NDGS NEWSLETTER

Industrial Commission of North Dakota
North Dakota Geological Survey

Volume 24, No. 2
Summer 1997

Neither rain, nor sleet, nor snow . . . In March of this year, NDGS geologists were in Devils Lake, North Dakota, to complete a field study to determine the amount of recent sedimentation that has occurred in the natural outlets of Devils Lake. This truck-mounted soil auger used by the Survey is shown in the Tolna outlet. See story on page 16.

FEATURES

8 Fifth International Williston Basin Horizontal Well Workshop

10 The Sheyenne National Grasslands

16 Study of Devils Lake and Stump Lake Outlets

22 Toils Induced by Weak Soils

DEPARTMENTS

1 From the State Geologist

3 News in Brief

5 ESIC News

NDGS Newsletter (ISSN: 0889-3594) is published quarterly by the North Dakota Geological Survey, a division of the Industrial Commission of North Dakota. *NDGS Newsletter* is designed to reach a wide spectrum of readers interested in the geology and mineral resources of North Dakota. Single copies of *NDGS Newsletter* are distributed free upon request. Please share the *NDGS Newsletter*; we encourage its reproduction if recognition is given.

Your comments - and contributed articles, photographs, meeting announcements, and news items - are welcome. Correspondance, subscription requests, and address changes should be addressed to: Editor, *NDGS Newsletter*, North Dakota Geological Survey, 600 East Boulevard Avenue, Bismarck, ND 58505-0840 • (701) 328-9700.

When requesting a change of address, please include the number on the upper right hand corner of the mailing label.

From the State Geologist

By John. P. Bluemle

A lot has been said and written lately about the floods in the Red River Valley and at Devils Lake. As State Geologist, I have been quoted several times about things I've said, especially about Devils Lake, but also a few times regarding the flood in Grand Forks. Someone called in to a local radio program in late March or early April and noted that I had "predicted" a 54 or 55- foot crest on the Red River in Grand Forks. That's not really true. What I said, in response to a question from a newspaper reporter, was that I thought it was possible that the Red River could reach 54 or 55 feet in Grand Forks.

It's important to point out that I don't, and the North Dakota Geological Survey doesn't, make official predictions about flood crests or other weather-related phenomena. The National Weather Service does that. Neither do we maintain flood gages or measure water levels, a job done by the United States Geological Survey. Rather, we try to provide factual, geologic background information that will be useful to those people who do make those kinds of predictions.

I've been interested in, and worked on, the geology of floods for a long time. In 1980, following the 1979 flood in Grand Forks, I wrote, and the North Dakota Geological Survey published, a report titled "The Flood Problem in Grand Forks-East Grand Forks" (and please note that, even though we are the North Dakota Geological Survey, I did include East Grand Forks prominently in that report!).

Our 1980 report was intended to provide some basic facts about the flooding problem in the area. It was a fairly detailed analysis of the factors that impact the flooding problem. Too much water, yes, but a lot of other things enter in and can contribute to the problem. Some of the flood "factors" are fixed (northerly flow, flat slopes, etc.). Others are variable (amount of snow to melt, precipitation during the melt, depth of frost, speed and timing of melt, etc.). Still other factors are related to human intervention (bridges, drainage ditches, placement and quality of dikes, etc.). I also included a floodplain map in our 1980 report and indicated on that map which areas of Grand Forks-East Grand Forks would be flooded at various river levels.

In reviewing my 1980 report, I believe it is essentially correct and still pertinent to the present situation, and can help us understand the 1997 flood. The flood-prone areas map we provided is still the most accurate I've seen for the area. We did send copies of the report to various media, but I have no idea whether anyone used it or found it useful.

I've also done a lot of work over the years on the geology of Devils Lake. My main concern there has been to try to come to an understanding of, first, the geology and origin of the lake and, second, how the level of the lake has fluctuated over time. We continue to work on the geology of Devils Lake right now. In March, two of our geologists spent two weeks drilling the outlet areas (the routes the lake will take if and when it overflows into Stump Lake and into the Sheyenne River, *see article page 16*). We want to know how much sedimentation has taken place in the outlet areas during the past 100 years or so.

Last summer I wrote an article about the flood problem at Devils Lake for the *North Dakota Weekly*. The headline on the article might have been somewhat misleading - *Devils Lake 'Could' Rise Another 20 Feet.* Most of you probably realize that newspaper editors provide the headlines for articles that they receive or their reporters write. I might not have chosen that headline, but even so it isn't all that bad and it's not really inaccurate. I didn't say or predict that Devils Lake would rise 20 feet; I said it could rise 20 feet, and that is entirely true.

Since I wrote the Devils Lake article, I've given about a dozen talks about the problem (including twice to Legislative committees during the recently-completed Session). I've tried to provide some factual basis for decisions that have to be made about how to deal with the problem.

One important area of our understanding relating to flooding that I've always had misgivings about is the idea of a 100-year flood or a 500-year flood. It's a purely statistical concept that most people simply don't understand and I wish we could just trash it. Too many people take the idea seriously - that because a certain water level is considered to be a 100-year flood, then it must be a rare event. Quite honestly, we don't have enough data, and our historical record isn't long enough to assign such categories. For example, we could have four "500-year" floods in three years. We would then recalculate and reconfigure our statistics and such a flood would no longer be a "500-year" flood.

Our own (NDGS) research over the past 20 years indicates that severe flooding is more common (in a recent geologic sense) than we had thought. Our human experience in North Dakota is skewed by a long period of dry conditions. During the late 19th century and the first half of the 20th century - an interval which coincides largely with the time the state was settled - is our perception of reality, that is what we, our parents, and our grandparents experienced during ours and their lifetimes. With a couple of notable exceptions, the 110-year period from about 1830 until the 1940's, the period during which the plains were settled, was one of dry conditions. Since about 1940, we seem to have "turned the corner" and are - have been since about 1940 - in a wet cycle. I've pointed out in the talks I've given on Devils Lake that the cycles apparently last from 100 to 200 years.

There has been a lot of misunderstanding - and criticism - about the flood-crest predictions that the National Weather Service provides. I saw a comment in an issue of the *Grand Forks Herald* just prior to the disaster there, a response to a NWS prediction at that time that the Red River would crest at 50.5 feet or some such level. The question raised was whether they could rely on that prediction and the answer was that the sophisticated computer models now available gave [the writer] confidence that they could. Four days after that 50.5-foot prediction, the river finally reached a level of 54.2 feet. It's easy to second-guess, but that's not my point. I think the National Weather Service did a good job under difficult circumstances. My point is that, even though computer models have advanced immeasurably since (for example) 1980 when I wrote my report on the flooding problem in the Grand Forks area, flood-crest predictions are still subject to a variety of vagaries. The computer models are still no better than the data supplied to them or the ability of the user to understand them.

Finally, I'd like to make one more point. It seems that some people want to attribute the recent flood on the Red River and the ongoing flood at Devils Lake to the results of human activity. It's human nature to want to "blame" someone. I don't know how many times I've heard that the flooding is the result of drainage of wetlands and if only those wetlands hadn't been drained the lake would still be "normal" or if the wetlands were restored, the lake level would drop or if there weren't so many drainage ditches in the Red River Valley and farmers were more conservation-conscious or some such thing, we wouldn't be having these floods. I think that such self-serving misstatements by various special interest groups are somewhat disingenuous and do a disservice as they keep attention from being focused on the real problem. The floods are not abnormal and no one is to blame for them. Devils Lake is behaving normally, doing what it has done many times in the past - rising toward overflow into Stump Lake an ultimately into the Sheyenne River. Similarly, the Red River and its tributaries are behaving normally when they spread out onto their floodplains when the winter snows melt. Quite simply, the floods are being caused by increased precipitation and that increase, as I have pointed out in all of the talks I've given on Devils Lake, is an entirely normal occurrence. Certainly we need to take whatever action we can to alleviate the effects of the floods; there are many things we can do to deal with the problem and we should do them.

Now, for my part, I have to stop writing and head back up to Grand Forks to continue cleaning out the basement in my mother's home. It's a real mess!

To order a copy of Educational Series 12, *"Flooding in the Grand Forks-East Grand Forks Area"*, please see order form in back. Cost is $2.00 per copy.

NEWS IN BRIEF

Compiled by Ann M.K. Fritz

Digital Spatial Data Update

The North Dakota GIS Digital Spatial Data Clearinghouse (DSDC) has recently been updated. The DSDC now has all of the 1:100,000-scale political boundary data. The final 13 quads were distributed by the U.S. Geological Survey National Mapping Division in Minnesota. On September 30th of this year we will receive the last of the 1:100,000-scale hypsography (contour lines) coverages of the Eastern Half of North Dakota. This will complete all of the major 1:100,000-scale data for the state. Once these file are converted they will also be available on our DSDC. We have also added many new 1:24,000-scale Digital Elevation Models and a few new 1:24,000-scale Public Land Survey System maps. The Clearinghouse can be reached via the World Wide Web at **http://www.gis.swc.state.nd.us** or can be accessed through FTP at **165.234.108.90**.

North-Central GSA Presentation

NDGS geologist John Hoganson was co-author of a poster presented at the 31st Annual Meeting of the North-Central Section of the Geological Society of America. The meeting was held in Madison, WI, May 1-2. The poster, titled "*Large Death Assemblage of Plastomenid Turtles in the Sentinel Butte Formation (Paleocene) of Billings County, North Dakota*" was presented by Glenn Kays, a student at University of North Dakota in Grand Forks.

The Fifty-fifth Legislative Session

by John P. Bluemle

Soils Digitizing

The North Dakota Geological Survey was significantly affected by action taken during the recently-completed legislative session. The most important change is the assignment of soils compilation and digitizing responsibilities to the Survey. As a result of the Survey being assigned this new program, we will establish a central state Soil Digitizing Center. This will entail adding five new positions to our staff. We have also been granted additional funding to accomplish the added duties.

The new positions include two that were transferred from the Soil Conservation Committee and three newly-created ones. The new soil-digitizing program will be in effect as of July 1, 1997. There will be more information regarding this program in the fall *NDGS Newsletter.*

"State Rock" Legislation

The Legislature again considered a bill to name a state rock, but the proposal came up short of becoming law. House Bill 1082, which was introduced by Representative Dale Henegar, would have designated Knife River Flint as North Dakota's Official State Rock. Rep. Henegar commented that he knew the bill would be controversial. He wanted the rock honored because it is unique to North Dakota and represents the state's first exported material. Although the bill passed the House, it failed to get enough votes to pass the Senate.

The "state rock" bill generated a lot of discussion, both in the Legislature and in the media. Representative Arlo Schmidt, a farmer from Maddock who opposed the bill, commented that "*. . . we had a lot of problems with rocks. And you know, ladies and gentlemen . . . they're going to dig a hole, probably bust up a couple of backhoes getting it done, and put my mortal remains in that hole, and the last indignity, they're going to put a rock on top of my head. I'm against this bill.*" He also commented "*I know of no other mineral, or no other substance that has caused more abuse of the Second Commandment than a rock.*"

Other representatives spoke in favor of the bill. Representative Darrell Nottestad, Grand Forks, pointed out that the flint was the state's first commercial material. School children will learn much during North Dakota studies classes that feature the state flower, state bird, and other items. Representative Paul Murphy of Carrington, said teaching children about the wide trade that flint saw among indigenous people can help them understand commerce and "*link the past with the present.*"

Senator Jack Traynor, who carried the bill in the Senate, also spoke eloquently in favor of the state rock bill, but it failed to pass in spite of his efforts. Fears were expressed that naming Knife River Flint as the official state rock would make it difficult for construction or development to occur because the material would have an "official" protection. This is not the case. Naming flint as the "official" state rock would not have bestowed any kind of protection on it, or prohibit construction or development if flint was found at a construction site — no more so than finding a wild rose, elm tree, or a stand of Western Wheatgrass (North Dakota's official state flower, state tree, and state grass, respectively) at a construction site holds up construction.

As State Geologist, I have advocated naming Knife River Flint as North Dakota's state rock (article in the *NDGS Newsletter*, Spring 1993) but it was Representative Henegar's idea to introduce the bill. A similar bill, introduced two years ago, failed for much the same reasons it was defeated this time. About 45 other states have named official state rocks, stones, minerals, or gems.

First Forest Ecosystem Camp for K-12 Educators Set

The North Dakota Forest Service and MSU-Bottineau campus have formed a partnership to provide a workshop on *"North Dakota's Forest Ecosystems - Wood, Water and Wildlife"* from August 11-14, 1997. The workshop is designed for educators, youth leaders and natural resource professionals working with students in grades K-12. No previous environmental education experience is required.

Hands-on investigations will help participants appreciate the diversity of life in forests, understand the interdependencies of such forest life, and develop an awareness of the importance of forests in our daily lives. Classes will touch on: forest diversity, succession, silviculture, global forestry, multiple-use, wildlife enhancement techniques and different forests of the state due to soil types, climate, rainfall and plant life.

In addition to classroom instruction, the following field experiences to various forest types will include: International Peace Garden, Lake Metigoshe State Park, Turtle Mountain State Forest, Towner State Nursery, USDA FS Denbigh Experimental Forest, J. Clark Salyer Wildlife Refuge and the Bottineau Community Forest.

The cost for the four-day workshop is $130 which includes board, room and tuition. Participants will be housed on the Bottineau campus in modern dorm rooms with their own private bath. Two semester hours of graduate credit are optional and available through Minot State University for an additional $70 fee. A minimum of 15 participants is required and registrations will be accepted on a first come, first served basis until August 1, 1997. Educators should check with their local soil conservation district or school Eisenhower funds for scholarship assistance. For more information or to register, contact:

Glenda Fauske
North Dakota Forest Service
307 First Street East
Bottineau, ND 58318-1100
(701) 228-5446

Graham Joins Survey

Dr. John Graham has joined the North Dakota Geological Survey. John, a geologist who will primarily be involved with the surface mapping program, received his B.S. degree in geology from the University of Iowa in 1980 and his Master's degree in geology from Oregon State University in 1982. He was employed by the petroleum industry to evaluate the reservoir and source rocks in Nevada, Utah, New Mexico, the Williston Basin (briefly), and off-shore Trinidad and Tobago. John quit the oil buisiness in 1990 and joined the Minnesota Pollution Control Agency as a hydrogeologist. After two years of developing groundwater monitoring plans for closed landfills, John returned to graduate school in the Ph.D. program at Colorado State University. His research focused on the sedimentology, stratigraphy, and diagenesis of the Muddy Sandstone, a Cretaceous unit that is the major hydrocarbon-bearing unit in the Denver Basin as well as part of the extensive Dakota aquifer. While finishing his dissertation, John taught geology at the University of Wisconsin-River Falls campus.

Red River Basin Board

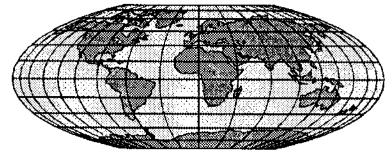
When the ProGold wet corn processing plant decided to locate their plant in southeastern North Dakota, local leaders learned that there was no central place for them to go to meet their needs for information on water quality of the Red River (RRN) Basin. At the same time, state officials charged with administering the permits for the plant found that there was no central forum for the public discussion of permit applications. A number of RRN Basin leaders from the U.S. and Canada met in October, 1995 to discuss their mutual concerns about water issues. The basin leaders decided that an organization was needed to facilitate a basin wide water management plan and to provide a mechanism to resolve inter-jurisdictional disputes. The Red River Basin Board concept was born.

