

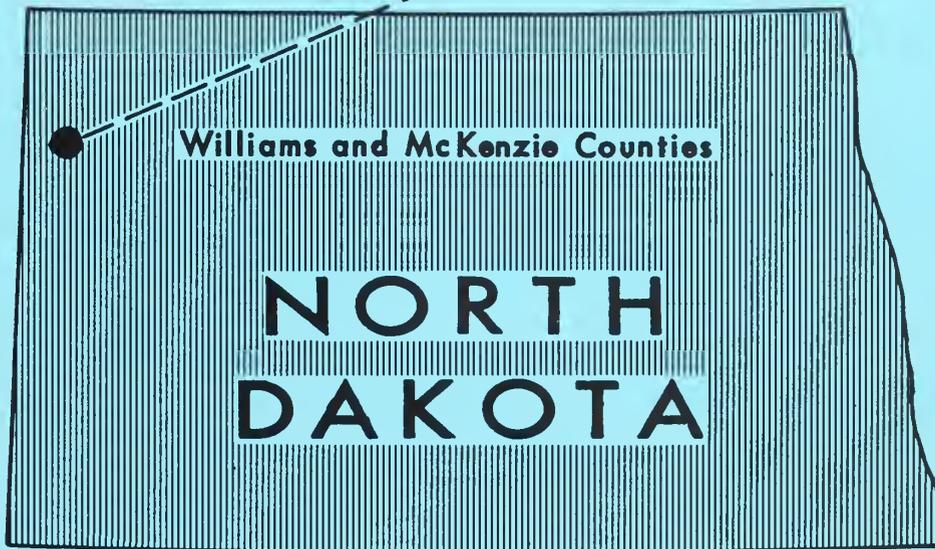
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# **Williams and McKenzie Counties Study Report**



**RESOURCE & POTENTIAL  
RECLAMATION EVALUATION**

Williams and McKenzie Counties Study Report  
Published July 1983

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Williams and McKenzie Counties Study Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management and Bureau of Reclamation. The study effort began in 1981 and was concluded in 1983 with the publication of this report.

The areas described in this report have been tentatively determined to

be potential Federal coal development areas. The purpose of the report is to provide information on the areas' reclamation potential, should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Limited copies of the report are available from:

Bureau of Land Management  
Montana State Office  
222 N. 32nd Street  
Billings, MT 59107

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16. Abstract The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The area of study, located in northwestern North Dakota, is situated in the glaciated Missouri Plateau section of the Great Plains Physiographic Province. The topography of the area is predominantly flat to gently rolling uplands which are locally dissected along drainages. Bedrock exposed in the area consists of the Sentinel Butte or Tongue River Members of the Paleocene Fort Union Formation. Pre-Pleistocene to Holocene gravel terraces, Pleistocene glacial deposits, and Holocene loessal and alluvial deposits locally mantle the bedrock in the area. Twelve fairly persistent lignite beds were penetrated by drilling in the area. These are the R-, Y-, B-, G-, Pittsley, Tyrone, Blacktail, Avoco, Williston, Judson (H-bed), I- or J-, and Mormon beds. Soil/overburden samples from 20 representative drill holes were evaluated for suitability as plant media in reconstructed profiles. Most of the materials were rated as limited suitability or unsuitable due to textural limitations, high exchangeable sodium percentage, moderate salinity, and/or moderately high levels of manganese or nickel. Suitable materials generally included the surface soil (6-18"), a few tills, and selected sedimentary strata which were medium textured, nonsaline, and nonsodic. X-ray diffraction analyses were performed on about 200 overburden samples. Illite and random mixed-layer clays, together, generally comprised 75-90% of the clay fraction. Kaolinite and chlorite were also common constituents, but averaged only 10% and 5%, respectively, of the clay fraction. Other minor constituents included quartz, carbonate, and feldspar.			
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RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
OF  
WILLIAMS AND MC KENZIE COUNTIES STUDY  
NORTH DAKOTA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic energy sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior, principally the Bureau of Land Management, to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide baseline information for establishing reclamation objectives and lease requirements. Data is given on geology and overburden. Background information is also provided on area physiography.

REPORT OBJECTIVES

1. To provide information for leasing site selection procedures as set forth by the Secretary of the Interior.
2. To provide information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.
3. To provide information to support State and local regional development and land use planning efforts.
4. To determine the suitability of the overburden to support and maintain vegetation.
5. To provide physical and chemical data on the overburden so that realistic stipulations may be prepared for exploration, mining, and reclamation plans.
7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

## RESPONSIBILITY

### BUREAU OF LAND MANAGEMENT

1. Selects study area for overburden investigations.
2. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.
3. Procures easements and rights-of-way to conduct the studies.

### BUREAU OF RECLAMATION

1. Conducts drilling operations for the procurement of core samples for suitability analysis.
2. Characterizes and interprets suitability of overburden materials stratigraphically above and below the coal horizons.
3. Summarizes the geology of the area.

## GENERAL DESCRIPTION

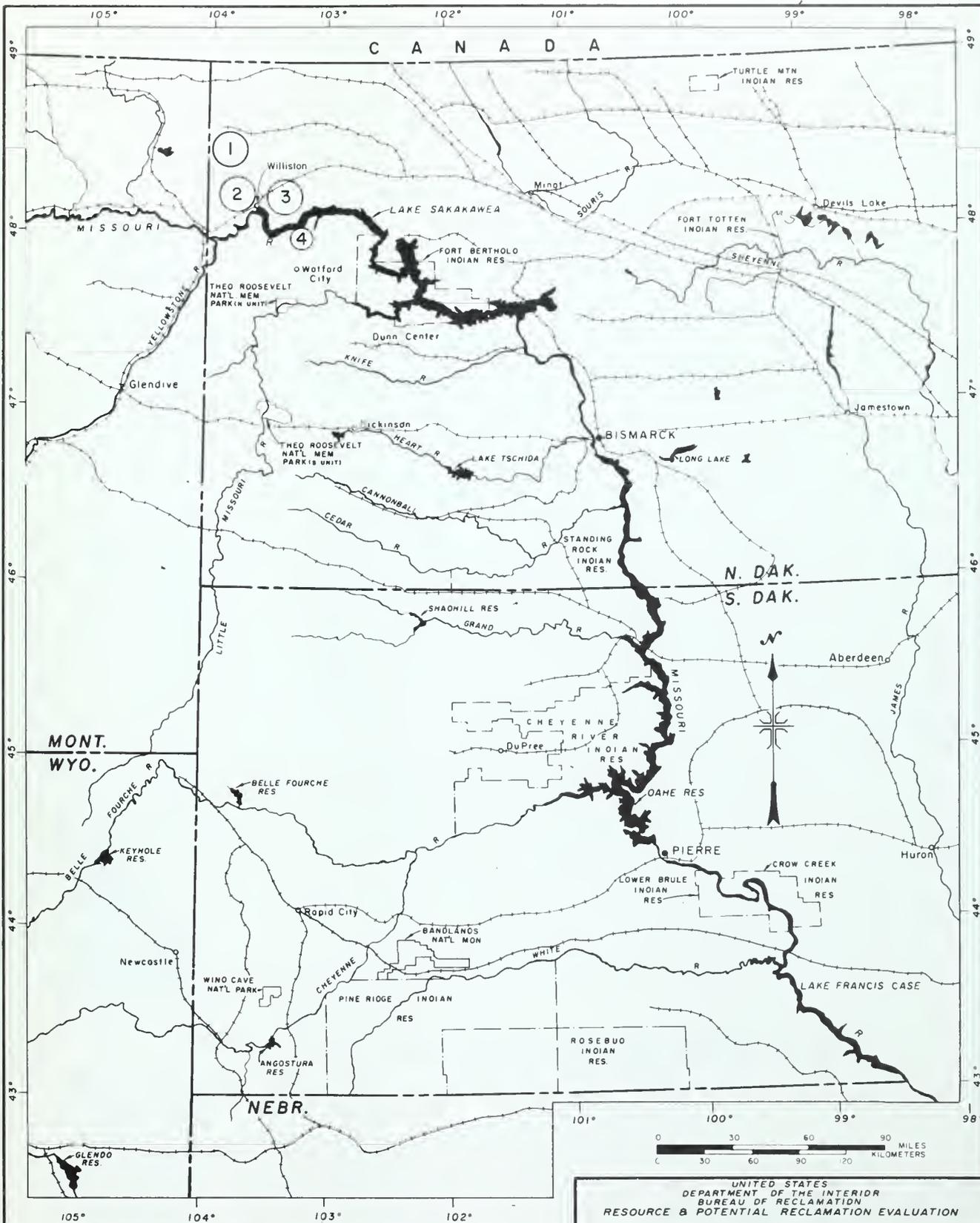
### LOCATION

The Williams and McKenzie Counties Study is located in northwestern North Dakota. Plate 1 shows the general location of the study area. Four smaller areas were selected within the two county area for overburden studies. These include the Hanks, Sand Creek, Williston, and Tobacco Garden Study Areas. The four study areas include a total of 1,037 full or partial sections as shown on Plate 2 and as listed on Table 1. Federal and State coal ownership is interspersed in the study areas, as shown on Plates 3 through 6. The majority of surface ownership in these areas is private. Only a limited amount is controlled by the Federal government as shown on Plates 7 through 10.

The original study area (Beaver Creek) was intended to be a comprehensive study of a portion of the present "Williston Study Area". The investigations program was to include drilling and testing samples from 25 core holes. At the commencement of the program, however, the emphasis of the study was changed to an overview of several study areas. These studies eventually included the completion of 27 core holes.

Study Area	Location Description (Range - Township)	
1. Tobacco Garden	T. 152 N., R. 97 W. R. 98 W.	
	T. 153 N., R. 97 W. R. 98 W.	
	T. 154 N., R. 97 W.	
	2. Williston	T. 153 N., R. 98 W. R. 99 W. R. 100 W.
		T. 154 N., R. 95 W. R. 96 W. R. 97 W. R. 98 W. R. 99 W. R. 100 W.
		T. 155 N., R. 95 W. R. 96 W. R. 97 W. R. 98 W. R. 99 W. R. 100 W.
T. 156 N., R. 96 W. R. 97 W. R. 100 W.		
3. Sand Creek		T. 153 N., R. 101 W. R. 102 W. R. 103 W. R. 104 W.
		T. 154 N., R. 101 W. R. 102 W. R. 103 W. R. 104 W.
		T. 155 N., R. 101 W. R. 102 W. R. 103 W. R. 104 W.
		T. 156 N., R. 101 W. R. 102 W. R. 103 W.

Study Area	Location Description (Range - Township)
4. Hanks	T. 156 N., R. 101 W. T. 157 N., R. 100 W. R. 101 W. R. 102 W. R. 103 W. T. 158 N., R. 100 W. R. 101 W. R. 102 W. R. 103 W. T. 159 N., R. 100 W. R. 101 W. R. 102 W. R. 103 W. T. 160 N., R. 100 W. R. 101 W. R. 102 W.



- ① HANKS STUDY AREA
- ② SAND CREEK STUDY AREA
- ③ WILLISTON STUDY AREA
- ④ TOBACCO GARDEN STUDY AREA

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 RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

**GENERAL LOCATION MAP**

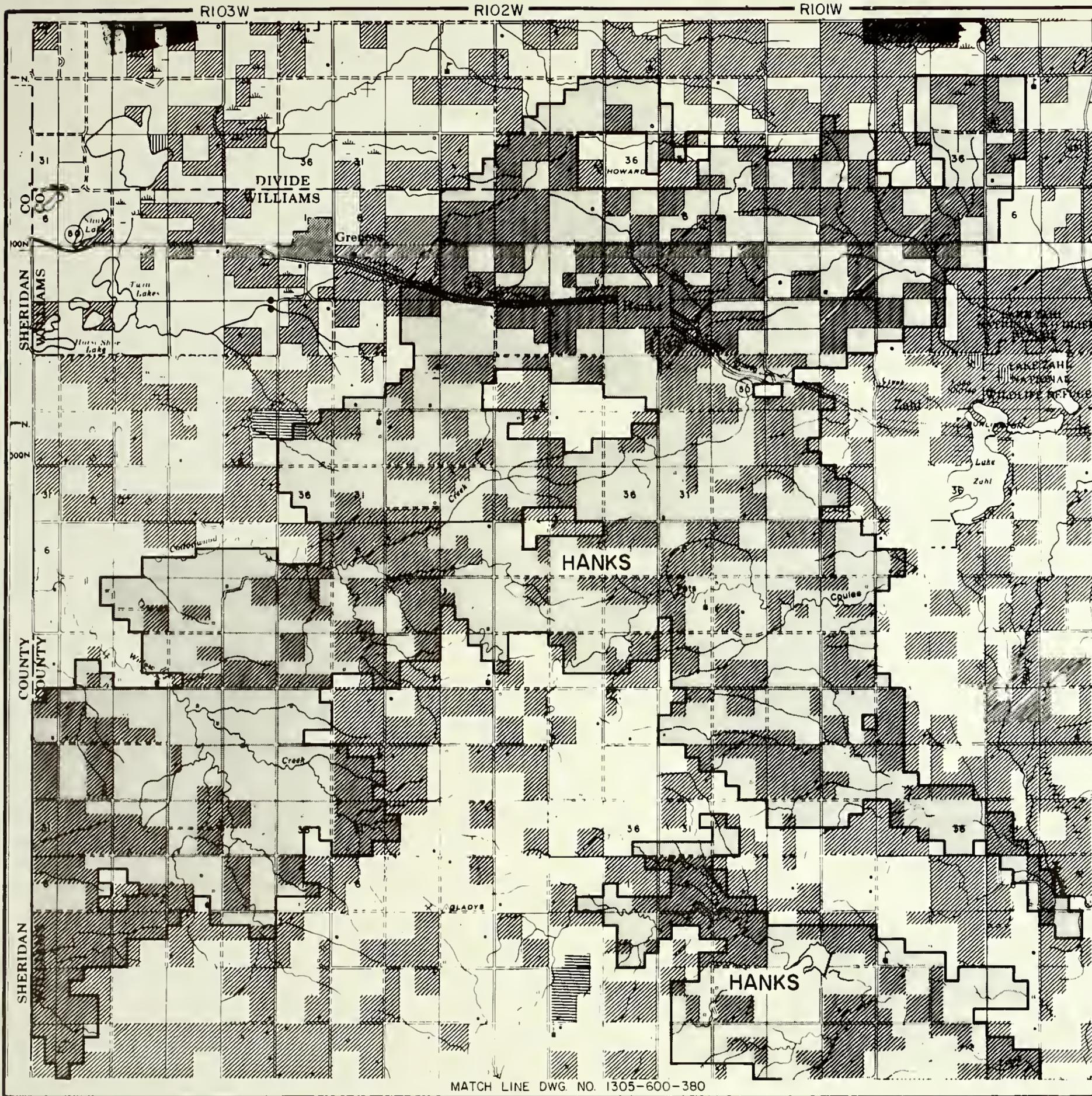
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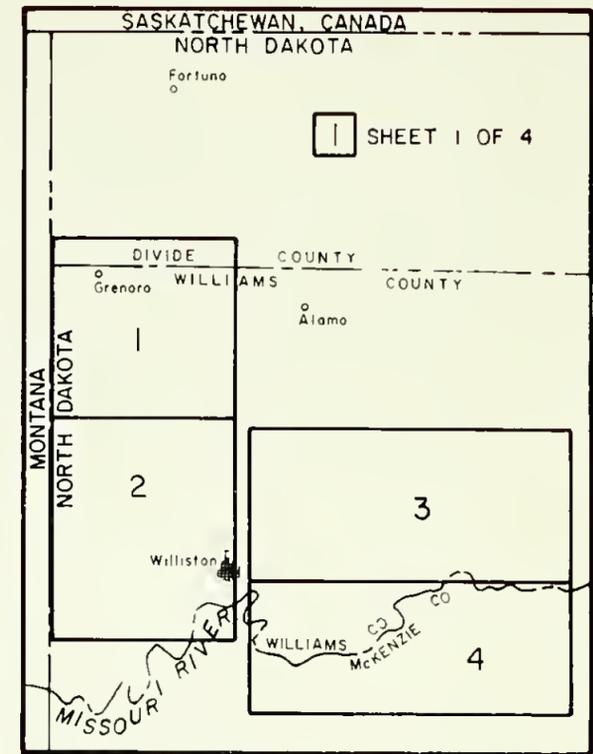






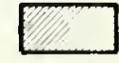


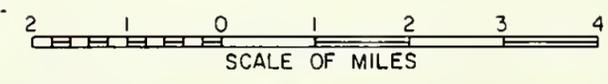
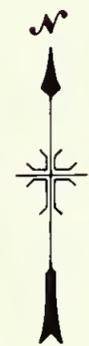
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INDEX MAP

EXPLANATION

-  Study Areas
-  MINERALS OWNED BY THE FEDERAL GOVERNMENT
-  All Minerals
-  Coal Only
-  Other



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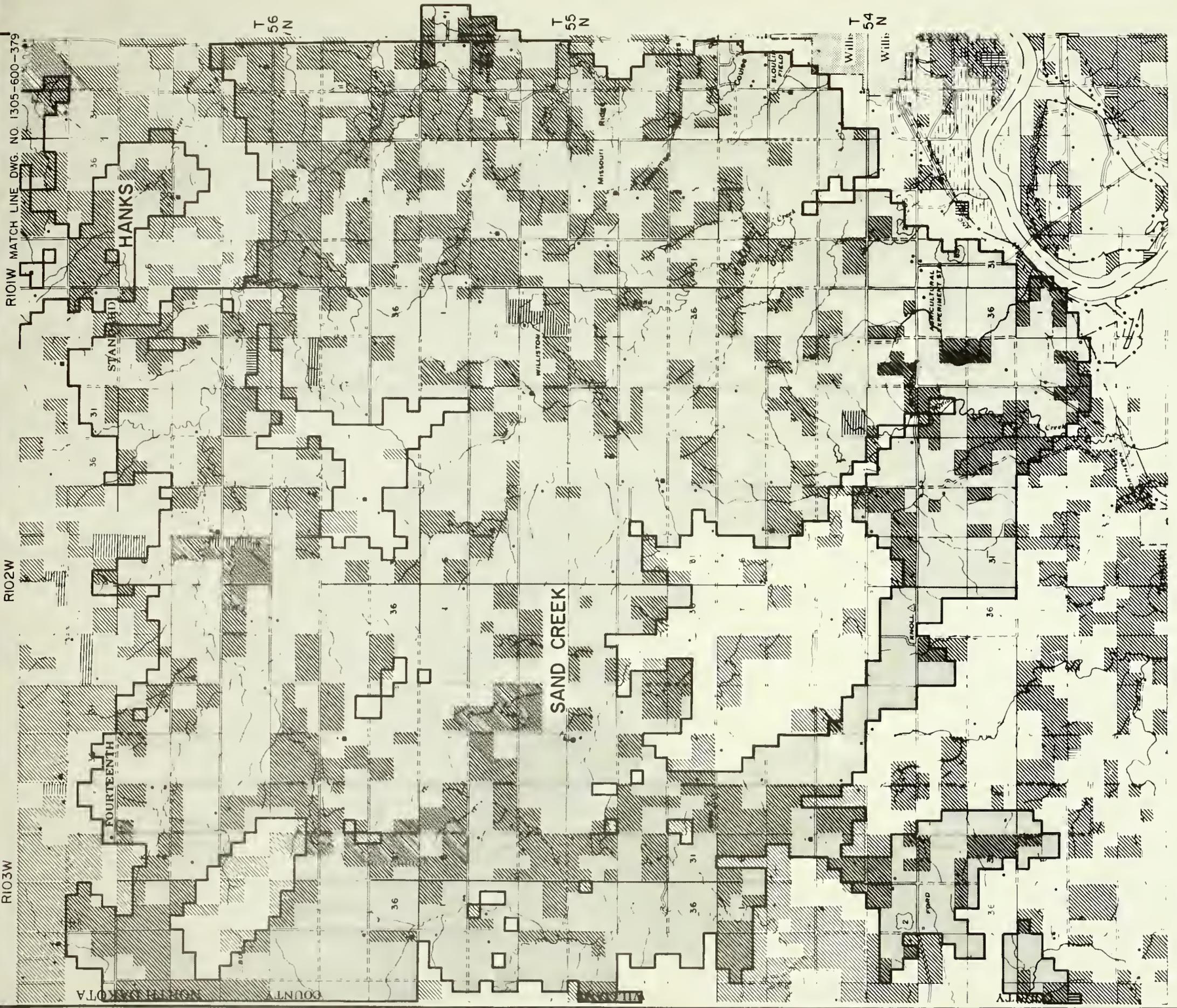
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**MINERALS OWNERSHIP MAP**

