Oil Exploration and Development in the North Dakota Williston Basin: 1998-1999 Update

By Thomas J. Heck

MISCELLANEOUS SERIES NO. 88
North Dakota Geological Survey
John P. Bluemle, State Geologist
2000

OIL EXPLORATION AND DEVELOPMENT IN THE NORTH DAKOTA WILLISTON BASIN: 1998-1999 Update
Thomas J. Heck
North Dakota Geological Survey
2000
M.S. 88

Cover photo:

During the summer of 1999, a 205-mile pipeline was installed from the Great Plains Synfuels Plant near Beulah, North Dakota, to an oil field near Weyburn, Saskatchewan. The pipeline will transport carbon dioxide (CO_2), a byproduct of the coal gasification process, to the Weyburn Oil Field. CO_2 will be used by PanCanadian Resources, operator of the field, for tertiary oil recovery. Deliveries of CO_2 began in September 2000. PanCanadian will use up to 95 million cubic feet of CO_2 daily.

Ground breaking ceremonies for the pipeline were held May 12, 1999, signaling the start of construction.

The pipeline was installed in four "spreads." Spread one was the pipeline from the Synfuels Plant to Lake Sakakawea. Spread two continued from the lake to the Canadian border. The third spread was an almost three-mile crossing of Lake Sakakawea, shown in the photo. The fourth spread was the 38-mile Canadian portion. From the gasification plant to Tioga, N.D., the pipe diameter is 14 inches. From Tioga to the Weyburn Oil Field, the diameter is 12 inches.

Spread three was completed in less than 24 hours. It involved pulling more than 13,000 feet of pipeline across Lake Sakakawea. Five 2,600-foot sections - pre-assembled on the north shore - were joined and then pulled across the lake. (see cover)

At the shoreline, trenches were dug on both sides of the lake. The trenches, each 1,400-feet long and eight feet deep, are covered and rip-rapped so the pipeline will not be exposed to wave action or if the water level reaches its minimum level. Most of the line, between trenches, lies on the lake bottom at a maximum depth of 60 feet.

On Dec. 1, 1999, the final weld connecting the U.S. and Canadian portions of the $100 million-pipeline project was made.

Taps were installed in the pipeline for transporting CO_2 to other oil-field recovery projects, if needed.

The Great Plains Synfuels Plant is owned and operated by Dakota Gasification Company, a subsidiary of Basin Electric Power Cooperative, Bismarck, N.D. The Synfuels Plant produces about 150 million standard cubic feet of natural gas daily from its coal gasification process. Seven other byproducts, besides CO_2, are also produced. They include anhydrous ammonia, ammonium sulfate (DakSul 45â), naphtha, crude cresylic acid, phenol, krypton-xenon and liquid nitrogen.

ISSN:0078-1576

Oil Exploration and Development in the North Dakota Williston Basin 1998-1999 Update

By Thomas J. Heck

MISCELLANEOUS SERIES NO. 88
North Dakota Geological Survey
John P. Bluemle, State Geologist
2000

TABLE OF CONTENTS

Illustrations ii

Introduction 1

1980-1989 1

1990-1999 4

Drilling 4
- Oil Production 8
- Exploration Potential 13

Historical Summary 13

1998 14
- Statistics 14
- Drilling 15

1999 19
- Statistics 19
- Drilling 20

1998-1999 Highlights 22

References 24

Appendix I. 1998 New Pool Discoveries 25

Appendix II. 1999 New Pool Discoveries 27

ILLUSTRATIONS

Figure

1. Bar diagram of annual state Land Department lease sale revenue for the period 1970 to 1999 2
2. Bar diagram of annual production and extraction tax revenue from crude oil production for the period 1970 to 1999 3
3. Line graph of the number of oil and gas wells drilled annually in North Dakota since 1951 ... 4
4. Line graph of the number of wildcat wells drilled annually in North Dakota since 1951 5
5. Line graph of the number of new oil and/or natural gas pools discovered annually since 1951 6
6. Line graph of annual oil production in North Dakota since 1951 7
7. Bar diagram of the net tax collections in North Dakota since 1980 8
8. Line graph of the monthly average posted price for Williston Basin 40-gravity "sweet" crude oil and the number of wells spudded monthly since January 1, 1986 9
9. Bar diagram of the annual oil production from Cedar Hills Field, all known Lodgepole mound fields, and all other producing oil wells in North Dakota 10
10. Line graph of monthly average price for Williston Basin 40-gravity "sweet" crude oil and the number of producing oil wells monthly for 1998 and 1999 11
11. Bar diagram of the annual number of unitized oil fields since 1950 12
12. Map of the approximate route of Dakota Gasification Company's CO_2 pipeline from its origin at the gas plant near Beulah, ND to its terminus at Weyburn Field in Saskatchewan 13
13. Bar diagram of the number of horizontal and vertical wells drilled annually in the Saskatchewan Williston Basin since 1989 15
14. Bar diagram of annual oil production from vertical and horizontal wells in the Saskatchewan Williston Basin 16
15. Map of western North Dakota with the location of all known producing wells and all 1998 new field discoveries 17
16. Well plat of several horizontal boreholes in Lakeside Field, Burke County on which the birds foot pattern of the horizontal borehole legs is shown 18
17. Map of western North Dakota with the location of all known producing wells and all 1999 new field discoveries 20

Table

1. Abbreviations most commonly used in this report 1
2. 1998 and 1999 New Pool and Field Discoveries 14

ACKNOWLEDGEMENTS

I thank Dakota Gasification Company, Bismarck, ND for the cover photograph and description of the CO_2 pipeline. I also thank John Bluemle for reviewing the manuscript and Linda Johnson who compiled all the pieces into our final publication. Their help is greatly appreciated.

INTRODUCTION

This update summarizes oil exploration and development in North Dakota during the 1980s and 1990s, but focuses on the events of 1998 and 1999. The 1980s and 1990s saw many changes in North Dakota's oil industry. The 1980s began with domestic oil industry activity at record highs in response to the Arab oil embargo and subsequent rapid price increases during the late 1970s. Record high crude oil prices were reached during the early 1980s, but crude oil prices began to decline in the mid-1980s. Exploration, which had increased during the 1970s, began to decrease in response to lower prices during the early 1980s. Many had thought that prices had hit bottom in 1985, but overproduction by OPEC caused oil prices to fall even further in 1986. Between 1986 and 1998, oil prices fluctuated between $12 and $22 per barrel. North Dakota's oil industry had adjusted to the level of price uncertainty that price range brought when, in early 1998, oil prices began to drop. Crude oil prices fell below $10/barrel during early 1999, many wells were shut-in, and new drilling nearly stopped. Despite rising oil prices for the rest of 1999, reaching the highest price since 1991, the number of wells drilled during the year was the lowest since 1951, the year oil was discovered in North Dakota. Thus the 1990s ended with high oil prices, but little drilling.

Data included in this report are primarily from the files of the North Dakota Industrial Commission-Oil and Gas Division. Additional data were provided by the State Tax Department, the State Land Department, and Amoco Oil. Help from these sources is gratefully acknowledged. Interpretations of the data, however, are my own. Following the precedent set in the 1988-1989 Update (Heck, 1990), the historical overview of exploration in North Dakota before 1980, included in many earlier updates, has been dropped. The reader is referred to Fischer and Bluemle (1988) for this information. For those readers unfamiliar with the oil-field abbreviations used in this report, Table 1 lists the most common ones.

Table 1
Land Terminology

BO	Barrel(s) of oil. One barrel equals 42 U.S. gallons
BOPD	Barrels of oil per day. Daily production rate of an oil well
BW	Barrel(s) of water
BWPD	Barrels of water per day
MCF	One thousand cubic feet of natural gas
MCFPD	Thousand(s) of cubic feet of gas per day
Oil Pool	One or more oil wells producing from a single zone
Oil Field	One or more wells producing oil from one or more pools
Wildcat	A well drilled more than one mile from existing oil production
IP	Initial potential or daily rate a well is completed at
Incremental oil	New reserves added by secondary recovery or infill drilling

1980-1989

The oil-industry entered the 1980s with activity at record levels, both nationally and in North Dakota. Oil prices were high, averaging $28 per barrel in North Dakota (Fischer and Bluemle, 1988), and operators aggressively pursued new plays and prospects. State lease sales brought record revenues (Figure 1) and tax revenues in 1980 more than doubled from 1979 (Figure 2). Of the nearly 600 wells drilled in North Dakota during 1980 (Figure 3), 182 (31%) were wildcats (Figure 4). There were 84 new pools discovered (Figure 5) and annual production rose to 40,354,030 BO, a second consecutive record (Figure 6).

The records set during 1980 fell in 1981 as the "oil boom" peaked in North Dakota. New records

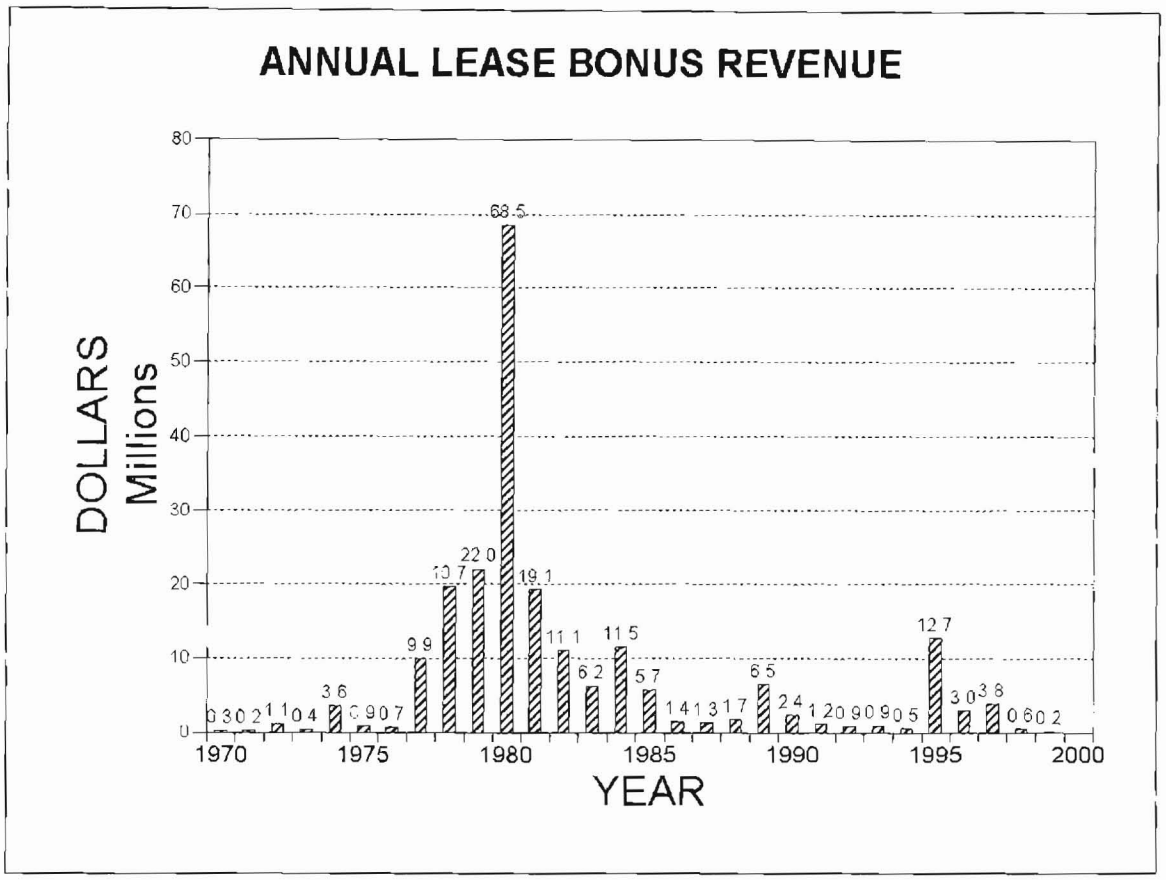

Figure 1. Bar diagram of annual state Land Department lease sale revenue for the period 1970 to 1999. (Source N. D. State Land Dept.)

of 834 total wells drilled, 267 wildcats drilled, and 102 new pools discovered were set. The 1980 annual production record was surpassed in 1981 when 45,706,999 BO were produced during 1981, setting a third straight annual production record. State revenues increased as the new extraction tax began generating its first revenue (Figure 2). Together, the extraction and production taxes supplied more than 20 percent of the state's collections in 1981, the first year the extraction tax was in place (Figure 7).

The oil industry could not maintain a high level of activity after oil prices began to slip during 1982. However, oil production and tax revenues continued to climb despite reduced drilling because the drilling emphasis shifted toward developing existing fields and away from exploration. Another reason for the continued increase in oil production is that there typically is a one- to three-year lag between the discovery and peak production from an oil field. In general, the larger the field the longer the lag because more wells are required to develop the field. Many fields discovered during 1980 and 1981 did not reach peak production until 1982 to 1984.

Oil prices continued to decline during 1983, further reducing drilling. Wildcat drilling (Figure 4) was one-third of 1981 levels, reflecting the lower oil prices, but development drilling remained high as fields were developed. Oil production continued to rise, as did tax revenues (Figures 2 & 6). Both wildcat and development drilling rose slightly during 1984 (Figures 3 & 4) and oil production in North Dakota reached its all-time high of 52,654,336 barrels (Figure 6). Despite record oil production, tax revenues declined for the first time since 1973 because of lower oil prices (Figure 2). Drilling resumed its decline during 1985 as oil prices slid further and began to fluctuate. Overproduction by OPEC caused a rapid price drop in early 1986, with prices falling below $10 a barrel for certain types of crude oil. Drilling plummeted and oil companies began to downsize and reduce spending in response to lower crude oil

prices and uncertainties about future prices. The impact on North Dakota's oil industry was a drop in drilling and a decrease in the number and size of oilfield service companies. Many either went bankrupt and closed their doors or moved out of state to cut costs.

