailed tank cars**

| | |
|---|---|
| Tank car shells | 37 cars |
| Tank car heads | 31 cars |
| Top fittings and protective housings | 20 cars |
| Pressure relief devices | 12 cars |
| Bottom outlet valves | 7 cars |
| Thermal tears | 4 cars |
| Manway covers | 2 cars |

Three-dimensional (3D) laser scanning was performed on selected derailed tank cars (Engineering Laboratory Report LP165/2013). Analysis of the data revealed that the shells of the tank cars exhibited impact damage ranging from localized buckles to large-scale buckling, and sustained significant reductions in volume (for example, close to 40% reduction in volume was sustained by the most deformed tank) (Photo 16).

Photo 16. 3D laser scan of badly deformed tank



### 1.18.2.1 *Damage to stub sills and couplers*

Stub sills are located at each end of a tank. For cars so equipped, the tank not only carries the product, but is also used as the primary structural member to carry in-train forces. The stub sills contain draft gear components that help absorb in-train dynamic buff (push) and draft (pull) forces, as well as coupler vertical forces (Photo 17).

The field examination showed the following:

- Five tank cars had no impact damage to either the stub sill or coupler.
- Fifty-eight tank cars exhibited at least 1 damaged stub sill or coupler.
- Forty-six tank cars were damaged at both ends of the car, including damage to the stub sill or coupler.
- The last 2 derailed cars exhibited significant impact damage to their stub sills and couplers.
- Nine tank cars exhibited separations at the stub sill attachments (Photo 18).

Photo 17. Complete stub sill

Photo 18. Damaged stub sill

### 1.18.2.2 *Damage to tank car shells*

More than half of the tank cars (37 cars) released product due to impact damage to their shells (Photo 19). Other tank car shell damage included deformed/dented shells with no breach, as well as breaches due to thermal tears.

Photo 19. Tank cars with breaches to their shells (colour indicates relative size of breach: orange = large, yellow = medium, blue = small). The relative size of the breaches is also identified in Appendix B.


### 1.18.2.3 *Damage to tank car heads*

All but 4 of the 63 derailed cars exhibited some form of impact damage (for example, denting or breach) in the top portion of at least one head (Photo 20). About half of the tank cars (31) released product due to damage to the tank car head.

**Photo 20. Head puncture due to rail impact**

### *1.18.2.4 Damage to top fittings and housings*

The majority of the tank cars with damaged top fittings came to rest on their sides or upside down, allowing the product to flow from the damaged top fittings and feed the pool fire.

The top fittings of 32 of the 63 tank cars were housed in a ¾-inch-thick steel circular protective housing designed to provide top discontinuity protection in accordance with applicable AAR requirements[40] (Photo 21).

The top fittings of the remaining 31 tank cars were located in a hinged housing that did not have to meet any of the top discontinuity protection requirements (Photo 22).

---

40 Association of American Railroads (AAR), *Manual of Standards and Recommended Practices* (2007), Specification M-1002, Chapter 2.6: Top Fittings Protection Requirements for Nonpressure Cars.

Photo 21. Protective housing providing top discontinuity protection for tank car fittings (removed cover)

Photo 22. Hinged housing for tank car fittings

The field examination determined the following:

- The top fittings were breached on 4 of the 27 cars (15%) that were equipped with top discontinuity protection housings and that sustained impact damage.
- The top fittings were breached on 16 of the 26 cars (62%) that were equipped with a hinged housing and that sustained impact damage.

#### *1.18.2.5 Damage to manway covers*

A manway cover is used to seal the large opening at the top of the tank (Photo 23). This opening is used by personnel to gain entry into the tank for inspection and maintenance activities and, in Class 111 tank cars, may also be used to load product into the tank car. The manway cover is secured to the manway nozzle using a hinge and typically 6 to 8 bolts. It is sealed by tightening the bolts onto a manway cover gasket.

The field examination determined the following:

- The manway gaskets on most of the derailed tank cars were damaged by extended exposure to the post-derailment fire.
- The manway cover of 2 cars had separated as a result of impact damage.
- The manway cover hinges, bolts, or lugs of 22 tank cars exhibited impact damage that may have compromised their seals.

Photo 23. Manway cover and opening

### 1.18.2.6 *Damage to pressure relief devices*

All 63 derailed tank cars were equipped with at least 1 reclosing pressure relief device (PRD),[41] as per the federal regulations.[42] The start-to-discharge (STD) pressure[43] of these PRDs was either 75 psi (on 48 tank cars) or 165 psi (on 15 tank cars). In addition to different STD pressures, PRDs are designed with different flow capacities.[44] A PRD that can discharge product at greater than 27 000 cubic feet per minute (CFM) is considered to have high flow capacity. In this accident, 13 of the 15 PRDs with STD pressure of 165 psi had flow capacities of about 38 900 CFM.

The field examination determined the following:

- Most of the cars with damaged PRDs came to rest on their sides or upside down, putting the PRD in contact with the liquid space inside the tank; product flowed from the damaged PRD and fed the pool fire.
- On 32 cars, the PRD was fastened to the top unloading nozzle assembly within the top discontinuity protection housing. The PRD of 3 of these 32 cars, or 9%, were breached.
- On the 31 other cars, the PRD was fastened to a safety valve nozzle attached to the top of the tank (Photo 24). The PRDs of 9 of these, or 29%, were breached.

---

41 A reclosing pressure relief device (PRD) uses positive pressure from a return spring to keep the PRD valve in a closed position during normal operation. Some cars had 2 PRDs (that is, a PRD located on either side of the top fitting housing and manway).

42 In order to ensure that PRDs are capable of relieving pressure build-up in the tank in prescribed fire conditions, a combination of various parameters and performance standards, such as minimum and maximum start-to-discharge (STD) pressures and minimum flow capacities, are specified.

43 This is the pressure at which the PRD will activate to relieve pressure within the tank.

44 The STD pressure and the flow capacity of a PRD together determine how efficiently the pressure in a tank car tank can be relieved in fire conditions.

**Photo 24. Pressure relief device**

### *1.18.2.7 Damage to bottom outlet valves*

Federal regulations require that tank cars equipped with bottom outlet valves (BOVs) be built to prevent damage to the valve and the subsequent loss of product during a derailment. Design features include various combinations of breakaway designs and skid protection structures around the valve, as well as a locking arrangement to ensure that the BOV stays closed during transit (Photo 25). The AAR *Manual of Standards and Recommended Practices* (MSRP) specification M-1002, Appendix E, section 10.1.2.8, specifies that BOV handles, unless stowed separately, must either be designed to bend or break free on impact or be positioned so that the handles, in the closed position, are above the bottom surface of the skid protection.

The field examination determined the following:

- There were 36 tank cars with sheared-off BOV nozzles (Photo 26).
- Seven of these tank cars had damaged or missing BOV handles, resulting in the ball valve being open or partially open, which led to a release of product.
- Six tank cars were equipped with internal plug-type BOVs. None of these BOVs were breached.
- The BOV handle assemblies of 43 tank cars were deformed, impact-damaged, or missing.

Photo 25. Bottom outlet valve

Photo 26. Bottom outlet valve with sheared-off nozzle

### 1.18.2.8 *Damage due to thermal tears*

A thermal tear occurs when a tank car is exposed to elevated temperatures such as that from a post-derailment fire. As the temperature inside the tank rises, the product vapourizes, causing an increase in both its internal pressure and the stresses in the tank wall. If the pressure is not relieved, the tank ruptures. Ruptures involving the sudden release of built-up pressure can result in large explosions and fire.

Thermal protection helps delay the rate at which the internal tank temperature rises. It typically consists of an insulating material applied to the exterior of the tank and covered by a steel jacket. Federal regulations specify when thermal protection is required, as well as the performance standard it has to meet (for example, prevention of tank failure for at least 100 minutes in a pool fire and at least 30 minutes in a torch fire). Most general-service Class 111 tank cars are not required to have thermal protection.

Examination of the 63 derailed tank cars showed the following:

- None of the cars were equipped with thermal protection.
- Four cars that had sustained only minor impact damage due to the derailment experienced thermal tears, resulting in an energetic release.
- The length of the thermal tears ranged from 1.6 m to 4.4 m. No fragments of tank material were separated as a result of the thermal tears.
- All of the thermal tears were situated in the vapour space, and the PRDs were located in the liquid space.
- The car with the largest thermal tear (4.4 m) (Photo 27) was equipped with a PRD with an STD pressure of 75 psi, whereas the car with the smallest thermal tear (1.6 m) had a 165-psi PRD.
- Two tank cars experienced a thermal tear within approximately 20 minutes after the fire began.

**Photo 27. Thermal tear**

### *1.18.2.9 Damage due to burn-through*

Thirteen tank cars had localized loss of tank material in the form of a burn-through[45] as a result of extreme fire damage (Photo 28). In the regions around these perforations, there were jagged edges and the tank material exhibited reduced wall thickness, and in some cases, contained brittle cracks.

**Photo 28. Burn-through**

45 A burn-through is a perforation of the tank shell caused by fire damage.

### *1.18.2.10 Metallurgical examination of tank cars*

Selected samples were taken from tank cars involved in the derailment and sent for metallurgical analysis (Engineering Laboratory Report LP168/2013). At least 1 tank car from each car builder was selected.

It was determined that the tank car material generally met all applicable specifications at the time of manufacture. The sample examination did not find any material deficiency that would have affected the performance of the tank cars during the derailment.

### *1.18.3 Regulatory activities related to Class 111 tank cars*

Following a TSB investigation[46] into an accident in August 2004 involving a petroleum product unit train near Lévis, Quebec, the Board recommended that:

> The Department of Transport extend the safety provisions of the construction standards applicable to 286 000-pound cars to all new non-pressurized tank cars carrying dangerous goods.
>
> **TSB Recommendation R07-04 (issued 2007)**

Subsequently, an AAR task force examined improvements to tank car safety, and the AAR tank car standards were amended (Casualty Prevention Circular No. CPC-1232)[47] to incorporate a number of enhancements to all Class 111 tank cars built after 01 October 2011 for the transportation of crude oil and ethanol in PG I or PG II. These enhancements include construction of the tank cars to 286 000-pound standards, protection of the service equipment on the top shell, use of reclosing PRDs, use of normalized steel for tank shells and heads, increased minimum thickness for all tank cars not jacketed and insulated, and at least ½-inch half-head shields. As all of the tank cars had been built before October 2011, none were subject to the requirements of AAR Circular No. CPC-1232.

In 2011, the AAR petitioned Canadian and U.S. regulators to adopt these changes in regulations.

In 2012, following the Cherry Valley, Illinois, investigation,[48] the NTSB recommended that the Pipeline and Hazardous Materials Safety Administration (PHMSA):

---

46 TSB Rail Investigation Report R04Q0040

47 Association of American Railroads (AAR), Casualty Prevention Circular No. CPC-1232 (issued 31 August 2011) pertains to cars built for the transportation of PG I and PG II materials with the proper shipping names "Petroleum Crude Oil", "Alcohols, n.o.s." (denatured ethanol), and "Ethanol/Gasoline Mixture" in packing groups (PGs) I and II.

48 United States National Transportation Safety Board (NTSB), Accident Report NTSB/RAR-12-01, *Derailment of CN Freight Train U70691-18 With Subsequent Hazardous Materials Release and Fire*, Cherry Valley, Illinois, June 19, 2009 (Washington, DC, 14 February 2012).

> Require that all newly manufactured and existing general service cars authorized for the transportation of denatured fuel ethanol and crude oil in Packing Groups I and II have enhanced tank head and shell puncture resistance systems and top fittings protection that exceeds existing design requirements for DOT-111 tank cars.
>
> NTSB Recommendation R-12-5

In the same investigation, the NTSB recommended that the AAR:

> Review the design requirements in the Association of American Railroads Manual of Standards and Recommended Practices C-III, "Specifications for Tank Cars for Attaching Center Sills or Draft Sills," and revise those requirements as needed to ensure that appropriate distances between the welds attaching the draft sill to the reinforcement pads and the welds attaching the reinforcement pads to the tank are maintained in all directions in accidents, including the longitudinal direction.
>
> NTSB Recommendation R-12-9

In September 2013, PHMSA announced its intent to propose a regulation[49] adopting new tank car requirements in the *Hazardous Materials Regulations* (49 CFR). PHMSA requested comments from stakeholders on the AAR's 2011 Class 111 tank car improvements.

In November 2013, both the AAR and the American Short Line and Regional Railroad Association (ASLRRA) expressed support for even more stringent tank car standards. They called for additional improvements to tank cars transporting flammable liquids (including PG III flammable liquids), retrofitting of existing tank cars in flammable liquid service, and aggressive phase-out of tank cars that cannot meet retrofit requirements. The tank car improvements include modifications such as:

- tank car jackets, for added puncture resistance;
- full-height head shields;
- thermal protection blanket or coatings in conjunction with jackets;
- high-capacity PRDs;
- reconfiguration of the BOV handles; and
- possible designation of a new tank car class.

In January 2014, TC proposed[50] adopting AAR's 2011 Class 111 tank car improvements in the *Transportation of Dangerous Goods Regulations* (*TDG Regulations*).

In January 2014, TSB Recommendation R14-01 called for enhanced protection standards for tank cars used to transport flammable liquids. See section 4.1.2.1 for further details.

---

[49] Pipeline and Hazardous Materials Safety Administration, PHMSA-2012-0082 (HM-251): Hazardous Materials: Rail Petitions and Recommendations to Improve the Safety of Railroad Tank Car Transportation (06 September 2013).

[50] Government of Canada, *Canada Gazette*, Part I, Vol. 148, No. 2 (11 January 2014), Regulations Amending the Transportation of Dangerous Goods Regulations (Safety Standard TP14877: Containers for Transport of Dangerous Goods by Rail).

## 1.19 Dangerous goods

The transportation of dangerous goods[51] (DGs) is governed in Canada[52] and the United States[53] by federal regulations, which are based on the *United Nations Recommendations on the Transport of Dangerous Goods*.

### 1.19.1 Class 3 – Flammable liquids

Flammable liquids in Class 3 are DGs whose vapours form an ignitable mixture with air at or below a temperature of 60 °C. Flammable liquids can pose serious hazards due to their volatility and flammability, which are determined respectively by the initial boiling point[54] and by flashpoint.[55]

Given that volatility and flammability of flammable liquids vary widely, they are grouped together based on these characteristics so that different requirements, including packaging, storage, handling, and transportation, can be established. According to the *TDG Regulations*, Class 3s are divided into 3 packing groups (PGs), ranging from PG I (highest hazard) to PG III (lowest hazard):

- PG I, if the flammable liquid has an initial boiling point of 35 °C or less at an absolute pressure of 101.3 kPa and any flashpoint.
- PG II, if the flammable liquid has an initial boiling point greater than 35 °C at an absolute pressure of 101.3 kPa and a flashpoint less than 23 °C.
- PG III, if the criteria for inclusion in PG I or PG II are not met.

The PG is established by determining a flammable liquid's flashpoint and boiling point.

### 1.19.2 Petroleum crude oil

Petroleum crude oil is a Class 3 flammable liquid with a wide range of flammability and volatility characteristics, and is therefore assigned to one of the 3 PGs. It is most prominently qualified in terms of its sulphur content (sweet to sour) and density (light to heavy).

---

51 Dangerous goods are also referred to as "hazardous materials" in the United States. In this report, the term "dangerous goods" is used, except when referring to United States regulations or standards.

52 *Transportation of Dangerous Goods Act* and *Transportation of Dangerous Goods (TDG) Regulations*.

53 United States *Code of Federal Regulations*, Title 49 (49 CFR), *Hazardous Materials Regulations*.

54 The initial boiling point of a liquid mixture is the temperature value when the first bubble of vapour is formed from the liquid mixture, at a given pressure. The initial boiling point is a function of pressure and composition of the liquid mixture.

55 The flashpoint of a liquid is the minimum temperature at which the liquid gives off vapour in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. A lower flashpoint represents a greater flammability hazard under laboratory conditions.

The density of petroleum crude oil is described in terms of its American Petroleum Institute (API) gravity[56] (expressed in degrees), whereby a higher number indicates lower density. The thresholds defining "light," "medium," and "heavy" crude oil vary by the product's region of origin and by the organization making the determination.[57]

#### 1.19.2.1 *Testing of crude oil samples*

Crude oil samples were collected from 9 tank cars on MMA-002 that did not derail. Samples were also taken from 2 tank cars in Farnham that were part of another MMA unit train (MMA-874). This train was transporting petroleum crude oil from the same origin.

All crude oil samples were collected at atmospheric pressure and tested for characteristics relevant to the classification of the petroleum crude oil and to its behaviour and effects during the post-accident spill and fire. The level of hazard posed by the petroleum crude on MMA-002 had not been accurately documented, as the samples that were tested had the properties of a flammable liquid of Class 3, PG II. It was concluded that the large quantities of spilled crude oil, the rapid rate of release, and the oil's high volatility and low viscosity were the major contributors to the large post-derailment fireballs and pool fire. There was no indication that the crude oil's properties had been affected by contamination from fracturing process fluid additives. No detectable levels of hydrogen sulphide gas were found at the derailment site. See Appendix F for a summary of the test results of the crude oil samples, and Engineering Laboratory Report LP148/2013 for further details.

### 1.19.3 *Regulatory requirements for classification and packaging*

The federal regulations[58] require DGs to be properly classified and packaged[59] before they are offered for transport. For flammable liquids, the classification consists of determining the primary class, subsidiary class, UN number, proper shipping name, and PG. Once a DG is properly classified, an authorized container must be selected.

For DGs imported into Canada, the *Transportation of Dangerous Goods Regulations*[60] (*TDG Regulations*) require the importer (consignor)[61] to ensure that the DGs have the correct classification before they are transported in Canada. For flammable liquids, the *TDG Regulations* also permit[62] a consignor to use a classification that was determined by a previous consignor or the manufacturer.

---

56 The American Petroleum Institute (API) gravity is a measure of a crude oil's relative density in degrees API, as defined by the American Petroleum Institute.

57 Petroleum crude oil with an API gravity range above 32° to 37° is generally referred to as a "light" crude oil. Petroleum crude oil with an API gravity range below 20° to 26° is considered a "heavy" crude oil.

58 *Transportation of Dangerous Goods (TDG) Regulations*, Section 2.2; United States: *Hazardous Materials Regulations*, Section 171.1.

59 Packaging refers to the means of containment for the dangerous goods. In this accident, the containers were the tank cars.

60 *Transportation of Dangerous Goods (TDG) Regulations* (23 November 2012), subsection 2.2(2).

61 Ibid., Section 1.4.

62 Ibid., paragraphs 2.2(3)(c) and (d).

The *TDG Regulations* allow dangerous goods to be included in PG I if the packing group is unknown, and in PG II if it is known (or reasonably believed) to be PG II or III.[63] They also contain provisions in case of detected or suspected classification errors.

### *1.19.4 Safety data sheets*

A safety data sheet (SDS)[64] is produced by chemical manufacturers, distributors or suppliers pursuant to federal hazardous products legislation and standards.[65] The primary purpose of the SDS is to communicate the dangers of the hazardous chemical product. It contains detailed information about the nature of the hazardous product, including physical and chemical properties, and health, safety, fire and environmental hazards. Although not required by federal law, an SDS may also include other information, such as DG classification and transportation information.

Some products, such as petroleum crude oil, contain many ingredients whose concentrations can vary depending on the product's origin and vintage. Common industry practice, as permitted by federal hazardous products legislation, is to prepare and provide generic, representative SDSs that apply to products having similar characteristics.

The petroleum crude oil transported by MMA-002 originated from oil wells belonging to 11 different producers in the Bakken shale formation in North Dakota. WFSI provided 10 different SDSs representing the petroleum crude oil in the train (Appendix G). The classification of the petroleum crude oil for the purpose of transportation was not based on SDS information.

There was no specific practice or procedure to either verify that each SDS accurately reflected the properties of the product or family of products it represented, or that the products were properly classified for transport. Further, where there were multiple SDSs for products having similar characteristics, there was no review to compare and reconcile the provided information for consistency.

### *1.19.5 Transportation of petroleum crude oil from North Dakota toward New Brunswick*

#### *1.19.5.1 Transportation of petroleum crude oil by road*

The petroleum crude oil was loaded in DOT-407[66] cargo tank trucks operated by Prairie Field Services at each product supplier facility, and transported by road to the rail loading facility at New Town, North Dakota, operated by Strobel Starostka Transfer, LLC (SST).

The shipping documents indicated that the shipper was the product's supplier and that the consignee was WFSI. The product was described on the majority of the shipping documents

---

63 Ibid., subsection 2.19(2).

64 A safety data sheet (SDS) is the term used by the Globally Harmonized System of Classification and Labelling of Chemicals, and will be the term used in this report. In Canada, it was previously known as a material safety data sheet.

65 Canada: *Hazardous Products Act*; United States: *Occupational Safety and Health Standards*.

66 DOT-407 cargo tank trucks are authorized by federal regulations to transport petroleum crude oil, UN 1267, Class 3, PGs I, II, and III by road.

as UN 1267, petroleum crude oil, Class 3, PG II.[67] The majority of producers in the Bakken region considered crude oil from the region as PG II product, and had cargo tank truck shipping documents preprinted to reflect this designation.

There was no practice, procedure, or activity to verify, confirm, or validate the classification of the product transported by cargo tank trucks from the suppliers' facilities to the rail loading facility. The product was not being tested for the purpose of classification for transportation by road.

SST's standard operating procedures were to collect and test (on a monthly basis) composite samples representing the product being shipped from New Town. The tests primarily determined sulphur content, API gravity, boiling point, and the presence of light-end gases. The testing was performed primarily for quality assurance and control purposes and to establish the product's market value. The product's flashpoint was not being determined.

#### *1.19.5.2 Transportation of petroleum crude oil by rail*

At the New Town rail loading facility, the product was transloaded directly from the cargo tank trucks into Class 111[68] rail tank cars, with about 3 truckloads filling 1 tank car. The tank cars were leased by the Western Petroleum Company. The product was loaded, offered for transport, and being transported from New Town to Saint John pursuant to the applicable provisions of the United States *Code of Federal Regulations*, Title 49 (49 CFR).[69]

The shipping documents for the tank cars identified the shipper as Western Petroleum Company and the consignee as Irving Oil Ltd. The product was identified as UN 1267, petroleum crude oil, Class 3, PG III.

The tank car shipping documents were generated by CPR based on the shipper's instructions. These instructions were provided by SST on behalf of the shipper, using CPR's web-based bill-of-lading instruction system. The shipper had no procedure to verify, validate, or confirm the classification of the DGs being offered for transport, or to reconcile the shipping document information of the tank cars being offered for transport with those of the inbound product transloaded into those tank cars prior to releasing the tank cars to CPR.

The characteristics of the product for the purpose of classification for transportation by rail were not tested prior to being offered for transport. At destination, Irving sampled petroleum crude oil based on the volume of product being unloaded. Tests at an on-site laboratory determined density (which is used to calculate the API gravity), Reid vapour pressure, and whether bottom sediment or water were present.

This testing was performed for quality assurance and control purposes, and the product's flashpoint and initial boiling point were not determined. Irving relied on its suppliers to

---

67 A few shipping documents indicated the product to be a PG III.

68 Class 111 rail tank cars are authorized by federal regulations to transport petroleum crude oil, UN 1267, Class 3, PGs I, II and III by rail.

69 Dangerous goods (hazardous materials) shipments by rail originating in the United States are allowed under the *TDG Regulations* (subsection 10.1) to be transported from the United States to Canada pursuant to the applicable provisions of 49 CFR, under certain conditions.

determine the classification of imported petroleum crude oil, as permitted by the *TDG Regulations*.[70]

## *1.20 Route planning and analysis for trains carrying dangerous goods*

The frequency and consequences of derailments are dependent on several operational factors, such as train speed, rail integrity, braking systems, and emergency response.

Train speed is a factor because the energy dissipated during a derailment depends on the kinetic energy of the train in movement, and thus on its speed and mass. TSB data on main-track derailments from 2003 to 2012 indicate that higher derailment speeds are significantly associated with a higher number of derailed cars; the number of derailed cars is an indicator of accident severity. Speed reduction has the potential to reduce the severity and consequences of derailments, but would not necessarily result in a reduction in the number of derailments. This is because track maintenance standards are less stringent for lower classes of track.

In January 1990, the AAR issued Circular OT-55, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials*. Circular OT-55 gave the rail industry guidance on railroad operating practices for the transport of selected dangerous goods, including poisonous-by-inhalation (PIH) or toxic-by-inhalation (TIH) products and radioactive materials. It also identified technical and handling requirements for "key trains" and "key routes." Key trains were restricted to 50 mph, and main tracks on key routes had to be inspected by rail defect detection cars and track geometry inspection cars (or be subject to an equivalent level of inspection) at least twice per year, and all sidings at least once per year. Following the Lac-Mégantic accident, the definition of a "key train" was expanded in Circular OT-55-N.[71]

Route planning and analysis involves a comprehensive, system-wide review of all operations, infrastructure, traffic, and other factors affecting the safety of train movements. Factors to be considered in selecting the route that presents the fewest overall safety risks include hazards related to the nature of the product, the volume being transported, the handling of the product, railway infrastructure characteristics (for example, signalling, track class, crossings, wayside systems, traffic density), passenger traffic (that is, shared track), geography, environmentally sensitive areas, population density, and emergency response capability along the route. Route planning and analysis, as well as periodic assessments of the safety risks along the selected route, are critical to enhancing rail transportation safety because they allow the identified vulnerabilities to be proactively addressed (Figure 7).

---

70 *Transportation of Dangerous Goods (TDG) Regulations* (23 November 2012), paragraphs 2.2(3)(c) and (d).

71 Association of American Railroads (AAR), Circular OT-55-N, Recommended Railroad Operating Practices for Transportation of Hazardous Materials (effective 05 August 2013), available at http://www.boe.aar.com/CPC-1258%20OT-55-N%208-5-13.pdf (last accessed on 15 July 2014). OT-55-N was expanded by reducing from 5 to 1 the required number of car loads of poisonous or toxic-inhalation hazard and anhydrous ammonia and ammonia solutions. Also, the circular was expanded to include any combination of hazardous materials when transported as a car load or intermodal portable tank load.

**Figure 7. Approximate route of the tank cars on MMA-002, which travelled through Toronto and Montréal en route to Lac-Mégantic**


In January 2014, TSB Recommendation R14-02 called for route planning and analysis, as well as periodic risk assessments, for trains carrying dangerous goods. See section 4.1.2.2 for further details.

## *1.21 Emergency response*

The Lac-Mégantic Fire Department was notified by 911 calls immediately after the accident. Given the size of the fire, the city's emergency response plan was put into effect. The first general alarm was sounded at 0119 on 06 July 2013. The first fire rescue vehicle and the SQ arrived at the accident site at about 0122 on 06 July 2013.

The Lac-Mégantic Fire Department and the Nantes and Saint-Augustin-de-Woburn fire departments have intermunicipal mutual aid agreements to allow joint action in case of major disasters. More than 1000 firefighters from 80 different municipalities in Quebec, and from 6 counties in the state of Maine, participated in the response, which was reported to be the largest fire response in recent Quebec history. At any given time, approximately 150 firefighters were on site. Initial firefighting efforts focused on evacuating people and preventing further spread of the fire to nearby buildings and structures. Approximately 2000 people were evacuated.

Following confirmation that the DGs involved in the fire consisted of a Class 3 flammable liquid hydrocarbon, the emergency responders assessed the situation and estimated that approximately 33 000 litres of foam concentrate would be required to allow a continuous, uninterrupted production of foam to be applied to the fire. As that quantity of supply was not available locally, the Lac-Mégantic Fire Department arranged to transport the foam concentrate from a refinery in Lévis, about 180 km away.

The foam concentrate arrived on site at approximately 1800 on 06 July 2013. Application of the foam started at approximately 2200 and continued uninterrupted for about 8 hours, until the fire was under control at 0600 on 07 July 2013. The fire was extinguished at approximately 1100 on 07 July 2013, with minor occasional flare-ups afterward.

Class 3 flammable liquid hydrocarbons present a risk of fire and explosion if exposed to heat, sparks, or flames. All firefighters in Quebec are trained in accordance with provincial requirements. The training, which includes a DG component, is not specific to rail transportation.

Support from numerous organizations arrived at various intervals, including personnel from MMA, CN, the Railway Association of Canada (RAC), the federal and provincial governments, WFSI, the importer (Irving Oil Commercial G.P.), the petroleum industry, and environmental remediation companies.

Throughout the emergency response, regular coordination meetings were held with all involved. During these meetings, priorities were established, and participants discussed what action should be taken and possible response methods, as well as the impact on the progress of the overall operations. For several hours, all work at the site stopped due to concerns about the ability of the railway to cover all emergency response costs. The stoppage affected the progress of the emergency response and environmental remediation, resulting in oil migrating back to zones that had earlier been declared safe.

### *1.21.1 Emergency response assistance plans*

The risks posed by specific DGs are determined based on the properties, characteristics, and quantities of the DGs being transported. An emergency response assistance plan (ERAP) is required by the *TDG Regulations* for certain DGs[72] that pose a higher than average risk when transported in certain quantities. Persons who offer such DGs for transport or import must have an ERAP approved by TC.

When there is an accident, the handling of these DGs requires special expertise, resources, supplies, and equipment. An approved ERAP describes the specialized response capabilities, equipment and procedures that are available to local emergency responders to assist with addressing the consequences of the accident.

In 2013, the *TDG Regulations* did not require an approved ERAP for petroleum crude oil (UN 1267). However, meetings were held between MMA and a number of stakeholders in April 2013 to discuss mutual assistance plans in the event of a petroleum crude oil spill.

#### *1.21.1.1 Previous recommendation*

Following the TSB investigation into the 1999 derailment, collision, and fire involving a unit train carrying flammable liquid hydrocarbons near Mont-Saint-Hilaire, Quebec (TSB report R99H0010), the Board determined that a comprehensive emergency response plan, for which roles, resources, and priorities for emergency response are defined ahead of time, would enhance the emergency response and alleviate post-accident risks. The Board recommended that:

> Transport Canada review the provisions of Schedule I and the requirements for emergency response plans to ensure that the transportation of liquid hydrocarbons is consistent with the risks posed to the public.

**TSB Recommendation R02-03 (issued June 2002)**

---

72 Dangerous goods such as explosives, flammable gases, certain acids, and toxic substances.

At that time, liquid hydrocarbons were not routinely transported in unit trains of tank cars. The *TDG Regulations* were amended to require an approved ERAP for diesel fuel, gasoline, and aviation fuel when offered for transport or imported in a configuration of 17 or more interconnected rail tank cars that are each at least 70% full.

In assessing the response to TSB Recommendation R02-03, the Board found that the updated ERAP application criteria, as implemented by TC, mitigated the risks to the public posed by the transportation of large volumes of liquid hydrocarbons that were regularly transported between Québec and Montréal in interconnected tank cars. The Board therefore assessed the response to TSB Recommendation R02-03 as Fully Satisfactory in August 2008.

In January 2014, TSB Recommendation R14-03 called for emergency response assistance plans for the transportation of large volumes of liquid hydrocarbons. See section 4.1.2.3 for further details.

## 1.22 Montreal, Maine & Atlantic Railway

MMA was formed in January 2003, when RWI acquired the Bangor & Aroostook assets, including the former QSR, from Iron Road Railways. RWI is a railway management, consulting and investment corporation specializing in privatizations and restructurings.

MMA owned 510 miles of track in Maine, Vermont, and Quebec, and employed approximately 170 people. Its head office was in Bangor, Maine, and there was a Canadian office in Farnham, where about 25 LEs and train conductors were based. At the time of the accident, MMA operated about 15 trains daily, with a fleet of 52 locomotives, 38 of which were available for service. Main-track operations were conducted regularly between Millinocket, Maine, and Searsport, Maine, and from Brownville Junction, Maine, to Montréal, Quebec. Service was also provided between Newport, Vermont, and Farnham to connect the northeastern United States westbound trains to Montréal for CPR destinations in the United States and Western Canada.

MMA connected with 7 railways (Class 1, short line, and local) and provided the shortest, most direct rail link through Maine, between Saint John and Montréal.

### 1.22.1 Montreal, Maine & Atlantic Railway's operations for MMA-001 and MMA-002

Prior to June 2012, westbound MMA-001 from Brownville Junction, and eastbound MMA-002 from Saint-Luc Yard through Farnham, were operating 3 times per week. These trains carried mixed freight, which included some DGs. Upon arrival at Megantic, MMA-002 would be immediately taken over by a Brownville Junction crew for the continuation of its journey. At the beginning of each week, an extra Brownville Junction crew would travel by road to Megantic to ensure the uninterrupted journey of MMA-002. On occasion, when these crews were not immediately available, MMA-002 was left unattended at Nantes on the main track or in the siding. After arrival, a Farnham crew would lay over for rest, and the next day would take MMA-001, which would have been tied up for the night at Vachon, westward to Farnham.

Starting in June 2012, the addition of unit trains to transport crude oil resulted in an increase in MMA's train traffic. Eastward weekly train traffic consisted of about 2 unit fuel trains and 5 mixed freight (that is, 1 train per day). Westward train traffic was also about 1 train per day. All crew changes were performed near Lac-Mégantic. As a result of this increase in traffic, both the Brownville Junction crew and the Farnham crew would lay over and, once they met the work/rest requirements, they would take control of the opposing train for their return trip. The next day, the LE for MMA-002 would be called earlier than the LE for MMA-001. The trains would meet at Vachon; MMA-001 would be in the siding while MMA-002 would pass on the main track.

This crew-change practice usually resulted in MMA-002 being left unattended on the main track at Nantes and MMA-001 being left unattended at Vachon, often for 6 or more hours. As per normal MMA operating practice, these trains were left with the reverser[73] removed from the control stand and placed with the train's paperwork on the console or on the LE seat. The doors on all locomotives were left unlocked.

Travel time for an MMA train between Farnham and Nantes typically was between 10 to 12 hours. Trains were normally left at Nantes instead of Vachon so that the crew would not exceed the maximum of 12 hours on duty. On some occasions, the trip to Nantes took longer than expected, resulting in the crew members exceeding their allowable duty time or leaving the train at Gould, Quebec, at Mile 31.00 of the Sherbrooke Subdivision.

### *1.22.2 Mandatory off-duty times for operating employees*

The maximum continuous on-duty time for operating employees on a single tour of duty is 12 hours. The *Work/Rest Rules for Railway Operating Employees*[74] specify that operating employees who are off duty after being on duty in excess of 10 hours at other than the home terminal must have at least 6 continuous hours off duty, with the mandatory off-duty time commencing upon arrival at the accommodations provided by the railway company. In case of an emergency, off-duty employees can be recalled. If a crew's rest is interrupted, the rest time is reset.

The continuous duty time of the LE for MMA-002 was 10 hours and 15 minutes. The LE for MMA-001 was under the same mandatory off-duty time and was lodging at the same accommodations in Lac-Mégantic as the LE for MMA-002.

### *1.22.3 Securement of trains (MMA-002) at Nantes*

With the new train schedule, trains were left at Nantes and at Vachon (the location where the 2 trains could meet, some 10 miles away). By leaving MMA-002 at Nantes, the train could be parked in a location where no crossing would be blocked, where access would be easy for pick-up and drop-off of crews, and where rail access to the siding would be allowed where cars were normally stored. There were no regulations precluding trains, including those carrying DGs, from being left unattended on a main track. When trains were secured at Nantes, they would be left on the main track with at least 1 locomotive running, the automatic brakes released, the independent brakes applied, and a number of hand brakes applied.

---

73 The reverser is a directional control handle that must be inserted into the controls of a locomotive before it can be operated, thereby acting as a key for the locomotive.

74 Transport Canada, TC O 0-140, *Work/Rest Rules for Railway Operating Employees* (February 2011), available at http://www.tc.gc.ca/eng/railsafety/rules-tco140-364.htm (last accessed on 15 July 2014).

For 2-person crews, train securement was the responsibility of both crew members. Securement consisted of applying a number of hand brakes and then testing their effectiveness. The conductor would determine the number of hand brakes to be applied and would apply them once the train was brought to a stop. On occasion, LEs would assist in the application of the hand brakes.

With a single-person train operator, the responsibility rested with the LE for both the application and the effectiveness testing of the hand brakes. To ensure that the train would not roll away while the LE was applying the hand brakes, the automatic brakes were applied.

TSB conducted a survey of LEs and conductors to determine train securement practices at Nantes, and it showed that the number of hand brakes applied to trains varied. Two-person crews would consistently apply at least the minimum number of hand brakes specified in MMA's GSIs. Some single-person train operators reported applying less than the minimum number of hand brakes.

To perform a hand brake effectiveness test, some LEs would release the automatic and independent brakes and attempt to move the train, while others would not release the independent brakes and would not attempt to move the train. When a proper hand brake effectiveness test was performed, additional hand brakes would be applied, if required.

For fuel conservation purposes, MMA instructions were to shut down all idling locomotives not equipped with an auto-start. To comply with U.S. regulations (requiring brake testing by qualified employees if a train is off air for more than 4 hours), the MMA practice was to leave at least 1 locomotive running on U.S.-bound trains. Some crews left all of the locomotives running in all weather.

### *1.22.4 Securement of trains (MMA-001) at Vachon*

Shortly before the accident, MMA-001 was parked in the siding at Vachon by a Brownville Junction single-person train operator who was to be assigned to MMA-002 the following morning. MMA-001, consisting of 5 locomotives and 98 residue tank cars, had been secured with 5 hand brakes, and the independent brakes were applied. The locomotive cab door was not locked, and the train's paperwork along with the reverser were sitting on the locomotive console. The minimum hand brake requirement for a train of this length, as per MMA's instructions, was 11 hand brakes.

### *1.22.5 Recent runaway train history at Montreal, Maine & Atlantic Railway and previous TSB investigations*

According to TSB's Rail Occurrence Database System (RODS), there were 5 occurrences involving runaway MMA equipment between 20 September 2004 and the date of the accident. All 5 involved yard-switching movements, 1 of which involved cars rolling onto the main track.

The TSB has investigated 9 runaway train occurrences since 2005; in addition to this accident, 5 others involved short line railway operations. In all of these occurrences, the investigation into the operations of these railways identified safety deficiencies in training, oversight, and operational practices (Appendix H).

### 1.22.6 *Training and requalification of Montreal, Maine & Atlantic Railway crews in Farnham*

Section 10 of the *Railway Employee Qualification Standards Regulations* (SOR/87-150) states that "a railway company shall, at intervals of not more than three years, have each employee in an occupational category re-examined on the required subjects."[75] CROR General Rule A requires every employee in any service connected with movements to:

> [...]
> (vi) be conversant with and governed by every safety rule and instruction of the company pertaining to their occupation;
> (vii) pass the required examination at prescribed intervals, not to exceed three years, and carry while on duty, a valid certificate of rules qualification;[76]
> [...]

Railways design and administer training and requalification programs according to their needs. The programs usually take place in a classroom setting, where the exam topics are reviewed with an instructor and discussions take place to ensure that the rules are properly understood and applied. Exams vary from knowledge-based to scenario-based, with short-answer questions requiring written responses or with multiple-choice questions. Knowledge-based exams contain questions that test specific rules or instructions and are typically closed-book. Scenario-based exams require the interpretation and application of CRORs, as well as of special instructions, to frequent scenarios. These exams are usually open-book and promote the development of problem-solving skills while using the company-provided manuals. Instructor feedback is a component of a requalification program. TC has the authority to review companies' training and requalification programs.

MMA delivered training to RTCs, locomotive engineers, conductors, and engineering employees. A review of MMA's training and requalification program determined the following:

- MMA's requalification exams tested employees on most CRORs and several MMA special instructions. They were knowledge-based, with short answers and multiple-choice questions.
- Requalification typically consisted of 1 day to complete the exam, and did not always involve classroom training. On many occasions, employees would take the exam home for completion.
- MMA employees did not have the opportunity to review their requalification exam after it was corrected, and received no feedback on their mistakes.
- A comparison between multiple requalification exams revealed that, over the years, they had essentially remained the same. However, there was increased use of multiple-choice questions.

---

75 Canadian Transport Commission, SOR/87-150, *Railway Employee Qualification Standards Regulations* (12 March 1987), General, 10 (1).

76 Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR) (2008), General Rules, A (vi) and (vii).

- The exams repeated the same question on the minimum number of hand brakes for leaving unattended equipment. They did not have questions on the hand brake effectiveness test, the conditions requiring application of more than the minimum number of hand brakes, nor the stipulation that air brakes cannot be relied upon to prevent an undesired movement.
- Inconsistencies in the correction and grading of exams were noted. On some multiple-choice questions, more than one answer was accepted as correct, and some short-answer questions were answered by writing the applicable CROR number rather than writing the procedure to be followed.
- MMA did not consistently comply with the 3-year interval for requalification. For several employees, the deadlines were exceeded by several months, with temporary certificates being issued.

### 1.22.7 *Training and requalification of the locomotive engineer*

The accident LE had completed a requalification exam in September 2006. The next requalification was completed in December 2009, which was 3 months beyond the mandatory deadline. The LE received a new certificate of rules qualifications in March 2013, again 3 months after the expiration of his certificate. In April 2013, the LE completed the requalification exam at home, after having received the new certificate. The LE did not receive feedback on the results of that exam.

The LE's requalification exams in 2006 and 2009 included the same question on the number of hand brakes for a cut of cars left in a siding. In both exams, the LE's answers complied with MMA's hand brake requirements as per the instructions. In 2012, the LE's requalification exam contained 2 multiple-choice questions on the minimum number of hand brakes required for a cut of cars left unattended. Again, the LE's answers complied with MMA's hand brake instructions.

CROR General Rule A requires every employee in any service connected with movements to:

> (ii) have a copy of this rule book, the general operating instructions, current time table and any supplements, and other documents specified by the company accessible while on duty.[77]

At MMA, the other required documents under CROR General Rule A included its GSIs and *Safety Rules*. At the time of the accident, the LE was not in possession of all of the mandatory documents, including the GSIs and *Safety Rules*.

### 1.22.8 *Operational tests and inspections at Montreal, Maine & Atlantic Railway*

MMA developed the Operational Tests and Inspections (OTIS) Program for its supervisors to monitor employees' adherence to railway safety rules and instructions. The OTIS program at MMA involved field supervisors observing employees as they performed their work. These observations were to be conducted unannounced. The employee evaluations

[77] Ibid., (ii).

were based on compliance with GSIs, operating bulletins (OBs), *Safety Rules*, timetables, GOIs, and CROR.

Non-compliance with rules and instructions would be noted, and corrective action could result. Depending on the severity of the infraction, the non-compliance could result in a verbal correction, a letter of reprimand, or a suspension. All observations were entered into the OTIS system with either a "pass" or "failure" evaluation. Employees were notified of the result only if they failed the test.

MMA developed an OTIS manual to aid supervisors in the implementation of the program. The manual outlined the program's objectives, provided guidance on the methods and frequency of test administration, and provided general field instructions on implementing the program. Each supervisor was required to conduct a minimum of 15 OTIS tests per month (that is, 180 per year). Additional guidance provided to the supervisors included:

- instruction in ensuring that observations are conducted at various times and locations so that employees perceive that they may be tested at any time;
- direction in identifying those employees who need remedial rules training or appropriate discipline;
- guidance in periodically advising employees who consistently comply with all operating instructions that they were found to be in compliance with a recent test;
- development of a list of "Core Rules". The 2013 list, on which supervisors were to focus, included CROR 112(a) and (b), and OB 2-133, which covered the application and testing of hand brakes;
- identification of several rules in which a minimum number of tests per month were to be conducted. For example, CROR 112 was to be tested at least 2 times per month per supervisor.

Supervisors were provided with periodic reports (at least quarterly) on their progress in completing the required number of tests and were reminded of which rules to focus on. Table 4 summarizes the number of OTIS observations completed by each supervisor.

**Table 4. Operational Tests and Inspections (OTIS) observations completed per supervisor**

| | Supervisor 1 | Supervisor 2 | Supervisor 3 | Supervisor 4 | Supervisor 5 |
|---|---|---|---|---|---|
| 2012 | 197 | 58 | 116 | 89 | N/A |
| 2011 | 208 | 84 | 137 | 216 | 154 |
| 2010 | 232 | 181 | 216 | 224 | 260 |
| 2009 | 233 | 140 | 199 | 177 | 230 |

Note:
Supervisor 5 was no longer employed at MMA after July 2011.

For the 4-year period from 2009 to 2012, the OTIS results were as follows:

- Of the 3789 tests conducted, 128 of the observations were entered into the system as "Failure".
- Testing on CROR 112 and GSI 112 had been conducted 31 times. There were 2 failures.

- Testing on OB 2-133 had been conducted 35 times. There were 5 failures.

During a test for compliance with hand brakes, supervisors checked the number of hand brakes applied to ensure that the number met the minimum requirement. However, they seldom checked to ensure that a proper hand brake effectiveness test was conducted. To test for a proper hand brake effectiveness test, supervisors had to be at the site, unannounced, when the train arrived. Failing that, supervisors had to review the LER download after the trip. MMA reviewed downloads only after accidents. Since 2009, no employee had been tested on CROR 112(b), which targeted the hand brake effectiveness test. In 2012, U.S. employees had been tested twice on that rule; both tests had resulted in a "Failure".

Since 01 January 2009, the LE had been tested 97 times, and had failed 3 of these tests. Eight of the tests had been conducted outside of the hours of 0800 to 1800. Of the 97 tests, 70 were conducted within 27 miles of Farnham, and the remaining 27 were conducted in Sherbrooke. Seven of the 97 tests were on CROR 112 or OB 2-133, and the LE had successfully passed. None of the tests targeted the hand brake effectiveness test, and none were performed at Nantes.

## 1.23 Single-person train operations

### 1.23.1 Implementation of single-person train operations

At the time of the accident, there were no rules or regulations preventing railways from implementing SPTO (single-person train operations). In Canada, there are only 2 federally regulated railways to have operated using SPTO: MMA, and Quebec North Shore and Labrador Railway (QNS&L).

QNS&L implemented SPTO in 1996, without seeking a Minister's exemption to certain CROR provisions.[78] A collision occurred on the second day of operation.[79] TSB's investigation determined that, without a comprehensive analysis and the implementation of effective compensatory safety measures by the railway, SPTO operation was a contributory factor. As a result, a working group was formed involving TC, QNS&L management and employees, and representatives from industry and labour. Recommencement of SPTO was conditional on arriving at a consensus on minimum operating conditions to ensure a level of safety equivalent to that of 2-person operating crews.

In September 1996, rather than requiring railways to obtain exemptions, TC suggested to the RAC that rules be developed for SPTO.

In 1997, SPTO was re-implemented at QNS&L with 69 new conditions. Some of the key conditions were to:

- provide LEs and RTCs with 120 to 130 hours of training, including in SPTO emergency procedures, with the training program to be monitored by TC;

---

78 This was Canada's first experience with single-person train operations (SPTO) in freight service. QNS&L is a closed-loop railway based in Sept-Îles, Quebec, that primarily services the iron ore mines and operates mostly in rural areas.

79 TSB Rail Investigation Report R96Q0050: An SPTO-operated train collided with the tail end of a stationary train at Mile 131.68 of the Wacouna Subdivision near Mai, Quebec.

- provide increased supervision of LEs; and
- install proximity detection devices (PDDs) on all lead locomotives, track units, and on-track vehicles operating on the main track.

In June 1997, TC acknowledged that the RAC had been developing an SPTO circular for its members, while repeating the expectation that the RAC develop SPTO rules for inclusion in the CROR.

In 1998, the RAC first proposed rule changes to the CROR under Section 20 of the RSA relating to SPTO. TC rejected these proposed changes, as they did not establish rules for SPTO that would ensure a level of safety equivalent to that of existing crew requirements.

In 2000, the RAC produced SPTO guidelines based on industry review and consultation[80] and made them available to its members.[81] The guidelines were based on the principles of risk assessment, mitigation, and monitoring. They were not approved by TC, nor were they required to be. The guidelines specified the following:

> Railway companies must advise Transport Canada in writing at least 60 days prior to implementing One Person train operations.
>
> [...]
>
> Prior to implementation of One Person operations, the railway company shall identify safety issues and concerns associated with One Person Train Operations, evaluate the risk involved with such an operation, and take appropriate measures to mitigate the risk.
>
> [...]
>
> Each railway company shall develop and institute an appropriate monitoring program for One Person operations that measures the safety performance of the operation.
>
> This program shall be described to Transport Canada and may be subject to follow-up regulatory review.[82]

A copy of the guidelines was provided to MMA.

---

80 W. Hanafi, Beauchemin Beaton Lapointe Inc., *Study of One-person Train Operations* (Transportation Development Centre: Montreal, May 1997). Information gathered for the report was through telephone interviews with railway officials of companies experienced in one-person operation.

81 Not all railways in Canada are members of the RAC.

82 Railway Association of Canada (RAC), Circular No. 8, R35-8, *Guidelines for One Person Train Operations* (21 February 2000), 3. Notification to Transport Canada, 4. Requirements, and 6. Monitoring Process.

### 1.23.2 *Canadian Railway Operating Rules (CROR)*

TC can order the development of a rule or the amendment of an existing rule. The RAC, in consultation with its member railways, would then draft the rule. Once completed, it must be circulated to employee associations for comment before it is submitted to the Minister for approval. If there are objections to the proposed changes, the RAC can respond to the employee association's objections, and then their comments, along with the RAC response, are provided to the Minister's representatives for consideration. The rules must be approved by the Minister before coming into force. Rules may also be formulated by individual railways on their own, which also requires union consultation and submission to the Minister for approval.

In 2008, a major revision of the CROR by the RAC, approved by TC, introduced General Rule M, which provided in part, "Where only one crew member is employed, operating rules and instructions requiring joint compliance may be carried out by either the locomotive engineer or conductor…"[83] The union consultation period for the rules was 90 days, and a 2-day meeting was held. These rule changes allowed railways to implement SPTO without the need for exemptions from TC to specific CROR rules, such as were required by QNS&L in 1997.[84]

### 1.23.3 *Single-person train operations at Montreal, Maine & Atlantic Railway*

In 2003, MMA discussed the implementation of SPTO in Canada with TC. TC advised that MMA should consider QNS&L's SPTO implementation and operation as a Canadian "best practices" model. Between 2004 and 2008, MMA did not pursue SPTO in Canada, as it considered the 69 conditions that had been implemented at QNS&L to be unattainable.

In April 2009, after being informed of MMA's intention to begin SPTO, TC initiated a research project[85] to develop internal guidelines to review SPTO applications. The targeted completion date was October 2009. The research was completed in March 2012 (see section 1.23.5).

In June 2009, MMA submitted its SPTO risk assessment and proposal to TC. MMA advised of its intent to pursue a phased approach to implementing SPTO, using the 23-mile segment between the Maine-Quebec border and Lac-Mégantic as a "test-bed" for further expansion, pending approval by TC. In its risk assessment, MMA stated that a single-person crew member is more attentive when working alone, and cited its previous success on its U.S. network.

In July 2009, TC expressed a number of concerns that centred on deficiencies in MMA operations, including lack of consultation with employees in doing risk assessments, problems managing equipment, problems with remote-control operations, issues with rules compliance, issues with fatigue management, and a lack of investment in infrastructure

---

83 Transport Canada, TC O-0-093, *Canadian Rail Operating Rules* (CROR) (2008), General Rules, M (i).

84 Canadian Rail Operating Rules (CROR) 3(b), 34(c), 81(b), 82(c), 82.1(b), 84, 102(a)(ii), 110(a), 135, 137.1, 143, 143.1, 146(b), 147(b), 147(c), 564.1(b), 567(a), 567.1(b), and 569(b).

85 The research was conducted by the National Research Council (NRC) and the report, titled *Identification and Evaluation of Risk Mitigating Countermeasures for Single-Person Train Operation (TP151176E)* was released in March 2012.

maintenance. TC reiterated its recommendation that MMA look at the QNS&L consensus-based process as a model in crafting operational conditions.

In May 2010, MMA began its test operation running SPTO. TC was told that MMA's SPTO crews were coming across the border[86] as far as Nantes. However, on a number of occasions, TC became aware that MMA had operated SPTO trains with U.S. crews beyond these limits when there had been weather issues or other operational demands, such as equipment failures. There were no performance indicators identified for tracking, nor was a formal monitoring program established. TC Quebec Region reiterated its concern about MMA's suitability as an SPTO candidate.

In the same month, TC Headquarters and the FRA conducted an informal review of MMA's U.S. operations, including SPTO. As a result of that review, TC and the FRA identified 4 areas for subsequent action, including the absence of a written emergency response plan and concerns over employee fatigue, efficacy of company oversight, and rules compliance.

In December 2011, MMA informed TC that, as of 09 January 2012, it was extending SPTO westward to Farnham. TC indicated that it viewed this expansion as a significant change to operations, reiterating that it required a new risk assessment. MMA submitted a revised risk assessment for its SPTO that identified 16 risks. Several mitigation measures were proposed, and where necessary, added to the company's SPTO special instructions, such as informing local authorities, establishing procedures for a single operator when taking control of an unattended train, allowing an SPTO engineer to stop the train for 20-minute naps, and requiring formal communications between the engineer and the RTC at least every 30 minutes. This risk assessment did not identify or address the specific risks of a single-person train operator performing tasks previously performed by 2 persons, such as securing a train and leaving it unattended at the end of a shift.

In February 2012, TC met with MMA and the RAC. TC advised MMA that TC did not approve SPTO. MMA only needed to comply with all applicable rules and regulations. TC Quebec Region remained concerned about the safety of SPTO on MMA.

In April 2012, the collective agreement was renegotiated to allow for SPTO. Later in April, TC Quebec Region acknowledged that MMA was going ahead with the expanded use of SPTO to Farnham once the employee consultations were completed and the crews were trained. MMA committed to informing the regulator in advance of the date when SPTO would commence.

The SPTO training plan for LEs (which scheduled training for approximately 4 hours) was intended to address the new SPTO special instructions.

The actual SPTO training for several LEs, including the accident LE, consisted of a short briefing in a manager's office on the need to report to the RTC every 30 minutes, on the allowance for power naps, and on the need to bring the train to a stop to write clearances. In some cases, training consisted of a briefing within the hour preceding the operator's first SPTO train departure. The training did not cover fatigue management or a review of tasks normally performed by conductors, such as determining the minimum number of hand

---

86 Brownville Junction crews were crossing the border and operating trains a short distance into Canada, near Lac-Mégantic, without TC being informed.

brakes. A review of RTC recordings determined that the instruction to communicate to the RTC at least every 30 minutes was not consistently followed.

In July 2012, MMA began operating SPTO between Lac-Mégantic and Farnham. However, no job task analysis with the employees in the territory specific to SPTO was performed, nor were all of the potential hazards associated with those tasks identified. MMA had no plan for further monitoring and evaluating SPTO. MMA did take specific measures, such as:

- extending train radio range to eliminate "dead spots";
- supplying SPTO crews with equipment so that they could operate the locomotive remotely;
- meeting with every community along the track;
- installing mirrors on the left-hand side of its locomotives;
- identifying locations along the track where a helicopter could safely land to evacuate employees; and
- making arrangements with emergency service companies to be on call if an evacuation was needed.

On 29 August 2012, TC became aware that MMA had extended SPTO operations to Farnham. TC did not verify that the mitigation measures identified in MMA's risk assessment were implemented and effective.

In March 2013, TC published an internal guideline to assist in evaluating SPTO applications. The purpose of the guideline was to provide TC regional staff with a guide to review and address SPTO risk assessments provided by railway companies.

### *1.23.4 Review of the Montreal, Maine & Atlantic Railway submission and its relation to the requirements of Standard CSA Q850*

In December 2011, 2 guidance documents published by TC for filing rule submissions recommended the use of Standard CSA-Q-850-97, *Risk Management Guidelines of Decision-Makers* (October 1997). A comparison was made between MMA's risk assessment on SPTO introduction and the requirements of standard CSA-Q-850-97. There were significant gaps identified in MMA's process. For example, MMA did not quantify safety data to indicate safety trends and to identify some of the possible hazards when major operational changes were being planned.

### *1.23.5 Research into single-person train operations*

MMA's 2009 request prompted TC to renew research into SPTO. TC recognized that it lacked the tools to review an SPTO risk assessment.

TC contracted the National Research Council (NRC) to conduct the research. The report was issued in 2012 and indicated that the safety impact of SPTO is unique to each individual task, and that risk-mitigating countermeasures should be designed accordingly. It stated that "reducing the train crew to one person without appropriate operational changes and technological intervention diminishes safety." The report recommended:[87]

- consolidating human factors knowledge into a best practices resource;
- identifying which technologies are required to fully support SPTO, depending on operational complexity;
- developing an SPTO guide with recommended training and refresher programs for operating personnel;
- developing communication protocols;
- developing a procedures guide to be used to determine if an operation is suitable for SPTO;
- conducting a workshop involving TC, NRC, and railways to review SPTO knowledge and identify one or two specific routes that could be used for a pilot test program; and
- running a pilot test program, complete with detailed monitoring and evaluation, over a 2-year period.

In the United States, the FRA conducted a series of cognitive task analyses pertaining to railway operating crews.[88] With respect to the role of the conductor, they found the following:

- Conductors and LEs not only work together to monitor the operating environment outside the locomotive cab, they also work together to plan activities, to solve problems, and to plan and implement risk mitigation strategies.
- Operating in mountain grade territory can significantly alter the complexity of a conductor's duties, introducing additional cognitive demands.
- When the conductor must handle unexpected situations, "these unanticipated situations impose cognitive as well as physical demands on the conductor."[89]
- New technologies, such as positive train control (PTC), will not account for all of the cognitive support that the conductor provides.

SPTO has been implemented in other parts of the world, including the U.S., Europe, Australia and New Zealand. In many countries, technological advancements were used to mitigate the risks of operating with one less crew member (Appendix I).

---

87 National Research Council of Canada (NRC), TP 15176E, *Identification and Evaluation of Risk Mitigating Countermeasures for Single-Person Train Operation*, prepared for Transport Canada (March 2012).

88 H. Rosenhand, E. Roth and J. Multer, DOT/FRA/ORD-12/13, *Cognitive and Collaborative Demands of Freight Conductors Activities: Results and Implications of a Cognitive Task Analysis* (Cambridge, MA: United States Department of Transportation, July 2012), available at http://ntl.bts.gov/lib/46000/46100/46162/TR_Cognitive_Collaborative_Demands_Freight_Conductor_Activities_edited_FINAL_10_9_12.pdf (last accessed on 16 July 2014).

89 Ibid., p. 5 and 43.

## 1.24 *Safety culture*

All members of an organization, and the decisions made at all levels, have an impact on safety. A recognized definition of an organization's "safety culture" is:

> shared values (what is important) and beliefs (how things work) that interact with an organization's structures and control systems to produce behavioural norms (the way we do things around here).[90]

TC's *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* states:

> An effective safety culture in a railway company can reduce public and employee fatalities and injuries, property damage resulting from railway accidents, and the impact of accidents on the environment.
>
> In simple terms, an organization's safety culture is demonstrated by the way people do their jobs—their decisions, actions and behaviours define the culture of an organization.
>
> *The safety culture of an organization is the result of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organization's health and safety management system.*
>
> *Organizations with a positive safety culture are characterized by communications from various stakeholders founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.*[91]

The Guide also states:

> Experience has shown that a railway company will be markedly more successful in developing a safety culture if employees and their representatives, where applicable, are involved in the development and implementation of the safety management system.[92]

The relationship between safety culture and safety management is reflected in part by the attitudes and behaviour of a company's management.

An effective safety culture includes proactive actions to identify and manage operational risk. It is characterized by an informed culture where people understand the hazards and risks involved in their own operation and work continuously to identify and overcome

---

90 B. Uttal, The Corporate Culture Vultures, *Fortune* (17 October 1983), pp. 66–72, as cited by J. Reason in *Managing the Risks of Organizational Accidents* (Ashgate Publishing, 1997), p. 192.

91 Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), section 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014). (Italics in original.)

92 Ibid., section 3.1(c).

threats to safety. It is a just culture, where the workforce knows and agrees on what is acceptable and unacceptable. It is a reporting culture, where safety concerns are reported and analyzed and where appropriate action is taken. And it is a learning culture, where safety is enhanced from lessons learned.[93]

A company's policies determine how safety objectives will be met by clearly defining responsibilities; by developing processes, structures and objectives to incorporate safety into all aspects of the operation; and by developing the skills and knowledge of personnel. Procedures are directives for employees and set management's instructions. Practices are what really happens on the job, which can differ from procedures and, in some cases, increase threats to safety.

The report on the review of the RSA states, "The cornerstone of a truly functioning SMS is an effective safety culture," and notes that "[a]n effective safety culture is one where past experience is not taken as a guarantee of future success and organizations are designed to be resilient in the face of unplanned events."[94] The RSA review recommended that the TC Rail Safety Directorate and the railway industry "take specific measures to attain an effective safety culture."[95] TC's SMS guide contains a section on achieving an effective safety culture, and TC has published a safety culture checklist for companies to perform a self-assessment on their safety culture.[96]

## 1.25 *Regulatory oversight*

### 1.25.1 *Transport Canada*

#### 1.25.1.1 *Background information*

TC promotes safe and secure transportation systems in the air, marine, rail, and road modes, as well as the safe transportation of dangerous goods. To do so, TC develops safety regulations and standards, or in the case of railways, it facilitates the development of rules by the rail industry. TC is then responsible for enforcement. It tests and promotes safety technologies and has also introduced safety management system (SMS) regulations requiring railways to manage their safety risks. Rail safety is governed by the *Railway Safety Act* (RSA). The transportation of dangerous goods is governed by the *Transportation of Dangerous Goods Act* (*TDG Act*).

---

93 Adapted from: Transport Canada, TP 13739, *Introduction to Safety Management Systems* (April 2001).

94 Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), available at http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

95 Ibid.

96 Transport Canada, TP 15062, *Rail Safety Oversight and Expertise: Safety Culture Checklist* (November 2010), available at http://www.tc.gc.ca/media/documents/railsafety/sms_checklist.pdf (last accessed on 16 July 2014).

The objectives of the RSA are:

> *(a)* to promote and provide for the safety and security of the public and personnel, and the protection of property and the environment, in railway operations;
> *(b)* to encourage the collaboration and participation of interested parties in improving railway safety and security;
> *(c)* to recognize the responsibility of companies to demonstrate, by using safety management systems and other means at their disposal, that they continuously manage risks related to safety matters; and
> *(d)* to facilitate a modern, flexible and efficient regulatory scheme that will ensure the continuing enhancement of railway safety and security.[97]

To carry out the objectives of the RSA, TC's Rail Safety Directorate, based at TC Headquarters in Ottawa, sets the direction for railway safety oversight through the development of policy and programs. TC's Surface Group, based out of regional offices, is responsible for implementing the policies and programs. Regional railway safety inspectors (RSIs) monitor and promote regulatory compliance regarding railway operations, equipment, infrastructure, and railway-roadway grade crossings. RSIs also promote education and awareness, as well as conducting SMS audits and enforcement activities.

The tools and strategies available to TC to promote safety and further the objectives of the RSA are outlined in *Rail Safety: Compliance and Enforcement Policy (September 2007)*. The tools and strategies for compliance and safety fall into 3 categories of activity: promoting, monitoring, and enforcing.

Promoting refers to the means by which TC ensures that regulations are workable and understood by the railways. It includes regulatory development, consisting of clear and enforceable requirements, as well as consultation. It also includes implementation, consisting of *Railway Safety Management System Regulations* (*SMS Regulations*) and providing information, education/awareness, and counselling. SMS is specifically mentioned due to the requirement in the *SMS Regulations* for companies to put processes in place to ensure awareness of the applicable regulations and to demonstrate compliance.

Monitoring refers to the types of activities undertaken to monitor the level of safety and compliance within the industry. Key monitoring tools include:

- inspections to verify compliance with rail safety regulatory requirements, to collect data, and to identify threats to rail safety that require corrective action;
- safety audits to verify compliance with regulatory requirements and to assess safety performance;
- SMS audits (audits) to examine the company's SMS, or a portion of it, to determine "whether the company's actual operations conform to the procedures they developed to demonstrate compliance with applicable regulatory requirements";[98] and
- accident and incident investigations.

---

97 *Railway Safety Act* (1985, c. 32 [4th Supp.]), Section 3.

98 Transport Canada, *Rail Safety: Compliance and Enforcement Policy* (September 2007), p. 8.

Inspections and audits are complementary processes. While inspections look at conditions (that is, what is wrong), audits look at systems and processes (that is, to identify why the conditions exist). Inspections should be used to help target future audits and to help monitor the corrective action taken following previous audits.

Enforcing refers to the tools available to TC where a non-compliant condition or a safety concern is identified. TC's enforcement tools include the following:

- Letter of non-compliance, which is issued by the RSI to promote regulatory compliance and to address non-compliance;
- Letter of concern, which is issued by the RSI to identify and inform railways of safety concerns;
- Notice, or notice and order, which is issued by the RSI to respond to threats (notice) or immediate threats (notice and order) to safe railway operations;
- Ministerial order, which is issued by the minister to address a rail safety problem;
- Emergency directive, which is issued by the minister to mitigate an immediate threat to safe railway operations by requiring companies to cease a particular unsafe action or to take a specific action;
- Order of the court, whereby a notice and order, ministerial order, or emergency directive can be made into an order of the court and enforced as such;
- Prosecution, which can be pursued at the discretion of the Attorney General of Canada. This enforcement tool may be considered when there is serious, willful, uncorrected and/or continued non-compliance, or if the company disobeys orders issued by RSIs or the Minister of Transport.

In May 2013, the RSA was amended to enable improvements to the *SMS Regulations* and the implementation of regulations pertaining to administrative monetary penalties and railway operating certificates.

#### *1.25.1.2 Rail Safety organization*

##### *1.25.1.2.1 Headquarters*

The Rail Safety Directorate is under the direction of the Assistant Deputy Minister (ADM) for the Safety and Security Group, which reports to the Deputy Minister. The ADM is responsible for the development and enforcement of regulations and national standards, as well as for the implementation of monitoring, testing, and inspection programs in the aviation, marine, rail, and road modes of transportation.

The Director General of the Rail Safety Directorate reports to the ADM and is responsible for implementing the rail safety program. The Rail Safety Directorate consists of 4 branches: Regulatory Affairs, Operations Management, Program Management and the Rail Safety Secretariat. The Director of Operations Management is responsible for developing and managing the oversight programs, monitoring national trends, monitoring and supporting SMS auditing activities, and monitoring the level of completion of the inspection program.

At the time of the accident, the Director of Operations Management was responsible for a number of functional areas, including operations, engineering, equipment, and the SMS program. All were based at TC Headquarters, but provided program support to their regional counterparts.

The Audit, Enforcement and Risk Evaluation Group, created in 2011, provides oversight of the SMS program. It develops policies and procedures, reviews railway's initial and annual SMS submissions, audits national railways, provides auditor training, and oversees SMS activities conducted in TC's Regions. Regional oversight activities include supplying auditing expertise and assisting in audit planning activities.

In 2013, enforcement programs for the *SMS Regulations* had not yet been developed, and there was no procedure for the follow-up of audit findings.

##### 1.25.1.2.2 Transport Canada Quebec Region

Each TC Region is headed by a regional director general, who is responsible for the delivery of transportation programs and services. The regional director general reports to the Deputy Minister.

The regional office is responsible for assessing the railways within its region, allocating regional inspection and auditing resources, and conducting any follow-up activities to ensure that the railways are in compliance with the rules and regulations and are operating safely.

When auditing regional railways,[99] the TC Regions identify the target of audits through a risk-based business planning process. The audit scope is also determined in the TC Regions by the audit team and approved by the convening authority, who is typically the regional director. The Rail Safety staff and TDG staff for TC Quebec Region report to the Surface Regional Director through the functional managers of Equipment and Operations, of Engineering, of Safety Systems Overview, and of Transportation of Dangerous Goods.

The role of the Manager, Safety Systems Overview, had evolved over time and initially included the responsibility for implementing SMS audits. In the 2006–2007 operating year, the responsibility for auditing in the Region was informally transferred to the functional groups (that is, to Equipment and Operations, and to Engineering). With this change, the Safety Systems Overview Manager assumed an advisory role with respect to the conduct of SMS audits, including the development and testing of audit tools for the inspectors. However, with limited support from the functional groups in advancing the implementation of SMS, the Safety Systems Overview Manager was subsequently assigned other projects that were not necessarily related to SMS oversight.

#### 1.25.1.3 Planning of inspections and audits

In the third quarter of each year, TC begins a risk-based business planning process to identify and prioritize safety and program management issues and to determine the number of rail cars and locomotives, train crews, crossings, and miles of track to inspect. With this information as input, TC Headquarters develops a national inspection plan for the following year. The national inspection plan identifies the number of inspections and audits to be

---

99 Regional railways are those railways that conduct activities in one of TC's Regions.

conducted by each TC Region, the time frame during which the inspections are to be completed, and the estimated level of effort required.

There are 3 components to the inspection system:

- The A-component inspection is a sampling process used to verify regulatory compliance and detect underlying safety issues. TC Headquarters, using a statistical model, identifies the number of inspections and target companies that are to receive these inspections.
- The B-component inspection is a planned inspection that focuses on specific recurring issues requiring closer monitoring. The TC Regions, using a risk-based method, identify the companies that are to receive these inspections.
- The C-component inspection is unplanned and responds to issues emerging through the year, such as derailments and ad hoc inspections.

Using the national inspection plan, each Region develops an operational plan to provide guidance to its RSIs on which companies, infrastructure locations, subdivision portions, operations, and maintenance employees to inspect. In TC Quebec Region, each functional group performs a risk assessment to rank the relevant subdivisions, yards, and maintenance facilities according to risk. Factors considered include accident history, compliance with standards and regulations, changes in operations, amount and type of traffic, hours of work, and type of work performed. From the risk assessment, the inspection sites are prioritized to ensure that the more risky sites are inspected in a timely manner.

TC Quebec Region is responsible for inspecting 3 national railways (CN, CPR, and VIA Rail Canada Inc. [VIA]) and 9 regional or inter-regional railways—1 passenger railway, 1 commuter railway, and 7 federally regulated short line railways. Together, these railways operate about 2900 miles of track in Quebec. Of this track, MMA operates 250 miles. In addition, TC Quebec Region inspects 8 provincially regulated short line railways, with another 1200 miles of track, on an as-requested basis.

TC Quebec Region is responsible for SMS audits at 4 regional railways, including MMA.

#### *1.25.1.4 Operations*

In the TC Quebec Region Operations Group, each inspector completes about 80 inspections per year, spread out on a level-of-risk basis among all of the regulated railways. Approximately 30 of those will be A-component inspections conducted at CN, CPR, and VIA. The remaining 50 are A-component inspections of regional railways, and the B- and C-component inspections of all of the railways. From the railway infrastructure in Quebec, the group has identified 27 subdivisions to be ranked annually according to level of risk. In each of the last 5 years, the Adirondack and Sherbrooke Subdivisions have been assessed as having either the second or third highest risk level. Factors considered include accident history, compliance with standards and regulations, human factors, operational factors (train activity, staffing levels, management), and type of work performed, as well as health and safety.

Table 5 lists the number of Operations Group inspections completed per year at MMA. When action was taken to resolve any non-compliance, MMA would report the completion date to TC Quebec Region.

**Table 5. Operations Group inspections at MMA**

| Year | Number of inspections |
|---|---|
| 2009 | 16 |
| 2010 | 0[100] |
| 2011 | 20 |
| 2012 | 8 |
| 2013 (January to June) | 6 |

A list of TC interventions with MMA follows:

- May 2009: A notice was issued regarding non-compliance with Rule 104.5 (Derails) in a yard, citing a history that went back to 2005, as well as a history of non-compliance with Rule 112 (Securing Equipment), also cited back to 2005 when cars were improperly secured in the siding at Nantes.
- May 2009: An inspection noted a lack of provision of first-aid training to 2 train crews.
- October 2011: An inspection noted 26 cars in Sherbrooke Yard that had been left without proper hand brake securement.
- February 2012: A notice was issued citing numerous infractions at the RTC office in Farnham, noting that some RTCs were not conversant with parts of the CROR and that there was no formal process to ensure compliance with the CROR by the RTCs. It was also noted that 1 RTC was allowed to work for over a year with expired minimal rule qualifications.
- February 2012: Two directions were issued under the *Canada Labour Code*, Part II, for failure to protect the employees from workplace hazards in Sherbrooke Yard and Farnham Yard.
- March 2012: A notice was issued citing the handling of rolling stock in a manner that disregarded the protection of workers on the track provided by red flags.
- April 2012: A "letter for insufficient action taken" was issued citing deficiencies in MMA's response to the notice regarding infractions at the RTC office.
- May 2012: An inspection noted that a crew left equipment without performing a hand brake effectiveness test.
- August 2012: A letter of non-compliance was issued regarding trains immobilized by mechanical error on or near crossings.

### *1.25.1.5 Equipment*

The TC Quebec Region Equipment Group divides the railway infrastructure in Quebec into 15 to 20 inspection stations and ranks them annually according to risk. The stations are inspected at least once per year. MMA's Farnham and Sherbrooke yards are listed as 1 station and were ranked ninth for the 2011–2012 operating year, and second and third for

---

[100] The inspector assigned to MMA was on a leave of absence during 2010.

the following 2 years. When assessing risk level, the Equipment Group used factors such as a railway's accident history, its history of compliance with standards and regulations, human factors, operational issues, and equipment activity.

Table 6 lists the number of Equipment Group inspections completed per year at MMA. When action was taken to resolve any infractions, MMA would report the completion date to TC Quebec Region.

**Table 6. Equipment Group inspections at MMA**

| Year | Number of inspections |
|---|---|
| 2009 | 4 |
| 2010 | 1 |
| 2011 | 2 |
| 2012 | 12 |
| 2013 (January to June) | 6 |

A list of TC Quebec Region interventions with MMA follows:

- January 2009: An inspection found that certified car inspectors were not qualified to perform single car air brake tests.
- January 2012: A letter of concern was issued regarding a broken truck side frame, 2 carmen without recent training, and 1 carman trainee performing safety inspections and a No. 1 brake test by himself without any training.
- June 2013: An inspection found that the employees performing the safety inspections were not qualified as certified locomotive inspectors.

#### *1.25.1.6 Engineering*

TC Headquarters determines segments of track to be inspected annually as part of the A-component inspections. The TC Quebec Region Engineering Group divides the remainder of the track into segments and rates each segment according to risk. These are the B-component inspections. Factors considered when determining risk include class of track; type and amount of traffic; derailment, inspection and maintenance histories; and environmental factors. Fifty-five different track segments were identified and rated. Since 2009, MMA's Sherbrooke Subdivision was ranked 13th most risky.

Tables 7 and 8 show the Engineering Group inspections on the Sherbrooke Subdivision and selected defects that were noted. Once action was taken to correct any defect, MMA would report the completion date to TC Quebec Region.

Table 7. Track and crossing inspections

| Year | Track inspections | Crossing inspections |
|---|---|---|
| 2009 | 12 | 3 |
| 2010 | 13 | 9 |
| 2011 | 9 | 11 |
| 2012 | 11 | 14 |
| 2013 (January to June) | 8 | 8 |

In each of these inspections, track defects were noted, with some of the track defects recurring. Recurring defects included rail corrugations, battered rail joints, crushed rail head, insufficient ballast, and excessive vegetation (Table 8).

Table 8. Defects from selected track and crossing inspections

| Date | Subdivision mileage | Defects noted | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Insufficient/ ineffective ties | Rail wear/ corrugation/ defects | Battered/ broken joints | Crushed heads/rail surface collapse | Defective crossing surface | Insufficient ballast | Excessive vegetation |
| July 2009 | 92.87 to 125.6 | X | | | | | | X |
| August 2009 | 0.28 to 124.9 | | | | | | | X |
| September 2009 | 101.8 to 115.85 | | | | | | | X |
| August 2010 | 41.6 to 87.0 | X | X | X | | | X | |
| September 2010 | 46.0 to 57.0 | X | X | X | | | | |
| August 2011 | 45.0 to 66.0 | X | X | | X | | X | X |
| July 2012 | 0.0 to 42.0 | | X | | X | | X | X |
| October 2012 | 38.0 to 87.0 | | X | | X | | | X |
| November 2012 | Not specified | | X | | X | | | |
| May 2013 | 0.0 to 87.0 | | X | | X | X | X | X |

On 24 July 2012, during a track inspection at the Megantic West turnout, the RSI observed that the fasteners on the frog, guard rail, and heel block were loose. On 14 May 2013, the RSI observed similar conditions at the turnout.

The following are engineering-related findings of a functional audit at MMA in April 2006:

- Some Engineering Group employees received incomplete track inspection training, received incomplete CWR maintenance training, and have not received proper fall-protection training, which is needed when working on bridges.
- Insufficient ties, insufficient rail restraint, rail wear beyond the limits, rail defects remaining in the track, battered joints and rails with crushed heads with no protection, insufficient ballast, and track geometry deviations between Mile 62.0 and Mile 125.5.

The following are the resulting interventions taken by TC Quebec Region:

- April 2006: A notice and order was issued restricting train speed from Mile 62.0 to Mile 125.5 to 10 mph, citing track conditions as a hazard. MMA worked in stages to have the speed restriction removed. Many speed restrictions remained at the time of the accident.
- October 2012: A letter of concern was issued regarding Mile 0.0 to 87.0, noting urgent track geometry defects, rail corrugation, gauge corner shelling and rail surface collapse, excessive rail end batter with marginal track surface profiles, and excessive vegetation.

### *1.25.2 Railway safety management systems*

#### *1.25.2.1 Safety Management System Regulations*

Traditional approaches to safety management were based primarily on compliance with regulations, reactive responses following accidents and incidents, and a "blame and punish, or retrain" philosophy.

An SMS is "a systematic, explicit and comprehensive process for managing safety risks."[101] It is a means to ensure that the railway has the processes in place to identify the hazards in its operation and mitigate the risks. SMS was designed around evolving concepts about safety that are believed to offer great potential for more effective risk management. Safety management systems were progressively introduced in the Canadian transportation industry because this approach to regulatory oversight, which seeks to ensure that organizations have processes in place to systematically manage risks, when combined with inspections and enforcement, is more effective in reducing accident rates.

One of the objectives of the RSA is to recognize the responsibility of companies to demonstrate, by using SMS and other means at their disposal, that they are continuously managing risks related to safety.