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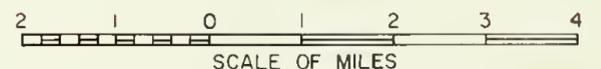
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EXPLANATION

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-  All Minerals
-  Coal Only
-  Other



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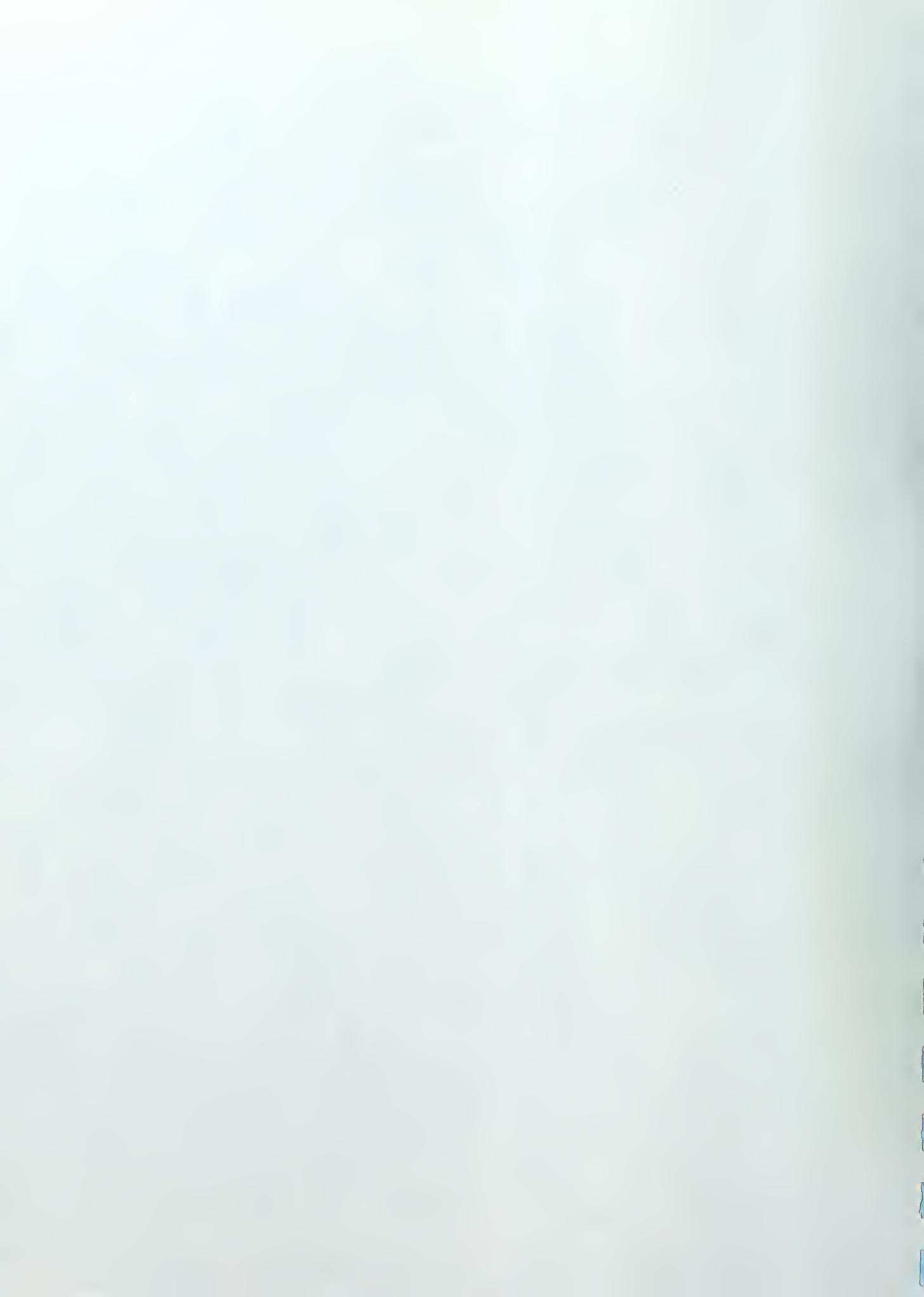
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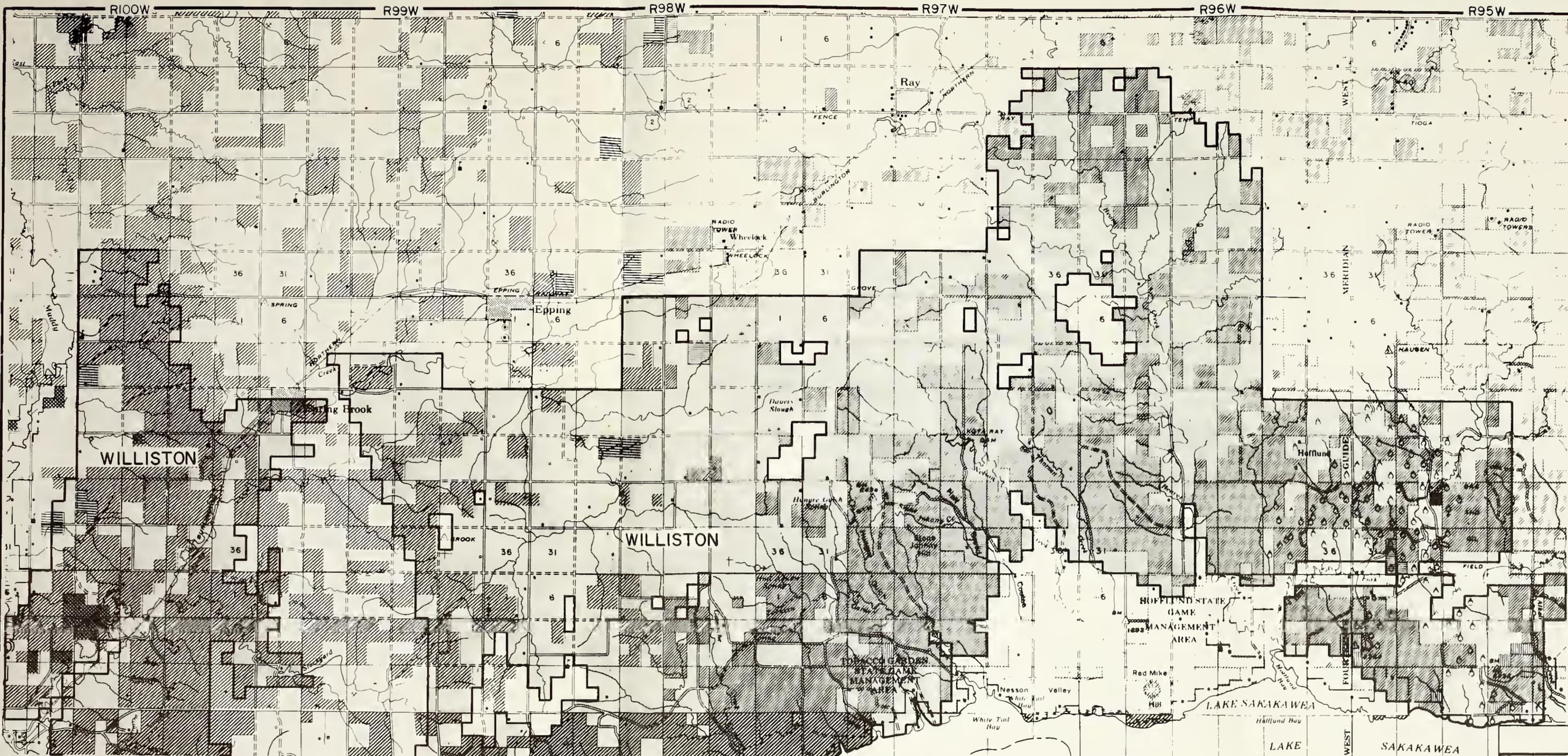
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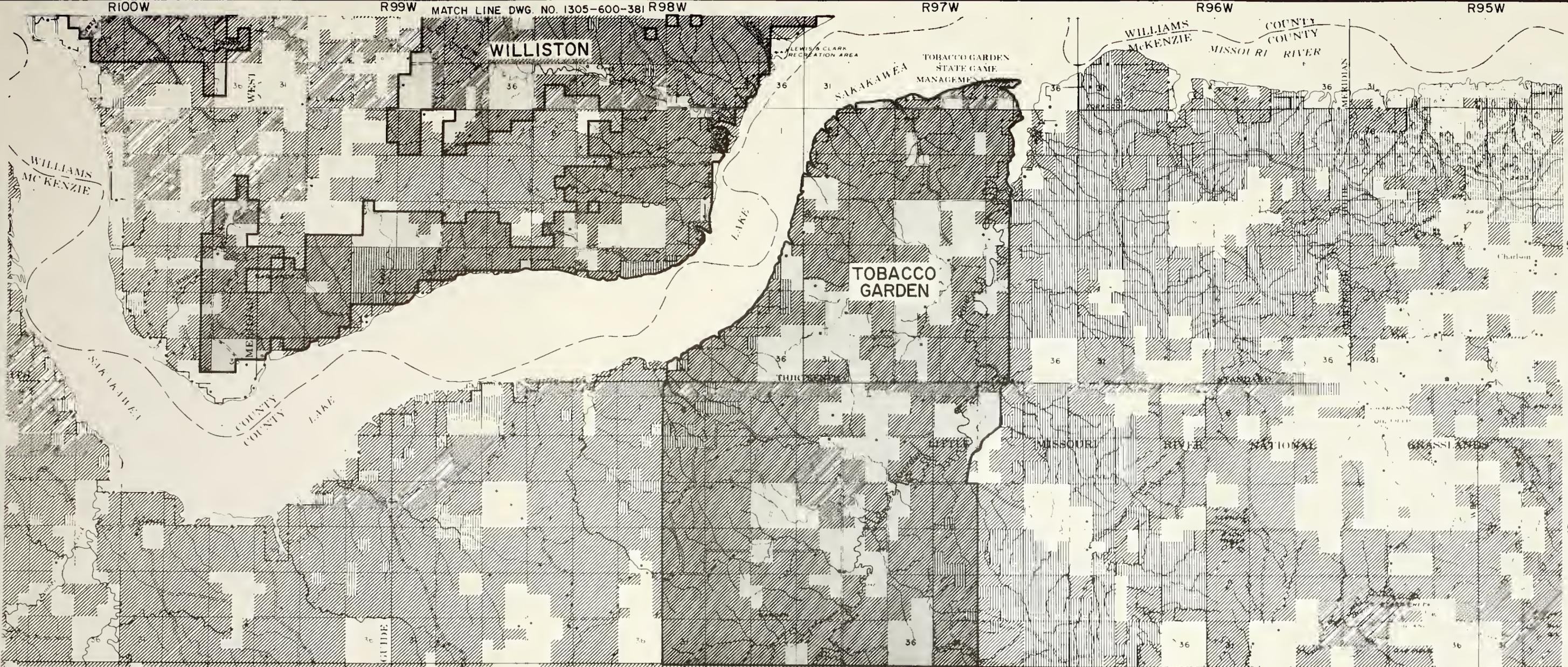
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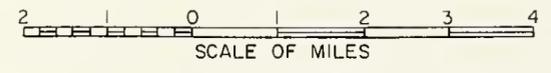
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EXPLANATION

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- MINERALS OWNED BY THE FEDERAL GOVERNMENT
-  All Minerals
-  Coal Only



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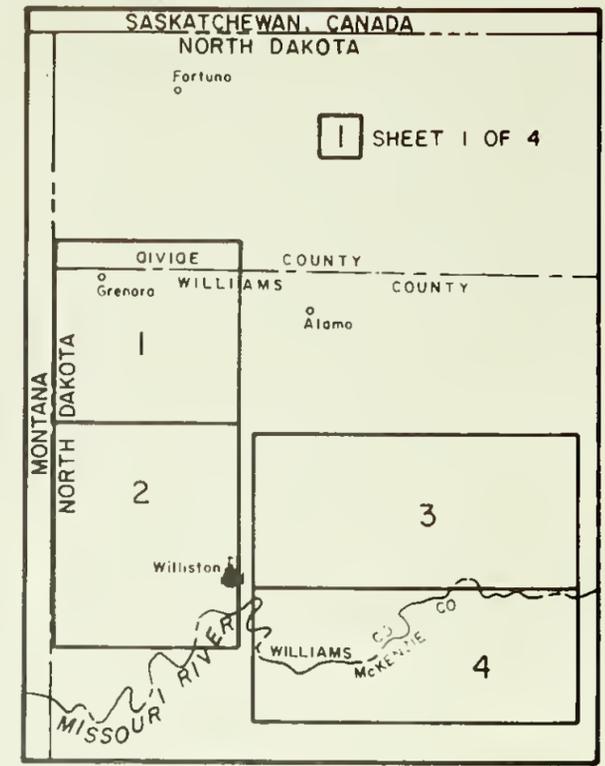
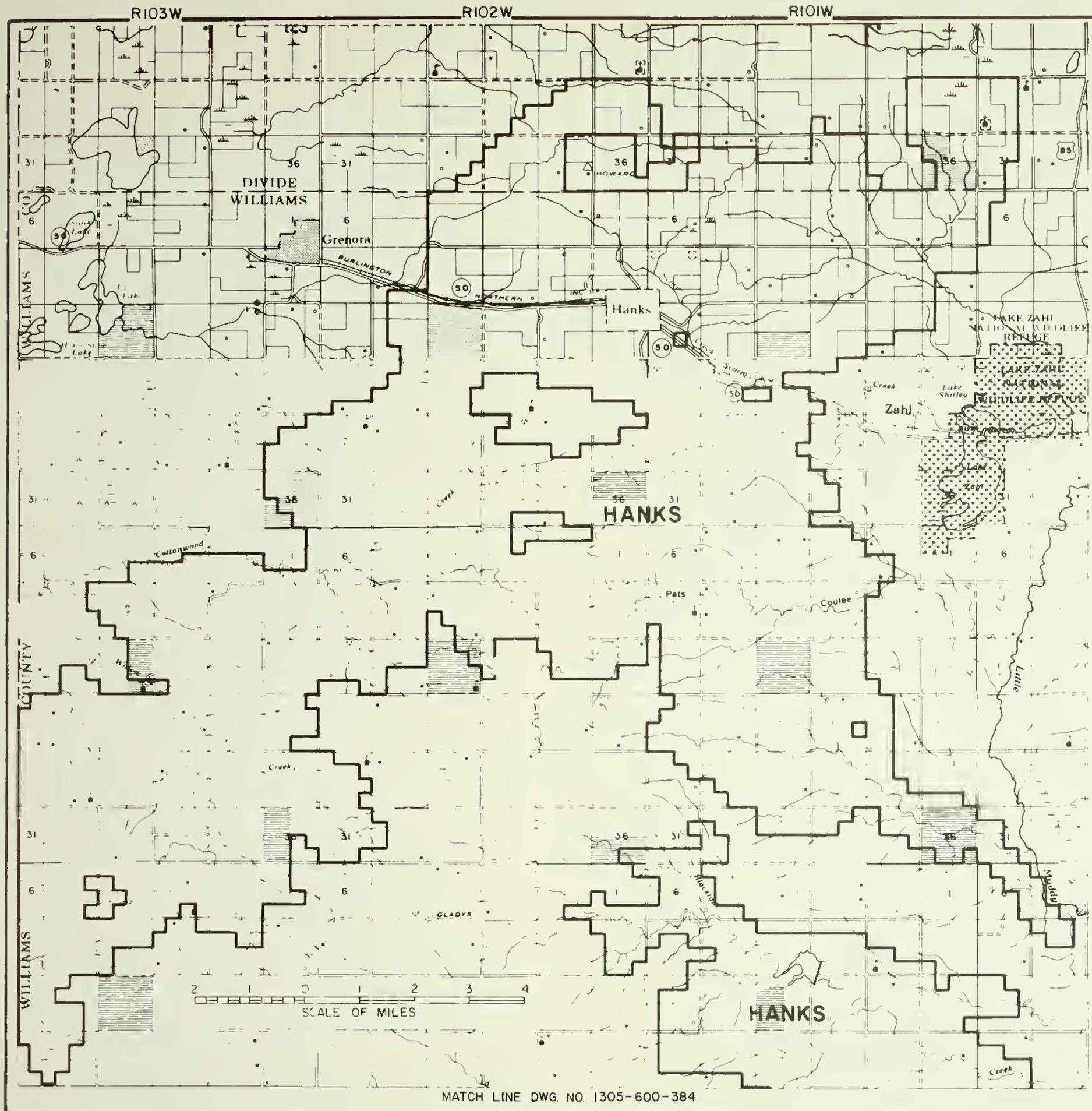
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INDEX MAP

LAND STATUS LEGEND

-  Private
-  State
-  Public Domain
-  National Forest
-  Wildlife Refuge
-  Bankhead-Jones L.U. Lands
-  Military Reservation and Military Withdrawal
-  Miscellaneous

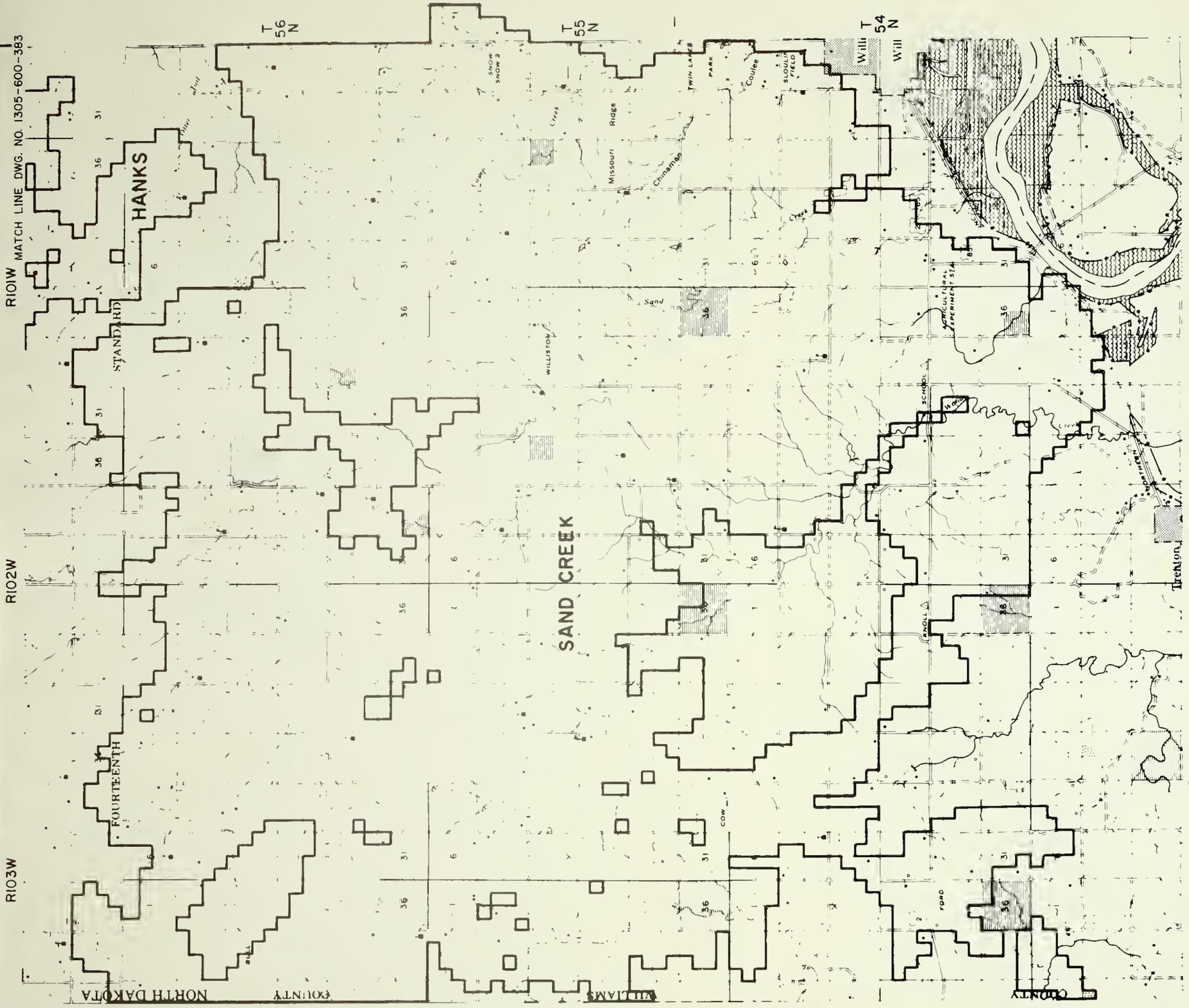
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**SURFACE OWNERSHIP MAP**