From mid-1986 through early 1987, crude oil prices rose gradually and a modest increase in drilling occurred between mid-1987 and early 1988. Although the number of wells spudded increased during the second half of 1987, activity during the first half of the year was so low that only 190 wells were drilled during the year (Figure 3). In 1988, drilling jumped sharply to 255 wells. Part of the increase was the result of development drilling in Wabek Field, an important new oil field discovered along the Mississippian Sherwood subinterval shoreline. Another important field, Plaza Field, was discovered near Wabek Field in 1989 and development of the field began. Plaza Field produces from the Bluell subinterval, which immediately overlies the Sherwood subinterval. Sperr, et al. (1993) estimate ultimate recoveries of six to eight million barrels from Wabek Field and 3.5 million barrels from Plaza Field. These two fields were the largest Madison fields discovered during the late 1980s.

From 1986 through 1991, between 188 and 274 wells were drilled annually. The 188 wells drilled in 1989 recorded the lowest numbers of wells drilled since 1974 (Figure 3). Between 35 and 67 of the wells drilled annually were wildcat wells during this period with 35 of the 188 wells drilled in 1989 being wildcats and 67 of the 190 total wells drilled in 1987. The number of wells drilled annually decreased steadily from 1990 until 1995, when a slight increase occurred. Wildcat drilling also decreased, declining to 20 and 17 wildcats during 1994 and 1995, respectively. The 17 wildcats drilled during 1995 were the fewest wildcats drilled in North Dakota since oil was discovered in 1951.

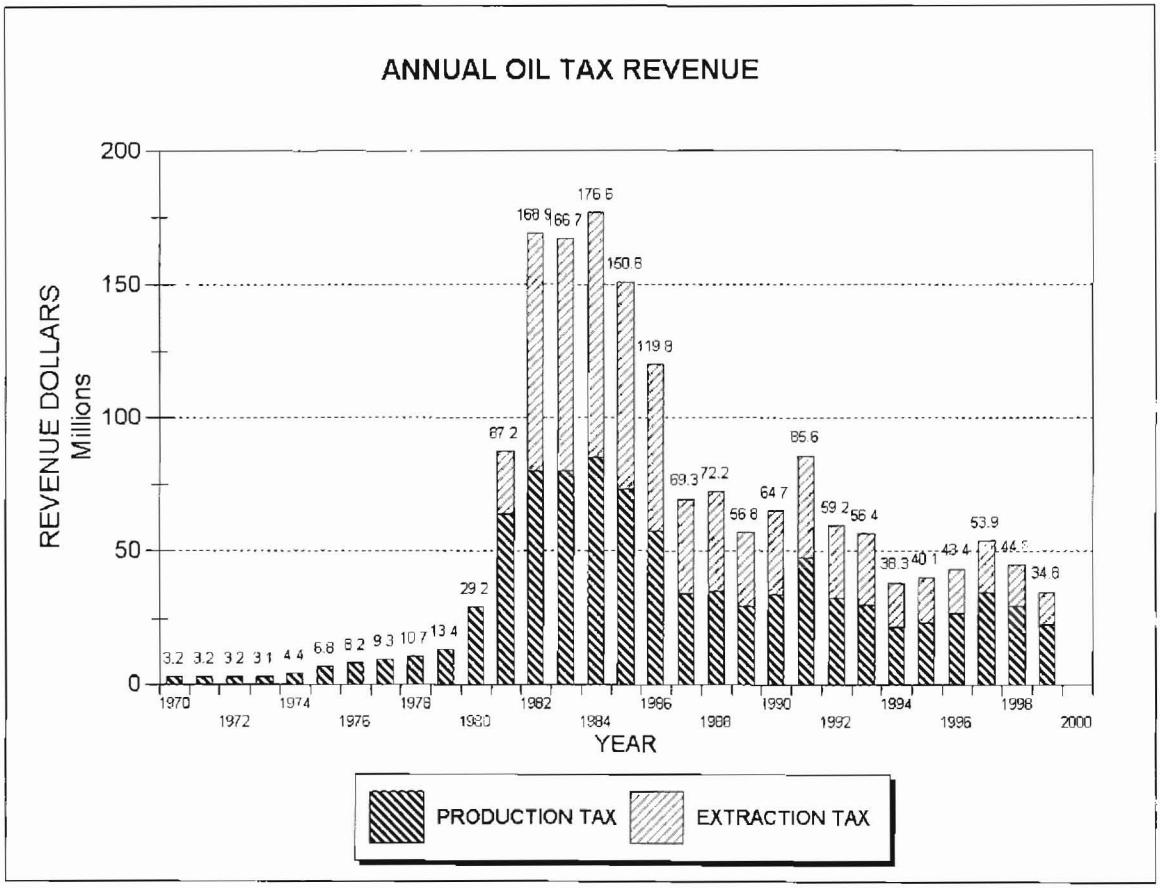

Figure 2. Bar diagram of annual production and extraction tax revenue from crude oil production for the period 1970 to 1999. The extraction tax took effect January 1, 1981. (Source N. D. State Tax commission).

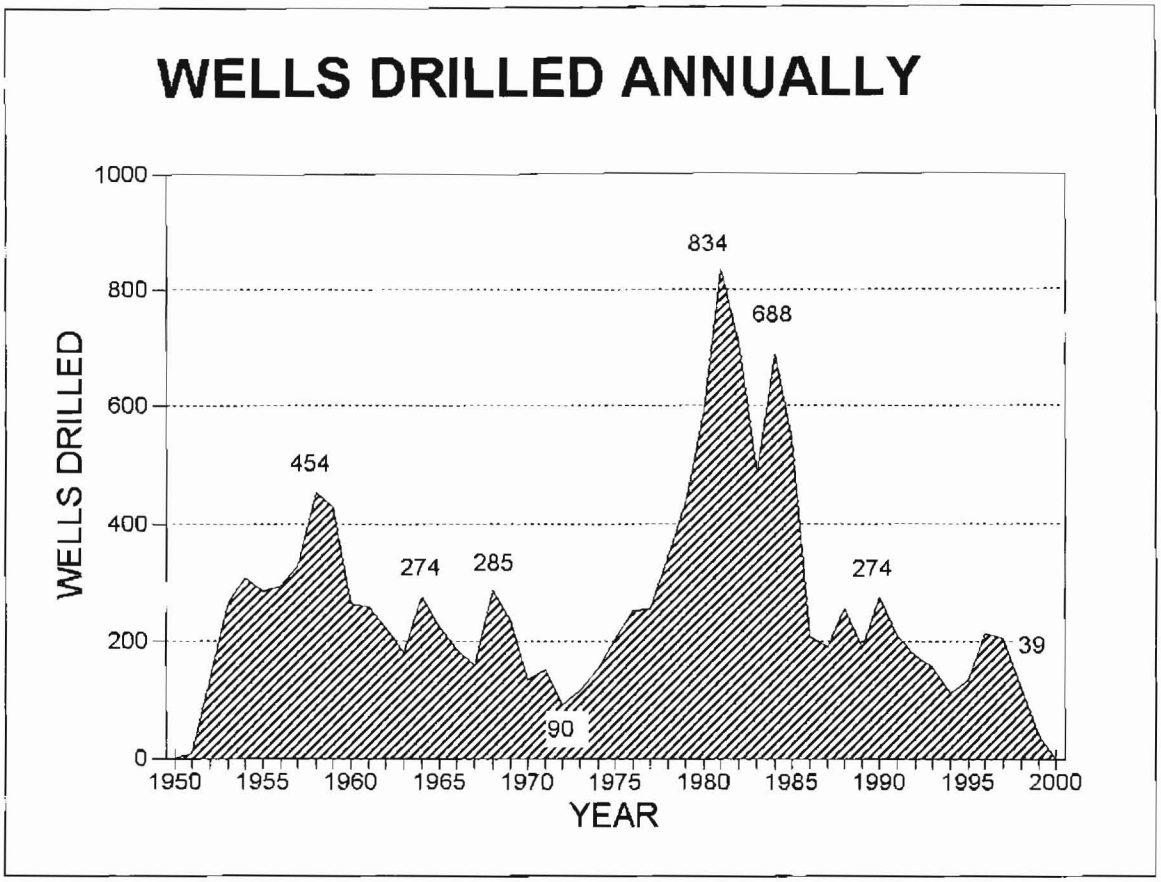

Figure 3. Line graph of the number of oil and gas wells drilled annually in North Dakota since 1951. (Source N. D. Geological Survey and N. D. Oil & Gas Division).

Horizontal drilling has become a major drilling method for the oil industry in North Dakota. Horizontal drilling in the Williston Basin began during 1987 when the first horizontal Bakken Shale wells were drilled in North Dakota and the first horizontal Madison wells were drilled in Saskatchewan. Horizontal drilling in these plays became commonplace during 1989. One result of the horizontal Bakken play was that state lease bonus revenue (Figure 1) jumped in 1989 as industry interest in the play continued to rise. Many state oil leases brought favorable per-acre bonuses at auctions during 1989 and 1990. In contrast, the U. S. Forest Service was unable to lease the Little Missouri National Grasslands (LMNG) at this time because of a court-imposed requirement for an environmental impact statement for the LMNG. As a result they lost both lease and production revenue that would have exceeded those of the State Land Department as the U. S. Forest Service had much more acreage in the Bakken play.

The 1980s ended with the North Dakota oil industry in the best shape it had been in for several years. Oil production and drilling were up with new plays to raise industry interest and horizontal drilling technology was becoming important in North Dakota. In addition, oil prices were up slightly, increasing the positive effects at the end of the decade.

1990-1999

Drilling

The 1990s began with many of the recently acquired leases in the horizontal Bakken Shale play being drilled as activity in the play peaked during 1990. The total number of wells drilled in the state rose significantly from 1989 to 1990, climbing 86 to a total 274 wells, the most wells drilled in any year since

1985 (Figure 3). Seventy-seven of those wells drilled were Bakken tests. During 1991, 48 Bakken tests were completed, while during 1992 and 1993, 30 and 24 Bakken tests were completed, respectively. Success rates for Bakken tests, as judged solely by a well being completed as a producing oil well, remained high. The success rate during 1991 was 97% and the success rates during both 1992 and 1993 were 100%. Despite the appearance of success by this one measure, many of these wells were economic failures because the volume of hydrocarbons recovered was not sufficient to pay for the drilling and completion costs.

The viable extent of the horizontal Bakken play was defined between 1990 and 1993 and two drawbacks to the play became apparent in this same period. First, many Bakken wells declined faster than expected, which meant that second, reserves were lower than expected. As a result, drilling activity decreased as companies re-evaluated the play. By 1994, the horizontal Bakken play was nearly over with only nine horizontal Bakken wells completed. In 1995, only three horizontal Bakken wells were completed, marking the end of the play.

A major factor in the 1990 drilling increase was Iraq's invasion of Kuwait in August 1990. World oil prices surged as uncertainties about the security of the Middle East oil supply rose. Oil prices in North Dakota also increased (Figure 8). Responding quickly to the price increase, oil companies nearly doubled the number of wells spudded each month in North Dakota (Figure 8). The rapid deployment of allied military forces during the fourth quarter of 1990 caused oil prices to fall and the number of wells spudded in North Dakota fell with the oil prices. The oil price fall began in late 1990 and continued into 1991, but remained $1 to $3 per barrel above the July 1990 price well into 1991. By late 1991, after Kuwait

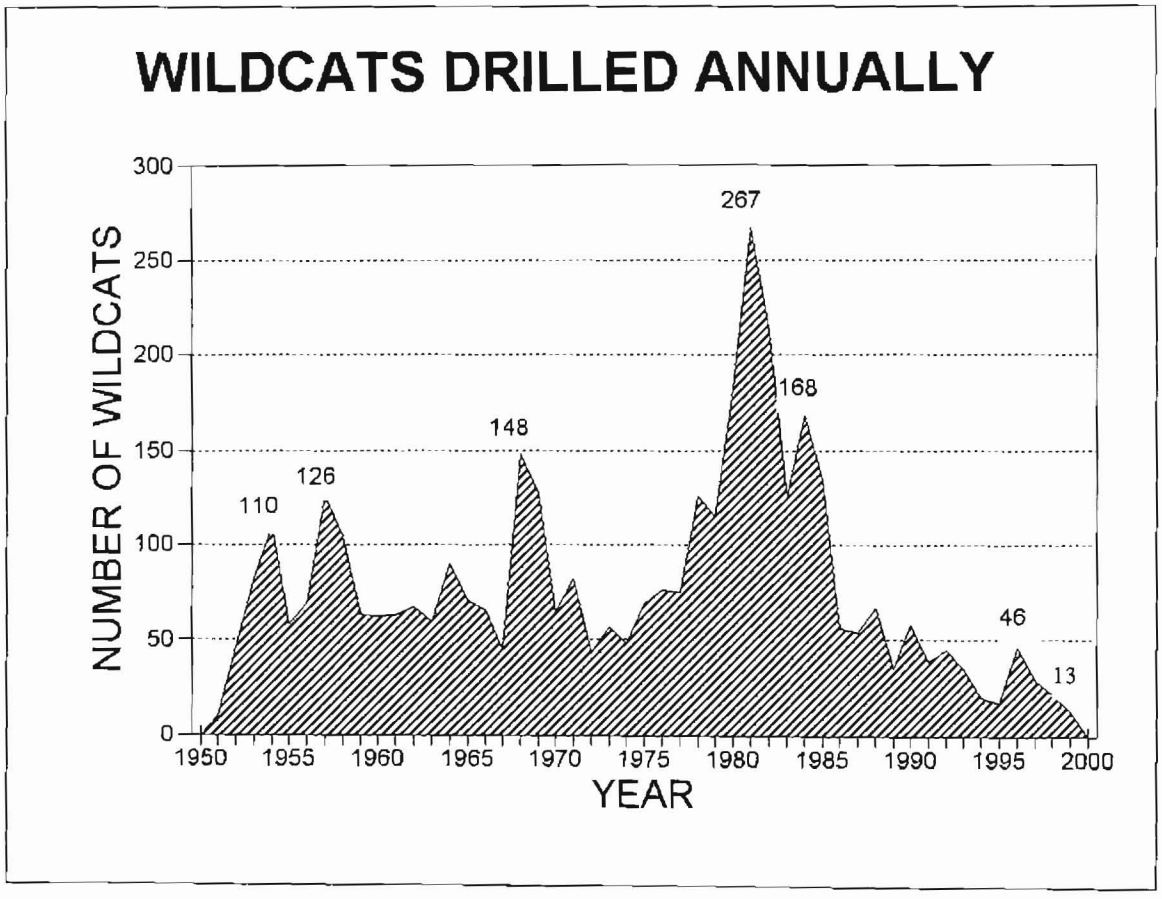

Figure 4. Line graph of the number of wildcat wells drilled annually in North Dakota since 1951. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).