The *SMS Regulations* came into force on 31 March 2001. Section 2 states:

> 2. A railway company shall implement and maintain a safety management system that includes, at a minimum, the following components:
> *(a)* the railway company safety policy and annual safety performance targets and the associated safety initiatives to achieve the targets, approved by a senior company officer and communicated to employees;
> *(b)* clear authorities, responsibilities and accountabilities for safety at all levels in the railway company;
> *(c)* a system for involving employees and their representatives in the development and implementation of the railway company's safety management system;
> *(d)* systems for identifying applicable

---

[101] Transport Canada, TP15058E, *Railway Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 3, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

  (i) railway safety regulations, rules, standards and orders, and the procedures for demonstrating compliance with them, and
  (ii) exemptions and the procedures for demonstrating compliance with the terms or conditions specified in the notice of exemption;
*(e)* a process for
  (i) identifying safety issues and concerns, including those associated with human factors, third-parties and significant changes to railway operations, and
  (ii) evaluating and classifying risks by means of a risk assessment;
*(f)* risk control strategies;
*(g)* systems for accident and incident reporting, investigation, analysis and corrective action;
*(h)* systems for ensuring that employees and any other persons to whom the railway company grants access to its property, have appropriate skills and training and adequate supervision to ensure that they comply with all safety requirements;
*(i)* procedures for the collection and analysis of data for assessing the safety performance of the railway company;
*(j)* procedures for periodic internal safety audits, reviews by management, monitoring and evaluations of the safety management system;
*(k)* systems for monitoring management-approved corrective actions resulting from the systems and processes required under paragraphs *(d)* to *(j)*; and
*(l)* consolidated documentation describing the systems for each component of the safety management system.[102]

The *SMS Regulations* also require railway companies to:

- maintain records to permit the assessment of safety performance,
- submit documentation and records to the Minister that demonstrate compliance with the regulations, and
- produce safety management documentation upon request.

#### *1.25.2.2 Montreal, Maine & Atlantic Railway's safety management system*

MMA had an SMS manual that described how it would comply with each of the 12 mandatory components of the *SMS Regulations*. A summary of key sections of MMA's SMS manual follows:

- Safety goals and initiatives: The company sets corporate safety goals each year. The goals for year 2013 included outcome performance targets (that is, the number of incidents not to be exceeded in various categories). These performance targets would be achieved through "improved maintenance and capital improvements to the infrastructure of approximately $3.75 million in Canada."[103]

---

[102] Transport Canada, SOR/2001-37, *Rail Safety Management System Regulations* (09 January 2001), Section 2, available at http://laws-lois.justice.gc.ca/eng/regulations/SOR-2001-37/ (last accessed on 17 July 2014).

[103] Montreal, Maine & Atlantic Railway (MMA), *Safety Management System Manual* (effective 15 February 2013), section SMS-01.

- Risk management process: The identification of safety issues and concerns is a critical first step in managing risks. A list of the means by which safety issues would be identified was presented, including: OTIS, accident and incident investigations, a telephone number to report safety concerns, and internal and external audit reports.
- Operating officers were responsible for identifying safety risks that may develop due to major changes in operations.[104] A 1-page flowchart described the high-level steps included in the risk management process.[105] No guidance was provided on how to complete or document the steps.
- Risk control strategies: In the area of train operations, one of the risks identified was "unintended movements." Among the risk control strategies noted were ensuring compliance with operating rules through OTIS, training of railway employees to ensure that qualifications were current, review of procedures for risks identified through the risk management process, and evaluation of supervisors on safety performance on a semi-annual basis.[106]
- Safety audit and evaluation: "The Company has developed an internal auditing system to measure compliance with the procedures outlined in the Safety Management System and to evaluate the effectiveness of the System."[107]
- Operational Tests and Inspections (OTIS) Program: This program was used to ensure employee compliance with rules, regulations, and standards, among other purposes. A section of the manual was devoted to describing the OTIS program and documenting how it was to be carried out.

In addition, MMA had a safety committee on its Board of Directors, which met quarterly and discussed issues such as employee injuries, derailments, and other accidents. MMA also had multi-departmental local safety committees based at 6 MMA locations (including Farnham), which met monthly to discuss safety concerns.

MMA management conducted daily and weekly operating meetings, during which safety issues and the performance of each department were discussed.

MMA maintained databases showing injuries, derailments, and a summary of the Operational Tests and Inspections (OTIS) testing. Periodically, MMA internally issued safety information on accidents occurring on other railways, on conditions being reported, and on other railway industry safety awareness information.

Between 2009 and 2013, MMA took a number of disciplinary actions against employees in Canada for rules violations.

#### *1.25.2.3 Transport Canada oversight of safety management systems*

TC's oversight of SMS is focused on verifying that the systems are in place, that they are being used, and that they are effectively improving safety.

---

104 Ibid., p. 13.

105 Ibid., section SMS-11.

106 Ibid., section SMS-05.

107 Ibid., p. 19.

Compliance with the *SMS Regulations* is established through TC's compliance monitoring program, which is designed to verify that:

- a railway's safety management system is in compliance with the minimum regulatory requirements;
- the railway is operating in accordance with the commitments, processes and procedures outlined in its SMS; and
- the SMS is effective in improving safety.[108]

The company's documented SMS is assessed using the following 3 processes:[109]

- An initial submission review, which verifies that the documentation required under section 4 of the *SMS Regulations* has been submitted to the Minister. Upon completion, a letter is provided to the company confirming compliance with section 4.
- A pre-audit, which verifies that a railway company has established the minimum processes required under section 2 of the *SMS Regulations*. A pre-audit report is issued to the railway describing deficiencies identified in documentation.
- A verification audit, which verifies that the required processes are being used and is intended to assess their effectiveness. An audit report is issued to the company, describing deficiencies in the implementation and maintenance of the SMS.

The procedural details for these reviews and audits include the following:

- The initial submission review and the pre-audit are conducted when a railway submits its SMS to the regulator for the first time.
- A verification audit can be conducted at any time after the pre-audit is completed, based on TC's risk-based planning process.
- There is no minimum frequency at which verification audits must be conducted, nor is there a requirement to conduct a verification audit on all components of a railway's SMS at any one time.
- The audit scope is determined by the convening authority.
- The procedure for conducting verification audits is described in TC's *Rail Safety Audit Procedure*.[110]
- Once an audit team determines its findings from the audit, the railway company must submit a corrective action plan.
- TC's follow-up action on the verification audit centres on the railway company's corrective action plan. The Audit Team Lead reviews the corrective action plan and notifies the railway if the plan is acceptable.

---

108 Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

109 Descriptions and outputs are adapted from the introduction to TC Quebec Region's MMA Preliminary Audit Report.

110 Transport Canada, Rail Safety Monitoring Directive, Rail Safety Audit Procedure, Directive 2TD (revised 23 October 2012).

- When an acceptable corrective action plan is received, the findings are closed.
- The audit report is forwarded to TC Headquarters and the regional managers for follow-up as required.
- The audit findings and corrective action plans serve as inputs to subsequent risk-based planning processes.

The *Railway Safety Management System Regulations* Enforcement Policy states:

> 3.3 While railway companies may be prosecuted for non-compliance to the *SMS Regulations*, they will not be prosecuted for deficiencies found in their implemented safety management systems.
>
> 3.4 In cases of serious deficiencies to railway companies safety management systems, section 32(3.1) Ministerial Order will be used [...][111]

Section 32 of the RSA states in part:

> (3.1) If the Minister is of the opinion that the safety management system established by a company has deficiencies that risk compromising railway safety, the Minister may, by notice sent to the company, order the company to take the necessary corrective measures.[112]

In practice, this means that railway companies are required to comply with the *SMS Regulations*. However, unless an RSI believes that there is an immediate threat, whatever deficiency is found concerning conformance with its SMS processes would not trigger an enforcement action, but would be flagged to the railway company as an opportunity to improve its system. Where a deficiency is found in the railway company's SMS that is serious enough to risk compromising safety, the Minister can issue an order under subsection 32(3.1) requiring the railway company to take the necessary corrective measures.

#### *1.25.2.3.1 Railway Safety Act review*

In 2007, the *Railway Safety Act* (RSA) Review Panel examined the implementation of SMS in some detail. The panel noted that progress in implementing SMS by railways and by TC had been inconsistent and was not in line with the panel's expectations 7 years after the *SMS Regulations* came into force. Specific to TC, the panel noted that: "clear direction and support are required from national headquarters to overcome inconsistent approaches to delivery throughout TC's five regions."[113] The panel also noted that TC was not assessing the implementation and effectiveness of railway companies' SMS, stating "Transport Canada seems to consider that a railway is compliant with SMS requirements if the railway

---

111 Transport Canada, *Railway Safety Management System Regulations Enforcement Policy* (23 April 2010), paragraphs 3.3–3.4.

112 *Railway Safety Act* (1985, c. 32 [4th Supp.]), Section 32 (3.1).

113 Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), p. 67, available at http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

demonstrates that the processes and management systems outlined in the SMS Regulations exist."[114]

The panel identified 2 significant obstacles for TC when overseeing the implementation of SMS. First, the panel noted that a significant shift in thinking was required to move toward a regulatory framework that places the onus on the operator to demonstrate that they are capable of operating safely. As a result, the panel highlighted a need for additional training to prepare TC inspectors to fill an auditing role, since audits and inspections require two distinctly different skill sets.[115] Second, the panel highlighted resourcing as an issue for TC, stating that: "Transport Canada is inadequately resourced to carry out its many responsibilities in the area of railway safety."[116] The effect of these challenges was described as follows:

> In the Panel's opinion, Transport Canada, Rail Safety was not provided with sufficient human and financial resources and the appropriate skill sets at the outset of the SMS program. This impeded the transition to a regulatory oversight program that focuses on risk assessment and performance-based auditing at the safety management systems level.[117]

The same year that the RSA Review Panel published its report, TC published a document entitled *Moving Forward: Changing the safety and security culture: A strategic direction for safety and security management*. Noting that it is possible for organizations to be compliant with prescriptive regulations without managing risks to acceptable levels, the document outlines TC's policy "for industry to be *accountable for systematically and proactively managing risks and threats within their transportation activities*."[118] The document notes that meeting this policy will require a significant cultural change and a change in approach on the part of the regulator:

> In the past, TC intervened at the operational level. Under the new approach, TC (or a delegate) will audit and assess organizations at the organizational or system level and be able to verify that day to day operations are compliant. When an operator is found to have a system problem or a day to day problem that is left unresolved or mitigated poorly, TC will intervene at the appropriate level. TC will maintain the capability to apply its traditional compliance inspection and audit activity while augmenting its capability to perform system audits and assessments.[119]

*Moving Forward* recognized the same resourcing and skill-set challenges as the RSA Review Panel and provided strategies for overcoming the challenges associated with the transition to SMS both within TC and industry.

---

114 Ibid., p. 81.

115 Ibid., pp. 74–75.

116 Ibid., p. 183.

117 Ibid., p. 185.

118 Transport Canada, TP 14678, *Moving Forward: Changing the safety and security culture: A strategic direction for safety and security management* (2007), p. 9. (Italics in original.)

119 Ibid., p. 10.

TC Rail Safety's Strategic Plan (2010–2015) restated the commitment to implementing SMS:

> At Transport Canada, safety management systems (SMS) remain a priority and Rail Safety continues to focus its efforts on fostering and promoting SMS implementation and advancing safety culture within the rail industry."[120]

The plan notes progress in addressing the challenges identified by the RSA Review Panel and *Moving Forward*. Specifically, it mentions that an organizational review of the Rail Safety Directorate was undertaken between September 2008 and March 2010, and that additional resources were added to the Rail Safety Budget for 2009, allowing an additional 53 positions to be added to support the national Rail Safety Program. Strategies outlined in the plan indicate that Rail Safety is focused on ensuring that all inspectors are trained in audit and risk management and on improving recruitment and retention, to ensure adequate human resources.

#### *1.25.2.3.2 Report of the Auditor General of Canada: Oversight of Rail Safety – Transport Canada*

The Office of the Auditor General (OAG) conducted an audit of TC (Rail Safety) for the 2011–2012 fiscal year to examine whether it has adequately overseen the management of rail safety risks for federal railways. The OAG report, tabled in Parliament on 26 November 2013, stated:

> Transport Canada does not have the assurance it needs that federal railways have implemented adequate and effective safety management systems. Federal railways were required to implement such systems 12 years ago. At the same time, the government approved risk-funding for Transport Canada to oversee the systems. The Department has yet to establish an audit approach that provides a minimum level of assurance to senior management that federal railways have implemented adequate and effective safety management systems for managing their safety risks in day-to-day operations, and for complying with safety requirements.[121]

The audit noted that TC had made progress in addressing issues identified in previous reviews of SMS implementation, while highlighting that there was still work to be done. Specifically, the audit identified the following:

- TC had set a target of auditing federally regulated railways every 3 years, but had conducted only 26% of these audits.
- The scope of the audits was too limited and examined the effectiveness of only a small portion of SMS components.
- TC did not take any enforcement action to require railways to maintain adequate and effective safety management systems, even when deficiencies were identified that could affect safety.

---

120 Transport Canada, TP 15083, *Rail Safety Strategic Plan 2010–2015* (November 2010), p. 5.

121 Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.47, p. 24.

- Audit reports identified whether the SMS met regulatory requirements, but did not identify whether it had been effectively implemented.
- In almost all cases, there was no follow-up by TC inspectors to ensure that corrective action plans submitted by companies in response to SMS audit reports had been implemented.
- Inspector skill sets required for the effective oversight of SMS have not been assessed, and position descriptions have not been updated, to reflect the need for oversight of SMS.
- Approximately 1/3 of inspectors and 2/3 of managers had not attended the available training courses provided by TC on audit methodology and on SMS concepts and principles.

### *1.25.2.4 Introduction of Safety Management System Oversight Program*

In 2002, the introduction of the SMS program came under the jurisdiction of the Director, Audit and Quality Assurance, whose responsibilities included the implementation of the *SMS Regulations*, the delivery of national audits, the national training program, the quality assurance program, and the creation of oversight tools. The Safety Systems Overview manager in each Region participated as an audit team member or team leader in the national SMS audits.

The Director of Audit and Quality Assurance and 1 junior employee provided support related to SMS oversight to the regional inspectors, and produced audit procedures and guidelines. They were also responsible for reviewing the national railway's initial SMS submission and overseeing the auditing of the national railways. Each of TC's 5 Regions had 2 temporary employees to oversee the implementation of SMS in the regional railways.

In 2009, after the RSA Review Panel indicated that a lack of resources impeded the transition to an SMS-based regulatory oversight program, TC underwent a reorganization to integrate SMS as the key focus of its oversight activities. In addition, Budget 2009 provided $44 million over 5 years to TC for rail safety initiatives, such as enhancing its regulatory oversight and enforcement capacity, and conducting research, which included the development and publishing in 2010 of its *Guide for Developing, Implementing and Enhancing Railway Safety Management Systems*.

### *1.25.2.5 Auditor training*

TC Rail Safety's Audit, Enforcement and Risk Evaluation Group began delivering a 4-day training program for SMS auditing in the 2012–2013 fiscal year. The training program for RSIs and managers included a 1-day course on SMS and a 3-day course on auditing. Prior to this new course, other auditor training had been available to the RSIs. In 2001, the regional Manager of Safety Systems Overview and 1 inspector in that group attended auditor and lead auditor training. Between 2003 and 2004, the Safety Systems Overview Manager and 1 inspector each attended program evaluation or auditor training courses provided by third parties. In 2007 and 2008, a number of inspectors and managers from TC Quebec Region attended audit team member and audit team leader training provided by TC.

Table 9 shows which RSIs and managers in the TC Quebec Region attended these auditing courses.

**Table 9. TC Quebec Region's attendance of auditing courses**

| Group | Managers | | | Inspectors | | |
|---|---|---|---|---|---|---|
| | New Auditor Skills Course | Previous Team Leader Course | Previous Audit Member Course | New Auditor Skills Course | Previous Team Leader Course | Previous Audit Member Course |
| Equipment and Operations | No | No | No | 5/5 | 0/5 | 4/5 |
| Engineering | Yes | No | Yes | 5/7 | 2/7 | 5/7 |
| Safety Systems Overview | No | No | Yes | N/A | N/A | N/A |

Notes:
- The total number of inspectors represents positions that were filled at the time of the accident.
- The dates on which courses were attended are as follows:
  - New Auditor Skills Course: March–September 2011
  - Previous Team Leader Course: April 2007
  - Previous Audit Member Course: May 2007–May 2008

Within the TC Quebec Region, some RSIs felt unprepared to participate effectively in SMS audits, particularly as audit team leaders, even after attending the courses. Many felt that resources devoted to SMS audits were poorly deployed, given that they believed that there was little that could be done if a railway company was not conforming to its SMS processes.

### *1.25.2.6 Safety management system audits*

#### *1.25.2.6.1 Transport Canada Quebec Region*

TC Quebec Region was responsible for auditing the SMS of 4 regional railways. Table 10 shows a summary of the audits conducted and indicates whether they were performed to validate the existence of safety management processes and/or performed to validate the effectiveness of the processes in improving safety.

**Table 10. Safety management system audits**

| Railway | Year | Note |
|---|---|---|
| Arnaud Railway | 2002–2003 | Document review and/or pre-audit. |
| MMA | 2002–2003 | Document review and pre-audit only (confirmed). |
| | 2006–2007 | Track audit. Did not examine existence or effectiveness of company's SMS track processes. |
| | 2009–2010 | Included evaluation of SMS components. |
| | 2012–2013 | Included evaluation of SMS components related to accident and incident reporting processes. |
| Quebec North Shore and Labrador Railway (QNS&L) | 2002–2003 | Document review and pre-audit only (confirmed). |
| | 2004–2005 | SMS-focused audit related to (1) accident/incident reporting, investigation and analysis; (2) CROR compliance; (3) data collection and analysis for CROR monitoring and accidents/ incidents; and (4) CROR qualifications and training. Convened in response to a number of incidents. |
| | 2005–2006 | Documentation provided relates to mechanical inspection of equipment. No validation of SMS processes. |
| | 2006–2007 | Documentation provided relates to mechanical inspection of equipment. No validation of SMS processes. |
| | 2013–2014 | SMS audit ongoing. Convened following accident at QNS&L. |
| St. Lawrence & Atlantic Railroad | 2002–2003 | Timing suggests that this was document review and/or pre-audit. |

Note:
A partial audit was conducted on Chemin de fer de la Matapédia et du Golfe in 2008. The railway was sold before the audit was completed.

In the 12 years since the *SMS Regulations* came into force, TC Quebec Region conducted initial pre-audits to verify that all 4 of the regional railways had documented the processes required by the *SMS Regulations*. From the time these pre-audits were completed to the date of the accident, only 3 audits were completed that were aimed at assessing the effectiveness of companies' SMS processes in improving safety. Two of these audits were conducted at MMA, and 1 was conducted at QNS&L. All 3 were limited in scope to part of the organization's SMS. An assessment of the effectiveness of all aspects of SMS has not been completed for the 4 regional railways in TC Quebec Region.

### *1.25.2.6.2 Montreal, Maine & Atlantic Railway*

#### *1.25.2.6.2.1 Initial submission and pre-audit (2002–2003)*

MMA made its initial submission to TC Quebec Region, as required under the *SMS Regulations*, in December 2002. TC reviewed the information submitted under section 4 of the regulations and found MMA to be compliant.

TC conducted a pre-audit at the MMA offices in Farnham on 23 and 24 January 2003. The pre-audit report recognized the efforts of MMA to develop an SMS, but found that its SMS did not meet the requirements of section 2 of the *SMS Regulations*. Areas of the SMS that were non-compliant or in need of improvement were described in detail. Some of the issues identified included the following:

- The documentation for safety-related roles, responsibilities, authorities, and relationships between management, employees and third parties was not detailed.
- The systems used by MMA to identify which regulations, rules, standards, and orders were applicable to operations were not clear.
- The means for approving and implementing risk control strategies were not documented.
- Occurrence reporting requirements were not clear, and the procedure for performing investigations was not complete.
- The procedures for collecting and analyzing safety data were incomplete.
- The procedure for periodic internal audits was incomplete.
- There was no procedure for monitoring the implementation of corrective action resulting from systems and processes contained in the SMS.

The overall result of the pre-audit was that MMA's SMS required a thorough review. TC provided MMA with the pre-audit report on 06 April 2003, and required the railway to provide a corrective action plan. On 11 September 2003, MMA submitted a revised SMS to TC.

1.25.2.6.2.2 *Period between the pre-audit and the first safety management system audit (2004–2009)*

MMA provided annual submissions required by section 5 of the *SMS Regulations* to TC Quebec Region in the spring of 2004, 2006, 2008, and 2009. There is no indication that TC solicited reports for the 2 missing years.

1.25.2.6.2.3 *Period surrounding the first safety management system audit (2010–2012)*

In March 2010, the TC Quebec Surface Regional Director convened an SMS audit of MMA. The on-site portion of the audit was conducted in Farnham and Sherbrooke yards between 15 and 24 March 2010. The audit was convened as a result of the number of non-conformances noted during inspections, the need to ensure that processes were in place to correct them, MMA's plan to implement SPTO, and its limited number of supervisory personnel.

The scope of the audit included elements of SMS and compliance with other rules, and was described as encompassing:

- systems for identifying applicable railway safety regulations, rules, standards, and orders, and the procedures for demonstrating compliance with them (subparagraph 2(d)(i) of the *SMS Regulations*);
- CROR 83, 103(c), 104(i), 104.5, and 112;
- freight car inspection and safety rules;
- freight and passenger train brake inspection and safety rules.

The audit report made 8 findings, the most significant of which was the fact that the SMS provided to TC Quebec Region had not been implemented. The auditors found that none of the 14 represented employees and managers interviewed during the audit had ever seen the SMS manual and that it had never been translated into French. MMA informed the auditors that it had been awaiting approval from TC following the 2003 submission of the revised SMS before proceeding with implementation. The company was informed that TC does not approve a railway's SMS. Under the *SMS Regulations*, it is the company's responsibility to implement and maintain an SMS and to submit documents to the Minister.

Other findings related to deficiencies in the company's SMS included the following:

- The risk management process was used solely by managers and only in the event of major operational changes or following employee injuries.
- Supervisors were not trained in how to perform efficiency tests under the company's OTIS.
- The company did not have a process in place for conducting an internal audit of its SMS and had never completed an internal audit.

Deficiencies related to employee training were also identified. Specifically, mechanical employees were not trained according to the CROR, and operating employees, as well as the rules instructor, were not properly qualified.

TC Quebec Region sent the audit report to MMA on 16 April 2010. A corrective action plan was provided on 28 May 2010. MMA indicated that its intention was to fully implement the SMS by 31 October 2010, following a review of the SMS manual by the Health and Safety Committee and translation into French. The corrective action plan also described the intention to involve employees more in risk mitigation through the health and safety committees, to conduct internal audits of the SMS by 31 August 2011, and to correct the various documentation and training deficiencies identified.

The corrective action plan was reviewed by the lead auditor when it was received, to verify that it addressed the findings. Only some of the findings were addressed with corrective action. No guidance was provided to the Regions stipulating who was the person responsible for ensuring that all of the findings were addressed with corrective action.

*1.25.2.6.2.4 Period surrounding the second safety management system audit (2012-2013)*

The TC Quebec Surface Regional Director convened a second SMS audit of MMA in October 2012. The lead auditor was provided by TC Headquarters and was assisted by 2 RSIs from TC Quebec Region. The scope of the audit included SMS components 2(b), (d), (g), (h), (k), and (l), which relate to accident and incident reporting, and covered the period from January 2010 to the time of the audit. The audit was convened by the Surface Regional Director in response to an occurrence in which an MMA train had blocked a crossing for a significant period of time. Given that TC Quebec Region had learned about the event through the media, a review of available occurrence data was conducted, and it was determined that an audit focused on MMA's reporting processes would be appropriate.

The audit report included 4 findings—3 related to documentation and record keeping, and 1 related to 4 reportable occurrences that were not found in the TSB database, suggesting that they had never been reported. Further examination by TSB revealed that MMA had not reported 22 occurrences over a 7-year period (2007–2013).

The audit report was provided to MMA on 10 December 2012, and a corrective action plan was provided to TC Quebec Region on 30 January 2013. MMA's corrective action plan was reviewed by the audit team.

MMA provided the annual submission required by section 5 of the *SMS Regulations* to TC Quebec Region in the spring of 2013.

#### *1.25.2.6.3 Other Transport Canada Regions*

Regulatory oversight activities for regional railways in TC's Atlantic and Ontario Regions were reviewed for comparison purposes. Specifically, the SMS audits and follow-up activities for New Brunswick Southern Railway (NB Southern) and for Rail America, Inc. were examined.

It was determined that:

- NB Southern received a pre-audit of its SMS in 2003, a verification audit in 2004, and additional audits in 2005, 2006, 2007, 2009, 2012, and 2013. The Safety Systems Overview Group was involved in planning, managing, and following up on the audits. The audits were focused on the processes and procedures associated with components listed in the SMS. Audit findings were presented to the railway in audit reports; railway corrective action plans were evaluated, and their implementation was monitored. The scope of subsequent audits incorporated the findings from the previous audits to verify their implementation.
- Rail America, Inc. received a pre-audit in 2002 and a verification audit in 2005, and was audited again in 2006 and 2011. The Safety Systems Overview Group was active in the SMS auditing and follow-up processes. Corrective action plans were requested, and follow-up action was undertaken after the 2006 and 2011 audits. Some findings from previous audits were incorporated into the scope of subsequent audits. For example, the lack of a risk assessment process and an internal SMS auditing process was identified in the 2002 pre-audit. The 2005, 2006, and 2011 audits examined the risk assessment processes and the internal SMS auditing processes, and found that they were not being completed. Because of Rail America, Inc.'s perceived failure to implement and follow its internal SMS processes, TC Ontario Region began the process of issuing a ministerial order in 2007 to compel the company to do so. In 2012, after 5 years, it abandoned its initiative, stating that it had no authority to require a railway to follow its own SMS processes and procedures; rather, its authority was limited to requiring railways to develop adequate processes and procedures.

### *1.25.3 Other Transportation Safety Board rail investigations involving safety management systems*

The TSB has conducted a number of investigations[122] that found deficiencies in the implementation of SMS. Through these investigations, the TSB has highlighted the following issues:

- companies not conducting risk assessments for changes in operations, or not effectively identifying the risks associated with operational changes;
- SMS processes that were ineffective in identifying unsafe practices, or differences between practices and procedures; and
- lack of SMS audits or ineffective SMS audits.

Following the investigation into a 2006 runaway freight train (R06V0136, near Lillooet, British Columbia), the Board noted the absence of formal risk assessments prior to the implementation of significant operational changes that contributed to the accident. In light of this instance and a similar lack of risk assessment to identify and mitigate risks prior to operational changes that preceded 2 other major derailments, the Board issued Recommendation R09-03:

> Canadian National take effective action to identify and mitigate risks to safety as required by its safety management system, and the Department of Transport require Canadian National to do so.[123]
>
> **TSB Recommendation R09-03**

Shortly after this recommendation was issued, TSB's 2010 Watchlist[124] highlighted a problem with SMS for the air, rail and marine modes of transportation. In describing the Watchlist issue, the TSB stated:

> Implemented properly, safety management systems (SMS) allow transportation companies to identify hazards, manage risks, and develop and follow effective safety processes. However, Transport Canada (TC) does not always provide effective oversight of transportation companies transitioning to SMS, while some companies are not even required to have one.[125]

---

122 TSB rail investigation reports R03V0083, R05V0141, R06V0136, R06V0183, R07V0213 and R09T0057.

123 Transportation Safety Board (TSB), Rail Safety Recommendation R09-03: CN's SMS Requirements (issued 28 May 2009), available at http://www.tsb.gc.ca/eng/recommandations-recommendations/
rail/2009/rec_r0903.asp (last accessed on 16 July 2014).

124 The TSB Watchlist is a list of safety issues investigated by the TSB that pose the greatest risk to Canadians.

125 Transportation Safety Board, Watchlist issues: Safety Management Systems (added 16 August 2010), available at http://www.tsb.gc.ca/eng/surveillance-watchlist/multi-modal/2010/mm_1.asp#n6 (last accessed on 16 July 2014).

Specific to the rail mode, the Watchlist issue stated:

> Although SMS has been in place in the rail industry since 2001, recent investigations have shown that the railways are not always taking effective action to identify and mitigate risk through their safety management systems. The TSB has also found that regulatory audits are not always effective and may not consistently produce the expected benefits.[126]

Following the inclusion of SMS on TSB's Watchlist, CN and TC provided information describing their respective responses to Recommendation R09-03. For TC's part, it provided the following information in October 2011:

> TC and the rail industry have developed guidelines and tools to assist railway companies in implementing and improving their safety management systems. Also, TC has completed staffing technical positions and is providing training for the new Audit, Enforcement and Risk Evaluation Division to provide leadership and functional direction to the industry. For TC this issue is completed.[127]

In February 2012, the Board assessed the response to Recommendation R09-03 as Fully Satisfactory. As a result of the reported progress in addressing this safety issue, the most recent version of the TSB Watchlist, published in 2012, did not include SMS as a systemic issue for the rail mode.

### *1.25.4 Substantial changes in railway operations: Increase in the transportation of crude oil by rail*

In recent years, the transportation of crude oil by rail has increased dramatically in North America. Shipments of crude oil by rail by Canadian Class 1 railways have increased from about 500 car loads in 2009 to 160 000 car loads in 2013.[128] In the United States, crude oil shipments have increased from 10 800 car loads in 2009 to about 400 000 in 2013.[129]

As North American production of oil continues to increase, shipments of oil by rail will continue to rise. In North America, roughly 1.0 million barrels per day (b/d) of crude is currently moved by rail, and the total volume of crude transported by rail is expected to grow to 4.5 million b/d in the next 10 years.

#### *1.25.4.1 MMA's assessment of risk: Increase in the transportation of crude oil*

Between 2011 and 2012, the number of car loads of DGs handled by MMA in Canada increased by 280%. Almost the entire increase was due to the increase in crude oil unit

---

126 Ibid.

127 Ibid.

128 Railway Association of Canada, Without Borders: Canadian, U.S. railways push government to require better tank cars, *Interchange* (Winter 2014), p. 30, available at http://www.railcan.ca/assets/images/interchange/Winter_2013/RACQ0114.pdf (last accessed on 17 July 2014).

129 Source: Association of American Railroads (AAR).

trains. This was a significant change to railway operations, changing the risk profile of the railway.

As MMA began to carry more and more crude oil, it discussed operating longer, heavier trains, and the effects on traction and braking. However, it did not perceive the need to systematically assess all of the changes through a formal risk assessment, and all risks were not identified.

#### 1.25.4.2 *Transport Canada's response to Montreal, Maine & Atlantic Railway's operational changes*

Although there are annual SMS reporting requirements, there is no specific requirement to advise the regulator of major changes to operations, including changes to the risk profile of the goods being carried. However, in some other countries, such as Australia, major operational changes in railway operations, such as SPTO, must be reviewed and approved through assessment by the rail safety regulator.

Similarly, other transportation industries require direct involvement of the regulator when there is a substantial operational change. For example, in the pipeline industry, companies are required to monitor any change in land use or increase in population density within a specified area around their pipelines, and to submit to the regulator a proposed plan to deal with the changes. Likewise, regulatory approval is required when the maximum operating pressure of the pipeline is increased, or when the fluid type transported by the pipeline is changed. The regulator reviews the plans and interacts with the companies throughout the approval process to ensure that adequate safety measures are in place for the proposed change in operation.

In 2011, TC's TDG Directorate identified the significant increase in crude oil volumes being transported in unit trains as one of the emerging issues potentially requiring greater regulatory oversight. The TDG Directorate's risk assessment identified that the majority of the increased risks were related to the facilities where petroleum crude oil was loaded into rail tank cars. As a result, inspections of such facilities, which were not being inspected prior to 2011, were increased. The TDG Directorate's risk analysis did not identify the misclassification of petroleum crude oil as having an elevated level of risk.

At the Irving facilities in Saint John, the loading and unloading facilities were inspected 4 times between 2009 and 2012. These inspections found no instances of non-compliance. The accuracy of the classification of the petroleum crude oil being imported, handled, or transported was not verified by either sampling and testing of the product or by inspecting the company's classification processes.

TC did not ensure that an assessment of the operational risks inherent in transporting substantial volumes of crude oil by rail was performed. Nor did it specifically consider the risks presented by MMA carrying increasing volumes of crude oil from the Bakken region on its Canadian lines.

### 1.25.4.3 *Canadian Transportation Agency's response to Montreal, Maine & Atlantic Railway's operational changes*

The Canadian Transportation Agency (CTA) is an independent, quasi-judicial tribunal and economic regulator. The role of the CTA in the regulation of Canada's rail transportation system is to consider applications for certificates of fitness (COF) for proposed construction or operation of railways under the *Canada Transportation Act*.

The *Canada Transportation Act* requires a person who is proposing to construct or operate a freight or passenger railway under federal jurisdiction to apply to the CTA for a COF. The CTA will issue the COF if it is satisfied that there will be adequate third-party liability insurance coverage[130] for the proposed construction or operation, as determined in accordance with the *Third Party Liability Coverage Regulations*.

When determining whether third-party liability insurance coverage is adequate, the CTA examines the risks associated with the proposed operation by considering information that is provided by the applicant, including information on passenger ridership, train miles, volume of traffic, class and volume of DGs transported, population areas served, number of level crossings, speed of trains, train crew size and training, method of train control and the overall safety record of the applicant. To obtain safety record data, the CTA contacts TC. The CTA identifies railways with similar risk profiles and compares their levels of insurance to make a determination of insurance adequacy.

Once a COF is issued, there is no requirement for renewal or for periodic reassessment of the applicant. However, on an ongoing basis, the certificate holder must notify the CTA whenever its liability insurance coverage is cancelled or altered, or whenever there is a change in construction or operation such that its liability insurance may no longer be adequate. The CTA does not proactively seek out this type of information. When an operational change, or a change to the construction of the railway occurs, the railway must apply for a variance to the certificate which would then trigger a CTA review. The magnitude and type of changes in operations that necessitate informing the CTA are subjective and left to the railway to determine. If the CTA determines that the insurance coverage is no longer adequate, it may suspend or cancel the COF.

The COF for MMA's freight operations in Quebec was issued in 2002. In 2003, MMA applied for and received a variance to its COF to reflect a reduction of track on which it operated. Again in 2003, MMA requested and received a variance to permit the operation of a passenger train for a 6-day period. In 2005, a third variance was obtained to permit the operation of passenger trains on its track.

When it came to more significant changes in operations, including the increase in DG traffic or the commencement of SPTO between Farnham and Lac-Mégantic, MMA did not seek a

---

130 Third-party liability insurance coverage is adequate if there is sufficient insurance, including self-insurance, to compensate for third-party bodily injury or death, including injury or death to passengers; third-party property damage, excluding damage to cargo; and named perils pollution; that may arise out of an applicant's proposed construction or operation of a railway.

variance to its COF, nor increase its liability insurance. The CTA was not aware of changes in operations that may have affected MMA's COF.

### 1.25.5 *Transportation of dangerous goods*

#### 1.25.5.1 *Directorate*

TC's TDG Directorate regulates the transportation of DGs under the authority of the *TDG Act*. The *TDG Act* applies, for the purpose of transport, to every person that imports, offers for transport, handles or transports DGs by all modes of transportation in Canada.

The TDG Directorate develops policies, regulations, and standards. It registers facilities involved in the manufacture, inspection, maintenance, or repair of containers. It also reviews and approves ERAPs, and provides guidance during emergency response activities (through its Canadian Transport Emergency Centre [CANUTEC]). Furthermore, the TDG Directorate conducts research to improve safety, and administers compliance monitoring and enforcement programs.

#### 1.25.5.2 *Compliance monitoring and enforcement*

TDG inspectors can inspect any facility or means of transport where DGs are handled, offered for transport or transported, as well as facilities where DG containers are manufactured, repaired, or tested.

The selection and prioritization of TDG inspection sites are determined by a risk-based methodology. Risk factors taken into account are:

- inspection and compliance history,
- regional and national issues,
- incident history,
- DG class and container type,
- facility type,
- the presence of an ERAP, and
- any emerging issues.

Inspections are carried out at the location where DGs enter the transportation system, commonly at the facility where they are offered for transport (such as where they are manufactured, produced, or shipped from). Inspections en route and at border crossings occur, but much less frequently.

Inspection of ERAPs or registered facilities that manufacture, repair, or test DG containers are also performed as part of the compliance monitoring activities.

During the course of an inspection, TDG inspectors may examine such things as safety marks and shipping documents, as well as loading and unloading operations. Inspections do not include verification of the accuracy of classification by either sampling and testing of the product or by examining the classification processes used by consignors.

All instances of non-compliance are documented in inspection reports. These are communicated to the person(s) responsible for the facility or activity that was inspected. Depending on the nature or seriousness of identified instances of non-compliance, notices of infractions may also be issued. Such notices are not explicitly authorized by the *TDG Act* and are used to warn companies that instances of non-compliance may result in stricter enforcement actions.

All instances of non-compliance are tracked in TDG's Inspection Information System (IIS). The sites for follow-up inspections (i.e., inspections to ensure that identified instances of non-compliance are remedied) are selected using a risk-based approach with data from the IIS. TDG inspectors may also take, as applicable, the following regulatory actions, in accordance with the procedures outlined in the TDG inspector manual, to address various types of non-compliance:

- Issuance of detention orders (section 17 of the *TDG Act*), and
- Issuance of directions (sections 7, 13, 17 and 19 of the *TDG Act*).

TDG inspectors may also initiate prosecutions by summary or indictable conviction pursuant to section 33 of the *TDG Act*, and have the option of issuing tickets[131] under the *Contraventions Act*. Only selected, more serious offences are considered for prosecution, due to the complexity, cost, and resource-intensive nature of the criminal prosecution process. When a prosecution is initiated, an investigation is undertaken in order to ensure that all evidence gathered is admissible in court.

The TDG legislation that was in effect at the time did not contain administrative monetary penalty provisions.[132]

### *1.25.5.3 Transportation of dangerous goods inspections*

There were approximately 11 000 TDG inspections performed over the past 5 years across Canada, of which 1650 were conducted in Quebec.

These inspections resulted in 186 actions taken to address identified instances of non-compliance (Table 11).

---

131 The *Contraventions Regulations* (Schedule XV) were amended in October 2007 to designate as contraventions several offences under the *TDG Act* and to establish an applicable fine for each of them.

132 An administrative monetary penalty system is a civil penalty regime designed to ensure compliance with legislative, regulatory or program requirements through the application of monetary penalties. It is more efficient and less costly than prosecution, since it is based on administrative, rather than criminal, processes.

Table 11. Transportation of dangerous goods inspections and actions taken (all modes)

| Year | No. of TDG inspections performed | Actions taken | | |
|---|---|---|---|---|
| | | No. of detention orders issued | No. of directions issued | No. of prosecutions initiated |
| 2009 | 2537 | 11 | 20 | 1 |
| 2010 | 2357 | 14 | 9 | 5 |
| 2011 | 2208 | 27 | 6 | 3 |
| 2012 | 2290 | 14 | 19 | 3 |
| 2013 | 1999 | 30 | 22 | 2 |
| Total | 11 391 | 96 | 76 | 14 |

Note:
2013 data represents January to June only.

### 1.25.5.4 *Transportation of dangerous goods inspections – Rail mode*

TDG inspections involve the inspecting of facilities where DGs are being loaded, unloaded, and offered for transport by rail, as well as inspections of shippers and ERAP holders. From 2009 to 2013, there were approximately 1320 TDG inspections performed in Canada for the rail mode, of which 12 were in Quebec (which does not have TDG inspectors dedicated to the rail mode).

These inspections resulted in a total number of 22 actions taken to address identified instances of non-compliance (Table 12).

Table 12. Transportation of dangerous goods inspections and actions taken (rail mode only)

| Year | No. of TDG rail mode inspections performed | Actions taken | | |
|---|---|---|---|---|
| | | No. of detention orders issued | No. of directions issued | No. of prosecutions initiated |
| 2009 | 249 | 0 | 2 | - |
| 2010 | 239 | 7 | 0 | - |
| 2011 | 315 | 2 | 0 | - |
| 2012 | 277 | 0 | 4 | - |
| 2013 | 237 | 3 | 4 | - |
| Total | 1317 | 12 | 10 | 0 |

Note:
2013 data represents January to June only.

There were 3 TDG inspections at MMA in the past 5 years. No detention orders or directions were issued, and no prosecutions had been initiated, and there was no identified reason to do so.

# 2.0 Analysis

In this accident, a 4700-foot train transporting petroleum crude oil, that was parked on the main track, ran away, travelling 7.2 miles down a descending grade. The train gained speed and derailed at 65 mph in the town of Lac-Mégantic, Quebec. Sixty-three tank cars spilled approximately 6 million litres of crude oil, which ignited, levelling buildings, destroying the centre of the town, and killing 47 people. There was environmental contamination of the downtown area, as well as contamination of the adjacent river and lake.

The investigation into this accident was complex. Using data from the locomotive event recorder (LER), the rail traffic control recordings, the information gathered from the locomotives, and what remained of the tank cars, as well as the recollections of those involved, the TSB was able to piece together what happened. This information led to an understanding of how the train was secured, what role the locomotive fire played, why the train began to roll on the descending grade, and the events that followed. The derailment and subsequent failure of the tank cars, as well as the manner in which the crude oil caught fire and fuelled many other fires, is now well understood. These factors will be analyzed in this section of the report.

However, understanding what happened is only the first step; it is important to determine why such accidents happen. This analysis will therefore focus on the underlying factors that played a role in this accident, including Transport Canada's (TC) oversight, as well as on organizational factors, such as Montreal, Maine & Atlantic Railway's (MMA's) safety culture and the effectiveness of its safety management system (SMS). The analysis will then look beyond this accident, with the objective of improving rail safety in Canada.

## 2.1 The accident

On the evening before the accident, MMA-002 arrived at Nantes, Quebec, and the locomotive engineer (LE) parked the train on a grade on the main track. A replacement LE was scheduled to continue the trip east in the morning. This was standard company procedure, and the LE had regularly parked the train overnight in this manner.

After bringing the train to a stop using the automatic brakes, the LE applied the independent brakes to the locomotive consist. He began applying hand brakes and shutting down the trailing locomotives, including the 2 locomotives that were equipped with an auto-start system. The lead locomotive was left running to comply with United States air brake rules.

In order to test whether the number of hand brakes applied on the train was sufficient, the LE released the automatic air brakes, but the independent brakes were left applied. As such, the train was held in place by a combination of the hand brakes and by the independent brakes on the locomotives, as opposed to being held by the hand brakes alone. When the train did not move, the LE deemed the test successful and the train adequately secured.

During this time, the LE also noted that the lead locomotive engine was producing excessive amounts of black and white smoke. This smoke was the result of engine oil that had superheated after building up in the body of the turbocharger. The build-up was caused by failure of a non-standard engine repair. The LE discussed the smoke with the rail traffic controller (RTC) in Bangor, Maine. It was expected that the situation would improve and be dealt with in the morning.

Upon arrival of the taxi sent to pick up the LE, the taxi driver noted the smoke and mentioned that oil droplets from the locomotive were landing on the taxi's windshield. The LE acknowledged this and took no further action. The taxi left the area for the hotel. At 2340, a 911 call was made to report a fire on a train at Nantes. The Nantes Fire Department responded to the call and extinguished the fire. To do so, the firefighters shut off the locomotive's fuel supply, thus stopping the engine, and moved the electrical breakers inside the cab to the off position, which was in keeping with railway instructions. The employee who was dispatched by MMA to meet the firefighters was a track foreman with no locomotive operations background. As a result, another locomotive was not started. After notifying the RTC in Farnham, Quebec, of the train's condition, this employee soon left the site with the firefighters.

Normally, when the electrical breakers were moved to the off position, an automatic penalty brake would have been applied to the entire train. The reset safety control (RSC), however, was wired in such a way that this did not occur, nullifying a potential safety defence. Moreover, with the locomotive's engine shut down (and no other locomotive started), the compressor was no longer supplying air to the air brake system. As air began to slowly leak from components of the train's brake system, the main reservoirs began to be depleted. This gradually reduced the effectiveness of the independent brakes on the locomotive consist and, as the air pressure dropped further, the securement of the train became progressively more reliant on the hand brakes.

Eventually, when the air pressure dropped sufficiently, the combination of the independent brakes and hand brakes was no longer sufficient to hold the train, and it began to roll. As it proceeded down the grade, the train picked up speed, reaching 65 mph. The train derailed in the curve at the Megantic West turnout.

## 2.2 *Unattended trains*

MMA-002 was left unattended adjacent to a public highway, with the locomotive cab doors unlocked, the reverser on the LE seat, and the lead locomotive still running; it was therefore at increased risk of unauthorized access. Even if the train had been properly secured, the consequences of vandalism and of locomotive controls tampering can be serious. Although there is no evidence of unauthorized entry that night, there are risks to leaving locomotives unlocked in easily accessible locations with the reverser handle in the cab.

## 2.3 *Securement of MMA-002 at Nantes*

### 2.3.1 *Number of hand brakes*

As demonstrated in this accident, railway rules related to the securement of trains are important because of the potential consequences of improperly secured equipment.

MMA followed *Canadian Rail Operating Rule* (CROR) 112, which stated that a "sufficient" number of hand brakes must be applied and an effectiveness test must be performed to verify that the retarding force is adequate. In addition, MMA had supplementary rules in its

*General Special Instructions* and *Safety Rules*. These rules reference a chart detailing the minimum number of hand brakes to be applied – the "10% + 2" instruction. Since all air brake systems leak, MMA's instructions also explicitly stated that air brakes "must not be depended upon to prevent an undesired movement."[133]

Furthermore, the chart detailing the minimum number of hand brakes was only meant to be a guideline and, as stated in the *Safety Rules*, "additional hand brakes may be required" because of factors such as grade, the number of cars, the weight of a train, and weather conditions.

In addition, TSB tests have demonstrated that a variety of other factors can affect the performance of individual hand brakes, including the amount of force applied by a person, the mechanical condition and the efficiency of the hand brake, as well as the presence of foreign matter between the brake shoes and the wheels. It is therefore imperative that an LE properly verify the securement of a train by performing a hand brake effectiveness test.

In this accident, the 7 hand brakes that were applied correlated to approximately 10% of the cars. This number proved insufficient once the air from the brake system leaked off and the independent brakes no longer provided supplementary retarding force.

Therefore, this investigation examined why work is not always performed in accordance with written procedures, and how adaptations of procedures sometimes occur. More specifically, the investigation examined why the LE considered 7 hand brakes to be sufficient, and why he did not perform a proper effectiveness test.

One reason for this decision may have been that the LE was not fully conversant with relevant rules and special instructions on train securement. Although the LE's results from his requalification tests indicated that he had correctly answered questions relating to the minimum number of hand brakes, these questions were relatively simple and did not demonstrate that the LE possessed knowledge of the significance and rationale behind the rules. Furthermore, the LE was never tested on the procedures for performing a hand brake effectiveness test, nor did the company's Operational Tests and Inspections (OTIS) Program confirm that hand brake effectiveness tests were being conducted correctly. In addition, the LE did not have all of the required documents with him on board the train, and could not easily refer to rules and company instructions.

The LE's previous experiences might also have been a factor in his selection of the number of hand brakes. The LE had previously secured trains at this location using hand brakes on just 10% of the cars. Furthermore, at other locations, circumstances were different (less challenging terrain and gentler grades), and applying only 10% may well have been sufficient or permitted by special instructions. The absence of previous problems may have been taken as an indicator of future success.

The TSB's investigation revealed that the LE's use of the independent brakes at Nantes on previous occasions influenced his perception of the force provided by the hand brakes, leading him to conclude that just 10% was sufficient. The LE was not alone in this belief;

---

[133] Montreal, Maine & Atlantic Railway (MMA), *General Special Instructions* (First Edition, 01 March 2012), Section 112-1: Hand Brakes.

some other MMA LEs also did not release the independent brakes when securing trains, which is indicative that poor train securement practices were not isolated to this accident.

In order to determine how many hand brakes would have been sufficient to hold MMA-002 on a 0.92% average descending grade—that is, without using the independent brakes on the locomotive consist—the TSB performed an extensive series of tests, taking into account a variety of factors affecting hand brake performance. The main conclusion of these tests was that 9 hand brakes, which is the minimum number set out in the MMA chart, would not have been sufficient to hold the train at Nantes.

In a scenario in which there was no application of automatic air brakes, and depending on the force applied,[134] the TSB concluded that the LE would have needed to apply between 18 and 26 hand brakes on the cars and locomotive consist.

Given that a 13-psi automatic air brake application was used to stop the train, the TSB concluded that, in this situation, the LE would have needed to apply between 15 and 20 hand brakes on the cars and locomotive consist.

The TSB also concluded that, since the hand brakes on the tank cars were more effective than the hand brakes on the locomotives, between 12 and 18 hand brakes would have been sufficient if the hand brakes were applied only to the cars.

The detailed results of these tests are shown in Appendix J.

However, as noted in the company's *Safety Rules*, the numbers set out in the chart are only minimums, and some conditions may require additional hand brakes. For this reason, the LE must determine, through a proper hand brake effectiveness test, the sufficient number of hand brakes.

Before the Lac-Mégantic accident, there had been no runaway trains as a result of unoccupied trains being left at Nantes or Vachon, Quebec. This was likely due to the fact that independent brakes were being used in addition to hand brakes to secure trains. Nonetheless, if a proper hand brake effectiveness test is not performed, equipment may not be adequately secured, increasing the risk of a runaway.

### 2.3.2 *Conducting a hand brake effectiveness test*

Locomotive independent air brakes can provide very effective braking force and are normally able to hold a train on their own. However, these brakes cannot be relied upon in all situations. If locomotives are shut down or become inoperative, system leakage will cause the brake cylinder pressure to drop and the air brakes to lose effectiveness. Hand brakes, which do not rely on air pressure, are therefore a critical defence, and must be able to hold a train on their own. Their effectiveness cannot be determined without a properly conducted effectiveness test.

---

134 Although the use of a train's automatic air brakes allows hand brakes to be applied more easily and allows significantly more brake force to be applied to the wheels, this practice is discouraged by railways, as it makes the brakes difficult to release, thus posing risk of personal injury and potential damage to brake components.

A hand brake effectiveness test involves isolating the effect of the hand brakes on the cars from that of any other brakes. This is done by releasing all of the air brakes on the train and on the locomotives, and allowing or causing the slack to adjust (through gravity or by applying throttle as necessary).

However, if, during a hand brake effectiveness test (when applying throttle), hand brakes are also applied on the operating locomotive(s), the retarding force from the locomotive hand brakes can give the false impression that the retarding force is that of the entire train. This can result in an inaccurate effectiveness test, increasing the risk of runaways. An LE would therefore have to compensate with a greater throttle application to overcome the retarding force of the locomotive hand brakes.

Because a locomotive was always left operating and therefore maintained the integrity of the independent brakes, there had been no previous train securement problems at Nantes. Therefore, any improperly conducted hand brake effectiveness test had not previously resulted in train movement.

### 2.3.3 *Locomotive hand brake maintenance*

Because the quick release brake (QRB) valve on MMA 5026 was defective, the brake cylinder air was not released when the hand brake was applied. Once the brake cylinder air leaked off, its hand brake force was lost. Consequently, only 6 of the 7 hand brakes applied were providing braking force. Therefore, in reality, even less hand brake force was being applied to the train than the LE had intended.

As a result of common malfunctions with QRB valves, MMA issued instructions on when and how to trip the QRB valve manually if it did not exhaust. The QRB valve on MMA 5026 had previously been modified to keep it working. However, the valve had sustained further wear and damage to the lifter, and the retaining disc was no longer operating. As a result, the QRB valve had to be manually tripped for the hand brake to be operational. Because the LE was not aware of these instructions, he did not know about the malfunction and did not manually trip the valve.

Furthermore, hand brake testing on the 5 locomotives determined that, at 100 foot-pounds of torque, only an average brake ratio of approximately 3.8% could be attained. Moreover, even at 150 foot-pounds of torque, the combined brake ratios of the hand brakes ranged from approximately 4.2% to 6.8% of the locomotives' gross weight on rail, which is below current Association of American Railroads (AAR) requirements. By comparison, the same testing on the occurrence tank cars determined that the cars generally met the AAR requirements, generating brake ratios in the range of 10% of their gross weight on rail. These ratios resulted in average brake shoe forces generated by the locomotives that were significantly less (below 2/3) than those generated by the tank cars when the same torque was applied. Therefore, hand brakes applied on 3 locomotives provided less brake shoe force than that of 2 tank cars.

Futhermore, hand brakes on some locomotives apply the brake shoes to only 2 wheels. Therefore, if a locomotive hand brake system is out of adjustment, the overall retarding brake force could be reduced. Although modern locomotives can have higher net braking ratios than do freight cars, older locomotives, especially if not well maintained, can be more susceptible to reduced effectiveness. Consequently, given the variable condition of locomotive hand brakes, counting them as part of the total number of required hand brakes can lead to an overestimation of the braking force, thereby increasing the risk of runaways.

## 2.4 *Locomotive fire on MMA-002*

In October 2012, 8 months before the accident, MMA 5017 was sent to the company's repair shop in Derby, Maine, following an engine failure. Given the significant resources (in time and money) required to carry out a standard repair to the engine block, as well as the need to return the locomotive to service because of increased traffic, the repair was performed using a non-standard and less costly method. This method involved the use of a polymeric material that lacked the required strength and durability.

This material eventually began to fail, leading to problems in the cam bearing area and, ultimately, to inadequate lubrication of the valves. The valve failure was not immediate, and the locomotive continued operating, but with increased engine oil consumption. As this slight increase was not unusual for an old locomotive, the underlying cause of this condition went undetected.

As the condition worsened, the engine began to surge, which was reported during the previous trip by another LE, and again by the accident LE when departing Farnham. Despite these reports, MMA did not immediately address the situation, either by removing the locomotive from service or by taking it out of the lead position.[135]

As the train worked up the grade toward Nantes, oil that was flowing from the damaged cylinder into the intake and exhaust manifold began to accumulate in the body of the turbocharger. There, it became superheated, creating the excessive black and white smoke observed by the LE.

The LE secured the train at Nantes and shut down all of the locomotives except the lead locomotive, including those with an auto-start system. The LE then had a discussion with the Bangor RTC, which did not resolve the situation. Despite MMA's safety rule regarding actions to be taken in the event of abnormal engine conditions, as well as the observed excessive smoke and significant mechanical problems, it was decided that no immediate remedial action was necessary. It was agreed that MMA 5017 would be assessed in the morning to address the engine performance issue, and the lead locomotive was left running.

Shortly after the LE departed by taxi for the hotel, the oil that had accumulated and superheated in the turbocharger caught fire. Neither the LE from MMA-001 or the LE from MMA-002 was called to return to Nantes, due to the impact that it would have on train departure time the following morning and due to mandatory rest provisions. Having to perform a No. 1 brake test the next morning may have been an inconvenience, but avoiding inconvenience was not a sufficient reason to bring the LE back to start another locomotive that night. Because another locomotive was not started, the pressure in the train's independent brakes was not maintained.

---

[135] For the portion of the trip from Farnham to Nantes, this train required all 5 locomotives to be in operation to generate sufficient tractive effort.

The RTC, who had experience securing trains at Nantes, was aware that no locomotive was left running. However, he knew that train securement should not be dependent on a running locomotive, and assumed that the train had been adequately secured with sufficient hand brakes. Without a compelling cue to the contrary, the RTC did not consider that shutting down the locomotives would affect the securement of the train.

## 2.5 *Train movement and defences against runaways*

MMA-002 began to run away when the retarding brake force from the locomotives' independent brakes was reduced to a level that, combined with the force of the hand brakes, was insufficient to hold the train on a 0.92% grade.

The hand brakes applied by the LE were providing only about 48 600 pounds (1/3) of the approximate 146 700 pounds of retarding brake force[136] required to hold the train (based on the grade of the track, the weight of the train, and the estimated rolling resistance). However, the train was initially secured effectively because the independent brakes, which are quite powerful, were providing an additional 215 500 pounds of retarding brake force, for a total of 264 100 pounds.

Air brake systems are designed to prevent automatic brake applications that might arise from normal fluctuations in air flow. In this accident, once the lead locomotive was shut down, the average rate of air leakage was approximately 1 psi per minute. Although somewhat excessive, this rate was still within industry norms and less than what was required to activate the air brake control valves (approximately 3 psi per minute). No automatic brake application was therefore triggered. Had this automatic brake application occurred, it likely would have been sufficient to hold the train until morning.[137]

The critical threshold was reached approximately 1 hour after the lead locomotive was shut down, when the brake cylinder pressure dropped to 27 psi. At that point, the independent brake force was reduced to 97 400 pounds, reducing the total retarding brake force (including the hand brakes) to just 146 000 pounds. The train began to roll downhill.

In the rail industry, there are a number of physical and administrative defences to prevent runaways, including where and how trains are parked, crew transfers, derails and chocking devices, mechanical emergency devices, and electronically controlled pneumatic (ECP) brakes. The following measures are also available on most trains, including MMA-002:

- Reset safety control (RSC): Usually, an RSC is expected to initiate a penalty brake application when the rear electrical panel breakers are opened. However, no such penalty brake application occurred on MMA-002 because of the manner in which the device was wired. Although there is no standard way to wire an RSC, had a penalty brake application occurred when the power was shut down, the train would likely have remained safely secured.
- Auto-start system: One of the benefits of an auto-start system is that it will restart a locomotive when the brake cylinder pressure drops below a certain level, thereby maintaining the integrity of the independent brakes. In this accident, the LE did not

---

136 Assuming a minimum coefficient of friction of 0.38

137 Any train that leaks at a rate below 3 psi per minute could be at risk of eventually running away.

have detailed knowledge of the auto-start system and was not aware of MMA's instruction to leave locomotives with an auto-start system running. Therefore, when the 2 locomotives equipped with the auto-start system were shut down, their pressure-maintaining capabilities were nullified. Sometime later, when the lead locomotive was also shut down, there was nothing maintaining the brake cylinder pressure, and it began to drop.

- Application of the automatic brakes: While MMA instructions did not allow the automatic brakes to be set following a proper hand brake effectiveness test, doing so would have acted as a temporary secondary defence, one that likely would have kept the train secured, even after the eventual release of the independent brakes.

Ultimately, none of these defences were used, and some were nullified by design or human intervention. Thus, they were unavailable to prevent the runaway. If equipment is left unattended without additional physical safety defences, there is an increased risk that it will run away leading to an accident.

## 2.6 *Derailment*

### 2.6.1 *Point of derailment and derailment sequence*

The train derailed near the Megantic West turnout as it negotiated the curve at 65 mph, which is more than 3 times the balanced speed of the track. The results of a dynamic simulation showed that in the body of the curve, where centrifugal forces would have been at their highest, the cars would have generated excessive lateral forces on the high rail and experienced complete wheel unloading on the low rail. Therefore, speed was the major contributing factor in the derailment.

Previously at this location, work had been performed to improve the geometry conditions recorded in 2012. However, without the use of mechanized equipment, the improvements were temporary; therefore, similar geometry conditions were likely present the day of the accident. The simulation showed that these conditions, although acceptable for 15-mph movements, would have exacerbated the effect of the centrifugal force and further destabilized the passing cars. Although the locomotives were able to negotiate the curve at about 65 mph without derailing, the tank cars—due to their rigidity and relatively high centre of gravity—could not.

The general trajectory of the derailed equipment also confirmed that the point of derailment (POD) was at or near the Megantic West turnout. To determine which cars were most likely the first to derail, the TSB analyzed LER information to establish the locations of the cars when the brake pipe pressure dropped to zero, as this indicated the moment of separation caused by the derailed equipment. Results show that tank cars 4 through 6 were closest to the POD at that time (Photo 29).

**Photo 29. Location of the train when the brake pipe pressure dropped to 0 psi (sources: AeroPhoto and locomotive event recorder data)**


An examination of the damage and of the final resting locations of the first derailed cars, starting from the front of the train, allowed the investigation to conclude that the derailment most likely occurred ahead of the sixth tank car.

It was determined that the knuckle on the leading end of the buffer car failed in torsion. The failure characteristics of the knuckle indicated that the buffer car was rolling toward the north when the knuckle failed. The marks on the trailing end of the buffer car indicated that the cars behind it derailed first, overturning the buffer car. The buffer car was relatively lightweight and was not severely damaged. It came to rest with its trucks still attached, and its wheel sets either with the trucks or located nearby. Its post-derailment condition and location close to the main track indicated that it did not travel an extended distance on its side.

The first tank car on the train came to rest on its side, with its trucks still attached. Its leading end was immediately next to the buffer car close to the main track, indicating that it had travelled toward that location when coupled to the buffer car. Two large pieces of rail ran through the car (1 through the head and 1 through the body bolster). The location of the rail through the body bolster indicated that the car was on its side when this occurred. Because the rails of the main track and of yard track 2 were relatively intact, these rails were likely picked up from the damaged yard track 1. Marks on the car draft gear indicated that the tank had rolled toward the north while coupled.

The draft gears of the second tank car indicated that it had been subjected to a torsional force from the third tank car. The second tank car most likely derailed after the third tank car and took the first tank car with it. The tank of the third tank car had rotated to the north relative to its draft system. The fourth tank car showed little sign of tank car rotation relative to its draft system; however, the lateral deformation of its stub sills indicated that its leading end had been derailed to the north. The fifth tank car was the only one of the first cars that had a broken coupler shank, and the damage to the bottom of the car's leading striker indicated that the coupler was exerting excessive force in that direction. Both the fourth and fifth cars showed more physical signs of overall damage than the first 3 cars, suggesting that they quickly lost their wheel sets.

The sixth and seventh cars showed little rotation of the coupler or draft sill components; however, both had extensive damage to the bottoms of the cars and significant denting of their heads or shells. This indicated that they came into contact with previously derailed equipment. Their trajectory, consistent with a tangent direction starting near the POD, indicated that the track was already destroyed at the time of their derailment. It is therefore most likely that the derailment occurred ahead of the sixth tank car.

### 2.6.2 *Separation of the locomotive consist during the derailment*

During the runaway and subsequent derailment, the locomotive consist separated into 2 sections at the same moment that (or just before) the consist separated from the rest of the train. The first section was comprised of MMA 5017, VB 1, and MMA 5026, and the second section was comprised of CITX 3053, MMA 5023, and CEFX 3166.

According to the LER, 1 sudden deceleration was recorded—the moment of derailment—at which point the brake pipe pressure dropped to zero.

Lab testing indicated that the knuckle that broke between locomotives MMA 5026 and CITX 3053 failed in tension, likely due to a pre-existing defect. As such, less tensile force would have been required to break it.

The second separation—due to a broken knuckle between the last locomotive (CEFX 3166) and the buffer car—occurred when the buffer car overturned. This failure occurred at the same moment as the initial separation or shortly thereafter; had it happened earlier, the LER would have recorded 2 notable decelerations instead of just 1. Moreover, both sections crossed de la Gare Street separated by 104 feet, and given the train speed (approximately 90 feet per second), that indicated that they were traveling just over 1 second apart.

The 2 sections of the locomotive consist then travelled an additional 4400 feet through Lac-Mégantic, eventually stopping approximately 475 feet apart. The first section came to rest on an approximately 1% grade, where it remained for about 90 minutes. As the independent brakes were no longer providing any retarding force, and the hand brake on MMA 5026 was defective, the first section was held only by the hand brakes on MMA 5017 and the VB car. This location was identified by the presence on the ground of the same black oily residue found on the ground at Nantes, where the engine fire had been extinguished. However, once the wheels and brake shoes sufficiently cooled, the first section began to move backwards, down the grade toward the downtown, due to the residual lessening of hand brake retarding force. It was travelling at about 8 mph when it collided with the stationary second section. Both sections then moved backwards for approximately 100 feet before coming to a final stop, and were held mainly by the retarding force from the hand brakes on the second section.

After the accident, MMA employees found the locomotive consist almost 1 mile east of the derailment site, and tightened the hand brakes on all 5 locomotives and the VB car. A hand brake that can be tightened is indicative of slack in the system; this slack was likely due to brake shoe wear from the uncontrolled movement.

Examination of the locomotive wheels also indicated that less than half of the wheels subjected to hand brake force showed full tread blueing or excessive brake shoe lining wear. This meant that several of the hand brakes had either not been applied securely, or could not have been applied securely, and confirms that the independent brakes had been providing most of the retarding force to hold the train on the grade at Nantes.

## 2.7 *Class 111 tank cars*

### 2.7.1 *Stub sills and couplers*

Almost every derailed tank car exhibited at least 1 damaged stub sill or coupler, and most were damaged on both ends. The last 2 derailed tank cars had significant impact damage to their stub sills and couplers. The damage was consistent with the generally severe impacts in this derailment.

Nine derailed tank cars exhibited separations at the stub sill attachments. One tank car separated at the fillet weld between the front sill pad and the tank, breaching the tank in 2 locations. This type of failure was present in a 2009 accident in Cherry Valley, Illinois, and resulted in U.S. National Transportation Safety Board (NTSB) Recommendation R-12-9.

### 2.7.2 *Tank heads and shells*

Damaged tank heads and shells were a major source of product loss. Fifty-nine of the 63 derailed tank cars exhibited some form of impact damage (denting or breach) to the heads or shells.

The majority of the tank cars exhibited impact damage (denting or breach) on the top portion of at least 1 head. This is not unexpected, as most of these cars came to rest on their sides, thereby bringing the top portion of the heads closer to the ground and increasing the probability of impacts with objects such as rail, couplers, and body bolsters. A full-head shield would have been beneficial, as half-head shields protect only the bottom portion of the head.

Almost 60% of the tank cars had a breached shell due to impact damage, and more than half of these breaches were of a size commensurate with the car's diameter, which would have caused an almost instantaneous release of the entire car's lading (Photo 30).

Photo 30. Concentration of large (orange) and medium (yellow) breaches toward the end of the derailment

About half of the cars with large breaches were clustered toward the end of the derailment. These cars would have encountered more severe derailment conditions than the conditions experienced by the cars located toward the front of the train, due to the large pileup ahead of them. This pileup likely acted as a wall for the cars derailing toward the end of the train. These highly constrained derailment conditions caused large-scale buckling and extreme tank deformations (that is, plastic collapse), which resulted in large shell ruptures. These cars derailed at a slower speed, and came to rest perpendicular to the track. Their thin wall construction (7/16 inch), as well as the absence of jackets, did not provide sufficient protection from the derailment forces. Consequently, large tank shell breaches occurred in a short period of time on about 1/3 of the derailed tank cars, which resulted in the rapid release of large quantities of petroleum crude oil.

### *2.7.3 Protection of tank car fittings*

With the majority of the tank cars coming to rest on their sides or upside down, the petroleum crude oil flowed from a number of damaged top fittings and fed the pool fire. Top fittings that were located within a housing that provided top discontinuity protection fared better than the top fittings that were not protected. Approximately 15% of the cars with impact-damaged top discontinuity protection housings had breached top fittings, whereas 62% of the cars with impact-damaged hinged housings had breached top fittings.

In addition, pressure relief device (PRD) survivability improved significantly when the fittings were located within a protective housing. About half of the PRDs were so protected, and only 9% of these exhibited release of product from impact damage. In the case of the unprotected PRDs, 29% exhibited impact damage resulting in product release. This comparison demonstrates that top discontinuity protection is effective in reducing the release of product from impact-damaged top fittings (including PRDs).

Examination of the derailed tank cars highlighted the need for a better bottom outlet valve (BOV) design, specifically with respect to ball valves equipped with handles. In most cases, the bottom outlet skid protection worked as intended, as the nozzles sheared off where designed (shear plane). However, some of the ball valves (7) opened due to handles being moved during the derailment. On cars equipped with an internal self-closing plug-style BOV, the valve's location inside the tank protected it from sliding damage, and the self-closing feature resulted in fewer valves being opened. Self-closing plug-style valves seem to perform better than external ball valves in preventing product loss during derailments.

Given that tank cars are prone to rollover in a derailment (due to their cylindrical shape), the need for enhanced protection of their fittings and valves is heightened. In this derailment, the high number of damaged unprotected top fittings, as well as the number of external ball valves that were opened, demonstrate the need for additional safety improvements in these areas. Without adequate top-fitting protection during a rollover, and without design improvements to BOVs, there is an increased risk of product release when general-service Class 111 cars are involved in derailments. If Class 111 tank cars that do not meet enhanced protection standards transport flammable liquids, there is an ongoing risk of product loss and significant damage to persons, property, and the environment when these cars are involved in accidents.

### 2.7.4 *Thermal tears and fire damage*

As no fragments of tank material were projected away from the tank cars, none experienced a BLEVE.[138]

There was no indication that the type of PRD on the cars that sustained thermal tears contributed to these tears. However, when some tank cars rolled over during the accident, their PRDs became located in the liquid space, reducing their ability to effectively relieve internal pressure. In the case of tank cars equipped with PRDs with low start-to-discharge (STD) pressure and high flow capacity, more vapours will vent faster, thereby reducing the risk of tank cars building up excessive internal pressure in a fire.

One of the tank cars that sustained a thermal tear came to rest adjacent to another car that did not sustain this type of tear. As these cars were both exposed to similar fire conditions, this configuration suggests that they experienced only a small difference in temperature and internal pressure. Therefore, a relatively modest improvement in fire survivability may prevent thermal tears. Thicker steel, jackets and thermal protection on tank cars, combined with adequate pressure-relief capacity, can significantly extend the time that these cars can survive in a pool fire. These features would also have helped better protect the 13 cars that lost product due to burn-throughs.

### 2.7.5 *Post-accident identification of tank cars*

The extent of the fire made identification of some cars difficult because car markings were illegible. This meant that the cars had to be identified by their identification plates or

---

138 A BLEVE (boiling liquid expanding vapour explosion) is "an explosion resulting from the failure of a vessel containing a liquid at a temperature significantly above its boiling point at normal atmospheric pressure" (SFPE Handbook of Fire Protection Engineering, 4th Edition [National Fire Protection Association, 2008], pp. 2–213).

stampings. However, some of the cars' identification plates were secured with aluminum fasteners that were consumed in the fire or melted, resulting in identification plates falling off the cars. Also, some of these stampings were light and, when oxidized after the fire, were difficult to read. If cars are missing identification plates and have illegible stampings, severely damaged cars may not be correctly identified in a timely manner.

### *2.7.6 Tank car: General*

The derailed tank cars were subjected to a range of impact speeds and forces depending on their position in the train. Even though some 15% of the tank cars derailed at estimated speeds of 40 mph or less, which are typical speeds for freight trains, these tank cars still experienced significant tank shell and head damage, as well as product loss.

The amount of product released could have been reduced had the tank car shells and heads been more impact-resistant. Specifically, tank cars built with thicker steel, full-head shields and tank jackets would have been better protected. In this accident, all but 4 of the 63 derailed Class 111 tank cars lost product from head or shell breaches, or through damaged valves and fittings.

This failure rate again demonstrates the poor performance in derailments of general-service Class 111 tank cars that are built to minimum requirements, and highlights the inability of these tank cars to withstand accident forces. Commodities posing significant risk must be shipped in safe containers, which include defences such as stronger tank shells, tank car jackets, full-height head shields, thermal protection, and high-capacity PRDs.

## *2.8 Dangerous goods*

### *2.8.1 Properties of petroleum crude oil*

The laboratory analysis of the petroleum crude oil samples determined that the product's properties were consistent with those of a light, sweet crude oil, with volatility comparable to that of gasoline. Given that the samples were taken at atmospheric pressure, the volatility of the crude oil may have been higher than measured at the time of the analysis. This is because some light hydrocarbons may have evaporated when the tank cars were opened for the first time to collect the samples.

The low flashpoint of the petroleum crude oil explains in part why it ignited so quickly once the tank cars were breached. The large quantities of spilled product, the rapid rate of release of the product, as well as the product's high volatility and low viscosity were the major contributors to the large post-derailment fireballs and pool fire.

### *2.8.2 Safety data sheets*

The purpose of a safety data sheet (SDS) is to communicate the dangers of hazardous chemicals; it is therefore critically important that the information contained in these documents be accurate. For naturally occurring substances, such as petroleum crude oil, the preparation of generic representative SDSs for a range of products with similar characteristics was permitted by U.S. and Canadian legislation.

In this accident, each petroleum crude oil supplier provided a different SDS characterizing its product. However, the information in each SDS was inconsistent and sometimes contradictory. There was no systematic method of verifying or reconciling the information contained in the different SDSs; these inconsistencies and contradictions were not picked up, and corrective action was not initiated.

The safety of personnel who handle or come in contact with hazardous chemicals is largely dependent on an accurate characterization of the hazards of the substances. Therefore, when an SDS contains inaccurate information on the properties of the product or family of products, the usefulness of the SDS for communicating the dangers of the product is compromised, increasing the risks of injury.

In addition, the usefulness of SDSs alone for the purpose of product classification is limited in cases where products from different sources are blended together when loaded in large bulk containers.

### *2.8.3 Testing and classification of dangerous goods*

An accurate characterization of the properties of a dangerous good is critical to ensuring its proper classification. This classification is required by federal regulations, and allows the dangerous good to be packaged in the appropriate container, as well as allowing for the proper equipment and procedures to be used when handling, loading, and unloading dangerous goods. The packing group (PG) is an integral part of the classification of Class 3 flammable liquids. It is dependent on determination of the product's flashpoint and initial boiling point through testing of representative samples. A system must be in place to determine, and then consistently validate, the classification of the product being offered for transport.

In this accident, the shipping documents for the majority of the cargo tank trucks used to transport the petroleum crude oil to the rail loading facility in New Town, North Dakota, correctly identified the product as PG II. However, this classification was not due to testing, but rather to a practice of considering crude oil from the Bakken region as PG II.

Although monthly tests on collected composite samples were being performed at the rail loading facility, these tests were not being carried out for product classification. Furthermore, the PG information in the rail cars' shipping documents was not reconciled with the corresponding information in the documents for the cargo tank trucks. Had this been done, the discrepancy could have been detected.

When the oil reached Irving's refinery in Saint John, New Brunswick, samples were collected and tests were performed, but mainly for operational reasons. There was neither determination nor verification of the product's initial boiling point and flashpoint, nor were these required or part of Irving's operational needs. Irving relied on its suppliers for proper classification of imported dangerous goods, as permitted by the *Transportation of Dangerous Goods Regulations* (*TDG Regulations*).

As a result, the petroleum crude oil being transported by the train was improperly classified, and remained that way throughout the transportation cycle. The product was assigned a PG III classification (lowest hazard), despite meeting the criteria for PG II. Therefore, its hazards were not correctly identified.

Moreover, as crude oil loaded in large bulk containers includes products from a variety of sources, the characteristics of the resultant blend may vary. If systematic testing is not conducted on representative samples of petroleum crude oil at an appropriate frequency, there is an increased risk that these dangerous goods will be improperly classified. When improperly classified and documented, dangerous goods may be moved and handled incorrectly, increasing the risk of injury to people, and of damage to property and the environment.

While proper classification of the petroleum crude oil would have allowed the railways to identify the true hazards of the product they were transporting, it is not known what effects (if any) this identification may have had on MMA's operating plans.

The incorrect classification did not result in the selection of an unauthorized container to package and transport the product. Federal regulations in effect at the time of the accident did not mandate the use of enhanced Class 111 tank cars similarly to the standards that the industry adopted on a voluntary basis in 2011 for transportation of petroleum crude oil in PG I and II. Furthermore, given that all of the tank cars involved in this accident were ordered before the effective date of that voluntary standard, none were covered by these industry provisions.

### 2.8.4 *Transportation of dangerous goods monitoring*

Between 2009 and 2013, TC's Transportation of Dangerous Goods (TDG) Directorate performed over 11 000 inspections throughout Canada, which resulted in the issuance of 99 notices of infractions, 96 detention orders, and 76 directions, as well as the initiation of 14 prosecutions.

In 2011, the TDG Directorate identified the rapid increase in the transportation by rail of petroleum crude oil as an emerging issue requiring greater regulatory oversight. As a result, the TDG Directorate started inspecting petroleum crude oil transloading facilities, focusing on specific areas of regulatory compliance in facility operations, such as tank car loading and securement practices. However, these inspections did not include verification of the classification of the petroleum crude oil being handled, offered for transport, transported, or imported. Such verifications would have included a review of company classification procedures to ensure that dangerous goods are being classified based on the appropriate tests. Without monitoring and effective enforcement of compliance with applicable classification provisions in the *TDG Regulations*, there is a risk that improperly classified dangerous goods will enter the transportation system.

## 2.9 *Emergency response*

The pileup of cars, combined with the large volume of petroleum crude oil on fire, made the firefighters' job extremely difficult. The 911 calls were received and responded to promptly, and the incident response protocols for response escalation worked as designed.

The firefighters were facing a major disaster involving a rail accident; this type of disaster was not specifically covered by their practical training. Nevertheless, the large emergency response was well coordinated, and the prompt assistance of other fire departments in the province and from the State of Maine was critical in the provision of adequate human resources and standard emergency-response equipment. The various fire departments were able to effectively coordinate their efforts and implement appropriate measures to protect the site, as well as ensure public safety after the derailment. The evacuations were conducted in a prompt and efficient manner. Despite the challenges of responding to a major disaster not specifically covered by many firefighters' practical training, the emergency response was conducted in a well coordinated and effective manner.

## *2.10 Emergency response assistance plan*

When the *TDG Regulations* were amended in 2008 to extend emergency response assistance plan (ERAP) requirements to include 3 additional flammable liquids, petroleum crude oil was not considered. At that time, the volume of petroleum crude oil transported by unit trains was not significant.

However, there has been a considerable increase in the shipment of petroleum crude oil by rail in the last 5 years, and it is projected to continue growing significantly in the coming decades. This increase is particularly true for crude oil from the Bakken field. Unit trains will continue to carry large volumes of petroleum crude oil over long distances and through populated areas. The large increase in the frequency of these unit trains, combined with the volumes of product transported by each train, have significantly increased the risks. One of the elements of an adequate defence system against these risks is ensuring that the consequences of any accident can be appropriately mitigated.