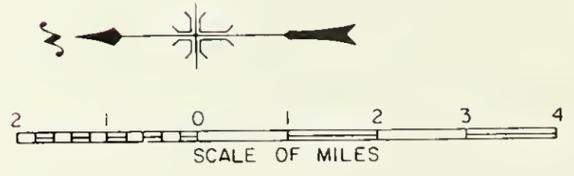
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LAND STATUS LEGEND

-  Private
-  State
-  Public Domain
-  National Forest
-  Wildlife Refuge
-  Bankhead-Jones L.U. Lands
-  Military Reservation and Military Withdrawal
-  Miscellaneous



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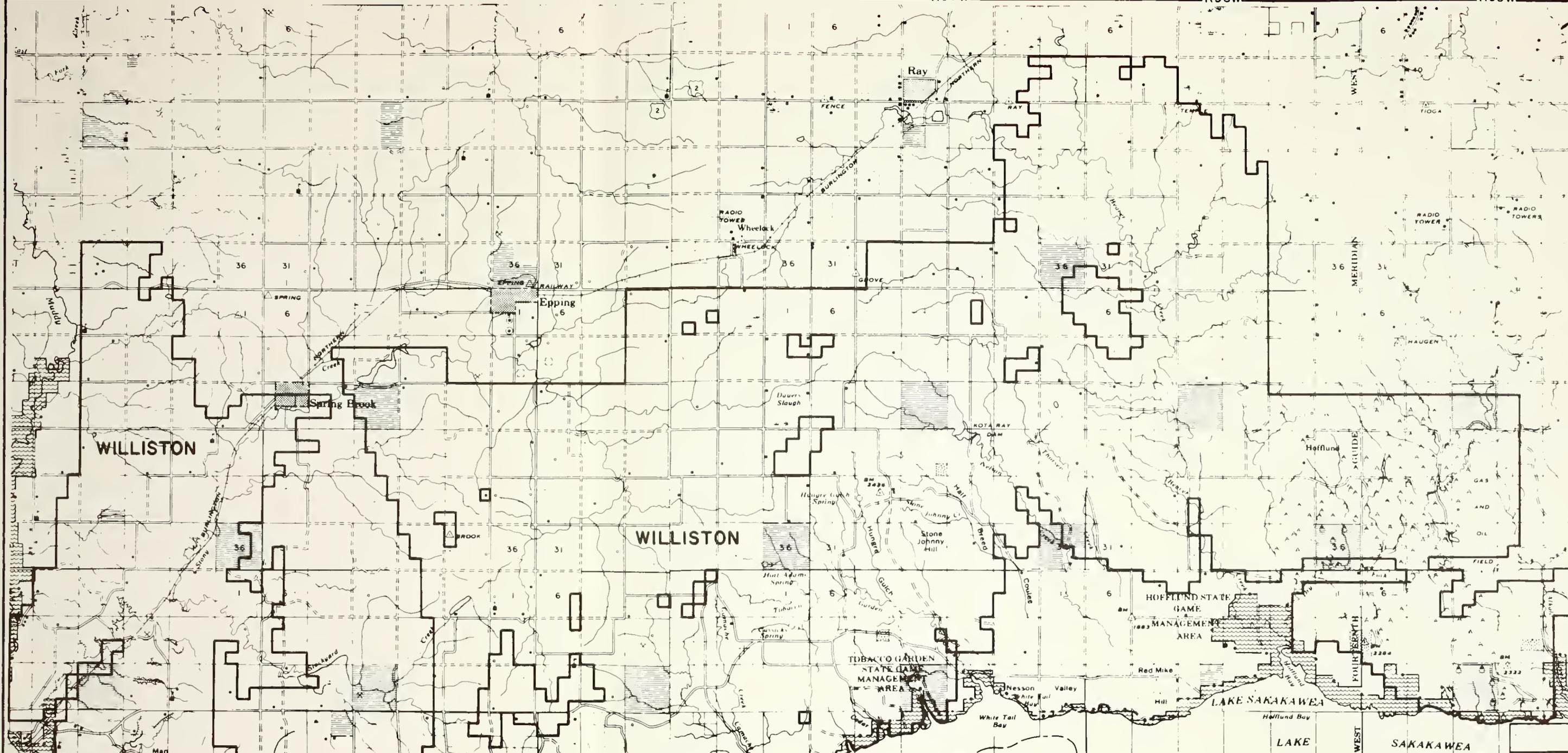
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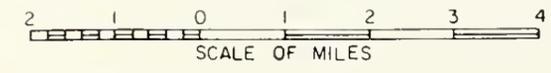




LAND STATUS LEGEND

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-  State
-  Public Domain
-  National Forest
-  Wildlife Refuge
-  Bonthead-Janes L.U. Lands
-  Military Reservation and Military Withdrawal
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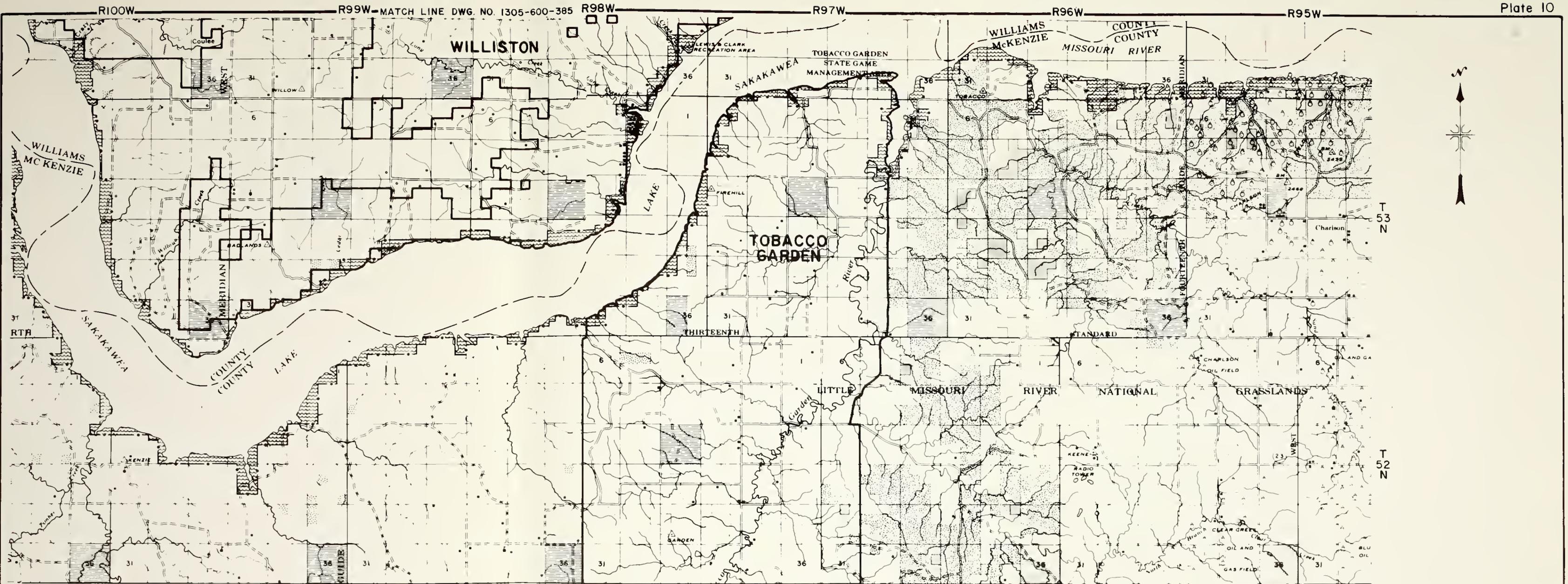
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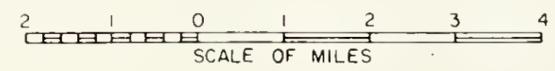
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LAND STATUS LEGEND

- |                                                                                     |                 |                                                                                       |                                              |
|-------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------|----------------------------------------------|
|  | Private         |  | Wildlife Refuge                              |
|  | State           |  | Bankhead-Jones L.U. Lands                    |
|  | Public Domain   |  | Military Reservation and Military Withdrawal |
|  | National Forest |  | Miscellaneous                                |



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## PHYSICAL PROFILE

### PHYSIOGRAPHY

The Williams and McKenzie Counties Study is situated in the glaciated Missouri Plateau section of the Great Plains Physiographic Province. The topography of the area is predominantly flat to gently rolling uplands which are locally dissected near drainages. Closer to Lake Sakakawea, dissection increases to a point where rugged badland topography is prevalent. Portions of the area, especially in the northwest, are characterized by knob and kettle topography.

Much of the area, especially north of the Missouri River, is mantled with deposits from continental ice sheets. The uplands are covered with till and boulders and the major valleys are often filled with glaciofluvial outwash. Sedimentary strata of the Fort Union Formation are exposed along deeply-incised drainage valleys and, especially south of the Missouri River, at higher elevations in the uplands. Resistant scoria (baked coal and shale) outcrops occur throughout this study area. These outcrops appear as thin, remnant "caps" over the sloping uplands.

The relief in the study area is approximately 640 feet, ranging from 1840 feet along Lake Sakakawea to 2480 feet in the uplands approximately 12 miles southeast and also 24 miles northwest of Williston, North Dakota.

The preglacial course of the Yellowstone River was along the present-day Little Muddy River valley and the course of the Little Missouri was along the Beaver Creek and Tobacco Garden River valleys. At present, small, shallow underfit streams flow in these broad valleys. Normally, such streams are perennial; however, during periods of drought they become intermittent. The Little Muddy, White Earth, and Tobacco Garden Rivers and Beaver and Stony Creeks are the most prominent drainages within the study area which all drain directly into Lake Sakakawea (Missouri River). The Missouri, which is the principal stream, flows eastward and drains this part of the glaciated Missouri Plateau. The dendritic drainage is generally well integrated, with few closed depressions; however, numerous freshwater and saline lakes and marshes are present in the poorly-drained knob and kettle topography to the northwest.

## GEOLOGY

### Regional Geology

The Williams and McKenzie Counties Study is located in the Williston Basin in northwestern North Dakota. This basin, a part of the Great Plains Physiographic Province, is a synclinal structure extending from South Dakota into Canada, a distance of about 500 miles.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. A sequence of carbonates, sandstones, and shales, mostly of marine origin, were deposited throughout North Dakota during the Paleozoic and Mesozoic Eras. These sediments, about 14,000 feet thick in the deepest part of the Williston Basin, thin rapidly eastward and are not present in the southeastern part of the State. Several unconformities exist throughout the Paleozoic and Mesozoic sequences in North Dakota, the most notable being the pre-Mesozoic erosional surface which truncates all Paleozoic sediments.

Deformation of the Rocky Mountains to the west and associated uplifting of the Great Plains area in North Dakota began with the Laramide Revolution at the close of Cretaceous time. Intermittent uplifting continued through the Paleocene and ended in Eocene time. Materials eroded from the mountains were spread in thick sheets over most of the Great Plains by the middle of the Cenozoic Period. A second regional uplift which occurred during Pliocene and Pleistocene times elevated sediments to their present position. Streams rejuvenated by the uplift began stripping Tertiary strata from the Great Plains and exhuming the buried mountain masses to the west.

During the Pleistocene Epoch, several continental ice sheets invaded most of North Dakota. A sequence of till, outwash, and associated glacial debris was deposited during the advance and retreat of each ice sheet.

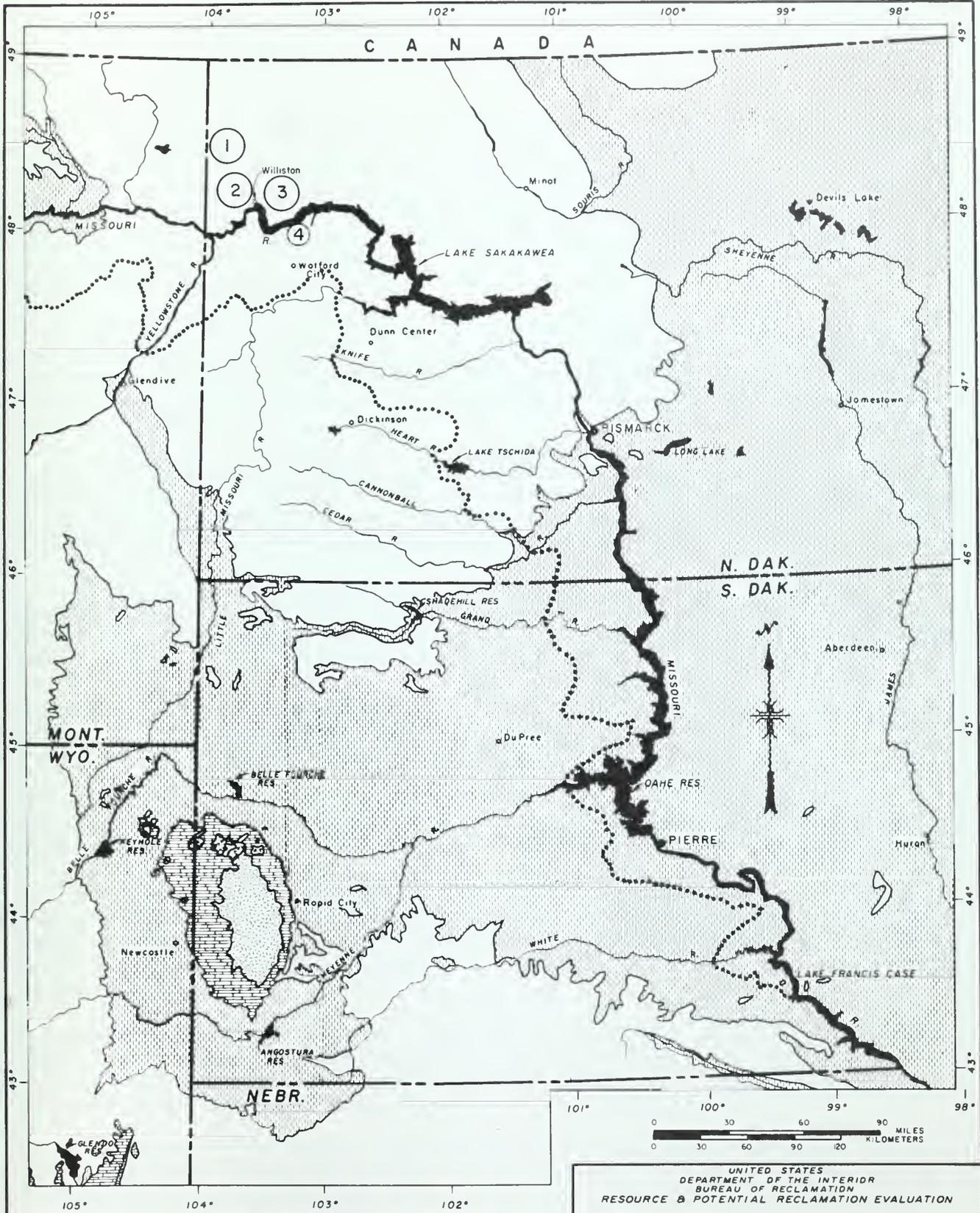
Today shales, siltstones, sandstones, and lignite of Cretaceous and Tertiary age cover the western part of North Dakota. Pleistocene glacial and Holocene eolian and alluvial deposits mantle the bedrock in much of the area. Plate 11 is a generalized regional geologic map showing the southern limits of glaciation.

### Area Geology

#### Investigations

Surface and subsurface investigations were conducted by the Bureau of Reclamation at the Williams and McKenzie Counties Study during the summer and late winter of 1981-82 and the late fall of 1982. These investigations included preparing a map of the surface geology and drilling a series of core holes.

Previous geologic investigations covering the area were very useful in preparing this report. Three of the references that were instrumental in preparing the surface geologic maps of the area are: (1) North Dakota Geological Survey Bulletin 48 - Part I, Plate 1, "Geology and Groundwater Resources of Williams County, North Dakota," by T.F. Freers, 1970; (2) U.S. Geological Survey Misc. Geologic Investigations Map I-331, "Preliminary Glacial Map of North Dakota," by



-  CENOZOIC
-  CENOZOIC (IGNEOUS)
-  MESOZOIC
-  PALEOZOIC
-  PRECAMBRIAN
-  SOUTHERN LIMITS OF GLACIATION
- ① HANKS STUDY AREA
- ② SAND CREEK STUDY AREA
- ③ WILLISTON STUDY AREA
- ④ TOBACCO GARDEN STUDY AREA

UNITED STATES  
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RESOURCE & POTENTIAL RECLAMATION EVALUATION

**NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING  
GENERALIZED  
REGIONAL GEOLOGIC MAP**

DESIGNED BY F. TAUCHER SUBMITTED \_\_\_\_\_  
 DRAWN BY E. STARCEWICZ RECOMMENDED \_\_\_\_\_  
 CHECKED BY A. I. APPROVED \_\_\_\_\_

BILLINGS, MONTANA      JUNE 1983      1305-600-387



R.B. Colton, et al., 1963; and (3) North Dakota Geological Survey, "Geologic Map of North Dakota," by L. Clayton, 1980. The surface geologic maps (Plates 12 through 16) were further modified by data from the USBR drill holes located in the study area.

Twenty-seven drill holes ranging in depth from 159 to 363 feet were completed in the study area. The location of the drill holes are plotted on the Geologic and Investigations Maps, Plates 13 through 16. Detailed geologic logs are shown on Plates 17 through 43 in the Appendix. Drilling was performed by a Danco 1250 and Failing Models 750 and 1500 rotary drills using wireline tools with an "H" series core barrel. Except for drive sampling in overlying glacial deposits with a Bx casing drive barrel, all drilling was done using bottom discharge core bits with tungsten carbide inserts.

Water was used as a drill fluid in all holes. The organic polymer, "Revert," was used in the drilling fluid in fractured or jointed rock where circulation was lost. Drill water was sterilized as required by the North Dakota Water Commission. After completion, all drill holes in the study area were backfilled with a sand-cement slurry.

Continuous cores were obtained from all holes for geologic logging. The core was immediately placed in boxes and wrapped with plastic to prevent drying until it could be logged and sampled. Five sets of samples were taken from representative core material from the study area as follows:

1. Typical overburden (6-inch core lengths) and coal samples (approximately 5-pound bags) from each drill hole were shipped to the U.S. Geological Survey Coal Resources Laboratory in Denver, Colorado. The samples are for their information and test results are not included in this report.

2. Typical overburden (approximately 1-foot core lengths) samples from representative drill holes were shipped to Greg Smith (University of Kentucky) c/o U.S. Geological Survey Regional Geochemistry Branch in Denver, Colorado.

These samples provide data for inclusion in a Core Book of Western Tertiary Sediments, showing material types, structure, and fracture conditions of the rock. Test results are not included in this report.

3. Typical overburden samples from four drill holes were shipped to the U.S. Geological Survey Regional Geochemistry Branch in Denver, Colorado, for trace element analysis. The results of these tests serve as a comparison to similar tests conducted by the U.S. Bureau of Reclamation and are not included in this report.