The overall mission of the Red River Basin Board (RRBB) is to "develop and cause to be implemented a comprehensive water management plan for the Red River Basin and to facilitate and pursue the resolution of interjurisdictional issues". The RRBB would provide many services such as being an access point for information regarding surface and groundwater resources within the basin, being a vehicle for determining the consensus view of basin residents about water management strategies, and providing a forum for the discussion and resolution of interjurisdictional disputes.

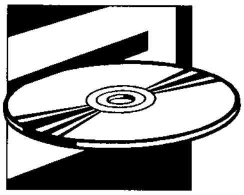
A proposed budget and expenditures have been developed through 1998. Quarterly meetings are being planned for that same period. If you live in the Red River Valley and are interested in water quality and water management issues, you may want to find out more about the RRBB. For more information, contact:

Red River Basin Water Planning Group
The International Coalition
P.O. Box 127
Moorhead, MN 56561-0127
(218)233-0292 (218) 233-1943 Fax

ESIC NEWS



The NDGS is an affiliate of the Earth Science Information Center (ESIC) network. Coordinated by the U.S. Geological Survey, the nationwide ESIC network provides information about geologic, hydrologic, topographic and land use maps, books and reports; aerial, satellite, and radar images and related products; earth science and map data in digital form and related applications software; and geodetic data. As an ESIC office, the NDGS can assist the public in locating earth science materials dealing with North Dakota, as well as other states. For more information, contact Ann Fritz or Ryan Waldkirch at (701) 328-9700.



DIGITAL SPATIAL DATA

Vector Smart Map Level 0

Vector Smart Map Level 0 (VMap0) is now available from the USGS. Published by the National Imagery and Mapping Agency (NIMA) on CD-ROM, the VMap0 database is designed to provide vector-based geospatial data at low resolution. The content of the database is similar to the previously published *Digital Chart of the World*, augmented with low resolution bathymetry for global coverage. A reference library with general information to orient the user and an index of geographic names to aid in locating areas of interest are provided. Data are separated into thematic layers: boundaries, elevation, hydrography, industry, physiography, population, transportation, utilities, and vegetation.

VMap0's world coverage is divided into four libraries based on geographic areas. The geographic areas and library names, by disc, are:

- Disc 1 - North America (NOAMER)
- Disc 2 - Europe and North Asia (EURNASIA)
- Disc 3 - South America, Africa, and Antarctic (SOAMAFR)
- Disc 4 - South Asia and Australia (SASAUS)

The primary source for the database is the 1:1,000,000-scale *Operation and Navigation Chart (ONC)* series co-produced by the military authorities of Australia, Canada, United States, and the United Kingdom. Data gaps may exist where source information is not available.

Application software, allowing users to access and view VMap0 data, has been developed by NIMA and is available on the DMAMUSE CD-ROM (see ESIC News, *NDGS Newsletter*, v. 24, no. 1). Called VPFVIEW, it will operate on IBM-PC, SUN, UNIX and MacIntosh platforms. Information about VMap0, VPFVIEW, and DMAMUSE is available on the NIMA Internet site at **http://www.nima.mil**. DMAMUSE can be downloaded from the web site: **http://www.nima.mil/DMAMUSE2/**.

VMap0 is sold as a four CD-ROM set for $82.50. The DMAMUSE CD-ROM is available for $11.50. Customers should order from: USGS Information Services, Box 25286, Denver, CO 80225. Please add a $3.50 handling charge for each order. VISA and MasterCard orders can be faxed to (303) 202-4693. Please include an expiration date for credit card orders. [Reprinted from *ESIC Information Bulletin 354*]

Digital Raster Graphics Available

In the fall of 1996, the National Mapping Division (NMD) discontinued production of Digital Raster Graphics (DRGs) on CD-ROM's for distribution from Denver. As a result of reduced funding for replication of CD-ROM's, slow sales of DRG's, and errors in the header files of DRG CD-ROM's, NMD has decided that DRG files will be sold in the same one-degree block format through the Sales Data Base on CD-Recordable media. Errors in the header files have been corrected and NMD is ready to begin filling customer orders for the approximately 400 one-degree blocks currently available. NMD will continue to create one-degree blocks until the whole country has been covered. Customers who have previously purchased a DRG CD-ROM and are unable to use the data because of a header file error can request a replacement at no charge.

Each one-degree DRG block will usually contain sixty-four 1:24,000-scale files, two 1:100,000-scale files, and one-half of a 1:250,000-scale file. In some cases, the DRG product will include files for two adjacent blocks, while in other cases, the product will require two CD-R's. A list of DRG blocks currently available can be found on the Internet at **http://mcmcweb.usgs.gov/drg/**.

Customers can order DRG's through any USGS ESIC office. Please list both the block number and block name of the area desired. The price of DRG's is $32.00 for one disc or $42.00 for a two disc set, plus $3.50 handling for each order. [Reprinted from *ESIC Information Bulletin 350*]

Digital Files Available On Line

Large-scale digital line graphs (DLGs) are now available on-line in the Spatial Data Transfer Standard (SDTS) format free of charge. The URL address for the 1:24,000-scale DLGs in SDTS is **http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html**. The user can choose to find and download or link to online documentation by choosing one of the following: Example; Status maps; Data User Guide; Condensed User Guide; FTP via Alphabetical List; FTP via State; or FTP via Graphics.

At the same URL address, EROS Data Center also provides links to online documentation and file transfer protocol (FTP) access to these additional data sets:

- 1-degree digital elevation model data
- 1:2,000,000-scale DLG data in SDTS format
- 1:100,000-scale land use and land cover data
- 1:250,000-scale land use and land cover data
- 1:100,000-scale digital line graph data, hydrography, and transportation layers in SDTS and optional format

The 1:100,000-scale DLG for North Dakota can be downloaded directly from the NDGS home page: **http://www.state.nd.us/ndgs/NDGS.HomePage**. Customers who do not have online access or require file manipulation are assessed a small fee. Contact the NDGS GIS Center at (701) 328-9703 for more information.

The SDTS is the approved data exchange standard for the National Spatial Data Infrastructure (NSDI). Spatial Data Transfer Standards facilitate the NSDI objective of making geospatial data accessible, providing an effective vehicle for the exchange of spatial data between different computing platforms. [Reprinted from *ESIC Information Bulletin 352]*

GROUND WATER / SURFACE WATER INFORMATION

National Water Summary on Wetland Resources

The *National Water Summary on Wetland Resources*, USGS Water Supply Paper 2425, has been released. It is a comprehensive state-by-state assessment of the nation's wetlands compiled by the U.S. Geological Survey in cooperation with other state and federal agencies as well as the academic community. This USGS wetlands report provides overviews of the wetland protection legislation, research by federal agencies related to wetlands, a discussion of the functions and values of wetlands, and a historic look at gains and losses of wetlands across the nation since the time of European settlement. Selected articles and highlights of the report are available on the Internet by accessing **http://water.usgs.gov/public/nwsum/WSP2425**.

Copies of Water Supply Paper 2425 are available for $49.00 from the Government Printing Office. The GPO stock number is 024-001-03604-5. Credit card orders can be placed by calling (202) 512-1800. A GPO order form can be obtained from *EarthFax* at (800) 872-6277. The document number is 5100. Also available on *EarthFax* are the *Executive Summary* (document 5101), *State Highlights A-M* (document 5102) and *State Highlights N-W* (document 5103).

A limited supply of *North Dakota's State Summary* are available from the USGS Water Resources Division (WRD) office in Bismarck, 821 East Interstate Avenue, (701) 250-4601, (701) 250-4552 fax. A list of state WRD offices is also available from *EarthFax* (document 5104).

Questions about the *National Water Summary* can be directed to the WRD's Information Delivery Services office at (703) 648-5604. Send e-mail to **gwendt@usgs.gov**. [Reprinted from *ESIC Information Bulletin 357*]

Water-Quality Monitoring Data Available on CD-ROM

Data from Selected U.S. Geological Survey National Stream Water-Quality Monitoring Networks (WQN) is available in a two CD-ROM set (item number DDS-37). The set contains water-quality data from the Hydrologic Benchmark Network and the National Stream Quality Accounting Network, operated during the past 30 years. All data are present in ASCII format on the "ASCII disc". Software programs on the "DOS disc" are capable of browsing text files as well as retrieving and printing data according to user-specified criteria. Cost of the two CD-ROM set is $42.00 plus $3.50 shipping and handling.

Additional information products designed to accompany DDS-37 include:

- Open-File Report 96-337, *Data From Selected U.S. Geological Survey National Stream Water-Quality Monitoring Networks on CD-ROM*. Cost is $12.75 for a paper copy or $4.00 for a microfiche copy.
- Fact Sheet FS-013-97, *Data From Selected U.S. Geological Survey National Stream Water-Quality Monitoring Networks on CD-ROM*. This fact sheet is free.

The CD-ROM, DDS-37, Open-File Report 96-337, and Fact Sheet FS-013-97 are all available from: USGS Information Services, Box 25286, Denver, CO, 80225. Please include $3.50 handling charge for each order. MasterCard and VISA orders can be faxed to (303) 202-4693. Please include an expiration date for credit card orders. [Reprinted from *ESIC Information Bulletin 351*]

EDUCATIONAL MATERIALS / GENERAL INFORMATION

EarthFax: Your Line to Geologic Information

Picture this . . . You are a sixth grade teacher. It is Sunday night and you are planning your next earth science unit for the following week. You have most of the information you need except for some current information on earthquakes. There is a lot of Hollywood hype over natural disasters these days, so you want to include information on the Northridge, California, earthquake and other seismically active areas in the U.S. The NDGS offices are closed, the public library is closed, and you can't get to your school's library. You suddenly remember that your home computer has fax capabilities. Thank your lucky stars for the *EarthFax* line.

The USGS ESIC office operates a 24-hour information and ordering line called *EarthFax*. A touch tone phone and a fax machine can get you information on earthquakes, natural hazards, water resources and volcanoes, as well as geologic news and current investigations of the U.S. Geological Survey. You can also receive price and ordering information on federally produced maps, aerial photographs, and digital spatial data. A wealth of geologic information is available simply by calling *EarthFax* at **(703) 648-4888** or **(800) USA-MAPS** (872-6277). Documents can be sent to your home or office fax machine usually within minutes after you place the call.

But how do you know what documents are available on *EarthFax*? You may notice that many of the items described in *ESIC News* contain a document number. This number can be used to order the document from *EarthFax*. You can also order an summary list of *EarthFax* documents for a particular specialization (news, maps and publications, water resources, and geologic information). For more information on what resources the U.S. Geological Survey has to offer, visit their home page at **http://www.usgs.gov**. The NDGS also has information available on-line. Visit our home page at **http://www.state.nd.us/ndgs/NDGS.HomePage**.

Volcanoes! - Teacher Packet Available

The new *Volcanoes!* teacher packets are now available from USGS Information Services. Designed for grades four through eight, the packet includes a two-sided color poster, a teaching guide with a glossary and bibliography, six lesson plans with timed activities, and an evaluation sheet. Although the study of volcanoes is an earth science subject, the activities in the packet incorporate various related subjects, including other sciences, social sciences, language arts, and mathematics.

Focusing on the Mount St. Helen's eruption on May 18, 1980, students will learn how this catastrophic eruption produced a ripple effect on the Earth's subsystems, causing numerous problems. They will also learn how to analyze these problems and develop solutions.

Educators can obtain *Volcanoes!*, as well as other teacher packets produced by the USGS, free of charge, by sending a request on school letterhead to: USGS Information Services, Box 25286, Denver, CO 80225. The FFS stock number is 97-0995.

For additional information about volcanoes, visit the USGS educational learning web home page at **http://www.usgs.gov/education/**. [Reprinted from *ESIC Information Bulletin 356*]

Fifth International Williston Basin Horizontal Well Workshop

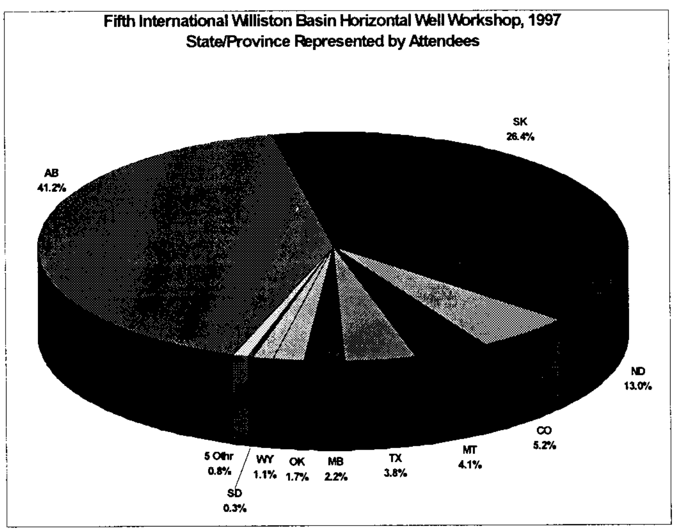
by John P. Bluemle and Paul Diehl

The North Dakota Geological Survey and Saskatchewan Energy and Mines co-sponsored the Fifth International Williston Basin Horizontal Well Workshop, April 13-15. This year's workshop was held in Regina, Saskatchewan at the Ramada Plaza Hotel and attracted more than 650 people from Canada and the United States.

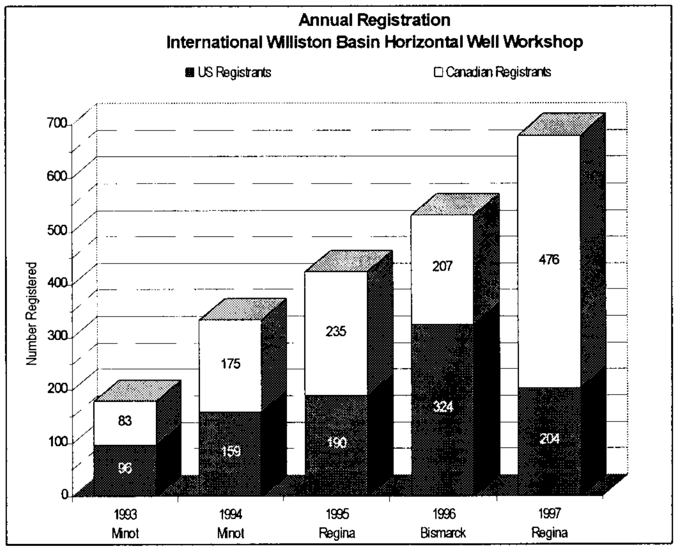
The Horizontal Well Workshop is the result of an idea Malcolm Wilson (SEM) approached me (John Bluemle) with back in 1992. Along with some of his colleagues, Malcolm met with three of us from the NDGS in Estevan, SK, in October, 1992, to rough out plans for the first workshop. Also, as a result of our discussion, we agreed that the two agencies should share and transfer geologic information more freely than we had up to that point.