The release of dangerous goods transported by rail can jeopardize the health, safety, and welfare of railway employees and of residents living near railway tracks. The risks are even greater in the case of tracks running through urban areas. As demonstrated in this accident, petroleum crude oil can be highly flammable. Firefighters may not always be equipped or trained to handle flammable liquid spills and fires of this magnitude. If the shipper has not developed an adequate, regulator-approved ERAP, the required resources to assist local responders may not be available in the event of an accident involving large quantities of liquid hydrocarbons.

## *2.11 Route planning and analysis*

A primary safety concern related to the transportation of dangerous goods by rail is prevention of a catastrophic release in a densely populated or environmentally sensitive area. Route planning for the transportation of dangerous goods identifies the route with the lowest overall risks to the public. Some railways have multiple lines servicing major centres, or pre-arranged running-right agreements with other carriers. Others railways offer logistical services, providing integrated transportation services from origin to destination. Route planning must cover the entire route, including any connecting railways that may form part of the transportation service. Each route needs to be evaluated to ensure that the safest route is chosen (Figure 8).

Figure 8. North American rail network map (source: Google Earth, with TSB annotations)


Once the safest route is selected, the risk of carrying dangerous commodities can be reduced by proactively examining all aspects of operations over the entire route to ensure that the identified risks are adequately mitigated. The measures included in Circular OT-55-N, such as restricting key trains to a maximum speed of 50 mph and requiring additional inspections on key routes, can reduce the risk when transporting dangerous goods. However, the level of mitigation provided by Circular OT-55-N may not be sufficient; as demonstrated in this accident, many tank cars that derailed, travelling at speeds below 50 mph, were heavily damaged and had severe loss of crude oil.

Once adequate mitigating measures are in place, periodic risk assessments will help ensure the continued safe movement of dangerous goods. If route planning, analysis, and follow-up risk assessments are not conducted by railways along routes where dangerous goods are carried, comprehensive safety measures to mitigate the risks may not be introduced.

## *2.12 Single-person train operations at Montreal, Maine & Atlantic Railway*

Some railways have argued that there are potential safety benefits to single-person train operations (SPTO), such as increased attentiveness by the lone operator because of the absence of a second crew member on whom to rely. It is also said that there are fewer distractions from extraneous conversations. Although most of the benefits of joint compliance are lost when operating as a single person, some benefits can still be achieved by confirming critical actions with another person (e.g., the RTC), albeit remotely.

However, there are also demonstrated risks to SPTO, including reduced joint compliance (which can help catch errors), a tendency to take shortcuts, additional physical and time-related requirements for a single person to perform tasks, the possibility that individuals working alone will be subject to fatigue and cognitive degradations, and the need for additional training to properly prepare LEs to work alone. It is also important to consider how a single operator might deal with the abnormal conditions that may arise, as well as whether all safety-critical tasks (such as the application of hand brakes and the performance of a hand brake effectiveness test) can be performed in a reasonable amount of time.

Following the 1996 Quebec North Shore and Labrador Railway (QNS&L) accident, in which SPTO was found to be contributory, TC facilitated the creation of a consensus-based working group. This group required all key stakeholders (including management and employees) to collaborate in crafting clear operating conditions that would ensure safety levels equivalent to those of multi-person operations. Under the 2008 changes to the CROR, MMA was not required to adopt these conditions, but rather worked with TC to develop customized conditions applicable to its operations.

After the QNS&L accident, although TC suggested that the Railway Association of Canada (RAC) develop new rules pertaining to SPTO within the CROR, TC did not order the RAC to do so. In 2000, the RAC adopted internal SPTO guidelines based on the principles of risk assessment, mitigation, and monitoring. These guidelines stipulated that member railways had to develop a monitoring program to measure the safety performance of its SPTO, and that TC had to be provided with a description of this program. In 2012, a National Research Council (NRC) study, sponsored by TC, made several recommendations, including the creation of a 2-year pilot project with detailed monitoring and evaluation. However, none of these guidelines and recommendations were binding.

Following the 2008 revision of the CROR, railways no longer needed exemptions to implement SPTO. As a result, there were no rules preventing operations with 1-person crews, nor a mandatory requirement to have plans reviewed and approved in advance by TC. Consequently, there was no longer a requirement to directly involve TC in the process of implementing SPTO.

In July 2009, MMA indicated to TC that SPTO between the Maine–Quebec border and Lac-Mégantic represented a "test-bed", which could be expanded upon successful implementation. Prior to MMA's implementation of SPTO in 2010 (east of Lac-Mégantic) and 2012 (Farnham to Lac-Mégantic), TC insisted that risk assessments be completed. These risk assessments, which were reviewed by TC, identified several risks and mitigation measures, with a focus on trains in movement (given that, in the past, this aspect had represented the greatest concern). As securement was covered by both CROR 112 and MMA's own instructions, the risk assessments did not identify single-person train securement as a risk.

Subsequently, between April 2011 and June 2012, TC engaged MMA through meetings, site visits, and correspondence to ensure that a substantial review was performed by the company, including meetings with municipalities. To allay TC's concerns, MMA cited its previous experience with SPTO in the U.S., as well as its SPTO experience east of

Lac-Mégantic. Contrary to the RAC guidelines, MMA had no plan to further monitor and evaluate SPTO beyond its normal supervisory activity.

Meanwhile, TC—despite concerns of its regional inspectors and without detailed SPTO monitoring and evaluation, as recommended by its own study—did not follow up to verify that the mitigation measures identified in MMA's risk assessment had been implemented and were effective.

MMA's SPTO risk assessment identified mitigation measures, such as informing local authorities of single-person operations, instituting a procedure for a single operator to take control of an unattended train, allowing an LE to stop a train for a 20-minute nap, and requiring an LE to contact the RTC once every 30 minutes. However, contrary to what MMA had proposed, there was very limited SPTO training. The SPTO training did not include a review of securement rules and instructions. Furthermore, no job task analysis was discussed with employees, nor were all of the potential hazards associated with the tasks identified, notably the risks associated with single-operator train securement at the end of a shift. Consequently, no mitigation measure was identified for this critical task, such as confirming with an RTC how a train was secured, or even questioning the practice of leaving a train on the main track in Nantes when securement relied on a single operator. Finally, MMA did not conduct a single OTIS inspection to verify SPTO train securement in Nantes.

In some countries, regulators consider a company's ability to execute its plan before granting authority to implement SPTO. Others require the operator to be accredited, and narrowly circumscribe its SPTO program to the territory and type of application, with all changes requiring pre-approval by the regulator. The experience in operations around the world shows that SPTO can be done safely when risks are identified, and when technologies and processes are put in place to ensure the physical and cognitive risks inherent to 1-person operations are effectively and reliably mitigated.

Despite concern over MMA's elevated risk profile, and knowledge of the weaknesses in its risk assessment process (as documented in audits going back to 2003), TC did not require MMA to use processes and technological advancements to mitigate the risks of operating with 1 less crew member.

The investigation carefully examined whether SPTO played a role in the securement of the train at Nantes, and whether SPTO influenced how the abnormal condition of the locomotive was addressed.

With respect to train securement, TSB testing showed that it was possible for a single operator to apply a sufficient number of hand brakes within a reasonable amount of time. A TSB survey also determined that there were instances when MMA LEs working as single operators applied less than the minimum number of hand brakes. The minimum hand brake requirement was more consistently met when trains were operated by 2 crew members. On the basis of this survey, it cannot be concluded how many more (if any) hand brakes would have been applied had the LE been paired with a conductor. Furthermore, even if the LE had applied the minimum number of hand brakes required by MMA's *General Special Instructions* (GSIs) (9, based on the "10% plus 2" chart), TSB testing showed that this number would not have provided sufficient retarding force to hold the train once the air pressure in the independent brake system was reduced. Moreover, since the LE did not perform the hand brake effectiveness test properly, he likely would not have recognized the need for additional hand brakes, even with the presence of a second crew member.

Given that the conductor and LE operate as an integrated team, contributing knowledge and providing backup for each other as necessary, the TSB considered whether the presence of a second crew member could have influenced how the abnormal engine condition was handled. Although fatigue was not considered to be a contributing factor in this accident, after having been awake for more than 17 hours, there may have been a slight degradation of the LE's cognitive performance, which would have affected his ability to solve the issue surrounding the source of the excessive smoke. When discussing the engine's abnormal condition with the Bangor RTC, the LE sought a second opinion, which is an example of joint compliance. However, the LE presented the situation in a manner that suggested it would settle down and that no further action was required that night. The pair did not discuss the MMA procedure requiring that a locomotive be shut down due to abnormal smoke, and the only person to question the decision to leave the locomotive was the taxi driver, whose comments did not carry the same weight as a qualified railway employee. It is therefore not possible to conclude whether the presence of another crew member would have resulted in different actions that night (either shutting down the lead locomotive and starting another, or putting another locomotive in the lead and keeping it running).

On the whole, it could not be concluded whether SPTO contributed to the incorrect securement of the train or to the decision to leave the locomotive running at Nantes despite its abnormal condition. However, it is clear that MMA's implementation of SPTO did not address all critical risks, specifically how a single operator might deal with any abnormal conditions, the risks of single-person securement, or the need for joint compliance. Moreover, TC did not develop an oversight plan to ensure that MMA implemented SPTO in accordance with MMA's risk assessment. Despite being aware of significant operational changes at MMA, TC did not provide adequate regulatory oversight to ensure that the associated risks were addressed.

The number of required crew members is related to the tasks that must be performed to accomplish the work safely and efficiently. To ensure an equivalent level of safety is maintained when reducing the number of crew members, railways must analyze the impact of the reduction on the activities to be performed and determine what, if any, new risks may be introduced. Mitigation measures can then be put in place, followed by subsequent monitoring to assess their effectiveness.

If railways implement SPTO without identifying all risks, and if mitigation measures are not implemented, an equivalent level of safety to that of multi-person crews will not be maintained. Moreover, if there are no rules and regulations for SPTO, nor a requirement for TC to approve and monitor railways' plans for SPTO, then single-person trains may operate without all of the necessary defences in place.

## *2.13 Montreal, Maine & Atlantic Railway operations*

### *2.13.1 Additional defences against runaways*

Workers will sometimes deviate from written rules and procedures, either because they do not know the rule or procedure or do not understand its purpose, or to accomplish the work more efficiently. When there are no negative consequences, these employee adaptations can persist and become widespread. In doing so, this way of working becomes normalized and can erode the safety margins that the rules and procedures were intended to provide.

The practice of leaving trains unattended on the main track had been in place for several months at MMA. This decision was based on convenience and efficiency, given crew scheduling, the length of the trains, and the need to avoid blocking crossings in the town. At Nantes, leaving the train on the main track clear of the east switch allowed access to the siding where cars were stored. However, as the siding was equipped with a special derail, this practice resulted in a potential safety device not being used. Since leaving a train on the main track was not prohibited by regulation, it was not questioned by TC inspectors. Further, it had not resulted in any adverse consequence, and so MMA's management did not examine the practice.

The concept of "defence in depth" is one that has been adopted by some industries for many years. Layers of defences, or safety redundancy, have proven successful in ensuring that a single-point failure does not lead to catastrophic consequences. In the rail industry, physical defences can be used as additional defences to prevent runaways. These additional defences were not used by MMA, nor were they required by regulation. This risk was never assessed or addressed, and no additional physical safety defences were put in place to prevent the uncontrolled movement of trains left unattended on the main track.

### *2.13.2 Excessive rail wear*

There was excessive rail wear (that is, exceeding the vertical wear limits in MMA's and other Class 1 railway standards) on some rail in the Lac-Mégantic area. Rail wear results in an increase in stresses and reduces rail fatigue life. Consequently, worn rail will become more susceptible to development and spread of cracks leading to rail breaks, thereby increasing the risk of derailment. Poor rail conditions, such as wear beyond limits, battered rail joints, and crushed head, were identified by TC during its many engineering inspections (53), resulting in a letter of concern being issued in the year prior to the accident.

If head wear exceeds 8 mm on 115-pound rail, standard joint bars can be struck by the wheel flanges of passing trains. This results in high impacts to wheels and rails, and can also increase the risk of derailment. The risk is elevated when wheel profiles have increased flange heights, or when new rail joint bars are applied to head-worn rail. Due to the extent of the vertical rail wear (as much as 25 mm in 1 location), impact marks were clearly visible on some rail joint bars during the TSB investigation; however, they had not been identified previously by MMA or TC inspections, nor had corrective action been taken. The application of maximum vertical rail wear limits and the use of high-clearance joint bars are intended to prevent such high impact forces, but these types of joint bars were not in use in MMA's track maintenance program.

Rail wear was normally accurately measured by the track geometry car used by MMA; however, due to the rail head's severely worn and deformed condition, a correct profile was not recorded. The condition of the rail (for example, whether there are shells, spalls, and corrugation) when conducting such inspections must also be taken into consideration. Therefore, although track geometry inspections were performed by MMA and TC, the excessive rail head wear was not identified, and maintenance crews were not being alerted to the severity of the wear. If poor rail and joint conditions are not addressed, there are increased stresses on wheels and rails, which may lead to damaged equipment or infrastructure, thus increasing the risk of derailment.

### 2.13.3 *Safety management*

All organizations must manage competing priorities; key among these priorities are safety, service, cost-effectiveness, technology, and return on investment. The challenge is to balance these priorities, while still reducing safety risks to an acceptable level. To do this, it is important that railways have the necessary safety processes in place to continually identify and mitigate the hazards and risks that may arise.

In 2001, TC developed regulations to further promote safety and to ensure that companies have a minimum standard for safety processes. Railways are required to implement and maintain an SMS that integrates safety in day-to-day operations, and that enables the company to find risks and take action before those risks lead to an accident. A well-implemented and actively used SMS promotes a highly-effective safety culture.

Although MMA had certain safety processes in place and had developed an SMS in 2002, the company did not begin implementing the program until 2010, and did so only in reaction to a TC audit. By 2013, many of the processes outlined in MMA's SMS manual were not contributing to the identification of hazards and mitigation of risks. For example, the company's toll-free number for reporting safety concerns was not being used.

There were 4 crucial indicators (analyzed in the next section) that MMA did not have a functioning SMS; these were:

- absence of an internal safety auditing process;
- weaknesses in the process for ensuring adequate employee training;
- weaknesses in the OTIS program, which limited its effectiveness in identifying areas of non-compliance; and
- inconsistently used risk assessment processes.

### 2.13.4 *Internal safety auditing*

Internal SMS audits play a critical role in the system's continual improvement, by providing the organization with an opportunity to observe whether SMS processes are being used as designed.

Although MMA's SMS manual indicated that a process was in place to conduct internal audits, no detail was provided. On 2 occasions, TC determined that MMA's procedures for conducting internal audits were incomplete. This issue was never resolved, and by the time of the accident, MMA had never conducted an internal audit to assess the effectiveness of its safety management processes.

The lack of internal audits caused other deficiencies in MMA's SMS to remain unidentified and unaddressed, which limited the company's ability to proactively identify hazards and manage risks.

### *2.13.5 Training and requalification*

Rail transportation is a rules-based industry that requires knowledge and understanding of, as well as adherence to, many rules and regulations in order to ensure safe and efficient operations. Employees must therefore receive proper training and testing, as well as adequate requalification testing.

Each railway determines the methods for training and requalification, yet the 3-year time frame for this is mandated by TC. MMA did not consistently comply with this requirement. For example, the company provided the LE with 3-month extensions in both 2009 and 2013, resulting in the LE's requalification training being delayed beyond the 3-year time frame specified by regulation. Furthermore, in 2013, the LE was allowed to complete his exams at home, without classroom training.

Several other problems existed within MMA's training and requalification program for LEs:

- Exams remained relatively unchanged year after year. This meant that MMA was not using the requalification program to address deficiencies identified through monitoring, and rule changes or new operational instructions could not be addressed.
- The increasing use of multiple-choice questions limited the ability of instructors to evaluate comprehension.
- Requalification sometimes consisted of only a written exam, without classroom training; this negated an opportunity for interactive employee-instructor discussions.
- A lack of feedback on exam results meant that employees missed learning opportunities, increasing the risk of potential misunderstanding and subsequent misapplication of rules and instructions.

Although several exams show that the LE correctly answered multiple-choice questions related to the minimum number of hand brakes, these questions were relatively simple, and did not adequately demonstrate the LE's knowledge of the significance and rationale of securement rules. Furthermore, the LE was never tested on the procedures for performing a hand brake effectiveness test, or on the fact that the air brake system must not be depended upon to prevent an undesired movement. There was also an indication that the LE had limited knowledge of MMA's instructions, namely on the use of the auto-start system, and the procedure for QRB valves as well as their significance to the proper operation of a locomotive hand brake.

Therefore, MMA did not provide effective training to ensure crews understood and correctly applied rules governing train securement.

This issue goes beyond the training and requalification of 1 LE. Between 2006 and 2013, inspectors from TC Quebec Region noted numerous instances of improperly qualified employees working in different departments, such as the operations, engineering, and mechanical departments, as well as the rail traffic control centre. In addition, during SPTO implementation, MMA had planned to provide LEs with approximately 4 hours of training, covering rules, instructions, and procedures for SPTO, as well as issues related to working alone, first-aid, and fatigue and lifestyle planning. The actual SPTO training was often significantly abbreviated, and delivered within the hour preceding an operator's first train departure as a 1-person crew.

### 2.13.6 Rules compliance

In order to promote consistent operating practices, railways must provide clear rules and instructions to employees, and must verify that these rules and instructions are being followed.

Rules and instructions need to be clearly documented, and employees must be kept abreast when changes occur. In addition, employees must have access to the necessary reference materials (rulebooks, supplements, and other documents) while on duty.

The accident LE did not have all of the required documents at the time of the accident. The company was not ensuring that all employees were familiar with new operating bulletins. The company's rules, supplements, and general operating instructions were organized in multiple documents, which made it difficult to refer to these documents and increased the risk of misinterpreting rules.

Clear rules and instructions are only valuable if they are consistently applied in day-to-day operations. MMA's OTIS program sought to verify compliance by observing employees unannounced. For this approach to be effective, employees must be aware that they could be tested at any location and at any time. Unannounced tests must then be performed at a satisfactory frequency across the railway's network, and the employees must be made aware that the tests have been performed, regardless of the results.

This investigation identified a number of weaknesses in MMA's oversight program.

At MMA, employees were only informed of tests if they failed. However, because the failure rate was so low, and because managers did not conduct even the minimum number of tests required, employees were rarely informed of these tests and so remained unaware of the full extent of the program. In addition, testing was performed much less frequently east of Sherbrooke. For example, the LE, who had made 60 trips to Nantes in the previous 12 months, had never been tested on train securement at Nantes during the previous 4 years. He had only been tested either at Sherbrooke or further west.

Moreover, CROR 112 is identified as one of a few rules warranting a minimum number of monthly tests. However, when a Rule 112 test was performed, MMA managers usually only ensured that the required number of hand brakes had been applied (Rule 112[a]). Because of practical difficulties associated with the test, managers seldom checked that a proper hand brake effectiveness test was conducted (Rule 112[b]). Therefore, MMA's oversight of equipment securement rules and procedures did not effectively ensure that crews properly verified that the hand brake retarding force was sufficient to hold a train.

Consequently, MMA's employee oversight program was not effective in identifying the unsafe train-securement practices being used in the Lac-Mégantic area.

### *2.13.7 Risk assessment*

Risk assessments are a cornerstone of a fully functioning and effective SMS, and are essential for a safe operating company. While important for day-to-day operations, risk assessments are particularly crucial when a company makes a change to its operations, since this is when new risks may emerge.

To be effective, a risk assessment process must be conducted for a sufficient range of situations, must encourage the identification of all anticipated hazards, and must ensure that mitigation measures have been effectively implemented. Although MMA had undertaken a few formal risk assessments, most risk-management initiatives were informal and undocumented.

This situation increased the likelihood that not all of the newly emerging risks would be properly assessed when significant operational changes were made. When increasing the number of unit oil trains, company personnel discussed issues surrounding the operation of the larger, heavier trains, such as traction and braking. However, no formal risk assessment was performed, and all of the risks of carrying increasingly more crude oil were neither evaluated nor mitigated.

Similarly, no risk assessment was conducted when the company moved the crew-change location to Nantes and began parking trains unattended on the main track on a descending grade. In this instance, it was believed that a risk assessment was not required, since rules and instructions governing train securement already existed, and trains had occasionally been parked at this location in the past. Securement relied on a single administrative line of defence: a properly conducted hand brake effectiveness test. As a result, this practice, although compliant with regulations, did not reduce risk to a level as low as reasonably practicable.

Finally, when implementing SPTO, the company only performed a formal risk assessment at TC's request. This risk assessment, however, did not address how the task of securing a train, previously performed by a crew of 2, would be completed, since the rules for train securement were already in place. In addition (as described in section 2.13.5), some of the mitigation measures identified in the assessment were not effectively implemented.

These weaknesses in MMA's use of risk assessments meant that, when making significant operational changes on its network, MMA did not thoroughly identify and manage the risks to ensure safe operations.

To help an organization manage risk, the required processes must be in place and used effectively. MMA submitted SMS documentation to TC in 2003 and was found compliant with the regulations. However, MMA's SMS was lacking key processes, and other processes were not being effectively used. As a result, MMA did not have a fully functioning SMS to effectively manage risk.

### 2.13.8 Safety culture

The 2007 report on the review of the *Railway Safety Act* (RSA)[139] notes, "The cornerstone of a truly functioning SMS is an effective safety culture." An effective safety culture in a railway can significantly reduce the number of accidents, and is the basis for an effective safety program. The strength of an organization's safety culture starts at the top, and is characterized by proactive measures to eliminate or mitigate operational risks. MMA was generally reactive in addressing safety issues. Furthermore, there were significant gaps between MMA's operating instructions and how work was actually conducted in day-to-day operations.

There were also other signs in MMA's operations that were indicative of a weak organizational safety culture, such as:

- MMA management's acceptance of rail wear on the main track that was well beyond industry norms and their own track standards;
- MMA management's tolerance of non-standard repairs (for example, to the locomotive engine and the QRB valve), which either subsequently failed, or did not return the parts to their proper operating condition;
- the systemic practice of leaving unattended trains on the main track, and on a descending grade, at Nantes for several hours without in-depth defences to prevent an uncontrolled movement;
- crews and single-person train operators not always correctly applying CROR 112 and MMA's instructions when securing trains at Nantes;
- inadequate company oversight to ensure the correct securement of trains at Nantes;
- MMA's inadequate recertification program and SPTO training that did not ensure that operating crews knew and understood the procedures for train securement;
- the giving of extensions for competency cards by MMA management, in some cases for several months beyond the mandatory limit of 3 years; and
- the fact that only local corrective action resulted from recurring deficiencies identified during TC inspections of MMA track and operations; the systemic issues contributing to these deficiencies were not fully analyzed by MMA, and thus persisted.

If instructions or rules are disregarded, and unsafe conditions and practices are allowed to persist, this leads to an increased acceptance of such situations. Deviations from the norm thus become the norm, and the likelihood of unsafe practices being reported and addressed is reduced. Although educational material about safety culture was provided to railway companies, safety culture was not formally assessed or documented within regulatory inspections or audits. MMA's weak safety culture contributed to the continuation of unsafe conditions and practices, and compromised MMA's ability to effectively manage safety.

---

[139] Transport Canada, Advisory Panel for the *Railway Safety Act* Review, *Stronger Ties: A Shared Commitment to Railway Safety: Review of the Railway Safety Act* (Ottawa, November 2007), available at http://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf (last accessed on 16 July 2014).

## 2.14 *Transport Canada oversight*

### 2.14.1 *Regulatory oversight of Montreal, Maine & Atlantic Railway*

#### 2.14.1.1 *Regulatory inspection program at Montreal, Maine & Atlantic Railway*

TC Quebec Region had been inspecting and monitoring MMA's operations, equipment, and infrastructure. For several years, MMA had been identified as a railway company with an elevated level of risk requiring more frequent inspections. Through inspections, TC Quebec Region identified a number of ongoing safety deficiencies requiring safety action. TC Quebec Region issued numerous notices, notices and orders, letters of concern, and letters of non-compliance. Although MMA normally took action after the inspection to address the identified safety deficiency, it was not uncommon for similar deficiencies or risks to be identified in subsequent inspections. The following are examples of such safety deficiencies:

- Problems with train securement were identified on multiple occasions since 2005, and were still present at the time of the accident.
- Between 2006 and the time of the accident, training deficiencies were noted in several functional groups, including the mechanical group, operations and engineering group, and rail traffic control.
- Track condition was noted as an ongoing issue between 2006 and the time of the accident.

TC Quebec Region did not follow up to ensure that recurring safety deficiencies at MMA were effectively analyzed and corrected; consequently, unsafe practices persisted.

Moreover, following MMA's implementation of SPTO, TC's oversight was insufficient in verifying that SPTO had been implemented in a manner consistent with the mitigation measures outlined in MMA's risk assessment.

#### 2.14.1.2 *Safety management system audits at Montreal, Maine & Atlantic Railway*

TC's guidance material indicates that TC verifies that an operator has an SMS that is documented, employed, and effective in improving safety.[140] While inspections are critical in identifying unsafe conditions, SMS audits are complementary to the inspection process. SMS audits allow the reasons for underlying unsafe conditions to be explored, and for verification that the organization has effective processes in place to identify and mitigate similar conditions in the future.

At MMA, the first SMS audit to assess the effectiveness of the company's safety management processes took place in 2010, which was 7 years after the company was found to be in compliance with the *SMS Regulations*. During this audit, inspectors were informed that the SMS had not yet been implemented because the company was awaiting regulatory approval. TC then clarified with MMA that TC does not approve a railway's SMS. A second SMS audit was conducted in 2012, and focused on a very limited subset of SMS elements.

---

[140] Transport Canada, TP 15058E, *Rail Safety Management Systems Guide: A Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* (November 2010), p. 5, available at http://www.tc.gc.ca/eng/railsafety/guide-sms.htm (last accessed on 16 July 2014).

Although TC Quebec Region reviewed the corrective action plans provided by MMA as a result of the audits, no specific follow-up was conducted to verify that the corrective action plans had been implemented. TC Quebec Region did not have a procedure in place for conducting such follow-ups. Moreover, no follow-up was conducted during the 2012 audit on the findings of the previous audit, since it was not within the scope of the audit as determined by the convening authority. Therefore, the auditors could not verify that effective corrective action plans had been developed to address previous identified deficiencies.

As a result, many of the deficiencies in MMA's SMS that came to light through the audit process were never resolved. For example, weaknesses in MMA's risk assessment process were identified during TC's pre-audit in 2003. The 2010 audit found that risk assessments were being conducted only for major operational changes. Since that time, very few risk assessments had been conducted, and no documented risk assessments were conducted for the practice of leaving unattended trains on a grade at Nantes.

The absence of an internal audit procedure at MMA was first identified during TC's pre-audit in 2003, and again in the 2010 SMS audit. An internal audit procedure had not been developed, and no internal SMS audits had taken place at MMA.

Other weaknesses in MMA's SMS, including the fact that the toll-free number for reporting safety concerns was not being used and that the required number of OTIS tests were not being conducted, were not identified during the verification process.

Although TC inspections identified problems at MMA between 2003 and 2010, and it was clear to TC that MMA's SMS was not effective, no SMS audits were conducted in that time frame. The 2010 TC audit determined that MMA had not implemented its SMS. The limited number and scope of SMS audits that were conducted by TC Quebec Region, as well as the absence of a follow-up procedure to ensure MMA's corrective action plans had been implemented, contributed to the fact that systemic weaknesses in MMA's SMS remained unaddressed.

If TC does not audit the SMS of railways in sufficient depth and frequency and confirm that corrective actions are effectively implemented, there is an increased risk that railways will not effectively manage safety.

### *2.14.2 Transport Canada's monitoring of regional audits*

Given that the *SMS Regulations* came into force in 2001, TC Rail Safety should have had enough time to confirm that all railways have an SMS in place that is effectively improving safety.

In 2007, the RSA Review Panel found that, while improvements had certainly been made, progress in implementing SMS had been inconsistent. The review panel expressed concern over the regulator's ability to implement the use of SMS successfully, citing a number of challenges, including resourcing issues, the skill sets required of inspectors, and a belief that demonstrating the existence of processes was sufficient to demonstrate compliance. Since then, TC has taken steps to address the recommendations made by the panel. For example, in 2011, a group responsible for leading national audits, overseeing audit planning, and developing auditor training for all inspectors was created in TC Headquarters. Through this group, TC Headquarters increased its oversight of SMS programs.

However, as the Office of the Auditor General's (OAG's) examination of the adequacy of rail safety oversight in November 2013 revealed, this objective has not been met. The OAG concluded that, 12 years after the implementation of SMS, TC does not have adequate assurance that federal railways have implemented effective SMS.

Despite TC's efforts, this accident demonstrated that a number of weaknesses are still present in the oversight of safety programs.

The TC Regions were the convening authority for SMS audits, and were responsible for identifying the target and scope of the audits. TC Quebec Region had not been conducting sufficient audits to verify the effectiveness of SMS in the province's 4 regional railways. Although all railways were subject to a pre-audit shortly after the regulations came into force, only 3 audits examining the use and effectiveness of SMS procedures had been completed at the time of the accident.

Although audits should be conducted periodically, or triggered in reaction to results from compliance inspection activities, neither of these approaches were used in TC Quebec Region; instead, MMA was audited in response to a railway accident. Auditing in response to accidents does not effectively place the onus on the railway company to demonstrate that it is continuously managing risks, as outlined in objective 3(*c*) of the RSA. The limited number and scope of the audits conducted by TC Quebec Region meant that many aspects of railways' SMS had not been validated for effectiveness.

The lack of audits and follow-up on audit findings was due to a number of factors. There was a belief by TC regional personnel that it would not be possible to conduct periodic SMS audits convering all elements required under the *SMS Regulations* for all regional railways, given the personnel requirements of SMS audits. Furthermore, some railway safety inspectors (RSIs) felt unprepared to participate effectively in SMS audits, particularly as audit team leaders.

Many inspectors felt that resources devoted to SMS audits were wasted; they believed that there was little that could be done if an operator was not conforming to its SMS. This belief originated from TC's Railway SMS Regulations Enforcement Policy, which established that a railway company could be prosecuted for non-compliance with *SMS Regulations*, but not for deficiencies in the implementation of SMS. Although the RSA provides tools to take action when an immediate threat to safety exists, the deficiencies identified during the implementation of a company's SMS would be presented to the company as an opportunity for improvement. However, inspectors were provided with few tools to require improvements if a company was unwilling or unable to effectively implement the processes required under the *SMS Regulations.*

Many inspectors in TC Quebec Region were not engaged in SMS implementation, and saw SMS in the Region as being within the domain of the Safety Systems Overview group. However, the Safety Systems Overview group was not actively supported from colleagues and management.

As a result, TC Quebec Region was not ensuring that regional railways had an effective SMS in place.

Because regional railways were the responsibility of each TC Region, TC Headquarters did not provide leadership, but rather limited its role to providing support for the regional oversight of the SMS program. The support focused on helping Regions prepare and deliver audits of regional railways. TC Headquarters did not provide the minimum requirements regarding audit frequency or audit scope to the Regions. Moreover, TC Headquarters did not monitor regional auditing activities to ensure that the minimum standards were being met and that all activities, such as following up on audit findings, were consistently performed. Consequently, TC Headquarters was unaware of any weaknesses in oversight of regional railways in Quebec, and did not intervene to provide additional support. Without sufficient national monitoring, TC does not have adequate assurance that its Regions are providing effective oversight of regional railways to ensure that the risks to the public are being properly managed.

## 2.15 *Canadian Transportation Agency reporting requirements*

The *Canada Transportation Act* requires railways to carry adequate insurance to cover the risk of operations. The Canadian Transportation Agency (CTA) initially examines insurance coverage when issuing a certificate of fitness (COF). Subsequently, a review can be triggered when the agency is advised by a railway company of operational changes. At the time of the accident, the magnitude and type of operational changes that needed to be reported were subjective; therefore, railways determined what they would report to the CTA.

MMA had requested 3 variances to its COF as a result of changes in operations. However, the railway did not consider the increase in crude oil to be a significant operational change, and therefore did not inform the CTA of this change in its risk profile. Moreover, the CTA did not routinely seek out this type of information or conduct periodic assessments of certificate holders' insurance. Consequently, the CTA was not aware of operational changes at MMA affecting the adequacy of its insurance coverage.

The significant increase in the transportation of dangerous goods and, in particular, the increasing number of unit trains of petroleum crude oil, raised the risk profile of MMA's operations. However, the regulatory requirements in place at the time of this accident did not ensure that an increase in risk was reflected in MMA's insurance coverage.

# 3.0 *Findings*

## 3.1 *Findings as to causes and contributing factors*

1. MMA-002 was parked unattended on the main line, on a descending grade, with the securement of the train reliant on a locomotive that was not in proper operating condition.

2. The 7 hand brakes that were applied to secure the train were insufficient to hold the train without the additional braking force provided by the locomotive's independent brakes.

3. No proper hand brake effectiveness test was conducted to confirm that there was sufficient retarding force to prevent movement, and no additional physical safety defences were in place to prevent the uncontrolled movement of the train.

4. Despite significant indications of mechanical problems with the lead locomotive, the locomotive engineer and the Bangor, Maine, rail traffic controller agreed that no immediate remedial action was necessary, and the locomotive was left running to maintain air pressure on the train.

5. The failure of the non-standard repair to the lead locomotive's engine allowed oil to accumulate in the turbocharger and exhaust manifold, resulting in a fire.

6. When the locomotive was shut down as a response to the engine fire, no other locomotive was started, and consequently, no air pressure was provided to the independent brakes. Further, locomotives with an auto-start system were shut down and not available to provide air pressure when the air brake system began to leak.

7. The reset safety control on the lead locomotive was not wired to initiate a penalty brake application when the rear electrical panel breakers were opened.

8. Because air leaked from the train at about 1 pound per square inch per minute, the rate was too slow to activate an automatic brake application.

9. When the retarding brake force provided by the independent brakes was reduced to about 97 400 pounds, bringing the overall retarding brake force for the train to approximately 146 000 pounds, the train started to roll.

10. The high speed of the train as it negotiated the curve near the Megantic West turnout caused the train to derail.

11. About one third of the derailed tank car shells had large breaches, which rapidly released vast quantities of highly volatile petroleum crude oil, which ignited, creating large fireballs and a pool fire.

12. Montreal, Maine & Atlantic Railway did not provide effective training or oversight to ensure that crews understood and complied with rules governing train securement.

13. When making significant operational changes on its network, Montreal, Maine & Atlantic Railway did not thoroughly identify and manage the risks to ensure safe operations.

14. Montreal, Maine & Atlantic Railway's safety management system was missing key processes, and others were not being effectively used. As a result, Montreal, Maine & Atlantic Railway did not have a fully functioning safety management system to effectively manage risk.

15. Montreal, Maine & Atlantic Railway's weak safety culture contributed to the continuation of unsafe conditions and unsafe practices, and compromised Montreal, Maine & Atlantic Railway's ability to effectively manage safety.

16. Despite being aware of significant operational changes at Montreal, Maine & Atlantic Railway, Transport Canada did not provide adequate regulatory oversight to ensure the associated risks were addressed.

17. Transport Canada Quebec Region did not follow up to ensure that recurring safety deficiencies at Montreal, Maine & Atlantic Railway were effectively analyzed and corrected, and consequently, unsafe practices persisted.

18. The limited number and scope of safety management system audits that were conducted by Transport Canada Quebec Region, and the absence of a follow-up procedure to ensure Montreal, Maine & Atlantic Railway's corrective action plans had been implemented, contributed to the systemic weaknesses in Montreal, Maine & Atlantic Railway's safety management system remaining unaddressed.

## 3.2 *Findings as to risk*

1. If a proper hand brake effectiveness test is not performed, equipment may not be adequately secured, increasing the risk of a runaway.

2. If hand brakes are applied on the operating locomotive(s) during a hand brake effectiveness test, this may result in an inaccurate effectiveness test, increasing the risk of runaways.

3. Given the variable condition of locomotive hand brakes, counting them as part of the total number of hand brakes required can lead to overestimating the braking force, thereby increasing the risk of a runaway.

4. If equipment is left unattended without additional physical safety defences, there is an increased risk that it will run away, leading to an accident.

5. If railways implement single-person train operations without identifying all risks, and if mitigation measures are not implemented, an equivalent level of safety to that provided by multi-person crews will not be maintained.

6. If there are no rules and regulations for single-person train operations, nor a requirement for Transport Canada to approve and monitor railways' plans, then single-person trains may operate without all of the necessary defences in place.

7. If trains are left unattended in easily accessible locations, with locomotive cab doors unlocked and the reverser handle available in the cab, the risk of unauthorized access, vandalism, and tampering with locomotive controls is increased.

8. If poor rail and joint conditions are not addressed, there are increased stresses on wheels and rails, which may lead to damaged equipment or infrastructure, thus increasing the risk of derailment.

9. If systematic testing is not conducted on representative samples of petroleum crude oil at an appropriate frequency, there is an increased risk that these dangerous goods will be improperly classified.

10. If not properly classified and documented, dangerous goods may be moved and handled incorrectly, increasing the risk of injury to people, and of damage to property and the environment.

11. Without monitoring and effective enforcement of compliance with applicable classification provisions of the Transportation of Dangerous Goods Regulations, there is a risk that improperly classified dangerous goods will enter the transportation system.

12. If Class 111 tank cars that do not meet enhanced protection standards transport flammable liquids, there is an ongoing risk of product loss and significant damage to persons, property, and the environment when these cars are involved in accidents.

13. If the shipper has not developed an adequate, regulator-approved emergency response assistance plan, the required resources to assist local responders may not be available in the event of an accident involving large quantities of liquid hydrocarbons.

14. If route planning, analysis and follow-up risk assessments are not conducted by railways along routes where dangerous goods are carried, comprehensive safety measures to mitigate the risks may not be introduced.

15. If Transport Canada does not audit the safety management systems of railways in sufficient depth and frequency and confirm that corrective actions are effectively implemented, there is an increased risk that railways will not effectively manage safety.

16. Without sufficient national monitoring, Transport Canada does not have adequate assurance that its Regions are providing effective oversight of regional railways to ensure that the risks to the public are being properly managed.

## *3.3 Other findings*

1. It could not be concluded whether single-person train operations contributed to the incorrect securement of the train or to the decision to leave the locomotive running at Nantes, Quebec, despite its abnormal condition.

2. The petroleum crude oil being transported by the train was improperly classified; it was assigned packing group III (lowest hazard), despite meeting the criteria for packing group II.

3. The Nantes Fire Department had to shut down the locomotive to stop the flow of oil, which was feeding the fire. Their actions were consistent with railway instructions.

4. The track geometry condition was adequate for the existing traffic and was acceptable for the speed allowed (15 mph) for trains travelling through Megantic Station.

5. Despite the challenges of responding to a major disaster not specifically covered by many firefighters' practical training, the emergency response was conducted in a well-coordinated and effective manner.

6. The regulatory requirements in place at the time of this accident did not ensure an increase in risk was reflected in Montreal, Maine & Atlantic Railway's insurance coverage.

# 4.0 *Safety action*

## 4.1 *Safety action taken*

### 4.1.1 *Montreal, Maine & Atlantic Railway*

To improve the safety of its rail operations, Montreal, Maine & Atlantic Railway (MMA) has:

- implemented all orders, directives, and safety advisories put in place by the Minister, Transport Canada (TC), the Transportation Safety Board (TSB), the United States Department of Transportation (DOT), and the Federal Railroad Administration (FRA);
- ceased, by agreement with the Canadian Transportation Agency (CTA), the handling of crude oil of any type from any location;
- addressed all TC notices, and notices and orders, regarding track and right-of-way;
- installed 1100 crossties at several locations to protect the integrity of the track structure;
- performed rail flaw detection and track geometry testing between St-Jean Station, Quebec, and the U.S. border, and addressed identified deficiencies;
- cut and removed brush between Magog, Quebec, and the U.S. border;
- eliminated single-person train operations (SPTO);
- increased field supervision as well as operating-rules testing and enforcement;
- instituted and complied with all procedures mandated or suggested by the Minister, TC, the TSB, or U.S. authorities. These included the securement of trains and locomotives, as well as the prohibition from leaving unattended trains containing dangerous goods on the main track;
- adopted the Association of American Railroads (AAR) Circular OT-55, titled *Recommended Railroad Operating Practices For Transportation of Hazardous Materials*.

### 4.1.2 *Transportation Safety Board rail safety recommendations*

On 23 January 2014, the TSB issued 3 recommendations.

#### 4.1.2.1 *Vulnerability of Class 111 tank cars to sustainment of damage*

The examination of the 63 general-service Class 111 tank cars that derailed in Lac-Mégantic revealed that 59 of the cars (94%) had released petroleum crude oil due to impact damage. The damage to the tank cars in Lac-Mégantic clearly indicates that product release could have been reduced had the tank car shells and heads been more impact-resistant. Recent accidents, including those that occurred in Aliceville, Alabama (November 2013), Casselton, North Dakota (December 2013), Plaster Rock, New Brunswick (January 2014), and Lynchburg, Virginia (April 2014), involving Class 111 tank cars, have again highlighted their vulnerability to accident damage and product release. Design improvements to these types of cars are needed to mitigate the risks of a dangerous goods release and the consequences observed in the Lac-Mégantic accident. Commodities posing significant risk must be shipped in safe containers that include defences, such as stronger tank shells, tank car jackets, full-height head shields, thermal protection, and high-capacity pressure relief devices. Given the magnitude of the risks, and given that tank car standards must be set for the North American rail industry, the Board recommended that:

> The Department of Transport and the Pipeline and Hazardous Materials Safety Administration require that all Class 111 tank cars used to transport flammable liquids meet enhanced protection standards that significantly reduce the risk of product loss when these cars are involved in accidents.
>
> **TSB Recommendation R14-01, issued January 2014**

In February 2014, both Class 1 Canadian railways (Canadian National [CN] and Canadian Pacific Railway [CPR]) announced a surcharge for customers using the pre-CPC-1232 Class 111 tank cars.

In March 2014, CPR and CN announced improvements to their Class 111 tank car fleets. CPR committed to phasing out or retrofitting its (fewer than 200) Class 111 tank cars. CN committed to phasing out or retrofitting its fleet of pre-CPC-1232 Class 111 tank cars. It will replace all 40 tank cars that it owns, and will replace the remaining 143 cars as their leases expire over the next 4 years.

In February 2014, Irving Oil Ltd. (Irving) stated that it intended to phase out by May 2014 the remainder of the pre-CPC-1232 Class 111 tank cars in its fleet. It further stated that 88% of its fleet already meets the Association of American Railroads (AAR) 2011 standard. It has also requested that all of its suppliers, by the end of the year, use cars that adhere to the AAR 2011 standard.

**Response from Transport Canada**

In response to TSB Recommendation R14-01, TC indicated that it will prohibit the use of the highest-risk group of pre-CPC-1232 Class 111 tanks cars. Under subsection 32(1) of the *Transportation of Dangerous Goods Act* (1992), Protective Direction No. 34 was issued on 23 April 2014 prohibiting the use of tank cars that have no continuous reinforcement of their bottom shell for carrying any Class 3 flammable liquids, including crude oil and ethanol. The industry had 30 days to fully comply.

TC further stated that it will require that all pre-CPC-1232/TP 14877 tank cars used for the transportation of crude oil and ethanol be phased out of service or retrofitted within 3 years.

In the interim, the train routing restrictions outlined in TC's response to Recommendation R14-02 (see section 4.1.2.2) are designed to reduce the associated risks. TC plans to meet or exceed any new U.S. standard; therefore, it will continue to work closely with its U.S. counterparts on the development of more stringent tank car construction and retrofit standards to further enhance safety of the integrated North American rail system.

In addition, TC will proceed expeditiously with the *Canada Gazette*, Part II, publication of the 13 updated means of containment standards, including the AAR 2011 CPC-1232 standard for DOT-111 tank cars, that were introduced for consultation in Canada on 11 January 2014.[141]

**Response from the Pipeline and Hazardous Materials Safety Administration**

In response to TSB Recommendation R14-01, the Pipeline and Hazardous Materials Safety Administration (PHMSA) indicated that on 30 April 2014, the DOT, on behalf of PHMSA and the FRA, submitted a notice of proposed rulemaking (NPRM). The NPRM, titled *Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains (HM-251)*,[142] was sent to the Office of Management and Budget's (OMB) Office of Information and Regulatory Affairs (OIRA) for review. This notice proposes a comprehensive approach to rail safety to improve tank car integrity, as well as to provide additional operational controls, enhance emergency response, and establish methods to improve the classification and characterization of hazardous materials.[143]

In addition, on 07 May 2014, PHMSA and the FRA issued Safety Advisory Notice No. 14-07: *Recommendations for Tank Cars Used for the Transportation of Petroleum Crude Oil by Rail*,[144] urging railroad carriers transporting petroleum crude oil from the Bakken formation in the Williston Basin to use the tank cars of the highest integrity within their existing fleet and to avoid using legacy DOT-111 tank cars to the extent practicable.

**Board assessment of Transport Canada's response to Recommendation R14-01**

TC immediately prohibited the use of some pre-CPC-1232 Class 111 tank cars, and will require the phasing-out or retrofitting of the existing fleet within 3 years. TC has also committed to expeditiously publishing updated regulations in the *Canada Gazette*, Part II, including the new standard TP 14877 (which adopts the AAR 2011 CPC-1232 standard for Class 111 tank cars), making it mandatory for new tank cars built for the transportation of dangerous goods (including crude oil and ethanol) in packing groups (PGs) I or II to include end-of-tank protection, thicker and more impact-resistant steel tanks, and protected top fittings, as a minimum, to improve accident performance.

However, the TP 14877 standard is not sufficiently robust to minimize the risk of dangerous goods releases when Class 111 tank cars are involved in a derailment. The railway industry is asking both the Canadian and U.S. regulators to go much further than the AAR 2011 CPC-1232 standard, and it would seem that both governments are actively discussing improvements.

The Board is encouraged by the safety actions and the immediate steps to mitigate the risks taken to date. However, the process of implementing safety enhancements to the North American fleet of tank cars will take time, and the specific improvements to new tank car designs will not be known until the process is finalized. Therefore, until all pre-CPC-

---

141 Subsequent to TC's response, amendments to the *TDG Regulations* were implemented on 02 July 2014. See section 4.1.6.

142 Docket No. PHMSA-2012-0082.

143 Subsequent to the response, PHMSA issued its NPRM on 23 July 2014. See updated information at the end of section 4.1.2.1.

144 Docket No. PHMSA-2014-0049; Safety Advisory No. 2014-01.

1232/TP 14877 tank cars are no longer used to transport flammable liquids, and a more robust tank car standard with enhanced protection is set for North America, the risk will remain.

**Board assessment of the Pipeline and Hazardous Materials Safety Administration's response to Recommendation R14-01**

PHMSA has accepted the recommendation, and an NPRM on enhanced tank car standards has been submitted for review. During the regulatory process, comments were received on a variety of topics, including on the redesign of DOT specification 111 tank cars, as well as operational practices such as speed limits, train securement, and track integrity.

However, because the process is ongoing, the final ruling on the enhanced tank car standards is not yet known. In the interim, the recommendations contained in Notice No. 14-07 (urging carriers to use the highest-integrity tank car specifications and recommending that they avoid use of the pre-CPC-1232—referred to as "legacy"—tank cars to the extent reasonably practicable) may in some small measure help reduce the risk of petroleum crude oil releases when tank cars are involved in a derailment. The Board is also encouraged by the actions taken to address issues raised in the NTSB safety recommendations (see section 4.1.12).

**Board rating of Transport Canada's and the Pipeline and Hazardous Materials Safety Administration's responses to Recommendation R14-01**

The Board notes favourably the close cooperation between Canada and the U.S. in addressing this issue, as it is important that federal regulations in both countries be harmonized to the greatest extent possible given that North America is an integrated market. However, the process of implementing safety enhancements to the North American fleet of tank cars will take time, and the specific improvements to new tank car designs will not be known until the process is finalized. Therefore, until all pre-CPC-1232/TP 14877 tank cars are no longer used to transport flammable liquids, and a more robust tank car standard with enhanced protection is set for North America, the risk will remain.

For these reasons, the Board assessed the TC and the PHMSA responses to Recommendation R14-01 as being Satisfactory in Part.

The TSB will continue to monitor progress on the development and implementation, on both sides of the border, of rules for tank cars used to transport flammable liquids to meet enhanced protection standards that significantly reduce the risk of product loss when these cars are involved in accidents.

Subsequently, on 18 July 2014, TC issued for consultation a proposal for a new class of tank car (TC-140). The proposal also included a retrofit schedule for older TC/DOT-111 tank cars and the CPC-1232/TP 14877 tank car. According to TC, the new car was specifically developed for the transportation of flammable liquids in Canada by rail, such as crude oil and ethanol, and would enhance the requirements of its TP 14877 standard. Stakeholders have 45 days to provide their comments. TC stated that it will expedite the pre-publication of the new requirements in the *Canada Gazette*, Part I, in the fall of 2014.

On 23 July 2014, PHMSA, in coordination with the FRA, issued an NPRM[145] proposing requirements for high-hazard flammable trains, such as unit trains carrying petroleum crude oil and ethanol. The NPRM included new operational requirements for certain trains transporting a large volume of Class 3 flammable liquids, improvements in tank car standards, and revision of the general requirements for offerors of hazardous materials to ensure the proper classification and characterization of mined gases and liquids. Comments were sought on 3 options for enhanced tank car standards. Stakeholders have 60 days to provide their comments.

#### 4.1.2.2 *Route planning and analysis for trains carrying dangerous goods*

A primary safety concern related to the transportation of dangerous goods by rail is prevention of a catastrophic release or explosion in a densely populated or environmentally sensitive area. The Lac-Mégantic accident heightened the public's awareness of the risks associated with the transportation of dangerous goods.

The AAR Circular OT-55-N, or similar operating restrictions, are necessary to alleviate many of the shortcomings identified during the Lac-Mégantic investigation and other investigations involving the release of dangerous goods. However, these measures need to be complemented by a more comprehensive and proactive approach. An approach based on Circular OT-55-N, strengthened with a requirement to conduct route planning and analysis as well as periodic risk assessments, would be a positive step toward improving the safety of transporting dangerous goods by rail. Therefore, the Board recommended that:

> The Department of Transport set stringent criteria for the operation of trains carrying dangerous goods, and require railway companies to conduct route planning and analysis as well as perform periodic risk assessments to ensure that risk control measures work.
>
> **TSB Recommendation R14-02, issued January 2014**

**Response from Transport Canada**

On 23 April 2014, in response to TSB Recommendation R14-02, TC issued an emergency directive under section 33 of the *Railway Safety Act* (RSA) requiring railways carrying dangerous goods to implement minimum critical operating practices, including speed restrictions, enhanced inspection and maintenance requirements, and risk assessments on key routes over which key trains operate. The emergency directive is in force for 6 months, and may need to be renewed to reflect further consultation with stakeholders and consideration of any additional U.S. requirements that may be established.

At the same time, TC also issued a ministerial order under section 19 of the RSA. This ministerial order requires railways carrying dangerous goods to formulate and submit for approval, within 180 days, new rules based on these above-described operating practices to further improve the safe transportation of dangerous goods by rail in the long term.

---

[145] Docket No. PHMSA-2012-0082, HM-251.

**Board assessment of Transport Canada's response to Recommendation R14-02**

On 18 June 2014, the TSB issued its assessment of TC's response to Recommendation R14-02, as follows:

> The Emergency Directive will require risk assessments to be conducted on key routes over which key trains operate. However, key routes are defined as a route over which 10 000 car loads of dangerous goods are transported annually. This threshold may limit the number of routes subject to these enhanced safety measures. A rigourous analysis should be conducted of the 10 000-car threshold to determine which routes will be excluded and whether the safety deficiency identified in R14-02 will be addressed.
>
> If the new rules developed pursuant to the Ministerial Order cover the same scope of activities or more, and are strengthened to include more railway routes, the risk posed by movements of dangerous goods could be significantly reduced. However, the proposed rules have not yet been developed, and the outcome cannot be known until the process is finalized.
>
> Therefore, the Board assessed the response to Recommendation R14-02 as having Satisfactory Intent.
>
> The TSB will monitor the railways' progress on the development and implementation of new rules to improve their operating practices for the safe transportation of dangerous goods.[146]

### 4.1.2.3 *Requirements for emergency response assistance plans*

An emergency response assistance plan (ERAP) is required by the *Transportation of Dangerous Goods Regulations* for certain goods that pose a higher-than-average risk when transported in certain quantities. When an accident occurs, the handling of these dangerous goods requires special expertise, resources, supplies, and equipment. At the time of the accident, an ERAP was not required for the transportation of all large volumes of flammable liquids, such as petroleum crude oil. However, approved ERAPs help ensure that first responders consistently have access, in a timely manner, to the required resources and assistance to deal with an accident involving significant quantities of flammable liquids.

Following this accident, an emergency response working group was established by TC's Transportation of Dangerous Goods General Policy Advisory Council in November 2013. The working group, chaired by the Canadian Association of Fire Chiefs, was tasked to examine the possibility of extending the ERAP program to include flammable liquids, such as crude oil, or to recommend other emergency response solutions aimed at ensuring access to appropriate response capability and specialized supplies.

---

146 Transportation Safety Board (TSB), Rail Recommendation R14-02: Route planning and analysis for trains transporting dangerous goods, Board assessment of response to R14-02 (June 2014), available at http://www.tsb.gc.ca/eng/recommandations-recommendations/rail/2014/rec-r1402.asp (last accessed on 24 July 2014).

The Board acknowledged this TC initiative. However, given the significant increase in the quantities of crude oil being transported by rail in Canada, as well as the potential for a large spill and the risks it would pose to the public and the environment, the Board recommended that, at a minimum:

> The Department of Transport require emergency response assistance plans for the transportation of large volumes of liquid hydrocarbons.
>
> **TSB Recommendation R14-03, issued January 2014**

**Response from Transport Canada**

On 23 April 2014, in response to TSB Recommendation R14-03, TC issued Protective Direction No. 33 under the *Transportation of Dangerous Goods Act* (1992). This protective direction, in effect 150 days from the issue date, requires an ERAP for certain higher-risk hydrocarbons and flammable liquids, including crude oil and ethanol, when offered for transport or imported by rail in 1 or more tank cars that are each filled to 10% of capacity or more.

TC indicated that it will establish an emergency response planning task force with members from key partners and stakeholders to provide a dedicated forum, and with support from a team of experts, to respond to recommendations of the emergency response working group of the Transportation of Dangerous Goods General Policy Advisory Council. The task force will focus on ERAP activation processes, cooperative industry approaches, development of information-sharing protocols, and promotion of unified incident command structures. The task force will also review and provide advice on the possible expansion of ERAP requirements to other Class 3 flammable liquids.

**Board assessment of Transport Canada's response to Recommendation R14-03**

In its assessment of TC's response to TSB Recommendation R14-03, issued on 18 June 2014, the TSB noted that the protective direction will require ERAPs for commonly transported hydrocarbons and flammable liquids that present a higher risk, even for volumes of 1 loaded tank car or more, and TC will also establish a task force to focus on ERAP requirements.

The protective direction ensures that there will be approved ERAPs in place for the shipment of higher-risk hydrocarbons and other flammable liquids, including ethanol. Therefore, the Board assessed the response to Recommendation R14-03 as Fully Satisfactory.

The TSB will continue to monitor progress of the industry task force on ERAPs for the transportation of large volumes of liquid hydrocarbons.

### *4.1.3 Transportation Safety Board rail safety advisories*

#### *4.1.3.1 Securement of locomotives, equipment, and trains left unattended*

On 18 July 2013, the TSB issued Rail Safety Advisory 08/13 to TC. The advisory stated that, given the importance of the safe movement of DGs and the vulnerability of unattended equipment, TC may wish to consider reviewing all railway operating procedures to ensure that trains carrying DGs are not left unattended on the main track.

Also on 18 July 2013, the TSB issued Rail Safety Advisory 09/13 to TC. The advisory stated that, given that there is considerable variability in the effectiveness of the hand brake system on rail cars, and that the hand brake effectiveness test used by railways to satisfy *Canadian Rail Operating Rules* (CROR) 112(b) does not always adequately verify whether the braking force of the hand brake application is sufficient to hold the cars, TC may wish to review CROR 112 and related railway special instructions to ensure that equipment and trains left unattended are properly secured in order to prevent unintended movements.

On 12 September 2013, in reply to Rail Safety Advisories 08/13 and 09/13, TC indicated that, on 23 July 2013, pursuant to section 33 of the RSA, it had issued an emergency directive[147] (which was to remain in effect until 31 December 2013) whereby all federally regulated railway companies and local railway companies operating equipment on federal railways were ordered to:

1. ensure that all unattended controlling locomotives on a main track and sidings[148] are protected from unauthorized entry into the cab of the locomotives;
2. ensure that reversers are removed from any unattended locomotive on a main track and sidings;
3. ensure that the company's special instructions on hand brakes referred to in CROR 112 are applied when any locomotive coupled to 1 or more cars is left unattended for more than 1 hour on a main track or sidings;
4. ensure that, when any locomotive coupled to 1 or more cars is left unattended for 1 hour or less on a main track or sidings, in addition to complying with the company's special instructions on hand brakes referred to in CROR 112, the locomotives have the automatic brake set in full service position and have the independent brake fully applied;
5. ensure that no locomotive coupled to 1 or more loaded tank cars transporting DGs is left unattended on a main track; and
6. ensure that no locomotive coupled to 1 or more loaded tank cars transporting DGs is operated on a main track or sidings with fewer than 2 persons qualified under the company's requirements for operating employees.

TC also indicated that it was following up on this emergency directive with all rail operators in federally regulated and local railway companies to ensure that the requirements contained therein were met. As a result of the emergency directive, several changes were made to the CROR, including Rules 62 and 112, as well as General Rule M. As for the order to not leave trains transporting dangerous goods unattended on the main track, this requirement does not appear to be covered in any subsequent rule change. Other conditions that appear to be less restrictive than the emergency directive relate to orders 3 and 4 (above) and CROR 112 (see 4.1.8 for more information).

---

147 Transport Canada, Emergency Directive Pursuant to Section 33 of the Railway Safety Act: Safety and Security of Locomotives in Canada (23 July 2013).

148 For the purpose of the emergency directive, "main track" and "sidings" do not include main track or sidings in yards and terminals.

#### 4.1.3.2 *Determination of petroleum crude oil properties for safe transportation*

On 11 September 2013, the TSB issued Rail Safety Advisory 12/13 to TC, which stated that the waybill information described the product carried in each tank car of MMA-002 as UN 1267, petroleum crude oil, Class 3, PG III.[149] However, the results of tests performed on the content of the 9 tank cars that did not derail indicated that the product sample was in the lower end of the petroleum crude oil flashpoint range, well below the PG III threshold, which corresponds to a product that is required to be identified as Class 3, PG II. Given that the safety of individuals who handle or otherwise come into contact with DGs during transport is dependent in large part on an accurate description of the product being transported, and considering the volatility of the type of petroleum crude oil involved in this accident and the potential consequences of its release during an accident, the advisory suggested that TC may wish to review the processes in place for suppliers and companies transporting or importing these products to ensure the product properties are accurately determined and documented for safe transportation.

TC responded that, on 17 October 2013, it issued Protective Direction No. 31, pursuant to section 32 of the *Transportation of Dangerous Goods Act* (*TDG Act*), requiring any person who imports, offers for transport or transports petroleum crude oil to:

- conduct classification testing of any petroleum crude oil being classified as UN 1267 or UN 1993 that has not been classification-tested since 07 July 2013;
- make those test results available to TC upon request;
- update their safety data sheets (SDSs) and immediately provide them to TC's CANUTEC (Canadian Transport Emergency Centre); and
- ship all petroleum crude oil classified as UN 1267 or UN 1993 as Class 3, flammable liquids, PG I, when shipping by rail, until classification testing has been completed.

In response to Rail Safety Advisory 12/13, TC published amendments to the *TDG Regulations* in the *Canada Gazette*, Part II, on 02 July 2014. These amendments include a requirement that the person who classifies a DG before transportation keep a record of classification of those goods, as well as a record of the sampling method for petroleum crude oil, and the requirement for consignors to certify that the person named on the shipping document has prepared the consignment to the regulations that apply.

Also on 11 September 2013, the TSB issued Rail Safety Advisory 13/13 to PHMSA on the same subject. On 23 September 2013, PHMSA responded that a joint safety advisory had been issued with the FRA on 02 August 2013, recommending that shippers of hazardous materials, including petroleum crude oil, reassess their operating procedures to ensure that the petroleum crude oil is properly classified and assigned the appropriate PG. This review is to include evaluation of the frequency of verification of flashpoint and boiling point, and the effects that blending of crude from different wells have on these characteristics. PHMSA also indicated that it continues to inspect shippers and carriers, and to monitor, among other things, the material classification of petroleum crude oil in the U.S. under a nationwide inspection campaign with the FRA.

---

149 Petroleum crude oil Class 3 flammable liquids are further divided into packing groups (PGs), based on their properties such as flashpoint and boiling point, to indicate the degree of danger presented as either great, medium, or minor (packing group I, II, or III, respectively).

On 14 November 2013, PHMSA and the FRA issued Safety Advisory No. 2013-07, emphasizing the importance of proper characterization, classification, and selection of a packing group for Class 3 materials, and the corresponding requirements in federal hazardous materials regulations for safety and security planning. In addition, offerors by rail and rail carriers are expected to revise their safety and security plans, including the required risk assessments, to address the safety and security issues identified in the FRA's 02 August 2013 Emergency Order No. 28 and joint safety advisory.

The United Nations is also working on issues related to the classification and safe transportation of crude oil. A subcommittee of the Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals is soliciting feedback with respect to the classification and hazard-communication elements of the United Nations Model Regulations currently applicable to crude oil. This subcommittee includes participants from Canada and the U.S.

On 15 August 2014, the TSB issued a safety advisory to TC. Rail Safety Advisory 06/14 related to the classification accuracy of mined gases and liquids, such as petroleum crude oil.

#### 4.1.3.3 *Short line railway employee training*

On 15 August 2014, the TSB issued Rail Safety Advisory 07/14 to TC, which related to the adequacy of employee training programs by short line railways.

### 4.1.4 *Tranportation Safety Board rail safety information letters*

Following this accident, the TSB received a number of reports concerning potential problems with sections of MMA track and with MMA railway equipment. As a result, the TSB issued to TC the rail safety information letters described below.

On 18 July 2013, the TSB issued Rail Safety Information Letter 10/13 on the track conditions at Lac-Brome, Quebec. In response, TC indicated on 30 September 2013 that it had inspected all MMA main tracks using a track assessment vehicle. In addition, an examination of the subject section of track by a TC inspector revealed some anomalies in certain rail joints that did not meet MMA's standards. As a result, MMA lowered its train operating speed in this section to the equivalent of a Class 1 track.

Also on 18 July 2013, the TSB sent Rail Safety Information Letter 11/13 to TC regarding the track conditions at Sherbrooke Yard, Quebec. TC conducted an inspection of the MMA Sherbrooke Yard and identified several significant safety concerns with respect to the infrastructure on all yard tracks. As a result, on 26 July 2013, a TC railway safety inspector issued a notice informing MMA that a threat to safe railway operations existed due to the track condition in the Sherbrooke Yard. On 09 August 2013, MMA replied to the notice, indicating that the company would make repairs to certain conditions found, apply remediation to other conditions found, make tracks "excepted", or close tracks, and would adjust operations in Sherbrooke Yard as well as develop a plan for further usage.

On 22 July 2013, the TSB issued Rail Safety Information Letter 13/13 on the soil conditions in Sherbrooke, Quebec. In its response dated 30 September 2013, TC informed the TSB that inspection of the Sherbrooke Yard had revealed that a broken City of Sherbrooke water pipe had eroded the soil under a bike path and the MMA right-of-way. MMA made appropriate repairs, and the problem was resolved.

On 26 August 2013, the TSB sent Rail Safety Information Letter 16/13 to TC regarding the crossing condition at Agnès Street in Lac-Mégantic. On 27 September 2013, TC advised the TSB that the Ministry of Transport of Quebec was planning to replace the crossing surface in the fall to address the reported unsafe condition at the Agnès Street public crossing. Subsequently, the Ministry of Transport of Quebec made a temporary repair to the road surface by adding asphalt where the road crosses the main track; the spur leading to a local industrial facility was covered over with asphalt, as it had not been used for 2 years.

Also on 26 August 2013, the TSB issued Rail Safety Information Letter 17/13 on the drainage condition near Chemin du Versant in Lac-Mégantic. On 18 October 2013, TC indicated that it had conducted an extensive site visit, which indicated erosion affecting the head wall of the culvert and a need for the embankment to be stabilized. TC recommended that a 10-mph temporary slow order (TSO) be applied until the situation was corrected. MMA advised that it would be transferring this issue to the new operator and would be involving the town of Lac-Mégantic to discuss an eventual work plan. In the meantime, MMA will continue to monitor the situation during its weekly inspections, and TC will continue to follow up.

### 4.1.5 *Other measures taken by the Transportation Safety Board*

On 08 October 2013, the TSB provided TC with the results of its examination of sections of track near Lac-Mégantic (see section 1.17.4 for details). TC combined this information with the results from its own inspections and followed up with MMA. In addition, on 09 October 2013, the TSB provided the same information to the municipality of Lac-Mégantic.

### 4.1.6 *Transport Canada*

On 23 July 2013, pursuant to section 33 of the RSA, TC issued an emergency directive to federally regulated railway companies and local railway companies operating equipment on federal railways. The emergency directive clarified the regulatory regime with respect to unattended locomotives on main track and sidings, and the prohibition of trains transporting dangerous goods from being operated with fewer than 2 persons (see section 4.1.3.1). In connection with the emergency directive, and pursuant to section 36 of the RSA, federal and local railway companies were ordered to file with the Minister, within 7 days:

- their special instructions on hand brakes, referred to in CROR 112 and mentioned in item 3 of the directive; and
- their requirements for operating employees, mentioned in item 6 of the directive.

Also on 23 July 2013, pursuant to section 19 of the RSA, TC issued Ministerial Order 07-2013, ordering all federally regulated railway companies and local railway companies to formulate and, as the case may be, to revise, within 120 days (by 20 November 2013), rules respecting the safety and security of unattended locomotives, uncontrolled movements, and crew size requirements. The order specified that the rules should be based on an assessment of safety and security risks, and shall, at a minimum:

1. Ensure that the cab(s) of unattended controlling locomotives are secure against unauthorized entry;
2. Ensure that the reversers of unattended locomotives are removed and secured;
3. Prevent uncontrolled movements of railway equipment [...] due to tampering or accidental release of brakes from defective components [*by addressing relevant factors*];
4. Ensure the security of stationary railway equipment transporting "dangerous goods" [...];[150] and
5. Provide for minimum operating crew requirements considering technology, length of train, speeds, classification of dangerous goods being transported, and other risk factors.[151]

A revised Ministerial Order, no. 07.1-2013, was issued on 25 November 2013 to extend the deadline for some companies to submit new or revised rules, by an extra 120 days (to 20 March 2014), to allow for further consultation with TC.

On 17 October 2013, pursuant to section 32 of the *TDG Act*, TC issued Protective Direction No. 31, directing any person engaged in importing or offering petroleum crude oil for transport to immediately test its classification if no classification testing has been conducted since 07 July 2013. The protective direction also states that, until such testing is completed, all such products being shipped by rail must be classified as a Class 3 flammable liquid PG I. (See section 4.1.3.2 for more details.)

On 18 November 2013, the Minister of Transport requested that the House of Commons Standing Committee on Transport, Infrastructure and Communities (commonly referred to as SCOTIC) conduct an in-depth review of the Canadian regime regarding the safe transportation of dangerous goods, and the role of safety management systems across all modes of transportation. It was requested that an interim report be presented by June 2014, followed by a final report by December 2014. SCOTIC accepted the request, undertook the study, and tabled its preliminary report in Parliament on 13 June 2014.

In November 2013, TC announced the creation of 3 industry-led working groups on classification, emergency response, and means of containment. All 3 working groups provided a report to TC on 31 January 2014, which have been posted on TC's website. The reports' recommendations are under consideration.

On 20 November 2013, TC issued Protective Direction No. 32, directing Canadian Class 1 railways and persons who transport DGs by rail to periodically provide specified DG traffic information to each municipality through which DGs are transported by rail, and to notify municipalities of any significant changes to that information. This information must also be provided to TC, through CANUTEC.

In December 2013, TC developed an action plan to address the recommendations contained in the *2013 Fall Report of the Auditor General of Canada*. TC stated that most action items are to

150 As defined in section 2 of the *Transportation of Dangerous Goods Act*.

151 Transport Canada, 07-2013, Minister of Transport Order Pursuant to Section 19 of the *Railway Safety Act* (23 July 2013).

be completed by fall 2014, and the entire action plan is expected to be fully implemented by fall 2015.

On 24 December 2013, TC issued another emergency directive similar to the one issued on 23 July 2013. It was issued to local railway companies, some of which were not covered by the earlier directive. The emergency directive was to be in effect for 6 months (that is, until 01 July 2014) or until rules are approved for all companies.

On 26 December 2013, TC approved changes to the CROR (TC O 0-167), including a new General Rule M (iii), which states, "The minimum operating crew requirement for a freight train or transfer carrying one or more loaded tank cars of dangerous goods is two (2) crew members".

On 30 December 2013, TC issued an order under section 36 of the RSA to all Railway Association of Canada (RAC) member railways to file their special instructions on CROR 112, governing testing the effectiveness of hand brakes.

Amendments to the RSA came into force on 01 May 2013, and enabled the making of regulations in a number of areas that strengthen the Minister's enforcement powers. Therefore, on 15 March 2014, TC published *Railway Operating Certificate Regulations* in the *Canada Gazette*, Part I. These proposed regulations would require a railway company to hold a railway operating certificate (ROC) issued by the Minister of Transport. The Minister may suspend or cancel an ROC if the company has contravened a provision of the Act or the regulations made under this Act.

On 23 April 2014, in response to the 3 railway safety recommendations issued by the TSB on 23 January 2014, TC took the following measures:

- Under the *TDG Act*, it issued Protective Direction No. 33, requiring ERAPs for smaller volumes of commonly transported flammable liquids, such as crude oil and ethanol (see section 4.1.2.3).
- It issued Protective Direction No. 34, removing the least crash-resistant Class 111 tank cars from dangerous goods service (see section 4.1.2.1).
- It issued Order MO 14-01 pursuant to section 19 of the *Railway Safety Act*, requiring railway companies to formulate rules respecting the safe and secure operations of trains carrying certain dangerous goods and flammable liquids. In conjunction with Order MO 14-01, TC issued an emergency directive pursuant to section 33 of the RSA, requiring railways to implement minimum operating practices on key routes over which they operate key trains (see section 4.1.2.2).

On 17 May 2014, *Administrative Monetary Penalties Regulations* (*AMP Regulations*) were published in the *Canada Gazette*, Part I. These proposed regulations would allow for monetary penalties ranging from $5000 to $50 000 for individuals, and from $25 000 to $250 000 for corporations, for contraventions to various sections of the *Railway Safety Management System Regulations* (*SMS Regulations*).

In June 2014, TC advised that follow-up procedures both for audits and for inspections had been developed. These procedures are expected to be released in mid-2014. Furthermore, a baseline audit plan has been developed in order to assess railway companies' implementation of their SMS. A baseline audit will be conducted on each railway on a 5-

year cycle and will include the components of section 2 of the *SMS Regulations*, effective fiscal year 2014 – 2015.

On 02 July 2014, TC published amendments to the *TDG Regulations* in the *Canada Gazette*, Part II. These amendments include requirements to build, after 15 July 2014, all Class 111 tank cars used for the transport of DGs in PG I or PG II (other than toxic by inhalation substances) to specifications similar to the AAR CPC-1232 standard. The amended regulations also apply to tank cars used for the transport of PG III petroleum crude oil (UN 1267) and petroleum products not otherwise specified (UN 1268).

Revised *SMS Regulations* were published in the *Canada Gazette*, Part I, on 05 July 2014. These proposed regulations, which would come into force on 01 April 2015, would expand the scope of application to all companies that operate on federal track, would introduce new provisions, and would clarify existing provisions to facilitate more effective compliance and enforcement.

TC collaborated with the National Municipal Rail Safety Working Group of the Federation of Canadian Municipalities to discuss rail and TDG safety-related concerns, such as improving risk assessments, emergency planning and response capability, and increasing insurance requirements for railways and shippers.

#### *4.1.6.1 Safety action taken by Transport Canada Quebec Region with respect to Montreal, Maine & Atlantic Railway*

TC Quebec Region took the following measures regarding safety concerns and safety deficiencies noted at MMA after the Lac-Mégantic accident:

- On 10 July 2013, a notice and order was issued to MMA regarding equipment left unattended.
- On 24 July 2013, a notice was sent to MMA and the Municipality of Eastman regarding damage on the overhead timber bridge crossing. This notice was superseded by the notice and order issued on 23 December 2013 and cited below.
- On 26 July 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on the Sherbrooke Subdivision.
- On 26 July 2013, a notice and order was issued regarding the state of the infrastructure on the Stanbridge Subdivision.
- On 26 July 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on all yard tracks in Sherbrooke Yard.
- On 09 August 2013, a notice was issued regarding significant safety concerns on the state of the infrastructure on the St-Guillaume Subdivision and in Farnham Yard.
- On 11 October 2013, a notice and order was issued regarding safety deficiencies of public and private crossings on the Sherbrooke Subdivision. On 31 October 2013, after a review and evaluation of actions taken by MMA, TC revoked the notice and order.
- On 31 October 2013, a notice and order was issued regarding rail wear and rail surface defects on the Moosehead Subdivision.

- On 31 October 2013, a notice and order was issued regarding the conditions of tracks on the Sherbrooke Subdivision.
- On 31 October 2013, a notice and order was issued regarding safety deficiencies of public and private crossings on the Sherbrooke Subdivision.
- On 23 December 2013, a notice and order was issued to MMA and to the Municipality of Eastman regarding the condition of the Chemin d'Orford-sur-le-Lac overhead bridge located in the Municipality of Eastman and crossing the MMA Sherbrooke Subdivision. On 28 January 2014, following a review and evaluation of actions taken by the Municipality of Eastman, TC revoked the notice and order, and issued a second notice and order regarding the condition of timber curbs, posts and handrails on the bridge. Repairs by the Municipality of Eastman were begun in the spring of 2014 and are ongoing.

### *4.1.7 Canadian Transportation Agency*

Following the derailment, on 13 August 2013, the CTA suspended MMA's certificate of fitness (COF). After MMA took a series of actions to improve the safety of its rail operations (see section 4.1.1) and demonstrated to the CTA's satisfaction that it had insurance in place, the CTA allowed the company to resume operations.

In the 16 October 2013 Speech from the Throne, the Governor General stated that the "government will require shippers and railways to carry additional insurance so they are held accountable." In the fall of 2013, the CTA conducted public consultations regarding the adequacy of the *Railway Third Party Liability Insurance Coverage Regulations*. After the first round of consultations ended in late January 2014, the CTA published a report entitled *What We Heard* and opened a second round of consultations, which closed on 09 May 2014. The CTA continues to work with TC on increased railway insurance requirements, and on a framework for railways and shippers to fund cleanup costs.

Regarding enhanced enforcement, the CTA is considering the introduction of administrative monetary penalties for non-compliance with regulatory requirements.

Furthermore, the CTA is expanding its memorandum of understanding with TC to include collaboration and information-sharing about federal railways to get a better understanding of the overall safety records of railways in connection with their COFs. The CTA is also aiming to have a similar memorandum in place with the TSB.

### *4.1.8 Railway Association of Canada*

On 20 November 2013, the RAC submitted to TC for approval a revised CROR 112 (Leaving Equipment Unattended). The revised rule, which was approved by TC on 26 December 2013, states the following:

> (a) Equipment must be secured if it is left unattended. The following are acceptable methods of ensuring securement:
> (i) Sufficient number of hand brakes;
> (ii) A mechanical device approved for use by a professional engineer;
> (iii) Equipment is left on a track designed to prevent the equipment from moving unintentionally (e.g. switching bowl or where grade

does not allow) and that design is approved by a qualified employee;
- (iv) Equipment is derailed or coupled to derailed equipment;
- (v) A movement secured as per paragraph (c) in this rule.

(b) While switching enroute, the standing portion must be protected as per paragraph (a) unless:
- (i) There are at least 15 cars;
- (ii) Not on a grade in excess of 1.25%;
- (iii) The equipment will not be left in excess of 2 hours;
- (iv) The air brake system is sufficiently charged to ensure proper air brake application; and
- (v) The brake pipe is fully vented at a service rate or an emergency application of the air brakes has been made, and the angle cock is left fully open.

Whenever it is possible that the portion left standing cannot be secured within the applicable time limit, the standing portion must be secured as per paragraph (a).

(c) A movement may be left unattended if:
- (i) Secured as per paragraph (a); or
- (ii) Left at a location where a derail protects the movement from unintentionally obstructing main track and
  - The air brake system is sufficiently charged to ensure proper brake application;
  - The locomotive controlling the air brake system maintains air pressure;
  - A full service or emergency air brake application is made; and
  - Independent brake is fully applied; or
- (iii) Air brake system is sufficiently charged to ensure a proper brake application and
  - The locomotive controlling the air brake system maintains air pressure;
  - A full service or emergency air brake application is made;
  - Independent brake is fully applied;
  - Hand brakes are applied on 10% of the equipment to a maximum of 5;
  - It is not on a grade exceeding 1.25%; and
  - Is not left in excess of 2 hours.

(d) Exceptional weather situations, such as high winds or other unusual conditions, must be considered and factored into securement decisions. Special instructions may contain location specific instructions where extreme weather events are prevalent.

(e) Instructions governing testing the effectiveness of hand brakes will be carried in special instructions.

(f) Application of hand brakes must not be made while equipment is being pulled or shoved.

(g) Before leaving equipment at any location, the employee securing such equipment must confirm with another employee the manner in which the equipment has been secured.

Following the issuance of TC's Order MO 14-01 in April 2014, the RAC established a working group to initiate the rule-making process in order to formulate rules respecting the safe and secure operations of trains carrying certain DGs and flammable liquids.

The RAC initiated the development of mutual aid agreements to improve DG accident response times and capabilities.

Railways and a number of industry stakeholders are collaborating and have initiated work to develop an ERAP process for liquid hydrocarbons and ethanol that will serve shippers, railways, and emergency response contractors.