4. The clay mineralogy of typical overburden samples (approximately 200) were determined by means of X-ray diffraction at the Department of Geological Sciences at Case Western Reserve University in Cleveland, Ohio. Results of these tests are included in the Appendix of this report.

5. Typical overburden samples (approximately 8-pound bags) from 20 of the 27 drill holes were tested for suitability in reconstructed profiles by Bureau of Reclamation Soils Laboratories in Bismarck, North Dakota; Boise, Idaho; and Denver, Colorado. Test results are graphically shown on the geologic logs (Plates 17 through 43) and listed on Tables 2 through 21 in the Appendix.

## Stratigraphy

The oldest rocks exposed in the study area are of Paleocene age. In North Dakota the U.S. Geological Survey has divided the Paleocene Series into the Ludlow-Cannonball, Tongue River, and Sentinel Butte Members of the Fort Union Formation. These subdivisions will be used in this section of the report. The Fort Union Formation is overlain by the Eocene Golden Valley Formation; however, it has been removed by erosion from the study area.

Fort Union sandstones, siltstones, shales, and lignite are overlain by Pleistocene and Holocene deposits (Plates 13 through 16).

### Fort Union Formation - Paleocene

Cannonball-Ludlow Member - These sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the Northern Great Plains region. It consists of shale and thin-bedded sandstone which thins and interfingers westward with the continentally-deposited Ludlow.

Tongue River Member - The Tongue River Member consists of an alternating sequence of fluvial deposited sandstone, siltstone, and shale with associated beds of lignite. It is similar to the overlying Sentinel Butte Member and, in places, cannot be distinguished from it. It crops out in the study area along Beaver Creek and Tobacco Garden River and along the northern and southern shorelines of Lake Sakakawea to the east.

Sentinel Butte Member - The Sentinel Butte Member consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale, and lignite with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and uncemented. Shales vary from soft, plastic clayshale to moderately indurated claystone. Shale and siltstone zones readily break down and form slopes beneath sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling, and variation in bedding thickness. Laboratory analyses conducted on core samples from the nearby Rattlesnake Butte Study Area indicate that chemical and physical properties of the bedrock generally cannot be projected between drill holes. Weathered exposures are usually pale olive or yellowish-gray in color; while fresh core samples vary from light to dark gray. Marcasite and/or pyrite nodules are found along zones of higher permeability, such as fractures and bedding planes. The Sentinel Butte Member was deposited in a continental environment which included swamps conducive to the production of thick lignite beds. This member is up to 650 feet thick.

The contact between the Tongue River and Sentinel Butte Members of the Fort Union Formation has been placed at the top of the Pittsley coalbed (HT Butte bed). U.S. Bureau of Reclamation drill holes in the study area have penetrated the upper 50 feet of the Tongue River and the lower 500 feet of the Sentinel Butte Members.

Striking features in the Sentinel Butte and Tongue River Members are the resistant clinker zones, locally called "scoria" that cap knobs or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of lignite beds along and back from their outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight

# EXPLANATION

- HOLOCENE**
  - Surface Water - includes larger sloughs, lakes, and rivers.
  - Alluvium - includes present day stream, river alluvium, and alluvial terrace deposits of unconsolidated sand, silt, and clay. Up to 30 feet thick. Postglacial.
  - Loess - includes windblown sand dunes and blowouts. Up to 10 feet thick. Postglacial.
- PLEISTOCENE**
  - Outwash - includes glacial outwash plains, proglacial outwash plains, and terraces of unconsolidated sand and gravel. Up to 100 feet thick.
  - Kames - includes kames, kame terraces, disintegration ridges, and ice-contact deposits of sand and gravel. Up to 50 feet thick. Glacial.
  - Lacustrine - includes lake plain and collapsed lake plain silts and clays. Up to 30 feet thick. Glacial.
  - End Moraine - linear ridges of till (gravel, sand, silt, clay, boulders). Up to 50 feet thick. Glacial.
  - Dead-Ice Moraine - includes hills, knobs, sloughs, kettles, etc. with no overall trend composed of till. Local nonintegrated drainage. Up to 150 feet thick. Glacial.
  - Till - includes ground and sheet moraines composed of till (boulders, gravel, sand, silt, and clay). Up to 100 feet thick. Glacial.
  - Wiota Gravel Terrace - unconsolidated sand and gravel on benches along preglacial Yellowstone River. Up to 18 feet thick. Preglacial.
- PALEOCENE**
  - Tertiary Fort Union Formation - tan sandstone, siltstone, shale, and lignite.



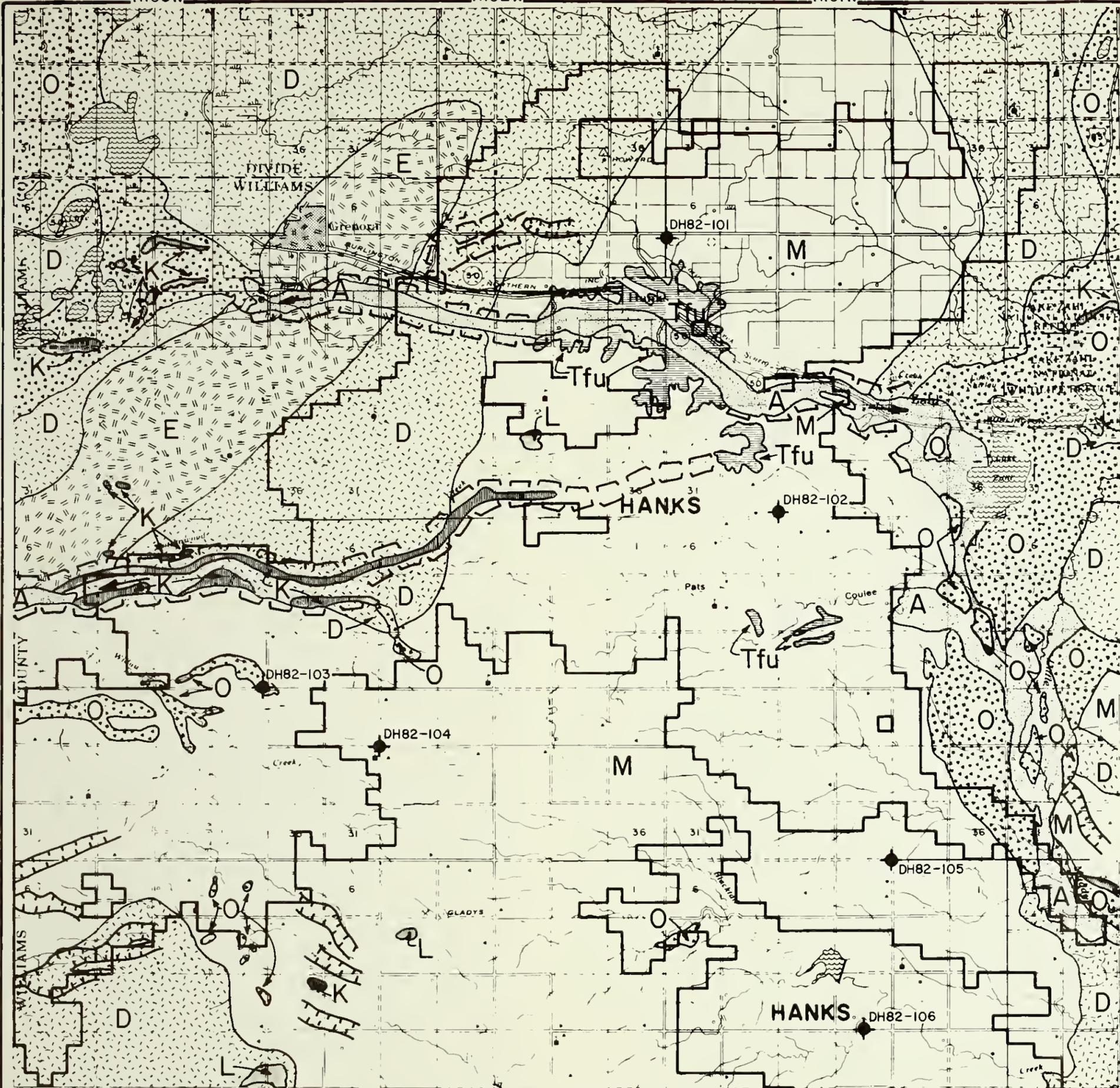
- Drift-mantled Channel or Kettle Chain - linear depression underlain by till.
- Meltwater Channel - steep-sided trench that carried glacial meltwater; underlain by sand, gravel, and/or till. Arrow shows direction of most recent flow of meltwater. Not all meltwater channels shown.
- Geologic Contact.
- USBR Drill Hole Location.

DH82-124

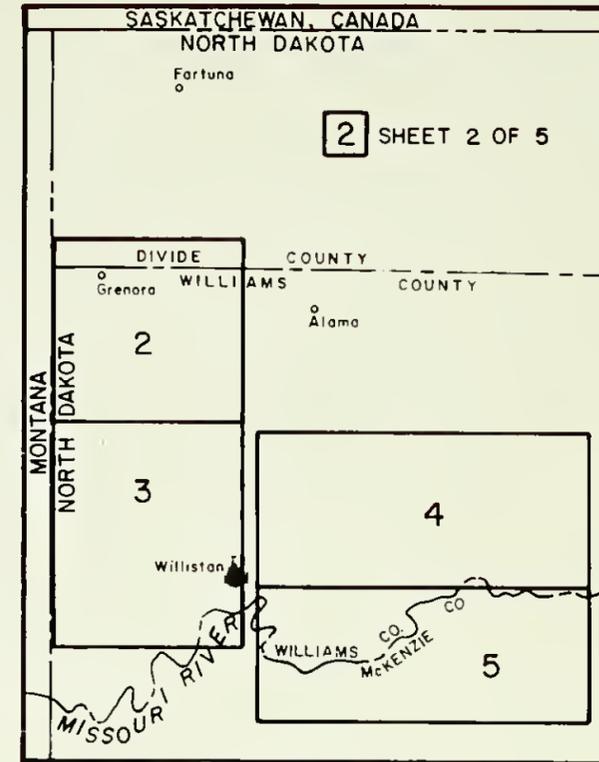
NOTE: This map was prepared from the following sources (See Bibliography): (1) Freers, 1970; (2) Colton, et al, 1963; and (3) Clayton, 1980. The map was further modified by data from U.S.B.R. drill holes.

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<b>EXPLANATION OF GEOLOGY MAPS</b>	
<b>PLATES 13-16</b>	
<b>GEOLOGY</b> <u>E. CALCAGNO</u>	<b>FIELD APPROVAL</b> _____
<b>DRAWN</b> <u>S. STARCEVICH</u>	<b>TECHNICAL APPROVAL</b> _____
<b>CHECKED</b> _____	<b>APPROVED</b> _____
<small>BILLINGS, MONTANA</small>	<small>MAY 1983</small>   <b>1305-600-388</b>
<small>SHEET 1 OF 5</small>	

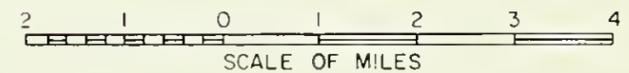




MATCH LINE DWG. NO. 1305-600-390



INDEX MAP



EXPLANATION on Dwg. No. 1305-600-388

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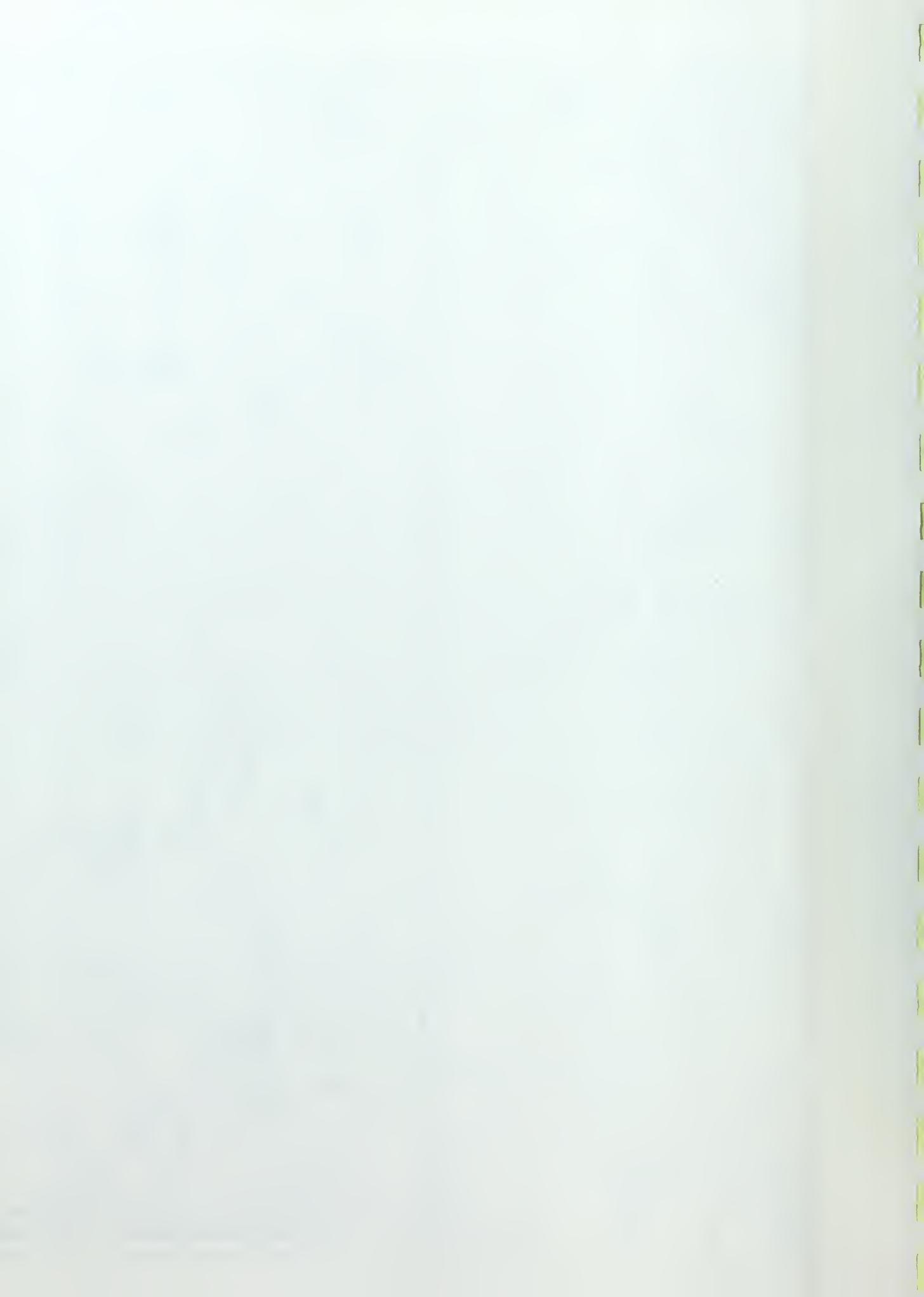
**GEOLOGIC & INVESTIGATIONS MAP**

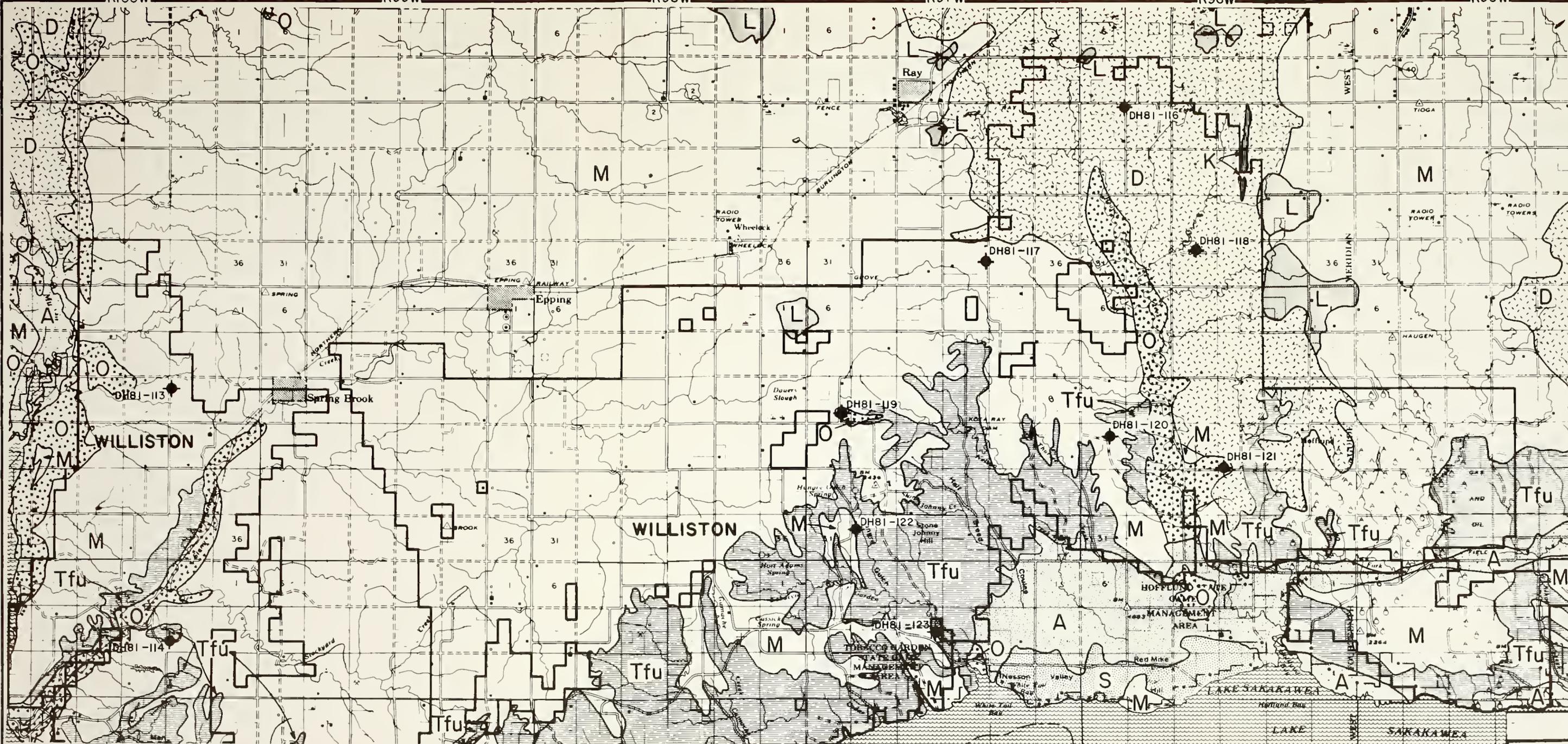
GEOLOGY F. CALCAGNO FIELD APPROVAL \_\_\_\_\_  
DRAWN S. STARCEVICH TECHNICAL APPROVAL \_\_\_\_\_  
CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