At that time, horizontal drilling technology was just beginning to take off in the Williston Basin. Our stated purpose in initiating this series of conferences was to *"better facilitate communication and cooperative efforts by companies and individuals interested in horizontal drilling and production in the Williston Basin."*

We wanted to bring people from both sides of the border together to foster an interchange of ideas. Prior to the first workshop (held in May of 1993, in Minot, ND), there just wasn't a lot of communication across the border among oil-industry people. Horizontal drilling technology *had* been used successfully in Saskatchewan but, apart from the Bakken horizontal play which was winding down at the time in North Dakota, we did not have nearly as much success south of the border as there had been in Saskatchewan. We hoped that, by bringing together a select group of oil and gas industry people, information about successes and failures could be shared and everyone would profit from the knowledge. We also wanted to point out opportunities in North Dakota in order to attract Canadian investment.



One thing we insisted upon was that we had to allow time for people to meet and visit with each other, to share ideas. It was stressed that the meeting was to be casual and informal. In 1992, we initially decided to invite about 70 people to an informal gathering to meet and discuss the issues relating to horizontal drilling. The number 70 wasn't a magic number. We just expected that would be about all that would be interested in attending; 35 people from the U.S. and 35 from Canada.



We were mistaken, as 170 people came to our first workshop. The message was - and is - clear: the people are out there and they want to get together. Following that first event in 1993, by far the most-requested item was the list of participants. Everyone wanted to know who the other "players" were.

In light of our successful 1993 workshop, we decided to have a second workshop in 1994. The second workshop was also held in Minot with an attendance of 325 people. In fact, each workshop has outdone the previous one (in attendance, at least). Approximately 450 people came to the third workshop, which was held in Regina. Over 500 people came to last year's workshop in Bismarck and at this year's workshop in Regina, attendance hit a high of over 650 people.

The focus this year was slightly different from previous years. This time we concentrated on specific topics of interest to operators who are active, or would like to become active, in further oil development in the Williston Basin on both sides of the border. We also focused on deeper plays within the Basin and discussed the regulatory aspects of Deep Rights Reversion in Saskatchewan. Following the workshop itself, we had a display - a kind of mini-workshop - of core from deeper strata. The core display was held at the

Saskatchewan Energy and Mines Subsurface Geological Laboratory.

This year's workshop attracted the attention of the highest-level government officials in both Saskatchewan and North Dakota. Premier Roy Romanow and Governor Edward Schafer both spoke at the luncheon on Tuesday, April 15. The Saskatchewan Energy Minister, Eldon Lautermilch, spoke at the Monday luncheon.

To quote Ian Richardson, Vice President of Canadian Operations for Northstar Drilling Systems, Inc., the Horizontal Well Workshop is the best opportunity for *"rolling up your sleeves and getting down to things."* Almost every imaginable professional in the oil industry attends the workshop; from mud loggers and geologists to managers and petroleum engineers. People in the industry agree that this workshop is the best way of getting a real diverse group in one place at one time.

The workshops have paid off in terms of real activity (i.e. the Red River "B" Zone in Bowman County, North Dakota). At the 1994 Horizontal Well Workshop in Minot, the idea of horizontal drilling in the zone was presented. Later that year, the first horizontal well was drilled. The presentation at the conference (by then NDGS Assistant State Geologist Bill McClellan) got others in the industry to think about it. That sparked enough interest to get the project started. The result was Bowman County emerging from one of the lowest oil-producing counties in the state (at approximately 100,000 barrels a month) to the top producing county, at approximately 500,000 barrels a month.

Our series of Horizontal Well Workshops have been a phenomenal success. We look forward to the Sixth International Horizontal Well Workshop in 1998!

North Dakota Horizontal Drilling Facts

1. Ninety-five of 104 horizontal tests drilled in North Dakota during 1996 were productive.[1]
2. Eighty-three of the 104 horizontal tests drilled in North Dakota were drilled in the Red River Formation; 79 of those were productive.[1]
3. Production from horizontal wells currently accounts for 23% of the total North Dakota oil production although only 10% of the state's producing wells are horizontal wells.[1]
4. Employing horizontal drilling technology, GeoResources, Inc. has successfully revived Wayne Field which was thought to be essentially depleted. Today's horizontal wells are producing at higher oil rates than did the original (vertical) field wells when they were newly completed. In the process, GeoResources set a number of records for the Williston Basin and the world:[2]
   - First use on the U.S. side of the Williston Basin of a parasite string for nitrogen injection to achieve underbalanced drilling conditions.
   - The longest multi-lateral drilled underbalanced well in the Basin - 6332 feet of horizontal lateral length drilled underbalanced.
   - A record run on a Reed Tool Co. 6⅛" rock bit; the same bit was used to drill the entire well (155.2 total hours).
5. Horizontal drilling has been instrumental in reversing North Dakota's declining production trend.
6. The completion of a Burlington Resources Oil and Gas Co. horizontal well in a new field zone in Carter Field has set off heavy leasing activity in Burke County.
7. Discovered in 1994 by using horizontal well technology, the Cedar Hills Red River "B" Field, being developed exclusively with horizontal drilling, has moved Bowman County into the number one producing county in North Dakota. Bowman County now produces over 500,000 barrels of oil per month.
8. From estimates of ultimate recoverable reserves, Cedar Hills Red River "B" horizontal field will most likely be the *largest oil field yet to be found in North Dakota.* Ultimate recovery estimates by Continental Resources, Inc. are from 130 million to over 200 million barrels of oil. Recovery of 100 million or more barrels of oil would classify a field as a "giant field" (according to the definition used in the USA, western Europe, Mexico, and much of Canada).
9. As a result of its production through horizontal wells, Saskatchewan has set consecutive single-year production records for each of the last four years. Remaining oil reserves have shown similar growth. However, production from vertical wells continued to decline during this same period. At year end 1996, horizontal wells accounted for about 54% of the monthly oil production while comprising only 19% of the total number of producing wells.[3]

[1] NDIC Oil & Gas Division production data
[2] *Improved Recovery Week,* December 2, 1996
[3] Saskatchewan Energy and Mines production data

The Sheyenne National Grasslands

by

Ann M.K. Fritz

While it may be easy to imagine the grass-covered prairie in North Dakota, it may be difficult to imagine sand dunes occupying that same prairie. Our cold winters, abundant snowfall and temperate summers are not typically associated with an area that has sand dunes. Sand dunes *do* occur in North Dakota - and Nebraska and even Michigan. What is needed for dunes to form is wind and sand; two very simple ingredients that certain regions of North Dakota have in abundance. One of these regions is located in the southeast corner of the state, the Sheyenne National Grasslands *(Figure 1)*. The rolling, grass-covered dunes and forested Sheyenne River valley make the Sheyenne National Grasslands one of the most scenic and unique regions in North Dakota.

The uniqueness of the Sheyenne National Grasslands and surrounding area is due to its complex geologic and cultural history. The Grasslands are located in the Red River Valley, in a region known as the Sheyenne Delta, one of the former inlets to former glacial Lake Agassiz. The area was covered by ice during Wisconsin time, and flooded by waters of Glacial Lake Agassiz thousands of years later. There is evidence of human occupation in the Sheyenne Delta region as early as 8,000 years ago. Considering the varied ranching and recreational activities that take place today, the Sheyenne Delta and the Sheyenne National Grasslands have a truly fascinating history.

Formation of the Sheyenne Delta

Perhaps the most perplexing issue of the Sheyenne Delta is its name. The Sheyenne Delta was first named by Warren Upham, a geologist who mapped the region in the late 1890's. Upham believed the extensive sand deposits were an ancient delta into Lake Agassiz. More recently, Clayton et al. (1980) describe the sediments as an underflow fan. Even though the interpretation of the way the sediments were deposited has changed, the name has persisted ever since Upham's time.

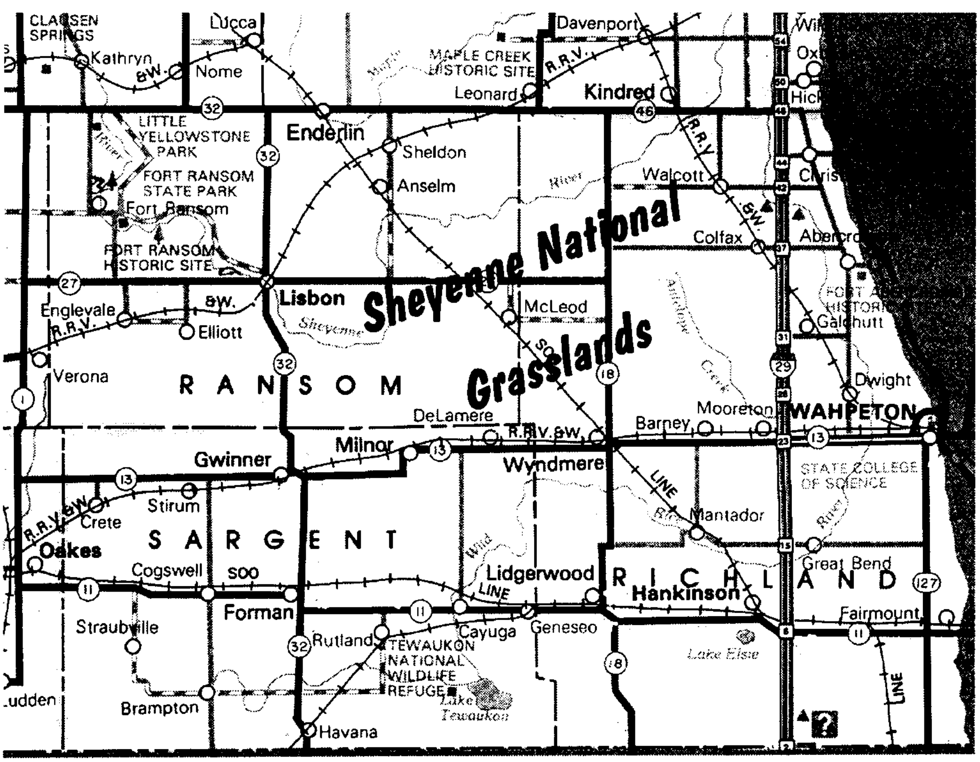


Figure 1. Location of the Sheyenne National Grasslands, southeastern North Dakota.

Along the western margin of former Lake Agassiz, a series of large underflow fans formed at the mouths of the major spillways entering the lake (Fenton et al., 1983). The occurrence of the underflow fans, which include the Sheyenne Delta, is one of the tools that geologists use to reconstruct the history of water levels in the lake. Underflow fans form in deep water (deeper than a deltaic deposit), as a river or stream deposits sediment into a larger body of water. In an underflow fan, "the deposits gradually grade downslope from coarse sand near the apex of the fan, through silt to clay in the deepest part of the basin" (Fenton et al., 1983). Missing in fan deposits are the foreset and topset beds characteristic of a delta *(Figure 2)*.

How did the Sheyenne River become a major spillway to Lake

Agassiz? Today, both the Sheyenne and James Rivers are called "underfit streams"; that is, the modern stream is much smaller than the valley it occupies. The Sheyenne and the James Rivers formed the two major meltwater drainages as the late Wisconsin ice sheet retreated north and eastward from North Dakota (Brophy and Bluemle, 1983). In late Wisconsin time (10,000 to 15,000 years ago), the Sheyenne established itself as an ice-marginal stream next to the receding ice sheet *(Figure 3)*.

Approximately 11,500 years ago, the ice began disintegrating and glacial Lake Agassiz began to form in the Red River lowlands. This first stage in the formation of Lake Agassiz is called the Cass Phase. (For a summary of the stages of Lake Agassiz, see *Warped Beaches of Glacial Lake Agassiz*, NDGS Newsletter, v. 20, no. 3. For a more thorough discussion of Lake Agassiz, see NDGS Report of Investigation 60 by Michael Arndt). As ice retreated, large proglacial lakes also began to form upstream *(Figure 4)*. The broad, deep trenches of the Sheyenne and James Rivers probably formed as a result of catastrophic drainage of glacial lakes Souris and Minnewaukan (Kehew and Lord, 1986). The sediments that the Sheyenne River carried were deposited in Lake Agassiz as a broad fan near the shore and deep-water clays farther from the fan margin.

By about 10,900 years ago, during a period in Lake Agassiz history called the Moorhead Phase, Lake Agassiz had established an eastern outlet into Lake Superior and the southern outlets were abandoned. The abandonment of the southern outlets was due to the disintegration of the glaciers in northwestern Ontario. The Sheyenne River, following a new, lower course, cut a trench into the sand and gravel fan that it had deposited earlier. The glacier advanced again about 9,900 years ago, plugging the eastern outlets into Lake Superior. With the eastern outlets plugged, the southern outlets again became active as Lake Agassiz filled once again to the level it was 1,700 years earlier. This level is known as the Campbell beach. Wave action and erosion at the northeastern margin of the fan created a steep escarpment marking the Campbell level *(Figure 5)*.

By 9,500 to 9,200 years ago, the southern Red River basin became dry land as Lake Agassiz was again using the eastern outlet into Lake Superior. The Sheyenne River retrenched its earlier deposits and extended its reach to a point just north of Fargo. At this point, the Sheyenne joins the Red River *(Figure 6)*. In the present day, the flow in the Sheyenne River is regulated by releases from Baldhill Dam, at the south end of Lake Ashtabula in Barnes County.

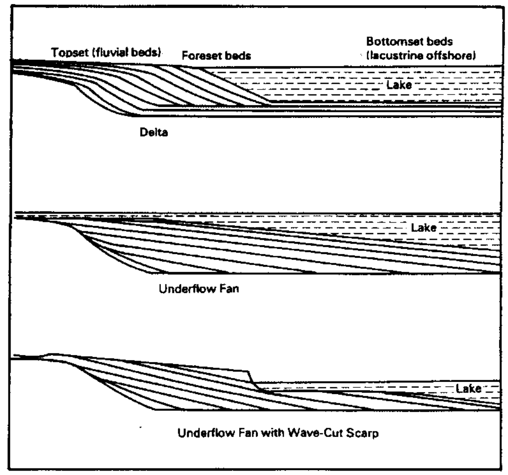


Figure 2. Comparison of delta, underflow fan and wave-cut underflow fan. The water level is higher on an underflow fan than on a delta (after Fenton et al., 1983).

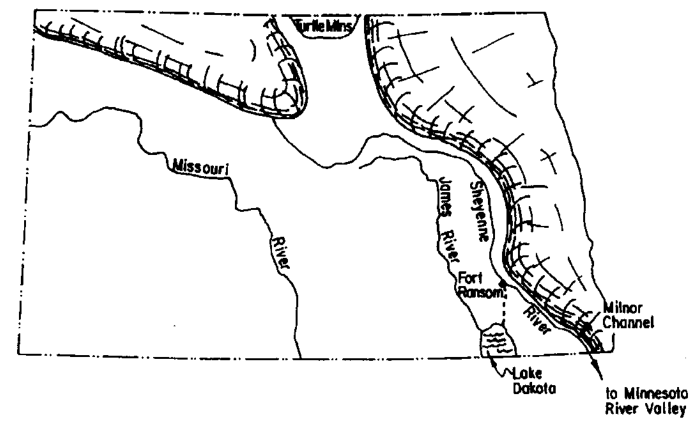


Figure 3. As ice retreated eastward, the Sheyenne River abandoned its previous course south of Fort Ransom (shown by dashed line) for the lower ground to the east. The course of this new channel took the Sheyenne eastward, towards the Red River lowlands and the Minnesota River Valley (after Brophy and Bluemle, 1983).