Railways and a number of industry stakeholders have established the Canadian Training Coalition for Transportation Incidents. This coalition's objective is to raise awareness of and competence in handling fires involving liquid hydrocarbons and ethanol among local first responders.

### *4.1.9 Canadian Pacific Railway*

In response to TC's order of 30 December 2013, CPR advised that its special instructions for CROR 112 state:

> Testing Hand Brake Effectiveness
>
> To ensure sufficient number of hand brakes are applied, release all air brakes and **allow or cause** the slack to adjust. It must be apparent when slack runs in or out, that the hand brakes are sufficient to prevent that equipment from moving. This must be done before uncoupling or before leaving equipment unattended.
>
> **IMPORTANT**: When brakes are released to test effectiveness, allow sufficient time for the air brakes to release.[152]

CPR and CN signed a joint mutual-aid agreement to improve DG accident response times and capabilities.

### *4.1.10 Canadian National Railway*

In response to TC's order of 30 December 2013, CN advised that its special instructions for CROR 112 state:

---

[152] Canadian Pacific Railway (CPR), General Operating Instructions (GOI) Section 4 —02/20/2014: Hand Brakes —Leaving Equipment (20 February 2014), p. 2. (Bold text in original.)

> Handbrake effectiveness must be tested before uncoupling and leaving equipment unattended or riding equipment to rest. To test the effectiveness, release all air brakes and **allow or cause** the slack to adjust. It must be apparent when slack runs in or out, that the handbrakes are sufficient to prevent that equipment from moving. When brakes are released to test effectiveness, allow sufficient time for the air brakes to release. If unable or difficult to observe slack movement, or securing less than 10 cars, slightly move the car(s) to ensure sufficient retarding force.[153]

As previously mentioned in section 4.1.9, CN and CPR signed a joint mutual-aid agreement to improve DG accident response times and capabilities.

### *4.1.11 Irving Oil Ltd.*

Following the accident, Irving took the following measures:

- amended its transportation of DGs training program to extend training to all company petroleum crude oil traders and rail logistics personnel;
- engaged petroleum crude oil suppliers and transloaders to ensure that they are correctly classifying the petroleum crude oil to be transported to Irving's facilities and providing accurate SDSs for the petroleum crude oil supplied;
- implemented processes to reconcile shipping documents with other product documentation (such as SDSs) to confirm the accuracy of the product's classification;
- conducted periodic testing for the classification of petroleum crude oil (for example, flashpoint and initial boiling point) at loading points to collect data in order to better understand the classification and the potential variability in petroleum crude oil from different producers and suppliers;
- increased its oversight of transloading facilities to ensure that all applicable regulatory provisions are met;
- continued working with its counterparts, including suppliers and transloading facilities, to determine how best to provide improved oversight on matters related to the transportation of DGs, given some of the unique commercial challenges presented by the transportation of petroleum crude oil.

### *4.1.12 Safety action taken in the United States*

Following the Lac-Mégantic derailment, a number of measures were taken in the U.S. to enhance railway safety.

On 02 August 2013, the FRA issued Emergency Order 28 (EO-28), strengthening train securement rules by requiring the development and submission of each railroad's process for securing unattended trains carrying DGs on the main line. The order established certain securement requirements for unattended trains, such as use of locks or removal and securement of the reverser on a locomotive, communication between train dispatchers and train crews, recording of information, daily job briefings, and notification to railroad

153 Canadian National Railway (CN), CN GOI Section 9: Handbrakes (01 July 2014), 9.1.2(g) Testing Handbrake Effectiveness, p.2. (Bold text in original.)

employees. EO-28 was later amended by the FRA based on a petition by the AAR to modify 2 of its provisions.

Also on 02 August 2013, PHMSA and the FRA jointly issued a Safety Advisory No. 2013-06 to railroad owners and hazardous materials shippers detailing recommended actions the industry is expected to take to better ensure the safe transportation of hazardous materials. The recommendations include guidance on train crew size; on operating, testing and classification procedures; on system-wide evaluations of security and safety plans; and on risk mitigation.

On 07 August 2013, PHMSA and the FRA announced a comprehensive review of operational factors that affect the safety of the transportation of hazardous materials by rail (Title 49, *Code of Federal Regulations* [49 CFR], Part 174). On 27 and 28 August 2013, PHMSA and the FRA held a public meeting to solicit input from the public, stakeholders, and interested parties.

In August 2013, "Operation Classification"was initiated. This compliance activity, also known as the "Bakken Blitz", consisted of unannounced inspections and testing by PHMSA and the FRA to verify the material classification and packing group assignments selected and certified by offerors of petroleum crude oil.

On 06 September 2013, PHMSA issued an advanced notice of proposed rulemaking (ANPRM), which was published in the *Federal Register*. The ANPRM requested comments on enhancements to the standards for DOT-111 tank cars used to transport PG I and PG II petroleum crude oil and ethanol. On 30 April 2014, the U.S. DOT, on behalf of PHMSA and the FRA, submitted an NPRM pertaining to enhanced tank car standards for the OMB's review. PHMSA and the FRA continue to work with the OMB to ensure the NPRM is published as quickly as possible (see section 4.1.2.1).

On 14 November 2013, PHMSA and the FRA jointly issued Safety Advisory No. 2013-07, emphasizing the importance of proper characterization, classification, and selection of a PG for Class 3 materials, and the corresponding requirements in the federal hazardous materials regulations for safety and security planning.

FRA draft regulations provide requirements to continue SPTO in place prior to 01 January 2014. A special approval procedure will be required for railroads commencing SPTO after that date.

On 02 January 2014, PHMSA issued a safety alert notifying the general public, emergency responders, shippers, and carriers that the type of crude oil being transported from the Bakken region of North Dakota may be more flammable than traditional heavy crude oil.

On 16 January 2014, the Secretary of Transportation met with members of the rail and the petroleum industries in a call-to-action meeting, to address the risks associated with the transportation of crude oil by rail.

On 22 January 2014, the AAR confirmed its agreement to apply, by no later than 01 July 2014, the routing requirements (49 CFR subsection 172.820) to trains carrying more than 20 cars of crude oil, as discussed at the 16 January call-to-action meeting. The AAR also agreed to further address risks by restricting the speeds of trains carrying more than 20 cars of crude oil to 50 mph, and to 40 mph for such trains with at least one DOT-111 or non-specification tank car travelling through high-threat urban areas, as designated by the Department of Homeland Security.

On 23 January 2014, as a result of its participation in the TSB's investigation into the Lac-Mégantic accident, the U.S. National Transportation Safety Board (NTSB) issued the following 3 safety recommendations to the FRA:

> Work with the Pipeline and Hazardous Materials Safety Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 *Code of Federal Regulations* 172.820 to include key trains transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.
>
> NTSB Recommendation R-14-1
>
> Develop a program to audit response plans for rail carriers of petroleum products to ensure that adequate provisions are in place to respond to and remove a worst-case discharge to the maximum extent practicable and to mitigate or prevent a substantial threat of a worst-case discharge.
>
> NTSB Recommendation R-14-2
>
> Audit shippers and rail carriers of crude oil to ensure they are using appropriate hazardous materials shipping classifications, have developed transportation safety and security plans, and have made adequate provision for safety and security.
>
> NTSB Recommendation R-14-3

The NTSB also issued 3 safety recommendations to PHMSA, as follows:

> Work with the Federal Railroad Administration to expand hazardous materials route planning and selection requirements for railroads under Title 49 Code of Federal Regulations 172.820 to include key trains transporting flammable liquids as defined by the Association of American Railroads Circular No. OT-55-N and, where technically feasible, require rerouting to avoid transportation of such hazardous materials through populated and other sensitive areas.
>
> NTSB Recommendation R-14-4
>
> Revise the spill response planning thresholds contained in Title 49 Code of Federal Regulations Part 130 to require comprehensive response plans to effectively provide for the carriers' ability to respond to worst-case discharges resulting from accidents involving unit trains or blocks of tank cars transporting oil and petroleum products.
>
> NTSB Recommendation R-14-5

> Require shippers to sufficiently test and document the physical and chemical characteristics of hazardous materials to ensure the proper classification, packaging, and record-keeping of products offered in transportation.
>
> NTSB Recommendation R-14-6

On 25 February 2014, the U.S. DOT issued an emergency restriction/prohibition order requiring all shippers to test petroleum crude oil from the Bakken region to ensure that it is properly classified before it is transported by rail. The order also states that Class 3 petroleum crude oil shipped by rail must only be treated as a PG I or PG II hazardous material. This order was later amended and restated on 06 March 2014 to clarify its provisions.

On 09 April 2014, the FRA announced its intention to issue a proposed rule establishing minimum crew-size standards for most main-line freight and passenger rail operations. The notice of proposed rulemaking (NPRM) would require a minimum of 2-person crews for most main-line train operations, including those trains carrying crude oil. The FRA plans to issue an additional NPRM that would prohibit certain unattended freight trains or standing freight cars on main track or sidings, and require railroads to adopt and implement procedures to verify securement of trains and unattended equipment for emergency responders. It would also require locomotive cabs to be locked and reversers to be removed and secured. Railroads would also be required to obtain advance approval from the FRA for locations where or circumstances in which cars or equipment may be left unattended.

On 07 May 2014, the U.S. DOT issued an emergency restriction/prohibition order requiring all railroad carriers that transport in a single train 1 000 000 gallons or more of petroleum crude oil (UN 1267) from the Bakken shale formation to notify the appropriate State Emergency Response Commission of expected movements of such trains through their jurisdiction.

On 07 May 2014, PHMSA and the FRA jointly issued Safety Advisory Notice No. 14-07, urging railroad carriers transporting petroleum crude oil from the Bakken formation to use tank cars of the highest integrity within their existing fleet (see section 4.1.2.1).

#### 4.1.13 Municipality of Nantes

Following the accident, the municipality of Nantes initiated a review of its rail response protocols and procedures.

## 4.2 Safety action in progress

### 4.2.1 Transport Canada oversight of regional railways

TC oversees railway safety by conducting inspections and audits. While inspections look at conditions (that is, what is wrong), audits look at systems and processes (that is, to identify why the conditions exist). Inspections should be used to help target future audits and to help monitor the corrective action taken following previous audits.

TC Headquarters oversees SMS in national railways and assigns the oversight of regional railways (both inspections and SMS audits) to its regional offices. These offices make the decisions on which regional railways will be inspected or audited, the scope of each activity, when they will be conducted, and with which frequency at each railway.

TC Quebec Region was inspecting and monitoring the operations, equipment, and infrastructure at MMA. For several years, MMA had been identified as a railway company with an elevated level of risk, requiring more frequent inspections. Through inspections, TC Quebec Region identified a number of ongoing safety deficiencies requiring safety action. TC Quebec Region issued a number of notices, notices and orders, letters of concern, and letters of non-compliance. Although MMA normally took action after the inspection to address the identified safety deficiency, it was not uncommon for similar deficiencies or risks to be identified during subsequent inspections.

TC Quebec Region was performing very few SMS audits, and was not following up on the corrective action plans that railways submitted to ensure that each railway's SMS was effective at reducing safety risks. In contrast, the Atlantic and Ontario Regions were much more active in auditing and follow-up.

As TC Headquarters did not review the oversight activities of its Regions, it was unaware that the Quebec Region was not following up on railways' corrective action plans or risk-mitigation activities. Although meetings were held between Regions and Headquarters several times per year, these meetings did not focus on regional railways. Consequently, TC Headquarters was unaware of the extent to which regional railways were implementing SMS and of the impact, or lack thereof, that SMS was having on each railway's safety performance. Without adequate oversight of regional activities by TC Headquarters, TC Regions may not be effectively ensuring that all of their regional railways have fully implemented their SMS. Consequently, TC cannot be assured that each regional railway's SMS is effective and improving safety.

The *2013 Fall Report of the Auditor General of Canada* examined TC's quality management framework for its Rail Safety Program and found that TC had not assessed whether the oversight methodology for conducting audits and inspections met best practices, and whether audits and inspections were conducted according to that methodology. Consequently, the Office of the Auditor General (OAG) recommended that TC:

> develop a detailed quality assurance plan to assess its oversight methodology against best practices and to regularly evaluate audits and inspections against its methodology, with the goal of promoting continuous improvement.[154]

TC agreed with this recommendation, stating that it will, by the fall of 2014:

> strengthen its quality assurance program by including periodic assessments of its oversight methodology against best practices and assessing whether audits and inspections are being carried out in accordance with this methodology.[155]

---

154 Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.47, p. 24.

155 Transport Canada, Detailed Management Action Plan for the OAG's Audit of Oversight of Rail Safety, Quality Assurance: Recommendation 7.81: Detailed Action Plan, Completion Date: Fall 2014.

If implemented, this action by TC would lead to a more robust regulatory oversight regime and promote continuous improvements in every regional railway's SMS. However, because TC's quality assurance program has not yet been implemented, it cannot be determined at this time whether the planned changes will be sufficient to ensure adequate Headquarters oversight of activities in all of TC's Regions. The Board considers it crucial that TC Headquarters follow through with the implementation of processes for it to confirm that all regional offices are effectively overseeing regional railways, including their safety management systems.

## 4.3 *Safety action required*

### 4.3.1 *Prevention of runaway trains: Unattended equipment*

In this accident, a 4700-foot train transporting petroleum crude oil that was parked on the main track ran away. It travelled 7.2 miles down a descending grade, gained speed, and derailed at 65 mph in the town of Lac-Mégantic, Quebec. Sixty-three tank cars spilled approximately 6 million litres of crude oil, which ignited, levelling buildings, destroying the centre of the town, and killing 47 people. There was environmental contamination of the downtown and of the adjacent river and lake.

In this accident, the train was secured at Nantes with both hand brakes and air brakes. However, a proper hand brake effectiveness test had not been conducted to ensure that the hand brakes alone would hold the train. When the locomotive supplying air pressure to the train was shut down, the air brake system leaked off in less than 1 hour. The force from the hand brakes was not sufficient to secure the train, and the train ran away.

Both air brake and hand brake systems are subject to failure, as the technology is not fail-proof.

For example, air brakes are prone to leakage and suffer from limitations in maintaining brake cylinder pressure; when brake pressure is low, fail-safe functions are compromised. In this accident, it took less than 1 hour for the air to be depleted to a point where it was no longer capable of holding the train on the 0.92% grade.

Hand brakes also have significant limitations, in that they cannot provide feedback to the operator about the force applied, and often do not provide the necessary braking force required due to their design and other mechanical and physical factors. In this accident, only 6 of the 7 hand brakes applied by the LE were providing retarding force, and the total force provided by the hand brakes was 48 600 pounds. As a result, it is necessary that a proper effectiveness test, as prescribed by railway operating instructions, be carried out to ensure effective securement of unattended equipment.

In the rail industry, these limitations in technology are addressed with the expectation that there will always be strict compliance with rules. For equipment securement, reliance is placed on CROR 112, company special instructions, and training. When failures occur, it is often concluded that either the rule or the operator is deficient and must therefore be corrected.

Training can improve the effectiveness of rules application. However, the Board found that some MMA employees lacked the knowledge or had not demonstrated the skills required to

safely and competently perform their jobs. This included knowledge of the CROR and the performance of a proper hand brake effectiveness test. Similar deficiencies in training and rules compliance have been observed in a number of other TSB investigations. Of the 9 TSB investigations into runaway equipment carried out in the past 20 years, misinterpretation or misapplication of rules was identified in most to be a cause or contributing factor.
In a system where the final layer of defence is reliance on the application of hand brakes and an effectiveness test, there needs to be clear rules that are well understood and consistently applied. However, no matter how clear and comprehensive rules are, these are administrative defences and, invariably, there will be instances where practices in the field will deviate from these written rules and procedures. TSB investigations into the Lac-Mégantic accident and other runaways have revealed that the chain of events almost always included the application of an insufficient number of hand brakes to secure the train. This means that no matter how well the rule is worded, it will not always be strictly complied with, thereby introducing vulnerability into the safety system. The following TSB data suggest that these vulnerabilities are magnified at short line railways. Of 16 investigations involving short line railways in the past 20 years (including 6 runaways), deficiencies in rules compliance, misinterpretation and/or training have been identified as causal or contributing in 10 cases (62%).

Following this accident, regulators and industry examined the adequacy of CROR 112 with a view to strengthening the procedures. However, the new rule is convoluted, and in some cases, is less restrictive than its previous version. The rule contains a circular reference; paragraph (a) (v) refers to paragraph (c), whereas paragraph (c) (i) refers to paragraph (a). Further, the rule states that "instructions governing testing of hand brakes will be carried in special instructions" but does not explicitly state that the effectiveness of the hand brake(s) must be tested.

Furthermore, under certain circumstances while switching, the amended CROR 112 allows for trains to be left unattended for up to 2 hours on the main track on a grade of up to 1.25%, secured only with air brakes. This is in contrast with the previous rule that did not allow any equipment to be left unattended without hand brakes. The amended rule also does not take into consideration TC's emergency directive that did not allow any equipment carrying dangerous goods to be left unattended on main lines. The lack of clarity in wording of the rule, and its confusing construction, make it difficult to understand. Because this safety-critical rule is not well worded and is more permissive than the emergency directive with respect to dangerous goods, there is an increased risk that equipment will not be properly secured. The train in Nantes ran away in 1 hour. The TSB has investigated other occurrences in which air leakage has resulted in trains running away, such as in Dorée, Quebec (R11Q0056), where the uncontrolled movement occurred in 1 hour. In consideration of the above and the advice of air brake manufacturers that air brake systems not be relied upon for securement, there is a risk that the 2-hour limit has reduced the margin of safety.

Even with the right rules, it has been demonstrated over the years that depending solely on the correct application of rules is not sufficient to maintain safety in a complex transportation system. The concept of "defence in depth" has shaped the thinking in the safety world for many years. Layers of defences, or safety redundancy, have proven to be a successful approach in many industries, including the space and nuclear industries, to ensuring that a single-point failure does not lead to catastrophic consequences.

There are physical defences to protect against the risk of runaway rolling stock, which are available to mitigate the risk of air brake pressure loss, and these include derails, wheel chocks, mechanical emergency devices, and locomotive auto-start systems. New technology is available, such as GPS-equipped devices that can be applied to a hand brake chain, allowing for the remote monitoring of the hand brake status. In addition, some existing technology, such as reset safety controls and sense and braking units, with minor programming changes, can offer additional protection.

Advanced air brake control valves, such as electronically controlled pneumatic (ECP) brakes, can provide added protection by overcoming some of the inherent limitations of the traditional air brake systems. ECP brakes protect against brake cylinder leakage, and will monitor brake pipe pressure and automatically generate an emergency brake application if the brake pipe pressure gets low. The instantaneous application and release of ECP brakes greatly diminishes in-train forces, reducing the risk of derailment. With ECP brakes, the brake pipe is solely dedicated to continuously supplying air, to keep all of the reservoirs charged on the train. ECP brakes also provide valuable information about the status of the train, and feedback on factors such as brake system health, brake pipe continuity, and the number of operative brakes.

The NTSB recently made a recommendation to address the need for redundant protection, such as wheel chocks and derails, to protect against runaway trains (NTSB Recommendation R-14-03 Urgent). The recommendation is derived from the NTSB's investigation into the collision between 2 Chicago Transit Authority trains that occurred on 30 September 2013, in Forest Park, Illinois.

The TSB has pointed out the need for robust defences to prevent runaways since 1996 (Rail Investigation R96C0172), and since then, there have been over 120 runaways in Canada that have affected main-track operations. Equipment runaways are low-probability events, but as this accident demonstrates, they can have extreme consequences, particularly if they involve dangerous goods. As demonstrated in Lac-Mégantic, the cost to human life and our communities can be incalculable. For this reason, the Board recommends that:

> The Department of Transport require Canadian railways to put in place additional physical defences to prevent runaway equipment.

**TSB Recommendation R14-04**

### *4.3.2 Safety management system audits and essential follow-up*

Managing risk to acceptable levels requires that railway companies analyze the findings of regulatory inspections and SMS audits, identify the underlying causes of these findings, and ensure that corrective actions are effectively implemented and are working. For railway companies to effectively manage risk using SMS, the related processes must not only be documented, they must be in place and actively used.

In addition, for effective regulatory oversight, the regulator must be assured that corrective action plans and measures to mitigate risks have been implemented. Furthermore, if they are not, the regulator must have the power to compel companies to improve their SMS.

Under TC Quebec Region, all railways had been the subject of a pre-audit to verify that the required SMS documentation was in place. However, audits assessing the effectiveness of the regional railways' SMS were extremely limited; some railways had never been the subject of an SMS audit, and none had been the subject of an audit of all SMS components. As such, the regulator could not know whether SMS at these railways was in place and working.

TC had identified a number of recurring problems at MMA. However, MMA had a poor history of analyzing and rectifying the systemic causes of these problems. Moreover, regional oversight did not identify or address this issue. Ten years after TC had informed MMA that it was in compliance with the *SMS Regulations*, MMA did not have a fully functioning SMS to effectively manage risk. The time between audits conducted at MMA, the limited scope of these audits, and the lack of regulatory follow-up on audit findings meant that the regulator remained unaware of the extent of the weaknesses in MMA's SMS. In contrast, other TC Regions were conducting more follow-ups to ensure corrective actions were addressing underlying causes or problems and were effectively improving safety.

In its 2013 report, the OAG concluded that "Transport Canada does not have the assurance it needs that federal railways have implemented adequate and effective safety management systems."[156] The OAG recommended, among other things, that TC establish a minimum level of oversight for SMS, that TC have its inspectors assess the quality and effectiveness of railways' SMS, and that TC require federal railways to correct deficiencies affecting the safety of their operations. It also recommended that TC "conduct timely follow-up on deficiencies affecting the safety of federal railways' operations, to assess whether they have been corrected."[157]

In response to these recommendations, TC indicated that it plans to improve procedures and training for inspectors and is pursuing a number of regulatory changes.

In the past, the *Railway Safety Act* and the *SMS Regulations* only allowed TC to require railway companies to have an SMS. They did not permit TC to assess the effectiveness of SMS components in order to determine whether the SMS was functioning properly and would therefore ensure a safe operation.

The 2013 amendments to the Act allow the Minister to order a company to take corrective measures where its SMS has deficiencies that risk compromising railway safety. The proposed *Railway Operating Certificate and Administrative Monetary Penalty Regulations* published in the *Canada Gazette*, Part I, in the spring of 2014, will also strengthen the Minister's enforcement powers. They are intended to provide the means for TC to encourage or require railway companies to address deficiencies without having to resort to prosecution. Whether monetary penalties or certificate action are a worthwhile tool in addressing an ineffective or poorly implemented SMS will depend largely on how and when these measures are applied.

Furthermore, proposed new *SMS Regulations*, if adopted in the spring of 2015, will provide greater accountability for SMS implementation within railways through, among other measures, the appointment of an accountable executive and requirements to designate persons responsible for individual processes and procedures outlined in a company's SMS.

---

156 Office of the Auditor General of Canada, *2013 Fall Report of the Auditor General of Canada* (Fall 2013), Chapter 7: Oversight of Rail Safety—Transport Canada, section 7.43, p. 24.

157 Ibid., section 7.58, p. 28.

The regulations should also make it easier to assess a company's SMS against the regulatory requirements, as the new regulations clearly describe the expectations related to required processes. For example, the requirements for a risk assessment would be expanded to include a number of defined triggers where risk assessment must be done, a requirement to identify remedial actions stemming from the risk assessment, and a process for following up to ensure these remedial actions are implemented.

With the legal framework and enforcement tools in place, TC will have the ability to determine whether a company has implemented an effective SMS and to require changes where it finds deficiencies that compromise rail safety. Further, it would appear that TC intends to audit to ensure that railway companies are effectively using their SMS to improve safety. The regulatory impact analysis statement accompanying the proposed *SMS Regulations* states:

> The oversight activities consist of a combination of inspections to verify compliance and audits to verify the effectiveness of company's safety management system. Once the proposed Regulations are in force, Transport Canada would continue to conduct a minimum baseline audit every five years for both railway and local companies. This audit cycle would be complemented by an emergent audit program where audits are conducted at any time during a year.[158]

However, although the impact statement specifies that audits would verify the effectiveness of a company's SMS, it is not clear how this would be carried out or whether the baseline audit would examine the effectiveness of all components of a company's SMS.

The success of this new approach in improving safety will depend on 2 factors. First, railways are rule-based cultures, and the full transition to SMS will require a cultural shift away from strict reliance on rules, to a culture that recognizes that administrative defences alone are not sufficient to maintain safe operations and that seeks to build multiple layers of defence to reduce risks.

Secondly, TC now has a legal and conceptual framework to require SMS implementation, but equally important is how the regulator uses these tools and what action it takes in the coming years. It is crucial that TC follow up on its commitments relating to SMS audits, and on truly ensuring that railways have an SMS in place that is capable of identifying risks and managing them to prevent accidents.

Until Canada's railways make the cultural shift to SMS, and TC makes sure that they have effectively implemented SMS, the safety benefits from SMS will not be realized. Therefore, the Board recommends that:

> The Department of Transport audit the safety management systems of railways in sufficient depth and frequency to confirm that the required processes are effective and that corrective actions are implemented to improve safety.

**TSB Recommendation R14-05**

---

[158] Government of Canada, *Canada Gazette*, Part I, Vol. 148, No. 27 (05 July 2014), Railway Safety Management System Regulations.

*This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 31 July 2014. It was officially released on 19 August 2014.*

*Visit the Transportation Safety Board's website (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.*

# Appendices

## Appendix A – Sequence of events

Notes:
- The data are from rail traffic control radio and telephone recordings, locomotive event recorder, 911 records, etc.
- For acronyms, see Appendix L – Glossary.

| Time | Description |
|---|---|
| 05 July 2013, 1100 | At Farnham, MMA-002 received a mechanical inspection by TC. |
| 1300 | MMA-002 received a brake continuity test with TC present. |
| 1330 | The LE reported for duty. Previously that morning, the LE had made a request to the Farnham RTC to delay the on-duty time from about 1230 to 1330. |
| 1357 | Shortly after departing Farnham, the LE advised the Farnham RTC that the lead locomotive (MMA 5017) could not attain full throttle power, and asked if anyone had reported engine surges on that locomotive. |
| 1456 | The LE advised the Farnham RTC that the train was losing speed, lead locomotive MMA 5017 could still not attain full throttle power, and it was affecting all the other locomotives in the consist. |
| 2000 (approx.) | The LE informed the Bangor RTC of problems with the lead locomotive. |
| 2249 | MMA-002 was stopped at the east siding switch on the main track at Nantes using an automatic air brake application. The locomotive independant air brakes were applied. The LE applied hand brakes to the train and shut down the 4 trailing locomotives. When the LE returned to the lead locomotive, the automatic air brake application was released; however, the independent air brakes remained fully applied. The hand brake effectiveness test was conducted without releasing the locomotive independent air brakes. |
| 2305 | The LE called the Farnham RTC after securing the train and asked the RTC to call a taxi. |
| 2315 | The LE called the Bangor RTC to tell him that the train was secured at Nantes, and that he had shut down 4 of the 5 locomotives. The LE also mentioned that, once he got to Nantes, he noted the excessive smoke from the lead locomotive, changing from black to white. The LE said that he expected it to settle on its own, but was not sure how the locomotive would be the next morning, considering the issues experienced during the day. They decided to leave the train as it was and they would deal with any locomotive performance issues in the morning.<br><br>As per normal practice, the train was left with the lead locomotive door unlocked, as well as the reverser removed and placed on the LE seat with the train's paperwork. |
| 2325 (approx.) | The taxi arrived at Nantes. The taxi driver noted the excessive smoke and oil droplets coming from the locomotive, and asked the LE whether it should be left like that, particularly considering the environmental pollution. |
| 2330 (approx.) | The taxi departed Nantes. |
| 2339 | The LE called the Farnham RTC to indicate his off-duty time of 2345. |
| 2340 | A 911 call was received reporting a fire on a train at Nantes. The call was assigned to the Nantes Fire Department. |

| Time | Description |
|---|---|
| 2350 | The Sûreté du Québec (SQ) informed the Farnham RTC of a fire on a train at Nantes. The SQ advised that firefighters and the SQ were on their way to the site. The Farnham RTC advised the SQ that the train was transporting crude oil. |
| 2352 | The Farnham RTC called the Manager of Operations to advise him of the fire at Nantes and inform him that it was a unit crude oil train. They decided that the closest MMA employee (a former LE and mechanic), residing in Marston, should be contacted and dispatched to Nantes. |
| 2353 | The Farnham RTC tried to reach the MMA employee in Marston twice on his company cellular phone, but was unsuccessful both times. |
| 2355 | The SQ called the Farnham RTC to inform him that the fire was on a locomotive and that the firefighters and SQ were on site. |
| 2358 | The Nantes Fire Department shut down the lead locomotive using the emergency fuel cut-off and opened the breakers on the back electrical panel located inside the locomotive cab. This was following an attempt to extinguish the fire using foam, which resulted in a black oily residue being dispersed onto the ground (discovered at Nantes and just east of where the locomotives were discovered on the Moosehead Subdivision). |
| 2359 | The MMA Track Manager for the Lac-Mégantic area called the Farnham RTC to advise that he had been contacted by the Nantes Fire Department, which had requested that a locomotive technician be sent to the site. After discussion with the fire department, the MMA Track Manager informed the Farnham RTC that the fire, which was on the lead locomotive, was under control, that the lead locomotive had been shut down, and that the Marston employee was on leave. The MMA Track Manager indicated that the MMA Track Foreman residing in Lac-Mégantic should be called and dispatched to the site. |
| 06 July 2013, 0000 | The Farnham RTC called the LE to ask which locomotives had been left running and to advise him of a fire, which he believed to be minor. The Farnham RTC informed the LE that the lead locomotive had been shut down. The LE advised the Farnham RTC that only the lead locomotive had been left running, and asked him if he was required to go to Nantes to start another locomotive. The LE was advised that the MMA Track Foreman was on his way and that they would wait until the morning to start the locomotives. |
| 0003 | The Farnham RTC advised the Bangor RTC that the lead locomotive on MMA-002 had caught fire, that it had been shut down, and that the MMA Track Foreman had been sent on site. They concluded that the lead locomotive would need to be removed and they discussed a workaround for the next morning. |
| 0018 | The SQ called the Farnham RTC to advise that the fire was under control, that the locomotive engine was stopped using the emergency fuel cut-off, and that the fire was in the smoke stack. The Farnham RTC mentioned that the lead locomotive was not usually shut down because of the air brake system. The SQ mentioned that there was damage to the lead locomotive due to the fire. |
| 0023 | The Manager of Operations called the Farnham RTC for an update. The Manager of Operations questioned why the lead locomotive was left running by the LE. The Farnham RTC replied that it was left running to avoid having to perform an air brake test the following day to meet U.S. requirements. |
| 0030 (approx.) | The MMA Track Foreman arrived at Nantes and met with 2 firefighters. |
| 0035 | The MMA Track Foreman informed the Farnham RTC that the fire was extinguished, that all locomotives were shut down and that the electrical breakers in the cab of the lead locomotive had been opened. The Farnham RTC told the MMA Track Foreman to leave things as they were and leave. |

| Time | Description |
|---|---|
| 0044 (approx.) | The MMA Track Foreman and the Nantes Fire Department left MMA-002. |
| 0044 | The Farnham RTC advised the Bangor RTC that the fire was in the smoke stack, that it had been extinguished and that the lead locomotive was shut down. They again discussed the workaround for the next day. |
| 0058 | When the air brake pressure leaked off, MMA-002 began to roll. |
| 0107 | MMA-002 reached a speed of 25 mph. |
| 0114 | MMA-002 reached a speed of 50 mph. |
| 0115 | At Mile 0.23 of the Sherbrooke Subdivision, cars derailed at 65 mph, resulting in a large loss of crude oil and large fire. |
| 0117 | A 911 call was received reporting a fire at Lac-Mégantic. The call was dispatched to the Lac-Mégantic Fire Department. |
| 0129 | The SQ informed the Farnham RTC that there were explosions at Lac-Mégantic and asked him to send someone as soon as possible. The Farnham RTC asked the SQ if the fire was at Nantes or Lac-Mégantic, because MMA-002 was at Nantes. The SQ asked if the Farnham RTC was certain that the train was still at Nantes. The Farnham RTC advised that someone from MMA would be dispatched. |
| 0131 | The Farnham RTC advised the MMA Track Manager of the fire at Lac-Mégantic and that the SQ thought that it involved the train from Nantes. The MMA Track Manager indicated that the MMA Track Foreman would be dispatched. |
| 0148 | The LE advised the Farnham RTC that the whole downtown was on fire and wondered what other cars were in the yard. The LE said that it was not MMA-002 or MMA-001, because they were tied up at Nantes and Vachon, respectively. The Farnham RTC confirmed that there were no dangerous goods in the yard. |
| Starting at 0150 | There were multiple telephone conversations within MMA to try to determine the cause of the fire. The Farnham RTC received reports that a train was seen travelling eastward into Lac-Mégantic. |
| 0239 | The MMA Track Foreman called from Nantes and confirmed to the Farnham RTC that MMA-002 was not there. |
| 0329 | The Farnham RTC told the LE that it was MMA-002 that had run away. The LE advised the Farnham RTC that the train was secured when he left Nantes, and that he had applied hand brakes on all locomotives, the VB car, and the buffer car. |
| 0330 (approx.) | The MMA Track Manager and MMA Track Foreman arrived at the location of the locomotives at Mile 116.41 of the Moosehead Subdivision and re-tightened hand brakes on the locomotives and the VB car. |
| 0436 | The Assistant Manager of Operations called the Farnham RTC who gave a summary of events and advised that hand brakes were applied on all locomotives, the VB car, and the buffer car. The Assistant Manager of Operations stated that this was not enough, and that it was supposed to be 10% + 1. The Farnham RTC mentioned that, normally, after applying hand brakes, they should be tested on the release, and if the LE had tested them, MMA-002 should have held. The Farnham RTC stated that the air likely leaked off and the emergency brakes did not apply. |
| 0539 | The LE advised the Farnham RTC that he had just finished moving the 9 tank cars at the end of the train that did not derail. |

# *Appendix B – MMA-002 train consist*

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| Locomotive 1 | MMA 5017 | 67 | 195 | Diesel-electric locomotive | N/A |
| 1 | VB 1 | 50 | 30 | Specialized caboose | N/A |
| Locomotive 2 | MMA 5026 | 56 | 195 | Diesel-electric locomotive | N/A |
| Locomotive 3 | CITX 3053 | 68 | 193 | Diesel-electric locomotive | N/A |
| Locomotive 4 | MMA 5023 | 56 | 195 | Diesel-electric locomotive | N/A |
| Locomotive 5 | CEFX 3166 | 68 | 196 | Diesel-electric locomotive | N/A |
| 2 | CIBX 172032 | 69 | 105 | Pebbles (used as buffer car) | N/A |
| 3 | TILX 316547 | 59 | 127 | Petroleum crude oil | Medium |
| 4 | WFIX 130608 | 59 | 127 | Petroleum crude oil | N/A |
| 5 | TILX 316359 | 59 | 127 | Petroleum crude oil | N/A |
| 6 | TILX 316338 | 59 | 127 | Petroleum crude oil | N/A |
| 7 | NATX 310428 | 59 | 128 | Petroleum crude oil | N/A |
| 8 | CTCX 735541 | 59 | 127 | Petroleum crude oil | N/A |
| 9 | DBUX 303879 | 59 | 126 | Petroleum crude oil | N/A |
| 10 | WFIX 130682 | 59 | 127 | Petroleum crude oil | N/A |
| 11 | TILX 316641 | 59 | 127 | Petroleum crude oil | N/A |
| 12 | TILX 316570 | 59 | 127 | Petroleum crude oil | Large |
| 13 | NATX 310457 | 59 | 128 | Petroleum crude oil | N/A |
| 14 | WFIX 130638 | 59 | 127 | Petroleum crude oil | Large |
| 15 | NATX 310473 | 59 | 128 | Petroleum crude oil | Small |
| 16 | TILX 316379 | 59 | 127 | Petroleum crude oil | N/A |
| 17 | ACFX 79709 | 59 | 128 | Petroleum crude oil | Large |
| 18 | TILX 316333 | 59 | 127 | Petroleum crude oil | N/A |
| 19 | TILX 316549 | 59 | 128 | Petroleum crude oil | N/A |
| 20 | CTCX 735527 | 59 | 127 | Petroleum crude oil | Large |
| 21 | NATX 310477 | 59 | 128 | Petroleum crude oil | N/A |
| 22 | WFIX 130603 | 59 | 127 | Petroleum crude oil | Large |
| 23 | TILX 316556 | 59 | 127 | Petroleum crude oil | Large |
| 24 | CTCX 735629 | 59 | 127 | Petroleum crude oil | Medium |
| 25 | ACFX 76605 | 59 | 128 | Petroleum crude oil | Large |
| 26 | PROX 44293 | 55 | 127 | Petroleum crude oil | N/A |
| 27 | NATX 310581 | 59 | 128 | Petroleum crude oil | N/A |
| 28 | PROX 44202 | 55 | 127 | Petroleum crude oil | Large |
| 29 | TILX 316234 | 59 | 128 | Petroleum crude oil | N/A |
| 30 | TILX 316584 | 59 | 127 | Petroleum crude oil | Medium |

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| 31 | WFIX 130571 | 59 | 127 | Petroleum crude oil | Medium |
| 32 | TILX 316330 | 59 | 128 | Petroleum crude oil | Large |
| 33 | NATX 310412 | 59 | 128 | Petroleum crude oil | N/A |
| 34 | TILX 316317 | 59 | 128 | Petroleum crude oil | N/A |
| 35 | WFIX 130545 | 59 | 128 | Petroleum crude oil | N/A |
| 36 | ACFX 79698 | 59 | 128 | Petroleum crude oil | N/A |
| 37 | NATX 302784 | 59 | 127 | Petroleum crude oil | N/A |
| 38 | ACFX 71505 | 59 | 128 | Petroleum crude oil | Medium |
| 39 | ACFX 71121 | 59 | 129 | Petroleum crude oil | Large |
| 40 | CTCX 735537 | 59 | 127 | Petroleum crude oil | Medium |
| 41 | NATX 303128 | 59 | 127 | Petroleum crude oil | Medium |
| 42 | CTCX 735572 | 59 | 127 | Petroleum crude oil | Medium |
| 43 | WFIX 130616 | 59 | 127 | Petroleum crude oil | Large |
| 44 | WFIX 130664 | 59 | 128 | Petroleum crude oil | Medium |
| 45 | WFIX 130630 | 59 | 128 | Petroleum crude oil | Small |
| 46 | TILX 316523 | 59 | 127 | Petroleum crude oil | Medium |
| 47 | TILX 316613 | 59 | 127 | Petroleum crude oil | Medium |
| 48 | TILX 316616 | 59 | 127 | Petroleum crude oil | Large |
| 49 | TILX 316206 | 59 | 128 | Petroleum crude oil | Large |
| 50 | TILX 316319 | 59 | 128 | Petroleum crude oil | Large |
| 51 | CTCX 735617 | 59 | 127 | Petroleum crude oil | Large |
| 52 | TILX 316572 | 59 | 127 | Petroleum crude oil | Large |
| 53 | CTCX 735526 | 59 | 127 | Petroleum crude oil | Large |
| 54 | TILX 316622 | 59 | 128 | Petroleum crude oil | Large |
| 55 | WFIX 130585 | 59 | 127 | Petroleum crude oil | Small |
| 56 | NATX 310508 | 59 | 128 | Petroleum crude oil | Small |
| 57 | CTCX 735525 | 59 | 127 | Petroleum crude oil | Large |
| 58 | ACFX 79383 | 59 | 128 | Petroleum crude oil | Medium |
| 59 | PROX 44428 | 59 | 127 | Petroleum crude oil | Large |
| 60 | PROX 44150 | 59 | 127 | Petroleum crude oil | N/A |
| 61 | TILX 316533 | 59 | 127 | Petroleum crude oil | N/A |
| 62 | ACFX 94578 | 59 | 129 | Petroleum crude oil | Large |
| 63 | NATX 310515 | 59 | 128 | Petroleum crude oil | N/A |
| 64 | TILX 316528 | 59 | 127 | Petroleum crude oil | N/A |
| 65 | NATX 310470 | 59 | 128 | Petroleum crude oil | N/A |
| 66 | NATX 310487 | 59 | 128 | Petroleum crude oil | N/A |
| 67 | NATX 310533 | 59 | 128 | Petroleum crude oil | N/A |

| Position in train | Car number | Length (feet) | Gross tons | Commodity | Relative size of breach (if applicable) |
|---|---|---|---|---|---|
| 68 | NATX 310572 | 59 | 128 | Petroleum crude oil | N/A |
| 69 | ACFX 73452 | 59 | 128 | Petroleum crude oil | N/A |
| 70 | NATX 310425 | 59 | 128 | Petroleum crude oil | N/A |
| 71 | PROX 44211 | 55 | 127 | Petroleum crude oil | N/A |
| 72 | WFIX 130629 | 59 | 127 | Petroleum crude oil | N/A |
| 73 | NATX 310406 | 59 | 128 | Petroleum crude oil | N/A |
| 74 | NATX 310595 | 59 | 128 | Petroleum crude oil | N/A |
| 75 | SBU 35924 | N/A | 0 | N/A | N/A |

# *Appendix C – Sources of measurable air leakage from each locomotive on MMA-002*

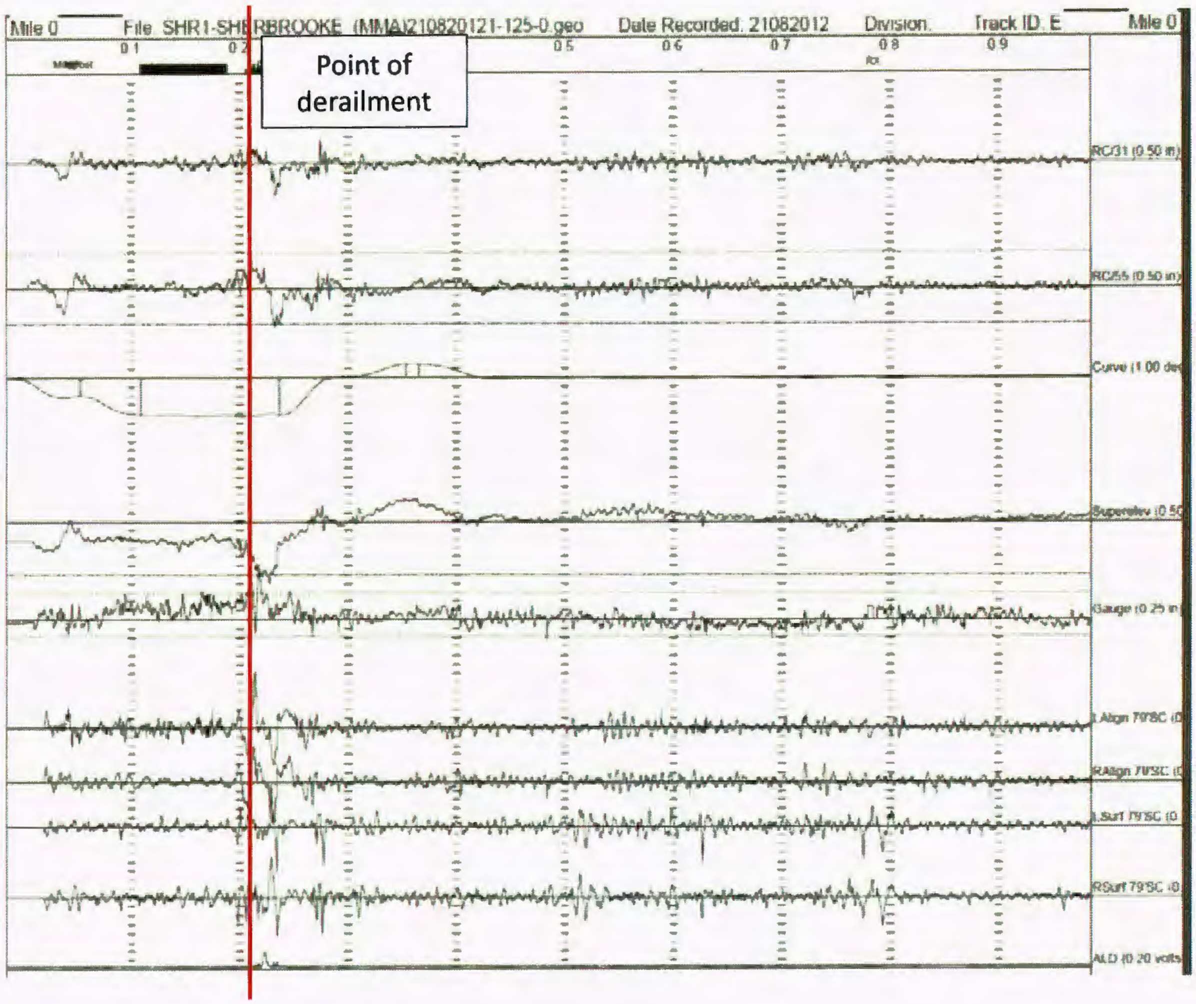
| | MMA 5017 | MMA 5026 | CITX 3053 | MMA 5023 | CEFX 3166 |
|---|---|---|---|---|---|
| Main reservoir | X | X | X | X | X |
| Main reservoir check valve | X | | | X | X |
| Brake pipe | X | X | | X | |
| Bell valve | X | | | | |
| N1 reducing valve | X | | | | |
| Dead engine regulating valve | | | | | X |
| Compressor relief valve | X | | | | |
| 20 line | | X | | X | X |
| Front truck | | X | X | X | X |
| Rear truck | X | | | | X |
| Equalizing valve | | | | | X |

## *Appendix D – Previous brake testing for other occurrences*

The TSB has investigated several other runaway train accidents where extensive hand brake tests were conducted (Coal Valley, Alberta, in 1995 [R95C0282]; Edson, Alberta, in 1996 [R96C0172]; and Dorée, Quebec, in 2011 [R11Q0056]). The following was determined:

- In the case of the 3 runaways, an average of 65 to 80 foot-pounds of torque had been applied on the hand brakes.
- For a constant torque (for example, 80 foot-pounds), the applied force on the wheels varied from 12 000 pounds to 21 000 pounds.
- With 8 hand brakes applied at 125 foot-pounds of brake wheel torque, the 55 cars would have moved down the 0.65% grade. (TSB Rail Investigation R95C0282)
- The cars remained stationary until the air brakes leaked off and released after approximately 7 hours in extreme cold. The retarding brake force was attributed to the applied hand brakes and the air brakes that had not completely released. (TSB Rail Investigation R95C0282)
- There was no guidance from the railway with respect to the sufficient number of hand brakes.( TSB Rail Investigation R95C0282)
- Hand brake operators do not receive any definitive feedback to confirm that sufficient brake shoe force has been attained. (TSB Rail Investigation R96C0172)
- Given the available guidelines and instructions, determining what is a sufficient hand brake application requires more information than the employees had available to them. (TSB Rail Investigation R96C0172)
- Training can provide a better understanding of the relevant variables affecting hand brake effectiveness. (TSB Rail Investigation R96C0172)
- The majority of the car brake cylinders leaked off after approximately 1 hour following the emergency brake application. The leakage was due to the poor condition of the cars. (TSB Rail Investigation R11Q0056)
- To determine the sufficient number of hand brakes to be applied, employees rely on their personal experience gained in situations where cars have either not moved or ran away. (TSB Rail Investigation R11Q0056)
- Without specific instructions that take into consideration local conditions, there is a risk that the number of hand brakes required to secure a train on a steep grade will be underestimated. (TSB Rail Investigation R11Q0056)

# *Appendix E – Track geometry inspection of the Montreal, Maine & Atlantic Railway Sherbrooke Subdivision, between Mile 0.0 and Mile 1.0 (21 August 2012)*[159]




159 Source: Montreal, Maine & Atlantic Railway

# *Appendix F – Summary of crude oil testing results*

The crude oil testing (Engineering Laboratory Report LP148/2013) focused on the characteristics relevant to the classification of the petroleum crude oil, as well as its behaviour and effects during the post-accident spill and fire.

| Characteristic determined | Method | Purpose | Results |
|---|---|---|---|
| Flashpoint (closed-cup) | ASTM[160] D93 | Determine the tendency of the product to form a flammable mixture with air under controlled conditions | < −35 °C |
| Initial boiling point (atmospheric distillation) | ASTM D86 | Determine the lightest fractions present in the product for the purpose of regulatory classification | 43.9 °C to 50.0 °C |
| Density | ASTM D5002 | Determine the tendency of the product to sink or float on water | 815.9 kg/m³ to 821.9 kg/m³ |
| API gravity | Calculated | | 41.8 to 40.5° |
| Reid vapour pressure | ASTM D323 Procedure A | Determine the rate at which the product will evaporate | 62.3 kPa to 66.1 kPa |
| Pour point | ASTM D5853 | - Determine the handling characteristics of the product at low temperatures<br>- Determine the rate at which spilled product in the environment will spread and the extent to which it will penetrate the soil | < −65 °C |
| Viscosity (kinematic) | ASTM D7042 | | 2.882 centistokes (cSt) to 3.259 cSt at 20 °C |
| Sulphur content (total) | ASTM D4294 | - Characterize the product as a sweet or sour crude oil<br>- Determine whether the product presents health hazards to on-site personnel | 0.096 mass % to 0.117 mass % |
| Volatile organic compounds (BTEX: benzene, toluene, ethylbenzene, xylene) | Gas chromatography mass spectrometry | Determine whether the product presents health hazards to on-site personnel | Benzene: 1470 ppm to 1850 ppm |
| | | | Toluene: 2770 ppm to 3170 ppm |
| | | | Ethylbenzene: 768 ppm to 852 ppm |
| | | | m/p-Xylene: 2890 ppm to 3500 ppm |
| | | | o-Xylene: 1500 ppm to 1660 ppm |

160 American Society for Testing and Materials

| Characteristic determined | Method | Purpose | Results |
|---|---|---|---|
| Heat of combustion | ASTM D240 | Determine the total amount of energy that can be released when the product is burned to completion | 42.905 MJ/kg to 45.160 MJ/kg |

## *Appendix G – Safety data sheets of the product loaded in the accident train*

A review of the 10 safety data sheets (SDSs) of the product loaded in the accident train determined the following:

- While most of the SDSs were generic, 1 referred to the product as "Bakken crude".
- There were differences in the chemical composition information presented in the SDSs. For example, while most SDSs identified benzene concentration values ranging between 0% and 1% by weight, 2 SDSs identified benzene concentration values of 2% and 9% respectively.
- All 10 SDSs contained dangerous goods classification and transportation information. All 10 SDSs identified the product as UN 1267, petroleum crude oil, Class 3.
- With respect to packing groups (PGs), the following information was provided:
    - 3 SDSs indicated that the product was a PG I, including the one that described the product as "Bakken crude";
    - 1 SDS that described the product as "Alaska Beaver Creek Crude Oil" indicated that it was PG II;
    - 1 SDS indicated that the product was a PG III;
    - 1 SDS indicated that the product was a PG I or PG II;
    - 2 SDSs did not indicate a PG, but stated that the flashpoint and explosive limits are highly dependent on crude oil source; and
    - 2 SDSs indicated that it was necessary to "determine flashpoint to accurately classify packing group."

# *Appendix H – Other short line runaway train accidents investigated by the Transportation Safety Board*

Since 2005, the TSB has conducted 9 investigations into runaway train events. In addition to this accident, 5 others have involved short line railway operations.

**R11Q0056:** On 11 December 2011, in Dorée, Quebec, a Quebec North Shore & Labrador Railway (QNS&L) freight train, with 2 locomotives and 112 Labrador Iron Mines (LIM) gondola cars, was experiencing problems with its automatic and dynamic brakes. It had been secured by the locomotive engineer on a steep grade with the train air brakes and 35 hand brakes. One hour later, the train's air brakes released, and the 35 hand brakes proved insufficient to hold the train. The locomotive engineer, who was finishing applying hand brakes on the train and waiting for assistance, saw the train moving and jumped on board the lead locomotive. He applied the dynamic brakes, which were not working properly, but the train continued to accelerate as it descended the grade. The train finally stopped when the track leveled off. No one was injured. In March 2012, the Newfoundland and Labrador government ordered thorough brake inspections on each of the iron ore cars. Transport Canada (TC) conducted a safety inspection in Sept-Îles, Quebec, that revealed many air brake deficiencies (for example the brake cylinders were not remaining applied). On 09 February 2012, a notice was issued under section 31 of the *Railway Safety Act* (RSA) to QNS&L regarding damaged rail cars being placed in service or continuing to be in service. The Newfoundland and Labrador government ordered LIM to conduct single-car tests on all its cars. All the necessary work for the cars to comply with the Association of American Railroads (AAR) specifications was completed. QNS&L modified its inspection and brake-test procedures for LIM cars; it now conducts walking brake tests to examine brake cylinders and brake shoes. QNS&L also committed to define the minimum number of required hand brakes to secure cars on heavy grades.

**R09T0057:** On 11 February 2009, in Nanticoke, Ontario, a Southern Ontario Railway (SOR) 0900 Hagersville Switcher, consisting of 4 locomotives and 43 predominantly dangerous goods and special dangerous goods tank cars, ran uncontrolled from Mile 0.10 to Mile 1.9 of the Hydro Spur track. Although the train had a 3-person crew, it had been secured by a single crew member on a 1% grade. After the last crew member departed, the train's automatic brakes released, and the hand brakes were insufficient to hold the train. It ran away, reaching a speed of 20.7 mph, before travelling over a split-switch derail and derailing 9 loaded dangerous goods tank cars. The split-switch derail had been installed at this location because of a previous runaway train accident in 1996 at the same location.

Three Class 111 tank cars loaded with gasoline (UN 1203, flammable liquid) were breached and released approximately 31 000 litres of gasoline. The gasoline did not ignite during the derailment. Two nearby homes were evacuated.

The TSB report noted the following:

- Securing a train consisting predominantly of dangerous and special dangerous goods, adjacent to a major refinery on a descending grade, requires increased vigilance to safely complete the task.
- When only 1 crew member is left to complete train securement tasks at the end of a work shift, the risk for runaway equipment is increased.

- With only 1 crew member left at the end of the shift, the other crew members did not have the opportunity to verify whether the train was properly secured.
- Insufficient company oversight allowed deviations in standard operating practices to occur.

On 20 February 2009, TC issued a notice and order under subsection 31(3) of the RSA, which required SOR management to report in writing by 06 March 2009 how the company intended to resolve the hazard or condition resulting from the failure of SOR employees to properly secure unattended equipment on the Hydro Spur at Nanticoke. On the same day, SOR issued 2 operating bulletins relating to the practice of leaving unattended cars or trains on the Hydro Spur. TC conducted inspections under its audit program between May and August 2009, and conducted follow-up interviews with selected members of management and employees.

**R08V0270:** On 29 December 2008, in Waneta, British Columbia, a Kettle Falls International Railway assignment with 2 locomotives and 12 cars started moving while switching and quickly began to head down a steep grade. When the train, with insufficiently charged air brakes, accelerated to about 20 mph, the locomotive engineer jumped from the train into deep snow and sustained minor injuries. The runaway train collided with stationary cars after travelling 2.8 miles, causing it to derail, along with some of the stationary cars. Subsequent to the accident, TC performed a regulatory inspection which led to the issuance of a notice and a notice and order under Section 31 of the RSA on 12 January 2009. The notice indicated that the operation of movements on grade without a complete understanding of the operation of the air brake system and the functionality of locomotive control features may result in experiencing an uncontrolled movement with serious consequences. The notice and order indicated that the lack of clear train handling instructions related to switching and descending the grade can lead to operating crews descending this grade with less than adequate air and operative brakes to properly control the movement.

**R06V0183:** On 03 September 2006, in Log Cabin, British Columbia, a White Pass and Yukon Route (WP&YR) work train, consisting of 1 locomotive and 8 overloaded ballast cars, ran away down a steep grade. The train reached a speed of about 45 mph before the locomotive and 6 of the cars derailed on a sharp curve. One person was fatally injured, and 3 others were seriously injured. The TSB determined that the train was too heavy due to overloading, and it is likely that the brake systems on all of the ballast cars were functioning at a diminished capacity. On 23 November 2006, the TSB issued to TC Rail Safety Advisory 07/06, Pressure Retaining Valves on WP&YR Ballast Car, indicating that TC may wish to assess the extent to which management ensures that cars are properly equipped and maintained, and that train crews handling these cars have adequate instruction and training to ensure that sufficient control is exercised on mountain grades. On 30 November 2006, the TSB issued to TC Rail Safety Advisory 08/06, Overloading of WP&YR Ballast Cars, indicating that TC may wish to assess the loading practices of engineering service cars. On 12 December 2006, TC issued a letter of non-compliance and a notice to WP&YR citing violations of various TC regulations referenced under the RSA concerning hazards and conditions related to the ballast cars and to the operation of ballast trains. On 05 June 2007, TC issued a notice and order requiring that trains not operate in certain areas unless they are equipped with a system that ensures direct positive communication with the RTC and that facilitates emergency calling recognizable by the RTC. From 04 to 07 June 2007, TC conducted an SMS audit. Following are some of the findings relevant to this investigation:

- Risk assessments were not being carried out.
- WP&YR was in non-compliance with the *Railway Employee Minimum Qualification Standards Regulations* (1987-3).
- There was no documented process describing how the company carries out air brake tests and how it ensures compliance with the *Railway Freight and Passenger Train Brake Rules*.

On 11 June 2007, TC issued a notice to WP&YR concerning several hazards and conditions related to the reliance by the railway on employee familiarity for protection on the main track. TC also sent a letter in regard to train-operation monitoring activities, which revealed several safety-related deficiencies. On 31 July 2007, TC sent a letter to WP&YR directing them to conduct a formal risk assessment on the safe operation of rolling stock when descending grades are greater than 2% and to then develop written procedures. On 31 July 2007, a TC issued a direction to the WP&YR concerning their contravention of Part II of the *Canada Labour Code* regarding the provision of information, training, and instructions to operating employees. WP&YR replied to TC indicating that numerous measures had been taken, such as in training, communications, operating bulletins, and mechanical equipment. WP&YR also provided TC with its corrective action plan to address the findings in TC's report on the June 2007 audit.

**R05H0011:** On 02 May 2005, in Maxville, Ontario, an Ottawa Central Railway (OCR) freight train left 74 cars on the main track with the air bottled at Mile 34.65 of the Alexandria Subdivision while the head-end movement went to switch 2 cars into a customer's spur. As the movement entered the spur, the 74 cars rolled uncontrolled and collided with the movement. As a result of the collision, a Class 111 tank car loaded with denatured alcohol was punctured, and about 98 000 litres of product was released. Approximately 200 people were evacuated for 8 hours. There was no derailment and there were no injuries. After the accident, OCR informed all employees about the risks associated with the practice of bottling the air. For 2 months after the accident, OCR doubled the number of train crew observations, emphasizing the securement of unattended cars while performing en route switching. The number of safety audits performed in 2005 was doubled. OCR also purchased a portable input and display unit (IDU) for transportation supervisors to remotely monitor the end-of-train air brake pipe pressure.

In all these occurrences, the investigation into the operations of these railways identified safety deficiencies in training, oversight, and operational practices. Although the companies had filed safety management system documentation as required by TC, the safety management system was not being used to identify and proactively address deficiencies through formal risk assessment or continuous improvement processes.

# *Appendix I – Single-person freight train operations*

*Single-person train operations implementation outside Canada*

Single-person train operations (SPTO) have been implemented in other parts of the world, including the United States, Europe, Australia, and New Zealand. For example, Danish and Swedish railways use sophisticated automatic train control (ATC) technologies to enforce signal and speed regulations. British railways use an audio-visual safety device called an advance warning system, which warns the driver of signal aspects. A driver's failure to acknowledge the restrictive signal warnings results in the automatic braking of the train. Tranzrail uses a vigilance device that sounds an alarm and stops the train if the driver fails to respond to its demands.

As previously mentioned, SPTO has also been implemented in the United States.

In the 1990s, the SPTO technology later used by MMA was developed and introduced as an efficiency measure at Wisconsin Central Limited (WC). The Federal Railroad Administration (FRA) was not made aware that WC had started SPTO until after a serious train accident (involving a 2-person crew) in Weyauwega, Wisconsin, in March 1996. Operation, maintenance, training, and funding issues were identified at WC during the accident investigation, conditions also identified at a subsidiary company, Tranz Rail Holdings Limited (Tranz Rail), in New Zealand.

In December 2004, MMA's operations in the United States began running dark territory[161] SPTO trains. SPTO operations at MMA had also commenced without FRA awareness. After the FRA became aware of MMA's SPTO operations in 2006, MMA indicated that SPTO had been used successfully on its United States network for about 2 years. MMA was allowed to continue its SPTO. However, the FRA required MMA to produce written SPTO special operating instructions.

In Australia, the Rail Safety Regulators' Panel[162] produced a guidance document for driver-only operations (DOO, the equivalent term in Australia for SPTO). The related regulatory legislation was developed, in conjunction with the rail industry and rail unions. Key elements include:

- Responsibility for the granting and monitoring of accreditation of single-person train operators lies with the local regulators.
- The appropriateness of the operators' approach to SPTO is considered as part of the accreditation process.
- Accreditation is only for the SPTO program as narrowly defined. Any change to the program requires re-accreditation (for example, the introduction of dangerous goods unit trains).

---

161 Dark territory is a term used to describe areas of railway operations where train movements are not governed by train signals.

162 The panel consists of rail safety regulators from all states and northern territories of Australia and New Zealand.

- Risks need to be mitigated "so far as is reasonably practicable"(SFAIRP); this includes considering the likelihood, degree of harm, what can be reasonably known about the risk, the availability of risk-reducing means, and the cost of eliminating the risk.
- Crew cabs must be designed for SPTO, crews must be trained, and clearly defined operating limits must be enforced.
- SPTO must be validated through consultation with stakeholders, including written agreements and testing, as well as trialling before implementation.
- SPTO must be reviewed and approved through a robust assessment by the rail safety regulator, in a manner similar to any other aspect of the company SMS.
- The applicant must provide supporting documentation that demonstrates that SPTO risks have been identified and evaluated, and that controls have been established that achieve management of risk SFAIRP.
- The plan needs to address minimum operating standards in situations where the work conditions have degraded.
- All SPTO-compliant equipment must be documented.
- It should be recognized that the work conditions can skew a worker's willingness to accept SPTO work, and workers should be empowered to refuse work if appropriate controls are not functional. The document recognizes that, when commercial, social, and industrial pressures are applied, it may be unlikely that a worker will refuse to work, even if work conditions are degraded.
- All accreditation decisions and variations are to be documented.

# *Appendix J – Estimated number of hand brakes to secure MMA-002*

The table below shows a summary of the estimated number of hand brakes required to safely secure MMA-002 in various scenarios, based on the factors identified in section 2.3.1. and the brake testing results.

The highlighting in the table indicates the minimum and maximum estimated number of hand brakes required for each scenario (depending on torque and coefficient of friction).

| Scenario | Coefficient of friction | Number of hand brakes required | |
|---|---|---|---|
| | | 80 foot-pounds of operator-applied torque | 100 foot-pounds of operator-applied torque |
| With no air brake application on the cars and including hand brakes on the locomotive consist | 0.38 | 25.9 | 21 |
| | 0.45 | 22.2 | 18 |
| When hand brakes are applied after a 13-psi air brake application, including hand brakes on the locomotive consist (the accident scenario) | 0.38 | 19.9 | 16.4 |
| | 0.45 | 17.2 | 14.2 |
| With no air brake application on the cars and hand brakes applied on the cars only | 0.38 | 24.0 | 19.1 |
| | 0.45 | 20.3 | 16.1 |
| When hand brakes are applied after a 13-psi air brake application and applied on the cars only | 0.38 | 17.1 | 13.6 |
| | 0.45 | 14.5 | 11.5 |

Notes:
- The stationary coefficient of friction between brake shoe and wheel surfaces is 0.38 for normal condition (Wabtec source) and 0.45 for extremely dry clean.
- A rolling resistance of 2.15 pounds/ton is used.
- For scenarios showing a 13-psi air brake application, a 40% improvement in hand brake force was included based on testing.

# *Appendix K – TSB Laboratory reports*

The following TSB Laboratory reports were completed, and are available on the TSB's website at www.tsb.gc.ca:

- LP132/2013 – End of Train Telemetry Download and Analysis
- LP136/2013 – LER Data Retrieval and Analysis
- LP141/2013 – Lac-Mégantic Video Analysis
- LP148/2013 – Analysis of Crude Oil Samples
- LP149/2013 – Field Examination of Tank Cars
- LP151/2013 – Examination of Switch Frog
- LP152/2013 – Examination of Box Car Wheel Set
- LP165/2013 – Tank Car Volume Measurements
- LP167/2013 – Site Survey and Grade Calculations
- LP168/2013 – Metallurgical Analysis of Tank Car Coupons
- LP181/2013 – Locomotive Engine Fire Examination
- LP182/2013 – Examination of Locomotive Wheels and Brake Shoes
- LP184/2013 – Examination of Knuckle and Pin
- LP185/2013 – Examination of Locomotive Air Brake
- LP187/2013 – Brake Force Analysis
- LP188/2013 – Dynamic Simulation and Derailment Forces Analysis
- LP233/2013 – Locomotive Electrical Examination
- LP039/2014 – Derailment Speed Calculation

# *Appendix L – Glossary*

| | |
|---|---|
| AAR | Association of American Railroads (United States) |
| API | American Petroleum Institute |
| ASLRRA | American Short Line and Regional Railroad Association (United States) |
| ASTM | American Society for Testing and Materials |
| b/d | barrels per day |
| BOV | bottom outlet valve |
| CANUTEC | Canadian Transport Emergency Centre |
| CFM | cubic feet per minute |
| CFR | *Code of Federal Regulations* (United States) |
| CN | Canadian National |
| CPR | Canadian Pacific Railway |
| CROR | *Canadian Rail Operating Rules* |
| CSA | Canadian Standards Association |
| CTA | Canadian Transportation Agency |
| CTC | centralized traffic control |
| CWR | continuous welded rail |
| DG | dangerous good |
| DOT | Department of Transportation (United States) |
| ECP | electronically controlled pneumatic (braking system) |
| ERAP | Emergency response assistance plan |
| ERG | *Emergency Response Guidebook* |
| FRA | Federal Railroad Administration (United States) |
| GE | General Electric Company |
| GM | General Motors |
| GOI | General Operating Instructions |
| GSI | General Special Instructions |
| IIS | Inspection Information System (TC) |
| Irving | Irving Oil Ltd. |
| kip | kilopound (1 kip = 1000 pounds) |
| km/h | kilometres per hour |
| LE | locomotive engineer |
| LER | locomotive event recorder |
| m | metres |
| mm | millimetres |
| MMA | Montreal, Maine & Atlantic Railway |
| mph | miles per hour |
| NB Southern | New Brunswick Southern Railway |
| NRC | National Research Council of Canada |
| NTSB | National Transportation Safety Board (United States) |
| OAG | Office of the Auditor General |
| OB | Operating Bulletin |
| OTIS | Operational Tests and Inspections Program |
| PDD | proximity detection device |
| PG | packing group |
| PHMSA | Pipeline and Hazardous Materials Safety Administration (United States) |
| PRD | pressure relief device |

| | |
|---|---|
| psi | pounds per square inch |
| QNS&L | Quebec North Shore and Labrador Railway |
| QRB | quick release brake (valve) |
| QSR | Quebec Southern Railway |
| RAC | Railway Association of Canada |
| RODS | Rail Occurrence Database System (TSB) |
| RSA | *Railway Safety Act* |
| RSC | reset safety control |
| RSI | railway safety inspector |
| RTC | rail traffic controller |
| RWI | Rail World, Inc. |
| SBU | sense and braking unit |
| SDS | safety data sheet |
| SMS | safety management system |
| SMS Implementation Guide | *Guide for Developing, Implementing and Enhancing Railway Safety Management Systems* |
| SMS Manual | Safety Management System Manual (MMA) |
| *SMS Regulations* | *Railway Safety Management System Regulations* |
| SOR | Southern Ontario Railway |
| SPTO | single-person train operations |
| SQ | Sûreté du Québec |
| SSO | Safety Systems Overview |
| SST | Strobel Starostka Transfer, LLC |
| STD | start-to-discharge (pressure) |
| TC | Transport Canada |
| TDG | transportation of dangerous goods |
| *TDG Act* | *Transportation of Dangerous Goods Act* |
| TDG Regulations | *Transportation of Dangerous Goods Regulations* |
| Tranz Rail | Tranz Rail Holdings Limited (New Zealand) |
| TSB | Transportation Safety Board of Canada |
| TSR | *Track Safety Rules* |
| UN | United Nations (product code) |
| VIA | VIA Rail Canada Inc. |
| WC | Wisconsin Central |
| WFSI | World Fuel Services, Inc. |
| 3D | three-dimensional |
| ° | degrees |
| °C | degrees Celsius |
| % | per cent |

# TSB Laboratory Report LP148/2013

## 1.0 Introduction

### 1.1 Description of Occurrence

#### 1.1.1

On 06 July 2013, a unit train carrying petroleum crude oil operated by Montreal, Maine & Atlantic Railway derailed in Lac-Mégantic, Quebec. Numerous tank cars ruptured and a fire ensued. The ambient air temperature at the time of the derailment was reported to be around 21 °C.

### 1.2 Engineering Services Requested

#### 1.2.1

A request was received from the Transportation Safety Board of Canada (TSB) Eastern Regional Operations - Rail/Pipeline office to analyze crude oil samples taken from selected tank cars.

## 2.0 Examination

### 2.1 Sampling Procedure

#### 2.1.1

Crude oil samples were taken from selected tank cars under the direction of a TSB investigator. Table 1 summarizes the sampling details. Samples were collected from the 9 non-derailed tank cars at the end of the occurrence train (MMA-002) that were pulled back to Nantes, Quebec, after the derailment. In addition, samples were taken from 2 tank cars located at Farnham, Quebec, that were part of another unit train operated by Montreal, Maine & Atlantic Railway (MMA-874) that was transporting petroleum crude oil from the same origin as the occurrence train.

#### 2.1.2

No attempt was made to collect samples from the derailed tank cars since all were exposed to the post-derailment fire to some extent. It was considered that this heat exposure would likely have caused volatile components of the crude oil to escape through breaches in the tank and/or during activation of the pressure relief device. Consequently, there was a high probability that any product samples collected from the derailed tank cars would not be representative of the lading prior to the derailment.

#### 2.1.3

Prior to the collection of samples, the vapour space of each tank car was tested using a portable hydrogen sulphide gas detector. No measurable amount of hydrogen sulphide gas was detected.

Table 1 : Crude Oil Samples

| Car initial & number | Location collected | Date collected (YY-MM-DD) | Sampling method (see para. 2.1.4) | Quantity collected | Sample identification |
|---|---|---|---|---|---|
| **NATX 310533** | Nantes | 13-07-07 | A | 250 mL<br>250 mL | NATX310533-A<br>NATX310533-B |
| **NATX 310533** | Nantes | 13-08-07 | C | 1000 mL<br>1000 mL | NATX310533-C-TOP<br>NATX31533-C-BOT |
| **NATX 310595** | Nantes | 13-07-17 | A | 250 mL<br>250 mL | NATX310595-A<br>NATX310595-B |
| **NATX 310595** | Nantes | 13-08-07 | C | 1000 mL<br>1000 mL | NATX310595-C-TOP<br>NATX310595-C-BOT |
| | Nantes | 13-07-23 | B | 250 mL | NATX310406 |

| Car initial & number | Location collected | Date collected (YY-MM-DD) | Sampling method (see para. 2.1.4) | Quantity collected | Sample identification |
|---|---|---|---|---|---|
| NATX 310406 | | | | | |
| NATX 310406 | Nantes | 13-08-08 | C | 1000 mL<br>1000 mL | NTAX310406-C-TOP<br>NATX310406-C-BOT |
| WFIX 130629 | Nantes | 13-07-23 | B | 250 mL | WFIX130629 |
| WFIX 130629 | Nantes | 13-08-08 | C | 1000 mL<br>1000 mL | WFIX130629-C-TOP<br>WFIX130629-C-BOT |
| PROX 44211 | Nantes | 13-07-23 | B | 250 mL | PROX44211 |
| PROX 44211 | Nantes | 13-08-08 | C | 1000 mL<br>1000 mL | PROX44211-C-TOP<br>PROX44211-C-BOT |
| NATX 310425 | Nantes | 13-07-23 | B | 250 mL | NATX310425 |
| NATX 310425 | Nantes | 13-08-08 | C | 1000 mL<br>1000 mL | NATX310425-C-TOP<br>NATX310425-C-BOT |
| ACFX 73452 | Nantes | 13-07-23 | B | 250 mL | ACFX73452 |
| ACFX 73452 | Nantes | 13-08-07 | C | 1000 mL<br>1000 mL | ACFX73452-C-TOP<br>ACFX73452-C-BOT |
| NATX 310572 | Nantes | 13-07-23 | B | 250 mL | NATX310572 |
| NATX 310572 | Nantes | 13-08-08 | C | 1000 mL<br>1000 mL | NATX310572-C-TOP<br>NATX310572-C-BOT |
| NATX 310487 | Nantes | 13-07-23 | B | 250 mL | NATX310487 |
| NATX 310487 | Nantes | 13-08-07 | C | 1000 mL<br>1000 mL | NATX310487-C-TOP<br>NATX310487-C-BOT |
| NATX 310487 | Nantes | 13-08-07 | C | 500 mL<br>500 mL | NATX310487-D-TOP<br>NATX310487-D-BOT |
| NATX 303425 | Farnham | 13-07-25 | A | 500 mL | NATX303425 |
| PROX 44169 | Farnham | 13-07-25 | B | 500 mL | PROX 44169 |

**2.1.4**

Three sampling methods (referred to as methods A, B and C in Table 1) were employed in accordance with ASTM D4057.[1] For method A, a middle sample[2] was collected using a glass pipette ( -inch diameter, 60-inch long). For method B, an upper sample[3] was collected using a plastic bailer.[4] For method C, a peristaltic pump was used to collect lower samples[5] (identified by the suffix BOT in Table 1) and upper samples (identified by the suffix TOP in Table 1), after verifying that no stratification had occurred in the tank car. This was accomplished by collecting a vertical column of liquid representing the liquid in the tank using a COLIWASA in accordance with ASTM D5495.[6] [7] Visual inspection of the COLIWASA samples did not reveal any visible stratification.

**2.1.5**

All samples were transferred immediately from the sampling tool to glass bottles that were hermetically sealed and stored at ambient temperature until testing. Figure 1 shows 2 representative occurrence crude oil samples. The oil was a dark grey, greenish color.

**2.1.6**

The crude oil samples were sent for testing to 4 external laboratories Core Lab.[8], Maxxam Analytical[9], AITF[10] and Casser.[11] The original analytical reports and certificates of analysis provided by the external laboratories are presented in Appendix A.

**2.2 Flash Point Temperature**

**2.2.1**

The flash point temperature is a measure of the tendency of a test specimen to form a flammable mixture with air under controlled laboratory conditions. The flash point is used in shipping and safety regulations to define flammable and combustible materials and to classify them according to their associated hazard. [12] [13] The flash point can indicate the possible presence of highly volatile and flammable constituents in a relatively nonvolatile or nonflammable material.

**2.2.2**

The ASTM D93 test methods cover the determination of the flash point of petroleum products in the temperature range from 40 to 370 °C by a Pensky-Martens closed-cup apparatus. [14] Values less than 40 °C can be measured using the D93 procedure but the precision [15] of such values has not been determined.

**2.2.3**

The ASTM D3828 test methods cover procedures for flash point of petroleum products and biodiesel liquid fuels within the range of -30 to 300 °C, using a small scale closed cup tester. [16] It should be noted that flash point values are a function of the operational procedures, design and condition of the apparatus used. Consequently, results obtained using different test methods may not provide valid correlations.

**2.2.4**

Selected crude oil samples were sent to Core Lab., Maxxam Analytical and AITF for determination of the flash point in accordance with ASTM D93 and ASTM D3828. Samples NATX310406, WFIX130629, NATX303425 and PROX44169 were split so that an approximately 65 mL portion was sent to AITF and the remaining portion (about 185 mL) was sent to Maxxam Analytical. The flash point results are summarized in Table 2. All of the samples gave corrected flash points that were significantly less than 23 °C. [17] Note that as mentioned previously, the different cut-off points reported by the 3 laboratories reflect the differences in apparatus and method used.

Table 2 : Flash Point Results

| Sample identification | Laboratory | Test method | Corrected flash point ( °C)[Note 1] |
|---|---|---|---|
| **NATX310533-A** | Core Lab. | ASTM D93 | <-5 |
| **NATX310533-B** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310595-A** | Core Lab. | ASTM D93 | <-5 |
| **NATX310595-B** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310406** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310406** | AITF | ASTM D3828 | <-30 |
| **WFIX130629** | Maxxam Analytical | ASTM D93 | <-35 |
| **WFIX130629** | AITF | ASTM D3828 | <-30 |
| **PROX44211** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310425** | Maxxam Analytical | ASTM D93 | <-35 |
| **ACFX73452** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310572** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX310487** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX303425** | Maxxam Analytical | ASTM D93 | <-35 |
| **NATX303425** | AITF | ASTM D3828 | <-30 |
| **PROX 44169** | Maxxam Analytical | ASTM D93 | <-35 |
| **PROX 44169** | AITF | ASTM D3828 | <-30 |

Note 1: observed flash point corrected for ambient barometric pressure.

### 2.3 Boiling Point Distribution

**2.3.1**

The ASTM D86 method (atmospheric distillation) is the basic test method for determining the boiling range characteristics of a petroleum product. [18] In this method, a 100-mL sample is distilled in a laboratory batch distillation apparatus at ambient pressure and under prescribed conditions. In ASTM D86 distillation, the initial boiling point (IBP) is the corrected temperature reading at the instant the first drop of condensate falls from the lower end of the condenser tube.

### 2.3.2

The ASTM D7169 method covers the determination of the boiling point distribution and cut point intervals of crude oils and residues using high temperature gas chromatography. [19] A gas chromatography apparatus is used to obtain a chromatogram of the sample (a plot of carbon signal versus retention time) and the boiling point distribution is calculated from this chromatogram after making appropriate corrections. The IBP is determined as the temperature corresponding to an accumulated 0.5% of eluted sample [20] after correcting for sample recovery.