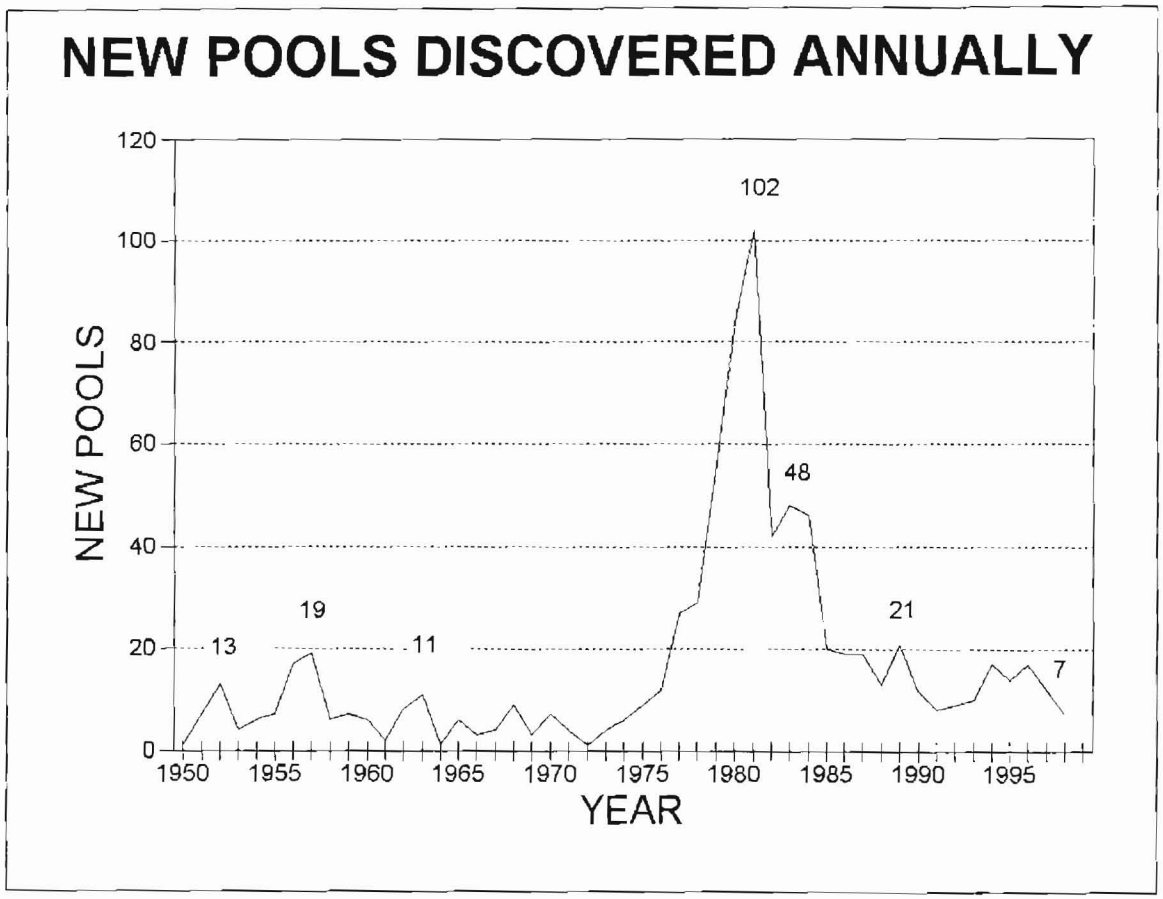

Figure 5. Line graph of the number of new oil and/or natural gas pools discovered annually since 1951. (Source: N. D. Geological Survey and N. D. Oil & Gas Division).

was liberated, prices had returned to pre-Gulf War levels.

Drilling activity during the 1990s generally decreased. From 1990 through 1994, the number of wells drilled annually in the state decreased from 274 to 111. A small increase occurred during 1995 and then rose to 212 and 202 during 1996 and 1997, respectively (Figure 3). The number of wells drilled then fell to 121 in 1998 and 39 in 1999 with the big oil price drop during this period. The 39 wells drilled in 1999 is the fewest wells drilled during a year since 1951, the year oil was discovered in North Dakota, when 10 were drilled. The 200-plus wells drilled per year during 1996-1998 were the result of activity in two new plays and one older play.

The first new play began when Conoco, Inc. discovered Waulsortian bioherms or Waulsortian-like mounds in the basal Lodgepole Formation while drilling a deep test in Dickinson Field during 1993 (Burke and Diehl, 1993). This well was the first economic Lodgepole production in North Dakota and the flow-rates of the discovery well, and subsequent wells, drew national attention. The last Lodgepole development wells were drilled during 1998. The hunt for similar mounds elsewhere in North Dakota continues, but unsuccessfully so far and only sporadically.

The second new play is the horizontal Red River B play in Bowman and Slope counties, North Dakota and in adjacent parts of Montana. The first horizontally drilled Red River well in North Dakota was completed in 1994 by Meridian Oil, Inc. (now Burlington Resources Oil & Gas Co.). Meridian Oil, Inc. (MOI) began the horizontal Bakken play during 1987 and drilled the first horizontal Red River B wells in Montana near East Lookout Butte Field on the Cedar Creek Anticline in 1988. The early horizontal Red

River B wells in Montana were disappointing, but the discovery of Bog Creek Field during 1994, later renamed Cedar Hills Field, sparked a large land play and widespread drilling.

Although the horizontal Red River B play did not immediately capture oil companies' attention as did the discovery of the first Lodgepole mound, it has proven to be economically attractive. By the end of 1999, 215 wells had been completed in Cedar Hills, Medicine Pole Hills, Cold Turkey Creek, and Horse Creek Red River B fields and the fields had produced 20,890,594 BO. Together the two plays have produced nearly 45,000,000 BO and averaged more than 23.6% of all the oil produced in the state during 1996-1999 (Figure 9). Ultimately, primary production from the Cedar Hills Field will probably exceed the total of primary and secondary production from all the presently known Lodgepole fields in Stark County. Whether it does or not, the two plays have been very large oil producers in North Dakota.

The old play being revitalized is the horizontal Madison play which is seeing continued drilling. Operators are drilling horizontally in those areas of North Dakota where they think their geologic criteria for a successful Madison well, whether those criteria are in an older field or in a new play or field, are met. The number of horizontal Madison wells drilled in North Dakota increased from 27 during 1997 to 32 during 1998 but dropped to 11 during 1999.

Wildcat drilling decreased from 58 wells during 1990 to 17 wells during 1995 (Figure 4), the fewest wildcat wells drilled in North Dakota since 1951 when oil was first discovered in the state. Wildcat drilling jumped to 46 in 1996 as the hunt for Lodgepole mounds peaked, but then dropped to 28 in 1997 when the play was not extended outside of the Dickinson area. Wildcat drilling during 1999 did not

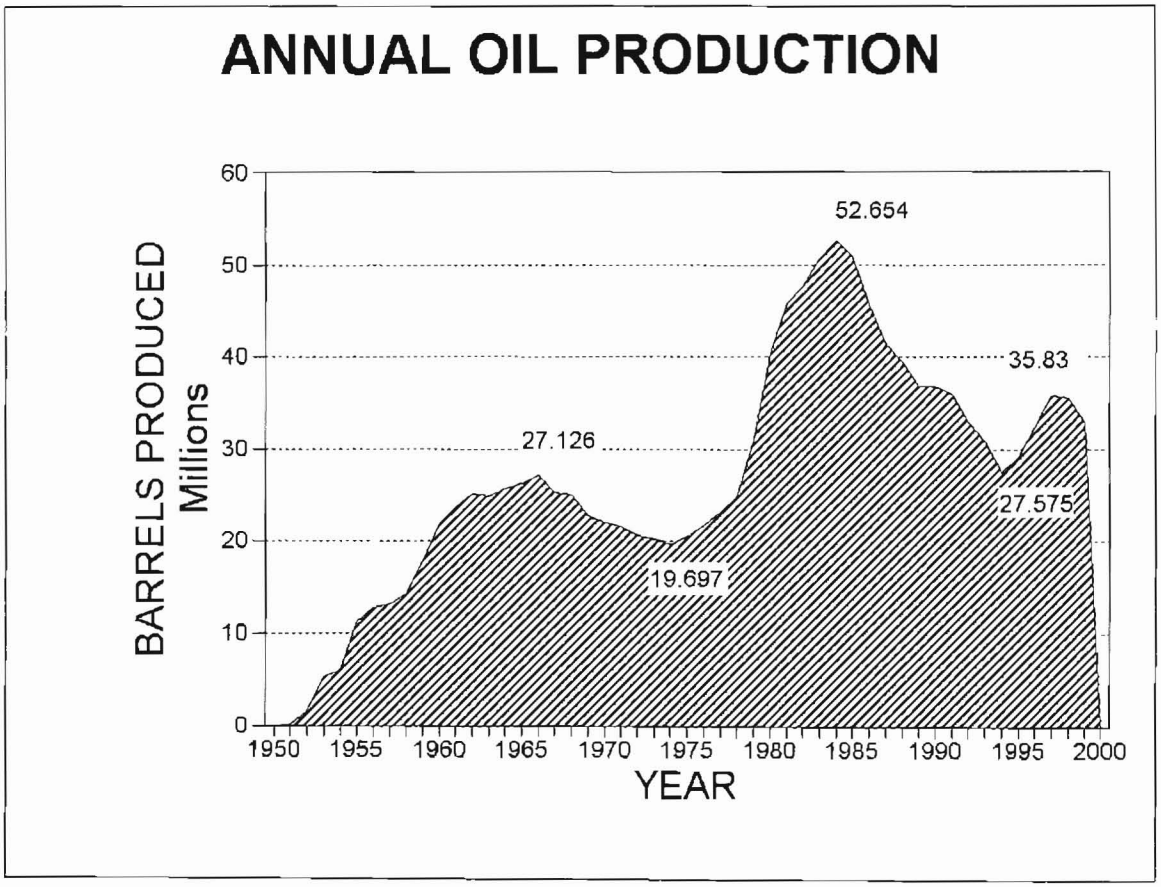

Figure 6. Line graph of annual oil production in North Dakota since 1951. Production is in millions of U. S. barrels. (Source N. D. Geological Survey and N. D. Oil & Gas Division).

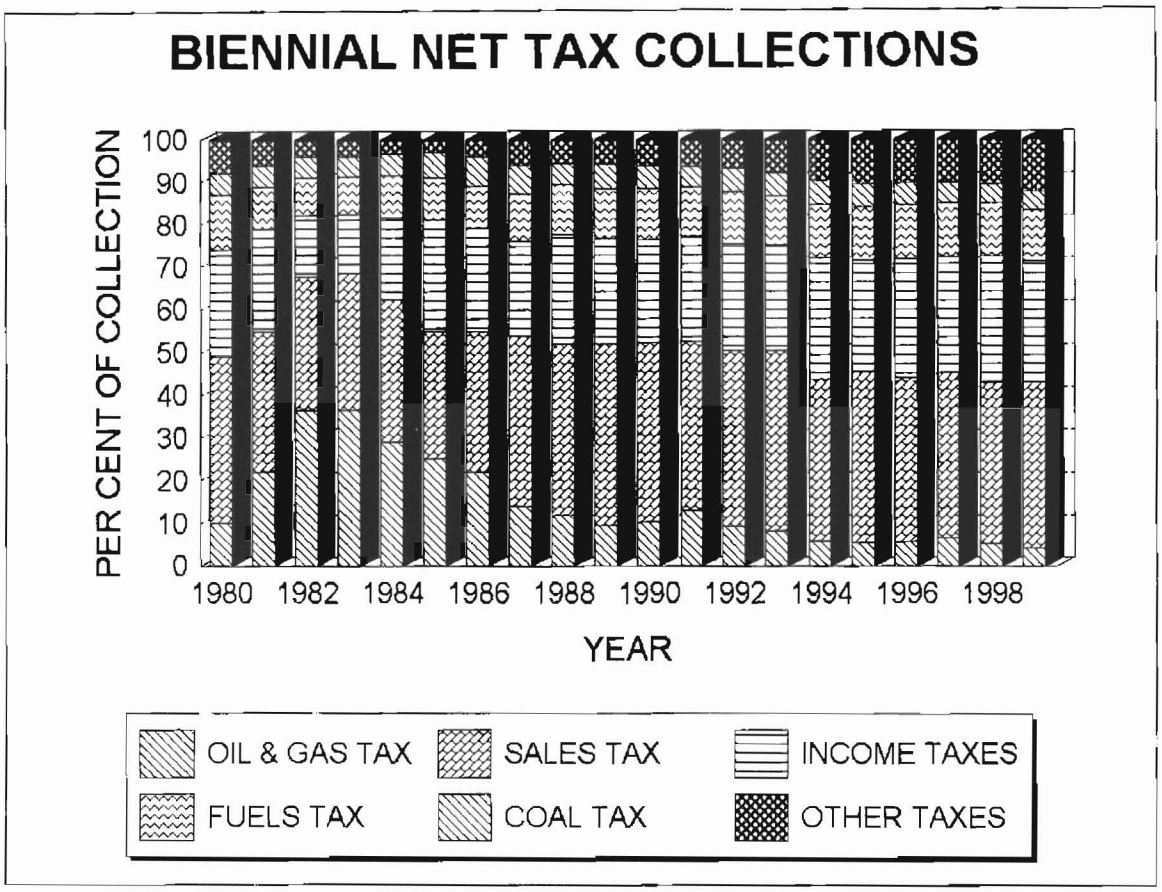

Figure 7. Bar diagram of the net tax collections in North Dakota since 1980. Source of tax collections are shown as a percentage of total collection. (Source N. D. State Tax Commission).

decrease as much as development drilling did. Twenty-two wildcat wells were drilled in 1998 and thirteen during 1999, replacing 1995 as the year with the fewest wildcat wells drilled since 1951. However, 33% of all the wells drilled during 1999 were wildcat wells. One possible explanation for such a high percentage of wildcat wells being drilled is that operators were still exploring for new fields in expectation of higher oil prices.