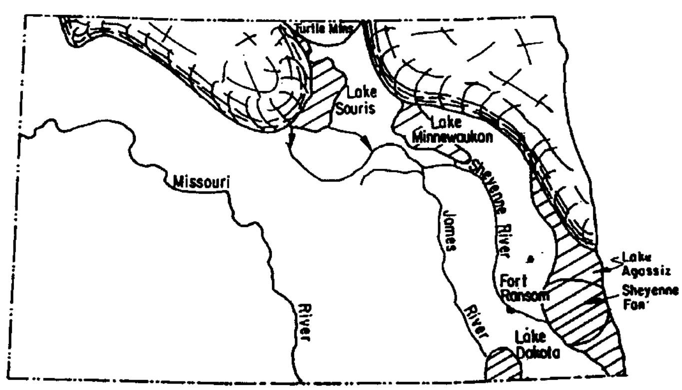


Figure 4. By 11,500 years ago, ice retreat in the north has created two proglacial lakes which drain into the Sheyenne Valley. To the south, Lake Agassiz has formed and the Sheyenne enters it and builds a large fan of sediments (from Brophy and Bluemle, 1983).

Landforms of the Sheyenne Delta Region

The most recent geologic map of the Sheyenne Delta region was completed in 1987 by Ken Harris. Harris subdivided the eolian landforms of the Sheyenne Delta into high-relief forms, low-relief forms, and sandsheets *(Figure 7)*. High-relief dunes are usually restricted to within one to two miles of the Sheyenne River trench. They are generally northwest to southeast trending transverse ridges that are higher than 30 feet. Low-relief dunes are less than 30-feet high. The dunes have a hummocky, wind-blown surface that is generally stabilized by vegetation. Blowouts occur when there is little or no vegetative cover on the sand. The sandsheet consists of sand and silt that can be up to ten feet thick in places. The surface of the sandsheet is undulating and wind-scoured.

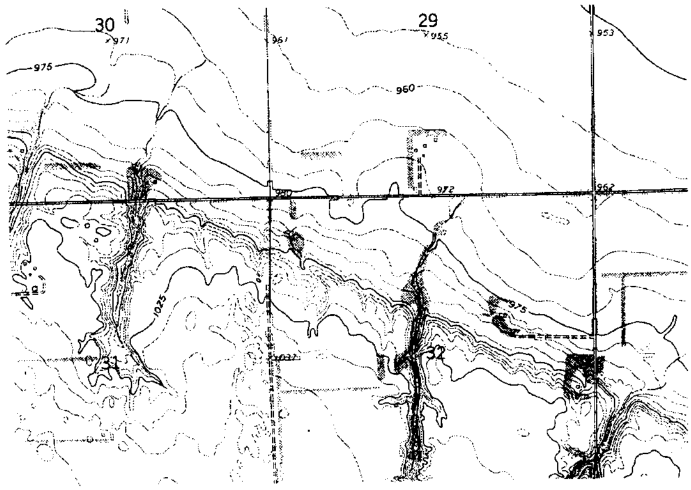


Figure 5. Wave cut and eroded scarp formed during the Emerson Phase (9,900 years ago). The region shown is in T. 137N, R. 51W, Secs. 31 & 32 (Leonard, ND 7.5 minute topographic quadrangle map).

The age of the high-relief dunes in not certain, but they are believed to be composed of glaciofluvial sediments that were originally deposited in the later stages of fan formation (Running, 1996). The dunes appear to have been formed by prevailing southerly winds, although the prevailing winds are now from the north. At the present time, some of the high-relief dunes appear to be migrating in a southeasterly direction on the north side of the trench as evidenced by sand enveloping nearby cottonwood trees (Running, 1996). Blowouts are common on dune and sandsheet surfaces that are not stabilized by a vegetative cover, making farming and ranching a challenging occupation in those areas.

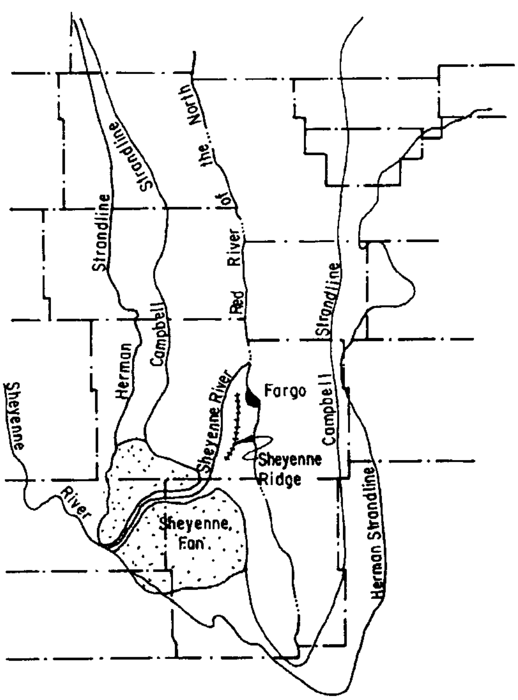


Figure 6. Lake Agassiz was using lower, eastern outlets by about 9,500 to 9,200 years ago and the southern basin became dry land. The Sheyenne River retrenched its fan and extended its course to a point just north of Fargo, ND, where it became a tributary to the Red River. The Sheyenne Ridge marks the Sheyenne's channel during the Mororhead Phase (from Brophy and Bluemle, 1983).

Designation: National Grasslands

There is a long history of human occupation in the Delta region. One archaeologic site south of Kindred, North Dakota, was occupied as early as 8,000 years ago (Michlovic, 1996). Early inhabitants of the Sheyenne River valley used the river banks as temporary camps and food processing sites (Michlovic, 1996). The majority of European settlement in the Delta region occurred in the 1870's through the 1890's (Richland County Historical Society, 1977). Under the Homestead Act of 1862, land was provided to individuals who would live on it and make certain improvements. The first homesteaders located along the river drainages where there was water, shelter, and wood. After the prime areas filled in, the later homesteaders settled on less desirable land. By the end of the 1870's, Native Americans lost their historic use of the Northern Great Plains as cattle replaced the buffalo.

The Dust Bowl of the 1930's plagued residents all over the Great Plains. In *The History of Sheyenne Township*, Mrs. Jurgen Haugen writes that "the Depression struck and with it the dry years. The light, sandy soil which had been used for crops started to blow around. About the only thing that grew was the Russian Thistle" (Haugen, 1974). Large scale, dryland farming methods were no longer profitable and area farmers reverted to a few milk cows, a few hogs, and enough corn and grain for feed (Milton, 1977). Although some farmers in the Sheyenne Delta region got by, it seemed that most residents of the Great Plains were on a course for financial ruin. By the early 1930's, as many as 70% of the

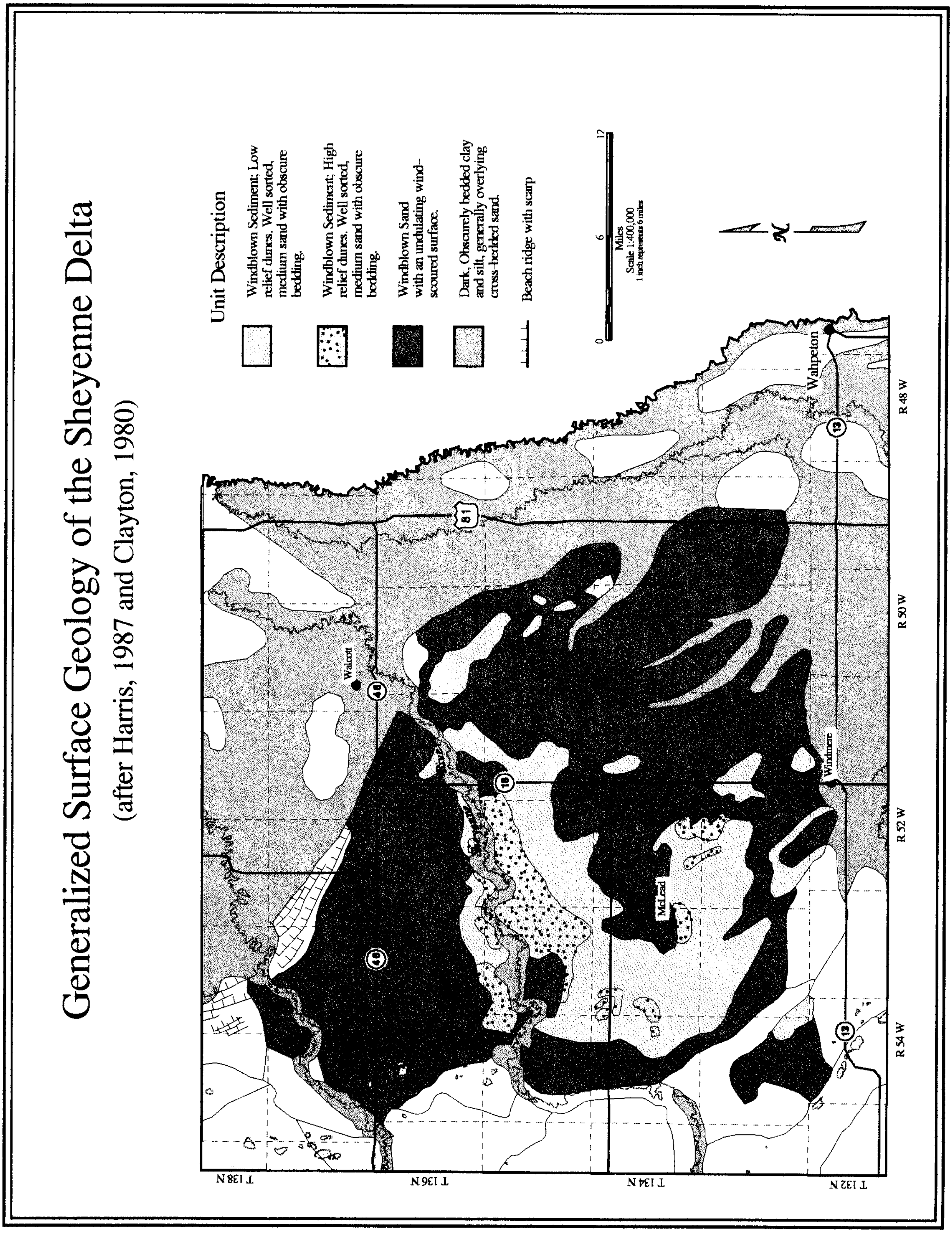


Figure 6. Surface geology of the Sheyenne Delta (after Harris, 1987 and Clayton, 1980).

homesteaders in the Great Plains were delinquent in their taxes. Hundreds of thousands of residents were forced to leave.

The U.S. Government proposed "proper land utilization" as a solution to the crisis and offered to purchase "submarginal land" that is, land that was deemed to be unacceptable for profitable farming. The National Industrial Recovery Act of 1933 and the Emergency Relief Appropriations Act of 1935 authorized federal purchase of damaged or abandoned land for an average of $4.40/acre. Another federal land-purchasing program was the Bankhead-Jones Farm Tenant Act of 1937. In Sheyenne Township alone, more than one third of the land was purchased by the government. Between 1933 and 1943, the federal government purchased nearly ten million acres of drought stricken and wind-eroded land throughout the U.S. The government's intervention was not always looked upon favorably, though. Some residents of the Great Plains believed that they were being offered an unfair price for their land. Mrs. Jurgen Haugen (1974) writes that the average value of land and buildings in Sheyenne Township was $10.32 per acre in 1934. The price the federal government paid for the land in 1937, however, was $6.45 per acre.

Most of the government-purchased land was used for conservation projects, demonstration plots or natural areas. From the Texas panhandle northward to Watford City, North Dakota, the majority of the submarginal land purchased in the Great Plains was designated as a "National Grassland" and was managed by the Soil Conservation Service (SCS) until 1954. At that time the federal government transferred the management of the land from the SCS to the U.S. Forest Service. Today, the Forest Service continues management of the nearly 4 million acres of land in the U.S. designated as National Grasslands. The Sheyenne National Grasslands are administered as part of Custer National Forest, headquartered in Billings, Montana.

The Sheyenne Grasslands Today

Visitors to the Sheyenne National Grasslands may ask, "Where's the grass as high as an elephants eye?" Part of the misconception visitors may have of the National Grasslands is due to some of the literature written by the Forest Service itself, "The land of grass . . .", touts a 1964 brochure written by the U.S. Forest Service. Even today, Forest Service brochures describe the Great Plains as a "sea of grass". Of the roughly 70,000 acres in the Sheyenne National Grasslands, there are only remnants of the tall grass prairie left. Most of the original sod was plowed under or used as pasture during the early European settlement period of the Delta region. Today, visitors will see a sea of grass, but it has most likely been grazed by hungry cattle from nearby ranches.

Using the National Grasslands for summer grazing is part of the Forest Service's multiple-use philosophy. Multiple-use management of the National Forest Service lands, including the National Grasslands, is a mandated authority given to the Forest Service through numerous laws and regulations, such as the Bankhead-Jones Farm Tenant Act mentioned earlier, and the Multiple-Use Sustained Yield Act of 1960 and amendment of 1976. The Multiple-Use Act states that the National Forests be administered for recreation, timber, watershed, wildlife, and fish purposes. This Act was amended in 1976 to include the National Grasslands.

Today, farmers, ranchers, hikers, hunters and campers all share the National Grasslands. The Forest Service grants a grazing permit to the Sheyenne Valley Grazing Association, which in turn permits ranchers grazing rights on National Grasslands property. The Grazing Association, formed in 1941, currently has about 80 permittees that use the National Grasslands for summer grazing. Multiple use also allows for increased recreational opportunities in the Grasslands. Hiking, horseback riding and hunting are the three dominant recreational activities in the area, according to Bryan Stotts, District Ranger of the Sheyenne National Grasslands. Twenty-five miles of the North Country Hiking Trail travel through the Grasslands, making the Grasslands a popular destination for hikers. The North Country Trail, part of the National Scenic Trail system, is planned to run from Crown Point, New York to Lake Sakakawea, North Dakota. Other recreational uses include camping, some canoeing and fishing along the Sheyenne River.

Wildlife and nature observation are also considered important uses in the multiple-use concept. Despite its relatively small size, the Sheyenne National Grasslands contain some of the most unique plant and animal species in the state. Oak, ash, elm, and basswood trees, uncommon in most other parts of North Dakota, occur in abundance along the lower reaches of the Sheyenne River. The Sheyenne National Grasslands contain the only viable reproducing population of the Greater Prairie Chicken in the state. The Greater Prairie Chicken is considered a threatened species and is protected by state law. Consequently both prairie chicken and sharptail grouse hunting is prohibited on the Sheyenne National Grassland. The grasslands also contain one of the largest populations of the Western Prairie White-Fringed Orchid known to exist.