### 2.3.3

The IBP and boiling point distribution of selected crude oil samples were determined by Core Lab., Maxxam Analytical and AITF in accordance with ASTM D86 and ASTM D7169. Table 3 summarizes the IBP results obtained on the crude oil samples. All of the samples tested using the ASTM D86 method gave IBPs ranging from 43.9 to 50.0 °C. The ASTM D86 IBP results obtained by Core Lab. were in good agreement with those obtained by Maxxam Analytical (the difference was 2.0 °C for sample NATX310533 and 4.5 °C for sample NATX310595).

### 2.3.4

Table 4 summarizes the atmospheric distillation results obtained by Maxxam Analytical for the crude oil samples. The atmospheric distillation analysis is also presented as plots of temperature versus volume percent for the 9 samples collected from the occurrence train (Figure 2) and for the 2 samples collected from the comparison unit train in Farnham (Figure 3). All 11 samples gave very similar boiling point distributions.

### 2.3.5

There was some concern that the tank cars lading might have been exposed to heat before the tank cars were pulled back to Nantes, thereby affecting the validity of test results. However, no sign of fire damage such as discolored or burned paint was noted on the tail end tank cars. In addition, no unusual variations were noted in the results obtained from the tail end tank car samples. These samples gave very similar results to those obtained from the comparison unit train, which was not exposed to fire (compare Figure 2 and Figure 3).

### 2.3.6

The ASTM D7169 IBP results obtained for the NATX310406, WFIX130629, NATX303425 and PROX44169 samples were at least 10 °C lower than those obtained using the ASTM D86 method (Table 3). Figure 4 displays the boiling point distributions obtained using the ASTM D7169 method. The 4 samples tested using this method gave similar results. It was noted that the ASTM D7169 method gives slightly higher percent recovered values than the ASTM D86 method in the low boiling point portion of the plot which corresponds to the lighter hydrocarbons (compare Figure 2 and Figure 4). As mentioned previously, the 2 methods have a different definition of IBP and use completely different equipment. Consequently, the temperature ranges covered and the precision are different. This likely explains the different results obtained for the light end portion of the samples.

Table 3 : Initial Boiling Point Results

| Sample identification | Laboratory | Test method | Initial boiling point (°C) Note 1 |
|---|---|---|---|
| **NATX310533-A** | Core Lab. | ASTM D86 | 48.0 |
| **NATX310533-B** | Maxxam Analytical | ASTM D86 | 46.0 |
| **NATX310595-A** | Core Lab. | ASTM D86 | 50.0 |
| **NATX310595-B** | Maxxam Analytical | ASTM D86 | 45.5 |
| **NATX310406** | Maxxam Analytical | ASTM D86 | 46.2 |
| **NATX310406** | AITF | ASTM D7169 | <36.1 |
| **WFIX130629** | Maxxam Analytical | ASTM D86 | 46.7 |
| **WFIX130629** | AITF | ASTM D7169 | <36.1 |
| **PROX44211** | Maxxam Analytical | ASTM D86 | 48.5 |
| **NATX310425** | Maxxam Analytical | ASTM D86 | 44.7 |
| **ACFX73452** | Maxxam Analytical | ASTM D86 | 48.5 |
| **NATX310572** | Maxxam Analytical | ASTM D86 | 43.9 |

| Sample identification | Laboratory | Test method | Initial boiling point (°C)[Note 1] |
|---|---|---|---|
| **NATX310487** | Maxxam Analytical | ASTM D86 | 46.3 |
| **NATX303425** | Maxxam Analytical | ASTM D86 | 46.2 |
| **NATX303425** | AITF | ASTM D7169 | <36.1 |
| **PROX44169** | Maxxam Analytical | ASTM D86 | 46.3 |
| **PROX44169** | AITF | ASTM D7169 | <36.1 |

Note 1: ASTM D86 results corrected to 101.3 kPa

Table 4 : Summary of Atmospheric Distillation Results (ASTM D86)

| Sample id. | Distillation residue (vol. %) | Distillation recovery (vol. %) | Distillation loss (vol. %) | Distillation naphta (vol. %) | Distillation kerosene (vol. %) |
|---|---|---|---|---|---|
| **NATX310533-B** | 32.6 | 66.4 | 1.0 | 32.4 | 15.2 |
| **NATX310595-B** | 23.8 | 75.2 | 1.0 | 34.7 | 15.2 |
| **NATX310406** | 26.2 | 72.8 | 1.0 | 35.9 | 15.0 |
| **WFIX130629** | 32.9 | 66.1 | 1.0 | 32.1 | 15.0 |
| **PROX44211** | 23.1 | 75.9 | 1.0 | 34.1 | 15.2 |
| **NATX310425** | 34.3 | 64.7 | 1.0 | 31.2 | 14.8 |
| **ACFX73452** | 19.7 | 79.3 | 1.0 | 32.4 | 15.2 |
| **NATX310572** | 30.3 | 68.7 | 1.0 | 33.3 | 15.2 |
| **NATX310487** | 31.7 | 67.3 | 1.0 | 33.7 | 14.5 |
| **NATX303425** | 33.8 | 65.2 | 1.0 | 31.3 | 14.9 |
| **PROX44169** | 32.8 | 66.2 | 1.0 | 32.2 | 15.1 |

### 2.4 Density Analysis

#### 2.4.1

The ASTM D5002 method covers the determination of the density and relative density of crude oils that can be handled as liquids at temperatures between 15 and 35 °C. [21] The density is defined as the mass per unit volume at a specified temperature. The relative density is the ratio of the density of a material to the density of water at a stated temperature. The API Gravity is a special function of the relative density at 15.56 °C (60 °F) and is calculated as follows: [22]

$$\text{API Gravity} = \left(\frac{141.5}{\text{Relative density at } 60°\text{F}}\right) - 131.5$$

#### 2.4.2

Four representative crude oil samples were sent to Maxxam Analytical for density analysis. Samples were selected from the tank cars that had given the lowest and highest IBP results (NATX 310572 and PROX 44211 - refer to Table 3). Lower and upper samples were tested for each to verify if any density gradient was present.

#### 2.4.3

The results indicate that the samples collected from tank cars NATX 310572 and PROX 44211 had similar density properties (Table 5). There was no significant difference between the upper and lower samples. This is consistent with the absence of stratification in the tank cars that was visually determined when samples were collected (see paragraph 2.1.4).

Table 5 : Density Analysis of Selected Crude Oil Samples

| Sample identification | Density at 15 °C< (kg/m$^3$) | Relative density at 15 °C | API Gravity |
|---|---|---|---|
| NATX310572-C-TOP | 815.9 | 0.8166 | 41.8 |
| NATX310572-C-BOT | 816.5 | 0.8172 | 41.7 |
| PROX44211-C-TOP | 821.9 | 0.8226 | 40.5 |
| PROX44211-C-BOT | 821.8 | 0.8225 | 40.5 |

### 2.5 Reid Vapour Pressure

#### 2.5.1

Vapour pressure of crude oils is an important physical property that affects general handling and refinery practices. It is also used as an indirect measure of the evaporation rate of volatile petroleum products. The ASTM D323 test method is used to determine the vapour pressure at 37.8 °C (100 °F) of petroleum products and crude oils with IBPs above 0 °C (32 °F). [23]

#### 2.5.2

The Reid vapour pressure of the 4 crude oil samples sent to Maxxam Analytical was determined in accordance with ASTM D323 Procedure A. The results indicate that samples collected from tank cars NATX 310572 and PROX 44211 had similar Reid vapour pressures ranging from 62.3 to 66.1 kPa (Table 6). There was no significant difference between the upper and lower samples.

Table 6 : Reid Vapour Pressure (ASTM D323) and Total Sulphur Content (ASTM D4294) Results

| Sample identification | Reid vapour pressure (kPa) | Total sulphur (mass %) |
|---|---|---|
| NATX310572-C-TOP | 66.1 | 0.096 |
| NATX310572-C-BOT | 64.3 | 0.096 |
| PROX44211-C-TOP | 62.3 | 0.117 |
| PROX44211-C-BOT | 62.4 | 0.117 |

### 2.6 Sulphur Content

#### 2.6.1

The sulphur content of crude oils affects their corrosiveness and toxicity. The ASTM D4294 test method covers the measurement of sulphur in hydrocarbons in the concentration range 0.0150 to 5.00 mass % sulphur. [24] The total sulphur content of the 4 samples sent to Maxxam Analytical was determined in accordance with ASTM D4294. The results indicate that the crude oil samples contained 0.096 to 0.117 mass % sulphur (Table 6). There was no difference between the upper and lower samples.

### 2.7 Fluidity Pour Point and Viscosity

#### 2.7.1

Pour point and viscosity determinations are used mainly to determine the handling characteristics of crude oils at low temperatures. The fluidity properties are also indicative of the crude oil composition. For example, crude oils with a greater concentration of paraffinic compounds generally have a higher viscosity than crude oils having higher concentrations of aromatic and naphthenic compounds. [25]

#### 2.7.2

The ASTM D5853 method covers the determination of the pour point of crude oils. [26] A sample is cooled at a specified rate and examined at intervals of 3 °C for flow characteristics. The pour point is the lowest temperature at which movement of the specimen is observed. Table 7 presents the pour point results obtained on the 4 samples sent to Maxxam Analytical. All of the samples gave pour points below -65 °C.

Table 7 : Pour Point (ASTM D5853) and Viscosity (ASTM D7042) Results

| Sample identification | Pour point ( C) | Kinematic viscosity (mm$^2$/s) Note 1 | | | |
|---|---|---|---|---|---|
| | | Viscosity at 10 °C | Viscosity at 20 °C | Viscosity at 30 °C | Viscosity at 40 °C |
| NATX310572-C-TOP | <-65 | 3.639 | 2.882 | 2.295 | 1.910 |

| Sample identification | Pour point ( C) | Kinematic viscosity ($mm^2/s$) Note 1 | | | |
|---|---|---|---|---|---|
| | | Viscosity at 10 °C | Viscosity at 20 °C | Viscosity at 30 °C | Viscosity at 40 °C |
| **NATX310572-C-BOT** | <-65 | 3.720 | 2.982 | 2.467 | 2.080 |
| **PROX44211-C-TOP** | <-65 | 4.100 | 3.259 | 2.665 | 2.230 |
| **PROX44211-C-BOT** | <-65 | 4.078 | 3.220 | 2.548 | 2.205 |

Note 1: 1 $mm^2/s$ = 1 centistoke (cSt)

### 2.7.3

The ASTM D7042 test method specifies a procedure for concurrent measurement of the dynamic viscosity and density of liquid petroleum products and crude oils. [27] The dynamic viscosity is a measure of the resistance to flow of a liquid under external shear forces. The kinematic viscosity is a measure of the resistance to flow of the liquid under gravity. The kinematic viscosity is obtained by dividing the dynamic viscosity by the density obtained at the same temperature.

### 2.7.4

The kinematic viscosity of the 4 samples sent to Maxxam Analytical was determined using a Stabinger viscometer in accordance with ASTM D7042. The samples were tested at 20 °C, 30 °C and 40 °C and these results were used to extrapolate the viscosity at 10 °C. The results are summarized in Table 7. Slightly higher values were obtained at each temperature for the samples collected from the PROX 44211 tank car than for those collected from the NATX 310572 tank car. In the case of the NATX 310572 samples, the lower sample (NATX310572-C-BOT) gave slightly higher results at each temperature than the upper sample (NATX310572-C-TOP). This trend was reversed for the PROX 44211 samples.

## 2.8 Heat of Combustion

### 2.8.1

The ASTM D240 test method [28] covers the determination of the heat of combustion of liquid hydrocarbon fuels ranging in volatility from light distillates to that of residual fuels. The heat of combustion is a measure of the energy available from a given fuel. The gross heat of combustion is defined in ASTM D240 as the quantity of energy released when a unit mass of fuel is burned in a constant volume enclosure, with the products being gaseous, other than water that is condensed to the liquid state.

### 2.8.2

Table 8 summarizes the gross heat of combustion results obtained on the 4 crude oil samples sent to Maxxam Analytical. Similar results were obtained for the 4 samples, ranging from 18,445 to 19,416 Btu/lb [29] (42.905 to 45.160 MJ/kg). The upper samples (NATX310572-C-TOP and PROX44211-C-TOP) gave slightly higher values than the corresponding lower samples (NATX310572-C-BOT and PROX44211-C-BOT).

Table 8 : Heat of Combustion (ASTM D240) Results

| Sample identification | Gross heat of combustion | |
|---|---|---|
| | (Btu/lb) | (MJ/kg) Note 1 |
| **NATX310572-C-TOP** | 19,247 | 44.770 |
| **NATX310572-C-BOT** | 18,445 | 42.905 |
| **PROX44211-C-TOP** | 19,416 | 45.160 |
| **PROX44211-C-BOT** | 19,164 | 44.575 |

Note 1: 1 Btu/lb = 0.002326 MJ/kg

## 2.9 BTEX Compounds

### 2.9.1

BTEX is the acronym used for a group of volatile aromatic compounds (VOCs): benzene, toluene, ethylbenzene and the xylene isomers. [30] [31] The BTEX compounds occur naturally as constituents of crude oil. They are the most soluble and mobile fraction of crude oil and consequently, readily enter soil and ground water during accidental spills. These substances have toxic effects and are subject to occupational exposure limits. BTEX are classified as priority pollutants regulated by Environment Canada and the U.S. Environmental Protection Agency.

#### 2.9.2

Aliquots (20 mL in volume) were taken from 4 selected crude oil samples and sent to the Cassen laboratory for BTEX analysis using a gas chromatography mass spectrometry (GC/MS) method. [32] The results are summarized in Table 9. The benzene content measured in the 4 samples ranged from 1470 to 1850 ppm [33] (0.147 to 0.185%). Overall, the concentrations obtained for the BTEX compounds ranged from a lowest result of 768 ppm (0.0768%) for toluene to a highest result of 3500 ppm (0.35%) for m/p-xylene. [34]

Table 9 : BTEX Results

| Analyte | CAS number [35] | Analytical results (ppm) | | | |
|---|---|---|---|---|---|
| | | NATX310572-C-TOP | NATX310533-C-TOP | NATX310595-C-TOP | ACFX73452-C-TOP |
| **Benzene** | 71-43-2 | 1850 | 1720 | 1800 | 1470 |
| **Toluene** | 108-88-3 | 3170 | 2870 | 2920 | 2770 |
| **Ethylbenzene** | 100-41-4 | 850 | 768 | 789 | 852 |
| **m/p-Xylene** | 106-42-3 | 3500 | 3300 | 3310 | 2890 |
| **o-Xylene** | 95-47-6 | 1660 | 1560 | 1620 | 1500 |

## 3.0 Discussion

### 3.1 Classification of the Occurrence Crude Oil

#### 3.1.1

According to the Transportation of Dangerous Goods (TDG) regulations [36] and the U.S. Code of Federal Regulations Title 49 [37], liquids or liquids containing solids in solution or suspension are included in Class 3, Flammable Liquids, if they have a flash point less than or equal to 60 °C using the closed-cup test method. Flammable liquids are further classified in one of three packing groups:

- Packing Group I, if they have an initial boiling point of 35 °C or less at an absolute pressure of 101.3 kPa and any flash point;
- Packing Group II, if they have an initial boiling point greater than 35 °C at an absolute pressure of 101.3 kPa and a flash point less than 23 °C; or
- Packing Group III, if the criteria for inclusion in Packing Group I or II are not met.

#### 3.1.2

The flash point results obtained for the subject crude oil samples were all significantly less than 23 °C (Table 2) whereas the IBP results determined using the ASTM D86 method ranged from 43.9 to 50.0 °C (Table 3). Consequently, all of these crude oil samples met the criteria for Class 3, Packing Group II.

### 3.2 Chemical and Physical Properties of the Occurrence Crude Oil

#### 3.2.1

The chemical and physical test results obtained on the 9 occurrence crude oil samples show that there was little variation from tank car to tank car. Lower and upper samples gave similar results suggesting there was no significant stratification of the liquid phase within the tank cars.

#### 3.2.2

Petroleum crude oil has been defined as A complex combination of hydrocarbons. It consists predominantly of aliphatic, alicyclic and aromatic hydrocarbons. It may also contain small amounts of nitrogen, oxygen and sulphur compounds. This category encompasses light, medium, and heavy petroleums, as well as the oils extracted from tar sands. [38] Crude oils are natural products and their chemical and physical properties can vary widely depending upon their origin and extraction method.

#### 3.2.3

Conventional oil, which can range from light to medium in grade, is found in reservoir rocks with sufficient permeability to allow the oil to flow through the rock to a well. The petroleum crude oil on the occurrence train originated from suppliers with producing wells in the Bakken Shale formation region of North Dakota. The Bakken Shale formation is a tight oil reservoir. Tight oil is a type of conventional oil that is found within reservoirs with very low permeability. Most oil produced from low-permeability reservoirs is of the light to medium variety, with a lower viscosity. Advanced production technologies such as horizontal drilling coupled with multi-stage fracturing are required to extract the oil from these tight reservoirs. [39] The hydraulic fracturing process applies pressure by pumping fluids into the wellbore to open up pathways through which the oil can flow into the wellbore. Water is commonly used as the main constituent of the fracturing process fluid to which small amounts of different additives are added to reduce friction and to prevent corrosion and biofouling. [40]

### 3.2.4

Table 10 compares the property results obtained for the occurrence crude oil samples with published values for petroleum products ranging from condensate to heavy crude oil. For simplicity, only the upper samples (NATX310572-C-TOP and PROX44211-C-TOP) are shown since similar results were obtained for upper and lower samples. The published values are taken from the 2013 Crude Characteristics Booklet [41], which is a summary of selected chemical and physical properties of crude oils moved in the Enbridge Pipelines/Enbridge Energy Partners system.

### 3.2.5

The National Energy Board of Canada (NEB) defines light crude oil as oil having a density equal to, or less than, 875.7 kg/m$^3$. [42] The density of the occurrence crude oil samples ranged from 815.9 to 821.9 kg/m$^3$, which meets the NEB definition for light crude oil . These density results were similar to the density reported for MST (Manitoba Sweet Tundra), a light crude oil product (Table 10). The vapour pressure and viscosity properties of the occurrence crude oil samples were also similar to those reported for MST. Heavy crude oils [43] have significantly lower vapour pressure, higher density and much higher viscosity than light crude oils - see for example the WCB product in Table 10.

### 3.2.6

Condensates are mixtures of light hydrocarbons (with some dissolved hydrocarbon gases such as butane and propane) that remain liquid under modest pressures at ambient temperatures. Condensate products are recovered mainly from gas reservoirs and have significantly lower density and viscosity than other crude oils - see for example the CPM (Pembina Condensate) product in Table 10. Published analyses indicate that CPM contains about 80 vol% total C12- (hydrocarbons with 12 carbon atoms or less). [44] It is interesting to note that the occurrence crude oil samples and MST product have similar vapour pressure as CPM, suggesting that their volatility is similar to that of this condensate product. Flash points are not reported in the 2013 Crude Characteristics Booklet.

Table 10 : Comparison of Occurrence and Published Crude Oil Properties

| Source | Product identifier | Total sulphur (mass %) | Reid vapour pressure (kPa) | Density (kg/m$^3$) | Viscosity (cSt) at temperature | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 10 °C | 20 °C | 30 °C | 40 °C |
| **Occurrence test results** | NATX310572-C-TOP | 0.096 | 66.1 | 815.9 | 3.639 | 2.882 | 2.295 | 1.910 |
| | PROX44211-C-TOP | 0.117 | 62.3 | 821.9 | 4.100 | 3.259 | 2.665 | 2.230 |
| **2013 Crude Characteristics Booklet** | CPM (Pembina Condensate) | 0.10 | 70.6 | 757.4 | 1.21 | 1.07 | 0.960 | 0.860 |
| | MST (Manitoba Sweet Tundra) | 0.41 | 71.0 | 825.3 | 4.44 | 3.50 | 2.83 | 2.36 |
| | WCB (Western Canadian Blend) | 3.04 | 22.0 | 927.5 | 285 | 149 | 85.4 | 53.1 |

### 3.2.7

The Environmental Technology Centre (ETC) Oil Properties Database reports the following properties for unleaded gasoline: [45]

- Flash point -30 °C
- Density at 15 °C 750 to 850 kg/m$^3$
- Kinematic viscosity <1 cSt at 38 °C

Comparing these values to the occurrence crude oil results summarized in Table 2, it is apparent that the occurrence crude oil s flash point is similar to that of unleaded gasoline. The density results obtained for the occurrence crude oil samples (see Table 10) are also within the range reported for unleaded gasoline. However, unleaded gasoline has lower viscosity than the occurrence crude oil samples.

## 3.3 Sulphur Content of the Occurrence Crude Oil

### 3.3.1

The Canadian Center for Energy defines sweet crude oil as oil containing less than 0.5 percent sulphur. [46] In the present case, sulphur analysis of representative occurrence crude oil samples gave total sulphur results ranging from 0.096 to 0.117 mass %, meeting the Canadian Center for Energy s definition for sweet crude oil. The total sulphur content of the occurrence crude oil is lower than that reported for the MST product and similar to the CPM product (Table 10). In comparison, the WCB product has significantly higher sulphur content, placing it in the sour crude category.

### 3.3.2

Hydrogen sulphide is a toxic gas that can be present as a dissolved compound in crude oil. It can also be evolved when sulphur compounds in the crude oil decompose during distillation or other heating processes. During an oil spill, the presence of hydrogen sulphide is a safety concern since it is extremely flammable and toxic. [47] In the present case, CTEH [48] monitored the derailment site during the TSB field investigation. No detectable levels of hydrogen sulphide were found. This is consistent with the low total sulphur content measured in the occurrence crude oil samples.

### 3.4 BTEX in the Occurrence Crude Oil

#### 3.4.1

The occurrence crude oil s BTEX content (Table 9) is comparable to typical values reported for crude oils. [49] Table 11 summarizes some of the exposure limits recommended for BTEX compounds. CTEH reported benzene and other VOC contents well above these exposure limits in portions of the derailment site that were extensively contaminated with the spilled crude oil. [50] This is consistent with the significant concentrations of benzene and other VOCs measured in the occurrence crude oil samples (Table 9).

Table 11 : Recommended Exposure Limits for BTEX Compounds [51]

| Substance | ACGIH [52] TLV [53] (ppm) | Exposure guideline comments |
|---|---|---|
| Benzene | 2.5 | Short term exposure limit (15 min)<br>Confirmed human carcinogen |
| Toluene | 20 | Time-weighted average (8 h)<br>Not classifiable as human carcinogen |
| Ethylbenzene | 20 | Short term exposure limit (15 min)<br>Possibly carcinogenic to humans |
| Xylene | 100 | Time-weighted average (8 h)<br>Not classifiable as human carcinogen |

### 3.5 Effect of Crude Oil Properties on the Post-derailment Spill and Fire

#### 3.5.1

Some of the properties that determine crude oil s behaviour and effects during an oil spill incident are: [54]

- the extent to which the oil evaporates, which is related to its vapour pressure;
- the rate at which spilled oil spreads and the extent to which it penetrates the soil, which depends on its viscosity;
- density of the oil, which determines if it is likely to sink or float on water;
- health hazards to on-site personnel from volatile organic compounds and hydrogen sulphide (if present).

#### 3.5.2

Overall, the occurrence crude oil gave low density, low total sulphur, low viscosity, low pour point and low flash point results, generally comparable with other light sweet crude oil products. A high vapour pressure was measured on the occurrence samples, similar to those reported for other light sweet crude oil and condensate products. The IBPs determined by the ASTM D7169 (gas chromatography) method were below 36 °C, corresponding to the normal boiling point for pentane (C5). [55] This suggests there was some content of lighter hydrocarbons in the samples, consistent with their high vapour pressure results.

#### 3.5.3

The low flash point, low IBP and high vapour pressure results obtained for the occurrence crude oil samples suggest that these samples contained some very light hydrocarbons. Given that the occurrence crude oil samples were taken at atmospheric pressure, this could lead to an underestimation of the volatility of the crude oil as the concentration of light hydrocarbons may have been higher at the time of loading, and later reduced due to evaporation losses.

#### 3.5.4

TSB is unaware of any standard methods intended to sample and to quantify the liquefied and/or dissolved gas content of crude oil in tank cars. Although the ASTM D3700 standard practice covers the equipment and procedures for obtaining representative samples of single-phase liquefied petroleum gas (LPG), [56] this practice is not intended for non-specification products that contain significant amounts of dissolved gases, free water or other separated phases, such as raw or unprocessed gas/liquids mixtures and related materials. The same equipment could be used for this purpose but additional precautions would be needed to obtain representative samples.

#### 3.5.5

The event tree for the release of crude oil from derailed tank cars can follow 2 pathways depending upon whether the release is accompanied or not by immediate ignition (Figure 5). Ignition is defined as the onset of combustion (flaming) and 3 conditions must be fulfilled for ignition to occur: [57]

- the material must emanate sufficient quantities of vapours or gases;
- the vapours or gases must be mixed with a sufficient quantity of oxidant (oxygen in air);
- the air-vapour mixture must be at a temperature high enough to auto-ignite (self-accelerative oxidation) or a source of ignition (a spark, small flame or other localized source of heat) must be provided.

**3.5.6**

In the present case, a large number of tank cars sustained large ruptures during the derailment and released their content very rapidly. The spilled crude oil had high vapour pressure and a low flash point (<-35 °C) that was much lower than the temperature at the time of the occurrence (21 °C), indicating it was readily ignitable. Multiple sources of ignition were present at the derailment site such as damaged power lines, derailed equipment, etc. Therefore, all of the conditions required for ignition to occur were present. When the release is a large spill accompanied by immediate ignition (left branch on Figure 5), the result is usually a fireball. The size of this fireball will depend strongly on the amount of flash vaporization and liquid entrainment that occur during the release. [58] This suggests that more volatile materials (with higher vapour pressure) and high speed derailments (with more energetic impacts and release of lading) will result in larger fireballs. Spilled material that does not ignite immediately (right branch on Figure 5) will spread and accumulate into a pool. The size of this pool will continue to increase until a physical boundary is reached or the material is ignited and burns, resulting in a pool fire.

**3.5.7**

The viscosity of the occurrence crude oil was similar to that of other light sweet crude oil products; hence it would be expected to have similar spreading characteristics during a spill. The occurrence crude oil s low viscosity was likely contributory to the rapid spread of the spill and flow of crude oil through the town towards the lake. The occurrence crude oil was very volatile, as indicated by its low flash point and high vapour pressure. To summarize, it is considered that the large quantities of spilled crude oil, the rapid rate of release and the oil s high volatility and low viscosity were likely the major contributors to the large fireball and pool fire.

**3.5.8**

The heat of combustion (also called heating value) is a measure of the total amount of energy that can be released when a fuel is burned to completion. Table 12 compares the gross heat of combustion obtained for the occurrence crude oil samples with values reported in the available literature for other types of fuels. [59] The results obtained for the occurrence crude oil samples are similar to those reported for crude oil, gasoline and diesel fuels, indicating that all of these fuels will release similar amounts of energy under ideal conditions where fuel is burned to completion. However, it is known that this is never the case in real fires. Even under conditions of unrestricted ventilation (in open air), the combustion products contain compounds that are only partially oxidized such as carbon monoxide, aldehydes, ketones and soot (carbon) particles, indicating that not all of the available energy has been released. [60]

Table 12 : Heat of Combustion of Selected Liquid Fuels

| Product | Heat of combustion (MJ/kg) | Density (kg/m³) | Reference |
|---|---|---|---|
| **Occurrence crude oil samples** | 42.905 to 45.160 | 815.9 to 821.9 | Table 8 |
| **Crude oil** | 45.543 | 821.8 | Biomass Energy Data Book |
| **Conventional gasoline** | 46.536 | 722.8 | Biomass Energy Data Book |
| **Conventional diesel** | 45.766 | 812.1 | Biomass Energy Data Book |
| **Ethanol** | 29.847 | 766.2 | Biomass Energy Data Book |
| **Liquefied petroleum gas** | 50.152 | 493.1 | Biomass Energy Data Book |

**3.5.9**

The thermal radiation hazards from hydrocarbon pool fires are known to depend on parameters such as the hydrocarbon composition, size and shape of the pool, duration of the fire and the proximity and thermal characteristics of objects exposed to the fire. [61] Semi-empirical methods are used to estimate the thermal radiation field surrounding a fire. The estimation of the thermal radiation field surrounding the occurrence fire is beyond the scope of the present report. However, temperatures within pool fires have been reported in the available literature. Over a wide range of pool sizes (0.1 to 50 m in diameter), the maximum time-averaged flame temperatures were found to be approximately 900 to 1100 °C, irrespective of the type of fuel. [62]

**4.0 Conclusion**

**4.1**

The flash point obtained for the occurrence crude oil samples was significantly less than 23 °C and the IBP determined using the ASTM D86 method ranged from 43.9 to 50.0 °C. Consequently, the crude oil samples clearly met the federal regulatory criteria for being classified as a flammable liquid of Class 3, Packing Group II.

**4.2**

The occurrence crude oil samples gave low density (815.9 to 821.9 kg/m$^3$), low total sulphur (0.096 to 0.117 mass %), low viscosity (2.882 to 3.259 cSt at 20 °C), low pour point (<-65 °C), low flash point (<-35 °C) and high Reid vapour pressure (62.3 to 66.1kPa) results.

**4.3**

The occurrence crude oil s properties were consistent with those of a light sweet crude oil, with volatility comparable to that of a condensate or gasoline product.

**4.4**

There was no indication that the occurrence crude oil s properties had been affected by contamination from fracturing process fluid additives.

**4.5**

The occurrence crude oil samples were taken at atmospheric pressure. This could lead to an underestimation of the crude oil s volatility due to evaporation loss of very light constituents.

**4.6**

The large quantities of spilled crude oil, the rapid rate of release, and the oil s high volatility and low viscosity were likely the major contributors to the large post-derailment fireball and pool fire.

**4.7**

The occurrence crude oil contained concentrations of BTEX that were comparable to typical values reported for crude oils. This explains why concentrations of benzene and other VOCs well above exposure limits were detected at the derailment site.

## 5.0 Figures

Figure 1 : Photograph showing 2 representative occurrence crude oil samples (NATX310406-C-BOT and NATX310406-C-TOP)


Figure 2 : Atmospheric distillation plots (ASTM D86) for 9 crude oil samples taken from the occurrence train MMA-002

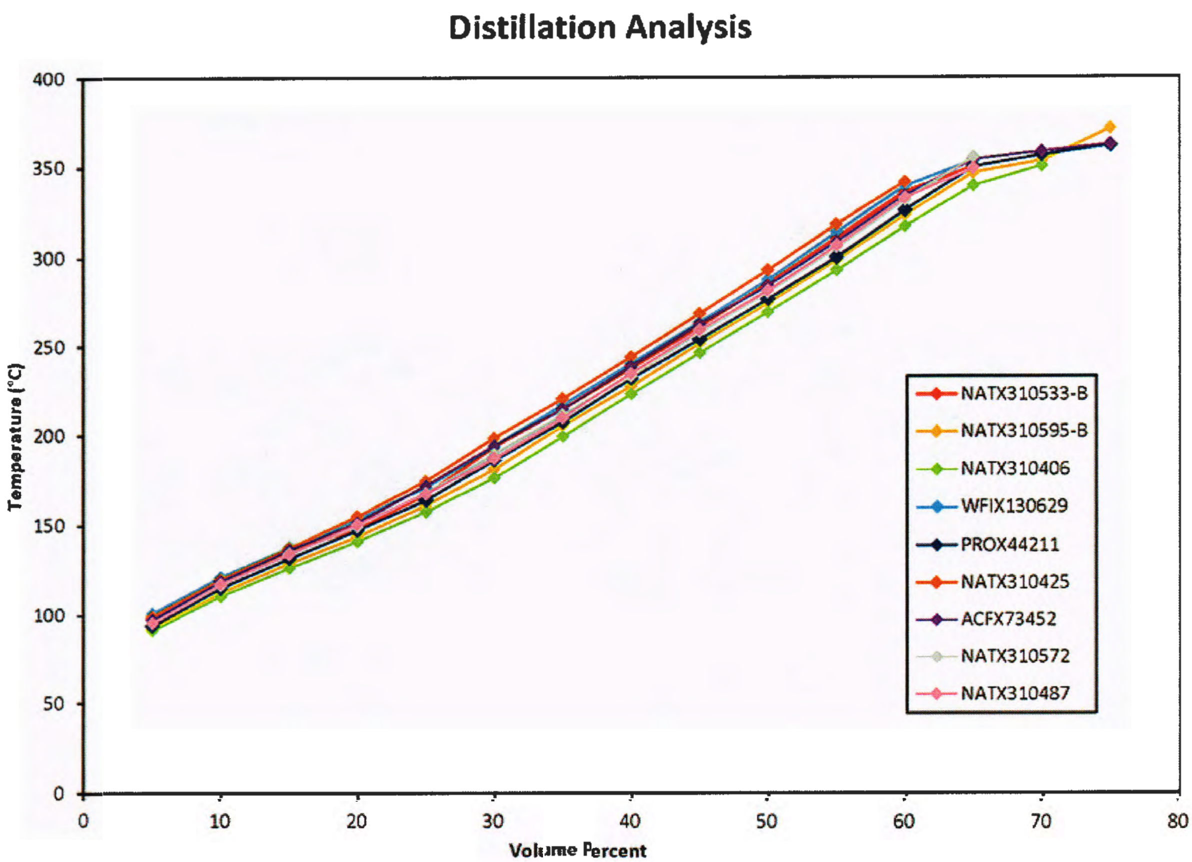



Figure 3 : Atmospheric distillation plots (ASTM D86) for 2 crude oil samples taken from the unit train MMA-874 located at Farnham, Quebec

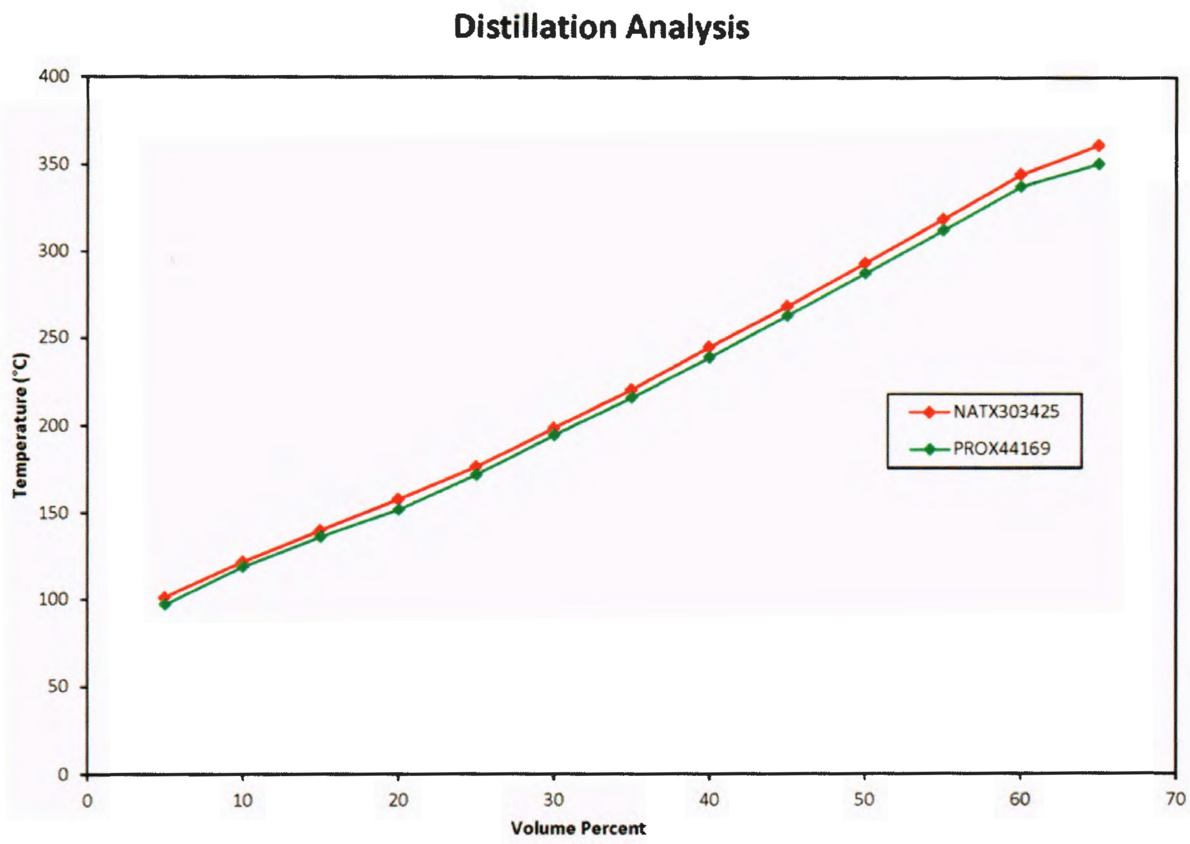



Figure 4 : Boiling point distribution (ASTM D7169)for 4 crude oil samples taken from the occurrence train MMA-002

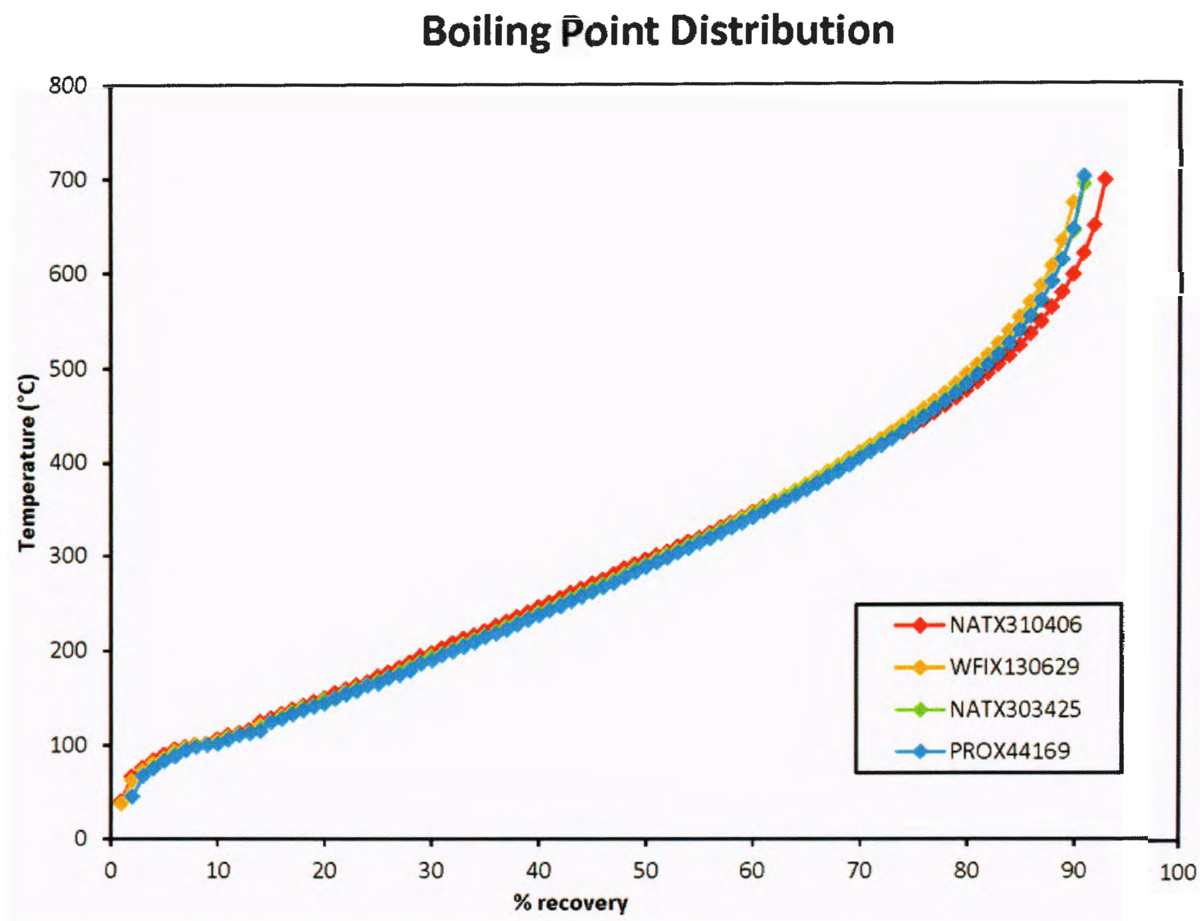
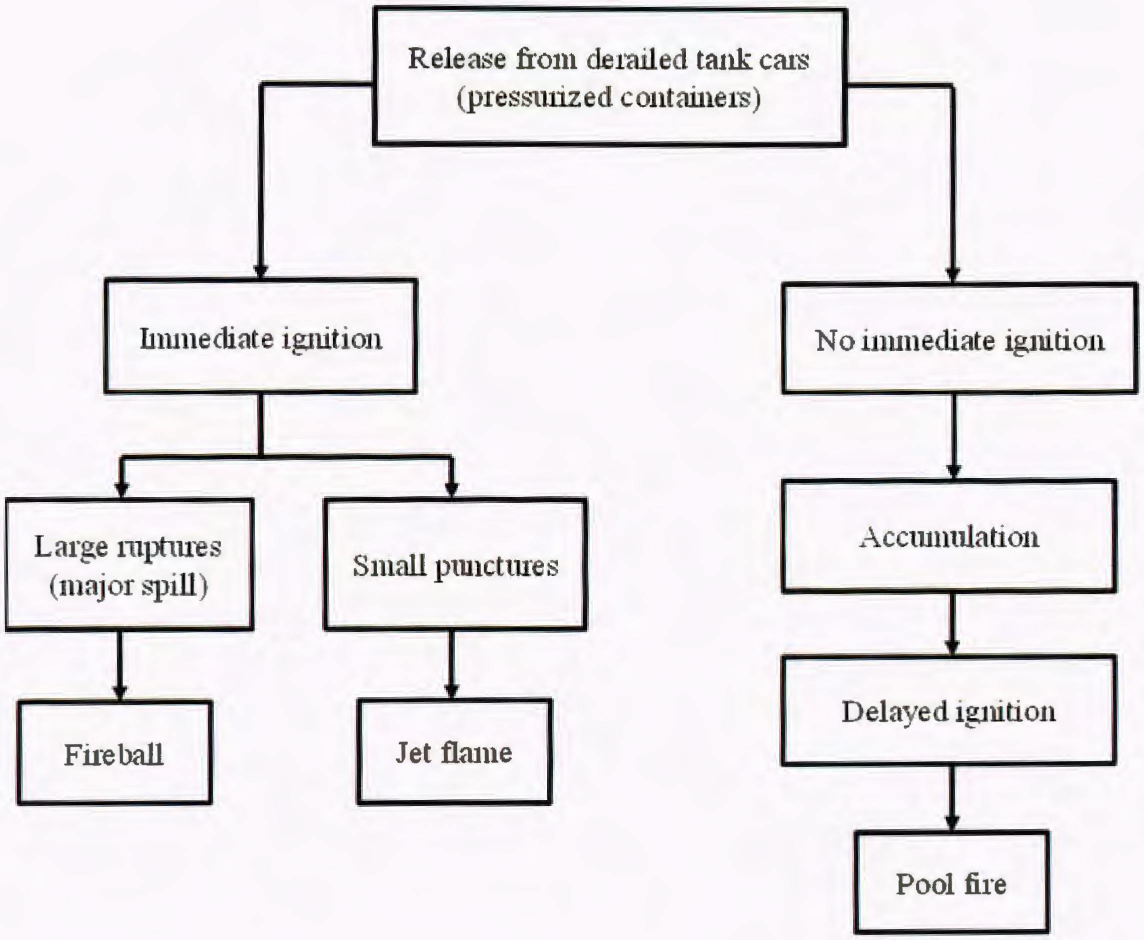



Figure 5 : Event tree for release of crude oil from derailed tank cars [63]




**6.0 Appendices**

**Appendix A: Analytical Reports Provided by External Laboratories**

Analytical reports provided by external laboratories (available in PDF only)

1 ASTM D4057-12 Standard Practice for Manual Sampling of Petroleum and Petroleum Products

2 A middle sample is a sample taken from the middle tank s contents (a distance of of the liquid depth below the liquid s surface) (refer to ASTM D4057)

3 An upper sample is a sample taken from the middle of the upper 1/3 of the tank s content (a distance of 1/6 of the liquid depth below the liquid s surface) (refer to ASTM D4057)

4 The bailer was a 1-meter long by 2-inch diameter cylinder with bottom closure

5 A lower sample is a sample taken from the middle of the lower 1/3 of the tank s content (a distance of 5/6 of the liquid depth below the liquid s surface) (refer to ASTM D4057)

6 ASTM D5495-03(2011) Standard Practice for Sampling with a Composite Liquid Waste Sampler (COLIWASA)

7 The COLIWASA was -inch diameter, 11.6-foot long and made of polypropylene

8 Core Laboratories Canada Ltd., 2810 - 12th Street N.E., Calgary, Alberta T2E 7P7 (accredited to ISO 9001)

9 Maxxam Analytical, 6744 50 Street, Edmonton, Alberta T6B 3M9 (accredited to ISO/IEC 17025)

10 Alberta Innovates-Technology Futures, Fuels and Lubricants Laboratory, 250 Karl Clark Road, Edmonton Alberta T6N 1E4 (accredited to ISO/IEC 17025)

11 Cassen Testing Laboratories, 51 International Blvd. Toronto, Ontario, M9W 6H3 (accredited to ISO/IEC 17025)

12 Canada Transportation of Dangerous Goods Regulations Part II, Class 3 Flammable Liquids, 2.18 General and 2.19 Packing Groups

13 U. S. Code of Federal Regulations Title 49 Part 173.120 Class 3-Definitions and 173.121 Class 3-Assignment of packing group

14 ASTM D93-13 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

15 In this context, precision refers to the statistical control of the test method, that is the degree of agreement among measurements obtained within a single laboratory (repeatability) and between different laboratories (reproducibility) using this method. (http://www.astm.org/COMMIT/D07PrecisonBias2.pdf, web site consulted on 21 January 2014)

16 ASTM D3828-12a Standard Test Methods for Flash Point by Small Scale Closed Cup Tester

17 A flash point less than 23 °C is one of the criteria for classifying a flammable liquid as Packing Group II, see paragraph 3.1.1

18 ASTM D86-12 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure

19 ASTM D7169-11 Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography

20 Elution is the process by which the components of a sample are separated for analysis within the gas chromatography apparatus

21 ASTM D5002-99(2010) Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer

22 Significance of Tests for Petroleum Products, MNL 1, Seventh Edition, Ed. S. J. Rand, (ASTM International, 2003), page 52

23 ASTM D323-08 Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)

24 ASTM D4294-10 Standard Test Method for Sulphur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry

25 Significance of Tests for Petroleum Products, MNL 1, Seventh Edition, Ed. S. J. Rand, (ASTM International, 2003), page 54

26 ASTM D5853-11 Standard Test Method for Pour Point of Crude Oils

27 ASTM D7042-12a Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

28 ASTM D240-09 Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

29 British thermal unit per pound

30 An isomer is one of two or more compounds with the same number and type of atoms but different structure and properties

31 There are 3 forms of xylene in which the methyl groups vary on the benzene ring: meta-xylene (m-xylene), para-xylene (p-xylene) and ortho-xylene (o-xylene)

32 Cassen method M.3005.R0, reference method EPA 600/R-03/072, Characteristics of Spilled Oils, Fuels, and Petroleum Products: 1. Composition and Properties of Selected Oils , July 2003

33 parts per million 34 m-/p-xylene is the combined content of meta- and para-xylene

35 The CAS (Chemical Abstracts Service) number is a unique identifier for a chemical substance. It has no inherent chemical significance but provides an unambiguous way to identify a chemical substance or molecular structure when there are many possible names in use

36 Transportation of Dangerous Goods Regulations Part II, Class 3 Flammable Liquids, 2.18 General and 2.19 Packing Groups

37 U. S. Code of Federal Regulations Title 49 Part 173.120 Class 3-Definitions and 173.121 Class 3-Assignment of packing group

38 Toxic Substances Control Act Definition 2008, http://chem.sis.nlm.nih.gov/chemidplus/rn/8002-05-9, website consulted on 20 November 2013

39 Understanding Tight Oils, Canadian Society for Unconventional Resources, http://www.csur.com/sites/default/files/Understanding_TightOil_FINAL.pdf, website consulted on 21 November 2013

40 http://fracfocus.org/water-protection/drilling-usage, website consulted on 21 November 2013

41 http://www.enbridge.com/DeliveringEnergy/Shippers/CrudeOilCharacteristics.aspx, website consulted on 13 January 2014

42 National Energy Board Act Part VI (Oil and Gas) Regulations SOR/96-244, Section 2

43 The NEB Regulations define heavy crude oil as oil with a density greater than 875.7 $kg/m^3$

44 http://www.crudemonitor.ca/condensate.php?acr=CPM, website consulted on 13 January 2014.

45 http://www.etc-cte.ec.gc.ca/databases/Oilproperties/pdf/WEB_Gasoline_(Unleaded).pdf, website consulted on 14 January 2014

46 http://www.centreforenergy.com/Glossary.asp?EnergyType=1&Template=1,1#83, website consulted on 20 November 2013

47 http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/hydrogen_sulfide.html, website consulted on 20 November 2013

48 Center for Toxicology and Environmental Health, L.L.C. (CTEH ) is a private company specialized in the provision of toxicology and human health consulting services.

49 http://www.etc-cte.ec.gc.ca/databases/oilproperties/Default.aspx

50 This portion of the derailment site, the so called red zone , was not accessible to the public in order to protect the site and prevent the public from any potential exposures.

51 Sources: CAREX Canada (http://www.carexcanada.ca/en/profiles_and_estimates/); Canadian Center for Occupational Health and Safety (http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/), websites consulted on 20 November 2013

52 American Conference of Governmental Industrial Hygienists 53 Threshold Limit Value

54 Properties of Crude Oils and Oil Products Database - Introduction, Environment Canada, http://www.oilproduction.net/files/Introduction.pdf (website consulted on 21 November 2013)

55 Refer to ASTM D7169-11 Table 3 Boiling Points of Paraffins

56 ASTM D3700-12 Standard Practice for Obtaining LPG Samples Using a Floating Piston Cylinder

57 SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Chapter 2-8 Ignition of Liquids

58 Ibid, Chapter 3-10 Fire Hazard Calculations for Large, Open Hydrocarbon Fires

59 Biomass Energy Data Book, Edition 4, Appendix A (U.S. Department of Energy, 2011), http://cta.ornl.gov/bedb, website consulted on 14 January 2014

60 SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Chapter 5-1 Thermochemistry

61 Ibid, Chapter 3-10 Fire Hazard Calculations for Large, Open Hydrocarbon Fires 62 Ibid, page 3-295

63 Adapted from SPFE Handbook of Fire Protection Engineering, 4th Edition (National Fire Protection Association, 2008), Figure 3-10.1, page 3-272

Date modified: 2014-08-19

# The North Dakota Petroleum Council Study on Bakken Crude Properties

## Bakken Crude Characterization Task Force

**Prepared for the**

NORTH DAKOTA
PETROLEUM
COUNCIL

**By**


Turner, Mason & Company
CONSULTING ENGINEERS

Suite 2920, LB 38
2100 Ross Avenue
Dallas, Texas 75201
www.turnermason.com


August 4, 2014


John R. Auers, P.E.
Ryan M. Couture
Dennis L. Sutton

## Table of Contents

## Figures



## Tables

## Appendices

Appendix 1: Additional Figures

Appendix 2: Summary Data

Appendix 3: Sample Conditions - Rail

Appendix 4: Sample Conditions - Well

Appendix 5: Operational Conditions – Well Only

Appendix 6: Lab Data – Rail

Appendix 7: Lab Data – Well

Appendix 8: Light Ends Data – Rail

Appendix 9: Light Ends Data – Well

Appendix 10: Simulated Distillation Data – Rail

Appendix 11: Simulated Distillation Data – Well

Appendix 12: Seasonality Data (Member Contributed)

Appendix 13: Interlaboratory (Round-Robin) Data

Appendix 14: Glossary of Terms

**The North Dakota Petroleum Council Study on Bakken Crude Properties**

**Bakken Crude Characterization Task Force**

**Project Coordinator: Turner, Mason & Company**

## Executive Summary

This report documents the detailed sampling and testing program recently conducted on Bakken crude oil. This program is the most thorough and comprehensive study of crude quality from a tight oil production basin to date.

In the past year, considerable attention has been focused on transportation and quality issues related to Bakken crude oil. As a result of several high profile railcar incidents in the U.S. and Canada, various investigations have been launched by governmental and industry groups to better understand the safety aspects of moving Bakken crude by rail. Questions as to whether Bakken is materially different from other crude oils and if the current railroad materials classification is appropriate have been raised. Investigations are ongoing as to the cause of the railcar accidents and potential hazards to the public associated with crude oil rail movements in general. In response to these concerns, the North Dakota Petroleum Council (NDPC) commissioned a comprehensive sampling and testing program to answer questions regarding the chemical and physical composition of Bakken, issues regarding proper classification and establish a Bakken quality baseline. This program collected samples from seven rail terminals and 15 well sites. The crude producers that provided the well samples account for over 50% of total North Dakota (ND) production, and the rail facilities sampled represent a similar proportion of total ND crude-by-rail capacity. The sampling locations cover the entire producing region and include both "old" and "new" wells, giving a good representation of any property variations that result either from geography, production rate, or during processing and transit. At this time, we are not aware of any field-level crude oil quality assessments as extensive or as controlled as this study in the Bakken or elsewhere.

The NDPC commissioned this program to establish Bakken crude properties (Quality Characterization) and to understand if these properties pose transportation and handling risks unique to Bakken compared to other light crude oils. The results from the study will be used to help establish and maintain a Bakken quality baseline to ensure continued crude quality and consistency. The study was also used to evaluate the impact of field-operating conditions (ambient temperature, tank settling times/production rates, and field equipment operating temperatures and pressures) on Bakken qualities. These study results, together with follow-up efforts, will be used to establish "management best practices" for operating production field equipment to minimize the light ends content and vapor pressure of Bakken crude sent to rail-loading facilities and to meet the proposed quality specifications.

NDPC engaged Turner, Mason & Company (TM&C), an internationally recognized engineering consultancy with over 40 years of experience in the petroleum industry (including a significant background in crude oil quality and processing), to serve as project coordinator. The TM&C team

included engineers with extensive refining and crude characterization/evaluation experience and a chemist with over 40 years of laboratory experience in crude oil analyses who serves as Executive Director of the Crude Oil Quality Association and on the Board of the Canadian Crude Quality Technical Association. Analyses of all primary samples were conducted by SGS, a global leader in testing and inspection with over 135 years in the business. Both the local North Dakota and U.S. Gulf Coast SGS labs participated in the sampling and testing process.

The key findings were as follows:

**Quality Characterization**

- Bakken crude is a light sweet crude oil with an API gravity generally between 40° and 43° and a sulfur content <0.2 wt.%. As such, it is similar to many other light sweet crude oils produced and transported in the United States.
    - As a point of reference, the Energy Information Administration (EIA) categorizes crude oil that has an API gravity between 35° and 50° and less than 0.3 wt% sulfur as light sweet. Bakken falls in the middle of those ranges for both properties.
- Although testing for sulfur, Total Acid Number (TAN) and other corrosivity-specific testing were outside the scope of this project. Results from other test programs, as summarized below in Table 1, indicate that Bakken has very low sulfur and TAN properties.
- Table 1 compares key Bakken qualities to other important domestic and international crude oils:
    - Note the quality data in Table 1 for crudes other than Bakken came from sources without the extensive controls and systematic sampling procedures used in the NDPC study.

**Table 1: Comparison of Crude Properties**

| Domestic Light Sweet Crudes | API Gravity | Sulfur (wt. %) | TAN (mg KOH) |
|---|---|---|---|
| Bakken (1) (2) | 40 to 43* | 0.1 | < 0.1 |
| WTI (4) (5) | 37-42 | 0.42 | 0.28 |
| LLS (2) (4) | 36-40 | 0.39 | 0.4 |
| Eagle Ford (2) | 47.7 | 0.1 | 0.03 |
| Eagle Ford Light (2) | 58.8 | 0.04 | 0.02 |

| International Crudes | API Gravity | Sulfur (wt. %) | TAN (mg KOH) |
|---|---|---|---|
| **Light Sweet** | | | |
| Brent (2) (6) | 37-39 | 0.4 | < 0.05 |
| **Medium** | | | |
| Arabian Light (2) | 33 | 1.98 | < 0.1 |
| Arabian Heavy (2) | 27.7 | 2.99 | < 0.1 |
| **Heavy** | | | |
| Western Canadian Select (Heavy Sour) (3) | 21.3 | 3.46 | 0.93 |
| Dalia (High TAN) (2) (7) | 23.1 | 0.51 | 1.6 |

| Sources: | |
|---|---|
| 1 - NDPC Study Data | 5 - Crude Oil Quality Association |
| 2 – Capline | 6 - BP Crude Assay |
| 3 - crudemonitor.ca | 7 - ExxonMobil Crude Assay |
| 4 - AFPM Bakken Report, 5/14/2014 | * Majority of NDPC samples in this range |

- The qualities of Bakken were very consistent within our sample population and throughout the supply chain – from wellhead to rail terminal to refining destination. Test results showed no evidence of "spiking" with Natural Gas Liquids (NGLs) before rail shipment.

- The test results from this study are also consistent with reported results from others, including the American Fuel & Petrochemical Manufacturers (AFPM) Bakken Report, the Pipeline and Hazardous Safety Materials Administration (PHMSA) Operation Safe Delivery Report, NDPC member-gathered data and other recent studies and presentations on the quality of Bakken crude oil.

**Table 2: Bakken Quality Comparison, NDPC to AFPM and PHMSA**

| | NDPC Rail Avg (1) | AFPM Report | PHMSA Report (5) |
|---|---|---|---|
| API Gravity | 41.7 | 42 | Not Reported |
| Vapor Pressure (psi) | 11.5 | 7.83 (2) | 12.3 |
| IBP (°F) | 100.3 | 69.6 (3) | 87.0 |
| Light Ends (C2-C4s) (Liq. Vol. %) | 4.95 | 3.5-11.9 (4) | 4.65 (6) |

**Comments:**

| |
|---|
| (1) Rail chosen because AFPM samples from Bakken at point of delivery, Rail data from NDPC closest to direct comparison. |
| (2) AFPM reported RVP, NDPC reported $VPCR_4$ (D6377) at 37.8°C. AFPM also reported $VPCR_4$ done at 50°C, results 13.9-16.7 psi. |
| (3) 87.3 Median, Multiple tests in AFPM data, some of which can report lower than D86, which skewed average lower. |
| (4) AFPM report, three respondents average 3.5%, fourth had 12 samples, range 5.9-11.9%. |
| (5) PHMSA data from Table E, data ranging from 3/17 to 5/2, to maximize overlap with NDPC study data timeframe. |
| (6) PHMSA does not report isobutane, and C2-C4 results do not appear to include isobutane. By comparison, NDPC C2-C4 without isobutane was 4.37 Liq. Vol. %. |

- While the test results from PHMSA's report agreed closely with the NDPC results, PHMSA did make some assertions in their Executive Summary which do not appear to be supported by their study or our findings.

- The PHMSA report makes the statement that, "We conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude." No comparative data was provided to support this statement; and, as we note elsewhere in this report, the limited data available on other crudes (that we were able to obtain) would not support that conclusion.

- PHMSA also claims that a higher degree of volatility "correlates to increased ignitability and flammability." Again, no support is provided for this statement in the report. While we are aware that some groups, including API, are studying this very complex subject, we are not aware of any results or conclusions from those studies to date.

- During the time frame of our sampling program, Bakken had an average vapor pressure of between 11.5 and 11.8 psi, which is more than 60% below the vapor pressure threshold limit for liquids under the Hazardous Materials Regulations (43.5 psi).
  - It should be noted that the vapor pressure testing was done using the EPA approved method for crude oils (ASTM D6377), which results in readings about 1 psi higher than if the Reid Vapor Pressure (RVP) test method (ASTM D323) was used.
  - Test data from an NDPC member's rail terminal taken over a seven-month period from August 2013 through March 2014 showed RVP's in the range of 8 to 11 psi; consistent with the NDPC test results when adjusted for seasonality and test method.
  - It is difficult to compare the "typical" vapor pressure of Bakken to other crudes because of the dearth of consistent data (regarding sampling and testing methodologies) for other crudes. Most data show Bakken vapor pressure to be within 2 to 3 psi of other light sweet crudes (some higher, others lower). The AFPM Bakken Report contained the following comparison (versus key crudes), shown below in Table 3. Comparisons from other studies (which are shown later in this report) show similar results.

**Table 3: AFPM Bakken Report, Crude Quality Comparison Table**

| | RVP (psi) | Vol. % Light Ends (C2-C5s) |
|---|---|---|
| LLS | 4.18 | 3.0 |
| WTI | 5.90 | 6.1 |
| Alberta Dilbit | 7.18 | 7.30 wt. % |
| DJ Basin | 7.82 | 8.0 |
| Bakken | 7.83 | 7.2 |
| Eagle Ford | 7.95 | 8.3 |
| Brent | 9.33 | 5.28 wt. % |

- The flash point of Bakken is below 73°F, and the Initial Boiling Point (IBP) generally averaged between 95°F and 100°F, both of which are in the normal range for a light crude oil.

- The data supports the current Department of Transportation (DOT) Pipeline and PHMSA classification for Bakken crude as a Class 3 Flammable Liquid (similar to other crude oils, as well as gasoline, ethanol and other materials containing light components).
- As a result, Bakken crude oil meets all specifications for transport using existing DOT-111 tank cars.
- This conclusion is consistent with the recent AFPM Bakken Report, which stated "Bakken crude oil does not pose risks significantly different than other crude oils or other flammable liquids authorized for rail transport. Bakken and other crude oils have been classified as flammable liquids. As noted, Bakken crude poses a lower risk than other flammable liquids authorized for transport by rail in the same specification tank cars."

- Flammable liquids fall into packing groups (PG) depending on their IBP as defined by the ASTM D86 method. The testing performed in this study highlighted the difficulty with using this test method for packing group determination. The results showed significant (10°F+) variability between labs on the same sample.
    - This is because D86 was not developed for *wide boiling range* materials like crude oil, with no specifically defined lab-operating parameters specified. Therefore, different labs used different operating conditions during testing, resulting in a wide variability of values for the IBP.
- Because of the difficulty with achieving consistent IBP results, groups including API are working on recommendations to update the current regulations.
    - Based upon the findings of this study, the NDPC encourages all members to classify their BKN crude as a Class 3 PG I flammable liquid until a more definitive testing protocol is established.
- It is critical to note that the determination of PG I versus PG II has no impact on the type of rail car used or on first responder response to an incident and had no impact on any of the incidents in which Bakken was involved.
- The accuracy and precision of our test program were ratified by a series of round-robin tests between both SGS laboratories (Williston, ND and St. Rose, LA) and a second internationally recognized testing company.
    - The results of the round-robin testing, using identical samples (from four locations) of Bakken (tested at each of the three laboratories) showed excellent agreement on API gravity and vapor pressure.
    - Significant variance did occur in the measured IBP from the D86 testing, as noted earlier.

- A member company conducted a similar round-robin test comparison with samples of Bakken taken from four rail cars. Duplicate samples were sent to SGS and a second laboratory and the results of this testing also showed excellent agreement on API and vapor pressure and significant differences on D86 IBP.

- A series of side-by-side tests were performed using both the standard sealed glass jars (Boston Rounds, used for testing during the study) and Floating Piston Cylinders (FPCs) which have been suggested by some industry groups for testing vapor pressure.

  - Preliminary results proved inconclusive. Results of samples taken from the atmospheric tanks using the glass bottles came back with higher vapor pressure readings than when tested using either glass bottles or FPCs on the pressurized tank discharge.

  - Due to the requirement to sample from a pressurized tap with FPCs, there are difficulties with sampling and finding appropriate sample locations, which restricts where samples can be collected.

  - These initial results, though limited, indicate that sampling with the glass bottles was at least as representative as testing with FPCs for vapor pressure, and allowed for a greater variety of sample locations with greater consistency.

Table 4 below summarizes the results from the sampling and testing program.

- API gravity of Bakken was generally in the low 40's which falls in the range of what is considered a light crude oil.

- Vapor pressure (via ASTM D6377 at 37.8°C/100°F) was in a fairly tight range, averaging between 11.5 and 11.8 psi, with over 90% of well and 100% of rail samples measuring below 13 psi. As noted earlier, D6377 shows readings about 1 psi higher than the RVP test method (ASTM D323).

- D86 IBP showed a range of approximately 15°F on samples. All samples measured as either a PG I or II, with most of the test results close to the 95°F determination threshold. Because of the limitations of the test and variability of test conditions, the exact result varied depending on which laboratory conducted the testing.

- The light ends (C2-C4s) content of Bakken, which averaged just below 5.5 liquid volume %, is generally within 1 or 2% of other light crudes. Comprehensive data comparable to that obtained in this study for the other major Light Tight Oil (LTO) basins is not available. However, the data, which is available, indicates that Bakken light ends content is more consistent; and in many cases, lower than for most of the light crudes and condensates produced in the major LTO basins (including Eagle Ford, Utica, Niobrara and Permian basins).

- It is important to note that the DOT-111 cars used to transport this crude are rated for 100 psig, and the type of car used is the same for both PG I and PG II material transport.

**Table 4: NDPC Bakken Crude Sampling Data Summary**

| Sample Date Range | 3/25 to 4/24/2014 | | |
|---|---|---|---|
| **Total (152 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 41.0 | 36.7 | 46.3 |
| Vapor Pressure (psi) | 11.7 | 8.9 | 14.4 |
| D86 IBP (°F) | 99.5 (PG II) | 91.9 (PG I) | 106.8 (PG II) |
| Light Ends (C2-C4s) | 5.45 | 3.33 | 9.30 |
| **Rail (49 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 41.7 | 39.2 | 44.0 |
| Vapor Pressure (psi) | 11.5 | 9.6 | 12.9 |
| D86 IBP (°F) | 100.3 (PG II) | 96.7 (PG II) | 104.1 (PG II) |
| Light Ends (C2-C4s) | 4.95 | 3.91 | 6.44 |
| **Well (103 Samples)** | **Avg** | **Min** | **Max** |
| API Gravity | 40.6 | 36.7 | 46.3 |
| Vapor Pressure (psi) | 11.8 | 8.9 | 14.4 |
| D86 IBP (°F) | 99.1 (PG II) | 91.9 (PG I) | 106.8 (PG II) |
| Light Ends (C2-C4s) | 5.69 | 3.33 | 9.30 |

The results indicate that the well-to-well quality of Bakken is very consistent. Testing across the geographic area showed very limited geographical variation in key properties such as API, vapor pressure and light ends content. Data provided by one of the NDPC member companies (which involved testing over an eight-month period) showed that while there was some seasonality in vapor pressure, it was not significant (3 psi lower in summer months vs. winter months) and it agreed very closely with the AFPM seasonality data. The data was also consistent with the NDPC test results during the period when the sampling overlapped.

Bakken quality, throughout the supply chain in our sample pool, was also consistent. There was no evidence of "spiking" of Bakken crude with NGLs between the well and rail terminals, with rail terminals showing less variation and tighter averages than well-readings. This was expected, given that regional rail facilities receive oil from many wells. Additionally, limited sampling at both the rail terminal and destination refinery showed no significant weathering or off-gassing of light ends in transit.

**Operating Conditions/Impact on Bakken Quality**

In addition to characterizing the quality of Bakken crude, our study looked at the impact that well site operating conditions have on the quality. These conditions include ambient temperature, production volume flow rates/field tank settling time, vapor capture status and field equipment operating parameters such as separator and treater temperatures and pressures. All of these measurements were recorded during the sampling program and have been correlated to determine how they impact test results. Based on this analysis, we offer the following observations and conclusions:

- The samples were gathered during the spring season (late March to late April) and ambient temperatures varied from a low of 10°F to a high of 65°F (average of about 34°F).

- Vapor pressure will vary by season with lower vapor pressures (lower levels of dissolved light ends) in the hotter summer months and higher vapor pressures (higher levels of dissolved light ends) in the colder winter months. This was confirmed by the member-contributed data referred to earlier in this section (and included later in this report).
    - The results during this sampling program were in the intermediate range due to the mid range ambient temperatures experienced during sampling.
    - Although the temperature range was limited, vapor pressure levels did correlate with temperatures (consistent with the more extensive member contributed data and the AFPM data), and with higher measured vapor pressure for crude sampled with lower ambient temperatures.

- While the companies operating in the Bakken, which participated in our sampling program, use a variety of well site production equipment and operating conditions (production rates, equipment operating pressures and temperatures) varied across the study, key crude qualities from our study were distributed across a fairly narrow range.
    - The data consistency indicates that field equipment is limited in its ability to significantly impact vapor pressure and light ends content.
    - This is consistent with the expected capabilities of the equipment.
    - The field equipment is designed to separate gas, remove water and break emulsions to prepare crude for transport, and not remove significant levels of dissolved light ends from the crude.

- Despite the limitations of the field equipment, the data did show that the content of some of the lighter components, specifically ethane and propane, was reduced in a measureable way by running the equipment at higher temperatures.
    - The difference between running cold (50°F) and running at close to the maximum practical temperature (150°F) resulted in an average reduction of 0.13 liquid vol. % ethane and 0.25 liquid vol. % propane, and about 0.40 liquid vol. % of total light ends reduction.
    - Total ethane levels were almost universally below 0.20 liquid vol. % (and often closer to 0.10 liquid vol. %) when treaters were run at temperatures above 140°F, compared to levels averaging around 0.30 liquid vol. % (and as high as 0.40%) when temperatures were less than 100°F.
    - It is important to note that true "plant tests" were not conducted where the field equipment temperatures and pressures were varied systematically at individual well sites, but rather results correlated across all samples at all locations.

- Production rates were also obtained at the time of sampling in an effort to determine whether higher flowing wells retained more light ends and had a higher vapor pressure than lower flowing wells where there was more opportunity to "weather" off the light components.
    - The data from the study showed very limited correlation between production rates and vapor pressure.
    - There was also little difference observed in vapor pressure between samples which were obtained from wells which were directly connected to a gathering system (no settling time) versus those which were obtained from stock tanks (where there was an opportunity for settling).
    - As with the analysis of treater conditions impact on crude quality, the fact that this analysis was not done under systematic "plant test" conditions does not confirm that there is not some impact on vapor pressure, but rather that the impact is likely limited.

**Conclusions and Recommended Action Steps**

- Bakken is a light sweet crude oil with very consistent properties throughout the entire production basin, and the properties measured meet all the requirements of 49 CFR 171-180 for safe transport by rail or truck.
- Based on the results of this study, the NDPC has developed a set of Field Operations Recommended Best Practices. These cover the operation of the field treating equipment, Bakken crude oil quality, testing procedures and shipping classification, and are detailed in Table 5 below:

**Table 5: BKN Field Operations Recommended Best Practices**

| Field Treating Equipment (In an effort to minimize light ends in crude oil presented for market) |
|---|
| • Design and operate all equipment within manufacturers recommended operating limits.<br>• Operate Gas/Liquid Separator (if utilized) at the lowest pressure to accommodate gas sales and fluid delivery to the Emulsion Separator/Heater Treater.<br>• Operate Emulsion Separator/Heater Treater pressure to the lowest operating pressure to safely accommodate gas sales and fluid delivery to the production tank battery.<br>• Maintain all fired treating equipment (Emulsion Heater Treater, etc.) temperature between 90° and 120° F+ year round.<br>• Provide maximum tank settling time possible prior to shipment.<br>• Reduce stock tank pressure to lowest pressure possible to maintain vapor collection equipment (engineered flare, vapor recovery, etc.) operational integrity. |

Typical **BKN** * Specifications (ranges reflect expected seasonality)

| | Range | Typical |
|---|---|---|
| • API Gravity (hydrometer at 60°F) | 35° to 45° | 42° |
| • Vapor Pressure (ASTM D6377 @ 100°F) | 8 to 15 psi | 11.5 psi |
| • Initial Boiling Point (ASTM D86) | 90°F to 105°F | 95°F |
| • Sulfur | <0.3% | 0.15% |
| • $H_2S$ | <10 ppm | <1 ppm |
| • Light Ends (C2 – C4s) | 3% to 9% | 5% |

***BKN** refers to light sweet crude aggregated at rail and pipeline terminals within the Williston Basin. This crude is predominantly sourced from the Bakken common source of supply, but also includes legacy production from various other producing formations located within the proximity of the Bakken field. **BKN** does not include nonstabilized condensate recovered from wet gas gathering pipelines or from product derived outside the U.S. Williston Basin. Individual well values may be higher or lower than the aggregated values observed at the rail terminals.

Testing Procedures

- Well Site Operators/Purchasers – Prior to each custody transfer or LACT EOM
  - API gravity corrected to 60° F using hydrometer
  - Basic Sediment & Water (BS&W) by field centrifugal grind-out
  - Spot test vapor pressure pending available field testing equipment
- Rail/Pipeline Terminal Operators
  - Test each unit train loading or tank shipment batch
    - API gravity corrected to 60° F using hydrometer
    - BS&W by field centrifugal grind-out
  - Test at least midmonth and EOM
    - ASTM D6377 @100° F vapor pressure using certified laboratory
- DOT PHMSA Hazmat Shipping Category
  - Flammable Liquid Category 3
  - Packing Group I**

** PG I is recommended even though the majority of samples tested for the study would fall within specifications for PG II. The margin of error for the test methodology can result in different labs testing the same sample with values meeting both PGs. PG I has the more stringent standards and is therefore recommended to avoid further confusion.

- Other recommended procedures
  - DO NOT deliver fluid recovered from gas pipe lines (a.k.a. "pigging operations") to crude oil sales system unless processed by stabilization unit capable of lowering vapor pressure below 10 psi at 100° F.
  - DO NOT blend non-Williston Basin crude oils into the BKN common stream.
  - DO NOT blend plant liquids (plant condensates, pentanes, butanes or propane) into the BKN common stream.

## Introduction

Bakken crude has been produced for over 60 years, recently passing the one-billion-barrel produced milestone. Bakken is moved by rail, pipeline and truck, and has been for decades. In the last few years, crude-by-rail has increased rapidly as production has topped one million barrels per day, and as such, the opportunities for incidents to occur have increased. Bakken is finding its way to refining markets across the country, including along new routes to the East and West Coasts, increasing rail traffic on those tracks. Recently, several high profile incidents in which Bakken crude was being transported brought public attention on the potential hazards of crude-by-rail. Bakken has had an increased focus recently, in large part due to the disaster in Lac Megantic, Quebec, in July 2013, where 47 persons lost their lives. While human error played a significant role in the cause of the accident, the DOT-111 rail cars involved have been heavily scrutinized. The reality is that no rail car is designed to always withstand the full force of a high-speed derailment; and once containment is breached during such an event, there are countless ignition sources.

Government focus on these accidents has brought up the potential for changing regulations around the transport of Bakken (or other light crudes). The oil and gas industry has been building newer style rail cars since 2011, moving toward replacing the older DOT-111 cars with revised cars that have thicker side shells and other safety improvements. Additionally, regulations imposed since the accident in Quebec have required both increased testing of crudes and notification of routes before shipment. Industry focus is on ensuring that all activities are conducted with a focus on safety, but the industry expresses concerns about additional testing requirements, regulations, or transitions to new transportation or handling methods without a scientific basis that those changes will have a significant safety impact. The industry supports regulations that are implemented through scientific investigation and factual basis, not implemented emotionally. The PHMSA Bakken Blitz study was started for that purpose. While the federal government has been criticized for not moving immediately, they recognized the importance of researching the material, railcars and railcar movements to propose rules that increase overall safety. It is with the focus on maintaining a scientific basis for decisions that this study was commissioned.

The scope of this NDPC study was to perform a comprehensive, controlled sampling of Bakken from a wide range of geographic locations at both individual wells and rail terminals. The controlled sampling ensured the same, consistent sampling techniques were used. Samples were sent to a single laboratory for testing, and thus the same methods and equipment were used. This ensured the data would be more consistent than data aggregated from many member companies, each using different labs and sometimes different test methods.

In addition to the direct sampling of the seven rail terminals and 15 well sites, additional data was collected. In order to evaluate the impact that shipping may have on crude; samples were taken at the rail terminal in Fryburg, ND, as well as upon receipt in St. James, LA. The same rail cars were sampled in both locations, and samples were sent to the same testing provider for analyses. Another set of testing on an individual well was performed to determine laboratory test variability. Samples were taken at the same time, but sent to two different labs: SGS (the primary lab used for this study) and a second internationally recognized lab. This resulted in some variance, primarily around D86 IBP measurements, which are critical for proper PG determination. A third test was performed to compare D86 measurements between two SGS labs. One lab also did testing by varying some of the test parameters around D86 instrument setup. The results highlighted the opportunity for significant variability of results and the limitations of using the D86 test method on crude oil samples, which have wider boiling ranges than the method was intended.