Oil Production

Annual oil production in North Dakota declined between five and 10 percent per year from 1985 through 1989. From 1989 to 1990, annual production remained virtually flat, declining only 21,057 barrels (.0005%) over the year (Figure 6). The fact that annual production did not decline between 1989 and 1990 was due to production from two new fields and wells completed in the horizontal Bakken play. Approximately 2.2 million BO were produced from Wabek and Plaza fields along the Sherwood and Bluell shorelines in Ward and Mountrail counties and another 2.7 million BO were produced from horizontal Bakken wells in western North Dakota. The 4.9 million BO that they produced canceled the production decline of the other 3,500 wells in the state.

Production declined a modest 2% to 35,895,278 BO in 1991 as new production was no longer able to stave off decline. During 1992, 1993, and 1994 production fell eight, six, and 11%, respectively (Figure 6). During 1995, oil from two new plays, the horizontal Red River and the Lodgepole mound plays, came on-line and annual production rose 1,758,147 BO, more than 6% above 1994 annual production. Annual production again rose during 1996 and 1997 to 35,832,705 BO. Part of the increase can be attributed to the number of wells completed in Cedar Hills Field, but as much oil came from the discovery

and subsequent unitization of the Lodgepole mound fields around Dickinson (Figure 9). During 1998, annual production was nearly flat at 35,562,201 BO, a 0.75% decrease from 1997, despite low oil prices. A much greater decrease occurred during 1999 when a 7.6% decrease was recorded and annual production fell to 32,874,867 BO. The annual percentage decline recorded during 1999 is close to the average decline recorded between 1992 and 1994. This decline rate appears to be typical of what should be expected in North Dakota over the next few years without some new production coming on-line.

Part of the 1999 decrease was due to low oil prices. Some wells were shut-in because operating costs exceeded earnings (Figure 10) at the low price. Once prices began to rise again, shut-in wells were put back on production. Amoco's average 1998 posted price for 40-gravity sweet crude was $10.47/ barrel, but during the first three months of 1999 it fell below $9/barrel. Some of North Dakota's crude oils received less than the average price because they are lower gravity crudes and/or are sour (contain sulfur). The net effect is that, in order for an operator to break even on a lower gravity or sour crude well, the well must produce more oil.

There are several ways declining annual oil production could be halted or reversed. The discovery and development of a single large oil field is one; another is to develop one or more new oil plays containing new fields; a third is to unitize sufficient oil fields with successful secondary recovery projects; or some combination of the three. Whatever the combination, there must be either a number of new, high IP and high EUR wells; many average new wells; or a large number of marginal wells completed to increase annual production. However, the capital requirements to drill and complete the required number of wells increases with each option making each more dependant upon higher oil prices.

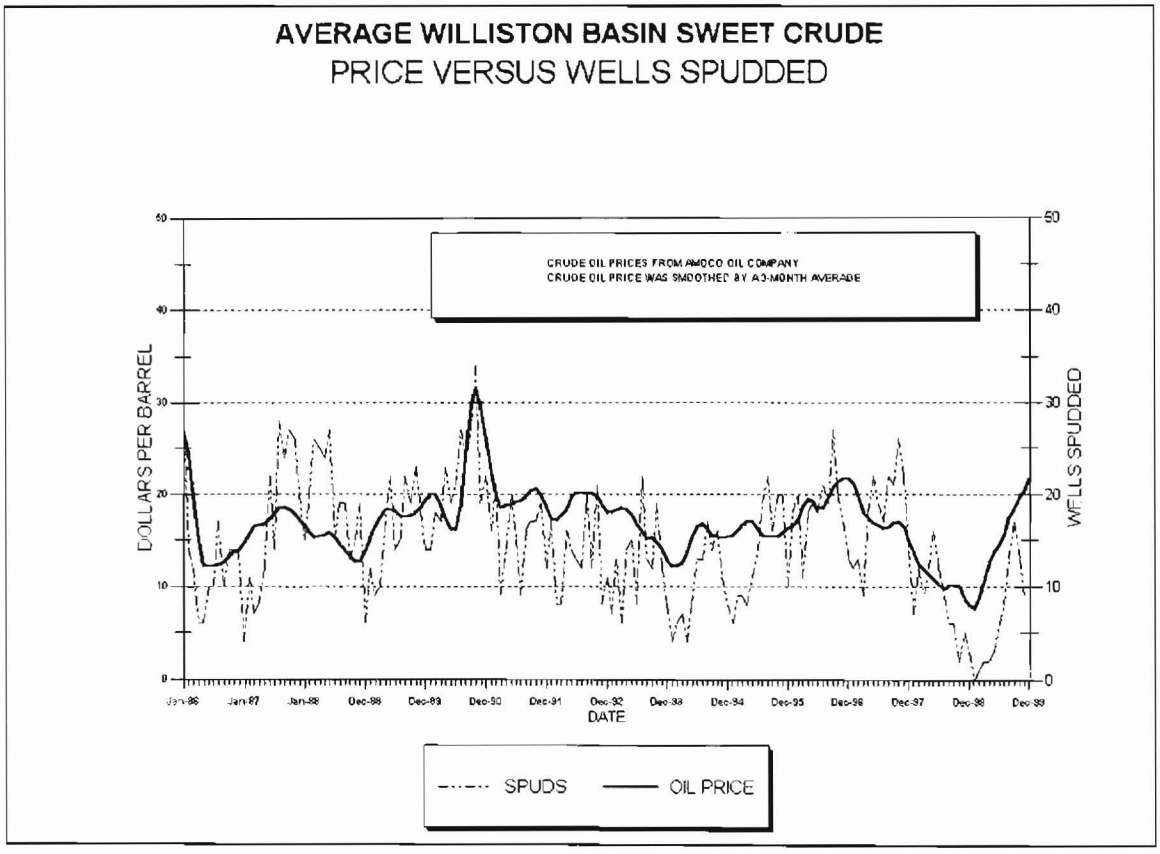

Figure 8. Line graph of the monthly average posted price for Williston Basin 40-gravity "sweet" crude oil and the number of wells spudded monthly since January 1, 1986. (Source: Oil prices are from Amoco Oil Company and wells spudded from the N. D. Oil & Gas Division).

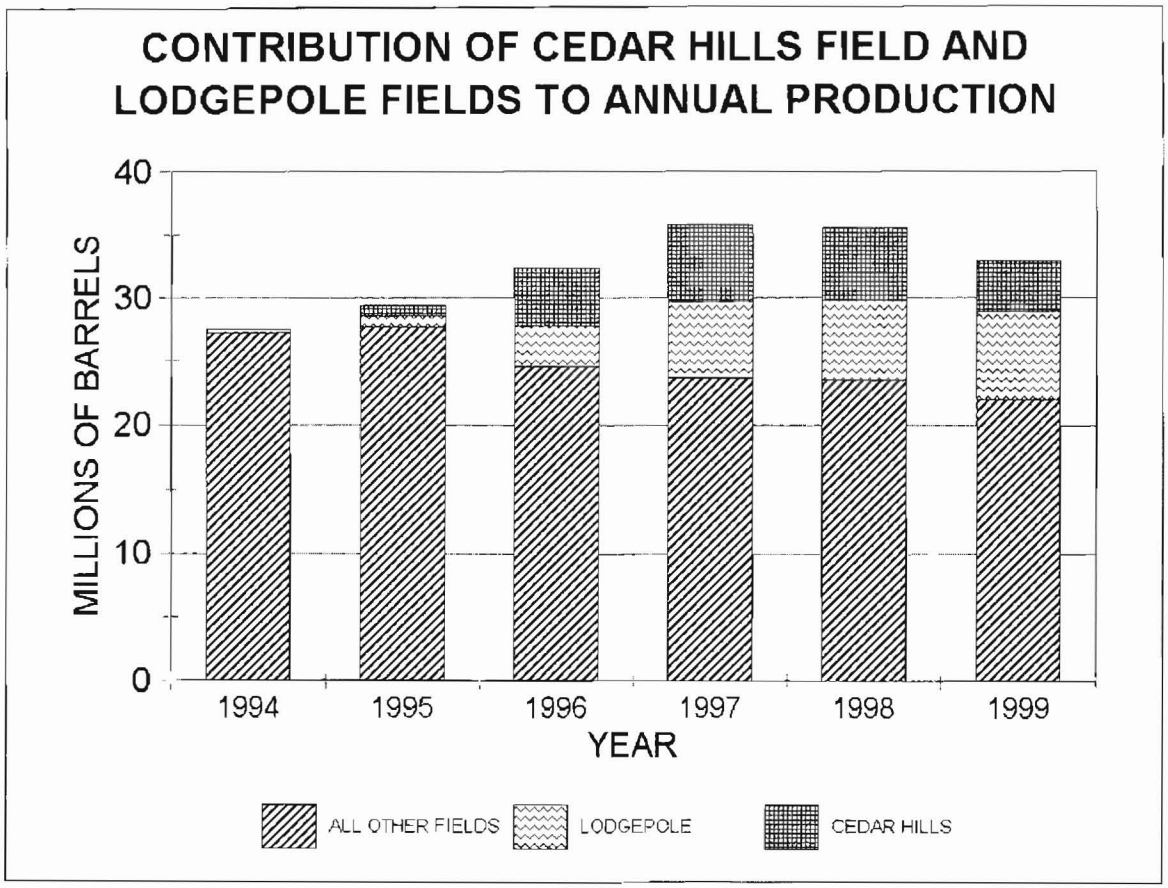

Figure 9. Bar diagram of the annual oil production from Cedar Hills Field, all known Lodgepole mound fields, and all other producing oil wells in North Dakota. (Source: N. D. Oil & Gas Division).

The 1991 North Dakota legislature encouraged the unitization of oil fields by enacting legislation that lowered the percentage of mineral and working interest owners required to form a unit. An increase in unitizations began in North Dakota during 1992 just when many oil fields were approaching the end of their primary productive life-spans. Legislation like this encourages companies to invest the capital necessary to unitize an oil field.

Unitizing more oil fields is an important tool in minimizing declining oil production in North Dakota. A successful secondary recovery project will produce the remaining primary reserves in an oil field at a higher rate than an equivalent non-unitized field, and then go on to produce additional barrels of secondary reserves that otherwise could not be produced. Units can be a cost-effective way of increasing production in existing oil fields. The number of units formed during 1998 was the same as in 1997 with four new units being formed, but only two were formed during 1999 (Figure 11). One of the 1998 units was a Lodgepole field as were both of the 1999 new units. These were the last ununitized Lodgepole fields to be unitized.

During the period covered by this report, Burlington Resources Oil & Gas Co. and Continental Resources, Inc. were attempting to unitize the Red River B reservoir in Cedar Hills Field, Bowman County. These efforts are continuing because a difference of opinion over which injection fluid will give the best results has delayed unitization. Burlington Resources favors a traditional waterflood while Continental Resources wants to use air-injection. Each company has shown example secondary recovery units employing their preferred recovery method that they maintain are both successful examples and proof that their proposed method is the best choice in Cedar Hills Field. The two

companies are the major working interest owners in the field and have been able to block the other because it is impossible to get the required minimum of 70% of the working interest owners to ratify any proposed unit without both companies agreeing to it. As things stand, unless one of the companies changes its mind, no unit can be formed. A deal to trade producing properties so the field could be split into two separate units where each company would operate its own unit independent of the other ended up in court and fell through. The result is that one of North Dakota's newest and largest oil fields cannot be unitized until the main operators in the field reach an agreement.

In an event related to unitization in North Dakota, Dakota Gasification Company completed its CO_2 pipeline to the Weyburn Midale Unit in southeastern Saskatchewan, the location of a CO_2 enhanced recovery project by PanCanadian Petroleum. Dakota Gasification completed a 200-mile pipeline that runs from its gasification plant near Beulah, ND to the oil field near Weyburn, Saskatchewan (Figure 12). The last weld on the pipeline was made on 12/1/1999 and the first CO_2 entered the pipeline on 9/14/2000. The pipeline route takes it past the oil fields on the Nesson Anticline, many of which have been unitized. Any CO_2 beyond the requirements at Weyburn Field could easily be supplied to units on the Nesson Anticline for enhanced recovery programs.

Another way to slow or possibly reverse declining annual production in North Dakota might be to drill horizontal wells in existing Madison Group fields. Horizontal drilling in Saskatchewan has significantly increased oil production in the province. Stalwick (1994) reported that between 1987, when the first horizontal Madison wells were drilled, and the end of 1992, a total of 452 horizontal wells had been drilled in the province. During 1997 alone, 461 horizontal wells were drilled in the Saskatchewan Williston Basin, the most in any year (Figure 13). From 1989 through 1999, 2,321 horizontal wells were drilled

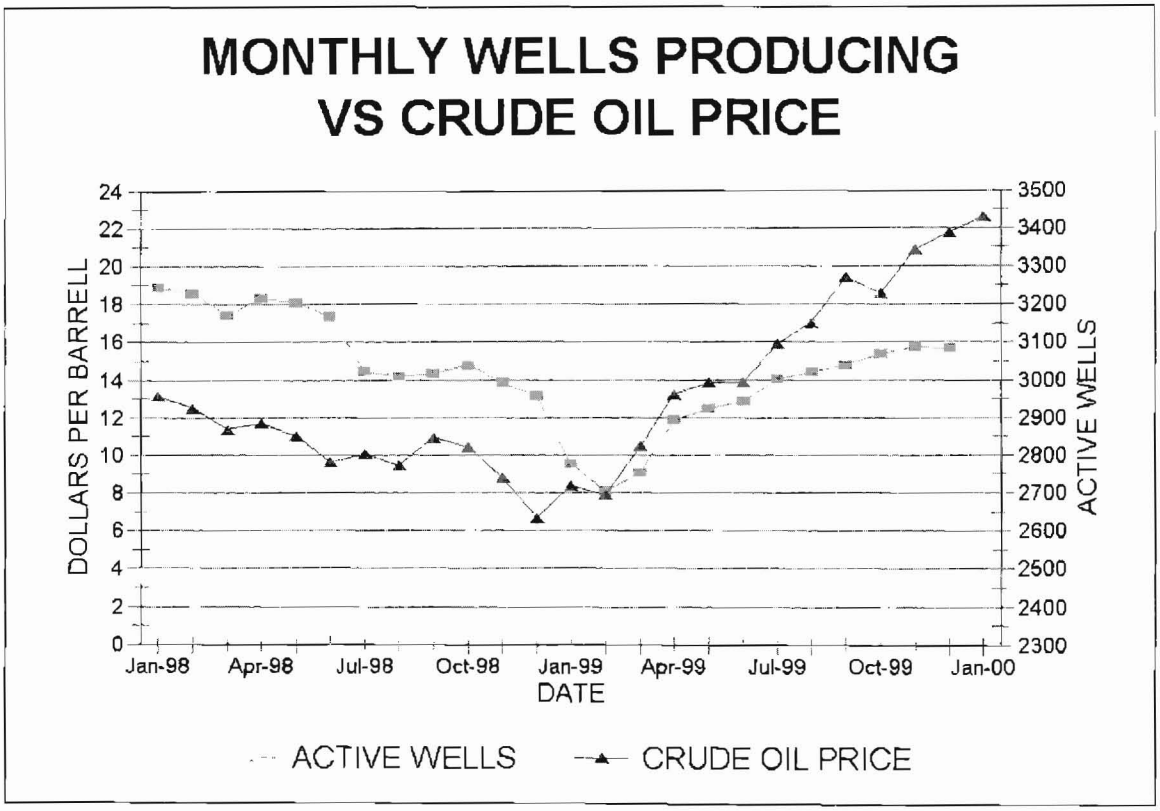

Figure 10. Line graph of monthly average price for Williston Basin 40-gravity "sweet" crude oil and the number of producing oil wells monthly for 1998 and 1999. (Source: Oil prices are from Amoco Oil Company and number of producing oil wells from the N. D. Oil & Gas Division).