Resource management in the grasslands is a careful balancing act between seemingly conflicting uses; wildlife photography and cattle ranching, hunting and bird watching, horseback riding and hiking. Currently, a comprehensive recreation plan does not exist; there are no developed campsites and the North Country Trail is one of the few designated hiking trails through the area. Excessive off-trail travel contributes to blow-outs, causing erosion to happen even more quickly. Such open use, while exciting for an outdoor enthusiast, can create havoc on the fragile ecosystem. Erosion is probably the most serious geologic hazard in the National Grasslands. The easily eroded soil makes it difficult for plant communities to become established. Increased flows in the Sheyenne River also contribute to bank erosion and loss of trees and valuable habitat along the river.

Over the past year, the U.S. Forest Service has been developing revised land and resource management plans. The management plans would address rangeland and forest health, community and lifestyle relationships, livestock grazing, oil and gas leasing, plant and animal control, recreation management, and special area designation. Bryan Stotts is currently in the process of developing a recreation plan for the Sheyenne National Grasslands. The plan would include hiking trails with interpretive signs featuring different cultural, geological and other natural features of the Grasslands. A recreation plan would involve the assistance of botanists, landscape architects, and wildlife specialists to achieve the maximum beneficial use of the land. Although the Grasslands do not yet have a recreation plan in place, don't let that stop you from visiting one of the most scenic and unique parts of North Dakota. For information on the Sheyenne National Grasslands, contact: Sheyenne Ranger District, P.O. Box 946, Lisbon, ND, 58054, (701) 683-4342.

I would like to thank Bryan Stotts, District Ranger of the Sheyenne National Grasslands, for his cooperation and interest in preparing this article. Also my thanks to Dave Cawrse, Nebraska National Forest Planning Coordinator, for permission to use information reported in the Revision Reporter-Northern Great Plains Management Plans Revisions, March 1997, v. 2 (1).

References

Arndt, Michael, 1977, *Stratigraphy of Offshore Sediment - Lake Agassiz, North Dakota,* NDGS Report of Investigation 60, 63 p.

Bluemle, John P., 1979, *Geology of Ransom and Sargent Counties,* Grand Forks, NDGS Bulletin 69, Part I, 84 p.

Bluemle, John P., 1991, *The Face of North Dakota, Revised Edition,* Bismarck, NDGS Educational Series 21, 178 p.

Brophy, J.A., and J.P. Bluemle, 1983, *The Sheyenne River: Its Geological History and Effects on Lake Agassiz,* in J.T. Teller and L. Clayton, eds., *Glacial Lake Agassiz,* St. Johns, Newfoundland, The Geological Association of Canada Special Paper 26, p. 173-185.

Clayton, Lee, and S.R. Moran, and J.P. Bluemle, 1980, *Explanatory Text to Accompany the Geologic Map of North Dakota,* Fargo, NDGS Report of Investigation No. 69, 93 p.

Fenton, M.M., S.R. Moran, J.T. Teller, and L. Clayton, 1983, *Quaternary Stratigraphy and History in the Southern Part of the Lake Agassiz Basin,* in J.T. Teller and L. Clayton, Ed., *Glacial Lake Agassiz,* St. Johns, Newfoundland, The Geological Association of Canada Special Paper 26, p. 49-74.

Harris, K.L., 1987, *Surface Geology of the Sheyenne River Map Area,* NDGS Atlas Series Map 15, AS-15-A1, 1 p.

Haugen, Mrs. Jurgen, 1974, *The History of Sheyenne Township,* Richland County Historical Society, 26 p.

Kehew, Alan and Mark Lord, 1986, "Origin and Large-scale Erositional Features of Glacial-Lake Spillways in the Northern Great Plains," *Geological Society of America Bulletin*, v. 97, p. 162-177.

Milton, Joseph, 1977, *The Dirty Thirties,* in Richland County Historical Society, 1977, *A History of Richland County,* Dallas, TX, Taylor Publishing Company, p. 477.

Richland County Historical Society, 1977, *A History of Richland County,* Dallas, TX, Taylor Publishing Company, 632 p.

Running, Gary, 1996, *The Sheyenne Delta from the Cass Phase to the Present: Landscape Evolution and Paleoenvironment,* in K. Harris, M. Luther, and J. Reid, eds., *Quaternary Geology of the Southern Lake Agassiz Basin*, NDGS Miscellaneous Series 82, p. 136-152.

Study of Devils Lake and Stump Lake Outlets

by

Ann M.K. Fritz and Edward C. Murphy

Introduction

Devils Lake, the largest natural body of water in North Dakota (Bluemle, 1981), has been getting larger every year for the past three years, much to the frustration of area residents. The North Dakota State Water Commission (NDSWC), in cooperation with the North Dakota Geological Survey (NDGS), was requested by the Devils Lake Basin Joint Water Resource Board to conduct a field study of sedimentation in the Jerusalem and Tolna outlets *(Figure 1)*. The purpose of the investigation was to determine as precisely as possible the geologic history of the outlets with an emphasis on the amount of sedimentation that has occurred in the outlets during recent time.

Our field work consisted of drilling auger holes along a north-south transect through each outlet. In addition, a series of trenches was dug, also in a north-south transect across each outlet. We collected sediment samples from selected horizons for pollen analysis and radiocarbon (^{14}C) dating to determine the sedimentation history of the outlets. When encountered in the trenches, wood was also collected for radiocarbon dating.

The purpose of this article is to provide a summary of field activities and preliminary conclusions based on the sediments encountered in the trenches and drill holes. Pollen analysis and radiocarbon dating have not been completed, therefore, we cannot develop a chronostratigraphy (the age of the sediment and their time relation) at this time.

Background

As most residents of North Dakota and longtime readers of the *NDGS Newsletter* are aware, Devils Lake has a long history of fluctuating water levels (Bluemle, 1983 and 1995). Water levels have risen over 16 feet in the past three years flooding pasture, farmland, homes, businesses, and roads. As the *NDGS Newsletter* goes to press, water elevation in the lake is 1,441 feet above sea level. The NDSWC estimates that the water level in Devils Lake will rise to between 1,443.5 to 1,444 this year. If water levels continue to rise even higher, the scenario will be something like this: if the water level in Devils Lake reaches an elevation of 1,446.6 feet, water will flow into Stump Lake through what is referred to as the Jerusalem outlet *(Figure 1)*. If the water level in the combined Devils-Stump Lake reaches an elevation of approximately 1,457, water will flow through the Tolna outlet and into the Sheyenne River *(Figure 1)*. The Sheyenne River flows southeast to the Red River, which in turn flows north

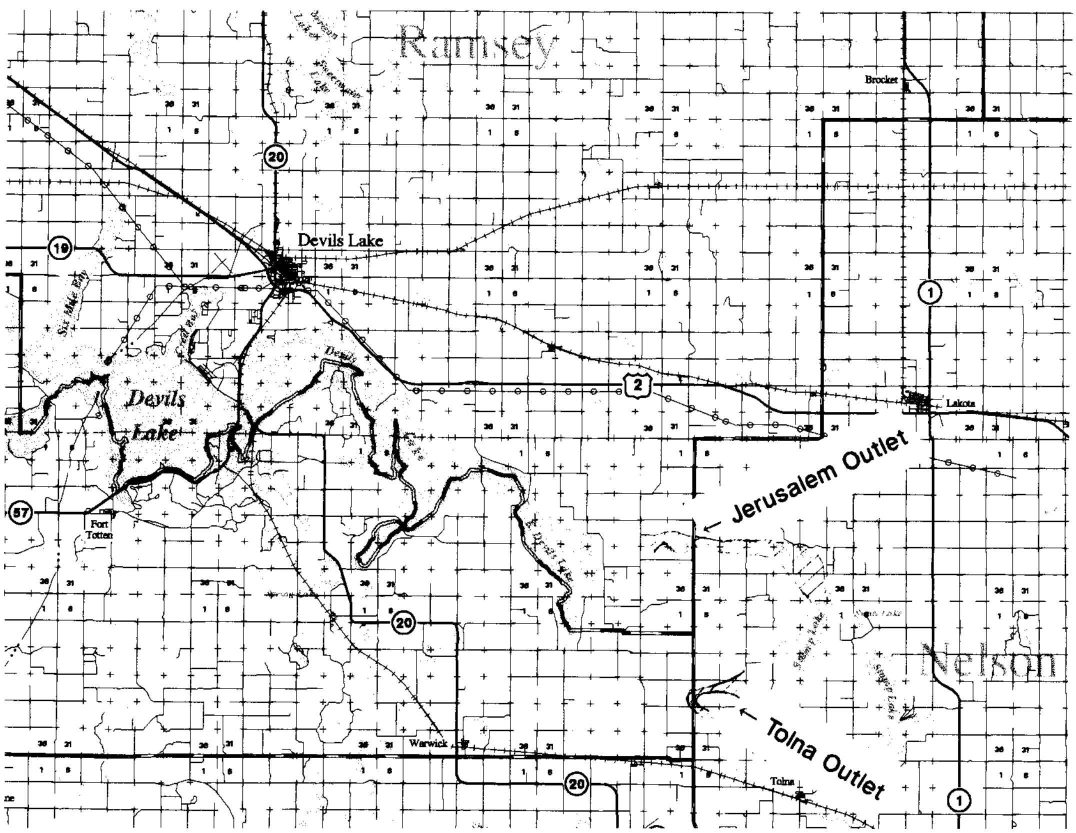


Figure 1. Location of the Jerusalem outlet for Devils Lake and the Tolna outlet for Stump Lake.

Figure 2. View looking northwest toward Camp Grafton, taken by Dr. Gordon Bell in March, 1962.

The pole was located near the junction of State Highways 57 and 20, about four miles south of the town of Devils Lake. The sign graphically illustrates how the lake fell from earlier water levels.

The bottom sign marks the level of the lake in the year 1910 when the lake stood at 1,424 feet above sea level. The next sign up marks the 1900 level (1,424 feet). The placard immediately above that marker reads "1,425 Proposed level under Missouri Diversion".

The marker immediately above the sign is the 1890 level of 1,425 feet. This level (1,425) is also the lake level in 1994, the date of the USGS Camp Grafton 7.5 minute quadrangle. The second sign from the top reads "1880 Lake elev. 1,433". The top marker reads "1870 lake elev. 1,437".

Dr. Bell estimated the lake level to be 1,417 at the time he took this photo.

Figure 3. NDGS Geologist Ann Fritz near the Jerusalem outlet site. Large quantities of snow had to be removed to enable us to gain access to both outlets. Photo by Ed Murphy.

into Canada. A more exact overflow elevation of 1,446.6 for the Jerusalem outlet was recently determined by a global positioning system (GPS) survey conducted by the NDSWC and replaces the 1,445 elevation previously used by the NDGS. The Tolna outlet elevation, however, has not been surveyed and is estimated from a U.S. Geological Survey 7.5 minute topographic quadrangle.

The fluctuating water level of Devils Lake has been a concern to area residents for a number of years. *Figure 2* graphically illustrates declining water levels in the lake from 1870 to 1962. In 1983, then Governor Olson issued a Disaster Emergency Proclamation for the area due to the damage to roads and property caused by flooding (Bluemle, 1983). A drought that began in 1988 caused the lake level to decline again. More recently, however, the water level in the lake has been rising, reaching an elevation of 1,439.32; the highest recorded water elevation in this century. The continued fluctuating water level has caused some residents to demand an artificial means to control the water levels to protect their homes and property from flooding. Although President Clinton approved the inclusion of the Devils Lake outlet in the appropriation for the Garrison Diversion Project, the U.S. House of Representatives voted down all but the planning portion of the request. The House stated that the inlet/outlet is a long-term solution and not an emergency measure (the type of funding being considered in the appropriation request) and voted down the full request.

One of the objectives of this field study was to determine the amount of recent sedimentation that has occurred in the outlets; this can only be done by determining the relative age of the sediment. Radiocarbon dating and pollen analysis are two useful tools scientists use to determine the relative age of sediment. Pollen analysis can be a particularly useful tool in trying to determine "recent" sedimentation. Russian thistle (*Salsoa iberica*) was introduced into North Dakota around the time of statehood. Pollen grains of this plant, along with pollen of cultivated grains such as wheat, rye and barley, are commonly used by scientists to determine an upper date (approximately 1889 in north-central North Dakota) in sediment cores. Carbon-14 dating is used for organic material, such as wood, bone, or plant matter found in buried soils. The radiocarbon dating method measures the amount of radioactive decay of ^{14}C in a particular organic sample (Libby, 1952). The method became common in the 1940's and 1950's and has routinely been used since that time. These proven methods, pollen analysis and radiocarbon dating, will be used to approximate the historic and pre-historic position of the Devils Lake and Stump Lake outlets. The methods are, of course, dependant on the presence of preserved pollen grains and other organic matter in the sediment. Pollen is commonly preserved in topographic depressions frequented by standing water; this situation is common in the Devils Lake region. Buried soil horizons, wood and bone have previously been dated in the area (Bluemle, 1991).

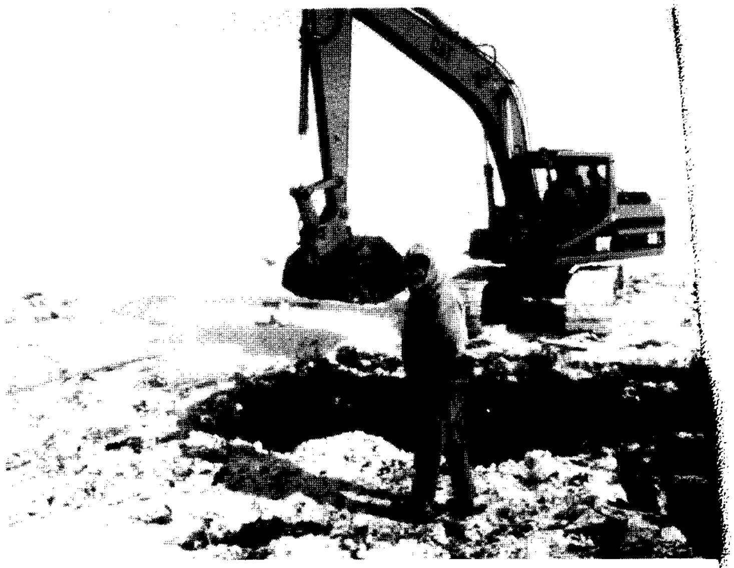


Figure 4. Backhoe used to dig trenches in both outlets. Roger Johnson is pictured obse trenches being dug in his pasture in the Tolna outlet. Shown in the background is the truck-m Giddings soil auger. Photo by Ed Murphy.

Description of Field Investigation

Working in either near blizzard conditions or sub temperatures, we completed our field work during the we of March 3 and March 10, 1997. The working conditions w unusually harsh, even for a North Dakota winter *(Figure* The reason we completed the field work in the winter because of the high water-table: if the ground was thawed would not have access to the outlets with our equipment. used a Giddings truck mounted soil probe to auger three holes in the Tolna outlet. Two deep trenches in the To outlet were completed using a backhoe *(Figure 4)*. Fi shallow trenches and eight auger holes were completed in Jerusalem outlet.