Testing was conducted starting March 25 and continued through April 24, 2014. Through the course of testing, sample data was collected, including the following:

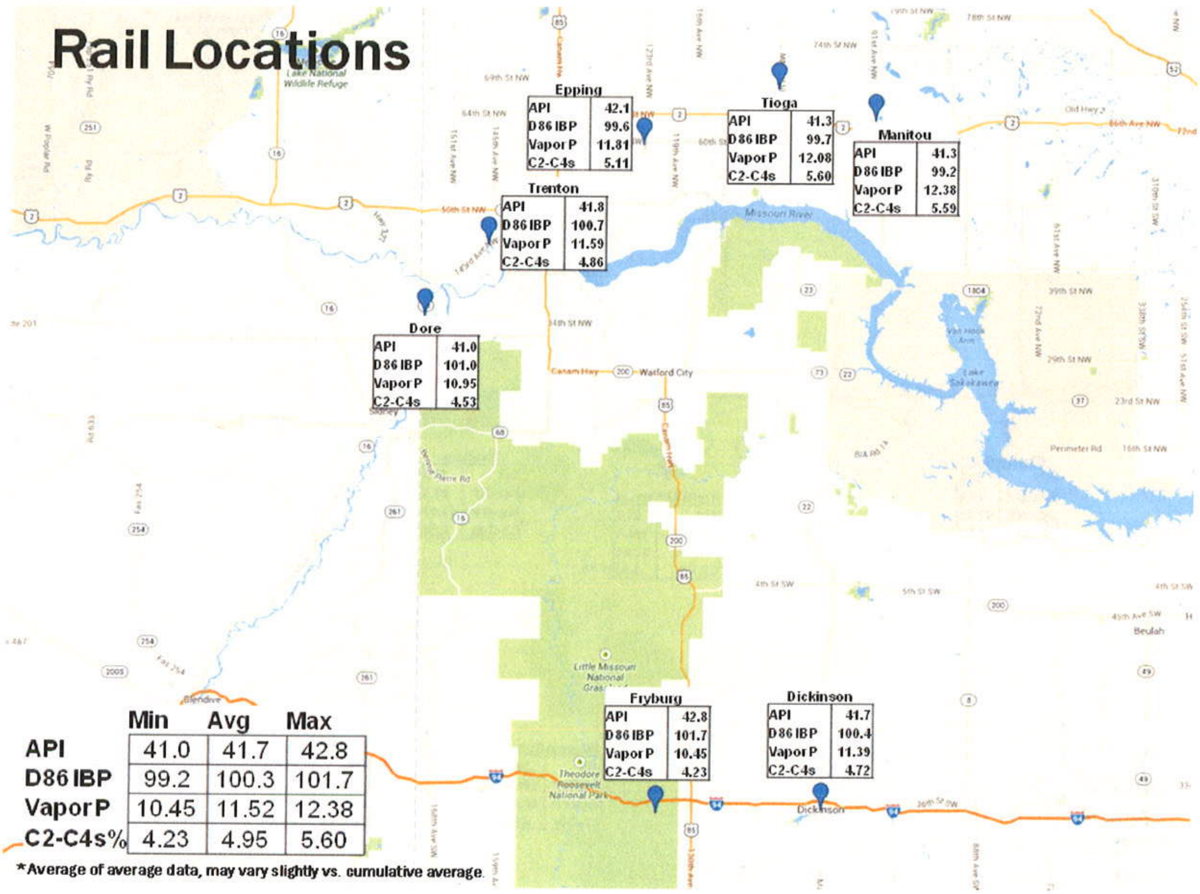
- Sample Date, Time, Company, Location (Geographic and Facility/Well ID);
- Ambient temperature at time of sampling;
- Size of tank where sample was pulled from;
- Location in tank (top, bottom, or composite) where sample was taken;
- For samples taken at well, operating conditions including treater/separator operating pressure and temperature, as well as production rates were recorded;
- API Gravity;
- D86 IBP;
- Vapor Pressure via D6377, as measured at 37.8°C/100°F with a 4:1 V/L ratio;
- Flash Point via D3278;
- Light Ends via IP344; and
- Simulated Distillation via D7169.

Details on the sample conditions at time of sampling were recorded to evaluate what parameters may have an impact on the sample results. All samples were taken in sealed one-quart glass bottles, consistent with testing for stock oil tanks. The process was similar to the procedure used for finished gasoline testing with RVPs up to 15 psi.

On the first visit to each location, samples were taken at both the top and bottom of the tank. This was done to determine if there was a variance or stratification taking place in tanks, either at the well or at the rail terminals. On subsequent visits, samples at each location were composite samples of the tanks.

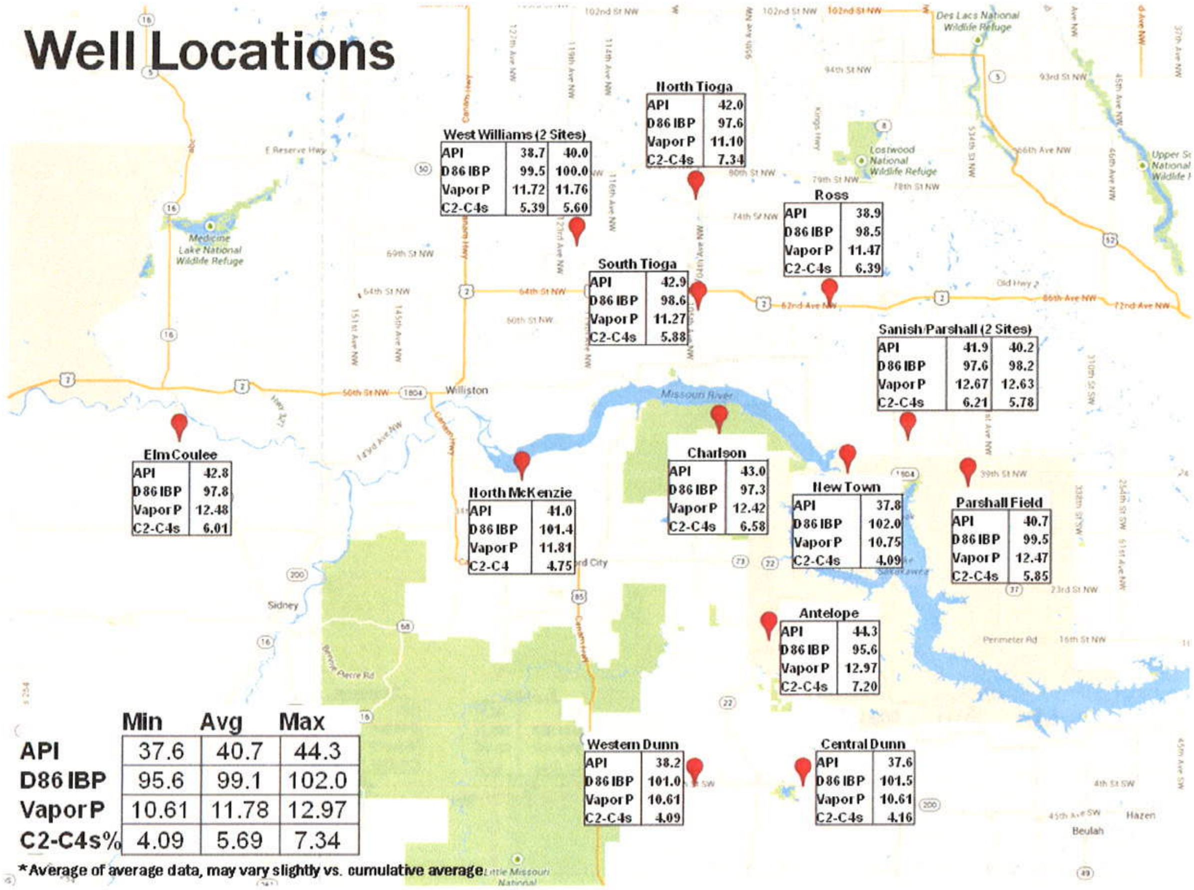
In order to capture any variances seen across the Bakken formation, sites were chosen to ensure a wide variety of locations. The points have been plotted on the maps below with corresponding average sample data for each location. The map of rail locations sampled, along with corresponding data is shown in Figure 1.

**Figure 1: Rail Sample Locations, With Average Sample Results**




The map of well locations sampled, along with corresponding data is shown in Figure 2.

**Figure 2: Well Sample Locations, With Average Sample Results**




## Test Results/Analyses

Sampling was conducted beginning March 25, 2014. Each site was sampled from their stock or storage tank. For each location, a top and bottom tank sample was taken once, with the remainder of samples taken as a composite. Samples were spaced every few days to gain the most representative snapshot during the test period. All testing was completed on April 24, 2014. A complete listing of sample dates/times by location (along with all data) can be seen in the appendix. A breakdown of the samples is as follows:

- API Gravity: 152 Samples;
- D86 Initial Boiling Point (IBP): 152 Samples;
- Vapor Pressure (D6377): 152 Samples;
- Flash Point (D3278): 152 Samples;
- Light Ends (IP344): 152 Samples; and
- Simulated Distillation (D7169): 111 Samples.

## API Gravity

API Gravity was measured on all samples taken. API is a common property used to compare the relative density of a given petroleum liquid. While reported in degrees API gravity, it inversely correlates to the measured density of the liquid tested. For light crudes, the API gravity is generally around 40-45 API. Of all Bakken samples tested, the API gravity ranged from 36.7 to 46.3 API, averaging 41.0 API. The average for rail samples was slightly higher at 41.7 API, but with a tighter range of 39.2 to 44.0 API. These are all within the range expected for light crudes. By comparison, the common benchmark conventional light crudes, West Texas Intermediate (WTI) and Light Louisiana Sweet (LLS), measure 36-42 API. Bakken is not substantially lighter than other conventional light crudes. Higher API crudes may, but do not necessarily correlate with higher vapor pressure crudes. Figure 3 shows the distribution of API gravity data, and Figure 4 shows a plot of API gravity vs. measured vapor pressure.

**Figure 3: API Distribution; Total, Rail, Well**

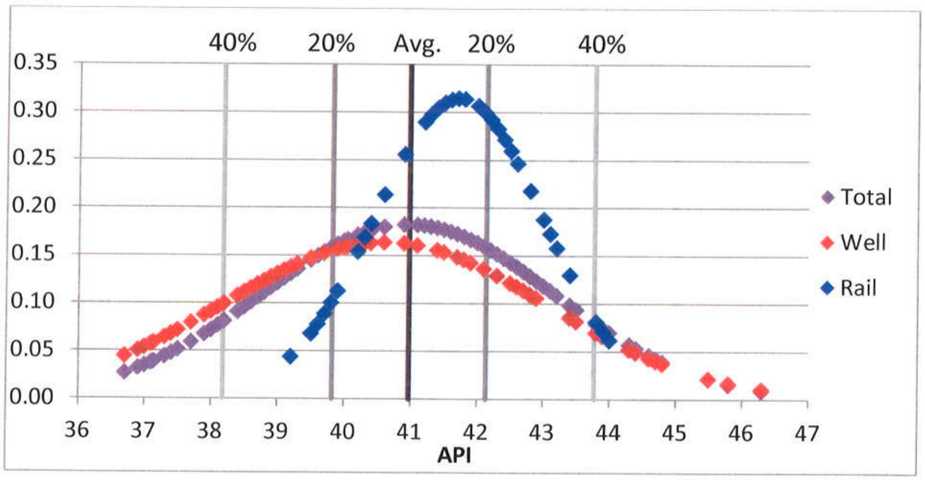
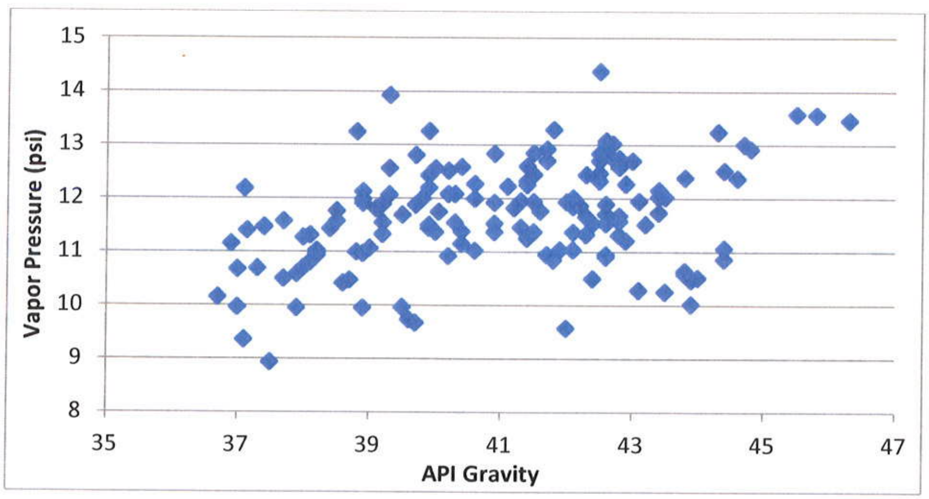


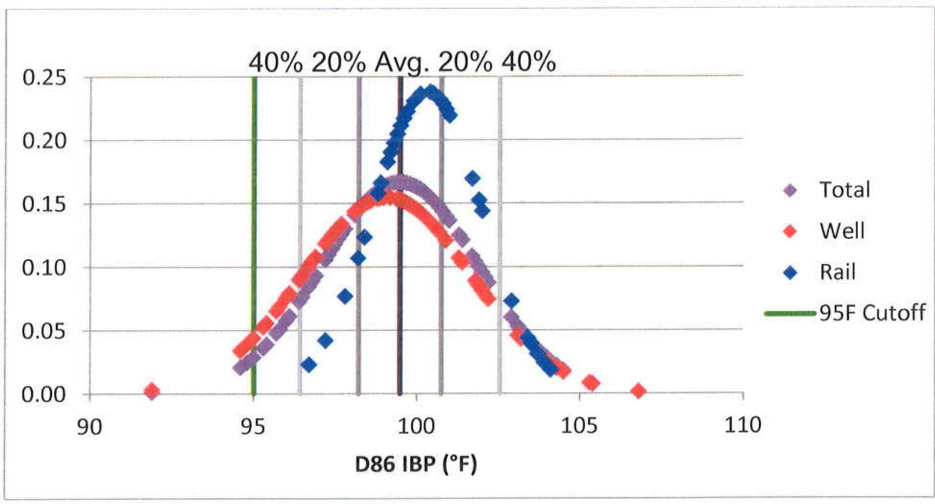

**Figure 4: API Gravity vs. Measured Vapor Pressure ($VPCR_4$)**



**D86 IBP**

D86 IBP measurements were conducted on all samples. As discussed in the summary section, the D86 distillation IBP is used for determining the appropriate PG for a flammable liquid. Measured D86 IBP ranged from 91.9°F to 106.8°F. Only 3 of the 152 readings, all of which were well samples, fell below the 95°F threshold for PG I versus PG II. The IBP results are clustered around the 95°F value. Thus, it is extremely difficult to properly define the PG because laboratory variance could indicate differing PG designations. While laboratory variance is a factor with any test, D86 is particularly susceptible because D86 distillation was never intended for wide boiling range materials; and, as a result, the test can have a significant amount of variance. Due to the importance of this test, and the proximity to the cutoff, additional laboratory comparisons were performed to determine the consistency of several properties, with special attention paid to D86 IBP. This will be discussed in detail in the section covering the interlaboratory (round-robin testing) later in this report. Figure 5 shows the distribution curve for measured D86 IBP measurements. The line in green shows the 95°F cutoff.

**Figure 5: D86 IBP Distribution; Total, Rail, Well**

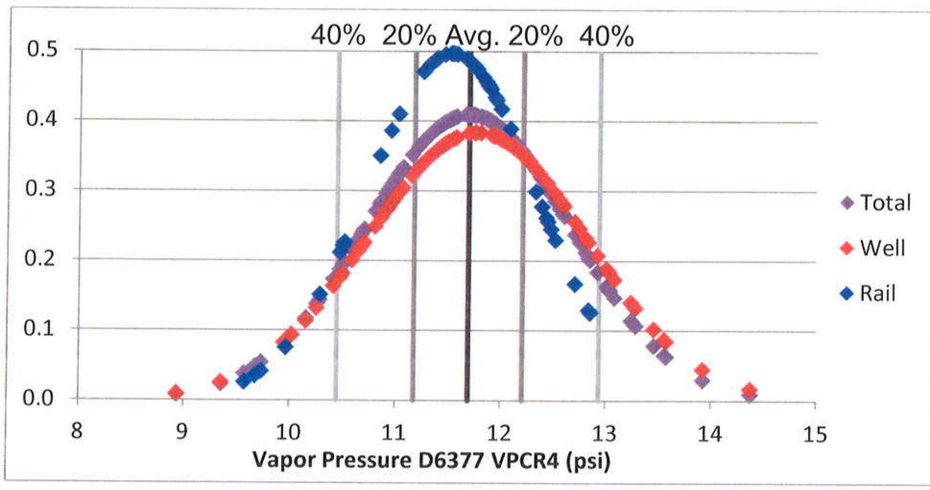



**Vapor Pressure**

Vapor pressure was measured using ASTM D6377, Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method) on all samples. It is important to note that the more traditional ASTM D323 Reid Vapor Pressure was not used. Within the past few years, ASTM D6377 has become widely accepted by industry and the U.S. EPA. For this reason, all vapor pressure analyses for this project were conducted using D6377, with the standard conditions of 100°F (37.8°C) and a vapor-liquid ratio of 4:1. In contrast, ASTM D323: Test Method for Vapor Pressure of Petroleum Products (Reid Method) is one of the oldest methods for determining vapor pressure of crude oils, and much of the older data in the public domain was obtained using this method. In the vapor pressure range of the samples tested in this study, the RVP values will tend to be about 1 psi lower than the VPCR values.

Vapor pressure samples in this study averaged 11.69 psi, well below the limit for the shipping classification. Rail averaged slightly lower at 11.52 psi, with a range of 9.57 to 12.85 psi. This is a more accurate representation of the quality being transported. This is in line with the vapor pressure of gasoline, which is transported under the same classification. Well vapor pressure averaged slightly higher at 11.77 psi, with a slightly broader range of 8.93 to 14.37 psi. The aggregation of crude and mixing that takes place at terminals, in addition to the potential slight losses of light ends during handling and storage, accounts for the difference in ranges and absolute vapor pressure seen between well and rail. Figure 6 shows the distribution of vapor pressures measured.

**Figure 6: Vapor Pressure Distribution; Total, Rail, Well**



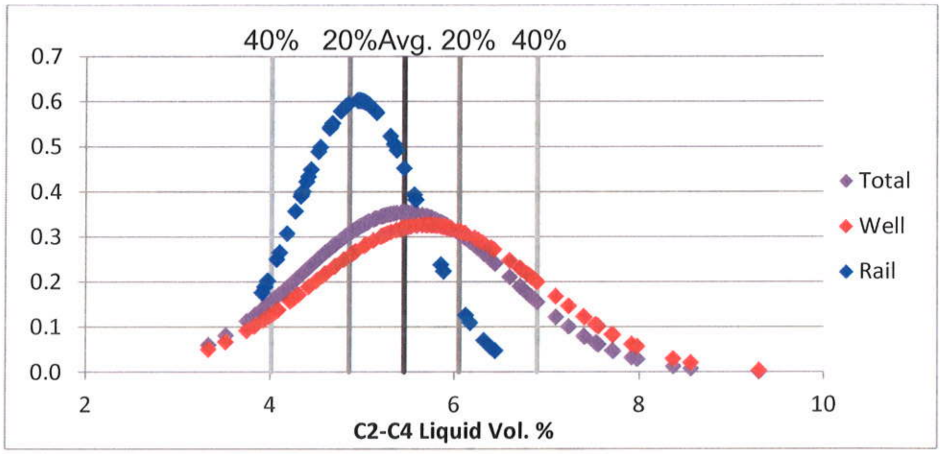

### Flash Point

Flash point tested via D3278 was performed on all samples. All flash point readings were <73°F (<23°C), which is the threshold value to distinguish between PG I or II and PG III. This threshold means all Bakken samples tested would fall in the PG I or PG II categories, and the ultimate PG I vs. II determination would be based on the D86 IBP, as discussed above. Because all samples were <73°F, no data analysis was performed.

### Light Ends

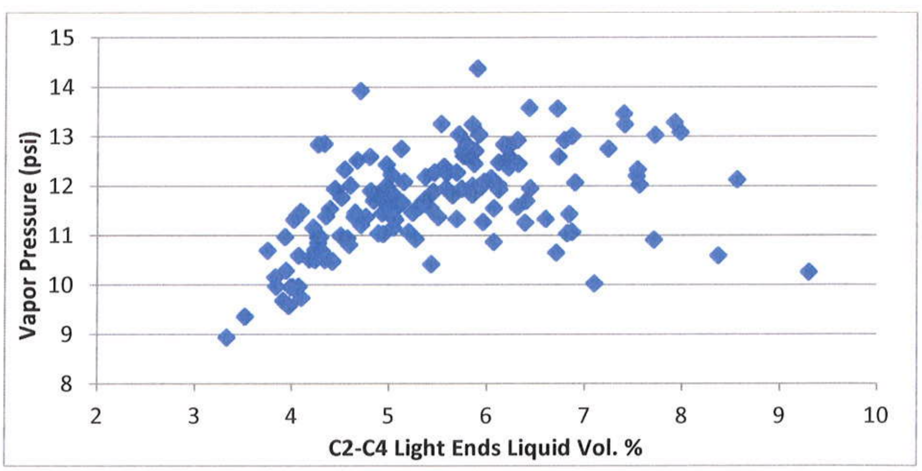
Light ends-testing via IP344 was performed on all samples. While the test measured concentrations of C1 (methane) to C6 (hexanes) individually by compound, the following light ends numbers account for the sum of C2-C4s only. Methane was excluded because it was at or below detection limits (0.01 liquid vol. %) for all samples, and C5+ has less impact on vapor pressure. The well samples had both a wider range (3.33-9.30 liquid vol. %) and average (5.69 liquid vol. %) concentration than rail (3.91-6.44 and 4.95 liquid vol. %, respectively). This is expected, as some small amount of light ends may be lost to storage tank vapor recovery systems while in atmospheric storage tanks at the well or rail terminals. Also, the mixing of various crudes into single tanks would help normalize any high or low concentration crudes. This corresponds with the vapor pressure readings in the previous section. Figure 7 shows the distribution of C2-C4s as measured.

**Figure 7: C2-C4 Distribution: Total, Rail, Well**




Light ends concentration was plotted versus measured vapor pressure on Figure 8, below. There is some correlation between the two, although significant scatter appears as the light ends concentration increases. With a rough correlation between measured vapor pressure and C2-C4s concentration, looking at seasonality data presented later, one could conclude that ambient temperature would have an effect on vapor pressure. Due to the short duration of testing, it was difficult to draw a clear correlation between the effects of ambient temperature on light ends content directly, although based on the seasonality data, colder temperatures would have the potential to leave greater amounts of light ends in the crude. The maps shown in the introduction section highlight the variance in properties from a geographic standpoint. While there is some variance in geographic measurements of light ends content, there does not appear to be any specific north to south or east to west correlations visible.

**Figure 8: Light Ends (C2-C4s) Concentration vs. Vapor Pressure**



**Simulated Distillation**

Simulated distillation (SimDist) via D7169 was conducted on 111 of the 152 samples. SimDist testing was performed on the first five samples for those samples that started on or around March 25, and three to four of the samples for the remaining few sites that had a more compressed sampling schedule. As testing progressed, the results appeared very consistent, and the importance of the SimDist results on overall analysis was determined to be limited. The test was subsequently excluded from later samples. Simulated distillation data showed consistent crude quality with the expected variance, ranging from an IBP of <97°F (minimum detection limit) to a final boiling point over 1200°F. Comparing Bakken to a pure liquid such as ethanol in a fire, the crude would vaporize more slowly in a fire should cars be heated versus ethanol, which has a single boiling point (173°F) where the entire cargo would vaporize. This temperature is roughly the SimDist 10% point for Bakken crude. Figure 9 and Table 6, below, show the distillation curve and average distillation data for well, rail and cumulative measurements.

**Figure 9: Bakken Crude Distillation Curve**

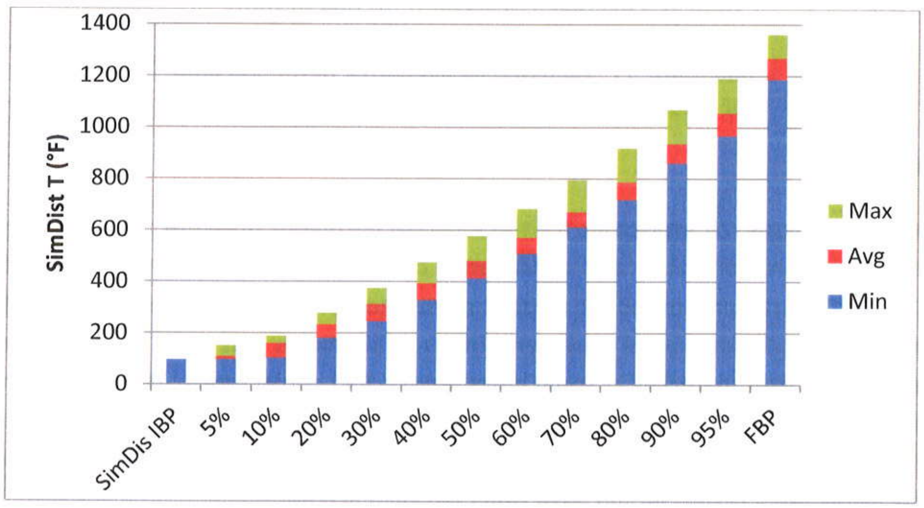


**Table 6: Distillation Data; Well, Rail, Total**

| SimDist | Well | Rail | Total |
|---|---|---|---|
| **IBP** | < 97 | < 97 | < 97 |
| **5%*** | 106 | 113 | 108 |
| **10%*** | 153 | 165 | 157 |
| **20%** | 231 | 238 | 234 |
| **30%** | 310 | 316 | 312 |
| **40%** | 394 | 396 | 395 |
| **50%** | 481 | 482 | 481 |
| **60%** | 572 | 572 | 572 |
| **70%** | 671 | 670 | 671 |
| **80%** | 785 | 787 | 786 |
| **90%** | 935 | 939 | 936 |
| **95%** | 1053 | 1060 | 1056 |
| **FBP*** | 1305 | 1317 | 1309 |

All values shown are in °F.

*Adjusted averages to account for one or more values in group above/below detection limits (97 °F and 1382 °F). Adjusted by averaging detection limit for values, raw data in appendix.

**Sample Consistency**

Comparing the well versus rail properties for the API/D86 IBP/vapor pressure, as well as light ends and SimDist, the qualities are very close and consistently correlate, as expected, with some slightly lower light ends numbers for rail properties for reasons discussed above. The light ends showed on average lower numbers and distillation curves were very similar. This shows that there is no evidence of spiking of Bakken crudes with light materials as some news reports had conjectured. The rail terminals sampled accounted for approximately 50% of total rail capacity out of the Bakken. These terminals receive crudes from many regional wells, not just member companies that contributed data: and, given the span of testing, it is highly likely results would have reflected such activity.

**Table 7: Quality Comparison – Well vs. Rail Test Results**

| | Well | Rail |
|---|---|---|
| API Gravity | 40.6 | 41.7 |
| D86 IBP (°F) | 99.1 | 100 |
| VPCR D6377 (psi) | 11.8 | 11.5 |
| **Light Ends (Liquid Vol. %)** | | |
| Ethane | 0.24 | 0.23 |
| Propane | 1.63 | 1.39 |
| Isobutane | 0.65 | 0.58 |
| n-Butane | 3.16 | 2.75 |
| Isopentane | 1.52 | 1.42 |
| n-Pentane | 2.90 | 2.72 |
| C2-C4s | 5.69 | 4.95 |
| C2-C5s* | 10.12 | 9.10 |

*Excludes Cyclopentane

**Sample Methodology Comparison: Floating Piston Cylinder (FPC) versus Standard Glass Bottle**

The sampling methodology employed in the NDPC Study was the industry standard technique of capturing material from tanks at either the well site or rail location in a glass bottle and sealing them with a screw-on cap. These quart-sized (32oz) glass bottles, referred to as "Boston Rounds" are the standard for sampling crude, gasoline and other hydrocarbons with similar vapor pressures to Bakken crude. Recently, a new technique has begun to gain acceptance as an alternate method, which involves the use of a FPC. The sample is captured under pressure in a cylinder with a hydraulic piston which minimizes any vapor space. The purpose of this is to minimize potential gas losses that could flash off from a liquid sample as it is captured at atmospheric pressure in a bottle, or is lost to the vapor space left when capturing a sample in a bottle.

In order to determine if there was any variance between the standard bottle sampling technique and the FPC, a set of four comparison tests at rail locations were performed. Rail locations were chosen because the floating piston cylinders require a pressurized sample location in order to overcome the pressure of the hydraulic piston in the cylinder. In each case, the samples were taken at the tap (spigot) located downstream of the loading pumps from the storage tanks to the rail car loading racks. Samples were taken while the line was in service and had flow (and adequate pressure) to fill the FPC's. By comparison, the samples taken during the NDPC testing were from the tank itself at atmospheric pressure upstream of the loading pumps where the FPC samples were taken.

The initial results from this testing proved inclusive. While some samples showed excellent agreement both with historic NDPC sampling and between the glass bottle and FPC samples at the pressurized sample point, others showed variation, with samples taken off the line having lower vapor pressure values than the samples collected from the tank. This implies that samples taken at the pressurized sample point downstream of the tank somehow lost light ends by comparison. This brings into question sampling techniques, sample point location and effects of sampling while under pressure in some locations such as after a pump. Further evaluation, regarding the comparison of FPC results to standard sampling with Boston Round glass jars, is being considered and will be provided as an addendum to this report if conducted.

**Interlaboratory (Round-Robin) Testing**

Due to the importance of ensuring both accuracy and precision in testing, and to gain a better understanding of potential laboratory variability, a series of round-robin tests were performed. These tests were designed to determine what, if any, differences the individual labs had for identical samples. SGS (the testing provider for this study) participated using both their St. Rose, LA and Williston, ND laboratories. Additionally, a second internationally recognized testing company participated to provide a third-party comparison (referred to as Lab M, in the Tables below). Four different well locations were sampled during this test. Three identical samples were taken, and one was sent to each of the three labs. Tests for API gravity, vapor pressure and D86 IBP were performed.

The results of this round-robin showed extremely good consistency between labs on both API gravity and vapor pressure. The consistency validated that the integrity of the samples were not compromised during this test and that they were not affected by handling or shipping. Table 8 shows the consistency among samples. Most samples had near zero maximum deltas between readings, with the exception of one vapor pressure sample that was slightly lower than the others.

**Table 8: Round-Robin API and Vapor Pressure**

**API Gravity (Density, D5002)**

| Sample Location | Date @ Time | Lab M | SGS St. Rose | SGS Williston | Max Delta |
|---|---|---|---|---|---|
| 1 | 5/1/14 @ 16:30 | 40.2 | 40.2 | 40.2 | 0.0 |
| 2 | 5/1/14 @ 16:30 | 43.0 | 42.9 | 42.9 | 0.1 |
| 3 | 4/30/14 @ 16:00 | 43.6 | 43.6 | 43.6 | 0.0 |
| 4 | 5/1/14 @ 16:30 | 43.0 | 42.9 | 42.9 | 0.1 |

**Vapor Pressure (VPCR4, psi)**

| Sample Location | Date @ Time | Lab M | SGS St. Rose | SGS Williston | Max Delta |
|---|---|---|---|---|---|
| 1 | 5/1/14 @ 16:30 | 10.1 | 10.3 | 10.1 | 0.2 |
| 2 | 5/1/14 @ 16:30 | 15.0 | 15.4 | 13.8 | 1.6 |
| 3 | 4/30/14 @ 16:00 | 10.6 | 10.6 | 10.6 | 0.0 |
| 4 | 5/1/14 @ 16:30 | 11.4 | 11.5 | 11.2 | 0.3 |

The consistency did not carry through for the D86 testing. There was noticeable inconsistency between each lab, with samples varying by as much as 19.5°F for a given sample. While all samples tested during this would fall within a Class 3 Flammable liquid, depending on the lab used, the same sample could fall above or below the 95°F mark for PG I vs. PG II. Table 9 shows the readings for each sample, and the maximum deltas measured.

**Table 9: Round-Robin D86 IBP**

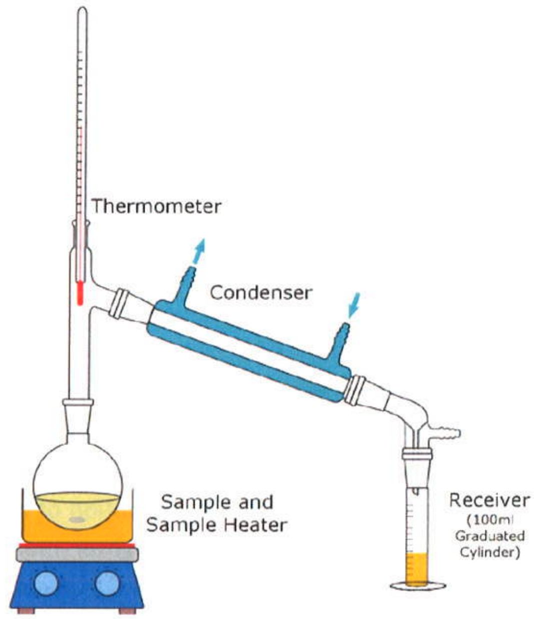
| | | D86 IBP (°F) | | | |
|---|---|---|---|---|---|
| **Sample Location** | **Date @ Time** | **Lab M** | **SGS St. Rose** | **SGS Williston** | **Max Delta** |
| **1** | 5/1/14 @ 16:30 | 89.9 | 95.4 | 101.8 | 11.9 |
| **2** | 5/1/14 @ 16:30 | 83.1 | 89.1 | 102.6 | 19.5 |
| **3** | 4/30/14 @ 16:00 | 87.8 | 90.7 | 105.5 | 17.7 |
| **4** | 5/1/14 @ 16:30 | 89.2 | 94.5 | 102.2 | 13.0 |

**D86 Variation**

The D86 testing showed that, in fact, there were problems with variability between labs. This is a result of the test not being designed for evaluating such a wide boiling range material, and thus different labs choose different heating, condenser temperature and receiver temperature parameters. In addition, the D86 distillation conditions do not allow for the accurate retention of butane and lighter material. Thus, samples containing significant quantities of butane and lighter material will not have this material detected and will still yield an IBP in the 80-100°F range. The C1-C4 compounds do not readily condense at the condenser temperatures the D86 test is conducted at, and thus are not accurately measured.

Before we discuss this further, a brief description of how a D86 distillation is performed is warranted. The setup consists of a flask of 100ml of liquid to be tested, a heater to boil the liquid, associated instrumentation to measure the temperature and volume, an overhead condenser which condenses the vapor boiled off and a receiver which collects the condensed material. While it is allowable to perform this test manually, almost all current analyses are conducted utilizing automatic instrumentation, which uses microprocessor controlled instrumentation to produce more precise results with minimal human intervention. All analyses conducted on this project utilized this type of automated instrumentation. Current D86 instruments are automatic; and typically, the type of liquid being tested will dictate parameters such as the condenser temperature and heat rate. The liquid is heated at the given rate dictated by the operator, and as it boils, it is condensed overhead, and drops into the receiver, which is maintained at a fixed temperature. The amount of liquid in the receiver is measured, and the distillation curve is generated. The liquid at the end is measured to determine the total recovery, as light components dissolved in the original sample can be lost if they are not able to be condensed at the condenser's operating temperature. Figure 10 shows a sample simple distillation, similar in principle to that used during D86 testing. The sample is heated, condenses, and is collected in the receiver. The volume at a given temperature is recorded to generate the distillation curve.

**Figure 10: Simple Distillation Apparatus**




Initial boiling point by D86 is defined as the overhead temperature (corrected for atmospheric pressure) observed at the instant the first drop of condensate falls from the lower end of the condenser tube. For a material such as gasoline, which typically has a boiling range of about 100-400°F, the liquid must first be heated at least some before enough vaporization occurs and vapor begins to condense. This is well above the condenser temperature, and as such, a more complete recovery is achieved. In the case of a light crude sample, which contains dissolved gases (C1-C4s) which do not condense at the typical condenser temperature, a lower recovery is achieved and less accurate actual IBP is measured.

The implications of this are that if parameters are not identical, the temperature with which the first drop is perceived to form can vary considerably. The difference for a given sample will normalize out as the 5% and 10% points are reached, but those values are not considered as part of the overall requirement for DOT classification. The rate at which the sample is heated can affect how well the sample was able to reach equilibrium temperature and drive off any light ends. The same goes for how cold the condenser is; the colder, the more it will condense. Faster heat rates and colder condenser temperatures tend to drive the IBP temperature lower than if the sample is more slowly heated with a higher condenser temperature.

Table 10 shows the impact that these parameters have on the boiling points. For the same sample, significant error can be introduced, over 14°F in the case of this set, for the same lab and same instrument, with slightly different operating parameters. This highlights a serious flaw in using the D86 test for compliance on determining PGs for materials such as Bakken crude. Because of the difficulty with achieving consistent IBP results, groups including API are working on recommendations to update the current regulations.

**Table 10: D86 IBP Variability Testing**

| Lab | SGS St. Rose | | SGS Williston | | SGS Williston | |
|---|---|---|---|---|---|---|
| Condenser Temp | 60°F | | 60°F | | 31°F | |
| Receiver Temp | 73°F | | 81°F | | 81°F | |
| Sample | D86 IBP | Time to IBP | D86 IBP | Time to IBP | D86 IBP | Time to IBP |
| 1 | 95.4 | 4 min 53 sec | 101.8 | 7 min 56 sec | 91.1 | 7 min 45 sec |
| 2 | 89.1 | 3 min 22 sec | 102.6 | 6 min 27 sec | 88.7 | 6 min 07 sec |
| 3 | 90.7 | 3 min 37 sec | 105.5 | 7 min 26 sec | 91.4 | 7 min 11 sec |
| 4 | 94.5 | 3 min 42 sec | 102.2 | 6 min 50 sec | 94.4 | 8 min 00 sec |

**Rail Testing**

A separate set of testing was conducted in order to evaluate whether there was merit in the claims that Bakken sees substantial weathering during transport. Five individual rail cars were sampled at their origin in Fryburg, ND, and destination of St. James, LA. Samples were tested by local labs in ND and LA of the same company for vapor pressure via D6377 at 100°F, flash point via D86, $H_2S$ in vapor phase at 77°F via ITM 3468 and light ends analysis by modified D6730. The results were then compared to average NDPC test results from the same rail terminal. The testing showed that throughout transportation, vapor pressure and C2-C4 concentration were consistent, indicating there were no light ends losses. Additionally, no detectable $H_2S$ was present in the samples. Comparing the samples tested at the two labs, the greatest variance in results was with the D86 IBP, for reasons discussed previously. Table 11 shows the table of average test data from both Fryburg and St. James and compares it to the other data collected at the Fryburg rail terminal. The appendix contains the full set of sample data for the cars.

**Table 11: Rail Car Source and Destination Testing**

| Test | Units | Avg. ND Rail Terminal 5 Car Samples | Avg. St. James Rail Terminal 5 Car Samples | Avg. NDPC Data for ND Rail Terminal |
|---|---|---|---|---|
| **VPCR 4 (37.8° C)** | psi | 10.47 | 10.61 | 10.45 |
| **IBP** | °F | 94.7 | 90.4 | 101.7 |
| **Flash Point** | °F | <50 | <50 | <73 |
| **$H_2S$ in Vapor Phase** | ppm v/v | <1 | <1 | |
| **C2-C4s** | Vol % | 4.00 | 4.08 | 4.23 |
| **C2-C5s*** | Vol % | 8.01 | 7.89 | 8.13 |

*Excludes Cyclopentane

**Member Contributed Data**

In addition to the data collected, member companies voluntarily submitted data to supplement data gathered in this study. The data contributed consisted of a smaller, less controlled round-robin sample test between one SGS laboratory and a second independent laboratory, and a NDPC member rail company terminal who contributed vapor pressure operating data collected over a seven-month period from late August 2013 to late March 2014.

A round-robin test was conducted by a NDPC member company who sent samples from four rail cars to both SGS and Lab M independently. The company had testing for API gravity, vapor pressure and D86 IBP measured on each sample. The results were similar to those found by NDPC conducted round-robin. API and vapor pressure had little variance, but the D86 IBP variance averaged over 13°F with a maximum variance of 15.6°F. This, again, highlights the difficulty with getting consistent and accurate D86 IBP measurements on a full boiling point material such as crude oil.

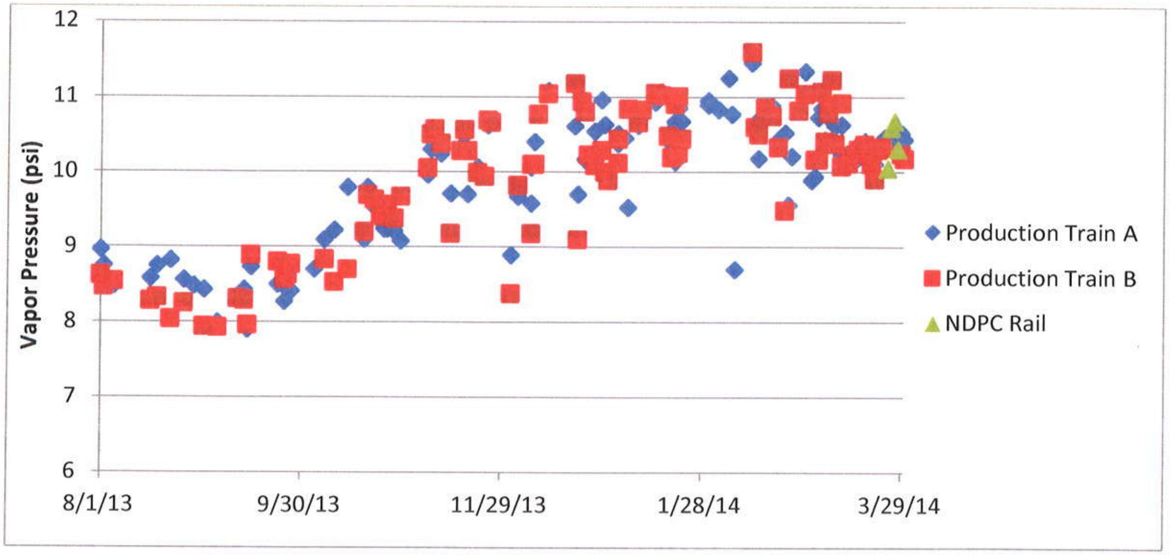
**Table 12: Member Company Laboratory Comparison (Round-Robin)**

| Sample ID | API Gravity | D86 IBP (°F) | VPCR4 D6377 (psi) |
|---|---|---|---|
| Sample 1: SGS | 44.0 | 101 | 10.52 |
| Sample 1: Lab M | 44.4 | 85.4 | 11.35 |
| Sample 2: SGS | 43.9 | 101.9 | 10.47 |
| Sample 2: Lab M | 44.3 | 92.4 | 11.47 |
| Sample 3: SGS | 42.4 | 100.5 | 10.50 |
| Sample 3: Lab M | 44.4 | 86.5 | 11.29 |
| Sample 4: SGS | 43.1 | 103.7 | 10.28 |
| Sample 4: Lab M | 44.2 | 89.9 | 11.29 |
| | | | |
| Avg. Variance | 1.0 | 13.2 | 0.91 |
| Max Variance | 2.0 | 15.6 | 1.01 |

A second member company contributed operating data collected over the course of normal operations on vapor pressure of Bakken crude being loaded into rail cars. It is known that as ambient temperature changes, the amount of light ends material separated from the raw crude at the wellhead, changes. Higher temperatures lead to higher gas separation, so winter and early spring conditions (when the NDPC test was performed) would highlight some of the higher vapor pressure Bakken crude throughout the year. The range of vapor pressure data collected shows that while there is some change, even the highest RVP readings in the winter peak at about 11 psi, nearly an order of magnitude below the 100 psig for which the DOT-111 rail cars are rated.

The samples from this member company were analyzed in their in-house lab and were measured for RVP versus $VPCR_4$ that was used throughout the NDPC testing. Due to the differences in test methodology, RVP readings typically are 1 psi lower than $VPCR_4$ readings. There was a brief overlap of time when sample data overlapped in late March, 2014. The data did correlate very well between measured vapor pressure at rail terminals tested compared to measurements at the member rail terminal when accounting for the testing difference. Figure 11 shows the chart of member contributed seasonality data, with NDPC test data overlaid, with the 1 psi correction.

**Figure 11: Seasonality Data Collected by Member Company**




The seasonality results are in line with the report from Transport Canada on the derailment in Quebec which showed RVP results ranging from 9.0-9.6 psi. The derailment took place in July 2013, and the RVP results recorded by Transport Canada are consistent with the summer results measured by the seasonality data above.

## AFPM Report Comparison

AFPM released a report on Bakken crude titled, *"A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transportation"* dated May 14, 2014. The report assembled a variety of Bakken data and compared its results to the parameters as laid out by DOT PHMSA and other international regulations for shipping. While raw data was not given for analysis, a statistical breakdown and walkthrough of each captured parameter gave a good overview of Bakken crude properties from a broad data set.

- The APFM report concluded that Bakken was not materially different and posed no special hazards versus other light crude oils.
    - These findings coincide with the findings from this NDPC report.
- The AFPM report came to the same conclusions regarding the safety of Bakken in DOT-111 rail cars.
    - Vapor pressure was well below the allowable pressure for DOT-111 rail cars.
    - Bakken was well within all specifications for a Class 3 flammable liquid.
- Despite the same conclusions, a direct comparison between AFPM and NDPC cannot be performed on all data points collected.

- The AFPM report collected voluntary data submissions from its members, instead of a controlled study.
    - Its members consist largely of fuel producers who sample and test the Bakken as it arrives at their facility, versus at the well or rail terminal.
- Sampling procedures and test methods were not uniform across all data.
    - The AFPM report listed all test methods used for various properties.
    - Samples were run at different labs, resulting in increased variability.
- The report did not indicate if tests of differing methods were correlated in any way prior to comparison, nor what the minimum detection limits were or how samples were handled.

- This variety of testing led to certain peculiarities, such as the initial boiling point or flash point data having what appeared to be varying test ranges.

Of particular focus was the IBP testing. For the NDPC report, all data in the main data set was tested by a single testing provider, SGS. Samples were consistently collected and handled throughout the testing process, with all testing using the same ASTM D86 testing protocol. In contrast, the AFPM report used five different test methods for distillation alone, as discussed in their appendix. This resulted in IBP data ranging down to 32°F (0°C). In particular, gas chromatographic methods are referenced as being used. These methods, e.g. D2887, are known to yield much lower IBPs than the D86 method. Thus, this data must be both used and compared with caution. Based on our earlier discussion of how D86 testing is conducted, the D86 test method does not lend itself to measuring boiling points that low. The condenser does not operate at a temperature low enough (it would have to operate below 32°F to condense materials boiling at that temperature). Additionally, the initial sample is not cooled to that level before testing and the collector is held at roughly room temperature, meaning any collected sample would evaporate. Thus, any IBP results below about 60°F must, therefore, have been conducted with another test method, assumed to be a gas chromatographic simulated distillation method. Since there was no indication that the data was correlated to D86, and the regulations are based around D86 testing, it raises questions about what the equivalent boiling points were for those samples, based on DOT requirements. Similarly, other data that used multiple test methods did not show an indication of a correlation between the two methods and makes the data good for information only, but not from which to draw firm conclusions or correlations. Table 13 shown below gives a brief comparison of the results of the two tests.

**Table 13: Comparison of NDPC to AFPM Study Data**

| | NDPC Average Well | NDPC Average Rail | NDPC Average Range | AFPM Study | | Comments |
|---|---|---|---|---|---|---|
| API Gravity | 40.6 | 41.7 | 36.7-46.3 | API Gravity | 42 | Reported in crude comparison table. |
| D86 IBP (°F) | 99.1 | 100.3 | 91.9-106.8 | IBP (Various Tests) | 69.6 | 87.3 median IBP, multiple tests in AFPM data, some of which can report lower than D86, which skewed average lower. |
| Vap. P D6377 (37.8C) (psi) | 11.8 | 11.5 | 8.9-14.4 | RVP (psi) (Various Tests) | 7.83 | RVP reported by AFPM. Also reported D6377 done at 50C (higher than NDPC), with range 13.9-16.7 psi. |
| Seasonality RVP (psi) | - | 9.98 | 7.9-11.6 | Seasonality RVP (psi) | 8-12.5 | AFPM 807 data points to 215 for NDPC, greater variety of locations. |

| NDPC Light Ends (Liquid Vol. %) | Well | Rail | Range | AFPM Light Ends (Liquid Vol. %) | | Comments |
|---|---|---|---|---|---|---|
| Ethane | 0.24 | 0.23 | 0.08-0.67 | Ethane | 0.5 | |
| Propane | 1.63 | 1.39 | 0.84-3.13 | Propane | <1-2% | |
| Isobutane | 0.65 | 0.58 | 0.35-0.95 | Isobutane | | |
| n-Butane | 3.16 | 2.75 | 2.00-4.55 | n-Butane | 3-4% | Reported as ranges only. |
| Isopentane | 1.52 | 1.42 | 1.10-1.93 | | | |
| n-Pentane | 2.90 | 2.72 | 2.07-3.70 | n-Pentane | - | |
| C2-C4s | 5.69 | 4.95 | 3.52-9.30 | C2-C4s | 3.5-11.9% | AFPM report, three respondents average 3.5%, fourth had 12 samples, range 5.9-11.9% |
| C2-C5s* | 10.12 | 9.10 | 6.77-14.71 | C2-C5 | 7.2 | *Excludes Cyclopentane |

The AFPM report did include additional data, which was not tested as part of the NDPC study. Many samples were tested for hydrogen sulfide ($H_2S$) in the vapor phase, and they were able to capture some samples that contained detectable $H_2S$. It is known that select pockets in legacy ND wells contain higher $H_2S$ concentrations, but that crude is typically segregated from low $H_2S$ Bakken crude for safety reasons. The AFPM study was also able to gather data on corrosivity using National Association of Corrosion Engineers (NACE) TM 172 testing, which confirmed the low corrosivity of Bakken crude. The AFPM paper also summarized data gathered on the pressure of rail cars measured as they reached their final destination. Over 380 cars were sampled, with a majority arriving to the refinery in the 7-10 psig range. The highest reported pressure recorded was 11.3 psig, well below the rated operating pressure of the DOT-111 rail cars or their minimum relief valve setting of 35 psig.

Despite the inability to draw a direct comparison between the AFPM and NDPC data, the results of both studies lead to the same conclusion. Bakken crude is a consistent product that clearly fits the classification of a Class 3 Flammable Liquid. The only point of debate would be the PG designation that is used, PG I versus PG II. That falls back to D86 testing of full boiling range materials, and the need for a reevaluation as to whether that is the most appropriate test method for the classification of materials such as Bakken for shipment.

### The Pipeline and Hazardous Materials Safety Administration (PHMSA) Report Comparison

PHMSA released a report on July 23, 2014, which included the results of their findings as part of *Operation Safe Delivery*. PHMSA found that, "Operation Classification has determined that the current classification applied to Bakken crude is accurate under the current classification system." The PHMSA report outlined the efforts of their testing program, which began in August 2013, and spanned through May 2014. Sampling was unannounced and intended to capture a representative sample of Bakken crude. The initial phase, from August-November 2013, was focused on verifying that appropriate hazard classes that were being used; and as such, testing was limited to flash point and boiling point. The second phase from February-May 2014 was to gain a complete understanding of Bakken properties and more closely align with the NDPC study. This data from Phase 2 was the data used to compare to the NDPC report.

The results outlined showed good agreement with the data collected as part of the NDPC study, especially when comparing data collected for the same general time period. Since the NDPC testing was done during the period from late March to late April 2014, the data points that fell in this general time frame were separated out and compared (11 total samples), as was the entire data set (88 total samples). Since the last round of PHMSA sampling was conducted at rail-loading facilities, for consistency, comparisons were made specifically with the NDPC rail data. As seen in Table 14 below, the results agreed very well, despite not being identical samples nor identical locations. The variation is minimal, and ranges agree well, with a trend toward slightly lower D86 IBP readings from PHMSA; although as discussed earlier, those results are subject to variation based on exact testing parameters and procedures.

**Table 14: Comparison of NDPC to PHMSA Study Data**

| | PHMSA Data Table E Mar-May (11 Samples) | | | NDPC Data Rail Only (49 Samples) | | |
|---|---|---|---|---|---|---|
| | Dates: | 3/17/14 | to 5/2/14 | Dates: | 3/25/14 | to 4/18/14 |
| | Average | Min | Max | Average | Min | Max |
| Flash Point (°F) | <50 | - | - | <73 | - | - |
| D86 IBP (°F) | 87.0 | 79.1 | 94.4 | 100.3 | 96.7 | 104.1 |
| VPCR 4 @ 100 °F (psi) | 12.28 | 10.22 | 14.28 | 11.52 | 9.57 | 12.85 |
| Ethane (% Vol) | 0.20 | 0.06 | 0.29 | 0.23 | 0.13 | 0.33 |
| Propane (% Vol) | 1.38 | 0.85 | 1.95 | 1.39 | 1.02 | 1.95 |
| Butane* (% Vol) | 3.49 | 3.01 | 4.44 | 3.32 | 2.63 | 4.24 |
| C2-C4 | 4.65 | 0.00 | 6.68 | 4.95 | 3.91 | 6.44 |

| | PHMSA Data Table E Total (88 Samples) | | | NDPC Data Total (152 Samples) | | |
|---|---|---|---|---|---|---|
| | Dates: | 2/24/14 | to 5/2/14 | Dates: | 3/25/14 | to 4/24/14 |
| | Average | Min | Max | Average | Min | Max |
| Flash Point (°F) | <50 | - | - | <73 | - | - |
| D86 IBP (°F) | 88.1 | 79.1 | 97.5 | 99.5 | 91.9 | 106.8 |
| VPCR 4 @ 100 °F (psi) | 12.42 | 10.10 | 15.10 | 11.69 | 8.93 | 14.37 |
| Ethane (Liq Vol %) | 0.23 | 0.06 | 0.40 | 0.24 | 0.08 | 0.67 |
| Propane (Liq Vol %) | 1.45 | 0.85 | 2.08 | 1.55 | 0.84 | 3.13 |
| Butane* (Liq Vol %) | 3.55 | 2.74 | 4.48 | 3.66 | 2.35 | 5.50 |
| C2-C4s | 5.17 | 0.00 | 6.88 | 5.45 | 3.33 | 9.30 |

*PHMSA report does not specify if isobutane was included in their measurements. For comparison purposes, this report assumes butane includes n-butane and isobutane.

In the conclusion of the report, PHMSA did note that, "We conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude." While PHMSA does say Bakken is currently classified appropriately as a Class 3 Flammable Liquid, PG 1 or 2, depending on D86 IBP, they claim that Bakken has "higher gas content, lower flash point, lower boiling point and higher vapor pressure than other crude oils." PHMSA makes this claim without testing or reporting what the values are for these other crude oils.

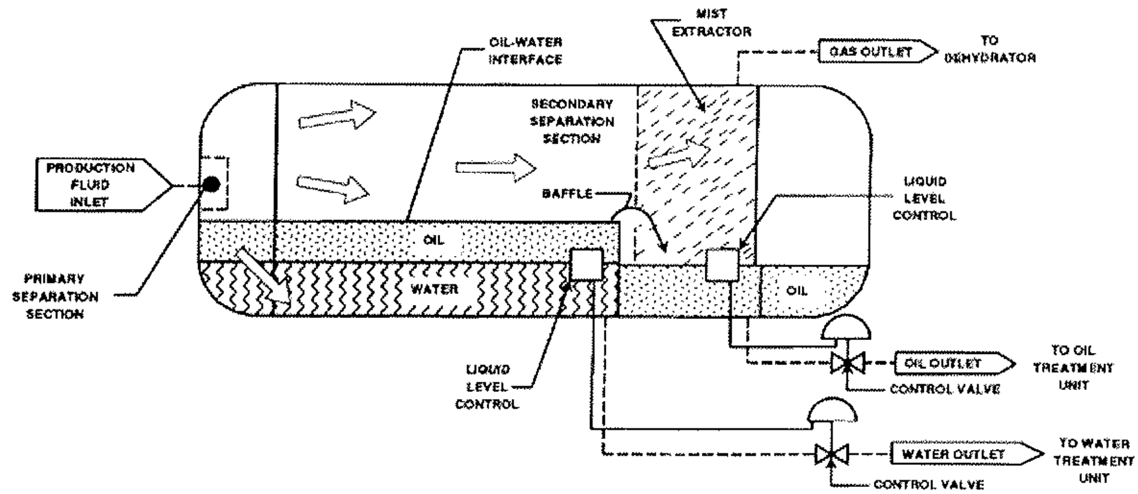
As we have noted previously, there have been no extensive or controlled sampling and testing programs for other light sweet crude oils, such as was done in both this NDPC study and the PHMSA program for Bakken; and, therefore, it is not possible to make a broad generalization on comparative properties. Based on limited information from the AFPM study, as well other publicly available data Bakken appears to be generally similar in vapor pressure and light ends content to most light crude oils, and there are certainly crudes, particularly those produced from tight oil formations, which are higher in those parameters. Additionally, making the claim that vapor pressure and light ends content correlates to increased ignitability and flammability is a broad statement that without extensive and complicated testing cannot be factually stated or supported.

## Operating Conditions

As part of the sampling program, operating conditions at the time of sample collection were taken for each well location sampled. This was done in order to determine if there were additional factors which may affect crude qualities. The conditions recorded included ambient temperature, separator and treater temperature and pressure, well production rate, equipment size and configuration, and for wells not attached to a gathering system, the time the stock tank was isolated from the well.

In order to better understand the impact the operational conditions play, a brief overview of wellhead crude processing is warranted. Raw crude, as it comes out of the ground, is a mix of gas, liquid hydrocarbons and water. The amount of each varies depending on geology and ambient temperature. The raw crude stream requires separation to remove the gas phase and separate entrained water before it is transferred to the stock tank. This is achieved by passing the crude through a separator and/or treater unit before it is stored and transported. Often, a standard three-phase (gas/oil/water) separator drum is used to separate the bulk water and gas from the hydrocarbon stream, as seen in Figure 12. The raw crude stream enters the separator drum and settles. Gas passes over and through a mist extractor, essentially a fine metal mesh, to collect and knock out entrained liquid before passing out of the drum to either be flared or captured. The liquid settles and separates as it flows through the vessel. In a three-phase separator, the liquid level is controlled so that the oil layer passes over a baffle and out of the vessel to tankage or for additional treatment. The water, which collects behind the baffle, is drained off and treated. Some wells may instead use a simple gas/liquid separator followed by a second liquid/liquid separator. In this configuration the liquid passes out without separating water and hydrocarbons, which then passes directly to a second separator or treater designed to separate the liquid hydrocarbons and water.

**Figure 12: Horizontal Three Phase (Gas/Liquid/Water) Separator Diagram**[1]

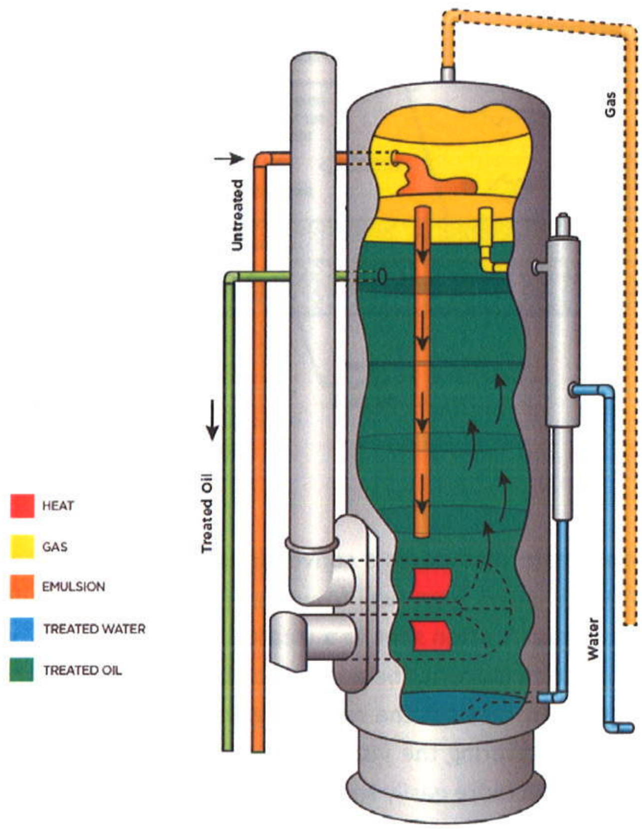



Often, the hydrocarbon stream that leaves a conventional separator still contains an emulsion of some water, the severity of which varies from well to well and on ambient conditions. In order to minimize water in the crude, the stream is often sent to a treater. A treater unit is, in effect, a second separator designed to help break the emulsion via the addition of heat and passing the crude through a coalescer or series of baffles to help separate out the remaining water. Heating the stream aids in separation of the oil and water in part by lowering the viscosity of the oil, which aids in coalescence of small water droplets to larger ones that can more easily separate.

Figure 13 shows how the untreated hydrocarbon stream, in orange, flows into the vessel and down through the heated section. In this section, the stream is heated and the water has a chance to separate. Similar to the separator, additional dissolved gasses evolved when the crude is heated are separated as well, and are either flared or collected. Some wells that do not have a lot of water in the crude, may use only a treater for oil treatment.

[1] Image: http://www.netl.doe.gov/Image%20Library/technologies/pwmis/BasSep_3PhaseSeparator.jpg

**Figure 13: Vertical Treater Diagram**[2]




The separator and treater operate at relatively constant conditions as set by the well operator. Typically, they operate under pressure (a range of 8-80 psig was recorded in this study) as the flow follows through the separator and treater to tankage. Adequate pressure is required to overcome any head pressure and allow movement of oil into the stock tank. When a treater is used, the stream is heated only enough to maximize separation of the emulsion (range up to 160°F was observed in this study), while minimizing the temperature to which the stream needs to be heated. There are several reasons to limiting temperature, including energy cost of heating, increased hydrocarbon losses to flare and potential for increased tank emissions.

Due to the difficulty and hazards associated with sampling a raw well stream, crude was sampled from the stock tank after it passed through the separator and/or treater. This is consistent with measuring the quality of the crude that would be transported via rail. Additional notes were taken on whether the wells were connected to gathering systems; small pipeline networks designed to take the oil to central facilities to be loaded to rail or major pipeline systems. Other wells fill stock tanks and require trucks to

[2] Image: http://www.des-co.com/portfolioentry/heater-treaters/

haul crude away. Wells not on gathering systems were sampled from their full stock tanks after they were safely filled and isolated from the well.

As discussed previously, on the first visit to each location, samples were taken at both the top and bottom of the tank. This was done to determine if there was a variance or stratification taking place in tanks, either at the well or at the rail terminals. No stratification was observed, with relative uniformity of properties from the top to bottom. On subsequent visits, samples at each location were composite samples of the tanks. The average delta (top-bottom) for rail, well and overall samples is summarized in Table 15, with complete data available in the appendix.

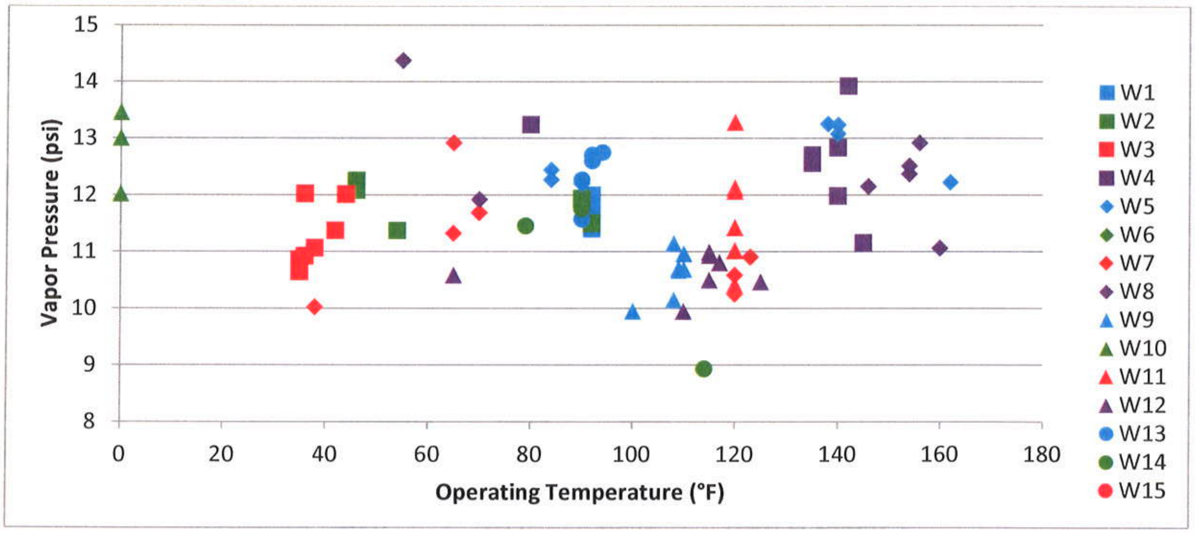
**Table 15: Average Delta (Top-Bottom) of Tank, Rail and Overall Samples**

| Avg. Delta (Top-Bottom) | Rail | Well | Overall |
|---|---|---|---|
| API Gravity | 0.0 | 0.2 | 0.1 |
| D86 IBP (°F) | 0.5 | -0.9 | -0.5 |
| Vapor P (psi) | 0.12 | 0.01 | 0.05 |
| **Light Ends (Liquid Vol. %)** | | | |
| Ethane | 0.00 | 0.02 | 0.01 |
| Propane | 0.00 | 0.05 | 0.03 |
| Isobutane | 0.00 | 0.01 | 0.01 |
| n- Butane | 0.00 | 0.05 | 0.03 |
| Isopentane | 0.00 | 0.01 | 0.01 |
| n- Pentane | 0.01 | 0.03 | 0.02 |
| Cyclopentane | 0.00 | 0.00 | 0.00 |
| C2-C4s | -0.01 | 0.12 | 0.08 |
| C2-C5s* | 0.00 | 0.15 | 0.10 |

*Excludes Cyclopentane

Vapor pressure showed no clear correlation with operating conditions. Production rate did not show any appreciable impact on the vapor pressure (this is covered later in this report). The same was seen with both operating pressure and temperature. The measured vapor pressure was scattered throughout the range of temperatures and pressures, with no clear correlation. Figure 14, below, shows a plot of vapor pressure versus operational temperature. A plot of vapor pressure versus operating pressure can be seen in Figure 1-1 in the Appendix.

**Figure 14: Vapor Pressure versus Operating Temperature**




The results of the testing did show a slight correlation between operating temperature and light ends (ethane/propane) content, which would be expected. Otherwise, there was no clear correlation between either operating pressure or production rate and the subsequent vapor pressure or ethane/propane content in the crude. While both the separator and treater separate out gas phase from the mixed stream, they are not designed as "stabilizers" to treat the crude. Their purpose is to remove entrained gases and water. Stabilizers, often used in condensate (crude API 50°+) service separate out the lightest components from a given hydrocarbon stream. Those components are then transported separately as liquefied petroleum gas (LPG) and NGLs in pressurized rail cars alongside Bakken crude. This would ultimately be shifting responsibility from one type of rail car to another, concentrating and magnifying potential risks. As with any crude oil, some dissolved light ends will exist in Bakken, and will only be completely removed when the crude is fully fractionated in a refinery setting. This is true of any light crude oil, regardless of the separator and treater setup is used.

Figure 15 and Figure 16 show the effect of operating temperature on the ethane and propane concentrations. There is a slight trend toward lower concentrations at higher temperatures. This is plausible, as some of the lightest components will be driven off as the crude is heated. This would be most apparent in winter months when this test was conducted and ambient temperatures are low. In the summer months, ambient temperatures may reach 100°F or more, making use of the treater less impactful. Figures 1-2 through 1-5 in the Appendix show the charts of the ethane and propane versus operating pressure and production rate, for reference.

Figure 15: Ethane Liquid Vol. % versus Operating Temperature

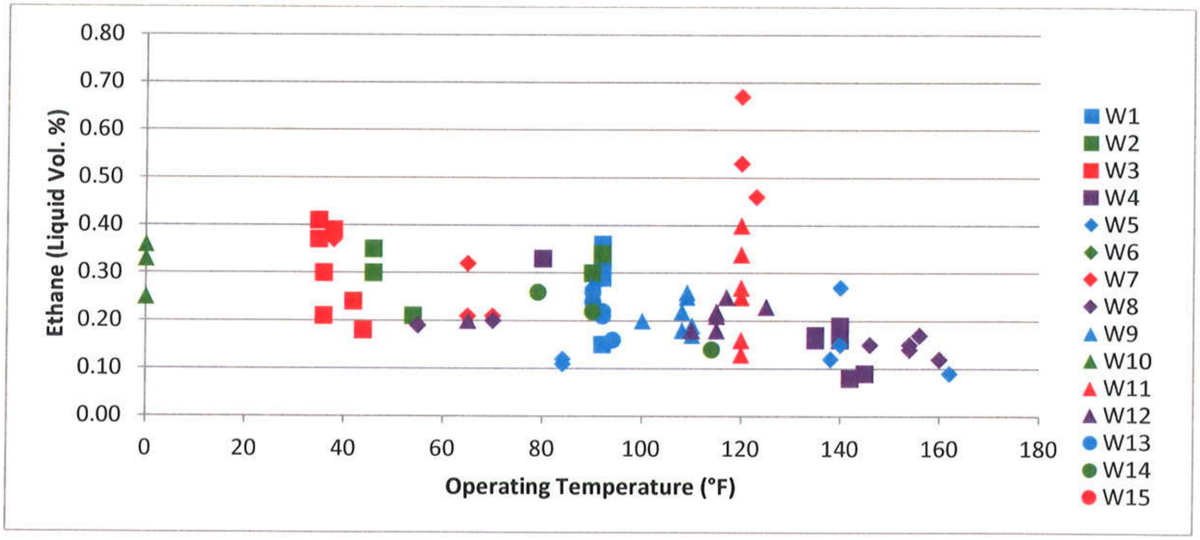
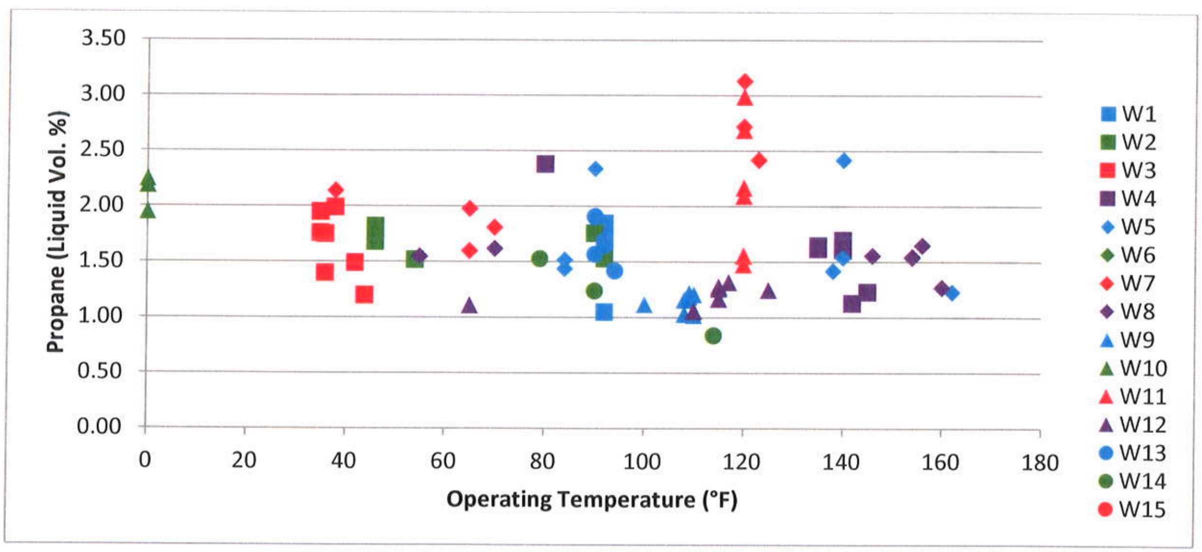



Figure 16: Propane Liquid Vol. % versus Operating Temperature




Based on these findings, a general correlation between the operating temperature of the treater and the ethane or propane concentration was developed. Excluding the few points that were anomalous from W7, the following correlations were developed (charts can be seen in the Appendix, Figures 1-6 and 1-7):

1. Ethane (Liquid Vol %) = -0.0013 * Temp (°F) + 0.3568; and
2. Propane (Liquid Vol %) = -0.0025 * Temp (°F) + 1.8414.

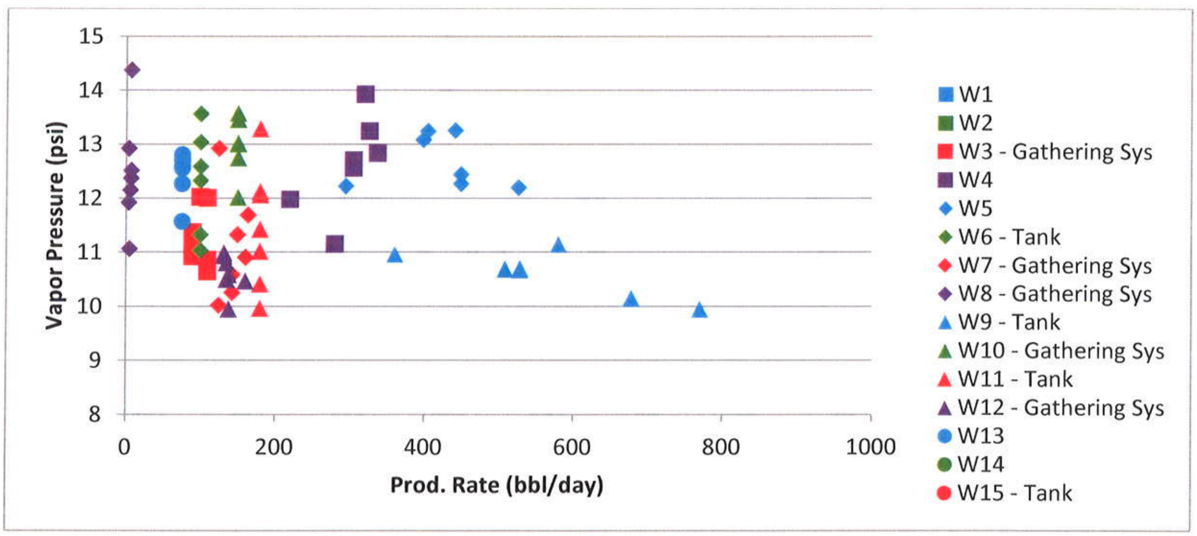
These equations hold that the difference in concentration between 50°F and 150°F operation is 0.13 and 0.25 liquid vol. % for ethane and propane, respectively. This represents approximately 0.4 liquid vol. %

of the total crude stream. It would stand that operating the treaters toward the higher end of their operating range would ensure maximum reduction of the light ends fractions of the crude oil with current equipment. Because of this, the NDPC recommends that operators run their treaters at the highest feasible operational temperature that allows for safe and consistent operation, to help minimize these components in the crude. This recognizes the limits of both treater design and the limits set forth for the safe storage of crude in stock tanks, which have upper bounds on crude storage temperature.

The impact of stock tanks for crude storage versus being connected to a gathering system on vapor pressure was also considered. Stock tanks hold produced crude and sit for a short time before being pumped out. In the case of this study, the duration between a filled stock tank and sample collection was as much as a day and a half. Because of this, there is a small opportunity for light ends to weather off. The comparison showed there was no appreciable trend between samples collected from wells on a gathering system versus those that used a stock tank and were isolated from the well before collection.

Figure 17 shows the data for this comparison, plotted for those wells with which we had distinct information on their configuration. This is expected, as tanks are designed to minimize evaporative emissions; so significant changes in vapor pressure would indicate the possibility of high tank emissions.

**Figure 17: Vapor Pressure versus Well Production Rate**




## Overview of Sampling, Analytical Methods and Quality Control/Quality Assurance

### Sampling

All samples were obtained at both the well and rail facilities by trained SGS personnel, based out of Williston, ND, following accepted industry practices for collection of crude oil samples. Sampling procedures in API Chapter 8.1 "Manual Sampling of Petroleum and Petroleum Products" formed the basis for their sampling methodology. SGS has also written in-house sampling procedures that supplement the API document, as part of their standard operating procedures.

The crude oil samples were collected in chilled one-quart glass bottles, immediately sealed, chilled, and transported to the Williston lab. This is very similar to sampling procedures used for finished gasoline, which has a RVP of up to 15 psi. All analyses in Williston were conducted within a few days of receipt.

As discussed before, on the first visit to each site, individual "top" and "bottom" level samples were obtained and analyzed. This was conducted to evaluate tank stratification. On subsequent visits to each site, "average" tank samples were collected.

On samples obtained from the last two visits to each site, the D7169 simulated distillation analysis was excluded. Results from this test were showing good consistency, and the continued analysis was adding little to the understanding of the light ends portion of the crude oil.

**Analytical Methods and Quality Control/Quality Assurance**

SGS, the primary contact lab utilized for the collection and analyses of the Bakken crude oil well and rail loading facility samples, is ISO 9001 certified at the corporate level. The St. Rose, LA lab, used to conduct the more sophisticated light ends and D7169 gas chromatographic simulated distillation analyses, is fully certified. The more recently acquired Williston, ND lab, used for the sample collection, API gravity, flash point, IBP by D86, and vapor pressure by D6377 analyses, is in the process of obtaining ISO 9001 certification.

ISO 9001:2008 is based on eight quality management principles:

- Customer focus;
- Leadership;
- Involvement of people;
- Process approach;
- System approach;
- Continual improvement;
- Fact-based decision making; and
- Mutually beneficial supplier relationships.

SGS follows standard ASTM methods. They ensure use of the most current standards by subscription to Tracker Alert biweekly, which provides prompt update notification. The updates are stored electronically for analyst referral at both labs.

Corporately, approximately 50 of the SGS labs participate in the ASTM Crude Oil Proficiency Program. This program, commonly referred to as a "round-robin" program, involves ASTM periodically preparing and supplying identical crude oil samples to labs all over the world. The labs then conduct their analyses and submit their results to ASTM. ASTM compiles the results and publishes the data, using lab code numbers to protect the identity of the labs. Each lab receives their own code number so they know their performance and how their results compare to the other participating labs, but do not know the identity of other participants. Programs such as this are vital for laboratories to evaluate their performance, take corrective action, and continually improve.

Specific QA/QC procedures for each of the analytical methods are described below.

- API Gravity by ASTM D5002 "Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Meter" - This method is specifically for the measurement of crude oils. The instrumentation is calibrated with freshly distilled water as described in Section 10 of the method.

- Flash Point by ASTM D3278 (Williston lab) or ASTM D56 (St. Rose lab) - Flash point measures the tendency of the material to form a flammable mixture with air under controlled laboratory conditions. Section §173.120 of Hazardous Material Regulations allows for the use of either ASTM D56 or D3828. Both D56 and D3278 are very similar. ASTM D56 is the "Standard Method for Flash Point by Tag Closed Cup Tester," while ASTM D3278 is "Standard Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus." Para-Xylene is used as a calibration/check standard for this method, and records were provided by SGS showing acceptable results for this material.