BILLINGS, MONTANA MAY 1983 SHEET 2 OF 5 1305-600-389









T 56 N

T 55 N



MATCH LINE DWG NO. 1305-600-392



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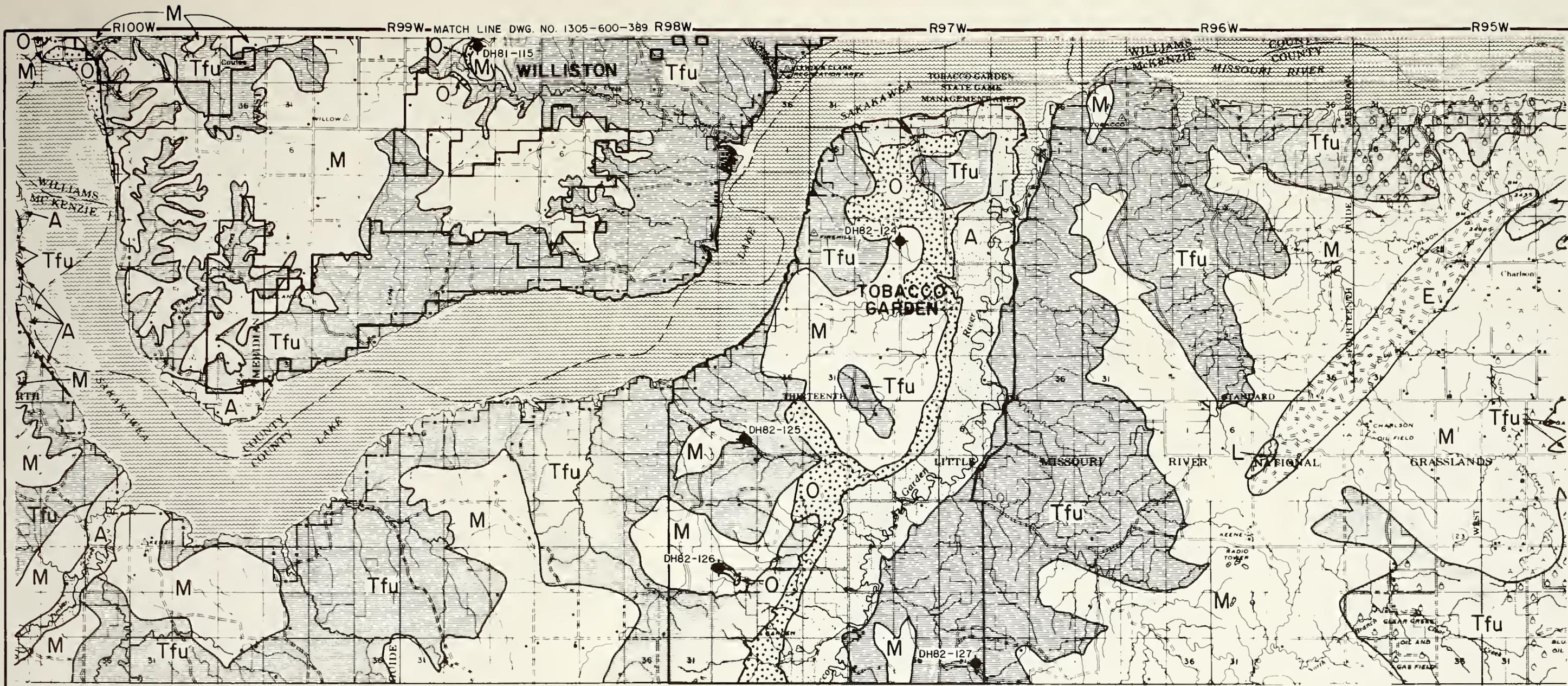
**GEOLOGIC & INVESTIGATIONS MAP**

GEOLOGY F. CALCAVO FIELD APPROVAL \_\_\_\_\_  
 DRAWN S. STARGOVICH TECHNICAL APPROVAL \_\_\_\_\_  
 CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

BILLINGS, MONTANA MAY 1983 1305-600-391  
 SHEET 4 OF 5

EXPLANATION on Dwg. No. 1305-600-388  
 Index Map on Dwg. No. 1305-600-389





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**GEOLOGIC & INVESTIGATIONS MAP**

GEOLOGY F CALCAGNO FIELD APPROVAL -----  
 DRAWN S STARCEVICH TECHNICAL APPROVAL -----  
 CHECKED ----- APPROVED -----

BILLINGS, MONTANA MAY 1983 SHEET 5 OF 5 **1305-600-392**

EXPLANATION on Dwg. No. 1305-600-388  
Index Map on Dwg. No. 1305-600-389



rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of lignite that has burned. A lignite bed 20 feet thick will produce clinker zones 40 to 60 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

#### Golden Valley Formation - Eocene

The Fort Union Formation is overlain by the Golden Valley Formation of Eocene age. These sediments have been eroded from the study area and crop out to the south of the study area along isolated high upland areas.

Upper Member - The Upper Member of the Golden Valley Formation consists of yellow-brown, fluvial, micaceous sandstone, sand, silt, and clay up to 200 feet thick.

Lower Member - The Lower Member consists of white or yellow clay, silt, and sand with a weathered zone developed on the underlying unit. The lower member is up to 65 feet thick.

#### Terrace Gravel - Pleistocene (Preglacial)

Wiota Gravel - The Wiota Gravel in the study area as reported by Freers, 1970, is a preglacial brown quartzitic gravel and associated sediment deposit which occurs at two, possibly three, levels on benches along the valley wall of the prediversion course of the Yellowstone River. The Wiota attains a thickness of from 6 to 18 feet.

#### Glacial Deposits - Pleistocene

Till - The glacial till deposits consist of a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by one or more continental glaciers. Till is widely distributed throughout the study area and is absent only where post-glacial erosion has removed it as in the areas adjacent to the shorelines of Lake Sakakawea. Where it occurs, it is present as a thin veneer or as remnant patches on the bedrock surface (most notably south of the Missouri River, where the extreme limits of glaciation are approached) to over 100 feet thick where till was deposited in preglacial bedrock valleys.

Outwash - The outwash deposits consist mostly of sand and gravel that fill buried channels and underlie Holocene alluvium along the Little Muddy River and Beaver and Tobacco Garden Creeks in depths up to 100 feet thick.

Lacustrine - The lacustrine deposits consist of glacial and proglacial lake silts and clays. They occur predominantly to the northeast and are up to 30 feet thick.

Terrace - Terrace deposits exist as erosional remnants of sand and gravel that were deposited by glacial meltwater. These deposits occur along the valley walls of Stony Creek and are up to 30 feet thick.

## Post-glacial deposits - Holocene

Windblown (loess) - Windblown silt and sand are locally present in the study area and overlie every type of deposit. In most areas they are thin and discontinuous and were not mapped. An exception to this occurs along the northern shoreline of Lake Sakakawea near Beaver Creek where the deposits are up to 10 feet thick.

Alluvium - Alluvial deposits consist of unconsolidated clay, silt, sand, and gravel that cover the modern valley floors and undrained depressions in the study area. Alluvial deposits along the Missouri River range from a few feet to over 150 feet thick, while alluvium in lesser tributaries attain thicknesses of 25 to 30 feet. Sloughs can contain up to 20 feet of alluvium.

### Structure

The study area is located on the northwestern flank of the Williston basin. Regional dips in the area are generally less than  $0.25^\circ$  to the southeast. The major structural feature within the study area is the Nesson anticline which trends north-south through the eastern portion of the Williston Study Area. The total structural effect is a somewhat asymmetrical trough-like depression that dips southward. The axis of this trough extends through the west-central portion of Williams County. Consequently, strata within the Hanks, Sand Creek, and western Williston Study Areas generally dip to the southeast (approximately  $0.25^\circ$ ) whereas strata within the Tobacco Garden and central and eastern portions of the Williston Study Areas, which overlie the axis and western flank of the Nesson anticline, generally dip from  $0.2$  to  $0.5^\circ$  to the west. Spencer (1978) has also identified other structural features within the area such as a depression centered on Stony Creek in T. 155 N., R. 100 W., and a structural high located in T. 154 and 155 N., R. 99 W.

Small local faults are common in the weak, plastic, carbonaceous shales immediately above or below lignite beds contained within the Fort Union Formation. Displacements along these fractures probably do not exceed 5 feet.

### Paleontology

Geologic investigations did not reveal any significant or unusual paleontological sites in the study area. Fossils in the Sentinel Butte Member are generally obscured by the mantle of glacial and alluvial soils. Fossils found in drill core samples included calcareous shell fragments (pelecypod?). The plant fossils found consisted of carbonaceous impressions of leaves and twigs. None of these were collected for identification.

### Mineral Resources

The most important economic resource within the area enclosed by the Williams and McKenzie Counties Study at the present time is petroleum. Oil and gas production along the Nesson anticline has progressed since 1951, displaying a dramatic rise in drilling activity in the past few years. New discoveries within the study area which have occurred during the past few years include such fields as the Bar Butte, Grinnell, Missouri Ridge, Indian Hill, Springbrook, Hoffland, Charlson, Catwalk, Sioux, and Hanks. Continued success on the Nesson anticline

has resulted in production in deeper zones in excess of 14,500 feet. Several new discoveries were also made to the northeast, east, and south of the area enclosed by the Williams and McKenzie Counties Study, especially along the Mondak trend and the "Billings Nose." Oil and gas production comes from Mississippian, Devonian, Silurian, and Ordovician rocks.

Lignite is also an important economic resource found in the study area. Lignite and its weathered equivalent, leonardite, have been mined in the study area on a small scale for a number of years. There are several lignite beds in the area thick enough to economically mine along with numerous very thin beds and stringers. The lateral continuity of many of the lignite beds in the area is only fair to good which makes correlation of beds difficult. Further information concerning lignite is presented below.

Other minerals of minor economic significance which have been produced within the study area include halite (hydraulically mined from the Mississippian "A" salt at depths of approximately 8,000 feet), bentonite (from bentonitic shales of the Fort Union Formation), sand and gravel (glacial origin), and scoria (road surfacing) from baked sediments.

### Lignite Beds

Approximately 25 lignite beds greater than 0.4 foot thick were penetrated by U.S. Bureau of Reclamation drilling within the Williams and McKenzie Counties Study. No one drill hole penetrated all lignite beds. Of these, 12 fairly consistently thick beds are present, some of which are more laterally continuous than others. The remaining lignite beds are of varying thickness and have little continuity. Additionally, several zones were penetrated containing thin, wispy lignitic laminations (often crossbedded) which may correlate with thin lignite beds. The 12 major lignite beds, from oldest to youngest, that were penetrated by drilling are: (1) R-bed; (2) Y-bed; (3) B-bed; (4) G-bed; (5) Pittsley; (6) Tyrone; (7) Blacktail; (8) Avoca; (9) Williston; (10) Judson (H-bed); (11) I- or J-bed (?); and (12) Mormon. Plate 44 shows general stratigraphic sections of the major lignite beds encountered in all four study areas.

Due to the wide spacing of drill hole information (only 27 drill holes in an area exceeding 1000 sections), coal resource data and structure/overburden contours were not determined in this study. The U.S. Geological Survey Open-File Report 78-168 (Spencer, 1978) provides coal resource data for the Williston Study Area. Additionally, the Bureau of Land Management presently has the Hanks, Sand Creek, and Tobacco Garden Areas under study. The remainder of the section of this report will discuss the general trends of the lignite deposits found within the Williams and McKenzie Counties Study as based on the data from the 27 drill holes.

R-, Y-, B-, G-beds - The R-, Y-, B-, and G-beds are the only significant lignite beds encountered by U.S. Bureau of Reclamation drilling in the Tobacco Garden Study Area. The designations R, Y, B, and G represent the Red, Yellow, Blue, and Green lignite beds of local industry terminology. Further geologic investigations, beyond the scope of this report, may reveal a correlation of a number of these beds to other lignite beds found within the Williston Study Area.

Within the Tobacco Garden Study Area, the R-bed attains a total thickness of 3 feet of lignite contained in three benches (approximately 6 feet of combined

interburden). The Y-bed ranges from 6.5 to 10 feet thick (average thickness of 8.5 feet) and is found in two benches (average interburden of 1.7 feet). The B-bed ranges from 8.5 to 11.5 feet thick (average 9.5 feet) and is found in from one to three benches (average interburden of 1 foot). The G-bed ranges from 5.0 to 10.5 feet thick (average 7.5 feet) and is found in two to three benches (average interburden of 8 feet). In general, average interburden thicknesses between the R- and Y-, Y- and B-, and B- and G-beds are, respectively, 30, 34, and 100 feet.

Pittsley Bed - The Pittsley lignite bed was encountered in only one drill hole (Williston Study Area) which displayed a thickness of 14.5 feet. The Pittsley bed apparently correlates with the HT Butte bed (Spencer, 1978) and may correlate with any of the R-, Y-, B-, or G-beds.

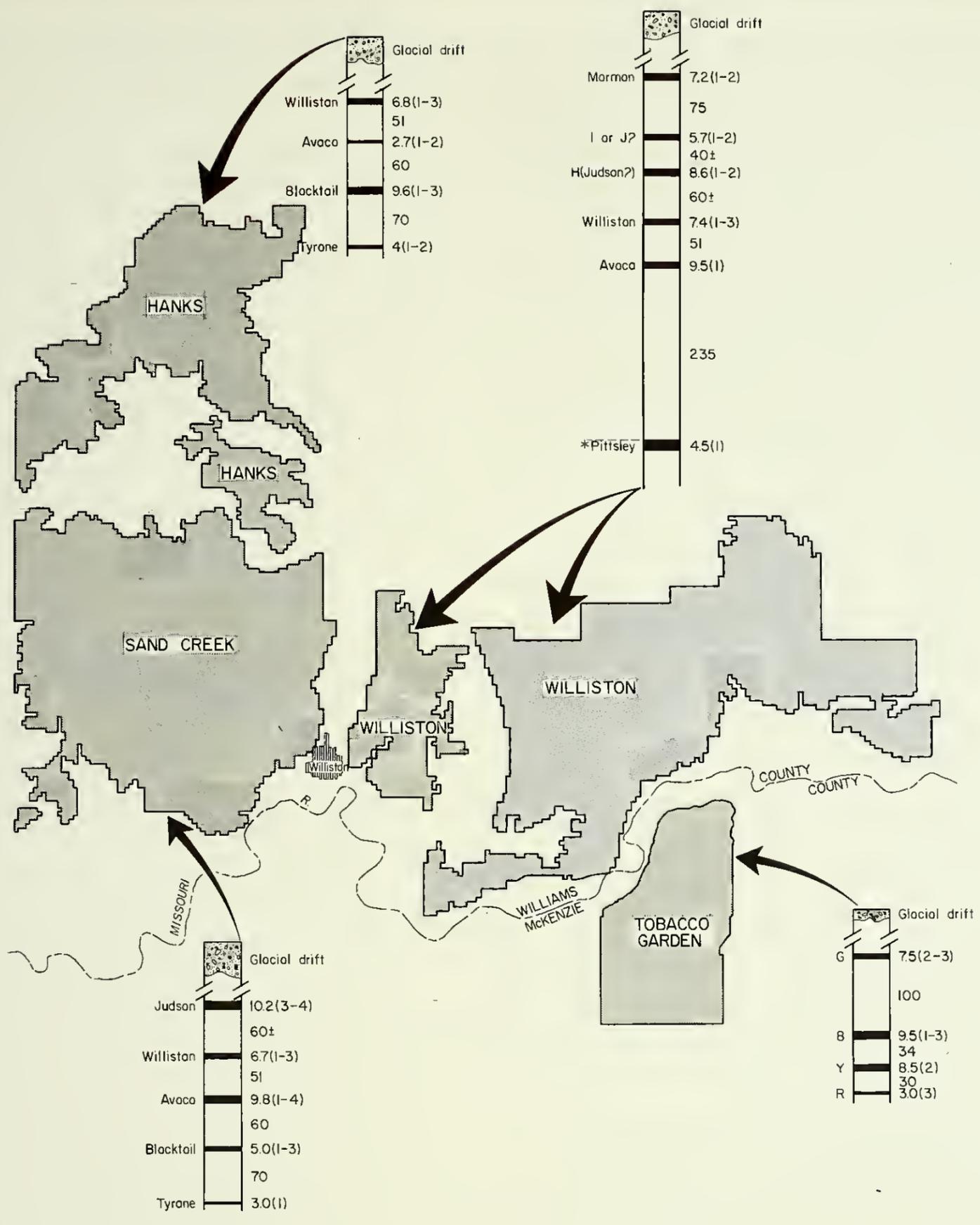
Tyrone Bed - The Tyrone lignite bed was encountered in the Sand Creek and Hanks Study Areas. The Tyrone bed attains a thickness of approximately 3 feet in the Sand Creek area and increases in thickness to the north (Hanks area) to an average of 4.0 feet (from 3.0 to 5.0 feet). The Tyrone locally contains two benches with up to 2 feet of interburden. The Tyrone bed pinches out to the east.

Blacktail Bed - The Blacktail bed lies approximately 70 feet above the Tyrone bed and similarly was only encountered in the Sand Creek and Hanks areas. In both areas the Blacktail contain from one to three benches with a combined average interburden thickness of 3 feet (0 to 8.5 feet). In the Sand Creek area the Blacktail ranges from 3.5 to 6.5 feet thick (average 5.0 feet) and increases in thickness in the Hanks area to an average of 9.6 feet (1.5 to 20.0 feet). The Blacktail lignite bed pinches out to the east.

Avoca Bed - The Avoca bed lies approximately 60 feet above the Blacktail bed. To the east (Williston Study Area), based upon limited data, it lies approximately 235 feet above the Pittsley bed. The Avoca bed was encountered in all three study areas to the north of the Missouri River and may correlate to one of the beds found in the Tobacco Garden Study Area as well. The Avoca apparently thickens to the south. It attains a thickness of from 2.0 to 4.0 feet (average 2.7 feet) in the Hanks area; from 9.0 to 11.0 feet (average 9.8 feet) in the Sand Creek area; and from 1.0 to 18.0 feet (average 9.5 feet) in the Williston area. The Avoca contains from one to two benches and splits into two additional benches in Sand Creek (average interburden of 2.0 feet).

Williston Bed - The Williston bed is the most laterally continuous lignite bed in the Williams and McKenzie Counties Study and has constituted the major target for mining in the area. The Williston bed lies approximately 51 feet (average) above the Avoca and similar to the Avoca, has been identified in all three areas north of the Missouri River and may also correlate to a lignite bed penetrated in the Tobacco Garden Study Area to the south. The Williston bed apparently thickens to the northeast. It attains a thickness of from 4.5 to 10.0 feet (average 6.7 feet) in the Sand Creek area; from 2.0 to 11.5 feet (average 6.8 feet) in the Hanks area; and from 1.0 to 13.7 feet (average 7.4 feet) in the Williston area. The Williston contains from one to three benches (average interburden thickness of 3.0 feet).

Judson Bed (H-bed) - The Judson lignite bed was identified in three drill holes within the Sand Creek Study Area. The Judson apparently correlates with the H-bed of Spencer (1981) in an easterly direction within the Williston Study Area



**EXPLANATION**

Variable overburden thickness due to topography.

Glacial drift

Number of benches contained in lignite bed.

Avaco 2.7(1-2)

70

Name of lignite bed

Average total thickness of lignite bed (ft.)

Average interburden thickness (ft.)

Generalized stratigraphic columns of lignite beds penetrated by U.S.B.R. drilling. The columns shown represent averages of drill holes for each of the four major study areas of the Williams and McKenzie Counties Study. Note that the upper several lignite beds at each site may locally be absent due to erosion.

\*Top of Pittsley lignite bed marks contact with Tongue River Member (below) to Sentinel Butte Member (above) of Fort Union Formation.

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WILLIAMS AND MCKENZIE COUNTIES STUDY  
NORTH DAKOTA

**GENERALIZED STRATIGRAPHIC COLUMNS**

GEOLOGY F. CALCAGNO FIELD APPROVAL \_\_\_\_\_  
DRAWN S. STARCEVICH TECHNICAL APPROVAL \_\_\_\_\_  
CHECKED \_\_\_\_\_ APPROVED \_\_\_\_\_

BILLINGS, MONTANA JUNE 1983 1305-600-420



where it was penetrated by an additional four drill holes. The Judson lies approximately 50 to 70 feet above the Williston bed. The Judson consists of from three to four benches (average interburden thickness of 5.7 feet) and attains a combined lignite thickness of from 8.0 to 14.5 feet (average thickness of 10.2 feet) in the Sand Creek Study Area, and 8.6 feet (from 3.0 to 15.0 feet) in its stratigraphic equivalent (the H-bed) in the Williston Study Area.

I- or J-bed(?) - A fairly thick lignite bed of 4.5 to 6.9 feet (average 5.7 feet) thickness, of rather limited lateral continuity, was penetrated by two drill holes within the Williston Study Area. This bed lies approximately 30 to 50 feet above the H-bed (Judson?) and may correlate to the I- or J-bed of Spencer (1981). This bed consists of predominantly one bench with some very thin shale partings.