The Jerusalem outlet is marked by a chain of mars lowlands and an intermittent stream at the base of a bro (two-mile-wide) valley between East Devils Lake and Stum Lake *(Figure 1)*. Based on eight drill holes and five trenche *(Figure 5)*, the sediments encountered in the Jerusalem outle generally consisted of brownish-black loam overlying san and gravel or laminated silty clay. All of the trenches in the Jerusalem outlet ended in an unsorted, unstratified, sandy clay that contained many pebbles (glacial till). *Figure 6* shows the geologic cross section through the Jerusalem outlet. A distinctive feature in trenches JT1 and JT5 was a buried soil horizon that occurred at a depth of 6.5 feet below the ground surface.

The Tolna outlet is a well-defined, narrow and steep-walled channel that exits Stump Lake from the southwest side of the lake, turns abruptly south, and then gradually trends in a southeastern direction toward the Sheyenne River. For accessibility reasons, we chose one of the narrowest parts of the channel to complete the trenches and the auger holes *(Figure 7)*. The sediment in the trenches in the Tolna outlet consisted of alternating layers of silt, silty clay, and sand and gravel *(Figure 8)*. We found at least one moderately-developed paleosol with an undulating lower surface at a

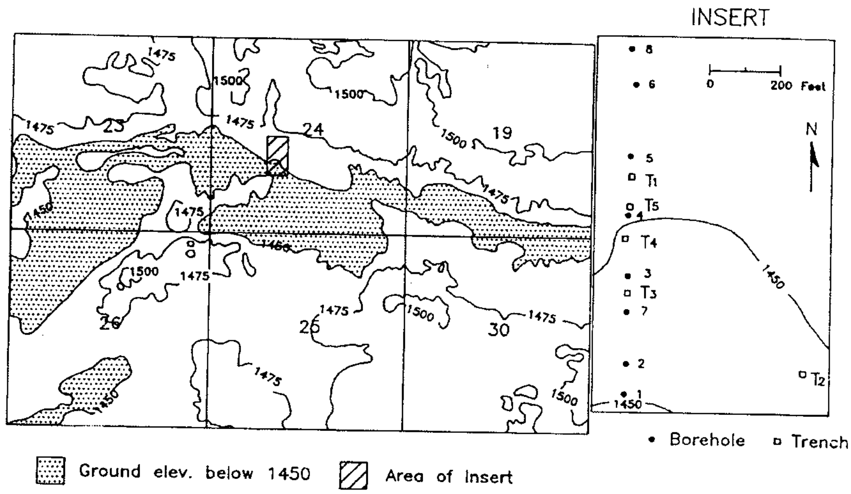


Figure 5. Location of drill holes and trenches in the Jerusalem outlet of Devils Lake in Ramsey County (T. 152N, R. 60W, Sec. 24).

'T' indicates trench location and numbers are drill hole locations. Contours are feet above mean sea level.

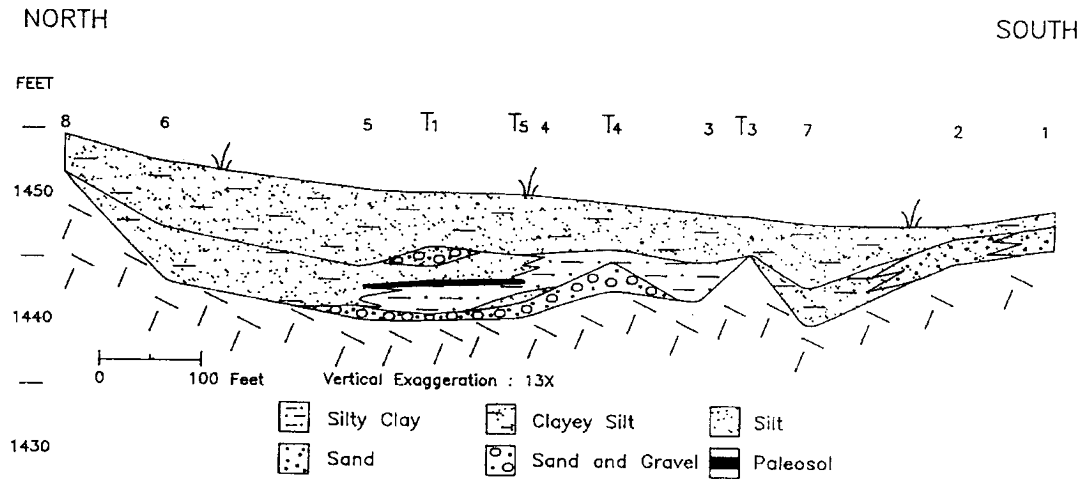


Figure 6. North-south geologic cross section through the Jerusalem outlet.

depth of approximately eight feet below the ground surface *(Figure 9)*. At the bottom of both trenches there was a brown, moderately decomposed and compacted peat. The peat contained poorly preserved shells and clams and some seed pods were visible. Peat samples have been submitted to Drs. Don Schwert and Allan Ashworth, Geology Department, North Dakota State University, for detailed analysis and identification of insect remains.

We collected a total of 133 sediment samples from the trenches in both the Jerusalem and Tolna outlets. We collected 50 sediment samples from the trenches in the Jerusalem outlet; 22 samples were submitted for pollen analysis and two were sent for radiocarbon dating. In the Tolna outlet, we collected 83 sediment samples as well as four wood samples, two paleosol samples and four high-carbon sediment samples for radiocarbon dating. *Figure 10* shows an example of some of the wood that was found in the Tolna outlet and submitted for radiocarbon dating. Fifteen samples were submitted for pollen analysis in the Tolna outlet. Samples for pollen analysis were first sent to Geolabs in Canada for processing, then to Dr. L. Farley Fleming in Denver, Colorado, for pollen identification.

Preliminary Conclusions

As this goes to press, we are currently waiting for the results of both the pollen analysis and radiocarbon dating and therefore it is emphasized that any conclusions we make at this point are preliminary. We do not know the age of the sediments in the outlets and therefore cannot yet develop a chronostratigraphy. However, based on the sediments themselves, we can infer something about the frequency of flooding in the outlets.

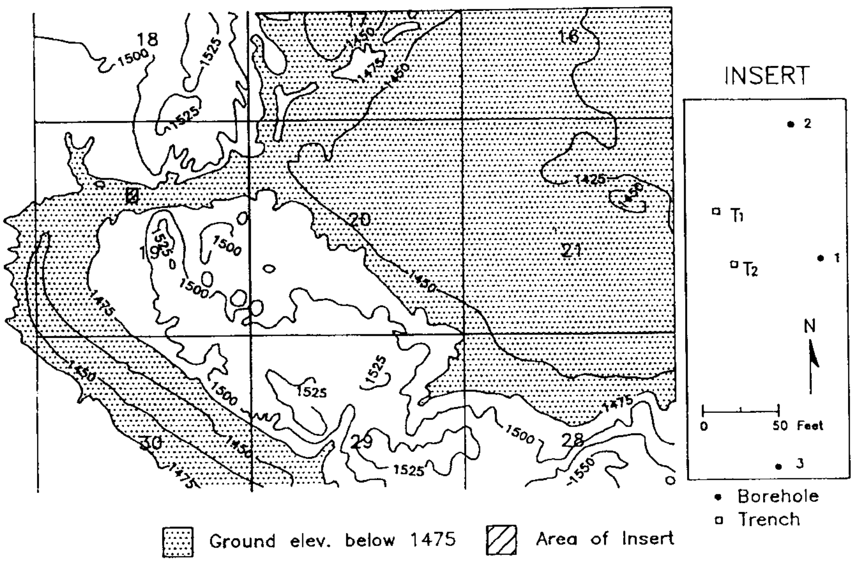


Figure 7. Location of drill holes and trenches in the Tolna outlet of Stump lake in Nelson County (T. 151N, R. 61W, Sec. 19). 'T' indicates trench location and numbers are drill hole locations. Contours are feet above mean sea level.

The sediments found in both outlets indicate alternating periods of flooding and subsequent exposure. In the Jerusalem outlet, silt containing abundant freshwater snails and clams indicate that there were prolonged periods of time that high water levels (greater than 1,446.6 feet) existed. Silt and silty clay containing abundant freshwater snails and clams also exist in the Tolna outlet also indicating high water levels (greater than 1,457 feet) for prolonged periods of time. The moderately well-developed buried soil horizons indicate that the surface was exposed long enough for soil to develop at least twice (present surface and 7 feet below the ground surface in JT1 and JT5, and eight feet below grade in TT1 and TT2). The presence of terrestrial snails is also evidence of dry periods.

The coarse-grained layers we encountered in Tolna outlet trenches, that is the layers of sand and gravel, may be more useful indicators of the frequency of flooding than the buried soils or silt loaded with shells. During times when water flowed from Stump Lake through the Tolna outlet, sand and gravel was often deposited over the pre-existing sediments. There are six layers of sand and gravel in TT1 and two layers of sand and gravel in TT2. An alternative hypothesis is that some of the coarse grained sediments in the Tolna outlet may not be flood deposits, but slope wash or colluvium. At the location of the trenches, the Tolna outlet is a narrow (300 to 400 feet wide), steep-walled channel. Heavy rain and gravity may have moved some sediment into the base of the channel. However, the grain size, fining upward sequences and pebble imbrication suggest that the sediments were deposited in moving water rather than by a gravity flow.

Using all of the information gathered during this field investigation, we hope to create a detailed sedimentation history (chronostratigraphy) of the Devils Lake basin. This information will be supplied to the NDSWC and the Devils Lake Joint Water Resource Board to assist them with their quest to find a long term solution for the fluctuating water levels at Devils Lake.

References

Bluemle, John P., 1981, "The Origins of Devils Lake", *NDGS Newsletter*, December, p. 7-9.

—, 1983, "Fluctuating Levels of Devils Lake", *NDGS Newsletter*, June, p. 33-36.

—, 1991, *Radiocarbon Dating of Beaches and Outlets of Devils Lake*, NDGS Miscellaneous Series No. 75, 10 p.

—, 1995, "Fluctuating Levels of Devils Lake", *NDGS Newsletter*, v. 22 (1), p. 7-9.

Libby, W.F., 1952, *Radiocarbon Dating*, Chicago, University of Chicago Press, 124 p.

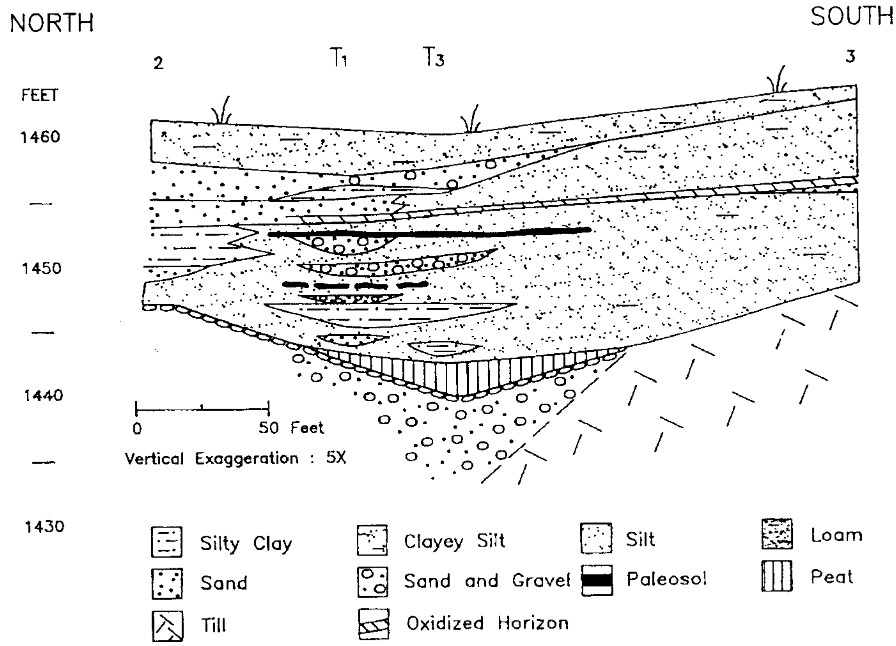


Figure 8. North-south geologic cross section through the Tolna outlet. See *Figure 7* for trench locations.

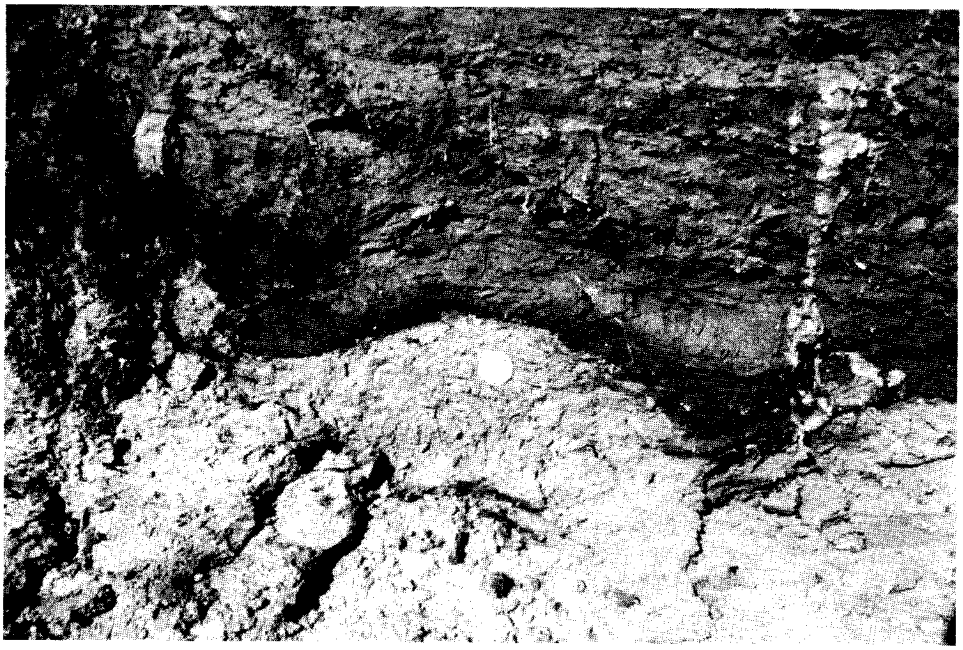


Figure 9. Buried soil, or paleosol, found at a depth of eight feet below the surface in Tolna Trench 2. Penny is shown for scale. Photo by Ed Murphy.

Figure 10. Example of wood sample taken from a depth of 19 feet in Tolna Trench 2. The piece of wood pictured here is eight inches long and approximately two inches in diameter. Photo by Ed Murphy.