  In the case of flash point, it was not necessary to determine the exact flash point, but only to determine whether the value was above or below the critical value of 73°F, which distinguishes between PG II and PG III.

- IBP by ASTM D86 "Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure" - This method, originally approved by ASTM in 1921 is still utilized for certification of petroleum products such as gasoline and diesel fuel. Temperature bias is determined using reagent grade toluene as a standard, as described in Section 9 of the method. To verify the temperature measurement, pure n-hexadecane is used. SGS provided examples of the instrument printouts for the analyses of both of these reference materials.

  It should be noted that full boiling range crude oils are not within the scope of this method as described in Section 1. Thus, various labs have employed different conditions for the condenser and receiver temperatures. These parameters were shown to have a significant impact on the recorded IBP of whole crudes. However, these differences have only a minimal effect on the analysis of the standard materials. Thus, acceptable results on the standard materials do NOT ensure correct IBPs on whole crude.

- Vapor Pressure of Crude Oil (VPCRx) by ASTM D6377 "Standard Test Method for Determination of Vapor Pressure of Crude Oil: VPCRx (Expansion Method)" - This newer method (originally published in 1999) has become the method of choice for vapor pressure measurements of whole crude oils, and EPA recommended its use in a recent publication for determining storage tank compliance. Section 11 of the method describes Quality Control Checks and indicates that Pentane, 2,2-Dimethylbutane, or 2,3-Dimethylbutane may be used as acceptable reference fluids. SGS uses 2,2-Dimethylbutane, and provided results showing all values within the acceptable limits of 10.58 psi – 10.92 psi for this standard material.

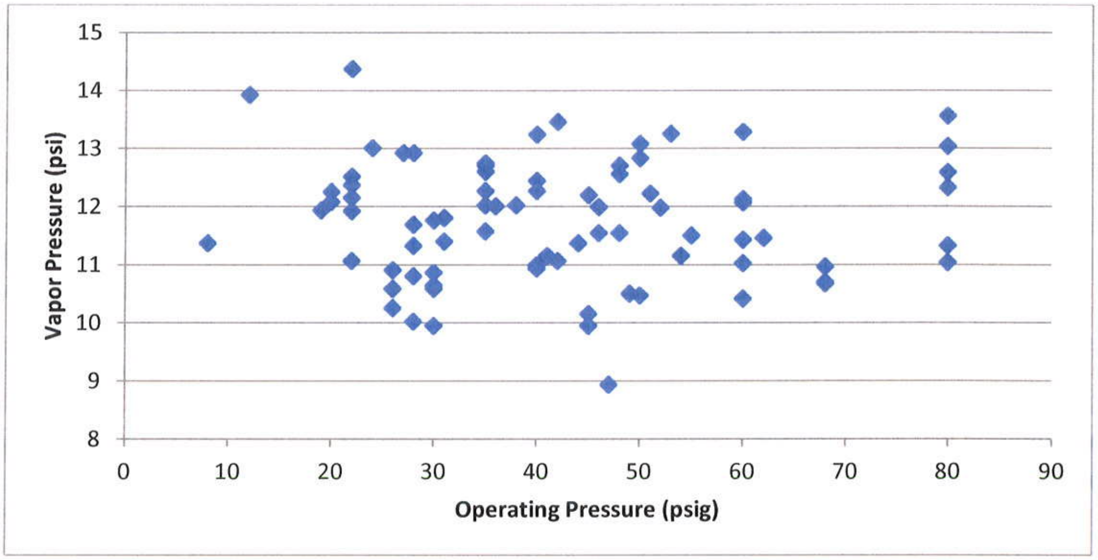
- Light Ends in Crude Oil by IP344-88 (2010) "Determination of light hydrocarbons in stabilized crude oils- Gas Chromatography method" - This is an Institute of Petroleum (IP) method. IP is the British equivalent of ASTM. This is an internal standard gas chromatography (GC) method. No reference standard is used, but participation in the ASTM Crude Oil Proficiency program is used to evaluate the accuracy of the results from this analysis.

- Boiling Range Distribution by ASTM D7169 "Standard Test Method for Boiling Point Distribution of Samples with Residues Such as Crude Oils and Atmospheric and Vacuum Residues by High Temperature Gas Chromatography" - This newer method (originally published in 2005) is an external standard approach to obtain distillation type data for full-range crude oils. A reference gas oil is used for determination of detector response and evaluation of boiling points. This standard is run regularly. Blank runs are made to determine the baseline correction.

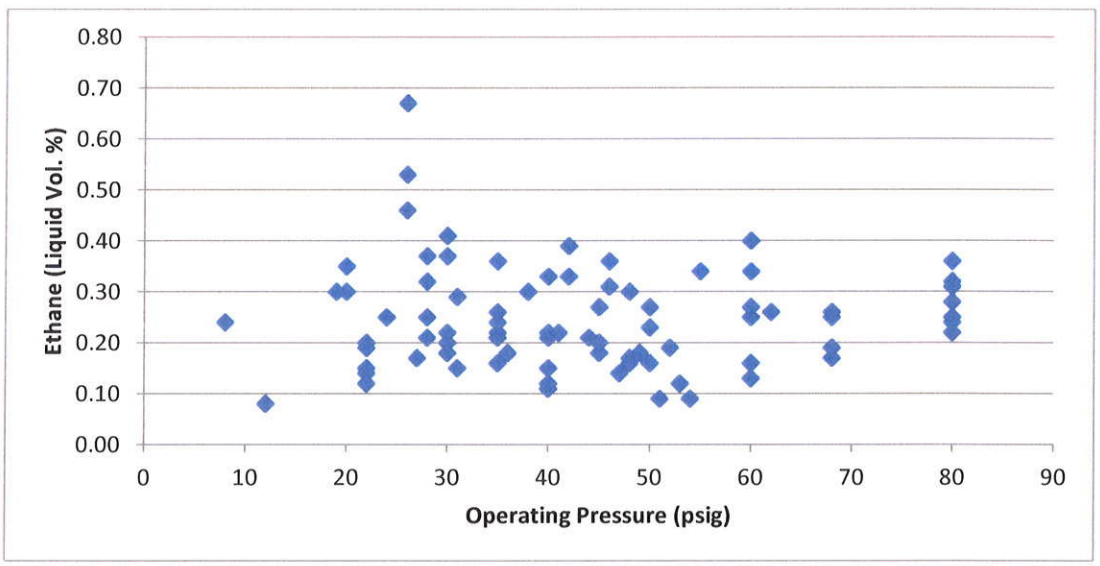
Documentation was also provided showing calibration information for balances and thermometers used in various laboratory methods.

## Appendix 1: Additional Figures

### Figure 1-1: Vapor Pressure versus Operating Pressure




### Figure 1-2: Ethane Liquid Vol. % versus Operating Pressure



## Appendix 1: Additional Figures

**Figure 1-3: Ethane Liquid Vol. % versus Production Rate**

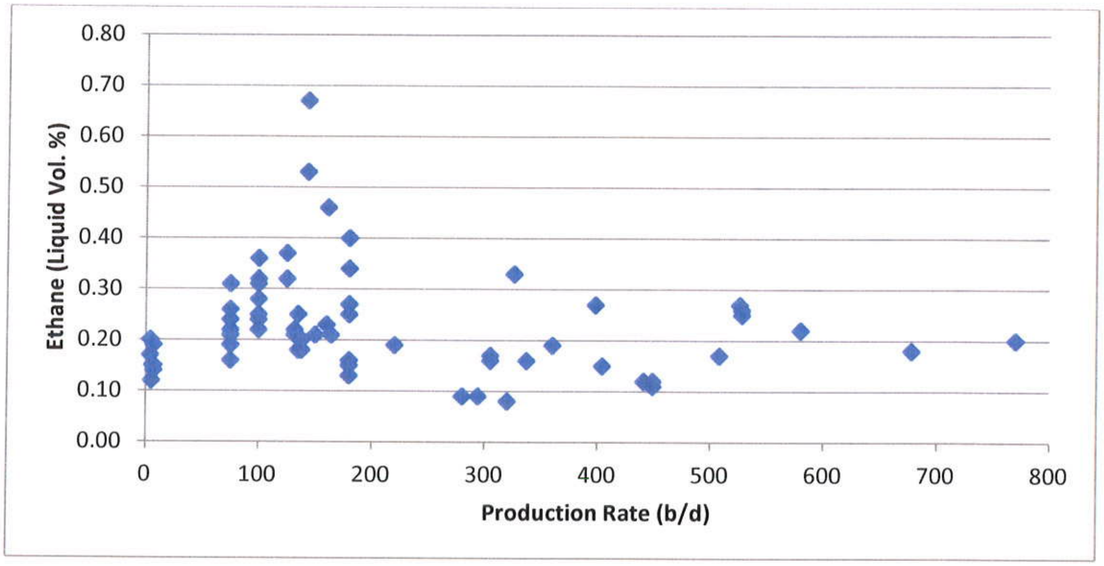
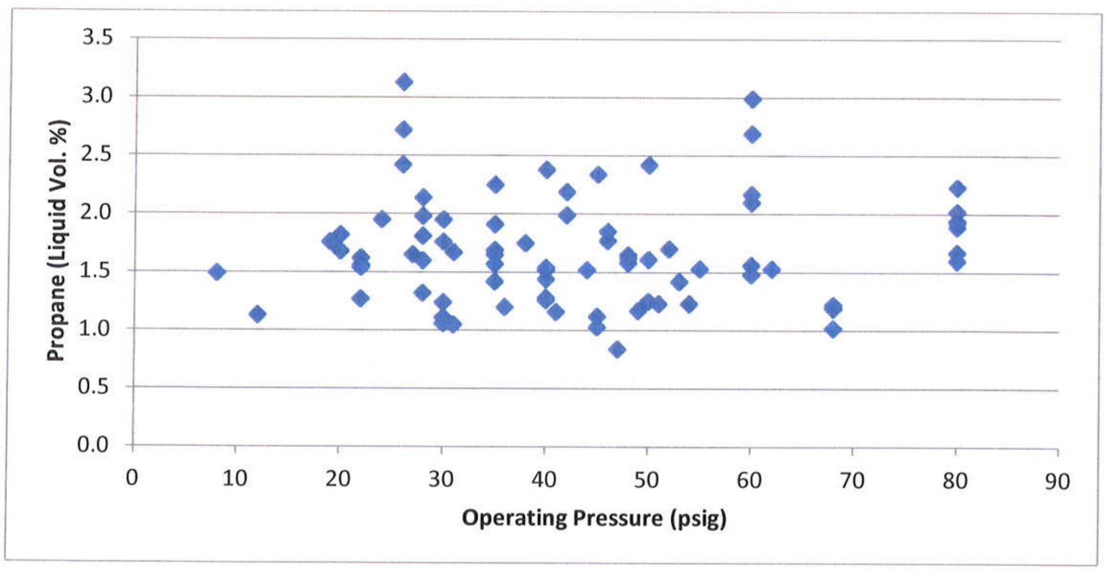



**Figure 1-4: Propane Liquid Vol. % versus Operating Pressure**



**Appendix 1: Additional Figures**

**Figure 1-5: Propane Liquid Vol. % versus Production Rate**

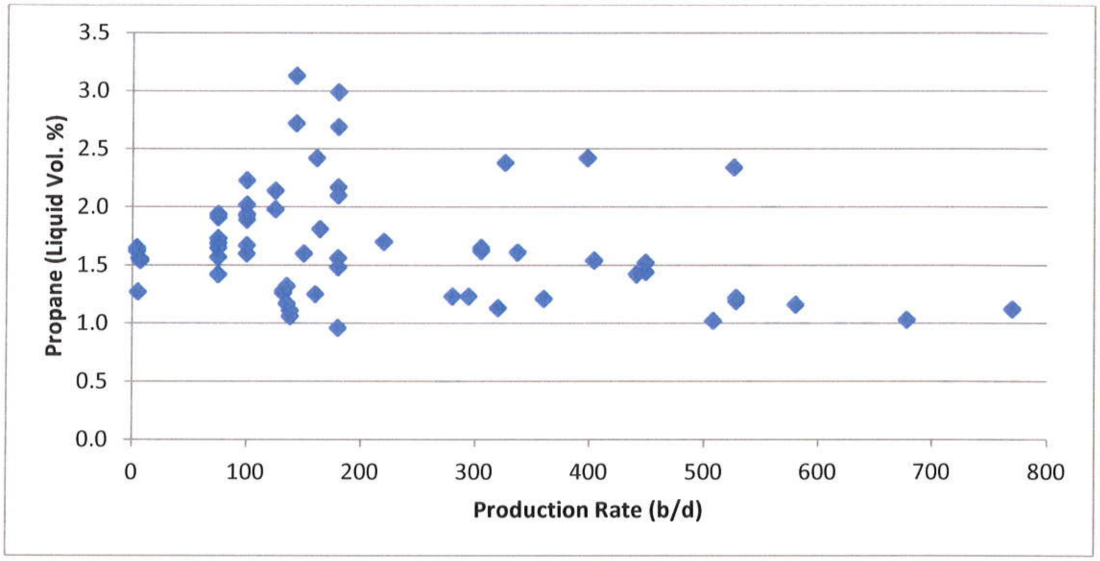



**Figure 1-6: Ethane Liquid Vol. % versus Operating Temperature: Correlation**
Note: anomalous readings from W7 excluded to improve correlation.

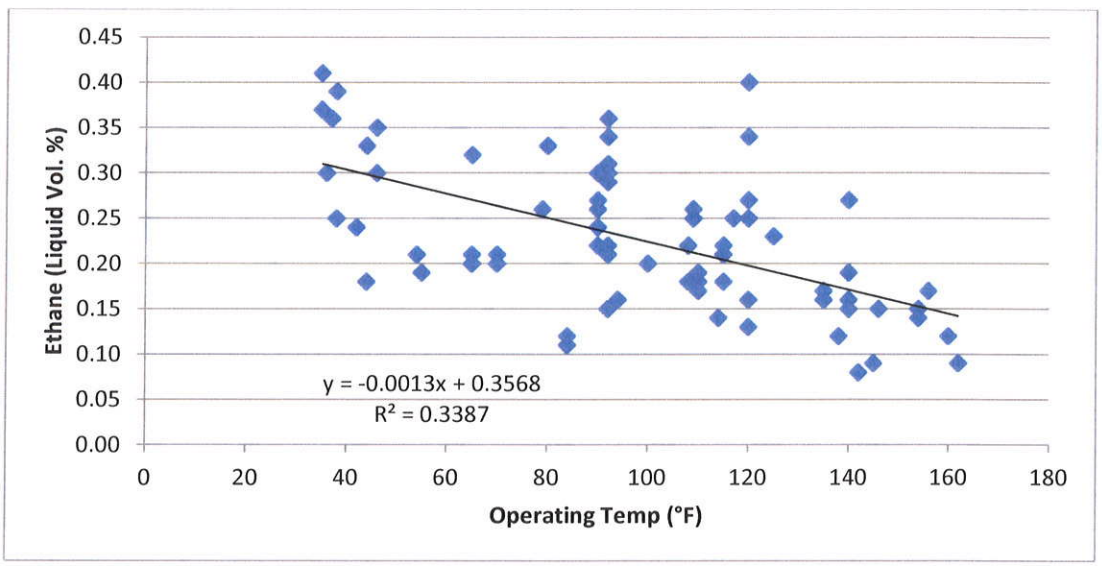
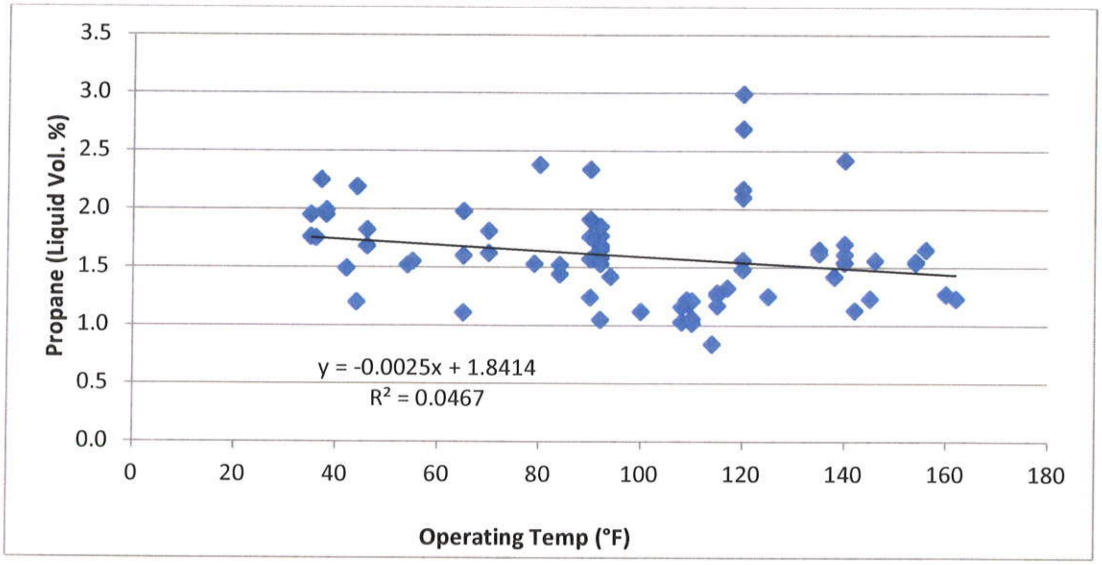


**Figure 1-7: Propane Liquid Vol. % versus Operating Temperature: Correlation**
Note: anomalous readings from W7 excluded to improve correlation.



## Appendix 2 - Summary Data

| | Total | | | | | Rail | | | | | Well | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev |
| Ambient Temp (°F) | 108 | 10.0 | **33.8** | 65.0 | 13.7 | 37 | 10.0 | **28.7** | 47.0 | 9.8 | 71 | 11.0 | **36.5** | 65.0 | 14.7 |
| API Gravity | 152 | 36.7 | **41.0** | 46.3 | 2.2 | 49 | 39.2 | **41.7** | 44.0 | 1.3 | 103 | 36.7 | **40.6** | 46.3 | 2.4 |
| D86 IBP (°F) | 152 | 91.9 | **99.5** | 106.8 | 2.4 | 49 | 96.7 | **100.3** | 104.1 | 1.7 | 103 | 91.9 | **99.1** | 106.8 | 2.6 |
| Vapor P via D6377 (100°F, 4:1 V/L) (psi) | 152 | 8.93 | **11.69** | 14.37 | 0.97 | 49 | 9.57 | **11.52** | 12.85 | 0.80 | 103 | 8.93 | **11.77** | 14.37 | 1.04 |
| **Light Ends via IP344** | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev |
| Methane | 152 | 0.00 | **0.00** | 0.01 | 0.00 | 27 | 0.00 | **0.00** | 0.01 | 0.00 | 79 | 0.00 | **0.00** | 0.01 | 0.00 |
| Ethane | 152 | 0.08 | **0.24** | 0.67 | 0.08 | 49 | 0.13 | **0.23** | 0.33 | 0.04 | 103 | 0.08 | **0.24** | 0.67 | 0.09 |
| Propane | 152 | 0.84 | **1.55** | 3.13 | 0.41 | 49 | 1.02 | **1.39** | 1.95 | 0.24 | 103 | 0.84 | **1.63** | 3.13 | 0.45 |
| Isobutane | 152 | 0.35 | **0.63** | 0.95 | 0.13 | 49 | 0.46 | **0.58** | 0.73 | 0.07 | 103 | 0.35 | **0.65** | 0.95 | 0.15 |
| n- Butane | 152 | 2.00 | **3.03** | 4.55 | 0.56 | 49 | 2.17 | **2.75** | 3.51 | 0.33 | 103 | 2.00 | **3.16** | 4.55 | 0.60 |
| Neopentane | 150 | 0.00 | **0.01** | 0.01 | 0.00 | 49 | 0.00 | **0.01** | 0.01 | 0.00 | 101 | 0.00 | **0.01** | 0.01 | 0.00 |
| Isopentane | 152 | 1.10 | **1.49** | 1.93 | 0.20 | 49 | 1.17 | **1.42** | 1.69 | 0.11 | 103 | 1.10 | **1.52** | 1.93 | 0.23 |
| n- Pentane | 152 | 2.07 | **2.84** | 3.70 | 0.38 | 49 | 2.12 | **2.72** | 3.33 | 0.23 | 103 | 2.07 | **2.90** | 3.70 | 0.43 |
| Cyclopentane | 152 | 0.17 | **0.22** | 0.30 | 0.03 | 49 | 0.17 | **0.21** | 0.25 | 0.02 | 103 | 0.17 | **0.23** | 0.30 | 0.03 |
| Hexanes | 152 | 4.98 | **6.33** | 7.64 | 0.56 | 49 | 5.46 | **6.33** | 6.96 | 0.32 | 103 | 4.98 | **6.34** | 7.64 | 0.64 |
| **Simulated Distillation via D7169** | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev | Count | Min | Avg | Max | StDev |
| IBP | 111 | <97 | **<97** | <97 | | 111 | <97 | **<97** | <97 | | 111 | <97 | **<97** | <97 | |
| 5%* | 111 | 97 | **108** | 151 | 17 | 21 | 98 | **113** | 151 | 17 | 28 | 97 | **106** | 150 | 18 |
| 10%* | 111 | 103 | **157** | 188 | 17 | 35 | 143 | **165** | 186 | 10 | 71 | 103 | **153** | 188 | 19 |
| 20% | 111 | 180 | **234** | 278 | 20 | 35 | 216 | **238** | 264 | 11 | 76 | 180 | **231** | 278 | 23 |
| 30% | 111 | 244 | **312** | 375 | 25 | 35 | 289 | **316** | 346 | 12 | 76 | 244 | **310** | 375 | 29 |
| 40% | 111 | 327 | **395** | 476 | 29 | 35 | 364 | **396** | 436 | 15 | 76 | 327 | **394** | 476 | 34 |
| 50% | 111 | 412 | **481** | 578 | 33 | 35 | 443 | **482** | 527 | 17 | 76 | 412 | **481** | 578 | 38 |
| 60% | 111 | 508 | **572** | 684 | 35 | 35 | 527 | **572** | 623 | 19 | 76 | 508 | **572** | 684 | 41 |
| 70% | 111 | 611 | **671** | 796 | 39 | 35 | 620 | **670** | 730 | 23 | 76 | 611 | **671** | 796 | 45 |
| 80% | 111 | 718 | **786** | 920 | 42 | 35 | 733 | **787** | 850 | 25 | 76 | 718 | **785** | 920 | 48 |
| 90% | 111 | 860 | **936** | 1069 | 43 | 35 | 888 | **939** | 1012 | 30 | 76 | 860 | **935** | 1069 | 48 |
| 95% | 111 | 966 | **1056** | 1192 | 52 | 35 | 1000 | **1060** | 1180 | 44 | 76 | 966 | **1053** | 1192 | 55 |
| FBP* | 111 | 1186 | **1309** | 1362 | 44 | 21 | 1217 | **1317** | 1342 | 40 | 51 | 1186 | **1305** | 1362 | 45 |
| Recovery (weight %) | 111 | 95.7 | **99.3** | 100.0 | 1.1 | 35 | 95.9 | **99.3** | 100.0 | 1.1 | 76 | 95.7 | **99.4** | 100.0 | 1.1 |

* Items with astricks were adjusted averages, to account for one or more values that were above or below detection limits (97°F and 1382°F, respectively).
Those items were adjusted by averaging the detection limit for those values, and thus the averages may be slightly above or below the actual value.
Raw data can be seen in the other sheets for reference.

## Appendix 3 - Sample Conditions - Rail Locations

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | 32 | Glass Bottle | 100,000 | 10ft | Top |
| R1 | 3/25/2014 | 17:00 | 32 | Glass Bottle | 100,000 | 10ft | Bottom |
| R1 | 3/27/2014 | 17:26 | 33 | Glass Bottle | 100,000 | 10ft | All Levels |
| R1 | 3/31/2014 | 14:08 | 19 | Glass Bottle | 100,000 | 16ft 2in | All Levels |
| R1 | 4/9/2014 | 10:38 | | Glass Bottle | 100,000 | | All Levels |
| R1 | 4/16/2014 | 15:30 | | Glass Bottle | 100,000 | | All Levels |
| R1 | 4/18/2014 | 11:00 | | Glass Bottle | 100,000 | | All Levels |
| R2 | 3/25/2014 | 18:00 | 20 | Glass Bottle | 250,000 | | Top |
| R2 | 3/25/2014 | 18:00 | 20 | Glass Bottle | 250,000 | | Bottom |
| R2 | 3/27/2014 | 10:30 | 25 | Glass Bottle | 250,000 | | All Levels |
| R2 | 3/31/2014 | 12:30 | 13 | Glass Bottle | 250,000 | 46ft 9in | All Levels |
| R2 | 4/8/2014 | 10:20 | 45 | Glass Bottle | 250,000 | 43ft | All Levels |
| R2 | 4/15/2014 | 11:30 | | Glass Bottle | 250,000 | 39ft 6in | All Levels |
| R2 | 4/18/2014 | 10:20 | 34 | Glass Bottle | 250,000 | 34ft | All Levels |
| R3 | 3/26/2014 | 14:30 | 29 | Glass Bottle | 50ft | 41ft | Top |
| R3 | 3/26/2014 | 14:30 | 29 | Glass Bottle | 50ft | 41ft | Bottom |
| R3 | 3/28/2014 | 13:30 | 32 | Glass Bottle | 50ft | 42ft | All Levels |
| R3 | 4/1/2014 | 16:10 | 17 | Glass Bottle | 50ft | 33ft | All Levels |
| R3 | 4/10/2014 | 14:50 | | Glass Bottle | 50ft | | All Levels |
| R3 | 4/15/2014 | 14:15 | 46 | Glass Bottle | 50ft | 42ft | All Levels |
| R3 | 4/17/2014 | 13:00 | 32 | Glass Bottle | 50ft | 42ft | All Levels |
| R4 | 3/25/2014 | 14:30 | 20 | Glass Bottle | 250,000 | 23ft | Top |
| R4 | 3/25/2014 | 14:30 | 20 | Glass Bottle | 250,000 | 23ft | Bottom |
| R4 | 3/27/2014 | 11:50 | 19 | Glass Bottle | 250,000 | 18ft | All Levels |
| R4 | 3/31/2014 | 11:20 | 10 | Glass Bottle | 250,000 | 17ft | All Levels |
| R4 | 4/7/2014 | 13:45 | 47 | Glass Bottle | 250,000 | 18ft | All Levels |
| R4 | 4/16/2014 | 12:35 | | Glass Bottle | 250,000 | | All Levels |
| R4 | 4/18/2014 | 12:05 | 37 | Glass Bottle | 250,000 | 23ft | All Levels |

## Appendix 3 - Sample Conditions - Rail Locations

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| R5 | 3/26/2014 | 12:00 | 36 | Glass Bottle | 45ft | 39ft | Top |
| R5 | 3/26/2014 | 12:00 | 36 | Glass Bottle | 45ft | 39ft | Bottom |
| R5 | 3/28/2014 | 12:00 | 32 | Glass Bottle | 45ft | 32ft | All Levels |
| R5 | 4/1/2014 | 14:30 | 15 | Glass Bottle | 45ft | 39ft | All Levels |
| R5 | 4/10/2014 | 13:15 | | Glass Bottle | 45ft | | All Levels |
| R5 | 4/15/2014 | 12:50 | 44 | Glass Bottle | 45ft | 40ft | All Levels |
| R5 | 4/17/2014 | 11:40 | 32 | Glass Bottle | 45ft | 28ft | All Levels |
| R6 | 3/26/2014 | 15:30 | 29 | Glass Bottle | 250,000 | | Top |
| R6 | 3/26/2014 | 15:30 | 29 | Glass Bottle | 250,000 | | Bottom |
| R6 | 3/27/2014 | 15:30 | 33 | Glass Bottle | 250,000 | | All Levels |
| R6 | 3/31/2014 | 14:00 | 13 | Glass Bottle | 250,000 | 27ft 4in | All Levels |
| R6 | 4/7/2014 | 15:00 | | Glass Bottle | 250,000 | | All Levels |
| R6 | 4/15/2014 | 14:00 | | Glass Bottle | 250,000 | 34ft 6in | All Levels |
| R6 | 4/17/2014 | 12:00 | | Glass Bottle | 250,000 | 38ft 6in | All Levels |
| R7 | 3/26/2014 | 19:30 | 28 | Glass Bottle | 250,000 | 40ft | Top |
| R7 | 3/26/2014 | 19:30 | 28 | Glass Bottle | 250,000 | 40ft | Bottom |
| R7 | 3/28/2014 | 13:00 | 46 | Glass Bottle | 250,000 | 42ft | All Levels |
| R7 | 3/31/2014 | 17:00 | 22 | Glass Bottle | 250,000 | 35ft 6in | All Levels |
| R7 | 4/11/2014 | 10:50 | | Glass Bottle | 250,000 | | All Levels |
| R7 | 4/14/2014 | 12:30 | 27 | Glass Bottle | 250,000 | 40ft | All Levels |
| R7 | 4/18/2014 | 10:00 | | Glass Bottle | 250,000 | 33ft | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 18 | Glass Bottle | 400 | 15ft | Top |
| W1 | 3/25/2014 | 19:45 | 18 | Glass Bottle | 400 | 15ft | Bottom |
| W1 | 3/27/2014 | 18:15 | 26 | Glass Bottle | 400 | 15ft | All Levels |
| W1 | 3/30/2014 | 16:00 | 39 | Glass Bottle | 400 | 15ft | All Levels |
| W1 | 4/1/2014 | 11:00 | | Glass Bottle | 400 | | All Levels |
| W1 | 4/7/2014 | 12:20 | 31 | Glass Bottle | 400 | 18ft | All Levels |
| W1 | 4/16/2014 | 11:30 | | Glass Bottle | 400 | 14ft | All Levels |
| W2 | 3/26/2014 | 12:45 | 30 | Glass Bottle | 400 | 14ft | Top |
| W2 | 3/26/2014 | 12:45 | 30 | Glass Bottle | 400 | 14ft | Bottom |
| W2 | 3/29/2014 | 15:00 | 52 | Glass Bottle | 400 | 10ft | All Levels |
| W2 | 3/31/2014 | 10:00 | 12 | Glass Bottle | 400 | 15ft | All Levels |
| W2 | 4/7/2014 | 13:05 | 51 | Glass Bottle | 400 | 16ft | All Levels |
| W2 | 4/16/2014 | 12:00 | | Glass Bottle | 400 | | All Levels |
| W2 | 4/19/2014 | 9:00 | | Glass Bottle | 400 | | All Levels |
| W3 | 3/25/2014 | 12:30 | 15 | Glass Bottle | 400 | 10ft | Top |
| W3 | 3/25/2014 | 12:30 | 15 | Glass Bottle | 400 | 10ft | Bottom |
| W3 | 3/27/2014 | 10:00 | 24 | Glass Bottle | 400 | 10ft | All Levels |
| W3 | 3/31/2014 | 10:00 | 11 | Glass Bottle | 400 | 10ft | All Levels |
| W3 | 4/7/2014 | 12:50 | 42 | Glass Bottle | 400 | 12ft | All Levels |
| W3 | 4/16/2014 | 10:30 | | Glass Bottle | 400 | 12ft | All Levels |
| W3 | 4/18/2014 | 11:20 | 37 | Glass Bottle | 400 | 10ft | All Levels |
| W4 | 3/26/2014 | 12:00 | 30 | Glass Bottle | 400 | 6ft | Top |
| W4 | 3/26/2014 | 12:00 | 30 | Glass Bottle | 400 | 6ft | Bottom |
| W4 | 3/28/2014 | 13:15 | 23 | Glass Bottle | 400 | 5ft 9in | All Levels |
| W4 | 4/3/2014 | 17:25 | 37 | Glass Bottle | 400 | 9ft | All Levels |
| W4 | 4/7/2014 | 18:14 | 49 | Glass Bottle | 400 | 10ft 6in | All Levels |
| W4 | 4/15/2014 | 16:00 | | Glass Bottle | 400 | 7ft 7in | All Levels |
| W4 | 4/17/2014 | 14:30 | | Glass Bottle | 400 | 7ft 2in | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W5 | 3/26/2014 | 15:50 | 30 | Glass Bottle | 400 | 5ft 6in | Top |
| W5 | 3/26/2014 | 15:50 | 30 | Glass Bottle | 400 | 5ft 6in | Bottom |
| W5 | 3/28/2014 | 13:50 | 23 | Glass Bottle | 400 | 5ft | All Levels |
| W5 | 4/4/2014 | 17:28 | 39 | Glass Bottle | 400 | 3ft | All Levels |
| W5 | 4/7/2014 | 19:08 | 46 | Glass Bottle | 400 | 6ft | All Levels |
| W5 | 4/15/2014 | 17:00 | 48 | Glass Bottle | 400 | 13ft 3in | All Levels |
| W5 | 4/17/2014 | 15:30 | 46 | Glass Bottle | 400 | 7ft 7in | All Levels |
| W6 | 4/6/2014 | 14:55 | 58 | Glass Bottle | 400 | 12ft 10.5in | Top |
| W6 | 4/6/2014 | 14:55 | 58 | Glass Bottle | 400 | 12ft 10.5in | Bottom |
| W6 | 4/8/2014 | 13:50 | 70 | Glass Bottle | 400 | 14ft 7in | All Levels |
| W6 | 4/15/2014 | 17:05 | 49 | Glass Bottle | 400 | 16ft 5.5in | All Levels |
| W6 | 4/17/2014 | 14:05 | 39 | Glass Bottle | 400 | 14ft 7.75in | All Levels |
| W6 | 4/21/2014 | 16:30 | 63 | Glass Bottle | 400 | 13ft 9in | All Levels |
| W6 | 4/24/2014 | 11:20 | 48 | Glass Bottle | 400 | 13ft 6in | All Levels |
| W7 | 3/25/2014 | 17:00 | 28 | Glass Bottle | 400 | 18ft | Top |
| W7 | 3/25/2014 | 17:00 | 28 | Glass Bottle | 400 | 18ft | Bottom |
| W7 | 3/27/2014 | 13:00 | 25 | Glass Bottle | 400 | 16ft | All Levels |
| W7 | 3/31/2014 | 13:00 | 16 | Glass Bottle | 400 | 15ft | All Levels |
| W7 | 4/7/2014 | 16:00 | 47 | Glass Bottle | 400 | 19ft | All Levels |
| W7 | 4/16/2014 | 14:20 |  | Glass Bottle | 400 | 7ft | All Levels |
| W7 | 4/21/2014 | 13:45 | 65 | Glass Bottle | 400 | 18ft | All Levels |
| W8 | 3/25/2014 | 14:53 | 27 | Glass Bottle | 400 | 13ft | Top |
| W8 | 3/25/2014 | 14:33 | 27 | Glass Bottle | 400 | 13ft | Bottom |
| W8 | 3/27/2014 | 15:30 | 32 | Glass Bottle | 400 | 7ft | All Levels |
| W8 | 3/31/2014 | 12:42 | 15 | Glass Bottle | 400 | 10ft | All Levels |
| W8 | 4/9/2014 | 12:30 | 65 | Glass Bottle | 400 | 8ft | All Levels |
| W8 | 4/16/2014 | 17:00 |  | Glass Bottle | 400 | 8ft 3in | All Levels |
| W8 | 4/18/2014 | 13:00 |  | Glass Bottle | 400 | 9ft | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W9 | 4/1/2014 | 11:20 | 13 | Glass Bottle | 400 | 13ft 6in | Top |
| W9 | 4/1/2014 | 12:10 | 13 | Glass Bottle | 400 | 13ft 6in | Bottom |
| W9 | 4/3/2014 | 13:00 | 25 | Glass Bottle | 400 | 13ft | All Levels |
| W9 | 4/8/2014 | 11:25 | 45 | Glass Bottle | 400 | 6ft 11in | All Levels |
| W9 | 4/15/2014 | 12:33 | 43 | Glass Bottle | 400 | 15ft | All Levels |
| W9 | 4/22/2014 | 11:35 | 63 | Glass Bottle | 400 | 12ft 1in | All Levels |
| W9 | 4/24/2014 | 14:20 | 53 | Glass Bottle | 400 | 18ft | All Levels |
| W10 | 4/15/2014 | 15:40 | 48 | Glass Bottle | 400 | 4ft | Top |
| W10 | 4/15/2014 | 15:40 | 48 | Glass Bottle | 400 | 4ft | Bottom |
| W10 | 4/17/2014 | 12:50 | 37 | Glass Bottle | 400 | 4ft | All Levels |
| W10 | 4/21/2014 | 15:30 | 58 | Glass Bottle | 400 | | All Levels |
| W10 | 4/24/2014 | 12:35 | 50 | Glass Bottle | 400 | 8ft | All Levels |
| W10 | 4/29/2014 | 11:00 | 32 | Glass Bottle | 400 | 10ft | All Levels |
| W11 | 4/7/2014 | 16:35 | 50 | Glass Bottle | 400 | 19ft | Top |
| W11 | 4/7/2014 | 16:35 | 50 | Glass Bottle | 400 | 19ft | Bottom |
| W11 | 4/11/2014 | 14:55 | 55 | Glass Bottle | 400 | 19ft | All Levels |
| W11 | 4/15/2014 | 15:00 | | Glass Bottle | 400 | 16ft 4in | All Levels |
| W11 | 4/17/2014 | 13:30 | | Glass Bottle | 400 | 12ft 2in | All Levels |
| W11 | 4/20/2014 | 11:00 | | Glass Bottle | 400 | 17ft 2in | All Levels |
| W11 | 4/23/2014 | 13:00 | | Glass Bottle | 400 | 16ft 4in | All Levels |
| W12 | 3/27/2014 | 12:46 | 27 | Glass Bottle | 400 | 12ft | Top |
| W12 | 3/27/2014 | 12:16 | 27 | Glass Bottle | 400 | 12ft | Bottom |
| W12 | 3/30/2014 | 13:00 | 42 | Glass Bottle | 400 | 18ft | All Levels |
| W12 | 4/1/2014 | 13:40 | 15 | Glass Bottle | 400 | 14ft | All Levels |
| W12 | 4/8/2014 | 13:20 | 59 | Glass Bottle | 400 | 10ft | All Levels |
| W12 | 4/17/2014 | 15:10 | 43 | Glass Bottle | 400 | 13ft | All Levels |
| W12 | 4/17/2014 | 15:30 | 35 | Glass Bottle | 400 | 8ft | All Levels |

## Appendix 4 - Sample Conditions - Well

| Client ID | Sample Date | Sample Time | Ambient Temp (°F) | Sample Container | Tank Size (barrels) | Level Height in Tank | Sample Location |
|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | 31 | Glass Bottle | 400 | 11ft | Top |
| W13 | 3/26/2014 | 17:00 | 31 | Glass Bottle | 400 | 11ft | Bottom |
| W13 | 3/28/2014 | 15:30 | 25 | Glass Bottle | 400 | 6ft | All Levels |
| W13 | 4/4/2014 | 15:15 | 39 | Glass Bottle | 400 | 6ft | All Levels |
| W13 | 4/8/2014 | 11:00 | 46 | Glass Bottle | 400 | 16ft | All Levels |
| W13 | 4/15/2014 | 19:30 | | Glass Bottle | 400 | | All Levels |
| W13 | 4/19/2014 | 14:00 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/6/2014 | 16:20 | | Glass Bottle | 400 | | Top |
| W14 | 4/6/2014 | 16:20 | | Glass Bottle | 400 | | Bottom |
| W14 | 4/4/2014 | 11:55 | 34 | Glass Bottle | 400 | 2ft 6in | All Levels |
| W14 | 4/8/2014 | 12:30 | 50 | Glass Bottle | 400 | 6ft | All Levels |
| W14 | 4/18/2014 | 16:30 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/20/2014 | 14:00 | | Glass Bottle | 400 | | All Levels |
| W14 | 4/22/2014 | 11:00 | | Glass Bottle | 400 | | All Levels |
| W15 | 4/9/2014 | 17:20 | | Glass Bottle | 40,000bbl/50 ft | 30ft 6in | Top |
| W15 | 4/9/2014 | 17:20 | | Glass Bottle | 40,000bbl/50 ft | 30ft 6in | Bottom |
| W15 | 4/18/2014 | 19:30 | | Glass Bottle | 40,000bbl/50 ft | 22ft 9in | All Levels |
| W15 | 4/21/2014 | 18:30 | | Glass Bottle | 40,000bbl/50 ft | 36ft 2in | All Levels |
| W15 | 4/23/2014 | 13:00 | | Glass Bottle | 40,000bbl/50 ft | 37ft 4in | All Levels |
| W15 | 4/24/2014 | 16:30 | 57 | Glass Bottle | 40,000bbl/50 ft | 32ft 9in | All Levels |

Appendix 5 - Operational Conditions - Well Only

| Client ID | Sample Date | Sample Time | Tank Vapor Capture - Flare Stack or VRU | Production Rates from Producer(b/d) | Last Movement from Tank (Date and Time) | Separator Size | Separator Operating Pressure (psig) | Separator Operating Temp (°F) | Treater/Emulsion Heater Size | Treater/Emulsion Heater Operating Pressure (psig) | Treater/Emulsion Heater Operating Temp (°F) | Treater/Emulsion Heater Oil Line Dia (inches) | Treater/Emulsion Heater Oil Dump Valve Size/Style | Additional Field Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/14 | 19:45 | | | | | | | | 46 | 92 | | | Treater |
| W1 | 3/25/14 | 19:45 | | | | | | | | 46 | 92 | | | Treater |
| W1 | 3/27/14 | 18:15 | | | | | | | | 48 | 92 | | | Treater |
| W1 | 3/30/14 | 16:00 | | | | | | | | 31 | 92 | | | Treater |
| W1 | 4/1/14 | 11:00 | | | | | | | | | | | | |
| W1 | 4/7/14 | 12:20 | | | | | | | | 31 | 92 | | | |
| W1 | 4/16/14 | 11:30 | | | | | | | | | | | | |
| W2 | 3/26/14 | 12:45 | | | | | | | | 20 | 46 | | | Treater |
| W2 | 3/26/14 | 12:45 | | | | | | | | 20 | 46 | | | Treater |
| W2 | 3/29/14 | 15:00 | | | | | | | | 19 | 90 | | | Treater |
| W2 | 3/31/14 | 10:00 | | | | | | | | 55 | 92 | | | Treater |
| W2 | 4/7/14 | 13:05 | | | | | | | | 44 | 54 | | | Treater |
| W2 | 4/16/14 | 12:00 | | | | | | | | | | | | |
| W2 | 4/19/14 | 9:00 | | | | | | | | | | | | |
| W3 | 3/25/14 | 12:30 | | 110 | N/A | | | | 6' x 20' | 30 | 35 | 3" | 3" Kimray | |
| W3 | 3/25/14 | 12:30 | | 110 | N/A | | | | 6' x 20' | 30 | 35 | 3" | 3" Kimray | |
| W3 | 3/27/14 | 10:00 | | 90 | N/A | | | | 6' x 20' | 42 | 38 | 3" | 3" Kimray | |
| W3 | 3/31/14 | 10:00 | | 100 | N/A | | | | 6' x 20' | 38 | 36 | 3" | 3" Kimray | |
| W3 | 4/7/14 | 12:50 | | 110 | N/A | | | | 6' x 20' | 36 | 44 | 3" | 3" Kimray | |
| W3 | 4/16/14 | 10:30 | | 90 | N/A | | | | 6' x 20' | 44 | 36 | 3" | 3" Kimray | |
| W3 | 4/18/14 | 11:20 | | 90 | N/A | | | | 6' x 20' | 8 | 42 | 3" | 3" Kimray | |
| W4 | 3/26/14 | 12:00 | Flare Stack | 305 | | N/A | N/A | N/A | 6' x 22' | 48 | 135 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 3/26/14 | 12:00 | Flare Stack | 305 | | N/A | N/A | N/A | 6' x 22' | 48 | 135 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 3/28/14 | 13:15 | Flare Stack | 337 | | N/A | N/A | N/A | 6' x 22' | 50 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/3/14 | 17:25 | Flare Stack | 280 | | N/A | N/A | N/A | 6' x 22' | 54 | 145 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/7/14 | 18:14 | Flare Stack | 320 | | N/A | N/A | N/A | 6' x 22' | 12 | 142 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/15/14 | 16:00 | Flare Stack | 220 | | N/A | N/A | N/A | 6' x 22' | 52 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W4 | 4/17/14 | 14:30 | Flare Stack | 326 | | N/A | N/A | N/A | 6' x 22' | 40 | 80 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/26/14 | 15:50 | Both (Stack/VRU) | 449 | | N/A | N/A | N/A | 6' x 22' | 40 | 84 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/26/14 | 15:50 | Both (Stack/VRU) | 449 | | N/A | N/A | N/A | 6' x 22' | 40 | 84 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 3/28/14 | 13:50 | Both (Stack/VRU) | 404 | | N/A | N/A | N/A | 6' x 22' | 40 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/4/14 | 17:28 | Both (Stack/VRU) | 294 | | N/A | N/A | N/A | 6' x 22' | 51 | 162 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/7/14 | 19:08 | Both (Stack/VRU) | 441 | | N/A | N/A | N/A | 6' x 22' | 53 | 138 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/15/14 | 17:00 | Both (Stack/VRU) | 526 | | N/A | N/A | N/A | 6' x 22' | 45 | 90 | 3" | 3" Gas Operated | On Gathering System |
| W5 | 4/17/14 | 15:30 | Both (Stack/VRU) | 398 | | N/A | N/A | N/A | 6' x 22' | 50 | 140 | 3" | 3" Gas Operated | On Gathering System |
| W6 | 4/6/14 | 14:55 | | 100 | 4/5/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/6/14 | 14:55 | | 100 | 4/5/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/8/14 | 13:50 | | 100 | 4/7/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/15/14 | 17:05 | | 100 | 4/14/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/17/14 | 14:05 | | 100 | 4/16/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/21/14 | 16:30 | | 100 | 4/20/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W6 | 4/24/14 | 11:20 | | 100 | 4/23/14 11:00 | 30" x 10' | 80 | | 6' x 20' | 30 | | 3" | 3" Steel | |
| W7 | 3/25/14 | 17:00 | Flare Stack | 143 | N/A | 30" x 10' | | | 6' x 20' | 26 | 120 | 3" | 3" float operated | |
| W7 | 3/25/14 | 17:00 | Flare Stack | 143 | N/A | 30" x 10' | | | 6' x 20' | 26 | 120 | 3" | 3" float operated | |
| W7 | 3/27/14 | 13:00 | Flare Stack | 161 | N/A | 30" x 10' | | | 6' x 20' | 26 | 123 | 3" | 3" float operated | |
| W7 | 3/31/14 | 13:00 | Flare Stack | 125 | N/A | 30" x 10' | | | 6' x 20' | 28 | 38 | 3" | 3" float operated | |
| W7 | 4/7/14 | 16:00 | Flare Stack | 150 | N/A | 30" x 10' | | | 6' x 20' | 28 | 65 | 3" | 3" float operated | |
| W7 | 4/16/14 | 14:20 | Flare Stack | 125 | N/A | 30" x 10' | | | 6' x 20' | 28 | 65 | 3" | 3" float operated | |
| W7 | 4/21/14 | 13:45 | Flare Stack | 164 | N/A | 30" x 10' | | | 6' x 20' | 28 | 70 | 3" | 3" float operated | |

| Client ID | Sample Date | Sample Time | Tank Vapor Capture - Flare Stack or VRU | Production Rates from Producer(b/d) | Last Movement from Tank (Date and Time) | Separator Size | Separator Operating Pressure (psig) | Separator Operating Temp (°F) | Treater/Emulsion Heater Size | Treater/Emulsion Heater Operating Pressure (psig) | Treater/Emulsion Heater Operating Temp (°F) | Treater/Emulsion Heater Oil Line Dia (inches) | Treater/Emulsion Heater Oil Dump Valve Size/Style | Additional Field Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W8 | 3/25/14 | 14:33 | Flare Stack | 7 | N/A | 30" x 10' | | | 6' x 20' | 22 | 154 | 3" | 3" float operated | |
| W8 | 3/27/14 | 15:30 | Flare Stack | 4 | N/A | 30" x 10' | | | 6' x 20' | 27 | 156 | 3" | 3" float operated | |
| W8 | 3/31/14 | 12:42 | Flare Stack | 6 | N/A | 30" x 10' | | | 6' x 20' | 22 | 146 | 3" | 3" float operated | |
| W8 | 4/9/14 | 12:30 | Flare Stack | 5 | N/A | 30" x 10' | | | 6' x 20' | 22 | 160 | 3" | 3" float operated | |
| W8 | 4/16/14 | 17:00 | Flare Stack | 4 | N/A | 30" x 10' | | | 6' x 20' | 22 | 70 | 3" | 3" float operated | |
| W8 | 4/18/14 | 13:00 | Flare Stack | 7 | N/A | 30" x 10' | | | 6' x 20' | 22 | 55 | 3" | 3" float operated | |
| W9 | 4/1/14 | 11:20 | Flare Stack | 528 | 3/31/14 8:30 | | | | 6' x 20' | 68 | 109 | | D3 | Sunny, Still weather |
| W9 | 4/1/14 | 12:10 | Flare Stack | 528 | 3/31/14 8:30 | | | | 6' x 20' | 68 | 109 | | D3 | Sunny, Still weather |
| W9 | 4/3/14 | 13:00 | Flare Stack | 508 | 4/3/14 10:20 | | | | 6' x 20' | 68 | 110 | | D3 | Windy and Cloudy |
| W9 | 4/8/14 | 11:25 | Flare Stack | 360 | Note Indicates N/A | | | | 6' x 20' | 68 | 110 | | D3 | Partially Cloudy |
| W9 | 4/15/14 | 12:33 | Flare Stack | 580 | 4/14/14 12:33 | | | | 6' x 20' | 41 | 108 | | D3 | Partially Cloudy and windy |
| W9 | 4/22/14 | 11:35 | Flare Stack | 678 | 4/21/14 0:00 | | | | 6' x 20' | 45 | 108 | | D3 | Sunny 20-25 mph winds |
| W9 | 4/24/14 | 14:20 | Flare Stack | 770 | 4/24/14 9:05 | | | | 6' x 20' | 45 | 100 | | D3 | Sunny |
| W10 | 4/15/14 | 15:40 | | 150 | N/A (Comingled) | | | | 6' x 20' | 35 | 37 | | | Observed: 0.05% BS&W |
| W10 | 4/15/14 | 15:40 | | 150 | N/A (Comingled) | | | | 6' x 20' | 35 | 37 | | | Observed: 0.05% BS&W |
| W10 | 4/17/14 | 12:50 | | 150 | N/A (Comingled) | | 35 | 37 | 6' x 20' | 35 | 37 | | | |
| W10 | 4/21/14 | 15:30 | | 150 | N/A (Comingled) | | 42 | 44 | 6' x 20' | 42 | 44 | | | |
| W10 | 4/24/14 | 12:35 | | 150 | N/A (Comingled) | | 24 | 38 | 6' x 20' | 24 | 38 | | | |
| W10 | 4/29/14 | 11:00 | | 150 | N/A (Comingled) | | | | 6' x 20' | 5 | 39 | | | |
| W11 | 4/7/14 | 16:35 | Flare Stack | 180 | 4/7/14 16:35 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W11 | 4/7/14 | 16:35 | Flare Stack | 180 | 4/7/14 16:35 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W11 | 4/11/14 | 14:55 | Flare Stack | 180 | 4/11/14 14:55 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 32 API at 76F, 0.05% BS&W |
| W11 | 4/15/14 | 15:00 | Flare Stack | 180 | 4/15/14 15:00 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 34 API at 72F, 0.05% BS&W |
| W11 | 4/17/14 | 13:30 | Flare Stack | 180 | 4/17/14 13:30 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 34 API at 73F, 0.05% BS&W |
| W11 | 4/20/14 | 11:00 | Flare Stack | 180 | 4/20/14 11:00 | 30" x 10' | 36 | | 6' x 22' | | | 3" | 3" | Observed: 36 API at 73F, 0.05% BS&W |
| W11 | 4/23/14 | 13:00 | Flare Stack | 180 | 4/23/14 15:30 | 30" x 10' | 36 | | 6' x 22' | 60 | 120 | 3" | 3" | Observed: 36 API at 75F, 0.05% BS&W |
| W12 | 3/27/14 | 12:46 | Flare Stack | 132 | N/A | 30" x 10' | | | 6' x 20' | 40 | 115 | 3" | 3" float operated | |
| W12 | 3/27/14 | 12:16 | Flare Stack | 132 | N/A | 30" x 10' | | | 6' x 20' | 40 | 115 | 3" | 3" float operated | |
| W12 | 3/30/14 | 13:00 | Flare Stack | 160 | N/A | 30" x 10' | | | 6' x 20' | 50 | 125 | 3" | 3" float operated | |
| W12 | 4/1/14 | 13:40 | Flare Stack | 135 | N/A | 30" x 10' | | | 6' x 20' | 28 | 117 | 3" | 3" float operated | |
| W12 | 4/8/14 | 13:20 | Flare Stack | 135 | N/A | 30" x 10' | | | 6' x 20' | 49 | 115 | 3" | 3" float operated | |
| W12 | 4/17/14 | 15:10 | Flare Stack | 138 | N/A | 30" x 10' | | | 6' x 20' | 30 | 110 | 3" | 3" float operated | |
| W12 | 4/17/14 | 15:30 | Flare Stack | 138 | N/A | 30" x 10' | | | 6' x 20' | 30 | 65 | 3" | 3" float operated | |
| W13 | 3/26/14 | 17:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 92 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 3/26/14 | 17:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 92 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 3/28/14 | 15:30 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 90 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/4/14 | 15:15 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 35 | 94 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/8/14 | 11:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | 36 | 90 | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/15/14 | 19:30 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | | | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W13 | 4/19/14 | 14:00 | | 75 | | 80 bbl | 35 | | 500,000 btu/hr | | | 3" | 3" Kimray | Observed 42.3 API at 60F |
| W14 | 4/6/14 | 16:20 | | | | | | | | | | | | |
| W14 | 4/6/14 | 16:20 | | | | | | | | | | | | |
| W14 | 4/4/14 | 11:55 | | | | | 30 | 90 | | 30 | 90 | | | |
| W14 | 4/8/14 | 12:30 | | | | | 62 | 79 | | 62 | 79 | | | |
| W14 | 4/18/14 | 16:30 | | | | | | | | | | | | |
| W14 | 4/20/14 | 14:00 | | | | | | | | | | | | |
| W14 | 4/22/14 | 11:00 | | | | | 47 | 114 | | 47 | 114 | | | |
| W15 | 4/9/14 | 17:20 | | | 4/9/14 17:20 | | | | | | | | | Observed 43 API |
| W15 | 4/9/14 | 17:20 | | | 4/9/14 17:20 | | | | | | | | | Observed 43 API |
| W15 | 4/18/14 | 19:30 | | | 4/18/14 19:30 | | | | | | | | | Observed 43 API |
| W15 | 4/21/14 | 18:30 | | | 4/21/14 18:30 | | | | | | | | | Observed 43 API |
| W15 | 4/23/14 | 13:00 | | | 4/23/14 13:00 | | | | | | | | | Observed 43 API |
| W15 | 4/24/14 | 16:30 | | | 4/24/14 16:30 | | | | | | | | | Observed 43 API |

## Appendix 6 - Lab Data - Rail

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | 39.6 | 100.5 | 9.73 | 67.1 | <73 |
| R1 | 3/25/2014 | 17:00 | 39.5 | 102.9 | 9.96 | 68.7 | <73 |
| R1 | 3/27/2014 | 17:26 | 39.7 | 103.9 | 9.67 | 66.7 | <73 |
| R1 | 3/31/2014 | 14:08 | 42.8 | 100.5 | 11.31 | 78.0 | <73 |
| R1 | 4/9/2014 | 10:38 | 41.6 | 100.8 | 11.76 | 81.1 | <73 |
| R1 | 4/16/2014 | 15:30 | 42.1 | 98.4 | 11.85 | 81.7 | <73 |
| R1 | 4/18/2014 | 11:00 | 41.4 | 99.9 | 12.33 | 85.0 | <73 |
| R2 | 3/25/2014 | 18:00 | 43.4 | 99.9 | 11.73 | 80.9 | <73 |
| R2 | 3/25/2014 | 18:00 | 42.8 | 100.7 | 11.68 | 80.5 | <73 |
| R2 | 3/27/2014 | 10:30 | 43.8 | 99.5 | 12.39 | 85.4 | <73 |
| R2 | 3/31/2014 | 12:30 | 43.2 | 99.4 | 11.52 | 79.4 | <73 |
| R2 | 4/8/2014 | 10:20 | 40.3 | 100.5 | 11.55 | 79.6 | <73 |
| R2 | 4/15/2014 | 11:30 | 42.0 | 97.8 | 11.94 | 82.3 | <73 |
| R2 | 4/18/2014 | 10:20 | 39.2 | 99.6 | 11.89 | 82.0 | <73 |
| R3 | 3/26/2014 | 14:30 | 42.4 | 103.5 | 11.53 | 79.5 | <73 |
| R3 | 3/26/2014 | 14:30 | 42.6 | 101.9 | 11.70 | 80.7 | <73 |
| R3 | 3/28/2014 | 13:30 | 42.6 | 100.9 | 11.53 | 79.5 | <73 |
| R3 | 4/1/2014 | 16:10 | 41.7 | 102.0 | 10.95 | 75.5 | <73 |
| R3 | 4/10/2014 | 14:50 | 40.9 | 97.2 | 11.53 | 79.5 | <73 |
| R3 | 4/15/2014 | 14:15 | 41.3 | 98.2 | 11.46 | 79.0 | <73 |
| R3 | 4/17/2014 | 13:00 | 40.6 | 98.8 | 11.02 | 76.0 | <73 |
| R4 | 3/25/2014 | 14:30 | 41.3 | 99.9 | 11.95 | 82.4 | <73 |
| R4 | 3/25/2014 | 14:30 | 41.4 | 99.2 | 11.25 | 77.6 | <73 |
| R4 | 3/27/2014 | 11:50 | 43.1 | 99.9 | 11.95 | 82.4 | <73 |
| R4 | 3/31/2014 | 11:20 | 41.5 | 99.5 | 12.44 | 85.8 | <73 |
| R4 | 4/7/2014 | 13:45 | 41.5 | 99.5 | 12.85 | 88.6 | <73 |
| R4 | 4/16/2014 | 12:35 | 40.3 | 99.1 | 12.08 | 83.3 | <73 |
| R4 | 4/18/2014 | 12:05 | 39.8 | 100.5 | 11.99 | 82.7 | <73 |

## Appendix 6 - Lab Data - Rail

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| R5 | 3/26/2014 | 12:00 | 44.0 | 101.0 | 10.52 | 72.5 | <73 |
| R5 | 3/26/2014 | 12:00 | 43.9 | 101.9 | 10.47 | 72.2 | <73 |
| R5 | 3/28/2014 | 12:00 | 42.4 | 100.5 | 10.50 | 72.4 | <73 |
| R5 | 4/1/2014 | 14:30 | 43.1 | 103.7 | 10.28 | 70.9 | <73 |
| R5 | 4/10/2014 | 13:15 | 42.6 | 100.4 | 10.95 | 75.5 | <73 |
| R5 | 4/15/2014 | 12:50 | 41.8 | 100.8 | 10.85 | 74.8 | <73 |
| R5 | 4/17/2014 | 11:40 | 42.0 | 103.4 | 9.57 | 66.0 | <73 |
| R6 | 3/26/2014 | 15:30 | 42.6 | 99.7 | 12.84 | 88.5 | <73 |
| R6 | 3/26/2014 | 15:30 | 42.5 | 98.9 | 12.47 | 86.0 | <73 |
| R6 | 3/27/2014 | 15:30 | 43.0 | 98.9 | 12.71 | 87.6 | <73 |
| R6 | 3/31/2014 | 14:00 | 41.2 | 99.4 | 11.82 | 81.5 | <73 |
| R6 | 4/7/2014 | 15:00 | 39.9 | 96.7 | 12.43 | 85.7 | <73 |
| R6 | 4/15/2014 | 14:00 | 40.2 | 100.8 | 12.52 | 86.3 | <73 |
| R6 | 4/17/2014 | 12:00 | 39.7 | 100.1 | 11.88 | 81.9 | <73 |
| R7 | 3/26/2014 | 19:30 | 42.3 | 104.1 | 11.66 | 80.4 | <73 |
| R7 | 3/26/2014 | 19:30 | 42.8 | 99.7 | 11.57 | 79.8 | <73 |
| R7 | 3/28/2014 | 13:00 | 42.6 | 99.5 | 11.89 | 82.0 | <73 |
| R7 | 3/31/2014 | 17:00 | 42.2 | 101.9 | 11.86 | 81.8 | <73 |
| R7 | 4/11/2014 | 10:50 | 40.9 | 99.3 | 11.37 | 78.4 | <73 |
| R7 | 4/14/2014 | 12:30 | 41.5 | 98.9 | 11.37 | 78.4 | <73 |
| R7 | 4/18/2014 | 10:00 | 40.4 | 101.7 | 11.39 | 78.5 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 40.6 | 98.2 | 11.99 | 82.7 | <73 |
| W1 | 3/25/2014 | 19:45 | 39.2 | 102.1 | 11.55 | 79.6 | <73 |
| W1 | 3/27/2014 | 18:15 | 40.3 | 99.7 | 11.55 | 79.6 | <73 |
| W1 | 3/30/2014 | 16:00 | 39.1 | 99.2 | 11.81 | 81.4 | <73 |
| W1 | 4/1/2014 | 11:00 | 37.1 | 98.8 | 12.18 | 84 | <73 |
| W1 | 4/7/2014 | 12:20 | 37.1 | 99.9 | 11.40 | 78.6 | <73 |
| W1 | 4/16/2014 | 11:30 | 37.7 | 98.6 | 11.57 | 79.8 | <73 |
| W2 | 3/26/2014 | 12:45 | 41.4 | 100.6 | 12.26 | 84.5 | <73 |
| W2 | 3/26/2014 | 12:45 | 40.2 | 100.3 | 12.08 | 83.3 | <73 |
| W2 | 3/29/2014 | 15:00 | 41.5 | 100.7 | 11.94 | 82.3 | <73 |
| W2 | 3/31/2014 | 10:00 | 39.9 | 101.9 | 11.50 | 79.3 | <73 |
| W2 | 4/7/2014 | 13:05 | 40.0 | 98.9 | 11.37 | 78.4 | <73 |
| W2 | 4/16/2014 | 12:00 | 38.0 | 98.1 | 11.27 | 77.7 | <73 |
| W2 | 4/19/2014 | 9:00 | 38.9 | 99.8 | 11.91 | 82.1 | <73 |
| W3 | 3/25/2014 | 12:30 | 43.8 | 96.8 | 10.65 | 73.4 | <73 |
| W3 | 3/25/2014 | 12:30 | 44.4 | 99.7 | 10.86 | 74.9 | <73 |
| W3 | 3/27/2014 | 10:00 | 44.4 | 98.6 | 11.07 | 76.3 | <73 |
| W3 | 3/31/2014 | 10:00 | 43.4 | 98.1 | 12.02 | 82.9 | <73 |
| W3 | 4/7/2014 | 12:50 | 42.1 | 99.4 | 12.01 | 82.8 | <73 |
| W3 | 4/16/2014 | 10:30 | 40.2 | 98.4 | 10.92 | 75.3 | <73 |
| W3 | 4/18/2014 | 11:20 | 42.1 | 98.9 | 11.37 | 78.4 | <73 |
| W4 | 3/26/2014 | 12:00 | 40.0 | 98.5 | 12.56 | 86.6 | <73 |
| W4 | 3/26/2014 | 12:00 | 41.7 | 97.7 | 12.71 | 87.6 | <73 |
| W4 | 3/28/2014 | 13:15 | 42.5 | 98.6 | 12.84 | 88.5 | <73 |
| W4 | 4/3/2014 | 17:25 | 40.4 | 98.2 | 11.15 | 76.9 | <73 |
| W4 | 4/7/2014 | 18:14 | 39.3 | 97.3 | 13.92 | 96 | <73 |
| W4 | 4/15/2014 | 16:00 | 38.9 | 97.4 | 11.98 | 82.6 | <73 |
| W4 | 4/17/2014 | 14:30 | 38.8 | 99.5 | 13.24 | 91.3 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W5 | 3/26/2014 | 15:50 | 42.9 | 97.3 | 12.27 | 84.6 | <73 |
| W5 | 3/26/2014 | 15:50 | 42.3 | 99.6 | 12.44 | 85.8 | <73 |
| W5 | 3/28/2014 | 13:50 | 44.3 | 98.2 | 13.24 | 91.3 | <73 |
| W5 | 4/4/2014 | 17:28 | 41.1 | 100.9 | 12.23 | 84.3 | <73 |
| W5 | 4/7/2014 | 19:08 | 39.9 | 94.6 | 13.26 | 91.4 | <73 |
| W5 | 4/15/2014 | 17:00 | 39.9 | 95.4 | 12.20 | 84.1 | <73 |
| W5 | 4/17/2014 | 15:30 | 42.6 | 97.5 | 13.08 | 90.2 | <73 |
| W6 | 4/6/2014 | 14:55 | 42.6 | 97.2 | 13.04 | 89.9 | <73 |
| W6 | 4/6/2014 | 14:55 | 42.6 | 96.5 | 13.04 | 89.9 | <73 |
| W6 | 4/8/2014 | 13:50 | 42.1 | 97.7 | 11.04 | 76.1 | <73 |
| W6 | 4/15/2014 | 17:05 | 42.5 | 96.7 | 12.33 | 85 | <73 |
| W6 | 4/17/2014 | 14:05 | 42.8 | 97.4 | 12.59 | 86.8 | <73 |
| W6 | 4/21/2014 | 16:30 | 42.3 | 98.9 | 11.33 | 78.1 | <73 |
| W6 | 4/24/2014 | 11:20 | 45.8 | 96.4 | 13.56 | 93.5 | <73 |
| W7 | 3/25/2014 | 17:00 | 43.5 | 97.6 | 10.25 | 70.7 | <73 |
| W7 | 3/25/2014 | 17:00 | 43.8 | 98.3 | 10.59 | 73 | <73 |
| W7 | 3/27/2014 | 13:00 | 42.6 | 99.9 | 10.91 | 75.2 | <73 |
| W7 | 3/31/2014 | 13:00 | 43.9 | 96.9 | 10.02 | 69.1 | <73 |
| W7 | 4/7/2014 | 16:00 | 39.2 | 96.7 | 11.33 | 78.1 | <73 |
| W7 | 4/16/2014 | 14:20 | 41.7 | 94.8 | 12.92 | 89.1 | <73 |
| W7 | 4/21/2014 | 13:45 | 39.5 | 99 | 11.69 | 80.6 | <73 |
| W8 | 3/25/2014 | 14:53 | 44.4 | 95 | 12.52 | 86.3 | <73 |
| W8 | 3/25/2014 | 14:33 | 44.6 | 99.2 | 12.37 | 85.3 | <73 |
| W8 | 3/27/2014 | 15:30 | 44.8 | 99 | 12.92 | 89.1 | <73 |
| W8 | 3/31/2014 | 12:42 | 43.4 | 97.5 | 12.15 | 83.8 | <73 |
| W8 | 4/9/2014 | 12:30 | 39.0 | 101.3 | 11.07 | 76.3 | <73 |
| W8 | 4/16/2014 | 17:00 | 40.9 | 96.1 | 11.92 | 82.2 | <73 |
| W8 | 4/18/2014 | 13:00 | 42.5 | 96.8 | 14.37 | 99.1 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W9 | 4/1/2014 | 11:20 | 38.0 | 104.3 | 10.70 | 73.8 | <73 |
| W9 | 4/1/2014 | 12:10 | 37.0 | 104 | 10.67 | 73.6 | <73 |
| W9 | 4/3/2014 | 13:00 | 37.3 | 101.4 | 10.69 | 73.7 | <73 |
| W9 | 4/8/2014 | 11:25 | 38.2 | 102 | 10.96 | 75.6 | <73 |
| W9 | 4/15/2014 | 12:33 | 36.9 | 101.4 | 11.15 | 76.9 | <73 |
| W9 | 4/22/2014 | 11:35 | 36.7 | 105.4 | 10.15 | 70 | <73 |
| W9 | 4/24/2014 | 14:20 | 38.9 | 91.9 | 9.95 | 68.6 | <73 |
| W10 | 4/15/2014 | 15:40 | 42.7 | 95 | 13.02 | 89.8 | <73 |
| W10 | 4/15/2014 | 15:40 | 42.8 | 95.4 | 12.75 | 87.9 | <73 |
| W10 | 4/17/2014 | 12:50 | 43.5 | 97.3 | 12.02 | 82.9 | <73 |
| W10 | 4/21/2014 | 15:30 | 46.3 | 95 | 13.46 | 92.8 | <73 |
| W10 | 4/24/2014 | 12:35 | 44.7 | 95.3 | 13.01 | 89.7 | <73 |
| W10 | | | 45.5 | 95.8 | 13.58 | 93.6 | <73 |
| W11 | 4/7/2014 | 16:35 | 38.6 | 96 | 10.41 | 71.8 | <73 |
| W11 | 4/7/2014 | 16:35 | 38.2 | 97.3 | 11.02 | 76 | <73 |
| W11 | 4/11/2014 | 14:55 | 41.8 | 95.7 | 13.29 | 91.6 | <73 |
| W11 | 4/15/2014 | 15:00 | 38.4 | 98.1 | 11.43 | 78.8 | <73 |
| W11 | 4/17/2014 | 13:30 | 39.3 | 99.4 | 12.07 | 83.2 | <73 |
| W11 | 4/20/2014 | 11:00 | 37.0 | 104.5 | 9.96 | 68.7 | <73 |
| W11 | 4/23/2014 | | 38.9 | 98.3 | 12.13 | 83.6 | <73 |
| W12 | 3/27/2014 | 12:46 | 38.8 | 100.1 | 10.99 | 75.8 | <73 |
| W12 | 3/27/2014 | 12:16 | 38.2 | 101.3 | 10.94 | 75.4 | <73 |
| W12 | 3/30/2014 | 13:00 | 38.7 | 101.9 | 10.47 | 72.2 | <73 |
| W12 | 4/1/2014 | 13:40 | 38.1 | 102.2 | 10.81 | 74.5 | <73 |
| W12 | 4/8/2014 | 13:20 | 37.7 | 98.9 | 10.50 | 72.4 | <73 |
| W12 | 4/17/2014 | 15:10 | 37.9 | 101.8 | 9.95 | 68.6 | <73 |
| W12 | 4/17/2014 | 15:30 | 37.9 | 100.7 | 10.59 | 73 | <73 |

## Appendix 7 - Lab Data - Well

| Client ID | Sample Date | Sample Time | API Gravity | D86 IBP (°F) | Vapor P via D6377 (100°F, 4:1 V/L) (psi) | Vapor P via D6377 (100°F, 4:1 V/L) (kPa) | Flash Point D3278 (°F) |
|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | 42.5 | 100.4 | 12.71 | 87.6 | <73 |
| W13 | 3/26/2014 | 17:00 | 41.4 | 99.9 | 12.60 | 86.9 | <73 |
| W13 | 3/28/2014 | 15:30 | 40.6 | 100.7 | 12.27 | 84.6 | <73 |
| W13 | 4/4/2014 | 15:15 | 42.7 | 99.4 | 12.75 | 87.9 | <73 |
| W13 | 4/8/2014 | 11:00 | 38.5 | 98.9 | 11.57 | 79.8 | <73 |
| W13 | 4/15/2014 | 19:30 | 39.3 | 98.3 | 12.56 | 86.6 | <73 |
| W13 | 4/19/2014 | 14:00 | 39.7 | 99 | 12.81 | 88.3 | <73 |
| W14 | 4/6/2014 | 16:20 | 37.4 | 99.8 | 11.47 | 79.1 | <73 |
| W14 | 4/6/2014 | 16:20 | 38.1 | 98.3 | 11.31 | 78 | <73 |
| W14 | 4/4/2014 | 11:55 | 38.5 | 103.1 | 11.76 | 81.1 | <73 |
| W14 | 4/8/2014 | 12:30 | 37.4 | 100.7 | 11.46 | 79 | <73 |
| W14 | 4/18/2014 | 16:30 | 38.9 | 100.2 | 10.96 | 75.6 | <73 |
| W14 | 4/20/2014 | 14:00 | 37.1 | 105.3 | 9.35 | 64.5 | <73 |
| W14 | 4/22/2014 | 11:00 | 37.5 | 106.8 | 8.93 | 61.6 | <73 |
| W15 | 4/9/2014 | 17:20 | 40.1 | 100 | 11.75 | 81 | <73 |
| W15 | 4/9/2014 | 17:20 | 39.9 | 101.3 | 11.44 | 78.9 | <73 |
| W15 | 4/18/2014 | 19:30 | 40.9 | 101.8 | 12.84 | 88.5 | <73 |
| W15 | 4/21/2014 | 18:30 | 40.4 | 103.2 | 12.59 | 86.8 | <73 |
| W15 | 4/23/2014 | 13:00 | 41.9 | 99.9 | 11.04 | 76.1 | <73 |
| W15 | 4/24/2014 | 16:30 | 42.9 | 102.2 | 11.21 | 77.3 | <73 |

# Appendix 8 - Light Ends Data - Rail

| Client ID | Sample Date | Sample Time | Light Ends IP344 - All results in liquid volume % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
| R1 | 3/25/2014 | 17:20 | <0.01 | 0.18 | 1.16 | 0.49 | 2.27 | 0.01 | 1.22 | 2.21 | 0.21 | 5.64 |
| R1 | 3/25/2014 | 17:00 | <0.01 | 0.17 | 1.14 | 0.49 | 2.27 | 0.01 | 1.22 | 2.21 | 0.21 | 5.66 |
| R1 | 3/27/2014 | 17:26 | 0.00 | 0.18 | 1.10 | 0.46 | 2.17 | 0.00 | 1.17 | 2.12 | 0.20 | 5.46 |
| R1 | 3/31/2014 | 14:08 | <0.01 | 0.25 | 1.46 | 0.62 | 2.73 | 0.01 | 1.46 | 2.67 | 0.21 | 6.48 |
| R1 | 4/9/2014 | 10:38 | 0.00 | 0.25 | 1.46 | 0.62 | 2.74 | 0.01 | 1.44 | 2.67 | 0.20 | 6.38 |
| R1 | 4/16/2014 | 15:30 | 0.01 | 0.23 | 1.35 | 0.60 | 2.78 | 0.01 | 1.59 | 2.84 | 0.21 | 6.68 |
| R1 | 4/18/2014 | 11:00 | 0.00 | 0.20 | 1.23 | 0.55 | 2.56 | 0.01 | 1.41 | 2.65 | 0.20 | 6.50 |
| R2 | 3/25/2014 | 18:00 | <0.01 | 0.28 | 1.56 | 0.62 | 2.91 | 0.01 | 1.46 | 2.87 | 0.21 | 6.49 |
| R2 | 3/25/2014 | 18:00 | <0.01 | 0.27 | 1.55 | 0.62 | 2.90 | 0.01 | 1.47 | 2.86 | 0.21 | 6.49 |
| R2 | 3/27/2014 | 10:30 | <0.01 | 0.26 | 1.60 | 0.66 | 3.04 | 0.01 | 1.57 | 2.98 | 0.21 | 6.88 |
| R2 | 3/31/2014 | 12:30 | 0.01 | 0.26 | 1.45 | 0.59 | 2.75 | 0.01 | 1.44 | 2.74 | 0.21 | 6.56 |
| R2 | 4/8/2014 | 10:20 | 0.00 | 0.25 | 1.46 | 0.58 | 2.74 | 0.01 | 1.38 | 2.66 | 0.21 | 6.10 |
| R2 | 4/15/2014 | 11:30 | 0.00 | 0.18 | 1.16 | 0.52 | 2.58 | 0.01 | 1.41 | 2.79 | 0.21 | 6.60 |
| R2 | 4/18/2014 | 10:20 | 0.00 | 0.21 | 1.37 | 0.56 | 2.81 | 0.01 | 1.43 | 2.80 | 0.23 | 6.49 |
| R3 | 3/26/2014 | 14:30 | <0.01 | 0.27 | 1.46 | 0.58 | 2.69 | 0.01 | 1.37 | 2.62 | 0.19 | 6.45 |
| R3 | 3/26/2014 | 14:30 | <0.01 | 0.25 | 1.39 | 0.57 | 2.63 | 0.01 | 1.35 | 2.58 | 0.20 | 6.08 |
| R3 | 3/28/2014 | 13:30 | 0.01 | 0.28 | 1.44 | 0.58 | 2.68 | 0.01 | 1.36 | 2.62 | 0.19 | 6.13 |
| R3 | 4/1/2014 | 16:10 | 0.00 | 0.20 | 1.18 | 0.50 | 2.39 | 0.01 | 1.27 | 2.46 | 0.18 | 5.61 |
| R3 | 4/10/2014 | 14:50 | 0.00 | 0.21 | 1.20 | 0.52 | 2.46 | 0.01 | 1.33 | 2.55 | 0.19 | 6.19 |
| R3 | 4/15/2014 | 14:15 | 0.00 | 0.25 | 1.31 | 0.54 | 2.55 | 0.01 | 1.35 | 2.59 | 0.19 | 6.22 |
| R3 | 4/17/2014 | 13:00 | 0.01 | 0.24 | 1.35 | 0.58 | 2.77 | 0.01 | 1.49 | 2.88 | 0.22 | 6.96 |
| R4 | 3/25/2014 | 14:30 | <0.01 | 0.33 | 1.95 | 0.73 | 3.43 | 0.01 | 1.60 | 3.13 | 0.22 | 6.60 |
| R4 | 3/25/2014 | 14:30 | <0.01 | 0.32 | 1.92 | 0.73 | 3.42 | 0.01 | 1.60 | 3.13 | 0.22 | 6.62 |
| R4 | 3/27/2014 | 11:50 | <0.01 | 0.28 | 1.62 | 0.64 | 3.04 | 0.01 | 1.48 | 2.93 | 0.22 | 6.46 |
| R4 | 3/31/2014 | 11:20 | <0.01 | 0.27 | 1.81 | 0.73 | 3.51 | 0.01 | 1.69 | 3.33 | 0.24 | 6.52 |
| R4 | 4/7/2014 | 13:45 | 0.00 | 0.13 | 1.09 | 0.51 | 2.60 | 0.01 | 1.37 | 2.74 | 0.20 | 5.97 |
| R4 | 4/16/2014 | 12:35 | 0.00 | 0.22 | 1.44 | 0.60 | 2.89 | 0.01 | 1.49 | 2.97 | 0.21 | 6.69 |
| R4 | 4/18/2014 | 12:05 | 0.00 | 0.20 | 1.35 | 0.58 | 2.84 | 0.01 | 1.47 | 2.93 | 0.21 | 6.62 |
| R5 | 3/26/2014 | 12:00 | <0.01 | 0.19 | 1.10 | 0.50 | 2.39 | 0.01 | 1.33 | 2.60 | 0.18 | 6.36 |
| R5 | 3/26/2014 | 12:00 | <0.01 | 0.22 | 1.20 | 0.53 | 2.46 | 0.01 | 1.34 | 2.60 | 0.18 | 6.29 |
| R5 | 3/28/2014 | 12:00 | <0.01 | 0.21 | 1.17 | 0.52 | 2.44 | 0.01 | 1.33 | 2.60 | 0.19 | 6.33 |
| R5 | 4/1/2014 | 14:30 | 0.01 | 0.18 | 1.04 | 0.47 | 2.25 | 0.01 | 1.25 | 2.42 | 0.17 | 5.69 |
| R5 | 4/10/2014 | 13:15 | 0.01 | 0.23 | 1.25 | 0.54 | 2.50 | 0.01 | 1.34 | 2.59 | 0.18 | 6.21 |
| R5 | 4/15/2014 | 12:50 | 0.01 | 0.20 | 1.13 | 0.51 | 2.43 | 0.01 | 1.35 | 2.62 | 0.19 | 6.48 |
| R5 | 4/17/2014 | 11:40 | 0.00 | 0.17 | 1.02 | 0.48 | 2.30 | 0.01 | 1.30 | 2.54 | 0.19 | 6.33 |