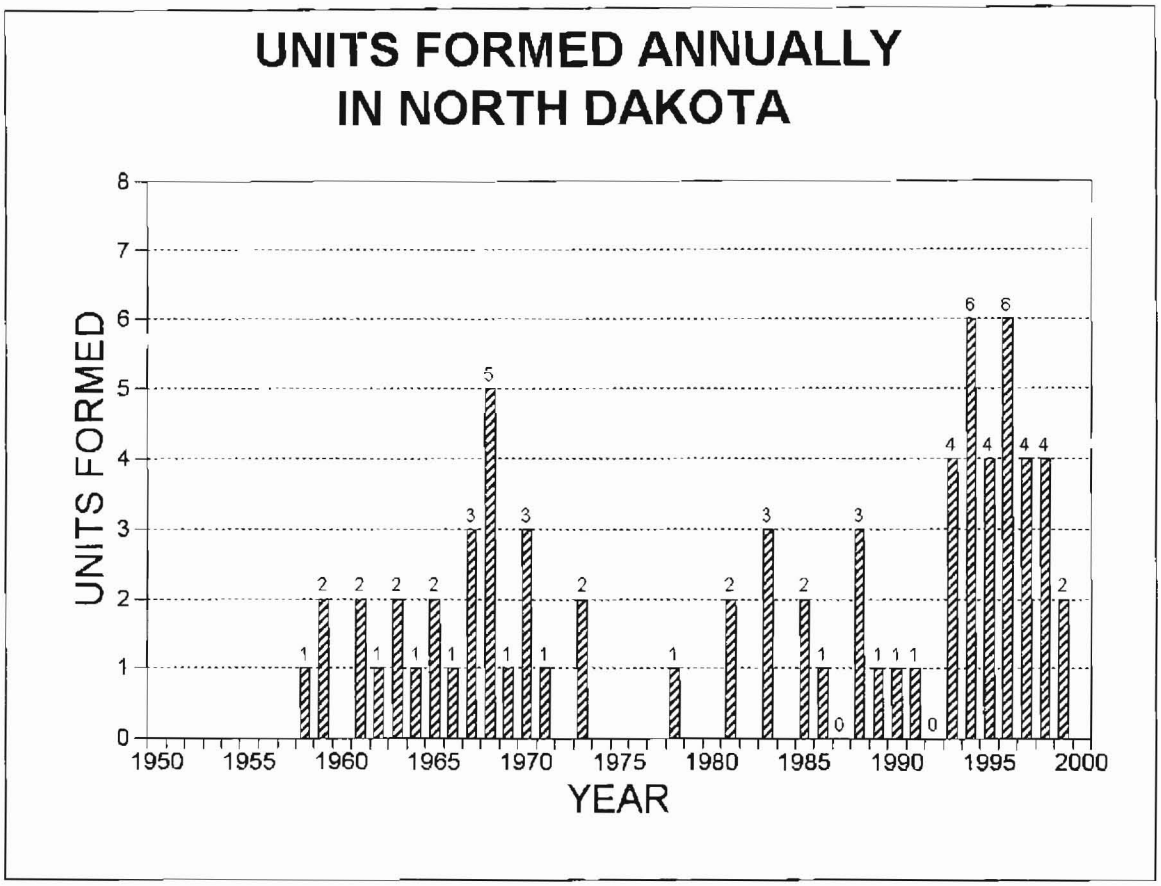

Figure 11. Bar diagram of the annual number of unitized oil fields since 1950. Units were included in the year in which operations began. (Source: N. D. Oil & Gas Division).

in the Saskatchewan Williston Basin. These wells contributed 56% of the year's oil production in Saskatchewan during 1999 (Figure 14). Horizontal wells have contributed so much oil that the province's oil production had increased for several years before beginning to decline again. It has been thought by many that a similar horizontal drilling program in North Dakota has the potential to dramatically increase the state's oil production, just as it did in Saskatchewan. It now appears that this may be beginning to take place.

A number of horizontal Madison wells have been re-entered and drilled-out horizontally both on the Nesson Anticline and elsewhere. In a recent study, decline curves from eight new or re-entered horizontal wells in Tioga Field were compared to decline curves from vertical wells close to the horizontal well bores. The study concluded that minimal interference occurs between the horizontal and vertical wells and that most of the produced oil was incremental reserves (Helms & Hicks,1999); the reserves of the eight horizontal wells was estimated to be 1,006,000 BO. The study also concluded that other horizontal wells in TR Madison, Wayne Madison, Cedar Creek Ordovician, and Haas Madison pools had also added incremental oil reserves. The report concluded that the 72 studied horizontal wells had added a total of 10,385,000 barrels of incremental oil in North Dakota. More horizontal wells are being drilled in older oil fields adding new reserves and increasing oil and natural gas production in the state.

At the end of 1999, thanks to some earlier important discoveries, North Dakota's oil industry was producing more oil than it had since the early 1990s. Drilling was minimal but focused on exploration drilling and, to a lesser extent, on horizontal drilling in older fields. The North Dakota oil-industry was not in good financial shape after the low oil prices of 1998 and early 1999, but the higher oil prices of late 1999

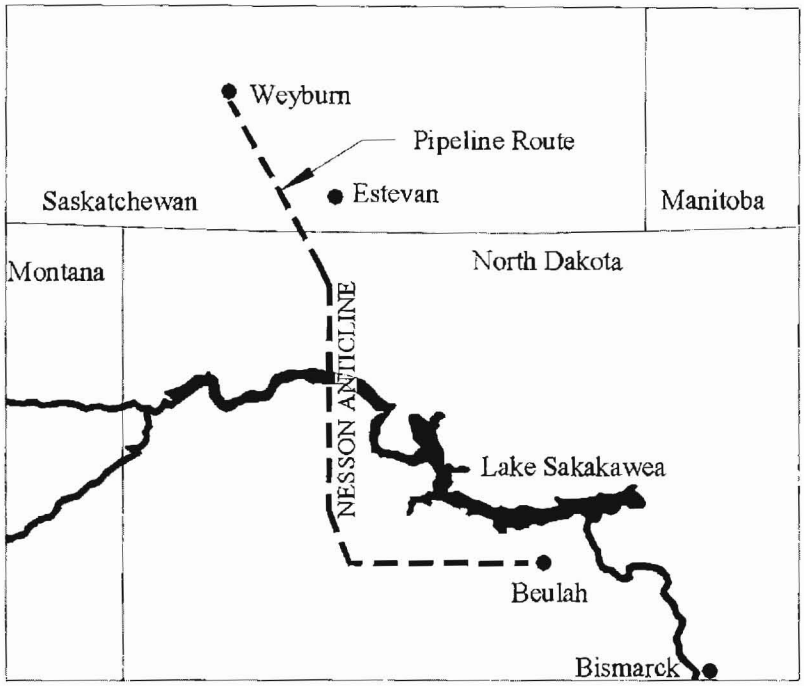

Figure 12. Map of the approximate route of Dakota Gasification Company's CO_2 pipeline from its origin at the gas plant near Beulah, ND to its terminus at Weyburn Field in Saskatchewan. (Source: Dakota Gasification Company).

were helping companies to recover.

Exploration Potential

The North Dakota Williston Basin is under-explored and many opportunities remain for finding large new oil fields and new plays. A study of the petroleum potential of the Little Missouri National Grasslands by Fischer, et al. (1991) estimated that at least 100 million barrels of oil equivalents remained undiscovered in McKenzie, Dunn, Billings, Golden Valley, Stark, and Slope counties. Some of this oil was discovered during the horizontal Bakken and the Lodgepole plays, but much of the potential resource in these area remains to be discovered. LeFever and Heck (1995) estimated that more than 800 million barrels of oil equivalents remained undiscovered in the productive portion of North Dakota. They suggested that Ordovician strata, like the Red River Formation, would contain the bulk of these resources. Cedar Hills Field will produce more than 40 million barrels during its primary production lifetime. This field is a very significant discovery in North Dakota as it will be one of the ten largest oil fields ever found in the state. In addition, it probably is one of the largest onshore oil fields discovered in the U.S. during the past five years. Bowman County, where the field was discovered, is an area where oil was first discovered more than 30 years ago. This discovery is proof that new concepts and technologies can lead to surprising results in mature areas. Similar opportunities may exist elsewhere in North Dakota.

HISTORICAL SUMMARY

From 1980-1985, records were set for oil prices, revenues, and numbers of wells drilled in North Dakota. In 1986, a major price drop caused drilling to plummet. Drilling remained in the 200-plus wells per year range during the late 1980s, but, with the exception if 1995 and 1996, steadily decreased after 1990 (Figure 3). It appears that if more than 175 wells are drilled during a year, it is because a large field or fields are being developed and/or a new play or plays are active. This is what happened during 1995

and 1996 when the Lodgepole play was active and Cedar Hills Field was being developed. If fewer than 175 wells are drilled then no significant plays or fields are being developed.

Annual oil production began to decline during 1983 as fields aged and uneconomic wells were plugged. In 1990, production from two important plays, the Sherwood shoreline and the horizontal Bakken Shale plays, temporarily stopped the decline. The effect, however, was short-lived and production declined again during 1991. Decline rates of 6% to 10% per year were recorded between 1992 and 1994. Annual production during 1995 rose more than 6% above1994 production as new wells in the Red River and Lodgepole plays were brought on-line. Annual production rose another 10% during 1996 and 11% during 1997 as Cedar Hills Field was further developed and most of the Lodgepole fields were unitized and producing at optimal rates (Figure 9). 1998 production was virtually the same as in 1997, declining less than 1%, but annual production declined by 7.6% in 1999 as the earlier increases of the Lodgepole and Cedar Hills discoveries were overcome by normal decline. However, voluntary production restrictions in the Cedar Hills Field and the number of wells shut-in exaggerated the 1999 decline.

1998

Statistics

One hundred and seventeen new wells were completed in North Dakota during 1998, a 42% decrease from 1997 (Figure 3). Twenty-two wells were wildcats and the other 95 were development or extension wells. Twelve new pools were discovered, a decrease of five from the 17 discovered during 1997. The 1998 new-pool discoveries are summarized in Appendix I. Those discoveries that were both new-field and new-pool discoveries are located on Figure 15. Divide and McKenzie counties each had three new pools discovered during 1998 (Table 2). Two new pools discovered in Golden Valley County while Bowman, Burke, Mountrail and Williams counties each had one new pool.

Table 2
1998 and 1999 New Pool and Field Discoveries
(Listed by County and Formation)

	1998	1999
Bowman County		
Total	1	0
West Red River	1	0
Billings County		
Total	0	1
Tyler	0	1
Burke County		
Total	1	1
Midale/Nesson	1	0
Red River	0	1
Divide County		
Total	3	2
Duperow	0	1
Madison	1	0
Red River	1	0
Silurian	1	0
Souris River	0	1
Golden Valley		
Total	2	0
Duperow	1	0
Silurian	1	1
McKenzie County		
Total	3	1
Duperow	1	1
Red River	1	0
Winnipeg/Deadwood	1	0
Mountrail County		
Total	1	0
Madison	1	0
Williams County		
Total	1	2
Duperow	1	1
Ratcliffe	0	1

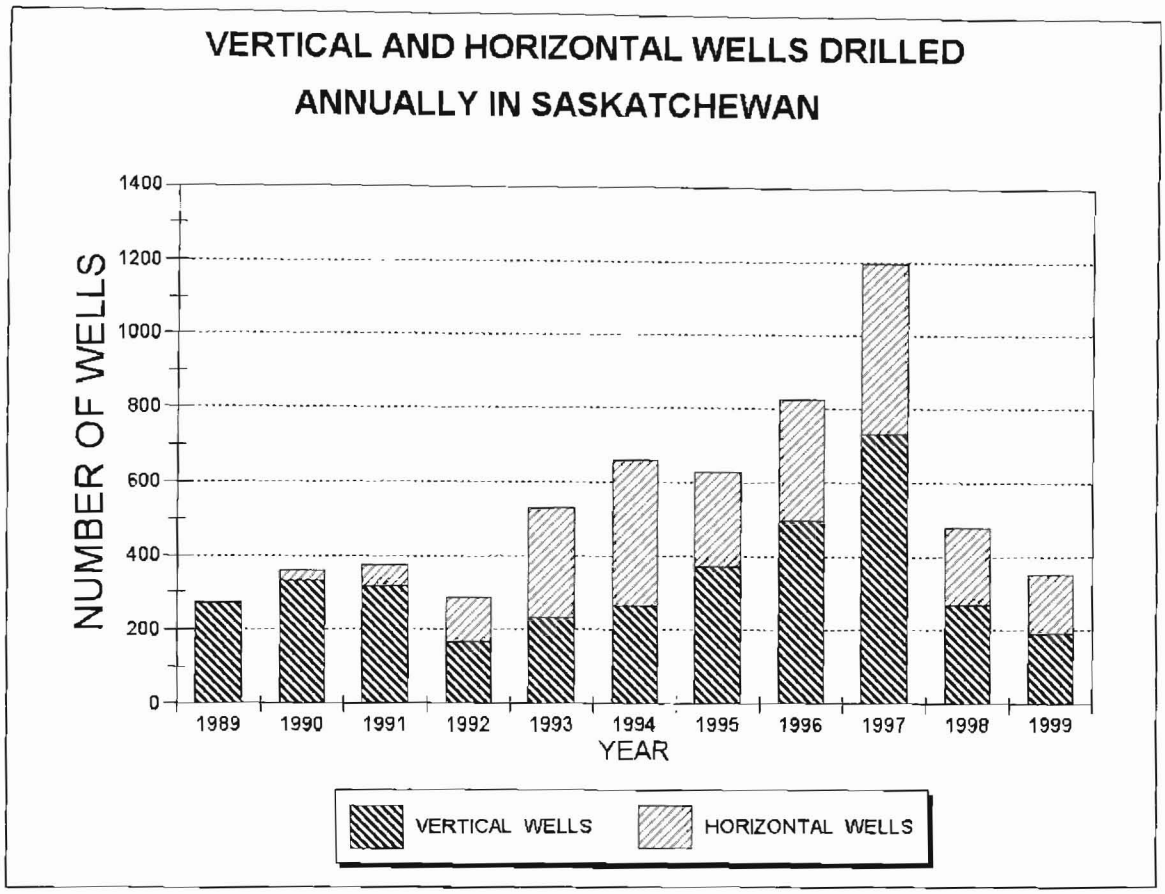

Figure 13. Bar diagram of the number of horizontal and vertical wells drilled annually in the Saskatchewan Williston Basin since 1989. (Source: Saskatchewan Energy and Mines).