Toils Induced by Weak Soils:

Geo-Historic Perspectives on Northern Pacific Railway's Construction of the Stockwood Fill, Clay County, Minnesota

by

Donald P. Schwert and Mark E. Peihl

Introduction

"The flatness of the surface that uniformly prevails throughout the valley may be regarded as a defect in its character that cannot be easily remedied." ~ William H. Keating (Geologist for the Long Expedition of the Red River Valley, 1823)

Underlying the flat surface of the Red River Valley of Minnesota and North Dakota are soils that induce some of the world's greatest agricultural productivity, as well some of its most challenging geotechnical conditions. The twin cities of Moorhead and Fargo rest on ≈ 32 m of smectitic clays and silty-clays, derived predominantly from late-glacial erosion and reworking of Pierre Shale (Cretaceous), and dispersed as suspended sediments into glacial Lake Agassiz. Beneath these cities, concrete caissons and steel pilings, emplaced generally to depths >32 m, support nearly all bridges, water towers, and high-rise structures. At the site of the Fargo water treatment plant (Midwest Testing Laboratory, 1989-91 data), typical soil engineering values for the Sherack Formation (depth: ≈ 1-6 m) are: PL=30, LL=85, N=12, and Qu=3000. For the uppermost Brenna Fm (depth: ≈ 8 m), typical values are PL=31, LL=113, N=6, and Qu=1370 (see box below). Where the lake sediments are unconfined, their high plasticity leads to slope instability; examples are prevalent along the valley walls and channel margins of the Red River and its tributaries. The high shrink-swell properties of these clays likewise cause foundation shifting, pavement failure, and utility line rupture.

Although Moorhead and Fargo, positioned near the axis of the basin, rest on some of the thickest accumulations of Lake Agassiz sediments, the stratigraphy underlying these cities is at least somewhat predictable. Approximately 6 m of the tan-buff, laminated silty-clays of the Sherack Formation are underlain by ≈ 26 m of the gray, slickensided, fat clays of the Brenna/Argusville formations, a monotony broken only by the occasional dropstone (albeit sometimes "house-sized") or a sand-cored compaction ridge. Toward the margins of the basin, however, the stratigraphy becomes much more problematic. Here, slope-wash, beach, spit, bar, submarine fan, and deltaic deposits often complexly interfinger the clay-rich lacustrine sediments.

Our report focuses on one such region: N½ of Secs. 7, 8 and 9, T. 139N, R. 46W, Downer and Glyndon South 7.5' quadrangles, Clay County, Minnesota. During the time of Lake Agassiz, this region received both fine-grained lacustrine sediments and coarser-grained deltaic/fan sediments, delivered by the Buffalo River from glacial uplands to the east. Waters of the Buffalo River today flow across the east and north of the region, producing frequent and occasionally severe flooding and deposition of backwater sediments. Although the study region lies on the floor of the Lake Agassiz basin, the Campbell strand and its associated shore and near-shore deposits lie within 2-3 km to the east. The eastward rise in topography from the study region is relatively striking; southeastward from the Minnesota Highway 9 underpass *(Figure 1)* at the Burlington-Northern (formerly Northern Pacific, or N.P.) tracks, the land rises up to 64 m (≈ 210 ft) over distances of ≈ 10 km (≈ 6 mi). Aquifers are numerous, generally local, often shallow, and frequently confined, with the regional slope inducing an artesian-pressure surface in many.

In other words . . .

All of the problems encountered at the Stockwood Fill site occured before the birth of a field of engineering called "soil mechanics". The foundation of soil mechanics and geotechnical engineering began in 1925 with the publication of *Erdbaumechanick* by Karl Terzaghi.

Geotechnical and civil engineers use different terms than geologists use to describe the physical properties of sediment. A geologist will describe the color, grain size (gravel, sand, silt or clay), the lithology (type of rock) of the sand and gravel grains, and describe how the sediment may have originally been deposited (genesis). The geotechnical engineer, on the other hand, will record the number of blows (N) and define the plastic limit (PL) and liquid limit (LL) by completing a series of laboratory tests. The PL, LL and N are all used to describe the engineering properties of sediment.

The moisture content of a soil determines how the soil will behave (in an engineering sense). If the moisture content of a soil is low, the soil behaves like a solid. If, on the other hand, the moisture content of a soil is very high, the soil may flow like a liquid. Depending on the moisture content, the behavior of a sediment can be divided into four basic states: solid, semi-solid, plastic and liquid. The moisture content of the soil at the transition from the semi-solid state to a plastic state is called the *plastic limit*. The moisture content of the soil at the transition from the plastic state to the liquid state is called the *liquid limit*. These limits are also called *Atterberg limits*, after the Swedish scientist who developed the laboratory methods used to measure them.

The number of blows, N, is the number of times it takes for a 140-pound-hammer dropped a height of 30 inches to sink a steel rod one foot into the sediment. The N-count is generally recorded on geologic logs that are written as a test hole is being drilled. The number of blows is a measure of the density of the soil.

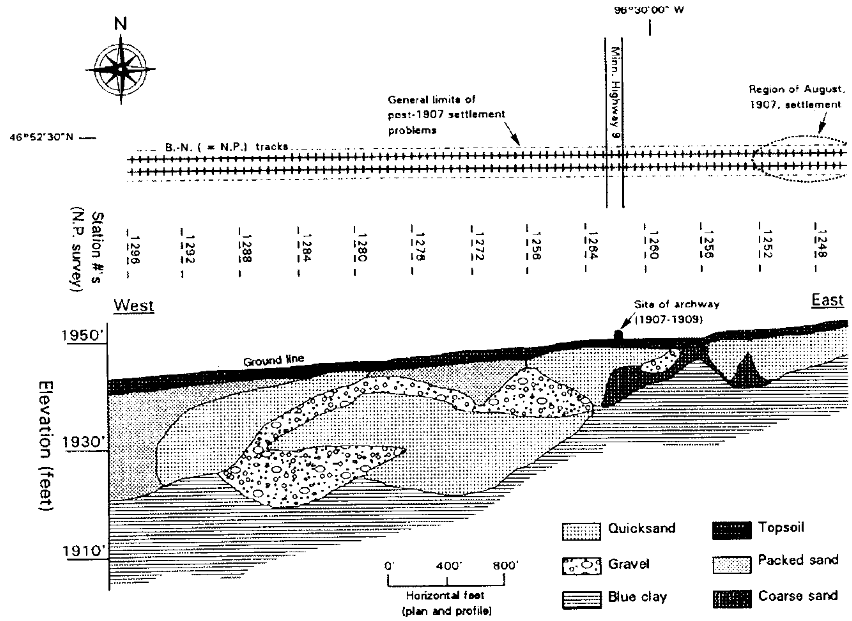


Figure 1. Plan view and geologic cross-section of Stockwood Fill in the region of the present-day Minnesota Highway 9 underpass.

Cross-section is re-sketched from soundings profile of S.A. McCoy (November 1, 1909).

Thus, the sediments underlying the study region have a complex depositional history involving interactions among lacustrine, glacial, coastal, and fluvial processes. Except for the lighter-colored, sandier nature of the soils and subtle changes in the associated prairie vegetation, however, the flat land surface here appears deceptively like that elsewhere within the Red River Valley. Therefore, just after the turn of the 20th century, engineers designing a grade change for the N.P. line anticipated few problems in accomplishing their task.

The Stockwood Fill

"The problem of raising from the Red River Valley eastward is . . . of particular importance as that will be the limiting grade on about 550 miles of main line." ~ Letter from N.P. Chief Engineer E.J. Pearson to N.P. President H. Elliot, April 11, 1905.

In 1870, the Northern Pacific Railroad began construction of a transcontinental rail line extending westward from Duluth, Minnesota. Tracks reached the Red River by 1872 and Puget Sound by 1883. Initial construction closely followed topography, resulting in many steep grades which slowed traffic and often forced uphill assistance by pusher engines. A grade reduction program for the eastern end of the line was initiated in 1897. By 1900, a dramatic increase in traffic made revision of all remaining steep grades imperative.

Among the problem grades was a 3.5 mile long, 0.75% eastbound grade rising from the Lake Agassiz plain up over the strands. This grade began just to the east of Stockwood, a tiny village that used to occupy the region about the Highway 9 underpass. At Stockwood, the N.P. maintained pusher engines to assist eastbound rail traffic. In February, 1906, the N.P. authorized its engineering department to reduce this and all regional grades to 0.3%. A decision was made to construct a huge earthen embankment (the "Stockwood Fill") rising eastward from Glyndon over a distance of 7.5 mi. Crews would raise and fill track on the ends of the embankment. In between, construction would involve building and filling a wooden, pile-supported trestle 4.75 mi long *(Figure 2)*, using ballast plows and side-opening dump cars. The trestle would require over two million board feet of lumber and would rise up to 50 ft in places. Wooden piles supporting the trestle would be driven to 15 ft in depth. The fill would primarily come from gravel and sands derived from railroad grade cuts in the glacial uplands to the east. Local road access through the fill would be via a 125 ft long, 16 ft high concrete archway *(Figure 3)* resting on wooden piles driven to 30 ft deep. Railroad survey crews marked "stations" every 100 ft along the N.P. line, with the station numbers increasing from east to west *(Figure 1)*. The N.P. engineering division placed S.A. McCoy in charge, with an overall project budget of $2,133,000 and an expectation that the embankment would be completed within two years. In April, 1906, pile driving began.

A Failing Grade for Northern Pacific

"For some thirteen hundred feet, it seemed to break through the prairie and stand a maximum of about thirty feet." ~ Letter from N.P. President H. Elliott to S. Rea, Vice President, Pennsylvania Railroad, November 30, 1907.

Except for persistent labor problems, construction of the Stockwood Fill progressed satisfactorily until about August 1, 1907. At that time, settlement of up to 2 ft was noted in the fill between stations #1244 and #1251 *(Figure 1)*, with the ground to either side of the embankment rising by about an equal amount. By August 4th, settlement had increased to 8 ft, and the adjacent ground had risen 7 ft. Over the next week, the embankment settled rapidly *(Figure 4)*. On August 13th, McCoy wrote, *"The bank was practically complete to grade on the 1st, and between August 1st and 8th we unloaded within the 600 feet . . . a total of 71,680 cubic yards, endeavoring to keep our track to grade; since August 8th to date, we have unloaded in the same hole 43540 cubic yards, and the condition is growing worse daily . . . The incline has become so steep that it is almost impossible to unload trains in the hole with the present equipment"* (letter to W.L. Darling, N.P. Chief Engineer).

On August 8th, McCoy initiated an investigation of substrate conditions extending westward from station #1240. These consisted of a series of *"test pits," "holes," "boarings,"* and *"soundings"* (we have been unable to determine exactly how the soundings were accomplished, although it was apparently commonplace for railroads to test penetration

Figure 2. Driving piles for the Stockwood Fill (circa spring, 1906). S.P. Wange photo, Clay County Historical Society.

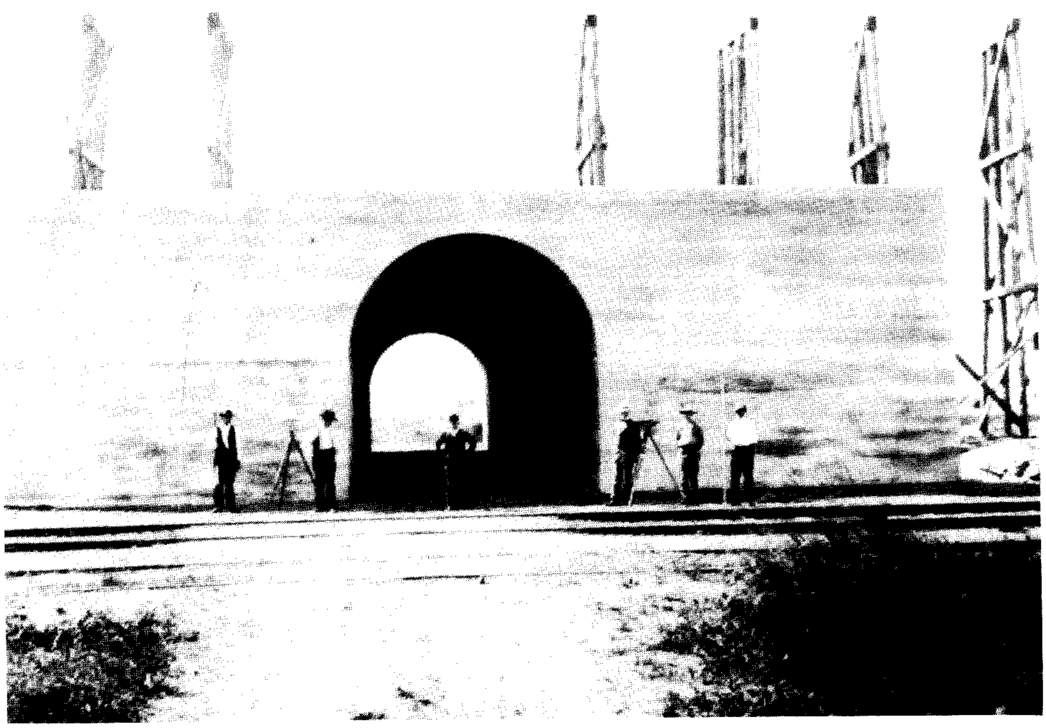


Figure 3. View facing to the south of the concrete archway near station #1262, Stockwood Fill (circa fall, 1906). The gentleman at the center is probably S.A. McCoy. S.P. Wange photo, Clay County Historical Society.

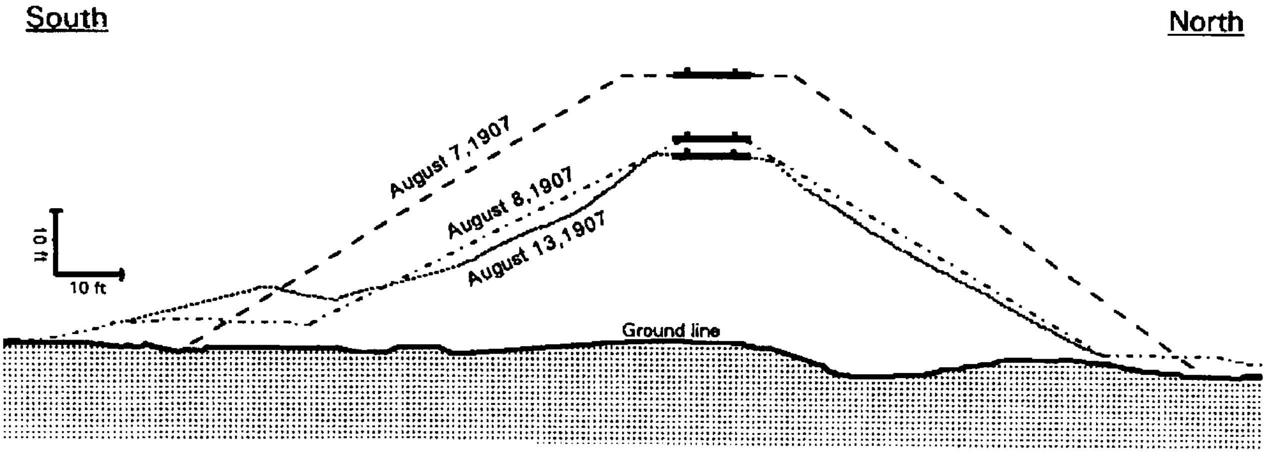


Figure 4. Profile changes at station #1245, Stockwood Fill, August 7-13, 1906. (Re-sketched from a N.P. profile, probably dating to August 13, 1907.)

resistance by using their pile driver to vertically drive piling or pieces of old rail). Sometime between August 13-20, a "drilling machine" was finally delivered. Borings were taken to depths of up to 75 ft, and McCoy continued to report the progress of these investigations daily by telegram to St. Paul. By early November, several stratigraphic profiles of soil conditions had been completed from stations #1240 to #1328 *(Figure 1).*

These profiles reveal a complex package of interfingered sands, gravels and clays of variable thickness and extent, resting on *"blue clay"* (apparently Brenna Fm). McCoy repeatedly dismissed any problems induced by the quick nature of the sands that were encountered: *"While the above soundings indicate that there is quicksand throughout the entire Stockwood country, I do not think that we need fear any serious results therefrom"* (letter to W.L. Darling, August 24, 1907).