Mormon Bed - The Mormon bed was encountered only in the Williston Study Area and, according to U.S. Bureau of Reclamation drill data, lies approximately 75 feet above the I- or J-bed (?) and approximately 200 feet above the Williston bed. The Mormon attains a thickness of from 5.0 to 10.5 feet (average 7.2 feet) and contains from one to two benches (average interburden thickness of approximately 5.0 feet).

### Engineering Geology

#### Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the Williams and McKenzie Counties Study. The physical property test results for this study area should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, particularly along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine-grained sandstones will readily erode and flow into excavations. This problem is sometimes encountered in drilling when the walls of holes collapse or slough. Depth of excavation will be limited by the water table until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

#### Stability of the Present Landscape

In its present undisturbed state, landscape within the Williams and McKenzie Counties Study experiences only minor problems with land stability. Small

landslides locally occur along oversteepened banks along the shoreline of Lake Sakakawea (Missouri River); however, the generally gentle slopes comprising the majority of land within the study area does not present serious problems. Land subsidence is not a problem in the study areas.

#### Overburden Expansion

Overburden volumes expand as the materials are broken up during mining. The increase in volume (bulking or swell) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after mining than the ground surface was before disturbance.

#### Instability of the Postmining Landscape 1/

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in midwinter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozercontouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, midwinter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in midwinter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoils.

1/ Groenewold, G.H., and Rehm, B.W., 1980.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

#### Weathering

Weathering tests were not performed on core samples collected in areas at the Williams and McKenzie Counties Study. However, weathering tests were conducted on similar materials of the Fort Union Formation (Sentinel Butte Member) at the Rattlesnake Butte Study Site, located approximately 90 miles to the south. These weathering tests revealed that shales break down more rapidly than either sandstones or siltstones, but the material produced may be difficult to move and place because of its plasticity. For further information, refer to the report on the Rattlesnake Butte Study Area.

#### Seismicity

The lands within the Williams and McKenzie Counties Study lie within a relatively stable part of North America. All of North Dakota is within Zone 1 of the Algermissen Seismic Risk Map. In this zone distant earthquakes can cause minor damage to structures with fundamental periods greater than 1.0 second (corresponds to Intensities V and VI of the Modified Mercalli Intensity Scale of 1931).

No earthquakes of Intensity V or above (Modified Mercalli) have occurred within North Dakota during historical times. Earthquakes centered in Iowa, Minnesota, Montana, South Dakota, Nebraska, and Canada have been felt in the State. A list of earthquakes that have been felt in North Dakota and that have occurred within 300 miles of the city of Williston follows, but some of the information on exact location and intensity is unknown.

<u>Date</u>	<u>Intensity (Modified Mercalli)</u>	<u>Distance From Williston, ND</u>	<u>Located Near</u>
Nov. 15, 1877	Unknown	Unknown	Iowa or Nebraska
Oct. 11, 1895	IV - V (2)	285	Hill City-Keystone, SD
May 15, 1909	Unknown	Unknown	Saskatchewan, Canada
Nov. 17, 1925	V	280	Bighorn, WY
Nov. 16, 1928	V	295	Custer, SD
June 24, 1943	VI	40	Froid, MT
Oct. 26, 1946	IV	0	Williston, ND
June 26, 1966	VI	275	Rapid City, SD
July 8, 1968	IV	170	Huff, ND

## OVERBURDEN SUITABILITY FOR REVEGETATION

### Introduction

Overburden samples from 20 representative Bureau of Reclamation drill holes were evaluated as to their suitability for use as a planting medium for revegetation. The representative drill holes were selected as follows:

Hanks Study Area: Drill Holes 82-101 through 82-106 (see Plates 17 through 22 in the Appendix).

Sand Creek Study Area: Drill Holes 82-107 through 82-109, 81-110, and 81-111 (see Plates 23 through 27 in the Appendix).

Williston Study Area: Drill Holes 81-113, 81-114, 81-117, 81-121, and 81-123 (see Plates 29, 30, 33, 37, and 39 in the Appendix).

Tobacco Garden Study Area: Drill Holes 82-124 through 82-127 (see Plates 40 through 43 in the Appendix).

### Procedures

The upper 10 feet of each drill hole were logged and sampled by a soil scientist (USBR). Below 10 feet, the core was logged and sampled by a geologist (USBR).

Four of the drill holes were sampled concurrently by the Bureau of Reclamation and U.S. Geological Survey<sup>1/</sup>. The purpose of this sampling process was for each agency to obtain identical samples (subsamples) and analyze for selected trace elements using different analytical techniques, i.e., atomic absorption spectrophotometry (USBR) versus inductively coupled plasma emission spectroscopy (USGS). Only the results from the USBR analyses are included in this report. The USGS data will be compared at a later date with those obtained by the USBR, and the pros and cons of using each of the analytical systems will be evaluated.

Complete laboratory analyses, including selected trace element determinations, were performed on the samples by Bureau of Reclamation laboratories in Bismarck, North Dakota, Boise, Idaho, and Denver, Colorado. The results of these analyses are presented in Tables 2 through 21 in the Appendix. In addition, x-ray diffraction analyses were performed on approximately 200 of the samples in order to identify the major clay mineral types occurring in the various overburden materials. The results of these analyses are discussed later in this report.

The suitability criteria listed in Table 22, Appendix, were applied to the laboratory data in order to place the overburden materials into one of three categories: Suitable, Limited Suitability, or Unsuitable.

### Results and Discussion

Tables 23 through 42 in the Appendix present the results of the overburden suitability evaluation for each representative drill hole. The results for each of the four study areas are discussed briefly below.

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<sup>1/</sup> Regional Geochemistry Branch, Denver, Colorado.

It should be recognized that this suitability evaluation is based on site-specific data collected at each drill hole. Any attempt to project the results within or between the study areas may be highly inaccurate due to wide variations in overburden characteristics. A much more detailed drilling program will be necessary prior to mining to more accurately determine the quantity and quality of the overburden materials.

#### Hanks Study Area - Drill Holes 82-101 through 82-106

Approximately 21 percent of the overburden materials from these six drill holes were determined to be suitable for use as plant media, 31 percent were of limited suitability, and 48 percent were unsuitable.

The overburden materials were of three distinct types: topsoil/subsoil, glacial till or outwash, and soft sedimentary beds.

Generally, 1 to 4 feet of topsoil/subsoil was present in each drill hole. In most cases, the topsoil (6 to 18 inches) is medium textured, nonsaline, and non-sodic, making it highly desirable for surface placement in a reconstructed profile. Most of the subsoil materials were of limited suitability due to their moderately fine texture. These slowly permeable materials could produce excessive runoff and erosion if they are placed on the surface. They are, however, suitable for subsurface placement in the plant rooting zone.

The soil (or outwash) in each drill hole was underlain by glacial till which extended to depths ranging from 7.5 feet in Drill Hole 82-105 to 71.6 feet in Drill Hole 82-104. Most of the till materials were rated as limited suitability due to moderately fine texture and/or moderate salinity (4-12 mmhos/cm). These materials are unsuitable for use as topsoil; however, they could be utilized to supplement available subsurface materials.

The soft sandstones, shales, or siltstones underlying the glacial till in these drill holes belong to the Sentinel Butte Member of the Paleocene Fort Union Formation. Most of these materials were rated as limited suitability or unsuitable for use as planting media. The limited suitability materials were restricted primarily by moderately fine or moderately coarse texture and/or moderate salinity. These materials are undesirable for surface placement, but could be utilized in the root zone beneath 12 to 18 inches of good quality topsoil. The materials rated as unsuitable were fine or coarse textured and/or highly sodic. In addition, moderately high levels of nickel occurred in a number of the samples. These unsuitable materials should be placed well below the root zone in reconstructed profiles. The suitable materials consisted of fine-grained sandstones and silty or sandy shales which were medium textured, nonsaline, and nonsodic. These materials could be selectively stripped and utilized to supplement available topsoil or subsoil.

#### Sand Creek Study Area - Drill Holes 82-107 through 82-109, 81-110, and 81-111

Of all overburden materials evaluated from these five drill holes, about 7 percent were determined to be suitable for use as revegetative media, 36 percent were of limited suitability, and 57 percent were unsuitable.

The overburden materials consisted either of topsoil/subsoil, glacial till, or weathered sedimentary beds.

The depth of available soil materials in these drill holes ranged from about 3 to 6 feet. The topsoil (6 to 18 inches) is of good quality; it is highly suitable for surface placement in a reconstructed profile. The subsoil materials are mostly of limited suitability due to their moderately fine texture. In addition, some of these materials are moderately saline and contain a moderately high level of manganese, i.e., DH-82-108.

Glacial till, underlying the soil material, occurred in each of the drill holes. It extended to depths ranging from 13.0 feet in DH-81-111 to 72.2 feet in DH-82-107. The majority of the till materials were rated as limited suitability due to moderately fine texture, moderate salinity, and, in Drill Holes 82-108 and 81-110, moderately high manganese levels. These materials are undesirable as a plant germination medium (topsoil), but could be utilized to supplement available subsoil materials.

Weathered sandstones, shales, and siltstones of the Sentinel Butte Member, Fort Union Formation, occurred beneath the glacial till in each of the drill holes. Most of these materials were classified as limited suitability or unsuitable due to one or more of the following factors: moderately fine to fine texture, moderate salinity, moderate to very high exchangeable sodium percentage, and moderately high levels of nickel. The limited suitability materials could be utilized in deficient areas to supplement available subsoil materials; they should not be utilized as topsoil, however. The unsuitable materials could severely restrict plant germination and development if they are placed in the root zone; therefore, they should be selectively placed beneath 2 to 3 feet of nonsaline/nonsodic soil or overburden in reconstructed profiles.

#### Williston Study Area - Drill Holes 81-113, 81-114, 81-117, 81-121, and 81-123

Approximately 5 percent of the overburden materials from the five drill holes in this study area were rated suitable for use as plant media, 25 percent were of limited suitability, and 70 percent were unsuitable.

Three material types were distinguished: topsoil/subsoil, glacial till or outwash, and soft sedimentary beds.

The depth of soil material over glacial till or outwash ranged from 3.2 feet in DH-81-117 to about 7.5 feet in DH-81-121. The topsoil, which consisted of 6 to 18 inches of medium textured, nonsaline, and nonsodic material, is highly suitable for surface placement in reconstructed profiles. The subsoil materials were nonsaline and nonsodic; however, most were moderately fine or moderately coarse textured, causing them to be placed in the limited suitability category. These materials, though undesirable for surface placement, are well suited for subsurface placement in the plant rooting zone.

Glacial till occurred in four of the five drill holes, the exception being DH-81-121, in which only glacial outwash occurred. The till extended to depths ranging from 10.0 feet (DH-81-113) to 68.8 feet (DH-81-117). The latter depth, however, was interrupted between 9.0 and 47.5 feet by glacial outwash. Most of the till materials were rated as limited suitability due to moderately fine texture or moderate salinity. These materials are not suitable for surface placement in reconstructed profiles, but could be used to supplement available subsoil materials in the plant rooting zone. The glacial outwash materials varied in texture from moderately coarse (sandy loam) to very coarse (gravelly

sand). The moderately coarse materials are undesirable as topsoiling material, but could be utilized in deficient areas as subsurface material. The coarser materials were rated unsuitable; the low water holding capacity and fertility of these materials would adversely affect plant growth if they were placed in the root zone in reconstructed profiles.

Soft shales, siltstones, and sandstones occurred beneath the glacial till or outwash in each drill hole. These sedimentary beds belong to the Sentinel Butte Member of the Fort Union Formation. Only a few of these materials, primarily silty or clayey sandstones, were rated suitable for use as revegetative media. Most of the materials were classified as limited suitability or unsuitable due to moderate or high exchangeable sodium percentages and/or textural limitations. In addition, moderate salinity levels were present in a few samples, and moderately high contents of nickel or manganese occurred in a number of the materials. The limited suitability materials could be utilized as subsurface material, preferably below 2 to 3 feet of nonsaline/nonsodic material. The unsuitable materials should be selectively placed well below the root zone in reconstructed profiles.

#### Tobacco Garden Study Area - Drill Holes 82-124, 82-125, 82-126, and 82-127

Of all overburden materials evaluated from these four drill holes, approximately 4 percent were determined to be suitable for use as plant media, 24 percent were of limited suitability, and 72 percent were unsuitable.

The overburden materials again consisted of topsoil/subsoil, glacial till or outwash, or soft sedimentary beds.

In Drill Holes 82-124 and 82-125, 4.2 and 4.3 feet, respectively, of soil material was present above glacial till. The upper 24 to 30 inches of this soil material was medium textured, nonsaline, and nonsodic, making it highly suitable for use as topsoiling material in a reconstructed profile. The lower 24 to 30 inches of the soil material was of limited suitability due to moderately fine texture. This material, though undesirable for surface placement in a reconstructed profile, is well suited for subsurface placement in the plant rooting zone.

Only 11 inches of soil material was present above sandy outwash in Drill Hole 82-126. This soil material was rated suitable for use as revegetative material.

In Drill Hole 82-127, 3.3 feet of colluvial soil material occurred above fine-grained sandstone. This soil material was moderately fine textured, causing it to be placed in the limited suitability category. It is not suitable for surface placement in a reconstructed profile, but could be utilized as subsurface material in the plant rooting zone.

The glacial till underlying the soil materials in Drill Holes 82-124, 82-125, and 82-126 was rated as limited suitability due to moderately fine texture and/or moderate salinity. A thin outwash zone occurring between the soil and till in Drill Hole 82-127 was also classed as limited suitability due to moderately coarse texture. Both the till and outwash materials are undesirable for use as topsoiling material in a reconstructed profile. They are, however, of suitable quality for subsurface placement in the root zone.

The sedimentary beds occurring in these drill holes belong to the Sentinel Butte Member of the Fort Union Formation. Only 2 beds, both sandstones, were rated suitable for use as plant media. These good quality materials could be utilized as either topsoil or subsurface material in a reconstructed profile. The remainder of the sedimentary materials were classified as limited suitability or unsuitable due primarily to textural limitations (fine or coarse) and/or moderate to high exchangeable sodium percentages. In addition, a number of the materials contained moderate amounts of soluble salts or moderately high levels of manganese or nickel. The limited suitability materials could be utilized as subsurface materials in reconstructed profiles, preferably below 2 to 3 feet of nonsaline/nonsodic material. The unsuitable materials are undesirable as a planting medium; they should be selectively placed well below the root zone in reconstructed profiles.

#### Summary of Overburden Suitability

Three distinct material types comprised the overburden in 20 representative drill holes from the Hanks, Sand Creek, Williston, and Tobacco Garden Study Areas. These were topsoil/subsoil, glacial till and/or outwash, and soft sedimentary beds.

Glacial till of variable depth occurred below the soil material in all but one of the drill holes. The till was underlain by the sedimentary beds, all belonging to the Sentinel Butte Member of the Paleocene Fort Union Formation.

Only a small percentage of the overburden materials were rated suitable for use as planting media. These materials commonly included the surface soil (1-2 feet) in each drill hole, as well as a few of the till materials and selected sedimentary strata. The latter typically consisted of sandstones, silty sandstones, or sandy siltstones/shales. The suitable materials were medium textured, non-saline, and nonsodic. They could be selectively stripped and utilized as either topsoil or subsurface material in reconstructed profiles.

Many of the subsoil, till, outwash, and sedimentary materials were placed in the limited suitability category due to moderately fine or moderately coarse texture and/or moderate salinity (4-12 mmhos/cm). In addition, some of these materials had moderately high exchangeable sodium percentages or contained moderate levels of manganese or nickel. The limited suitability materials are undesirable for use as topsoiling material; however, they could be utilized as subsurface material in reconstructed profiles, preferably below 2 to 3 feet of medium textured, nonsaline, and nonsodic material.

A significant percentage of the overburden materials were rated unsuitable for use as planting media. Most of these materials consisted of sedimentary beds which were fine or coarse textured and/or contained high percentages of exchangeable sodium. A number of these materials were also moderately saline and/or contained moderately high levels of nickel or manganese. In addition to the sedimentary beds, several outwash zones were rated unsuitable due to very coarse texture. The unfavorable physical and chemical characteristics of these materials make them undesirable for use as planting media. They should be selectively placed well below the plant rooting zone in reconstructed profiles.

## Introduction

X-ray diffraction analyses were performed on approximately 200 overburden samples from 14 Bureau of Reclamation drill holes in the Hanks, Sand Creek, Williston, and Tobacco Garden Study Areas. The purpose for these analyses was to differentiate the major clay types comprising the overburden materials. The following drill holes were selected for sampling:

Hanks: Drill Holes 82-101, 82-104, and 82-105.

Sand Creek: Drill Holes 81-110 and 81-111.

Williston: Drill Holes 81-113, 81-114, 81-117, 81-121, 81-122, and 81-123.

Tobacco Garden: Drill Holes 82-125, 82-126, and 82-127.

The overburden materials selected for analysis consisted of 1 soil sample (subsoil), 16 glacial till samples, 117 shale samples, 21 siltstone samples, and 41 sandstone samples. The samples from each drill hole are identified in the left-hand column of the geologic logs, as shown on Plates 17, 20, 21, 26, 27, 29, 30, 33, 37, 38, 39, 41, 42, and 43 in the Appendix.

## Results and Discussion

The percentages of the various clay mineral types occurring in each overburden sample analyzed are listed in Tables 43 through 56 in the Appendix. This data was condensed in Table 57 on the basis of material type (soil, till, shales, siltstones, and sandstones) to show the ranges and mean percentages of each clay type.

The following is a generalized discussion of clay type occurrence in the overburden materials examined in this study. A discussion pertaining to clay mineral formation, structure, and properties is beyond the scope of this report. The reader is referred to Grim (1968) for detailed information on this subject.

Illite and random mixed-layer clays were the dominant types comprising the overburden materials. Together, they generally constituted between 75 and 90 percent of the clay fraction. The random mixed-layer clays are composed of 2 or more clay minerals which are interlayered in an irregular pattern, i.e., nonuniform interstratification of illite and montmorillonite. Due to the inherent variability of these clay types, no attempt was made in this study to distinguish the individual clay species comprising them.

The smectite clay group, of which montmorillonite is a species, was only distinguished in one shale sample and three sandstone samples. However, it was the dominant type in these samples, comprising 97 to 100 percent of the clay fraction.

Kaolinite and chlorite were relatively common constituents in the overburden samples; however, they only constituted about 10 percent and 5 percent, respectively, of the clay fraction.

Other minerals occurring to a minor extent included quartz (about 0.5 percent), carbonate (about 0.3 percent), and feldspar (0.2 percent). An exception was the one soil (subsoil) sample analyzed, in which 3 percent quartz and 8 percent carbonate occurred.

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2/ Analyses performed by Case Western Reserve University, Cleveland, Ohio.

## BIBLIOGRAPHY

- Clayton, L., 1980, Geologic Map of North Dakota: North Dakota Geological Survey.
- Colton, R. B., Lemke, R. W., and Lindvall, R. M., 1963, Preliminary Glacial Map of North Dakota: United States Department of the Interior, Geological Survey, Miscellaneous Geologic Investigations Map I-331.
- Freers, T. F., 1970, Geology and Ground Water Resources - Williams County, North Dakota, Part I: North Dakota Geological Survey Bulletin 48.
- Grim, R.E., 1968, Clay Mineralogy (Second Edition), McGraw-Hill, Inc., New York, New York.
- Groenewold, G. H., and Rehm, B. W., 1980, Instability of Contoured Surface-Mined Landscapes in the Northern Great Plains: Causes and Implications, from: Adequate Reclamation of Mined Land? A Symposium, Billings, Montana, March 26-27, 1980.
- Pollard, B. C., Smith, J. B., and Knox, C. C., 1971, Strippable Coal Reserves of North Dakota: United States Department of the Interior, Bureau of Mines, Preliminary Report 182.
- Royse, C. F., 1967, Tongue River-Sentinel Butte Contact in Western North Dakota: North Dakota Geological Survey, Report of Investigations No. 95.
- Spencer, J. M., 1978, Lignite Geology of Southeast Williams County, North Dakota: United States Department of the Interior, Geological Survey Open File Report 78-168.
- Spencer, J. M., 1981, Geologic Map and Lignite Resources of the Cussicks Spring Quadrangle, Williams County, North Dakota: United States Department of the Interior, Geological Survey, Coal Investigations Map C-89.
- U.S. Department of the Interior, Bureau of Land Management, 1975, Otter Creek Study Site, EMRIA Report No. 1.
- U.S. Department of the Interior, Bureau of Land Management, 1982, Rattlesnake Butte Study Area.