The twenty-two wildcats drilled during 1998 is 76% of 1997s twenty-nine wildcats. Seven of the twenty-two 1998 wildcats were completed for a 32% success rate. This is a high wildcat success rate. Several of the tests were attempts to extend the Lodgepole mound play into western Dunn and eastern Mercer counties but they were dry. Several other wildcats were drilled in Divide County, which had not seen much drilling for several years, and one new field was discovered there.

Drilling

Drilling in North Dakota during 1998 was dominated by horizontal drilling with 65 of the 121 (54%) wells completed during the year being drilled horizontally. The two parts of the state where most of the horizontal wells were drilled were Bowman and Burke counties. Of the two, Bowman County the main one because horizontal development drilling in Cedar Hills Field continued. Thirty-one wells were completed in Cedar Hills Field during 1998. The wells had an average initial potential (IP) of 237 BO + 59 MCF + 196 BWPD. Seven of the 31 wells were later administratively moved into the Medicine Pole Hills West unit. Elsewhere in Bowman County, two wells were completed in Grand River Field and one in each of Horse Creek and State Line fields. Three of the four wells were drilled as vertical wells. One of the Grand River Field tests was a dry hole, but the other had an IP of 256 BO + 129 MCF + 1 BWPD. The Horse Creek and State Line field wells were both low-IP wells, averaging only 10 BO + 30 MCF + 147 BWPD. The Horse Creek test was drilled horizontally.

Another area where horizontal drilling dominated was Burlington Resources Oil & Gas Company's Midale/Nesson play in Burke County where, during 1997, Customs and Carter fields had been discovered. Seven Midale/Nesson pool development wells were completed in Customs Field

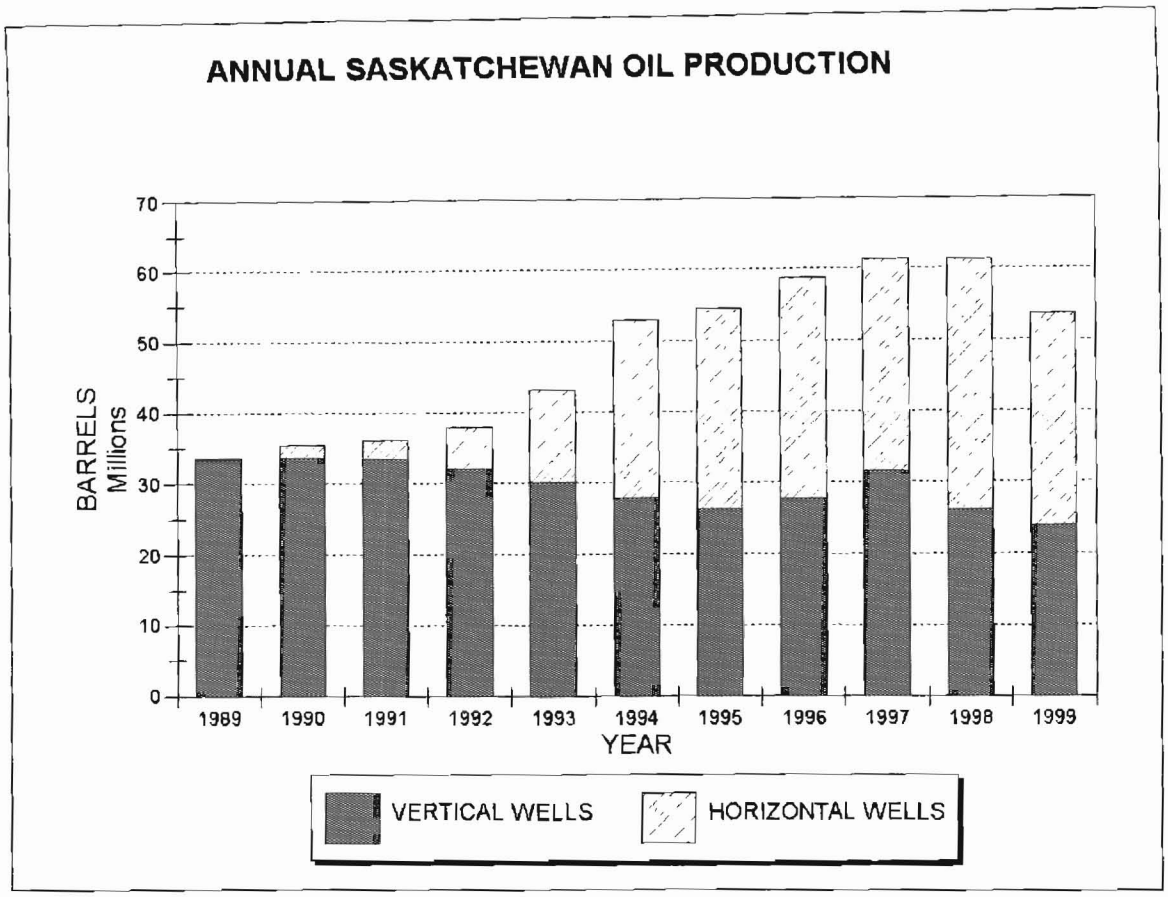

Figure 14. Bar diagram of annual oil production from vertical and horizontal wells in the Saskatchewan Williston Basin. Production has been converted from cubic meters to U. S. barrels (Source: Saskatchewan Energy and Mines).

during 1998 with an average IP of 264 BO + 199 MCF + 210 BWPD. Four more wells were completed in Carter Field, making the total six wells, with an average IP of 484 BO + 433 MCF + 219 BWPD. In contrast to the horizontal wells in Cedar Hills Field, which were usually drilled with a single lateral, most of the Burke County wells were drilled with multiple laterals in a pattern resembling a birds foot (Figure 16). Elsewhere in the county, a 1998 wildcat discovered a Lakeside Field located one township east of Customs Field. The Burlington Resources Oil & Gas Co. Knudson #11-21H, located in section 21-T160N-R89W, had an IP of 522 BO + 487 MCF + 115 BWPD. Unfortunately, the wells in these three fields have not held up as well as hoped. The average daily production, taken from the August, 2000 Oil & Gas Division monthly production report, was 22 BO + 54 MCF + 74 BWPD for five wells in Carter Field, 20 BO + 64 MCF + 32 BWPD from nine wells in Customs Field, and 62 BO + 111 MCF + 49 BWPD for the Knudson #11-21H in Lakeside Field.

In addition to the Midale/Nesson play, two other horizontal wells were drilled in Burke County. CamWest Limited Partnership completed the #25H2 and #25H3 in the Rival Madison Unit for an average IP of 97 BO + 100 MCF + 938 BWPD. The wells were located in section 25-T163N-R92W. Production from the wells has declined significantly since their initial completion averaging only 45 BO + 32 MCF + 602 BWPD at the end of 1999 and their combined oil production through 1999 was 43,919 BO.

Two horizontal Madison wells were drilled on the Nesson Anticline in the Beaver Lodge Madison Unit with an average IP of 162 BO + 764MCF + 1478 BWPD. Elsewhere on the anticline, one horizontal Madison well was drilled in each of Clear Creek, Tioga, and Camel Butte fields. Their average IP was 122 BO + 596MCF + 940 BWPD. If all these horizontal Madison wells added incremental reserves, as

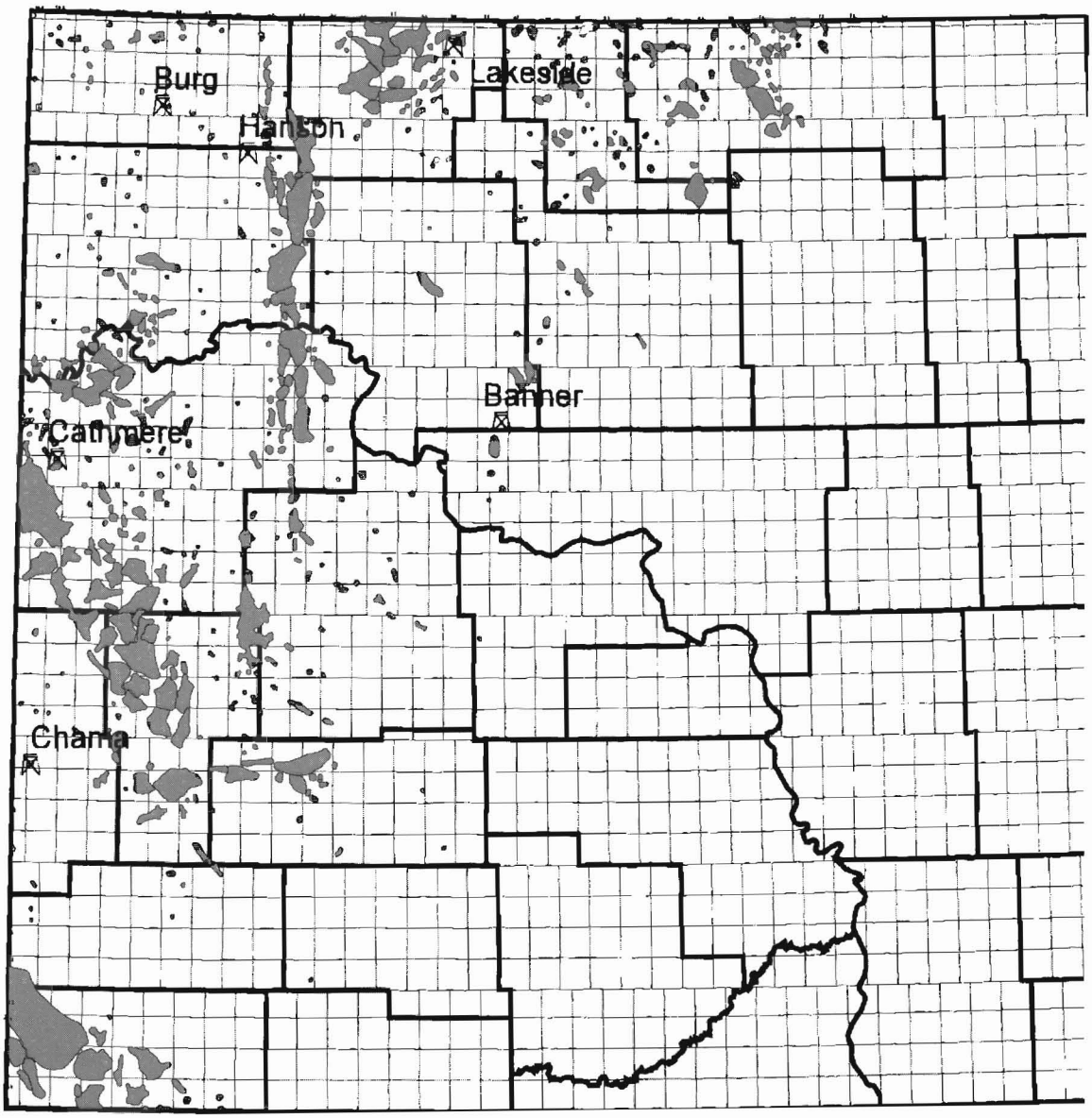

Figure 15. Map of western North Dakota with the location of all known producing wells and all 1998 new field discoveries.

might be thought after reading Helms & Hicks (1997), then a large reserves base may remain in Nesson Anticline oil fields despite nearly 50 years of production.

One or more horizontal wells were drilled in a number of other Madison pools across western North Dakota. The most successful appear to be wells completed in Wayne and Stockyard Creek fields. The Wayne Field well was the Geo Resources, Inc. Oscar Fossum #H4. This well, located in section 31-T162N-R81W, had an IP of 279 BO + 241 BWPD. At the end of 1999 the well had produced 69,438 BO and was still producing 53 BOPD. The Stockyard Creek well was the Ocean Energy, Inc. Boss #12-17, located in section 17-T154N-R99W with an IP of 228 BO + 10 BWPD. By the end of 1999 the wells had produced 73,970 BO, 78,5515 MCF and only 8,034 BW. The Boss #12-17 was still producing 78 BO + 89 MCF + 13 BWPD. Given the low oil prices of 1998 and early 1999, these wells will not be as profitable as they would have been if oil prices had been closer to what they are now.