Soon, however, the tracks on either end of the sag became too steep for the work trains *(Figure 5).* McCoy built and filled a second trestle over the problem region, but that also sank within days. McCoy ignored suggestions to simply build a strong trestle over the problem area and to then leave the sink alone until filling of the trestle to the west was completed. Instead, he doggedly continued to dump fill on the sink, only to watch it disappear.

By December, the embankment was no more complete than it was in August. McCoy sought employment elsewhere, and the N.P. placed its construction superintendent, F.L. Birdsall, in charge. In the spring and summer of 1908, Birdsall had a 3,000 ft long, permanent bridge constructed over the sink, extending westward over the archway (station #1262). Construction of this bridge allowed dump trains to access the west end of the embankment via Glyndon and to progress eastward from there in burying the trestle. Work progressed rapidly, but in May a second zone of settlement developed near station #1340 and in July a third zone of settlement between stations #1323 and #1331. Eight hundred feet of track sank 5 to 8 ft per day for a week. Birdsall extended the width of the fill outside of the slope of the trestle, hoping that a wider "mattress" would help support the embankment.

The strategy seemed to work, at least for a while. Birdsall reported no settling through early October, and it appeared that the N.P. might complete the embankment by November 1. However, on October 10, a fourth zone of settlement developed between stations #1272 and #1279. Cracks opened on either side of the embankment from stations #1272 to #1330, and Birdsall reported that *"indications are now that the entire fill for this distance will go*

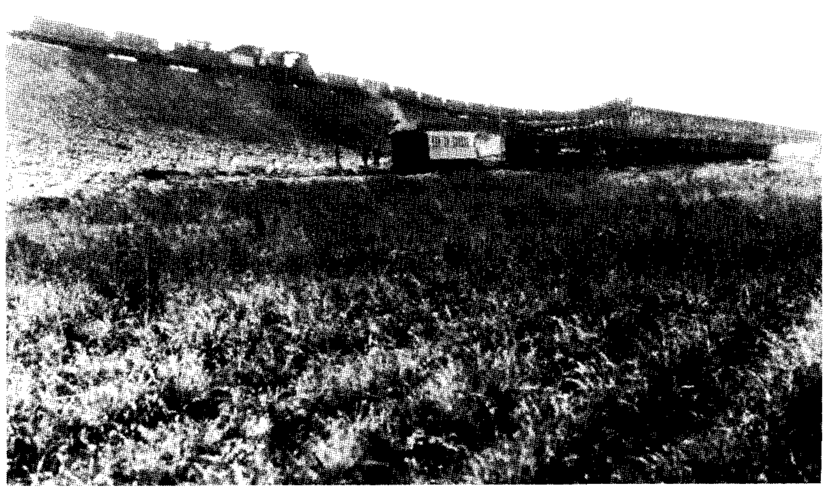


Figure 5. Attempting to fill the Stockwood Fill sink (circa fall, 1907). View is to the southwest. Note the concrete archway (≈ at station #1262) at the right and the settling embankment at the left, forcing the tracks and trestle downward. S.P. Wange photo, Clay County Historical Society.

down as we widen it out" (letter to W.C. Smith, N.P. Chief Maintenance-of-Way Engineer, October 25, 1908). Then on October 31, Birdsall wrote Smith: *"Had to stop work this P.M. on account of the permanent bridge opposite the Stockwood Depot settling so badly that we were not able to get over it."*

The Archway

"The arch has not shown any settlement lately . . . but it is just hanging on a balance." ~ Letter from F.L. Birdsall to W.C. Smith, November 1, 1908.

Smith and other N.P. officials were horrified to read this latest news from Birdsall, for just to the southwest of Stockwood Depot (region of station #1261) was their $11,000 archway (≈ station #1262) *(Figures 1 & 3)*. A "test pit" set at station #1262 on August 18, 1907, had shown 10 ft of quicksand overlying the 63 ft of blue clay *(Figure 6)*. Birdsall's superiors reluctantly agreed to let him fill in the permanent bridge, but they ordered him to keep the fill away from the archway until a wide "mattress" could be completed around the concrete structure. The photograph in *Figure 7* dates from this time. The view is from the north facing toward the southwest, with the concrete archway barely visible below and to the right of a sharp hump in the railroad tracks. The hump itself coincides with the only remaining stretch of unburied trestle, and the elevation of its peak is the last artifact of the intended (design) grade. The embankment to the east and west of this point shows significant settlement to elevations many feet below design grade. The zone of broken ground in the foreground represents a compressional ridge forced upward by recent fill settlement.

As filling progressed toward the region of the archway, the ground cracked in advance of dumping. Despite the decision to withhold filling of the archway, the stresses of embankment settling nonetheless reached this structure. By 1908, small cracks had begun to develop in the concrete, and these increased in size during the spring of 1909. In July, 1909, as fill loading of the archway's trestle was nearly completed, the embankment at station #1262 underwent severe settlement. The archway, stressed at its center by the downward pressures of embankment settlement and at its openings by the upward pressures of rising compression ridges, sheared across its center *(Figure 8)*. The embankment settlement and flaking compressional ridge are visible in this photograph, taken with the photographer facing northwestward toward the archway's south entrance. Measurements taken in September, 1909, showed the south end being forced upward 2 ft, the north end forced upward 3 ft, and the center section dropping 12 ft. The archway was abandoned as a project, and over the years it continued to sink until much or all of it disappeared. The inferred position of the arch in 1955 is shown in the architect's plans for the railroad bridge accommodating the present Highway 9 underpass *(Figure 6)*, later constructed across the former position of the structure. On the bridge design is noted, *"top portion of exist. conc. arch. to elev. 943.00 and fill with sand-gravel backfill . . ."*

The 1955 bridge design provides the only other soil engineering data that we could access for this region. These are minimal, consisting of soundings and a descriptive profile *(Figure 6)* from the construction site. An attempt to correlate McCoy's profile (August 18, 1907) with the, presumably more-detailed, 1955 profile *(Figure 6)* suggests that McCoy may have significantly underestimated the thickness of sand underlying the region of station #1262.

A Reluctant Acceptance of Equilibrium

"We ought to . . . perhaps give up the absolute completion of the grade until the question of settlement is over." ~ Letter from N.P. President H. Elliot to N.P. General Superintendent G.T. Slade, July 17, 1909.

In September, 1909, with the project two years behind schedule and $700,000 over budget, the N.P. gave in and

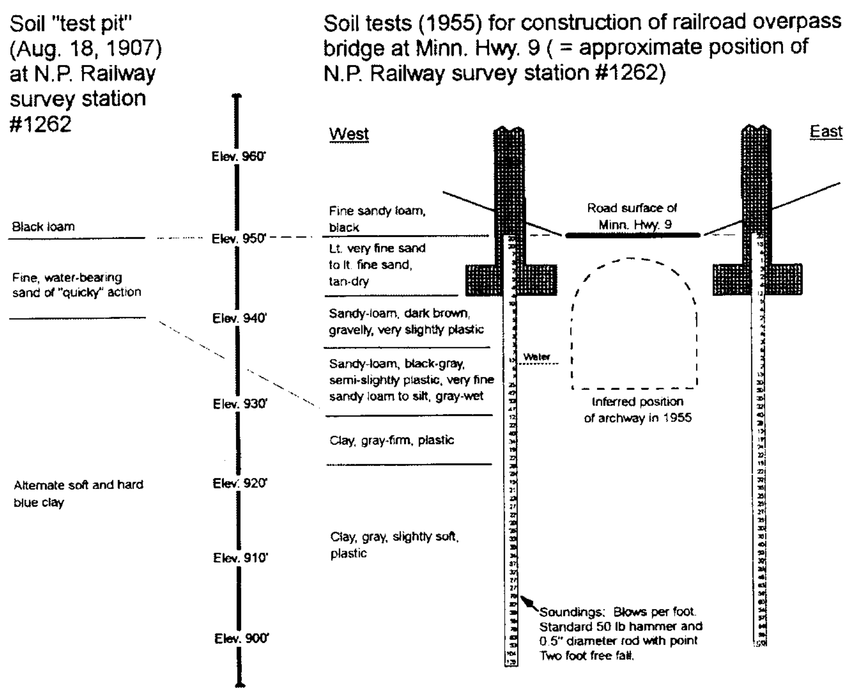


Figure 6. Comparison of soil test profiles in the region of Stockwood Fill station #1262 (data from S.A. McCloy, 1907, and Minnesota Department of Highways, 1955).

Figure 7. Filling trestle near concrete archway (circa June, 1909). View is to the southwest. A.F. Rusten photo, Clay County Historical Society.

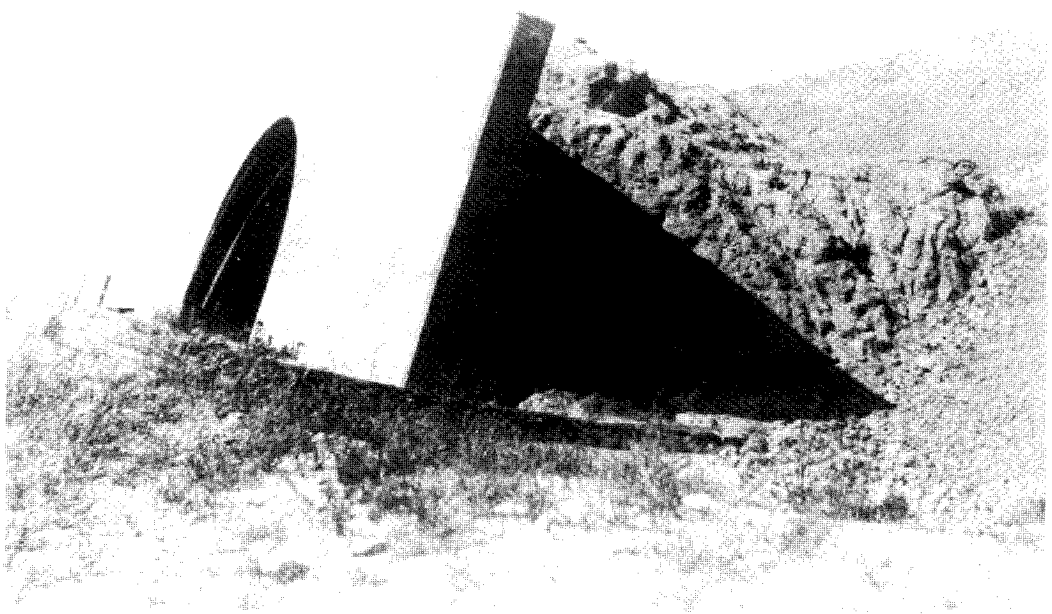


Figure 8. Collapsed archway, Stockwood Fill (circa fall, 1909). View is to the northwest. A.F. Rusten photo, Clay County Historical Society.

began using the embankment as it stood. However, for years afterwards, the N.P. tried to restore the intended grade of the Stockwood Fill. Thousands of yards of fill were added, only to have the embankment settle and the adjacent compressional ridges rise. The N.P. finally abandoned all of its efforts, and the sag in the grade became permanent. Pusher engines were still required to assist eastbound trains, until the arrival in the 1930's of the more powerful W-3 class locomotives. In all, it is estimated that 5,155,000 cubic yards of fill had been emplaced, of which only 4,067,000 remained above the original surface. The rest, presumably, sank. At least seven workers had lost their lives in this gigantic, but largely futile, construction effort.

In the absence of modern data, important clues still exist as to why soil loading by the embankment resulted in such dramatic and rapid settlement:

1. *Compression induced the lateral and then upward displacement of soil.* The evidence for this response is available in the historic and photographic records of compressional ridge formation, as well as in the presence of these ridges as landforms today. All such evidence shows that the tracks and fill settled vertically, while the compressional ridges rose symmetrically on each flank of the embankment. These observations contrast with those of other engineering failures tied to weak soils in the southern Lake Agassiz basin, where rotation induced by soil shear has generally been demonstrated (e.g., Nordlund and Deere, 1970). We have no data on the shear strengths of the soils underlying the Stockwood Fill, but they are undoubtedly low in the clays and essentially nil in the cohesionless sands. Alternatively, the ridges may represent displacement induced primarily by flow within fully hydrated, smectite-rich clays and/or in the saturated sands. However, soil displacement was apparently not the only mechanism, as the volume of up-squeezed sediment does not seem to have approached that which must have been displaced by settlement.

2. *Compression removed fluid pressure from confined bodies of cohesionless sands, causing permanent compaction.* Sands with quick properties were mapped throughout the site at the time of fill settlement, and the existence of artesian groundwater flow has since been well established. Although sediment compaction might seem to be the greatest factor behind the grade's settling, none of the often-detailed historic documents describing settlement present observations of water being forced to the surface. It seems probable, therefore, that any fluid displacement took place primarily through flow into interconnected aquifers.

The rails on top of the Stockwood Fill today support one of the busiest freight routes in the United States, and modern diesel engines hardly acknowledge existing problems with the grade. Burlington-Northern Railroad, which maintains this line, reports no problems with further fill settlement or with grade stability (David Douglas, B-N Engineering Division, personal communication, 1996).

From the railroad overpass bridge at Highway 9, however, one can still view physical evidence of the engineering dilemma once faced by McCoy and Birdsall. Over a distance >1 km, the railroad grade sags markedly downward. Facing westward toward Glyndon, one can see the tracks rise, when they should drop. To the east, they rise prominently out of the sag, throwing up a sudden 0.7% grade instead of the intended 0.2%. The remains of compressional ridges prominently flank both sides of the embankment in the sag area. Despite all of these features, the trees on the ridges stand tall and straight: evidence of decades of balance between the embankment and its underlying soils.

Acknowledgments

We are deeply grateful to the Minnesota Historical Society and to their staff for their assistance and for allowing us access to the Northern Pacific Railway Company records. We also thank David Douglas of the Burlington-Northern Railroad, Fargo, for helping to document foundation conditions for the grade.

References

Nordlund, R.L. and Deere, D.U., 1970, *Collapse of Fargo Grain Elevator,* Journal of Soil Mechanics and Foundations Division: Proceedings of the American Society of Civil Engineers, v. 96, n. SM2, p. 585-607.

Letters are from the archives of the Northern Pacific Railway Company, Minnesota Historical Society. We have maintained the use of English units of measurement when applying data recorded in historical documents. In our inclusion of direct quotations, we have maintained the grammar and spelling utilized in the original documents.

This article has been reprinted from:

Harris, K.L., Luther, M.R., and Reid, J.R. (eds.), 1996, *Quaternary Geology of the Southern Lake Agassiz Basin,* NDGS Miscellaneous Series 82, p. 116-126.

About the Authors

Dr. Don Schwert is a professor in the Department of Geosciences at North Dakota State University in Fargo.

Mark Piehl is employed with the Clay County Historical Society in Moorhead, Minnesota.