Ranges and Means (Percentages) of Clay Types  
 Occurring in Overburden Samples from the Hanks,  
 Sand Creek, Williston, and Tobacco Garden Study Areas

**Glacial Till - 16 Samples**

<u>Type</u>	<u>Range (%)</u>	<u>Mean (%)</u>
Kaolinite	3 - 18	13.3
Chlorite	0 - 14	4.4
Illite	15 - 58	42.5
Smectite	-	-
Mixed Layer*	26 - 70	41.4
Quartz	0 - 6	1.2
Carbonate	-	-

**Shales (Includes Shales, Silty Shales, and Sandy Shales) - 117 Samples**

<u>Type</u>	<u>Range (%)</u>	<u>Mean (%)</u>
Kaolinite	0 - 56	9.0
Chlorite	0 - 17	7.8
Illite	5 - 73	43.5
Smectite	0 - 100**	-
Mixed Layer*	11 - 93	36.3
Quartz	0 - 8	1.1
Carbonate	0 - 5	0.3
Other (Feldspar)	0 - 25	0.5

**Siltstones (Includes Siltstones, Sandy Siltstones, and Clayey Siltstones) - 21 Samples**

<u>Type</u>	<u>Range (%)</u>	<u>Mean (%)</u>
Kaolinite	0 - 40	7.0
Chlorite	0 - 18	8.5
Illite	26 - 69	53.4
Smectite	-	-
Mixed Layer*	16 - 63	28.6
Quartz	0 - 3	0.9
Carbonate	0 - 4	0.3
Other (Feldspar)	0 - 3	0.1

\* Random Type

\*\* Occurred in only one sample (100 percent)

Ranges and Means (Percentages) of Clay Types  
 Occurring in Overburden Samples from the Hanks,  
 Sand Creek, Williston, and Tobacco Garden Study Areas

**Sandstones** (Includes Sandstones, Silty Sandstones, and Clayey Sandstones) -  
 41 Samples

<u>Type</u>	<u>Range (%)</u>	<u>Mean (%)</u>
Kaolinite	Trace - 39	8.3
Chlorite	0 - 15	5.8
Illite	15 - 68	30.3
Smectite	0 - 100**	-
Mixed Layer*	0 - 95	46.5
Quartz	0 - 8	1.2
Carbonate	0 - 3	0.1
Other	0 - 5	0.2

**Soil Material** (Only one sample analyzed: 4-38" subsoil zone in DH-81-117)

<u>Type</u>	<u>Range (%)</u>	<u>Mean (%)</u>
Kaolinite	12	12.0
Chlorite	0	0.0
Illite	14	14.0
Smectite	0	0.0
Mixed Layer*	63	63.0
Quartz	3	3.0
Carbonate	8	8.0

\* Random type

\*\* Occurred in only one sample (100 percent)

## APPENDIX

ENGLISH TO METRIC (SI) CONVERSIONS

<u>Multiply English Units</u>	<u>By</u>	
Inches	25.40	Millimeters (mm)
Feet	0.3048	Meters (m)
Miles	1.609	Kilometers (km)
Acres	0.4047	Hectares (ha)
	0.004047	Square Kilometers (km <sup>2</sup> )
Square Miles	2.590	Square Kilometers (km <sup>2</sup> )
Acre-Feet	0.001233	Cubic Hectometers (hm <sup>3</sup> )
Cubic Yard	0.7646	Cubic Meter (m <sup>3</sup> )
Feet Per Mile	0.1894	Meters Per Kilometer (m/km)
Btu Per Pound	0.556	Kilogram Calories Per Kilogram (kcal/kg)
Pounds	453.60	Grams (g)
Convert Degrees Fahrenheit to Degrees Celsius: °C = 5/9(°F - 32)		

FEATURE Hanks Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO DH82-101 LOCATION 105° E. 6.224' S. of NW Corner Section 7, T. 159 N., R. 101 W. GROUND ELEV. 2243.0'± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 3/27/82 FINISHED 3/30/82 DEPTH OF OVERBURDEN 10.0' TOTAL DEPTH 177.8' BEARING \*\*\*\*\*
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED. See Notes. LOGGED BY Børdorf, 10,0-177.8' LOG REVIEWED BY \*\*\*\*\*

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, CORE RECOVERY, SOILS ANALYSIS SAMPLE, SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION, DEPTH, GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION.

EXPLANATION
\* = X-Ray Diffraction Samples
\*\*Nestman - Soil Scientist (Top 10' logged by Børdorf - Geologist inch breaks)
Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ea = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nc = 3"

FEATURE Hanks Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO DH82-101 LOCATION 105° E. 6.224' S. of NW Corner Section 7, T. 159 N., R. 101 W. GROUND ELEV. 2243.0'± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 3/27/82 FINISHED 3/30/82 DEPTH OF OVERBURDEN 10.0' TOTAL DEPTH 177.8' BEARING \*\*\*\*\*
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED. See Notes. LOGGED BY Børdorf, 10,0-177.8' LOG REVIEWED BY \*\*\*\*\*

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, CORE RECOVERY, SOILS ANALYSIS SAMPLE, SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION, DEPTH, GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION.

EXPLANATION
\* = X-Ray Diffraction Samples
\*\*Nestman - Soil Scientist (Top 10' logged by Børdorf - Geologist inch breaks)
Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ea = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nc = 3"

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA
GEOLOGIC LOG OF DH 82-101
GEOLOGY C. BØRDORF FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA JUNE 1983 1305-600-393

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



Bureau of Reclamation **GEOLOGIC LOG OF DRILL HOLE** SHEET 1 OF 2

FEATURE Hanks Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 NOLE NO DH 82-102 LOCATION 400' N., 25' W. of S.E. Corner Sec. 32, T. 159 N., R. 101 W. GROUND ELEV. 2228.0' ± DIP (ANGLE FROM HORIZ) Vertical  
 BEGUN 10-25-82 FINISHED 10-27-82 DEPTH OF OVERBURDEN \*Westman 0.0-10.0 ft. TOTAL DEPTH 170.0 ft. BEARING  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-170.0 ft. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)	FROM	TO	SUITABLE	LIMITED SUITABILITY				
Drill Falling 1500, truckmounted Driller R. V. Shaw Method 10/25/82 Moved equipment in and set up on site. Rock bit from 0.0 to 2.0 ft. Bx Cs drive to 15.9 ft. Rock bit from 15.9 to 18.0 ft. Hq wireline from 18.0 to 23.5 ft. Set Hw Cs to 20.5 ft. and cleaned hole. Continued Hq wireline to 33.5 ft. Mixed in revert at 27.0 ft. 10/26/82 Hole at 33.5 ft. WL at 16.0 ft. Hw Cs at 16.0 ft. Hq wireline from 33.5 to 113.5 ft. with complete water circulation. 10/27/82 Hole at 113.5 ft. WL not reported. Hw Cs at 20.5 ft. Continued Hq wireline from 113.5 to 170.0 ft. Pulled tools, casing, and backfilled hole with cement slurry. Drill waters were sterilized as per North Dakota Water Commission requirements.	Rock bit	0					2218.0	2.0		PLEISTOCENE	
		BxCs	93	01	5.5						0 to 10 feet***;
			40	02	9.0			2210.0	10		Parent Material - Glacial till over sandstone at 10 feet.
			66	03	10.0						24-66 inches - Loam; 2.5 Y 5/2; slight effervescence.
		Rock bit	0	04	24.0						66-108 inches - Sandy clay loam; 2.5 Y 4.5/2; very slight effervescence.
			100	05	24.0						108-120 inches - Clay loam; 2.5 Y 3.5/2; very slight effervescence.
			90	06	42.5						Notes - No sample recovered from 0-24"; weathered till contains about 5-10% small and medium sized gravel, numerous iron stains, and salt masses concentrated along fractures.
			93	07	60.0			2177.5	42.5		PALEOCENE - FORT UNION FORMATION - SENTINEL BUTTE MEMBER
			100	08	78.0						10.0-42.5' SANDSTONE: fine grained, noncalcareous, horizontal and cross-bedding; tan; soft, crumbles with light finger pressure; lightly oxidized, moderately weathered and weakly cemented from 23.3 to 23.5 ft.; core lengths to 1.0 to 2.0 ft.
			100	09	95.0						42.5-111.4' SANDSTONE: fine grained, generally noncalcareous, horizontal and cross bedding, moderately cemented by calcium carbonate from: 46.9 to 51.7 ft. 87.5 to 88.5 ft., and 111.0 to 111.4 ft. (scratches with moderate knife pressure); rust tan to brown; soft, crumbles with light finger pressure; moderately weathered throughout; core lengths to 1.0 ft.; rust stained; 20° tight joints at 47.3, 147.6, and 47.9 ft.; moist.

**EXPLANATION**  
 \* Westman - Soil Scientist  
 Botdorf - Geologist  
 \*\* Top 10.0 ft. logged in inch breaks.  
 \*\*\* All soil colors moist.

Type of hole: D = Diamond, M = Moxystellite, S = Shot, C = Chum  
 Hole sealed: P = Parker, C = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"  
 Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Hanks Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 1 OF 2 NOLE NO DH 82-102

Bureau of Reclamation **GEOLOGIC LOG OF DRILL HOLE** SHEET 2 OF 2

FEATURE Hanks Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 NOLE NO DH 82-102 LOCATION 400' N., 25' W. of S.E. Corner Sec. 32, T. 159 N., R. 101 W. GROUND ELEV. 2228.0' ± DIP (ANGLE FROM HORIZ) Vertical  
 BEGUN 10-25-82 FINISHED 10-27-82 DEPTH OF OVERBURDEN \*Westman 0.0-10.0 ft. TOTAL DEPTH 170.0 ft. BEARING  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-170.0 ft. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			DEPTH (FEET)	FROM	TO	SUITABLE	LIMITED SUITABILITY				
Hq wireline from 170.0 to 155.1 ft.		100	09	111.4						137.9-148.1' COAL: most of coal was sampled and bagged in the field; black; soft to medium hardness; moist; shale from 147.6 to 148.1 ft.; dense with scattered brown woody lignitic chips.	
		90	10	117.9			2108.5	111.4		148.1-149.2' SANDSTONE: fine grain sand with lignite streaks, slightly calcareous, cross laminated, small pyritic concretions at 149.2 ft.; gray; soft, core breaks under light manual pressure; core lengths to 0.8 ft.; moist.	
		65	11	123.8			2102.5	117.9		149.2-154.7' SHALE: waxy sheen when cut, noncalcareous, laminated; gray; medium hardness, breaks along horizontal bedding planes with moderate manual pressure; core lengths to 1.0 ft.; 70° slickenside at 153.0 ft.; moist.	
		80	12	137.9			2096.2	123.8		154.7-155.1' COAL: platy, brittle, black; moist.	
		100	13	154.7			2082.1	137.9		155.1-170.0' SANDSTONE: fine grain sand, noncalcareous, laminated, cross bedding; gray; soft to medium hardness, breaking along bedding planes with light manual pressure; core lengths to 0.7 ft.; moist.	
		47	14	170.0			2071.9	148.1		Blockfall	
		23	15	154.7			2070.8	149.2			
			100	16	155.1			2065.3	154.7		
			100	17	170.0			2064.3	155.1		
			100	18	170.0			2050.0	170.0		

**EXPLANATION**  
 \* Westman - Soil Scientist  
 Botdorf - Geologist

Type of hole: D = Diamond, M = Moxystellite, S = Shot, C = Chum  
 Hole sealed: P = Parker, C = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"  
 Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Hanks Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 2 OF 2 NOLE NO DH 82-102

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

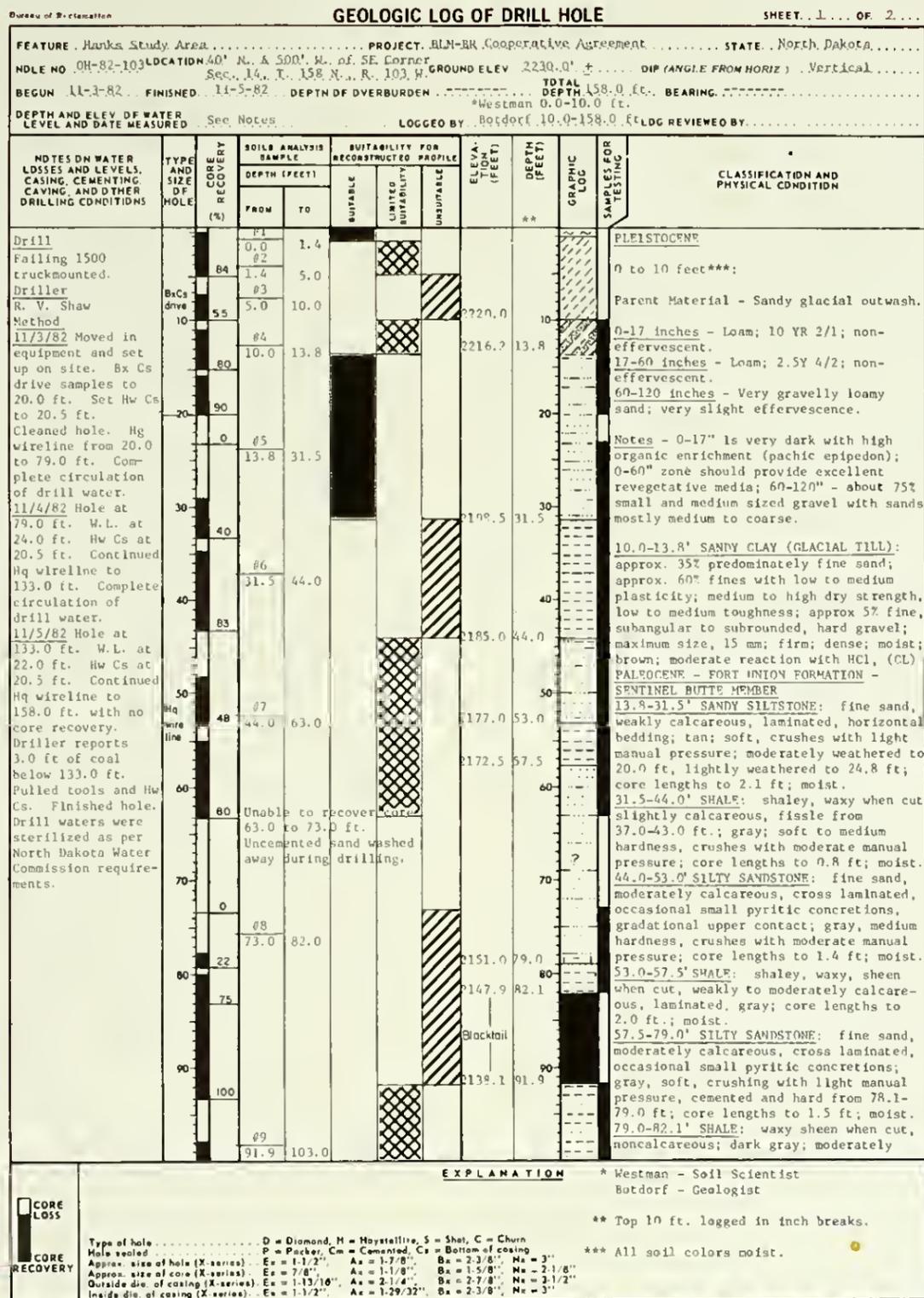
**GEOLOGIC LOG OF DH 82-102**

GEOLOGY C. BOTDORF FIELD APPROVAL  
 DRAWN S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED APPROVED

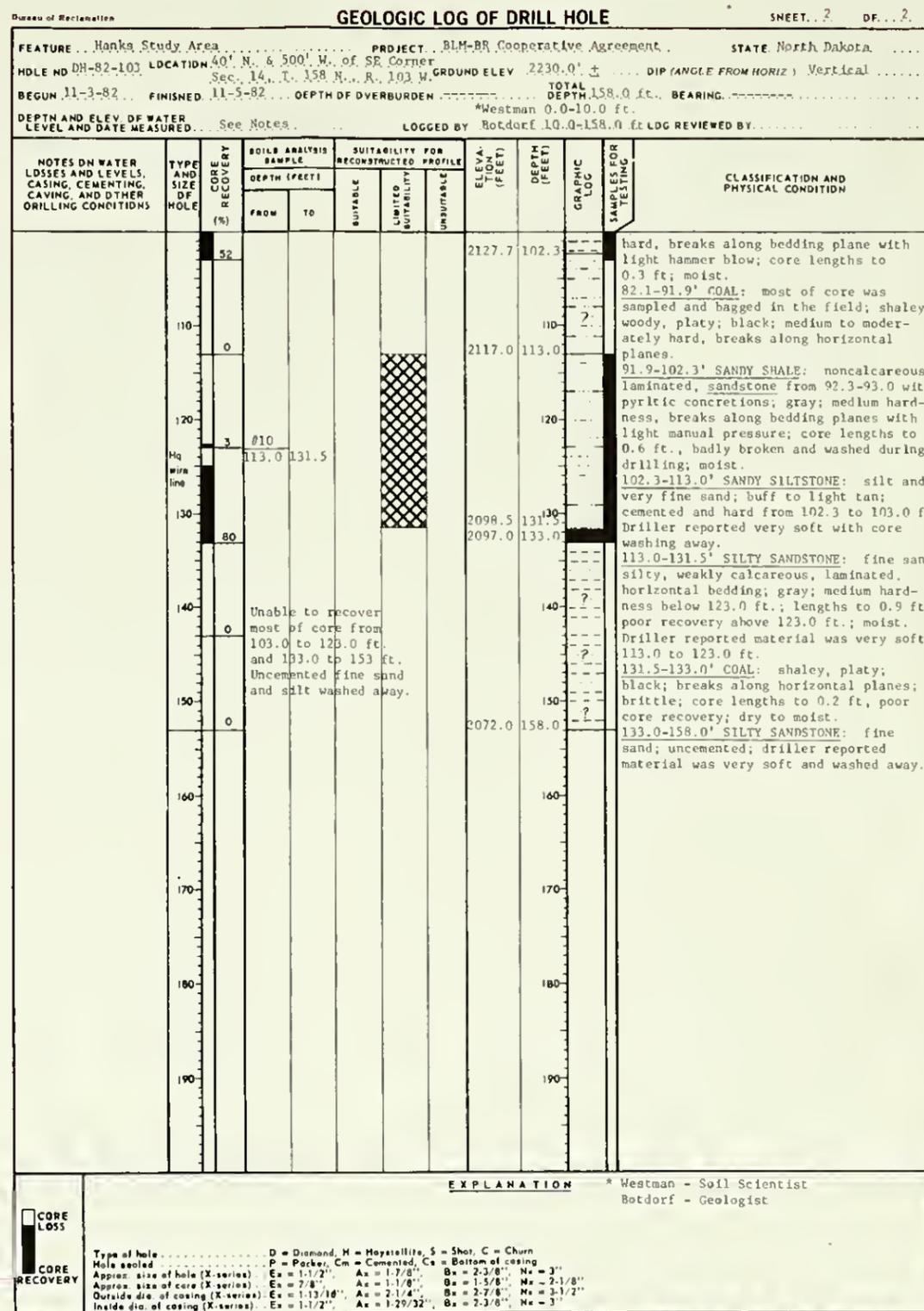
BILLINGS, MONTANA JUNE 1983 1305-600-394

Depth on logs in feet  
 Multiply feet by 0.3048 to obtain meters.