Although over half of the wells drilled during 1998 were horizontal wells, a number of the highest

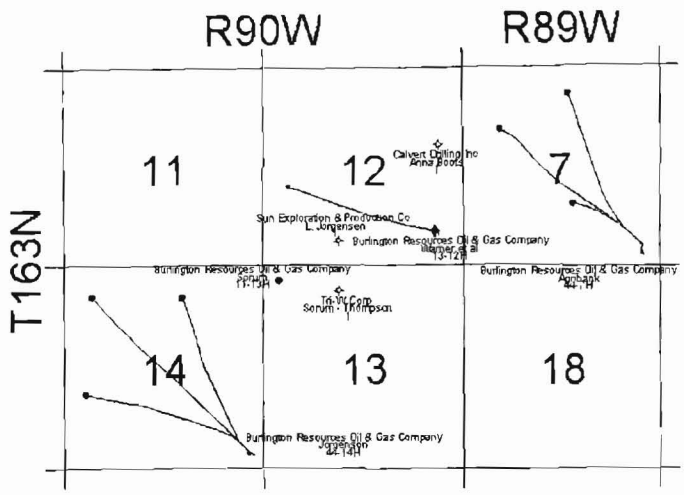

Figure 16. Well plat of several horizontal boreholes in Lakeside Field, Burke County on which the birds foot pattern of the horizontal borehole legs is shown.

IP wells were drilled vertically, as were most of the new field/pool discoveries. The Chama Field Silurian pool was discovered by the Best Pacific Resources (U. S.) #41-31 Mertz. The well, located in section 31-T140N-R105W, had an IP of 319 BOPD. Unfortunately the well did not live up to the promise of its IP. By the end of 1999 the well had produced 29,614 BO but was producing 27 BO + 180 BWPD.

A new pool was discovered by the Summit Resources, Inc. #42-26R Williamson Federal in section 26-T143N-R103W. The well had produced from the Red River Formation but was recompleted in the Duperow Formation at an IP of 298 BO + 325 MCF + 73 BWPD. The new Duperow completion had produced 61,011 BO by the end of 1999 and was still producing 72 BOPD.

A third well, the Lyco Operating Corp. #25-2 Plumer-Lundquist, discovered a new field and two new pools during 1998. The well, located in section 25-T161N-R99W, was initially completed in the Red River Formation producing 102 BO + 94 MCF + 7 BWPD. After producing 10,012 BO in four months, the zone was abandoned and the well was recompleted in the Silurian pumping 225 BO + 39 MCFPD. By the end of 1999 the well had produced 48,414 BO, 12,162 MCF, and 67,717 BW from the Silurian and was still producing 29 BOPD.

Banner Field was discovered by Alenco Oil & Gas (ND), Inc. at their Alenco Nordquist 151-89-23 #DCB test. The well is located in section 23-T151N-R89W and had an IP of 250 BO + 12 BWPD from the Bluell beds. The well has produced 36,079 BO through the end of 1999 and was still producing 61 BOPD at that time. However, several nearby dry holes raise a question about the areal extent of the new field. How large is it?

Another new-field discovery was made in section 5-T149N-R103W by Flying J Oil & Gas, Inc. Their Cathmere Field discovery well, the Federal #9-5, had an IP of 292 BO + 292 MCF + 12 BWPD. Since its discovery, the well has produced 57,398 BO + 67,096 MCF and was still producing 104 BO + 128 MCFPD at the end of 1999. Despite being a good producing well the Federal #9-5 has not yet been offset. From the field's 320-acre spacing and a field boundary that includes only one half-section it appears to be a one-well Red River field.

Two new Duperow wells were completed in Bear Creek Unit by Berco Resources LLC. The #3-1 Bear Creek Unit was completed for 820 BO + 216 MCF + 97 BWPD while the #27-1 Bear Creek Unit

was completed for 1,076 BO + 328 MCF + 147 BWPD. At the end of 1999 the two wells had already produced 180,928 and 292,500 BO, respectively. The wells were apparently drilled to fill gaps in the units well pattern and capture oil trapped there by the waterflood.

In McKenzie County two producing wells were added to Boxcar Butte Field by Devon Energy Production Company. The #2 J. W. Law was completed with an IP of 585 BO + 1,000 MCF + 10 BWPD and the #12-15 Federal had an IP of 231 BO + 1,371 MCF + 75 BWPD. The wells have produced 53,651 BO + 441,266 MCF and 15,440 BO + 99,264MCF, respectively. These two wells extended the field to the east and more wells are planned.

Two wells were completed in the Birdbear pool in Beaver Creek Field, a 1997 new-pool discovery. The first well, the Westport Oil & Gas, Inc. #24-15 Beaver Creek, was completed for 155 BO + 185 MCFPD. The second well was a recompletion in the Samson Resources Co. #32-22 Amerada Federal that had an IP of 641 BO + 500 MCFPD. Both new wells and the 1997 discovery well are located along the northwest end of the field. Through the end of 1999, the two 1998 completions had produced 292,263 and 556,330 BO, respectively. These are exceptionally good wells.

Burlington Resources Oil & Gas Co. re-established production in the Flat Top Butte Red River pool with the completion of their #43-14 Stensrud. Four other earlier wells had produced from the Red River, but all had been plugged and abandoned. Burlington's new well had an IP of 336 BO + 650 MCF + 60 BWPD and it produced 88,317 BO + 133,328 MCF + 14,106 BW through the end of 1999. At that time, the Stensrud was still producing 66 BO + 134 MCF + 16 BWPD. The volumes of hydrocarbons produced, together with the relatively small volume of water, make this a very good well.

On the Nesson Anticline Amerada Hess completed a new Winnipeg/Deadwood pool discovery in Charlson Field at their #6-32 Thompson. The well is located in section 6-T153N-R95W and was completed flowing 631 MCF + 2 BWPD. The lack of any oil production with the gas is unusual in North Dakota as most wells are not dry gas wells. Instead, gas in North Dakota is usually associated with oil production. There is no gas production reported before May, 1999, but the well produced 97,956 MCF in eight months and was still producing 321 MCF + 5 BWPD at the end of the year. However, despite relatively high natural gas prices, the well will probably not be economic as flow rates are too low. However, the well does prove that the deeper Winnipeg/Deadwood horizons on the Nesson Anticline are productive in Charlson Field and is a hint that it may be possible to produce economic volumes of hydrocarbons at other locations.

One of the year's disappointing projects was the of six wells drilled in the Antler Midale Unit. Two of the wells were completed as water injection wells and the other four had an average IP of 21 BOPD. The four wells have together produced only 8,259 BO by the end of 1999.

1999

Statistics

During 1999 fewer wells were completed than in any year since 1951. In fact, North Dakota is fortunate that oil prices rose during the second half of 1999 or even fewer wells would have been completed. In total, thirty-nine wells were completed, thirteen wildcat wells and twenty-six development or extension wells. Four of the thirteen wildcat wells were completed producing either oil or gas as were twenty of 26 other wells, success rates of 31% and 77%, respectively. The 33% figure for wildcat wells completed is not typical. Only during thirteen of the 48 years since the discovery of oil in North Dakota has the percentage of wildcat wells been higher but, from a different perspective, the percentage is only 3% greater than the annual average of 30% over those same 48 years.

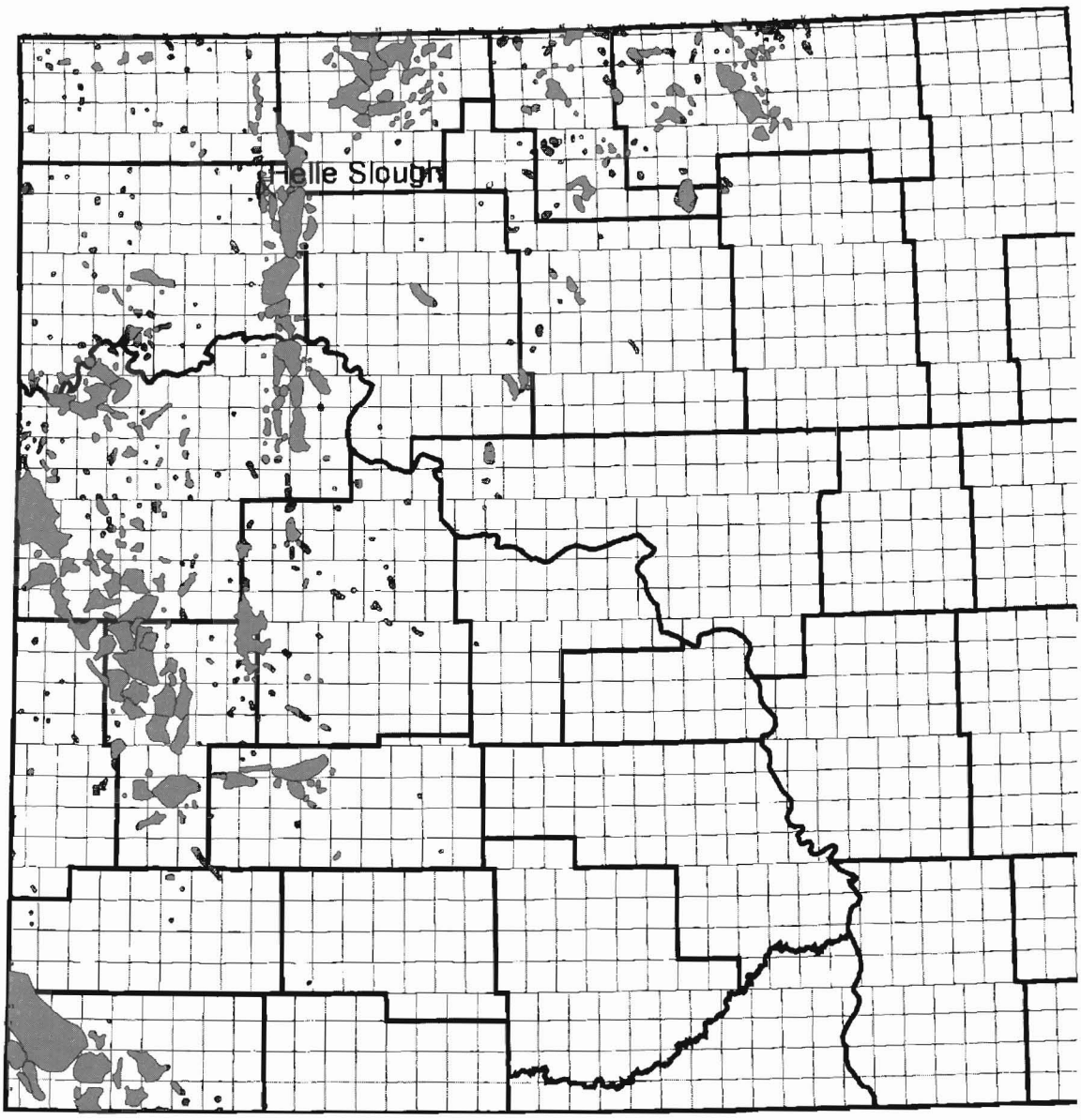

Figure 17. Map of western North Dakota with the location of all known producing wells and all 1999 new field discoveries.

The total of 39 wells completed during 1999 is 78 fewer, or one-third of the 117 completed during 1998. The thirteen wildcats completed were 16 less, or 45% of the 29 completed during 1998. Seven new fields or pools were discovered during the year and the new pool discoveries are summarized in Appendix II.

The northwest corner of the state saw the most new pool discoveries with two new pool discoveries in both Divide and Williams counties and one in each of Burke and McKenzie counties. One other new-pool discovery was made to the southeast in Billings County. The location of the only discovery that was both a new field and new pool, Helle Slough Field, is shown on Figure 17.

Drilling

Drilling was at a record low level during 1999 due to the low oil prices of 1998 and early 1999. Only thirty-nine new wells were completed, the fewest since 1951 when oil was discovered in North Dakota.

Horizontal drilling was still common but the percentage of wells being drilled horizontally dropped below 50% to 36% (fourteen of thirty-nine wells). With such a low level of drilling there were relatively few good wells during the year but some are interesting. Helle Slough Field was discovered by Prospect Oil & Gas, Inc. in section 31-T159N-R95W. The well, which is located on the Nesson Anticline, was drilled horizontally in the Ratcliffe beds. It appears that Prospect Oil & Gas believed that oil could be effectively produced from the high porosity, but low permeability, Ratcliffe reservoir by a horizontal well. The discovery well, the #1 Gohrick, was completed in May, 1999 producing 279 BO + 150 MCF + 83 BWPD. In eight months of production the well produced 24,419 BO but the daily oil production had fallen to 66 BOPD. Prospect Oil & Gas later drilled an offset well in section 32, the #1-32H Gohrick. This well had an IP of 81 BO + 160 BWPD but in the three months of 1999 the well was pumped, only 2,298 BO were produced and by the end of the year, the daily average had fallen to 23 BOPD. Prospect also drilled a third horizontal Ratcliffe well in South McGregor Field one township to the south. The #1-20H Nelson was drilled in section 20-T158N-R95W and was completed for 28 BO + 55 BWPD. The well produced for only 27 days during 1999 and made 491 BO, a daily average of 18 BOPD. It was an interesting idea that, if successful, would have generated interest in Ratcliffe targets across a large area of western North Dakota.

An unusual discovery was made in Wildrose Field by Armstrong Operating, Inc. Their #19-1 Burtman well was completed producing 428 BO + 262 MCFPD from the lower Souris River Formation. This is only the second well ever completed in the Souris River Formation in North Dakota. The other well, the #1 Rivers, in Dolphin Field, produced only 876 BO before being plugged. The Burtman produced for only 10 days during 1999 but made 3,071 BO. The producing strata are present in many other wells in North Dakota but are not porous everywhere. Perhaps more wells can be completed in this zone.

Several of 1998s drilling programs were continued into 1999. One of them was Burlington Resources horizontal program in Burke County, where two new wells were drilled. One well, the #44-32H Wilson, was drilled in section 32-T164N-R90W and was completed producing 141 BO + 60 MCF + 60 BWPD. The well is not a good one as it had produced only 5,664 BO by the end of 1999 when it was producing at a rate of 19 BOPD. The other well, the #11-15H Guerdett, was drilled in section 15-T163N-R89W and completed producing 880 BO + 550 MCF + 220 BWPD. It is a much better well as it produced 43,055 BO in just four months of production, but daily production had fallen to 281 BOPD by the end of 1999.