Appendix 8 - Light Ends Data - Rail

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R6 | 3/26/2014 | 15:30 | <0.01 | 0.26 | 1.84 | 0.69 | 3.38 | 0.01 | 1.56 | 2.96 | 0.25 | 6.38 |
| R6 | 3/26/2014 | 15:30 | <0.01 | 0.26 | 1.81 | 0.69 | 3.36 | 0.01 | 1.56 | 2.96 | 0.25 | 6.40 |
| R6 | 3/27/2014 | 15:30 | <0.01 | 0.25 | 1.71 | 0.66 | 3.26 | 0.01 | 1.54 | 2.94 | 0.25 | 6.43 |
| R6 | 3/31/2014 | 14:00 | <0.01 | 0.26 | 1.71 | 0.66 | 3.22 | 0.01 | 1.53 | 2.95 | 0.24 | 6.49 |
| R6 | 4/7/2014 | 15:00 | 0.00 | 0.19 | 1.38 | 0.57 | 2.83 | 0.01 | 1.40 | 2.71 | 0.22 | 5.89 |
| R6 | 4/15/2014 | 14:00 | 0.00 | 0.14 | 1.20 | 0.54 | 2.79 | 0.01 | 1.46 | 2.85 | 0.23 | 6.53 |
| R6 | 4/17/2014 | 12:00 | 0.00 | 0.22 | 1.53 | 0.62 | 3.08 | 0.01 | 1.52 | 2.93 | 0.24 | 6.61 |
| R7 | 3/26/2014 | 19:30 | <0.01 | 0.25 | 1.48 | 0.60 | 2.80 | 0.01 | 1.42 | 2.74 | 0.20 | 6.30 |
| R7 | 3/26/2014 | 19:30 | <0.01 | 0.29 | 1.55 | 0.61 | 2.85 | 0.01 | 1.43 | 2.74 | 0.20 | 6.27 |
| R7 | 3/28/2014 | 13:00 | <0.01 | 0.22 | 1.35 | 0.56 | 2.68 | 0.01 | 1.40 | 2.71 | 0.20 | 6.38 |
| R7 | 3/31/2014 | 17:00 | 0.01 | 0.28 | 1.45 | 0.58 | 2.71 | 0.01 | 1.39 | 2.67 | 0.20 | 6.25 |
| R7 | 4/11/2014 | 10:50 | 0.00 | 0.23 | 1.34 | 0.56 | 2.63 | 0.01 | 1.37 | 2.64 | 0.19 | 6.27 |
| R7 | 4/14/2014 | 12:30 | 0.00 | 0.22 | 1.29 | 0.55 | 2.58 | 0.01 | 1.36 | 2.62 | 0.19 | 6.21 |
| R7 | 4/18/2014 | 10:00 | 0.01 | 0.21 | 1.18 | 0.51 | 2.45 | 0.01 | 1.34 | 2.57 | 0.20 | 6.34 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Light Ends IP344 - All results in liquid volume % Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | 0.01 | 0.31 | 1.77 | 0.65 | 3.12 | 0.01 | 1.46 | 2.73 | 0.25 | 6.02 |
| W1 | 3/25/2014 | 19:45 | 0.01 | 0.36 | 1.85 | 0.67 | 3.19 | 0.01 | 1.48 | 2.76 | 0.25 | 6.02 |
| W1 | 3/27/2014 | 18:15 | 0.01 | 0.30 | 1.58 | 0.60 | 2.94 | 0.01 | 1.42 | 2.68 | 0.25 | 6.04 |
| W1 | 3/30/2014 | 16:00 | 0.01 | 0.29 | 1.67 | 0.63 | 3.06 | 0.01 | 1.45 | 2.73 | 0.25 | 6.13 |
| W1 | 4/1/2014 | 11:00 | 0.01 | 0.31 | 1.59 | 0.59 | 2.88 | 0.01 | 1.39 | 2.64 | 0.24 | 5.94 |
| W1 | 4/7/2014 | 12:20 | 0.00 | 0.15 | 1.05 | 0.46 | 2.39 | 0.01 | 1.28 | 2.46 | 0.23 | 5.75 |
| W1 | 4/16/2014 | 11:30 | 0.01 | 0.25 | 1.50 | 0.60 | 2.96 | 0.01 | 1.47 | 2.78 | 0.26 | 6.37 |
| W2 | 3/26/2014 | 12:45 | <0.01 | 0.30 | 1.68 | 0.61 | 3.00 | 0.01 | 1.42 | 2.71 | 0.24 | 6.10 |
| W2 | 3/26/2014 | 12:45 | 0.01 | 0.35 | 1.82 | 0.65 | 3.15 | 0.01 | 1.47 | 2.81 | 0.25 | 6.29 |
| W2 | 3/29/2014 | 15:00 | 0.01 | 0.30 | 1.76 | 0.63 | 3.05 | 0.01 | 1.42 | 2.73 | 0.24 | 6.14 |
| W2 | 3/31/2014 | 10:00 | 0.01 | 0.34 | 1.53 | 0.53 | 2.62 | 0.01 | 1.28 | 2.48 | 0.23 | 5.92 |
| W2 | 4/7/2014 | 13:05 | 0.00 | 0.21 | 1.52 | 0.56 | 2.75 | 0.01 | 1.31 | 2.52 | 0.23 | 5.43 |
| W2 | 4/16/2014 | 12:00 | 0.00 | 0.29 | 1.79 | 0.66 | 3.22 | 0.01 | 1.49 | 2.84 | 0.25 | 6.36 |
| W2 | 4/19/2014 | 9:00 | 0.00 | 0.26 | 1.78 | 0.66 | 3.18 | 0.01 | 1.46 | 2.77 | 0.24 | 6.12 |
| W3 | 3/25/2014 | 12:30 | 0.01 | 0.41 | 1.95 | 0.75 | 3.60 | 0.01 | 1.76 | 3.55 | 0.24 | 7.01 |
| W3 | 3/25/2014 | 12:30 | 0.01 | 0.37 | 1.76 | 0.68 | 3.26 | 0.01 | 1.59 | 3.21 | 0.21 | 6.79 |
| W3 | 3/27/2014 | 10:00 | 0.01 | 0.39 | 1.99 | 0.78 | 3.71 | 0.01 | 1.81 | 3.65 | 0.24 | 7.17 |
| W3 | 3/31/2014 | 10:00 | <0.01 | 0.30 | 1.75 | 0.70 | 3.36 | 0.01 | 1.63 | 3.28 | 0.22 | 7.00 |
| W3 | 4/7/2014 | 12:50 | 0.00 | 0.18 | 1.20 | 0.54 | 2.68 | 0.01 | 1.38 | 2.82 | 0.19 | 5.95 |
| W3 | 4/16/2014 | 10:30 | 0.00 | 0.21 | 1.40 | 0.61 | 3.05 | 0.01 | 1.57 | 3.19 | 0.22 | 6.93 |
| W3 | 4/18/2014 | 11:20 | 0.00 | 0.24 | 1.49 | 0.64 | 3.13 | 0.01 | 1.58 | 3.21 | 0.22 | 6.91 |
| W4 | 3/26/2014 | 12:00 | <0.01 | 0.17 | 1.65 | 0.66 | 3.33 | 0.01 | 1.54 | 2.87 | 0.26 | 6.22 |
| W4 | 3/26/2014 | 12:00 | <0.01 | 0.16 | 1.62 | 0.65 | 3.32 | 0.01 | 1.53 | 2.85 | 0.26 | 6.19 |
| W4 | 3/28/2014 | 13:15 | <0.01 | 0.16 | 1.61 | 0.66 | 3.36 | 0.01 | 1.57 | 2.43 | 0.26 | 6.34 |
| W4 | 4/3/2014 | 17:25 | 0.00 | 0.09 | 1.23 | 0.58 | 3.14 | 0.01 | 1.53 | 2.90 | 0.26 | 6.36 |
| W4 | 4/7/2014 | 18:14 | 0.00 | 0.08 | 1.13 | 0.55 | 2.94 | 0.00 | 1.49 | 2.79 | 0.25 | 6.13 |
| W4 | 4/15/2014 | 16:00 | 0.00 | 0.19 | 1.70 | 0.67 | 3.38 | 0.00 | 1.58 | 2.95 | 0.27 | 6.49 |
| W4 | 4/17/2014 | 14:30 | 0.01 | 0.33 | 2.38 | 0.81 | 3.89 | 0.01 | 1.66 | 3.02 | 0.30 | 6.31 |
| W5 | 3/26/2014 | 15:50 | <0.01 | 0.11 | 1.44 | 0.65 | 3.49 | 0.01 | 1.66 | 3.14 | 0.28 | 6.77 |
| W5 | 3/26/2014 | 15:50 | <0.01 | 0.12 | 1.52 | 0.67 | 3.56 | 0.01 | 1.68 | 3.17 | 0.28 | 6.81 |
| W5 | 3/28/2014 | 13:50 | <0.01 | 0.15 | 1.54 | 0.66 | 3.50 | 0.01 | 1.66 | 3.15 | 0.28 | 6.84 |
| W5 | 4/4/2014 | 17:28 | 0.00 | 0.09 | 1.23 | 0.57 | 3.13 | 0.01 | 1.53 | 2.89 | 0.26 | 6.10 |
| W5 | 4/7/2014 | 19:08 | 0.00 | 0.12 | 1.42 | 0.63 | 3.36 | 0.01 | 1.61 | 3.06 | 0.27 | 6.60 |
| W5 | 4/15/2014 | 17:00 | 0.00 | 0.27 | 2.34 | 0.86 | 4.06 | 0.01 | 1.86 | 3.46 | 0.30 | 7.23 |
| W5 | 4/17/2014 | 15:30 | 0.00 | 0.27 | 2.42 | 0.88 | 4.41 | 0.01 | 1.88 | 3.51 | 0.29 | 7.19 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W6 | 4/6/2014 | 14:55 | 0.00 | 0.24 | 1.67 | 0.73 | 3.28 | 0.01 | 1.61 | 3.11 | 0.17 | 6.38 |
| W6 | 4/6/2014 | 14:55 | 0.00 | 0.22 | 1.60 | 0.71 | 3.18 | 0.01 | 1.56 | 3.01 | 0.17 | 6.19 |
| W6 | 4/8/2014 | 13:50 | 0.00 | 0.32 | 2.02 | 0.83 | 3.65 | 0.01 | 1.72 | 3.30 | 0.18 | 6.82 |
| W6 | 4/15/2014 | 17:05 | 0.00 | 0.36 | 2.23 | 0.92 | 4.03 | 0.01 | 1.88 | 3.60 | 0.20 | 7.40 |
| W6 | 4/17/2014 | 14:05 | 0.00 | 0.31 | 1.94 | 0.82 | 3.66 | 0.01 | 1.76 | 3.38 | 0.19 | 7.07 |
| W6 | 4/21/2014 | 16:30 | 0.00 | 0.25 | 1.89 | 0.82 | 3.64 | 0.01 | 1.74 | 3.34 | 0.19 | 6.96 |
| W6 | 4/24/2014 | 11:20 | 0.00 | 0.28 | 1.93 | 0.83 | 3.68 | 0.01 | 1.75 | 3.35 | 0.21 | 6.87 |
| W7 | 3/25/2014 | 17:00 | 0.01 | 0.67 | 3.13 | 0.95 | 4.55 | 0.01 | 1.82 | 3.58 | 0.27 | 6.74 |
| W7 | 3/25/2014 | 17:00 | <0.01 | 0.53 | 2.72 | 0.88 | 4.24 | 0.01 | 1.78 | 3.50 | 0.27 | 6.84 |
| W7 | 3/27/2014 | 13:00 | 0.01 | 0.46 | 2.42 | 0.82 | 4.01 | 0.01 | 1.74 | 3.47 | 0.27 | 6.96 |
| W7 | 3/31/2014 | 13:00 | <0.01 | 0.37 | 2.14 | 0.77 | 3.82 | 0.01 | 1.71 | 3.41 | 0.27 | 6.96 |
| W7 | 4/7/2014 | 16:00 | 0.00 | 0.21 | 1.60 | 0.63 | 3.25 | 0.01 | 1.52 | 3.05 | 0.24 | 6.30 |
| W7 | 4/16/2014 | 14:20 | 0.00 | 0.32 | 1.98 | 0.74 | 3.75 | 0.01 | 1.72 | 3.43 | 0.27 | 7.06 |
| W7 | 4/21/2014 | 13:45 | 0.00 | 0.21 | 1.81 | 0.72 | 3.66 | 0.01 | 1.70 | 3.39 | 0.27 | 7.03 |
| W8 | 3/25/2014 | 14:53 | <0.01 | 0.15 | 1.55 | 0.83 | 3.73 | 0.01 | 1.93 | 3.37 | 0.28 | 7.26 |
| W8 | 3/25/2014 | 14:33 | <0.01 | 0.14 | 1.54 | 0.83 | 3.71 | 0.01 | 1.93 | 3.37 | 0.28 | 7.26 |
| W8 | 3/27/2014 | 15:30 | <0.01 | 0.17 | 1.65 | 0.83 | 3.66 | 0.01 | 1.89 | 3.40 | 0.27 | 7.53 |
| W8 | 3/31/2014 | 12:42 | <0.01 | 0.15 | 1.56 | 0.80 | 3.53 | 0.01 | 1.80 | 3.25 | 0.25 | 7.22 |
| W8 | 4/9/2014 | 12:30 | 0.00 | 0.12 | 1.27 | 0.68 | 3.13 | 0.01 | 1.68 | 3.20 | 0.26 | 6.84 |
| W8 | 4/16/2014 | 17:00 | 0.00 | 0.20 | 1.62 | 0.79 | 3.51 | 0.01 | 1.80 | 3.19 | 0.27 | 7.37 |
| W8 | 4/18/2014 | 13:00 | 0.00 | 0.19 | 1.55 | 0.76 | 3.40 | 0.01 | 1.80 | 3.27 | 0.30 | 7.64 |
| W9 | 4/1/2014 | 11:20 | 0.01 | 0.25 | 1.19 | 0.47 | 2.33 | 0.01 | 1.18 | 2.21 | 0.21 | 5.27 |
| W9 | 4/1/2014 | 12:10 | 0.01 | 0.26 | 1.22 | 0.47 | 2.36 | 0.01 | 1.19 | 2.23 | 0.21 | 5.30 |
| W9 | 4/3/2014 | 13:00 | 0.00 | 0.17 | 1.02 | 0.42 | 2.14 | 0.00 | 1.10 | 2.07 | 0.19 | 4.98 |
| W9 | 4/8/2014 | 11:25 | 0.00 | 0.19 | 1.21 | 0.48 | 2.41 | 0.01 | 1.20 | 2.24 | 0.20 | 5.24 |
| W9 | 4/15/2014 | 12:33 | 0.01 | 0.22 | 1.16 | 0.47 | 2.37 | 0.01 | 1.22 | 2.29 | 0.21 | 5.52 |
| W9 | 4/22/2014 | 11:35 | 0.01 | 0.18 | 1.03 | 0.43 | 2.19 | <0.01 | 1.15 | 2.18 | 0.20 | 5.35 |
| W9 | 4/24/2014 | 14:20 | <0.01 | 0.20 | 1.12 | 0.45 | 2.24 | 0.01 | 1.14 | 2.15 | 0.20 | 5.19 |
| W10 | 4/15/2014 | 15:40 | 0.00 | 0.37 | 2.29 | 0.94 | 4.12 | 0.01 | 1.91 | 3.70 | 0.20 | 7.41 |
| W10 | 4/15/2014 | 15:40 | 0.00 | 0.29 | 2.08 | 0.90 | 3.97 | 0.01 | 1.89 | 3.67 | 0.20 | 7.49 |
| W10 | 4/17/2014 | 12:50 | 0.00 | 0.36 | 2.25 | 0.92 | 4.03 | 0.01 | 1.88 | 3.64 | 0.19 | 7.36 |
| W10 | 4/21/2014 | 15:30 | <0.01 | 0.33 | 2.19 | 0.90 | 3.98 | 0.01 | 1.82 | 3.52 | 0.19 | 7.02 |
| W10 | 4/24/2014 | 12:35 | <0.01 | 0.25 | 1.95 | 0.86 | 3.81 | 0.01 | 1.82 | 3.54 | 0.19 | 7.23 |
| W10 | | | 0.00 | 0.20 | 1.76 | 0.81 | 3.66 | 0.01 | 1.78 | 3.46 | 0.19 | 7.09 |

## Appendix 9 - Light Ends Data - Well

| Client ID | Sample Date | Sample Time | Methane | Ethane | Propane | Isobutane | n- Butane | Neopentane | Isopentane | n- Pentane | Cyclopentane | Hexanes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W11 | 4/7/2014 | 16:35 | 0.00 | 0.16 | 1.56 | 0.62 | 3.09 | 0.01 | 1.42 | 2.63 | 0.24 | 5.62 |
| W11 | 4/7/2014 | 16:35 | 0.00 | 0.13 | 1.48 | 0.60 | 3.01 | 0.01 | 1.39 | 2.58 | 0.24 | 5.52 |
| W11 | 4/11/2014 | 14:55 | 0.00 | 0.34 | 2.69 | 0.86 | 4.03 | 0.01 | 1.60 | 2.91 | 0.26 | 5.99 |
| W11 | 4/15/2014 | 15:00 | 0.00 | 0.25 | 2.10 | 0.77 | 3.72 | 0.01 | 1.62 | 2.98 | 0.27 | 6.41 |
| W11 | 4/17/2014 | 13:30 | 0.00 | 0.27 | 2.17 | 0.77 | 3.69 | 0.01 | 1.59 | 2.92 | 0.27 | 6.23 |
| W11 | 4/20/2014 | 11:00 | 0.00 | 0.15 | 0.96 | 0.41 | 2.32 | 0.01 | 1.24 | 2.59 | 0.23 | 6.22 |
| W11 | 4/23/2014 | | <0.01 | 0.40 | 2.99 | 0.92 | 4.25 | 0.01 | 1.65 | 2.98 | 0.26 | 6.00 |
| W12 | 3/27/2014 | 12:46 | 0.00 | 0.21 | 1.26 | 0.50 | 2.53 | 0.01 | 1.26 | 2.41 | 0.21 | 5.57 |
| W12 | 3/27/2014 | 12:16 | 0.00 | 0.22 | 1.28 | 0.51 | 2.56 | 0.01 | 1.28 | 2.42 | 0.22 | 5.59 |
| W12 | 3/30/2014 | 13:00 | 0.01 | 0.23 | 1.25 | 0.49 | 2.45 | 0.01 | 1.22 | 2.31 | 0.21 | 5.48 |
| W12 | 4/1/2014 | 13:40 | 0.01 | 0.25 | 1.32 | 0.51 | 2.51 | 0.01 | 1.24 | 2.35 | 0.21 | 5.52 |
| W12 | 4/8/2014 | 13:20 | 0.00 | 0.18 | 1.17 | 0.48 | 2.41 | 0.01 | 1.22 | 2.32 | 0.21 | 5.42 |
| W12 | 4/17/2014 | 15:10 | 0.01 | 0.18 | 1.06 | 0.45 | 2.30 | 0.00 | 1.22 | 2.35 | 0.22 | 5.77 |
| W12 | 4/17/2014 | 15:30 | 0.01 | 0.20 | 1.11 | 0.46 | 2.30 | 0.01 | 1.21 | 2.32 | 0.21 | 5.63 |
| W13 | 3/26/2014 | 17:00 | <0.01 | 0.22 | 1.69 | 0.69 | 3.25 | 0.01 | 1.49 | 2.72 | 0.22 | 5.85 |
| W13 | 3/26/2014 | 17:00 | <0.01 | 0.21 | 1.65 | 0.68 | 3.22 | 0.01 | 1.49 | 2.72 | 0.22 | 5.88 |
| W13 | 3/28/2014 | 15:30 | 0.01 | 0.24 | 1.57 | 0.63 | 3.02 | 0.01 | 1.45 | 2.68 | 0.22 | 5.93 |
| W13 | 4/4/2014 | 15:15 | 0.00 | 0.16 | 1.42 | 0.61 | 2.93 | 0.01 | 1.38 | 2.52 | 0.20 | 5.34 |
| W13 | 4/8/2014 | 11:00 | 0.00 | 0.26 | 1.91 | 0.74 | 3.40 | 0.01 | 1.51 | 2.73 | 0.22 | 5.84 |
| W13 | 4/15/2014 | 19:30 | 0.00 | 0.19 | 1.73 | 0.74 | 3.56 | 0.01 | 1.69 | 3.10 | 0.25 | 6.84 |
| W13 | 4/19/2014 | 14:00 | 0.00 | 0.31 | 1.94 | 0.68 | 3.29 | 0.01 | 1.47 | 2.80 | 0.24 | 6.12 |
| W14 | 4/6/2014 | 16:20 | 0.01 | 0.22 | 1.12 | 0.43 | 2.32 | 0.01 | 1.20 | 2.49 | 0.21 | 5.63 |
| W14 | 4/6/2014 | 16:20 | 0.01 | 0.21 | 1.10 | 0.42 | 2.29 | 0.00 | 1.20 | 2.48 | 0.21 | 5.63 |
| W14 | 4/4/2014 | 11:55 | <0.01 | 0.22 | 1.24 | 0.48 | 2.57 | 0.01 | 1.32 | 2.73 | 0.23 | 6.35 |
| W14 | 4/8/2014 | 12:30 | 0.00 | 0.26 | 1.53 | 0.56 | 2.89 | 0.01 | 1.38 | 2.81 | 0.23 | 6.20 |
| W14 | 4/18/2014 | 16:30 | 0.01 | 0.16 | 1.00 | 0.42 | 2.35 | 0.01 | 1.25 | 2.58 | 0.22 | 6.11 |
| W14 | 4/20/2014 | 14:00 | 0.01 | 0.16 | 0.89 | 0.37 | 2.10 | 0.00 | 1.16 | 2.45 | 0.22 | 6.13 |
| W14 | 4/22/2014 | 11:00 | <0.01 | 0.14 | 0.84 | 0.35 | 2.00 | <0.01 | 1.11 | 2.33 | 0.21 | 5.84 |
| W15 | 4/9/2014 | 17:20 | 0.00 | 0.25 | 1.41 | 0.58 | 2.67 | 0.01 | 1.38 | 2.61 | 0.20 | 6.12 |
| W15 | 4/9/2014 | 17:20 | 0.00 | 0.24 | 1.42 | 0.58 | 2.69 | 0.01 | 1.38 | 2.62 | 0.20 | 6.14 |
| W15 | 4/18/2014 | 19:30 | 0.00 | 0.21 | 1.16 | 0.50 | 2.40 | 0.01 | 1.33 | 2.55 | 0.20 | 6.22 |
| W15 | 4/21/2014 | 18:30 | <0.01 | 0.24 | 1.38 | 0.56 | 2.62 | 0.01 | 1.36 | 2.59 | 0.20 | 6.13 |
| W15 | 4/23/2014 | 13:00 | <0.01 | 0.24 | 1.40 | 0.58 | 2.67 | 0.01 | 1.38 | 2.60 | 0.20 | 6.13 |
| W15 | 4/24/2014 | 16:30 | 0.00 | 0.18 | 1.31 | 0.56 | 2.66 | 0.01 | 1.40 | 2.66 | 0.21 | 6.26 |

## Appendix 10 - Simulated Distillation Data - Rail

Simulated Distillation by ASTM D7169- All results reported in °F

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 3/25/2014 | 17:20 | <97 | 151 | 186 | 264 | 343 | 430 | 517 | 609 | 710 | 823 | 967 | 1071 | 1278 | 100.0 | Oil Temp 35°F |
| R1 | 3/25/2014 | 17:00 | <97 | 151 | 183 | 263 | 346 | 436 | 527 | 623 | 730 | 850 | 1012 | 1150 | >1382 | 97.6 | |
| R1 | 3/27/2014 | 17:26 | <97 | 104 | 176 | 252 | 332 | 423 | 513 | 608 | 713 | 828 | 973 | 1076 | 1307 | 100.0 | |
| R1 | 3/31/2014 | 14:08 | <97 | 127 | 177 | 239 | 315 | 391 | 473 | 559 | 650 | 760 | 903 | 1009 | 1217 | 100.0 | |
| R1 | 4/9/2014 | 10:38 | <97 | <97 | 153 | 222 | 300 | 376 | 459 | 549 | 647 | 761 | 909 | 1019 | 1246 | 100.0 | |
| R1 | 4/16/2014 | 15:30 | | | | | | | | | | | | | | | |
| R1 | 4/18/2014 | 11:00 | | | | | | | | | | | | | | | |
| R2 | 3/25/2014 | 18:00 | <97 | 135 | 168 | 235 | 313 | 388 | 470 | 557 | 651 | 763 | 909 | 1017 | 1226 | 100.0 | |
| R2 | 3/25/2014 | 18:00 | <97 | 138 | 178 | 246 | 320 | 388 | 477 | 564 | 659 | 772 | 921 | 1033 | 1317 | 99.7 | |
| R2 | 3/27/2014 | 10:30 | <97 | 98 | 158 | 223 | 289 | 364 | 443 | 527 | 620 | 733 | 888 | 1013 | >1382 | 99.1 | |
| R2 | 3/31/2014 | 12:30 | <97 | 107 | 164 | 232 | 302 | 376 | 454 | 540 | 630 | 742 | 889 | 1000 | 1219 | 100.0 | |
| R2 | 4/8/2014 | 10:20 | <97 | <97 | 143 | 216 | 295 | 379 | 468 | 561 | 664 | 783 | 936 | 1048 | 1257 | 100.0 | |
| R2 | 4/15/2014 | 11:30 | | | | | | | | | | | | | | | |
| R2 | 4/18/2014 | 10:20 | | | | | | | | | | | | | | | |
| R3 | 3/26/2014 | 14:30 | <97 | 112 | 175 | 245 | 325 | 405 | 488 | 576 | 675 | 788 | 933 | 1039 | 1244 | 100.0 | Oil Temp 37°F |
| R3 | 3/26/2014 | 14:30 | <97 | 146 | 177 | 251 | 326 | 408 | 492 | 581 | 679 | 791 | 935 | 1040 | 1256 | 100.0 | Oil Temp 37°F |
| R3 | 3/28/2014 | 13:30 | <97 | <97 | 157 | 235 | 317 | 403 | 490 | 583 | 686 | 805 | 957 | 1073 | 1309 | 100.0 | Oil Temp 49°F |
| R3 | 4/1/2014 | 16:10 | <97 | <97 | 162 | 235 | 320 | 405 | 496 | 591 | 696 | 820 | 994 | 1180 | >1382 | 95.9 | |
| R3 | 4/10/2014 | 14:50 | <97 | <97 | 158 | 238 | 317 | 398 | 486 | 577 | 678 | 795 | 946 | 1062 | >1382 | 99.1 | |
| R3 | 4/15/2014 | 14:15 | | | | | | | | | | | | | | | |
| R3 | 4/17/2014 | 13:00 | | | | | | | | | | | | | | | |
| R4 | 3/25/2014 | 14:30 | <97 | 111 | 156 | 234 | 314 | 393 | 480 | 573 | 674 | 796 | 962 | 1107 | >1382 | 99.8 | |
| R4 | 3/25/2014 | 14:30 | <97 | 133 | 167 | 237 | 318 | 399 | 484 | 574 | 673 | 792 | 950 | 1077 | >1382 | 98.9 | |
| R4 | 3/27/2014 | 11:50 | <97 | <97 | 163 | 238 | 320 | 403 | 489 | 581 | 682 | 800 | 954 | 1072 | 1318 | 100.0 | |
| R4 | 3/31/2014 | 11:20 | <97 | 103 | 168 | 239 | 318 | 399 | 486 | 575 | 674 | 791 | 945 | 1065 | >1382 | 99.1 | |
| R4 | 4/7/2014 | 13:45 | <97 | <97 | 157 | 233 | 305 | 385 | 474 | 563 | 663 | 779 | 925 | 1029 | 1220 | 100.0 | |
| R4 | 4/16/2014 | 12:35 | | | | | | | | | | | | | | | |
| R4 | 4/18/2014 | 12:05 | | | | | | | | | | | | | | | |
| R5 | 3/26/2014 | 12:00 | <97 | 117 | 168 | 236 | 314 | 390 | 475 | 563 | 660 | 775 | 927 | 1049 | >1382 | 98.7 | |
| R5 | 3/26/2014 | 12:00 | <97 | <97 | 159 | 234 | 315 | 394 | 481 | 575 | 675 | 796 | 959 | 1089 | 1341 | 100.0 | |
| R5 | 3/28/2014 | 12:00 | <97 | <97 | 160 | 233 | 311 | 389 | 475 | 564 | 662 | 777 | 924 | 1037 | 1276 | 100.0 | |
| R5 | 4/1/2014 | 14:30 | <97 | <97 | 151 | 227 | 306 | 385 | 474 | 569 | 671 | 792 | 957 | 1116 | >1382 | 96.6 | |
| R5 | 4/10/2014 | 13:15 | <97 | <97 | 158 | 236 | 306 | 385 | 466 | 555 | 651 | 764 | 910 | 1019 | 1272 | 99.8 | |
| R5 | 4/15/2014 | 12:50 | | | | | | | | | | | | | | | |
| R5 | 4/17/2014 | 11:40 | | | | | | | | | | | | | | | |

# Appendix 10 - Simulated Distillation Data - Rail

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R6 | 3/26/2014 | 15:30 | <97 | 116 | 156 | 232 | 310 | 388 | 471 | 558 | 650 | 758 | 900 | 1008 | 1342 | 99.5 | |
| R6 | 3/26/2014 | 15:30 | <97 | 131 | 165 | 235 | 315 | 394 | 476 | 562 | 654 | 762 | 900 | 1004 | 1230 | 100.0 | |
| R6 | 3/27/2014 | 15:30 | <97 | <97 | 162 | 236 | 315 | 395 | 481 | 570 | 665 | 778 | 929 | 1056 | >1382 | 98.5 | |
| R6 | 3/31/2014 | 14:00 | <97 | 106 | 168 | 237 | 320 | 404 | 490 | 580 | 680 | 797 | 962 | 1126 | >1382 | 96.7 | |
| R6 | 4/7/2014 | 15:00 | <97 | <97 | 152 | 225 | 302 | 383 | 466 | 555 | 650 | 763 | 909 | 1021 | 1308 | 100.0 | |
| R6 | 4/15/2014 | 14:00 | | | | | | | | | | | | | | | |
| R6 | 4/17/2014 | 12:00 | | | | | | | | | | | | | | | |
| R7 | 3/26/2014 | 19:30 | <97 | 138 | 171 | 237 | 316 | 394 | 479 | 570 | 668 | 783 | 931 | 1040 | 1278 | 100.0 | |
| R7 | 3/26/2014 | 19:30 | <97 | 146 | 179 | 255 | 330 | 418 | 504 | 596 | 700 | 822 | 987 | 1122 | >1382 | 98.7 | |
| R7 | 3/28/2014 | 13:00 | <97 | 114 | 176 | 242 | 322 | 403 | 488 | 580 | 683 | 803 | 962 | 1086 | >1382 | 98.8 | |
| R7 | 3/31/2014 | 17:00 | <97 | 127 | 179 | 254 | 327 | 409 | 496 | 587 | 691 | 811 | 971 | 1099 | >1382 | 98.4 | |
| R7 | 4/11/2014 | 10:50 | <97 | <97 | 154 | 236 | 313 | 391 | 480 | 575 | 647 | 792 | 941 | 1052 | 1297 | 100.0 | |
| R7 | 4/14/2014 | 12:30 | | | | | | | | | | | | | | | |
| R7 | 4/18/2014 | 10:00 | | | | | | | | | | | | | | | |

## Appendix 11 - Simulated Distillation Data - Well

### Simulated Distillation by ASTM D7169- All results reported in °F

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 3/25/2014 | 19:45 | <97 | 135 | 178 | 259 | 342 | 428 | 517 | 610 | 713 | 827 | 974 | 1086 | 1329 | 100.0 | |
| W1 | 3/25/2014 | 19:45 | <97 | 150 | 188 | 272 | 355 | 442 | 531 | 623 | 725 | 839 | 987 | 1102 | 1337 | 100.0 | |
| W1 | 3/27/2014 | 18:15 | <97 | 119 | 179 | 257 | 334 | 422 | 510 | 601 | 703 | 815 | 958 | 1071 | >1382 | 98.8 | |
| W1 | 3/30/2014 | 16:00 | <97 | 142 | 180 | 262 | 344 | 432 | 524 | 621 | 726 | 846 | 1011 | 1176 | >1382 | 96.7 | |
| W1 | 4/1/2014 | 11:00 | <97 | <97 | 148 | 224 | 310 | 396 | 488 | 584 | 688 | 803 | 947 | 1050 | 1248 | 100.0 | |
| W1 | 4/7/2014 | 12:20 | | | | | | | | | | | | | | | |
| W1 | 4/16/2014 | 11:30 | | | | | | | | | | | | | | | |
| W2 | 3/26/2014 | 12:45 | <97 | 143 | 179 | 261 | 342 | 424 | 508 | 596 | 693 | 803 | 952 | 1072 | 1328 | 100.0 | |
| W2 | 3/26/2014 | 12:45 | <97 | 140 | 184 | 263 | 342 | 422 | 505 | 590 | 685 | 793 | 937 | 1050 | 1303 | 100.0 | |
| W2 | 3/29/2014 | 15:00 | <97 | 108 | 165 | 237 | 318 | 400 | 482 | 569 | 661 | 768 | 903 | 1004 | 1248 | 99.7 | |
| W2 | 3/31/2014 | 10:00 | <97 | 136 | 178 | 255 | 329 | 412 | 492 | 577 | 670 | 774 | 910 | 1013 | 1244 | 100.0 | |
| W2 | 4/7/2014 | 13:05 | <97 | <97 | 154 | 235 | 316 | 398 | 481 | 570 | 664 | 772 | 911 | 1018 | 1316 | 100.0 | |
| W2 | 4/16/2014 | 12:00 | | | | | | | | | | | | | | | |
| W2 | 4/19/2014 | 9:00 | | | | | | | | | | | | | | | |
| W3 | 3/25/2014 | 12:30 | <97 | <97 | 157 | 232 | 304 | 383 | 462 | 548 | 639 | 748 | 895 | 1016 | >1382 | 98.6 | |
| W3 | 3/25/2014 | 12:30 | <97 | <97 | 161 | 234 | 310 | 384 | 464 | 547 | 638 | 744 | 886 | 995 | 1283 | 99.8 | |
| W3 | 3/27/2014 | 10:00 | <97 | <97 | 159 | 230 | 300 | 374 | 456 | 545 | 638 | 750 | 903 | 1037 | >1382 | 98.1 | |
| W3 | 3/31/2014 | 10:00 | <97 | 97 | 159 | 230 | 298 | 371 | 453 | 537 | 629 | 737 | 879 | 990 | >1382 | 99.4 | |
| W3 | 4/7/2014 | 12:50 | <97 | <97 | 154 | 224 | 297 | 372 | 453 | 537 | 628 | 737 | 880 | 992 | 1329 | 100.0 | |
| W3 | 4/16/2014 | 10:30 | | | | | | | | | | | | | | | |
| W3 | 4/18/2014 | 11:20 | | | | | | | | | | | | | | | |
| W4 | 3/26/2014 | 12:00 | <97 | 100 | 158 | 236 | 318 | 406 | 491 | 579 | 675 | 788 | 940 | 1076 | >1382 | 97.7 | |
| W4 | 3/26/2014 | 12:00 | <97 | 110 | 165 | 239 | 319 | 405 | 488 | 575 | 667 | 774 | 914 | 1023 | >1382 | 99.4 | |
| W4 | 3/28/2014 | 13:15 | <97 | 119 | 169 | 243 | 322 | 409 | 493 | 581 | 678 | 792 | 947 | 1082 | >1382 | 98.2 | |
| W4 | 4/3/2014 | 17:25 | <97 | <97 | 104 | 207 | 286 | 373 | 460 | 552 | 648 | 760 | 904 | 1014 | 1273 | 100.0 | |
| W4 | 4/7/2014 | 18:14 | <97 | <97 | 152 | 233 | 315 | 402 | 490 | 582 | 683 | 801 | 966 | 1121 | >1382 | 98.3 | |
| W4 | 4/15/2014 | 16:00 | | | | | | | | | | | | | | | |
| W4 | 4/17/2014 | 14:30 | | | | | | | | | | | | | | | |
| W5 | 3/26/2014 | 15:50 | <97 | 101 | 160 | 234 | 312 | 390 | 475 | 562 | 656 | 767 | 914 | 1028 | 1289 | 100.0 | |
| W5 | 3/26/2014 | 15:50 | <97 | <97 | 146 | 216 | 292 | 374 | 458 | 548 | 642 | 753 | 898 | 1008 | 1257 | 100.0 | |
| W5 | 3/28/2014 | 13:50 | <97 | <97 | 156 | 225 | 300 | 377 | 458 | 547 | 640 | 751 | 896 | 1010 | 1272 | 100.0 | |
| W5 | 4/4/2014 | 17:28 | <97 | <97 | 132 | 205 | 280 | 366 | 454 | 548 | 645 | 757 | 903 | 1020 | >1382 | 98.7 | |
| W5 | 4/7/2014 | 19:08 | <97 | <97 | 135 | 209 | 285 | 364 | 448 | 538 | 633 | 747 | 894 | 1009 | 1322 | 100.0 | |
| W5 | 4/15/2014 | 17:00 | | | | | | | | | | | | | | | |
| W5 | 4/17/2014 | 15:30 | | | | | | | | | | | | | | | |
| W6 | 4/6/2014 | 14:55 | <97 | <97 | 129 | 204 | 277 | 349 | 436 | 528 | 629 | 751 | 914 | 1037 | >1382 | 98.9 | |
| W6 | 4/6/2014 | 14:55 | <97 | <97 | 103 | 189 | 264 | 336 | 420 | 513 | 613 | 734 | 891 | 1004 | 1218 | 99.9 | |
| W6 | 4/8/2014 | 13:50 | <97 | <97 | 156 | 236 | 304 | 377 | 461 | 554 | 658 | 789 | 977 | 1157 | >1382 | 96.6 | |
| W6 | 4/15/2014 | 17:05 | <97 | <97 | <97 | 188 | 257 | 331 | 419 | 510 | 611 | 734 | 895 | 1010 | 1217 | 100.0 | |
| W6 | 4/17/2014 | 14:05 | <97 | <97 | 145 | 206 | 278 | 348 | 433 | 521 | 622 | 741 | 899 | 1011 | 1214 | 100.0 | |
| W6 | 4/21/2014 | 16:30 | | | | | | | | | | | | | | | |
| W6 | 4/24/2014 | 11:20 | | | | | | | | | | | | | | | |

## Appendix 11 - Simulated Distillation Data - Well

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 3/25/2014 | 17:00 | <97 | 118 | 155 | 231 | 302 | 376 | 453 | 536 | 623 | 727 | 867 | 975 | 1220 | 100.0 | |
| W7 | 3/25/2014 | 17:00 | <97 | 135 | 177 | 252 | 326 | 404 | 484 | 568 | 661 | 777 | 955 | 1192 | >1382 | 95.7 | |
| W7 | 3/27/2014 | 13:00 | <97 | <97 | 104 | 204 | 285 | 366 | 450 | 538 | 633 | 747 | 905 | 1035 | 1328 | 100.0 | |
| W7 | 3/31/2014 | 13:00 | <97 | <97 | 156 | 221 | 296 | 372 | 453 | 536 | 627 | 735 | 883 | 1007 | >1382 | 98.7 | |
| W7 | 4/7/2014 | 16:00 | <97 | <97 | 132 | 208 | 282 | 356 | 437 | 520 | 611 | 718 | 860 | 971 | 1220 | 100.0 | |
| W7 | 4/16/2014 | 14:20 | | | | | | | | | | | | | | | |
| W7 | 4/21/2014 | 13:45 | | | | | | | | | | | | | | | |
| W8 | 3/25/2014 | 14:53 | <97 | 128 | 157 | 231 | 305 | 386 | 471 | 560 | 653 | 766 | 932 | 1121 | >1382 | 96.5 | |
| W8 | 3/25/2014 | 14:33 | <97 | 112 | 153 | 217 | 290 | 370 | 452 | 535 | 623 | 726 | 861 | 966 | 1198 | 100.0 | |
| W8 | 3/27/2014 | 15:30 | <97 | <97 | 158 | 219 | 294 | 376 | 461 | 549 | 643 | 755 | 914 | 1079 | >1382 | 96.9 | |
| W8 | 3/31/2014 | 12:42 | <97 | 104 | 163 | 232 | 311 | 391 | 477 | 566 | 660 | 776 | 937 | 1060 | 1293 | 100.0 | |
| W8 | 4/9/2014 | 12:30 | <97 | <97 | 153 | 222 | 301 | 381 | 459 | 545 | 629 | 734 | 870 | 976 | 1230 | 100.0 | |
| W8 | 4/16/2014 | 17:00 | | | | | | | | | | | | | | | |
| W8 | 4/18/2014 | 13:00 | | | | | | | | | | | | | | | |
| W9 | 4/1/2014 | 11:20 | <97 | 141 | 187 | 278 | 373 | 470 | 570 | 672 | 783 | 903 | 1044 | 1139 | 1320 | 100.0 | Stock Tank ID 43047 |
| W9 | 4/1/2014 | 12:10 | <97 | 137 | 180 | 276 | 375 | 476 | 578 | 684 | 796 | 920 | 1069 | 1182 | >1382 | 97.8 | Stock Tank ID 43047 |
| W9 | 4/3/2014 | 13:00 | <97 | 97 | 178 | 265 | 358 | 456 | 558 | 660 | 772 | 893 | 1037 | 1134 | 1362 | 99.7 | Stock Tank ID 43043 |
| W9 | 4/8/2014 | 11:25 | <97 | <97 | 174 | 263 | 353 | 451 | 549 | 649 | 758 | 879 | 1025 | 1124 | 1331 | 100.0 | Stock Tank ID 43043 |
| W9 | 4/15/2014 | 12:33 | <97 | <97 | 157 | 243 | 341 | 439 | 538 | 641 | 754 | 876 | 1023 | 1118 | 1284 | 100.0 | Stock Tank ID 43054 |
| W9 | 4/22/2014 | 11:35 | | | | | | | | | | | | | | | Stock Tank ID 43054 |
| W9 | 4/24/2014 | 14:20 | | | | | | | | | | | | | | | Stock Tank ID 43048 |
| W10 | 4/15/2014 | 15:40 | <97 | <97 | 126 | 200 | 267 | 344 | 432 | 525 | 631 | 754 | 912 | 1019 | 1209 | 100.0 | |
| W10 | 4/15/2014 | 15:40 | <97 | <97 | 145 | 205 | 278 | 349 | 437 | 528 | 630 | 750 | 901 | 1005 | 1186 | 100.0 | |
| W10 | 4/17/2014 | 12:50 | <97 | <97 | <97 | 182 | 251 | 330 | 419 | 513 | 621 | 749 | 906 | 1013 | 1209 | 100.0 | |
| W10 | 4/21/2014 | 15:30 | <97 | <97 | <97 | 180 | 244 | 327 | 413 | 509 | 615 | 740 | 900 | 1010 | 1222 | 100.0 | |
| W10 | 4/24/2014 | 12:35 | <97 | <97 | <97 | 181 | 246 | 327 | 412 | 508 | 613 | 738 | 896 | 1005 | 1219 | 100.0 | |
| W10 | | | | | | | | | | | | | | | | | |
| W11 | 4/7/2014 | 16:35 | <97 | <97 | 132 | 211 | 289 | 375 | 466 | 560 | 657 | 769 | 913 | 1023 | 1255 | 100.0 | |
| W11 | 4/7/2014 | 16:35 | <97 | <97 | 131 | 213 | 292 | 377 | 467 | 561 | 658 | 771 | 915 | 1025 | 1260 | 100.0 | |
| W11 | 4/11/2014 | 14:55 | <97 | <97 | 150 | 219 | 298 | 383 | 469 | 561 | 656 | 769 | 913 | 1023 | >1382 | 99.2 | |
| W11 | 4/15/2014 | 15:00 | <97 | <97 | 146 | 213 | 289 | 371 | 455 | 546 | 639 | 752 | 898 | 1007 | 1210 | 100.0 | |
| W11 | 4/17/2014 | 13:30 | <97 | <97 | <97 | 204 | 283 | 370 | 459 | 554 | 653 | 769 | 916 | 1026 | 1241 | 100.0 | |
| W11 | 4/20/2014 | 11:00 | | | | | | | | | | | | | | | |
| W11 | 4/23/2014 | | | | | | | | | | | | | | | | |
| W12 | 3/27/2014 | 12:46 | <97 | <97 | 164 | 254 | 343 | 439 | 536 | 636 | 748 | 869 | 1015 | 1114 | 1327 | 100.0 | |
| W12 | 3/27/2014 | 12:16 | <97 | <97 | 168 | 260 | 346 | 443 | 542 | 642 | 754 | 877 | 1025 | 1127 | >1382 | 99.4 | |
| W12 | 3/30/2014 | 13:00 | <97 | 141 | 181 | 267 | 354 | 451 | 547 | 647 | 756 | 878 | 1022 | 1120 | 1308 | 100.0 | |
| W12 | 4/1/2014 | 13:40 | <97 | 146 | 184 | 270 | 359 | 454 | 552 | 652 | 763 | 886 | 1036 | 1140 | >1382 | 99.0 | |
| W12 | 4/8/2014 | 13:20 | <97 | 100 | 179 | 266 | 355 | 453 | 550 | 651 | 762 | 885 | 1031 | 1130 | 1337 | 100.0 | |
| W12 | 4/17/2014 | 15:10 | | | | | | | | | | | | | | | |
| W12 | 4/17/2014 | 15:30 | | | | | | | | | | | | | | | |

## Appendix 11 - Simulated Distillation Data - Well

| Client ID | Sample Date | Sample Time | SimDis IBP | 5% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 95% | FBP | Recovery (weight %) | Additional Comments - Field or Lab |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W13 | 3/26/2014 | 17:00 | <97 | 110 | 165 | 240 | 327 | 418 | 503 | 589 | 684 | 792 | 938 | 1063 | >1382 | 98.5 | |
| W13 | 3/26/2014 | 17:00 | <97 | <97 | 155 | 231 | 313 | 403 | 490 | 578 | 674 | 783 | 924 | 1042 | >1382 | 98.9 | |
| W13 | 3/28/2014 | 15:30 | <97 | 120 | 175 | 247 | 332 | 425 | 514 | 602 | 702 | 814 | 978 | 1165 | >1382 | 96.5 | |
| W13 | 4/4/2014 | 15:15 | <97 | <97 | 136 | 219 | 303 | 394 | 488 | 582 | 683 | 797 | 959 | 1141 | >1382 | 96.2 | |
| W13 | 4/8/2014 | 11:00 | <97 | <97 | 154 | 233 | 313 | 400 | 488 | 576 | 670 | 777 | 913 | 1018 | 1270 | 100.0 | |
| W13 | 4/15/2014 | 19:30 | | | | | | | | | | | | | | | |
| W13 | 4/19/2014 | 14:00 | | | | | | | | | | | | | | | |
| W14 | 4/6/2014 | 16:20 | <97 | <97 | 149 | 229 | 315 | 397 | 484 | 574 | 670 | 780 | 926 | 1044 | >1382 | 99.5 | |
| W14 | 4/6/2014 | 16:20 | <97 | <97 | 168 | 248 | 325 | 409 | 495 | 584 | 679 | 789 | 936 | 1053 | 1298 | 100.0 | |
| W14 | 4/4/2014 | 11:55 | <97 | <97 | 137 | 217 | 300 | 384 | 473 | 563 | 661 | 774 | 923 | 1039 | 1262 | 100.0 | |
| W14 | 4/8/2014 | 12:30 | <97 | <97 | 155 | 236 | 315 | 392 | 477 | 565 | 660 | 768 | 910 | 1018 | 1257 | 100.0 | |
| W14 | 4/18/2014 | 16:30 | <97 | 98 | 174 | 244 | 328 | 411 | 496 | 585 | 681 | 790 | 931 | 1035 | 1225 | 100.0 | |
| W14 | 4/20/2014 | 14:00 | <97 | 110 | 181 | 250 | 331 | 416 | 500 | 587 | 683 | 792 | 931 | 1035 | 1225 | 100.0 | |
| W14 | 4/22/2014 | 11:00 | <97 | <97 | 153 | 238 | 320 | 403 | 489 | 579 | 677 | 789 | 932 | 1040 | 1262 | 100.0 | |
| W15 | 4/9/2014 | 17:20 | <97 | <97 | 158 | 237 | 313 | 390 | 477 | 570 | 671 | 789 | 942 | 1053 | 1282 | 100.0 | |
| W15 | 4/9/2014 | 17:20 | <97 | <97 | 154 | 235 | 309 | 388 | 476 | 570 | 672 | 790 | 945 | 1058 | 1307 | 100.0 | |
| W15 | 4/18/2014 | 19:30 | <97 | <97 | 153 | 232 | 307 | 389 | 478 | 572 | 674 | 794 | 947 | 1054 | 1251 | 100.0 | |
| W15 | 4/21/2014 | 18:30 | <97 | <97 | 147 | 221 | 301 | 383 | 472 | 566 | 670 | 791 | 946 | 1055 | 1263 | 100.0 | |
| W15 | 4/23/2014 | 13:00 | | | | | | | | | | | | | | | |
| W15 | 4/24/2014 | 16:30 | | | | | | | | | | | | | | | |

# Appendix 12 - Seasonality Data (Member Contributed)

| DATE | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 8/1/2013 | 8.96 | 8.62 |
| 8/2/2013 | 8.75 | 8.47 |
| 8/5/2013 | 8.48 | 8.54 |
| 8/16/2013 | 8.58 | 8.28 |
| 8/18/2013 | 8.75 | 8.33 |
| 8/22/2013 | 8.82 | 8.04 |
| 8/26/2013 | 8.56 | 8.25 |
| 8/29/2013 | 8.48 | |
| 9/1/2013 | 8.43 | 7.94 |
| 9/5/2013 | 7.99 | 7.93 |
| 9/11/2013 | 8.29 | 8.31 |
| 9/13/2013 | 8.43 | 8.29 |
| 9/14/2013 | 7.90 | 7.96 |
| 9/15/2013 | 8.73 | 8.89 |
| 9/23/2013 | 8.50 | 8.80 |
| 9/25/2013 | 8.27 | 8.57 |
| 9/26/2013 | 8.43 | 8.63 |
| 9/27/2013 | 8.41 | 8.77 |
| 10/4/2013 | 8.70 | |
| 10/7/2013 | 9.09 | 8.83 |
| 10/10/2013 | 9.22 | 8.53 |
| 10/14/2013 | 9.79 | 8.70 |
| 10/19/2013 | 9.10 | 9.20 |
| 10/20/2013 | 9.79 | 9.69 |
| 10/22/2013 | 9.53 | 9.63 |
| 10/24/2013 | | 9.44 |
| 10/25/2013 | 9.24 | 9.40 |
| 10/26/2013 | 9.24 | 9.56 |
| 10/28/2013 | 9.21 | 9.38 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 10/30/2013 | 9.08 | 9.67 |
| 11/7/2013 | 9.96 | 10.05 |
| 11/8/2013 | 10.30 | 10.50 |
| 11/9/2013 | 10.38 | 10.57 |
| 11/11/2013 | 10.24 | 10.38 |
| 11/14/2013 | 9.71 | 9.18 |
| 11/17/2013 | 10.33 | 10.28 |
| 11/18/2013 | 10.49 | 10.56 |
| 11/19/2013 | 9.70 | 10.28 |
| 11/22/2013 | 10.06 | 9.99 |
| 11/24/2013 | 9.94 | 9.94 |
| 11/25/2013 | 10.62 | 10.69 |
| 11/26/2013 | 10.69 | 10.66 |
| 12/2/2013 | 8.89 | 8.38 |
| 12/4/2013 | 9.67 | 9.82 |
| 12/8/2013 | 10.06 | 10.10 |
| 12/8/2013 | 9.58 | 9.18 |
| 12/9/2013 | 10.40 | 10.10 |
| 12/10/2013 | 10.76 | 10.77 |
| 12/13/2013 | 11.08 | 11.04 |
| 12/21/2013 | 10.61 | 11.18 |
| 12/22/2013 | 9.70 | 9.10 |
| 12/23/2013 | 10.90 | 10.94 |
| 12/24/2013 | 10.17 | 10.81 |
| 12/25/2013 | 10.21 | 10.23 |
| 12/27/2013 | 10.54 | 10.09 |
| 12/29/2013 | 10.96 | 10.29 |
| 12/30/2013 | 10.63 | 10.00 |
| 12/31/2013 | 9.89 | 9.89 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 1/3/2014 | 10.51 | 10.12 |
| 1/3/2014 | 10.38 | 10.44 |
| 1/5/2014 | 10.45 | |
| 1/6/2014 | 9.53 | 10.84 |
| 1/9/2014 | 10.62 | 10.66 |
| 1/10/2014 | 10.75 | 10.83 |
| 1/14/2014 | 10.93 | 11.05 |
| 1/16/2014 | 11.07 | 11.02 |
| 1/18/2014 | 10.42 | 10.48 |
| 1/19/2014 | 10.56 | 10.20 |
| 1/20/2014 | 10.14 | 10.91 |
| 1/20/2014 | 10.67 | 10.98 |
| 1/21/2014 | 10.86 | 11.01 |
| 1/21/2014 | 10.85 | 10.25 |
| 1/22/2014 | 10.67 | 10.44 |
| 1/30/2014 | 10.95 | |
| 1/30/2014 | 10.89 | |
| 2/2/2014 | 10.83 | |
| 2/5/2014 | 11.25 | |
| 2/6/2014 | 10.77 | |
| 2/7/2014 | 8.70 | |
| 2/12/2014 | 11.45 | 11.60 |
| 2/13/2014 | 10.66 | |
| 2/13/2014 | 10.62 | 10.60 |
| 2/14/2014 | 10.18 | 10.50 |
| 2/16/2014 | 10.81 | 10.86 |
| 2/18/2014 | 10.88 | 10.75 |
| 2/20/2014 | 10.43 | 10.33 |
| 2/22/2014 | 10.52 | 9.49 |

| | RVP (psi) Prod. Train A | RVP (psi) Prod. Train B |
|---|---|---|
| 2/23/2014 | 9.56 | 11.25 |
| 2/24/2014 | 10.21 | |
| 2/26/2014 | 10.83 | 10.82 |
| 2/28/2014 | 11.34 | 11.04 |
| 3/2/2014 | 9.89 | |
| 3/3/2014 | 9.94 | 10.17 |
| 3/4/2014 | 10.73 | 10.17 |
| 3/5/2014 | 10.85 | 11.07 |
| 3/6/2014 | 10.43 | 10.41 |
| 3/7/2014 | 10.73 | 10.79 |
| 3/7/2014 | 10.91 | 10.89 |
| 3/8/2014 | 11.23 | 11.23 |
| 3/9/2014 | 10.62 | 10.38 |
| 3/11/2014 | 10.23 | 10.08 |
| 3/11/2014 | 10.63 | 10.92 |
| 3/13/2014 | 10.25 | 10.12 |
| 3/15/2014 | 10.15 | 10.24 |
| 3/16/2014 | 10.37 | 10.30 |
| 3/18/2014 | 10.41 | 10.37 |
| 3/20/2014 | 10.12 | 10.11 |
| 3/21/2014 | 10.11 | 9.91 |
| 3/22/2014 | 10.25 | 10.30 |
| 3/22/2014 | 10.25 | 10.30 |
| 3/23/2014 | | 10.33 |
| 3/24/2014 | 10.46 | |
| 3/28/2014 | 10.41 | |
| 3/29/2014 | 10.52 | 10.24 |
| 3/30/2014 | 10.43 | 10.18 |

## Appendix 13 - Interlaboratory (Round-Robin) Data

| Lab | Sample | API | Vapor P D6377 (kPa) | Vapor P D6377 (psi) | D86 IBP (°F) | Condenser T (°F) | Reciever T (°F) |
|---|---|---|---|---|---|---|---|
| Lab M | 1 | 42.98 | 103.3 | 14.98 | 83.1 | 32.9 | 60.0 |
| SGS (St. Rose) | 1 | 42.91 | 106.5 | 15.44 | 89.1 | 60 | 73 |
| SGS (Williston) | 1 | 42.86 | 95.0 | 13.78 | 102.6 | 60 | 81 |
| | | | | | 88.7 | 31 | 82 |
| Lab M | 2 | 40.22 | 69.7 | 10.11 | 89.9 | 32.9 | 60.0 |
| SGS (St. Rose) | 2 | 40.18 | 70.7 | 10.26 | 95.4 | 60 | 73 |
| SGS (Williston) | 2 | 40.17 | 69.7 | 10.11 | 101.8 | 60 | 80 |
| | | | | | 91.1 | 31 | 82 |
| Lab M | 3 | 43.63 | 73.2 | 10.62 | 87.8 | 32.9 | 60.0 |
| SGS (St. Rose) | 3 | 43.56 | 73.4 | 10.64 | 90.7 | 60 | 73 |
| SGS (Williston) | 3 | 43.61 | 73.0 | 10.59 | 105.5 | 60 | 81 |
| | | | | | 91.4 | 31 | 81 |
| Lab M | 4 | 42.97 | 78.8 | 11.43 | 89.2 | 32.9 | 60.0 |
| SGS (St. Rose) | 4 | 42.89 | 79.5 | 11.53 | 94.5 | 60 | 73 |
| SGS (Williston) | 4 | 42.88 | 77.3 | 11.21 | 102..2 | 60 | 81 |
| | | | | | 94.4 | 31 | 82 |

| Lab | SGS (St. Rose) | | SGS (Williston) | | SGS (Williston) | |
|---|---|---|---|---|---|---|
| Condenser Temp (°F) | 60 | | 60 | | 31 | |
| Receiver Temp (°F) | 73 | | 81 | | 81 | |
| Sample | D86 IBP | D86 IBP (°F) | D86 IBP (°F) | Time to IBP | D86 IBP (°F) | Time to IBP |
| 1 | 89.1 | 3 min 22 sec | 102.6 | 6 min 27 sec | 88.7 | 6 min 07 sec |
| 2 | 95.4 | 4 min 53 sec | 101.8 | 7 min 56 sec | 91.1 | 7 min 45 sec |
| 3 | 90.7 | 3 min 37 sec | 105.5 | 7 min 26 sec | 91.4 | 7 min 11 sec |
| 4 | 94.5 | 3 min 42 sec | 102.2 | 6 min 50 sec | 94.4 | 8 min 00 sec |

## Appendix 14 – Glossary of Terms

AFPM – American Fuel & Petrochemical Manufacturers

API – American Petroleum Institute

ASTM – American Society for Testing and Materials

BKN – Bakken

BS&W – Basic Sediment & Water

DOT – Department of Transportation

EPA – Environmental Protection Agency

FPCs – Floating Piston Cylinders

$H_2S$ – Hydrogen Sulfide

IBP – Initial Boiling Point

LLS – Light Louisiana Sweet

LPG - Liquefied Petroleum Gas

LTO – Light Tight Oil

NACE – National Association of Corrosion Engineers

ND – North Dakota

NDPC – North Dakota Petroleum Council

NGL – Natural Gas Liquids

PG – Packing Group

PHMSA – Pipeline and Hazardous Safety Materials Administration

psi – Pounds per Square Inch

psig – Pounds per Square Inch Gauge

QA/QC – Quality Assurance/ Quality Control

RVP – Reid Vapor Pressure

SGS – Laboratory Testing Provider

## Appendix 14 – Glossary of Terms

SimDist – Simulated Distillation

TAN – Total Acid Number

TM&C – Turner, Mason & Company

VPCR – ASTM D6377 Vapor Pressure

WTI – West Texas Intermediate

## Affidavit of Publication

**The Dickinson Press**

Dickinson,North Dakota

STATE OF NORTH DAKOTA )
County of Stark ) ss

Sonya Sacks being first duly sworn, on my oath, say that I am the bookkeeper of The Dickinson Press, a daily newspaper of general circulation, printed and published at Dickinson, in said county and state, and the advertisement headed:

Sept 23 hearing

a printed copy of which is hereunto annexed, was printed and published in The Dickinson Press, and in the regular and entire issue of each and every number for 1 consecutive weeks, commencing on the 26 day of August A.D. 2014 and ending on the 26 day of August A.D. 2014, both inclusive.

| | | |
|---|---|---|
| Straight Matter Lines | 30 | ,2014 |
| First Time Line Rates | 0.77 | 26-Aug ,2014 |
| Subsequent Line Rates | 0.77 | ,2014 |
| Column Inches | | ,2014 |
| First Time Inch Rate | $8.41 | ,2014 |
| Subsequent Inch Rate | $8.41 | ,2014 |
| Total Cost of Legal | $ 23.10 | |

[signature]

Subscribed and sworn to before me this 15th day of September A.D. 2014.

(Seal) [signature]

Notary Public, State Of North Dakota

My Commission Expires

JOY SCHOCH
NOTARY PUBLIC, STATE OF NORTH DAKOTA
MY COMMISSION EXPIRES JAN 6, 2017

**NOTICE OF HEARING**
**N.D. INDUSTRIAL COMMISSION**
**OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N.D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

**STATE OF NORTH DAKOTA TO:**

*Case No. 23084:* In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial
(Published August 26, 2014)

SEP 2014
RECEIVED
ND OIL & GAS
DIVISION

The Bismarck Tribune
www.bismarcktribune.com
The Finder

# Classified Advertising Invoice

Bismarck Tribune
PO BOX 4001
LaCrosse, WI 54602-4001

888-418-6474

SEP 2014
RECEIVED
ND OIL & GAS DIVISION

OIL & GAS DIVISION

600 E BLVD AVE #405
BISMARCK ND 58505

Customer: 60010203
Phone: (701) 328-8020
Date: 08/25/2014

| Date | Order # | Type | Order Amt |
|---|---|---|---|
| 08/25/14 | 20741868 | INV | 22.91 |

Amount Paid: ____________ CK #: ____________

CashAmt

CREDIT CARD PAYMENT (circle one)

Card #: ____________
Exp Date: ____________
Signature: ____________
*Credit card users: Fax to 608-791-8212*

PLEASE DETACH AND RETURN TOP PORTION WITH YOUR PAYMENT

Lee Enterprises no longer accepts credit card payments sent via e-mail. Emails containing credit card numbers will be blocked. Please use the coupon above to send a credit card payment to remittance address located in the upper right corner.
You may also send the coupon to a secure fax at 608-791-8212.

| Date | Date | Times Run | Description | Lines | Class Code | Order Amt | Net Amt Due |
|---|---|---|---|---|---|---|---|
| | | | Case No. 23084 | 29.00 | Legals | 22.91 | 22.91 |
| 08/25/14 | 08/25/14 | 1 | Bismarck Tribune | | | | |
| | | | PO:Notice of Hearing | | | | |

Affidavit of Publication
State of North Dakota ) SS County of Burleigh
Before me, a Notary Public for the State of North Dakota personally appeared CK who being duly sworn, deposes and says that he (she) is the Clerk of Bismarck Tribune Co., and that the publication(s) were made through the Bismarck Tribune on the following dates: 5/25 Signed Calvin Kuntz
sworn and subscribed to before me this 11th day of September 2014
Morgan Doll
Notary Public in and for the State of North Dakota

MORGAN DOLL
Notary Public
State of North Dakota
My Commission Expires Jan. 26, 2017

**NOTICE OF HEARING**
**N.D. INDUSTRIAL COMMISSION**
**OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N.D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial Commission
8/25 - 20741868

Please return invoice or put order number on check. Thank You.

Remarks

Total Due: 22.91

Bismarck Tribune
www.bismarcktribune.com
PO BOX 4001
LaCrosse, WI 54602-4001

Terms: PAYMENT IS DUE UPON RECEIPT OF INVOICE

NDNA
NORTH DAKOTA NEWSPAPER ASSOCIATION

SEP 2014
RECEIVED
ND OIL & GAS
DIVISION

# Affidavit of Publication

Colleen Park, being duly sworn, states as follows:

1. I am the designated agent, under the provisions and for the purposes of, Section 31-04-06, NDCC, for the newspapers listed on the attached exhibits.

2. The newspapers listed on the exhibits published the advertisement of: **Oil & Gas Division – Cases beginning with No. 23084; 1** time(s) as required by law or ordinance.

3. All of the listed newspapers are legal newspapers in the State of North Dakota and, under the provisions of Section 46-05-01, NDCC, are qualified to publish any public notice or any matter required by law or ordinance to be printed or published in a newspaper in North Dakota.

Signed: Colleen Park

State of North Dakota

County of Burleigh

Subscribed and sworn to before me this 10 day of September, 20 14.

Sharon L. Peterson

SHARON L. PETERSON
Notary Public
State of North Dakota
My Commission Expires Nov. 8, 2017

No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.
Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial

**PUBLISHED IN THE DUNN COUNTY HERALD AUGUST 29, 2014**

NOTICE OF HEARING
N.D. INDUSTRIAL COMMISSION
OIL AND GAS DIVISION

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO: Case

AFFIDAVIT OF PUBLICATION

STATE OF NORTH DAKOTA )
SS
COUNTY OF Mercer )

SEP 2014
RECEIVED
ND OIL & GAS
DIVISION

I SHELLEY CHASE, being first duly sworn, on my own oath, say, that I am the bookkeeper of the Hazen Star , a weekly newspaper of general circulation, published in the city of Hazen, that the advertisement headed:

ND INDUSTRIAL COMM OIL & GAS HZ-NOTICE OF CASE #23084 HEARING/LEGAL

a printed copy of which is here annexed, was published in the regular and entire issue of said newspaper during the period and time of publication, and that the notice was published in the newspaper proper , and not in a supplement,

for 1 consecutive week 08/28/2014 to wit:

Straight Matter Lines 27 $0.72 $19.44 08/28/2014

Notary Fee $0.00 Total Cost of Legal $19.44

Shelley Chase

Subscribed and sworn to before me this 2nd day of September A.D. 2014.

(Seal) Darla J. Mautz

Notary Public, State of North Dakota

My Commission Expires

**DARLA J MAUTZ**
**Notary Public**
**State of North Dakota**
**My commission expires July 22, 2016**

NOTICE OF HEARING
N.D. INDUSTRIAL COMMISSION
OIL AND GAS DIVISION

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m.

Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial
(8-28-14)

NOTICE OF HEARING
N.D. INDUSTRIAL COMMISSION
OIL AND GAS DIVISION

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial Commission

(8/27)

# Affidavit of Publication

State of North Dakota, County of Divide, ss:

I, Cecile L. Krimm, being first duly sworn, on my oath, say that I am the publisher of The Journal, a weekly newspaper of general circulation and official newspaper of Divide County, State of North Dakota, published in the city of Crosby, ND, and that the advertisement headed

NOTICE OF HEARING

a printed copy of which is here attached, was published in The Journal on the following date:

**Aug. 27, 2014 .......... 32 lines @ 0.64 =$20.48**

**TOTAL CHARGE .......... $20.48**

Signed Cecile L Krimm
Cecile L. Krimm, Publisher

AUG 2014
RECEIVED
ND OIL & GAS
DIVISION

Subscribed and sworn to before me Aug. 27 , 2014

Holly R. Anderson
Notary Public, State of North Dakota

HOLLY R. ANDERSON
Notary Public
State of North Dakota
My Commission Expires July 18, 2018

# Affidavit of Publication

State of North Dakota)
:ss.
County of Williams)

**Wanda Olaf** being first duly sworn, deposes and says: That (he) (she) is the Agent to the Publisher of the WILLISTON HERALD a newspaper printed and published six days a week in the county of Williams, State of North Dakota, and of general circulation in the city of Williston, County of Williams, State of North Dakota and elsewhere, and the hereto attached.

AUG 2014
RECEIVED
ND OIL & GAS
DIVISION

**Notice of Hearing**
**Tuesday, September 23, 2014**

was printed and published correctly in the regular and entire issue of said WILLISTON HERALD FOR **1** issues, that the first was made on the **25th** day of **August** 20 **14** that said publication was made on each of the following dates to wit:

**8/25/14**

Request of

**ND Industrial Commission Oil & Gas Division**

**NOTICE OF HEARING**
**N.D. INDUSTRIAL COMMISSION**
**OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

**STATE OF NORTH DAKOTA TO:**

**Case No. 23084**: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

By: -s- JACK DALRYMPLE
Jack Dalrymple, Governor
Chairman, ND Industrial Commission
(August 25, 2014)

**Williston Herald**
www.willistonherald.com

By Wanda Olaf

Subscribed sworn to before me this **25th** day of **August** 20 **14**

Notary Public in and for the County of Williams, State of North Dakota

Legal Rate $.85 per line or $8.41 per column inch.

#2386 $27.91

**AFFIDAVIT OF PUBLICATION**
STATE OF NORTH DAKOTA

SS.

County of Ward

AMANDA STARBUCK-MATTSON of said County and State, being first duly sworn, on oath says: That the **MINOT DAILY NEWS** is a daily newspaper of general circulation, printed and published in the City of Minot, in said County and State. That the **MINOT DAILY NEWS** now is and during all times in the foregoing affidavit mentioned has been a newspaper qualified to do legal printing, in accordance with the Statutes of the State of North Dakota, and that I am clerk of the **MINOT DAILY NEWS** and during all such time covering the publication of this notice have occupied such position on said newspaper, and have personal knowledge of all the facts stated in this affidavit; and that the advertisement headed

SEPTEMBER 23, 2014 CASE #23084
PUBLIC HEARING

a printed copy of which is hereunto attached was printed and published in said newspaper ONE times to-wit:

AUGUST 27, 2014

Amanda L. Starbuck-Mattson, Clerk.

Subscribed and sworn to before me this 27th Day of August 2014

Shannon Grater

Notary Public, Ward Co, N.D.

D20731

AUG 2014 RECEIVED ND OIL & GAS DIVISION

**N.D. INDUSTRIAL COMMISSION OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice. PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:
Case No. 23084:

In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.
Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial
(August 27, 2014)

**PUBLICATION FEES**

No. Lines 39

Times ONE $ 26.91

39 ST LINES x .69 = $26.91

SHANNON GRATER
Notary Public
State of North Dakota
My Commission Expires December 8, 2015

STATE OF NORTH DAKOTA)
COUNTY OF BURKE)

Kristi M. Bohl of said County and State, being first duly sworn, on her oath, says that she is the owner of The Burke County Tribune, a weekly newspaper of general circulation, printed at Bowbells, in said County and State, and that she has been during the time hereinafter mentioned, and that the Notice of Publication of

Notice of Hearing
# 23084

a printed copy of which is hereto annexed, was published in the regular and entire issue of said newspaper during the period and time of publication, and that the Notice was published in the newspaper proper and not in supplement, once each week for 1 successive weeks, to wit:

8-27 2014 ______20___ ______20___

______20___ ______20___ ______20___

Kristi M Bohl
Kristi M. Bohl, Publisher

Subscribed and sworn to before me this 27th day of August, 2014.

Lyann Olson
Notary Public in and for
Burke County, North Dakota

1st time 31 lines at 70 per line 21.70

2nd time______lines at ______ per line________

3rd time______lines at ______ per line________

1st time____column inches at _____ per line _____
2nd time____column inches at _____ per line _____

TOTAL_______

AUG 2014
RECEIVED
ND OIL & GAS
DIVISION

## Notice of Hearing
### N.D. INDUSTRIAL COMMISSION
### OIL AND GAS DIVISION

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N.D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial
August 27, 2014

LYANN OLSON
Notary Public
State of North Dakota
My Commission Expires Aug. 6, 2020

AFFIDAVIT OF PUBLICATION



TATE OF NORTH DAKOTA )
SS
OUNTY OF McLean )

I SHELLEY CHASE, being first duly sworn, on my own oath, ay, that I am the bookkeeper of the McLean County Independent a weekly newspaper of general circulation, ublished in the city of Garrison, that the advertisement eaded:

ID INDUSTRIAL COMM OIL & GAS GR-NOTICE OF HEARING FOR CASE #23084/LEGAL

printed copy of which is here annexed, was published in ie regular and entire issue of said newspaper during the eriod and time of publication, and that the notice was ublished in the newspaper proper , and not in a supplement,

or 1 consecutive week 08/28/2014 to wit:

| | | | |
|---|---|---|---|
| Straight Matter Lines 32 | $0.72 | $23.04 | 08/28/2014 |

Notary Fee $0.00 Total Cost of Legal $23.04

Shelley Chase

Subscribed and sworn to before me this 29th day of August A.D. 2014.

Seal) Carla J. Martz

Notary Public, State of North Dakota

My Commission Expires

NOTICE OF HEARING
N.D. INDUSTRIAL COMMISSION
OIL AND GAS DIVISION

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m.

Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck,

N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084:

In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial
(Aug. 28, 2014)

# Affidavit of Publication

STATE OF NORTH DAKOTA ) ss
County of Mountrail )

I, Mary Kyler, being first duly sworn, on my oath, say that I am the bookkeeper of the Mountrail County Promoter, a weekly newspaper of general circulation, published in the city of Stanley, in said county and state, and that the advertisement headed:

Notice of Hearing

a printed copy of which is here annexed, was published in the regular and entire issue of said newspaper during the period and time of publication, and that the notice was published in the newspaper proper, and not in a supplement,

for 1 consecutive week to wit:

| | | |
|---|---|---|
| Straight Matter Lines | 29 | August 27, 2014 |
| First Time Line Rate | .75 | 21.75, 20 |
| Subsequent Line Rate | | , 20 |
| Column Inches | | , 20 |
| First Time Inch Rate | | , 20 |
| Subsequent Inch Rates | | , 20 |

Notary Fee ______ Total Cost of Legal, $ 21.75

Mary Kyler

Subscribed and sworn to before me this 29th day of August A.D. 20 14

(Seal) Connie J. Longmuir
Notary Public, State of North Dakota

~~My Commission Expires~~ 6-23 20 16

CONNIE J LONGMUIR
Notary Public
State of North Dakota
My Commission Expires June 23, 2016

**NOTICE OF HEARING**
**N.D. INDUSTRIAL COMMISSION**
**OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by,
Jack Dalrymple, Governor
Chairman, ND Industrial Commission
August 27, 2014

**NOTICE OF HEARING**
**N.D. INDUSTRIAL COMMISSION**
**OIL AND GAS DIVISION**

The North Dakota Industrial Commission will hold a public hearing at 9:00 a.m. Tuesday, September 23, 2014, at the N.D. Oil & Gas Division, 1000 East Calgary Ave., Bismarck, N. D. At the hearing the Commission will receive testimony and exhibits. Persons with any interest in the cases listed below, take notice.

PERSONS WITH DISABILITIES: If at the hearing you need special facilities or assistance, contact the Oil and Gas Division at 701-328-8038 by Wednesday, September 10, 2014.

STATE OF NORTH DAKOTA TO:

Case No. 23084: In the matter of a hearing called on a motion of the Commission to consider amending the Bakken, Bakken/Three Forks, Three Forks, and/or Sanish Pool field rules to establish oil conditioning standards and/or impose such provisions as deemed appropriate to improve the transportation safety and marketability of crude oil.

Signed by, JACK DALRYMPLE
Jack Dalrymple, Governor
Chairman, ND Industrial Commission
(August 27, 2014)
–mcf–

SEP 2014
RECEIVED
ND OIL & GAS
DIVISION

# AFFIDAVIT OF PUBLICATION

STATE OF NORTH DAKOTA )
County of McKenzie ) ss

I, Nancy Toy being first duly sworn, on my oath, say that I am the Production Manager of the McKenzie County Farmer, a weekly newspaper of general circulation, published in the city of Watford City, in said county and state, and that the advertisement headed:

ND Industrial Commission - September 23

a printed copy of which is here annexed, was published in the regular and entire issue of said newspaper during the period and time of publication, and that the notice was published in the newspaper proper, and not in a supplement, once a week for one week, as follows:

| | | | |
|---|---|---|---|
| Straight Matter Lines | 29 | | |
| First Time Line Rate | **82¢** | $23.78 | 08-27, 2014 |
| Subsequent Line Rates | **82¢** | | , |
| | **82¢** | | , |
| Column Inches | | | |
| First Time Inch Rate | **$6.06** | | , |
| Subsequent Inch Rates | **$6.06** | | , |

Total Cost of Legal, $23.78

Nancy Toy

Subscribed and sworn to before me this 27th day of August

A.D. 2014.

Lisa K. S

Notary Public,
State of North Dakota

LISA K. SHIPMAN
Notary Public
State of North Dakota
My Commission Expires July 9, 2016

My Commission Expires