Another continuing program is the horizontal infill drilling on the Nesson Anticline where some prolific wells were completed. Amerada Hess Corp. completed two more horizontal wells in Beaver Lodge Madison Unit. The first was completed for 257 BO + 365 MCF + 2,688 BWPD but the second, the BLMU #P-27H, was completed for 870 BO + 1008 MCF + 3,280 BWPD. The latter well produced 38,432 BO in 58 days for an average of 663 BOPD. The well also produced 104,202 MCF and 151,342 BW. Amerada Hess is also re-entering some older wells and drilling out horizontally with apparent success.

In the Medora Heath-Madison Unit, Amerada Hess Corp. drilled a horizontal Madison well, the MHMU #31-H. The well is located in section 14-T139N-R102W and was completed for 213 BO + 48 MCF + 342 BWPD. Since its completion in February, 1999, the well has produced 86,278 BO. The well produced for 325 days for an average of 265 BOPD, higher than the IP. If other suitable locations can be found, it is likely that Amerada Hess will drill more horizontal infill wells.

Amerada Hess also drilled two more vertical infill wells in the Beaver Lodge Devonian Unit. Both the BLDU #DD-309 and the BLDU #EE-310 were drilled in section 36-T156N-R96W. The former was completed for 81 BO + 135 MCF + 459 BWPD while the latter was completed for 351 BO + 368 MCF + 69 BWPD.

Another company, Berco Resources LLC, started a horizontal infill program in the Stoneview Stonewall Unit. Their first well, the Stoneview-Stonewall Unit #1311, was completed producing 370 BO + 400 MCF + 23 BWPD. The well made 11,548 BO in 35 days, an average of 330 BOPD. Several other locations are permitted in the unit.

In Beaver Creek Field, three Birdbear recompletions were attempted, one of which was dry. The other two, the Energy Equity Co. #24-23 Beaver Creek Federal had an IP of 48 BO + 32 MCF + 1 BWPD. Unfortunately, the well produced only 4,655 BO during 1999 and was producing 2 BOPD at the end of the year. The other recompletion was made in the Summit Resources, Inc. #24-25 Williamson Federal Twin. The well had an IP of 46 BO + 50 MCF + 19 BWPD. This well made 1,904 BO in 58 days and may pay back the recompletion attempt. The 1999 completions were attempts to extend Birdbear production into the southeastern end of the field.

Nearby, in Roosevelt Field, Griffon & Associates, LLC re-entered their #41-15H Prairie Dog Fee well in section 15-T142N-R102W. They plugged the horizontal Bakken leg and drilled deeper to test the Duperow Formation. Good oil shows were seen while drilling the Birdbear Formation and the well was completed for 254 BO + 230 MCFPD in the Birdbear. The well lies along a possible northwest-southeast linear trend extending from Beaver Creek Field southeast into Roosevelt Field. A 1995 Birdbear completion was made in section 9 along this apparent trend, but it has made only 49,978 BO through the end of 1999. After comparing the quality of the 1999 Birdbear completions in Beaver Creek Field to those in 1998, it appears that there are "sweet spots" of Birdbear production. The well in section 9-T142N-R102W is apparently not in one but the Griffon & Associates well is. Close to this trend, another Birdbear well was completed during 1999. The BTA Oil Producers 9210 JV-P Federal DL #1 in section 8-T142N-R102W was completed for 86 BO + 54 MCF + 45 BWPD. This well lies west of the possible northwest-southeast Birdbear trend and it's production may not be related to that in the Griffon & Associates well.

Texakota, Inc. recompleted the #4-2 H. Borstad in the Red River Formation. The well is located in West Tioga Field and was completed in May, 1999 for 36 BO + 1,100 MCFPD. By the end of the year the well had produced 229,566 MCF and was producing at a daily average of 1,261 MCFPD. This is an excellent gas well in a state where there aren't many gas wells yet. As natural gas prices are currently relatively high, this well should be an economic venture.

Finally, Nance Petroleum Corp. completed another Red River well in Mondak Field. The #1-33 Federal, located in section 33-T148N-R104W, had an IP of 163 BO + 127 MCFPD. In the five months the well produced during 1999, it made 33,493 BO and 27,266 MCF. The areal extent for the discovery's reservoir is unknown, but it is possible it is another one-well Red River structure.

1998-1999 HIGHLIGHTS

The most active play during the late 1980s and early 1990s was the horizontal Bakken Shale play, but by the end of 1995, drilling for the Bakken had ceased and the play was over. The play was important to North Dakota because it generated heightened interest in the state, caused new leases to be taken, caused many wells to be drilled, produced enough oil to help stop the decline in annual oil production during 1990, and helped prove that horizontal drilling was both mechanically possible and an economically desirable technology. The effect of horizontal drilling was seen during 1998 when 54% of all the wells completed during the year were horizontal wells. The percentage dropped to 36% during 1999, but 1999 is anomalous because there was so little drilling at the low oil prices recorded during 1998 and 1999. Horizontal drilling is commonplace now and will continue to be so in the future.

During 1994, the horizontal Red River B zone play in Bowman and Slope counties began with

the discovery of Cedar Hills Field. This play has some common origins with the horizontal Bakken play as the first wells in this play were drilled in Montana at about the same time that the first horizontal Bakken tests were drilled in 1986 and 1987. The two plays are also similar in that very few of the wells are dry holes and initial production rates are often high. By comparison, the horizontal Red River wells in Cedar Hills Field produced slightly more oil during 1997 than did all the known Lodgepole mounds combined. Lodgepole mound wells had extremely high initial flow rates, but the greater number of Red River wells has made up for the higher production rates from the Lodgepole units. Thirty-one wells were completed in Cedar Hills Field during 1998, but none during 1999, apparently marking the full development of the field. Unitization of Cedar Hills Field has been proposed by the operators, but disagreement over the best method of enhanced recovery has stalled the effort.

Unitizations slowed during the period of this report. The most obvious reason is the low price oil received for much of the period. Whether that is the only factor will be seen in 2000 and beyond now that oil prices are much higher. Stadium Field was unitized during 1999, the only Lodgepole mound unitized. It is an unusual event for every field in a particular play in North Dakota to be unitized.

Finally, construction of the CO_2 pipeline, running from the Dakota Gasification plant near Beulah to Weyburn Field in Saskatchewan, was completed in December, 1999. This pipeline has the potential to greatly impact oil production in North Dakota. The pipeline parallels the Nesson Anticline and is close to many of the largest oil fields in the state. Many of these fields are nearing the end of their productive life and a CO_2 flood could extend their life and recover a large volume of oil that otherwise might never be produced. The cost of such a project has been significantly reduced because a pipeline from a source of CO_2 to the fields is now in place. The potential is there. It remains to be seen if anyone takes advantage of it.

REFERENCES

Burke, R. B., and Diehl, P. D., 1993, Waulsortian Mounds and Conoco's New Lodgepole Well, North Dakota Geological Survey Newsletter, V. 20, No. 2, pp. 6-17.

Fischer, D. W., and Bluemle, J. P., 1988, Oil exploration and development in the North Dakota Williston Basin: 1986-1987 update: North Dakota Geological Survey Miscellaneous Series 72, 36 p.

Fischer, D. W., LeFever, J. A., Heck, T.J., & LeFever, R. D., 1991, Petroleum potential of the Little Missouri National Grasslands, North Dakota Geological Survey Report of Investigations No. 91, 52 p.

Heck, T. J., 1990, Oil exploration and development in the North Dakota Williston Basin: 1988-1989 update, North Dakota Geological Survey Miscellaneous Series No. 74, 22p.

Heck, T. J., 1998, Oil exploration and development in the North Dakota Williston Basin: 1996-1997 update, North Dakota Geological Survey Miscellaneous Series No. 85, 27 p.

Helms, L. D., and Hicks, B. E., 1998, Back from the Brink, in Seventh International Williston Basin Horizontal Well Workshop, North Dakota Geological Survey and Saskatchewan Energy and Mines, Regina, Saskatchewan, Canada, 40 p.

LeFever, R. D., and Heck, T. J., 1995, Hydrocarbon Resources of the North Dakota Williston Basin, in Seventh International Williston Basin Symposium, Montana, North Dakota, and Saskatchewan Geological Societies and Fort Peck Tribes, pp. 279-289.

Sperr, J.T., Stancel, S. G., McClellan, W. A., & Hendricks, M. L., 1993, Wabek and Plaza Fields: carbonate shoreline traps in the Williston Basin of North Dakota, North Dakota Geological Survey Field Study 1, 24 p.

Stalwick, K., 1994, Saskatchewan horizontal activity update, in Second International Williston Basin Horizontal Well Workshop, North Dakota Geological Survey and Saskatchewan Energy and Mines, Minot, North Dakota, pp. A1-1-A1-19.

APPENDIX I. 1998 NEW POOL DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/99	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GAS (MCF) GRAV.	 GOR	WATER
McKenzie 14706 8560	1/8/98	Samedan Oil Corp. Dodge #34-20 Sec. 20-T151N-R96W	Dimmick Lake Duperow 1	12,260 160	11,320-11,338	42 0	81 46	1880	133
Golden Valley 14757 8487	1/13/98	Best Pacific Resources (U. S.) Mertz #41-31 Sec. 31-T140N-R105W	Chama Silurian 1	12,825 320	10,672-10,684	319 27	0 44.9	0	0
Golden Valley 12539 8484	1/14/98	Summit Resources, Inc. Williamson Federal #42-26R Sec 26-T143N-R103W	Beaver Creek Duperow 2	12,825 320	11,057-11,076	298 72	325 36	1091	
Divide 9608 8203	1/21/98	Colt Resources Corp. Laverne Haugen #32-19 Sec. 19-T163N-R101W	Big Dipper Madison 0	10,298 160	6,746-6,772	5 0	0 38	0	87
Divide 14775 8229	2/1/98	Lyco Operating Co. Plumer-Lundquist #25-2 Sec. 25-T161N-R99W	Burg Red River 0	11,670 320	11,495-11,530	102 0	94 43.9	922	
**Bowman 14610 8307	4/17/98	Continental Resources, Inc. Nebo #1-21 Sec. 21-T130N-R104W	Medicine Pole Hills West Red River 19	15,031 640	9,724-15,031	133 28	33 34	250	255
Divide 14775 8351	6/15/98	Lyco Operating Co. Plumer-Lundquist #25-2 Sec. 25-T161N-R99W	Burg Silurian 1	11,670 320	11,440-11,468	225 29	39 46	160	
Mountrail 14815 8646	7/16/98	Alenco Oil & Gas (ND), Inc. Alenco Nordquist 151-89-23 #DCB Sec. 23-T151N-R89W	Banner Madison 1	13,136 160	7,862-7,876	250 90	0 33	0	12
McKenzie 14692 8609	8/7/98	Flying J Oil & Gas, Inc. Federal #9-5 Sec. 5-T149N-R103W	Cathmere Red River 1	13,350 320	13,159-13,165	292 104	292 49.5	1000	12
Burke 14845 8660	8/29/98	Burlington Northern Oil & Gas, Inc. Knudson #11-21H Sec. 21-T163N-R89W	Lakeside Midale/Nesson 2	11,245	5,623-11,245	522 86	487 39.6	934	115
Williams 14864 8607	9/12/98	Petro-Hunt LLC Hansen #5D-3-1 Sec. 5-T159N-R96W	Hanson Duperow 1	11,656 320	10,126-10,130	20 3	31 38.3	1550	63

APPENDIX I. 1998 NEW POOL DISCOVERIES CONTINUED

COUNTY FILE NO. ORDER #	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/99	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GAS (MCF) GRAV.	GOR	WATER
McKenzie 14724 8457	12/10/98	Amerada Hess Corp. Thompson #6-32 Sec. 6-T153N-R95W	Charlson Winnipeg/Deadwood 1	14,419 640	13,862-13,918	0 321MCF	631 NA	NA	2

**Note: Red River B zone production was established in Medicine Pole Hills Field much earlier when the field was first discovered so this is not a new pool discovery. The Red River West pool was created because some horizontal wells cross the unit boundary between Medicine Pole Hills and West Medicine Pole Hills Units and it was necessary to split the production between the units. The creation of a new pool is an administrative device to account for the production.

APPENDIX II. 1999 NEW POOL DISCOVERIES

COUNTY FILE NO. ORDER #	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (# OF PRODUCING WELLS IN POOL ON 12/31/99	TOTAL MEASURED DEPTH -SPACING	PERFORATED INTERVAL	IP (CUR. -BOPD	GAS (MCF) GRAV.	GOR	WATER
Williams 14898 8458	5/14/99	Prospect Oil & Gas, Inc. Gohrick #1 Sec. 31-T159N-R95W	Helle Slough Ratcliffe 2	13,174 640	8,449-13,174	279 66	150 39	538	83
Billings 14776 8492	5/28/99	JN Exploration & Production LTD Partnership JN Federal #44-18 Sec. 18-T138N-R100W	Davis Creek Tyler 1	10,953 160	8,012-8,022	33 27	0 37.3	NA	83
Divide 10625 8489	7/11/99	Basic Earth Science Systems, Inc. Drawbond 27 #2 Sec. 27-T163N-R102W	Skjermo Duperow 1	10,920 320	8,380-8,507	8 1	0 35.6	NA	3
McKenzie 11920 8556	10/7/99	Nance Petroleum Corp. Corps of Engineers #31-10 Sec. 10-T153N-R101W	Baker Duperow 1	13,480 320	10,965-11,115	104 81	87 37.1	839	228
Williams 7054 8557	10/20/99	Nance Petroleum Corp. Fedje #1-14 Sec. 14-T156N-R102W	Bonetrail Duperow 1	13,154 160	10,740-10,902	36 16	15 34.7	416	45
Burke 12329 8589	11/15/99	Berco Resources, LLC Strombeck FLB #1 Sec. 6-T159N-R94W	North Tioga Red River 1	12,605 160	12,414-12,430	81 0	385 NA	4750	39
Divide 14925 8590	12/22/99	Armstrong Operating, Inc. Burtman #19-1 Sec. 19-T160N-R97W	Wildrose Souris River 1	11,300 320	10,354-10,368	428 307	262 39	612	0