FEATURE: Hanks Study Area PROJECT: BLM-BR Coop. Agreement STATE: North Dakota SHEET 1 OF 2 HOLE NO: OH-82-103



FEATURE: Hanks Study Area PROJECT: BLM-BR Coop. Agreement STATE: North Dakota SHEET 2 OF 2 HOLE NO: OH-82-103

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
WILLIAMS AND MCKENZIE COUNTIES STUDY  
NORTH DAKOTA

**GEOLOGIC LOG OF DH 82-103**

GEOLOGY: C. BOTDORF FIELD APPROVAL: \_\_\_\_\_  
DRAWN: S. STARCEVICH TECHNICAL APPROVAL: \_\_\_\_\_  
CHECKED: \_\_\_\_\_ APPROVED: \_\_\_\_\_

BILLINGS, MONTANA JUNE 1983 1305-600-395

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 4

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... HOLE NO. DH82-104... LOCATION T. 251. N. and 150' W. of SE Corner Sec. 19... GROUND ELEV. 2405'... DIP (ANGLE FROM HORIZ.) Vertical... BEGUN 2-10-82 FINISHED 3-2-82 DEPTH OF OVERBURDEN 71.6' TOTAL DEPTH 332.5' BEARING... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY 10-112.5' F. Calcaagno 2/ LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, CLASSIFICATION AND PHYSICAL CONDITION, GRAFIC LOG, SAMPLES FOR TESTING. Includes detailed log entries from 0 to 332.5 feet depth.

EXPLANATION: X-Ray Samples listed on page 3 of 4. Soil Scientist / Geologist. Type of hole: D = Diamond, H = Hoya, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing. Approx. size of hole (X-section): Ex = 1 1/2", As = 1 1/8", Bs = 1 1/8", Ns = 2 1/8".

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 1. OF 4... HOLE NO. DH82-104

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 4

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... HOLE NO. DH82-104... LOCATION T. 251. N. and 150' W. of SE Corner Sec. 19... GROUND ELEV. 2405'... DIP (ANGLE FROM HORIZ.) Vertical... BEGUN 2-10-82 FINISHED 3-2-82 DEPTH OF OVERBURDEN 71.6' TOTAL DEPTH 332.5' BEARING... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY 10-112.5' F. Calcaagno 2/ LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, CLASSIFICATION AND PHYSICAL CONDITION, GRAFIC LOG, SAMPLES FOR TESTING. Includes detailed log entries from 115.0 to 332.5 feet depth.

EXPLANATION: X-Ray Samples listed on page 3 of 4. Soil Scientist / Geologist. Type of hole: D = Diamond, H = Hoya, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing. Approx. size of hole (X-section): Ex = 1 1/2", As = 1 1/8", Bs = 1 1/8", Ns = 2 1/8".

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 2. OF 4... HOLE NO. DH82-104

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 4

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... HOLE NO. DH82-104... LOCATION T. 251. N. and 150' W. of SE Corner Sec. 19... GROUND ELEV. 2405'... DIP (ANGLE FROM HORIZ.) Vertical... BEGUN 2-10-82 FINISHED 3-2-82 DEPTH OF OVERBURDEN 71.6' TOTAL DEPTH 332.5' BEARING... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY 10-112.5' F. Calcaagno 2/ LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, CLASSIFICATION AND PHYSICAL CONDITION, GRAFIC LOG, SAMPLES FOR TESTING. Includes detailed log entries from 218.5 to 332.5 feet depth.

EXPLANATION: X-Ray Samples listed on page 3 of 4. Soil Scientist / Geologist. Type of hole: D = Diamond, H = Hoya, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing. Approx. size of hole (X-section): Ex = 1 1/2", As = 1 1/8", Bs = 1 1/8", Ns = 2 1/8".

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 3. OF 4... HOLE NO. DH82-104

GEOLOGIC LOG OF DRILL HOLE SHEET 4 OF 4

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... HOLE NO. DH82-104... LOCATION T. 251. N. and 150' W. of SE Corner Sec. 19... GROUND ELEV. 2405'... DIP (ANGLE FROM HORIZ.) Vertical... BEGUN 2-10-82 FINISHED 3-2-82 DEPTH OF OVERBURDEN 71.6' TOTAL DEPTH 332.5' BEARING... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY 10-112.5' F. Calcaagno 2/ LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, CLASSIFICATION AND PHYSICAL CONDITION, GRAFIC LOG, SAMPLES FOR TESTING. Includes detailed log entries from 299.5 to 332.5 feet depth.

EXPLANATION: X-Ray Samples listed on page 3 of 4. Soil Scientist / Geologist. Type of hole: D = Diamond, H = Hoya, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing. Approx. size of hole (X-section): Ex = 1 1/2", As = 1 1/8", Bs = 1 1/8", Ns = 2 1/8".

FEATURE Hanks Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 4. OF 4... HOLE NO. DH82-104

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 82-104







GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE Hanks Study Site PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 85° N., 6.2275' E. of S.W. Corner Sec. 15, T. 157 N., R. 101 W. GROUND ELEV 2090.0' ± ... DIP (ANGLE FROM HORIZ) Vertical ...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed soil descriptions and depth measurements.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged in inch breaks. \*\*\* All Soil colors moist.

FEATURE Hanks Study Site PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 1 OF 3 HOLE NO. DH 82-106

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE Hanks Study Site PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 85° N., 6.2275' E. of S.W. Corner Sec. 15, T. 157 N., R. 101 W. GROUND ELEV 2090.0' ± ... DIP (ANGLE FROM HORIZ) Vertical ...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed soil descriptions and depth measurements.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged in inch breaks. \*\*\* All Soil colors moist.

FEATURE Hanks Study Site PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 2 OF 3 HOLE NO. DH 82-106

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE Hanks Study Site PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 85° N., 6.2275' E. of S.W. Corner Sec. 15, T. 157 N., R. 101 W. GROUND ELEV 2090.0' ± ... DIP (ANGLE FROM HORIZ) Vertical ...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed soil descriptions and depth measurements.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged in inch breaks. \*\*\* All Soil colors moist.

FEATURE Hanks Study Site PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 3 OF 3 HOLE NO. DH 82-106

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NDRTH DAKOTA GEOLOGIC LOG OF DH 82-106

Depth on logs in feet Multiply feet by 0.3048 to obtain meters



Revised 9/82 7-1337 (4-81) Bureau of Reclamation GPO 834-401 **GEOLOGIC LOG OF DRILL HOLE** SHEET 1 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
HOLE NO. DH 82-107 LOCATION 1125' S., 4 1/8' E. of N.W. Corner Sec. 11, T. 156 N., R. 103 W. GROUND ELEV. 2285.0' ± DIP (ANGLE FROM HORIZ) Vertical  
BEGUN 10-12-82 FINISHED 10-20-82 DEPTH OF OVERBURDEN 0.0-10.0 ft. BEARING Westman 0.0-10.0 ft.  
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-243.0 ft. LOG REVIEWED BY

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF MOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes soil analysis data for samples #1 through #12 and detailed lithological descriptions for Pleistocene and Paleocene formations.

**EXPLANATION**  
\* Westman - Soil Scientist  
Botdorf - Geologist  
\*\* Top 10 ft. logged by inch breaks.  
Type of hole: D = Diamond, H = Hydrastellite, S = Shot, C = Churn  
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
Approx. size of hole (X-series): Ex = 1-1/2", A = 1-7/8", B = 2-3/8", N = 3"  
Approx. size of core (X-series): Ex = 7/8", A = 1-1/8", B = 1-5/8", N = 2-1/8"  
Outside dia. of casing (X-series): Ex = 1-13/16", A = 2-1/4", B = 2-7/8", N = 3-1/2"  
Inside dia. of casing (X-series): Ex = 1-1/2", A = 1-29/32", B = 2-3/8", N = 3"

FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 1 OF 3 HOLE NO. DH 82-107

Bureau of Reclamation **GEOLOGIC LOG OF DRILL HOLE** SHEET 2 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
HOLE NO. DH 82-107 LOCATION 1125' S., 4 1/8' E. of N.W. Corner Sec. 11, T. 156 N., R. 103 W. GROUND ELEV. 2285.0' ± DIP (ANGLE FROM HORIZ) Vertical  
BEGUN 10-12-82 FINISHED 10-20-82 DEPTH OF OVERBURDEN 0.0-10.0 ft. BEARING Westman 0.0-10.0 ft.  
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-243.0 ft. LOG REVIEWED BY

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF MOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes soil analysis data for samples #13 through #20 and detailed lithological descriptions for Pleistocene and Paleocene formations.

**EXPLANATION**  
\* Westman - Soil Scientist  
Botdorf - Geologist  
Type of hole: D = Diamond, H = Hydrastellite, S = Shot, C = Churn  
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
Approx. size of hole (X-series): Ex = 1-1/2", A = 1-7/8", B = 2-3/8", N = 3"  
Approx. size of core (X-series): Ex = 7/8", A = 1-1/8", B = 1-5/8", N = 2-1/8"  
Outside dia. of casing (X-series): Ex = 1-13/16", A = 2-1/4", B = 2-7/8", N = 3-1/2"  
Inside dia. of casing (X-series): Ex = 1-1/2", A = 1-29/32", B = 2-3/8", N = 3"

FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 2 OF 3 HOLE NO. DH 82-107

Bureau of Reclamation **GEOLOGIC LOG OF DRILL HOLE** SHEET 3 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
HOLE NO. DH 82-107 LOCATION 1125' S., 4 1/8' E. of N.W. Corner Sec. 11, T. 156 N., R. 103 W. GROUND ELEV. 2285.0' ± DIP (ANGLE FROM HORIZ) Vertical  
BEGUN 10-12-82 FINISHED 10-20-82 DEPTH OF OVERBURDEN 0.0-10.0 ft. BEARING Westman 0.0-10.0 ft.  
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-243.0 ft. LOG REVIEWED BY

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF MOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes soil analysis data for samples #21 through #24 and detailed lithological descriptions for Pleistocene and Paleocene formations.

**EXPLANATION**  
\* Westman - Soil Scientist  
Botdorf - Geologist  
Type of hole: D = Diamond, H = Hydrastellite, S = Shot, C = Churn  
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
Approx. size of hole (X-series): Ex = 1-1/2", A = 1-7/8", B = 2-3/8", N = 3"  
Approx. size of core (X-series): Ex = 7/8", A = 1-1/8", B = 1-5/8", N = 2-1/8"  
Outside dia. of casing (X-series): Ex = 1-13/16", A = 2-1/4", B = 2-7/8", N = 3-1/2"  
Inside dia. of casing (X-series): Ex = 1-1/2", A = 1-29/32", B = 2-3/8", N = 3"

FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 3 OF 3 HOLE NO. DH 82-107

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION  
RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
WILLIAMS AND MCKENZIE COUNTIES STUDY  
NORTH DAKOTA  
**GEOLOGIC LOG OF DH 82-107**  
GEOLOGY C. BOTDORF FIELD APPROVAL  
DRAWN S. STARCEVICH TECHNICAL APPROVAL  
CHECKED APPROVED  
BILLINGS, MONTANA JUNE 1983 1305-600-399

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



**GEOLOGIC LOG OF ORILL HOLE**

SHEET 1 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2550' S, 6 50' W, of N.E. Corner Sec. 12, T. 156 N., R. 102 W. GROUND ELEV. 2180.0' ± DIP (ANGLE FROM HORIZ.) Vertical  
 BEGUN 10-8-82 FINISHED 10-11-82 DEPTH OF OVERBURDEN 0' TOTAL DEPTH 263.0 ft. BEARING  
 \*Westman 0.0-10.0 ft. LOGGED BY Botdorf 10.0-263.0 ft. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Drell Falling 1500, truck-mounted Dreller R. V. Shaw Method 10/8/82 Moved in equipment and set up on site. 10/9/82 Rock bit 0.0 to 2.0 ft. Bx Cs drive samples to 20.6 ft. Rock bit 20.6 to 24.3 ft. with Nk drive 23.0 to 23.2 ft. to cut rock. Set Hw Cs to 25.0 ft. Continued Bx drive to 40.0 ft. Hq wireline from 40.0 to 73.0 ft. Complete circulation of drill water. 10/10/82 Hole at 73.0 ft. Hw Cs at 25.0 ft. Continued Hq wireline from 73.0 to 153.0 ft. 10/11/82 Hole at 153.0 ft. Hw Cs at 25.0 ft. Continued Hq wireline from 153.0 to 263.0 ft. Pulled tools and Hw Cs. Backfilled hole with cement slurry. Drill waters were sterilized as per North Dakota Water Commission requirements.	0	#1	0			2178.0	2.0	<p>PLEISTOCENE (GLACIAL TILL)</p> <p>0 to 10 feet (All colors moist): Parent Material - Glacial till.</p> <p>24-60 inches - Clay loam; slight effervescence; 2.5 Y 5/2.</p> <p>60-120 inches - Heavy clay loam; very slight effervescence; 2.5 Y 4/2.</p> <p>Notes - No sample recovered from 0-24"; massive till contains about 5% small and medium sized gravel, numerous iron stains, and lime nodules.</p> <p>10.0-30.6' SANDY CLAY (GLACIAL TILL): approx. 55% fines with medium plasticity, high dry strength, medium toughness; approx 30% predominately fine to coarse subrounded to subangular hard sand; approx. 15% fine, subrounded, hard gravel; maximum size 20 mm; firm; dense; mottled; moist; brown; oxidized; weak reaction with HCl; core lengths to 3.5 ft. (CL) glacial erratic; from 20.0 to 21.3 ft.</p> <p>30.6-39.0' FAT CLAY (GLACIAL TILL): approx. 65% fines with medium to high plasticity, high dry strength, medium to high toughness; approx. 30% fine to coarse, subrounded, hard sand; approx. 5% fine, subrounded, hard, gravel; maximum size, 45 mm; firm; dense; moist; olive-drab; weak reaction with HCl; core lengths to 2.2 ft. (CH)</p> <p>PALEOCENE - FORT UNION FORMATION - SENTINEL BUTTE MEMBER</p> <p>39.0-49.0' SILTY SHALE: shaley, weakly calcareous, cross laminated; gray; soft to medium hardness; core lengths to 1.0 ft.; moist; hard, platy, black coal from 40.0 to 40.2 ft; banded by thin lignitic stringers from 46.0 to 49.0 ft.</p> <p>49.0-59.4' SANDY SILTSTONE: large amount of very fine sand, non and weakly calcareous, laminated, horizontal bedding, sandy and cross bedding from 50.8 to 51.9 ft., unconformably overlain; gray; soft to medium hardness, breaks with moderate manual pressure; core lengths to 2.0 ft.; moist.</p> <p>59.4-65.0' COAL: thinly bedded; black; medium hardness; broken; moist.</p> <p>65.0-104.0' SANDY SILTSTONE: large amount of fine sand, weakly calcareous, laminated, cross bedding, sandy from 80.0 to 83.0 ft. and 102.0 to 104.0 ft.; gray; soft to medium hardness; core</p>		
	2.0	#2	2.0			2170.0	10.0			
	10.0	#3	5.0			2160.0	20.0			
	20.6	#4	10.0			2149.4	30.6			
	30.6	#5	39.0			2141.0	39.0			
	39.0	#6	49.0			2131.0	49.0			
	49.0	#7	59.4			2120.6	59.4			
	59.4	#8	65.0			2115.0	65.0			
	65.0	#9	78.5			2102.6	78.5			
	78.5	#10	104.0			2088.6	104.0			

**EXPLANATION**

\* Westman - Soil Scientist  
 Botdorf - Geologist  
 \*\* Top 10 ft. logged in inch breaks.

Type of hole: D = Diamond, H = Hydrastelle, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1 1/2", As = 1 7/8", Bs = 2 3/8", Ns = 3"  
 Approx. size of core (X-series): Es = 7/8", As = 1 1/8", Bs = 1 5/8", Ns = 2 1/8"  
 Outside dia. of casing (X-series): Es = 1 13/16", As = 2 1/4", Bs = 2 7/8", Ns = 3 1/2"  
 Inside dia. of casing (X-series): Es = 1 1/2", As = 1 29/32", Bs = 2 3/8", Ns = 3"

FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 1 OF 3 HOLE NO. DH 82-108

**GEOLOGIC LOG OF ORILL HOLE**

SHEET 2 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2550' S, 6 50' W, of N.E. Corner Sec. 12, T. 156 N., R. 102 W. GROUND ELEV. 2180.0' ± DIP (ANGLE FROM HORIZ.) Vertical  
 BEGUN 10-8-82 FINISHED 10-11-82 DEPTH OF OVERBURDEN 0' TOTAL DEPTH 263.0 ft. BEARING  
 \*Westman 0.0-10.0 ft. LOGGED BY Botdorf 10.0-263.0 ft. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
lengths to 1.8 ft.; 60°-70° slickensides at 81.3 ft. and 83.5 ft.; moist. 104.0-132.4' SHALE: weakly calcareous, occasional pea size pyrite nodules, laminated; gray; soft to medium hardness; core lengths to 1.8 ft.; moist. Sandstone from 112.5 to 114.0 ft. and 124.8 to 131.2 ft.: fine grain sand with fines, weakly calcareous, laminated, horizontal bedding not readily apparent, weakly cemented, gradational contacts; gray; medium hardness, breaks with moderate manual pressure; core lengths to 1.7 ft.; moist. <p>137.4-145.9' COAL: most of core sampled and bagged in the field; black; soft to moderately hard; broken up; moist.</p> <p>145.9-170' SHALE: weakly calcareous, laminated, becomes sandy shale at 166.0 ft. and grades to shaly sandstone below 168.0 ft.; gray; medium hardness; core lengths to 1.8 ft.; moist. Platy moderately hard, dry, black coal from 159.4 to 162.4 ft.</p> <p>170.0-185.6' SANDSTONE: fine grained, weakly calcareous, laminated, grades from upper contact; gray; medium hardness; core lengths to 1.3 ft.; 30° closed joints at 176.7 and 177.1 ft.; cemented and hard from 181.8 to 183.0 ft.; moist.</p> <p>185.6-202.0' SANDY SILTSTONE: clayey silt with fine grained sand, non to weakly calcareous, cross laminated, gradational upper contact; gray; medium hardness; core lengths to 1.2 ft.; moist. Shale from 200.0 to 202.0 ft.</p> <p>202.0-210.0' COAL: most of coal sampled and bagged in field; black; medium to moderately hard; core lengths to 0.3 ft, broken; moist. Shale from 204.0 to 205.5 ft.: noncalcareous, laminated; gray; medium hardness; core lengths to 1.0 ft.; dry to moist.</p> <p>210.0-233.0' SILTY SHALE: shaley, weakly calcareous, laminated, poor recovery, occasional thin woody lignite inclusions; gray; medium hardness, breaks along bedding planes; core lengths to 1.9 ft.; moist.</p> <p>233.0-254.0' SANDY SHALE: large amount of fine sand; weakly calcareous, laminated; gradational upper contact; gray; medium hardness; core lengths to 0.8 ft. broken by drilling; moist.</p> <p>254.0-263.0' SANDY SILTSTONE: large amount of fine sand; weakly calcareous, cross laminated; gradational upper contact; gray; medium hardness; moist.</p>	15					2067.5	112.5	<p>104.0</p>		
	100	#9	104.0	124.8		2066.0	114.0			
	124.8	#10	124.8	131.2		2055.2	124.8			
	131.2	#11	131.2	137.4		2048.8	131.2			
	137.4	#12	145.9	159.4		2042.8	137.4			
	159.4	#13	162.4	168.0		2004.1	145.9			
	162.4	#14	185.6	202.0		2020.6	159.4			
	185.6					2017.6	162.4			
	202.0					1994.4	185.6			
	202.0									
	202.0									
	202.0									
	202.0									
	202.0									

**EXPLANATION**

\* Westman - Soil Scientist  
 Botdorf - Geologist

Type of hole: D = Diamond, H = Hydrastelle, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1 1/2", As = 1 7/8", Bs = 2 3/8", Ns = 3"  
 Approx. size of core (X-series): Es = 7/8", As = 1 1/8", Bs = 1 5/8", Ns = 2 1/8"  
 Outside dia. of casing (X-series): Es = 1 13/16", As = 2 1/4", Bs = 2 7/8", Ns = 3 1/2"  
 Inside dia. of casing (X-series): Es = 1 1/2", As = 1 29/32", Bs = 2 3/8", Ns = 3"

FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 2 OF 3 HOLE NO. DH 82-108

**GEOLOGIC LOG OF ORILL HOLE**

SHEET 3 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2550' S, 6 50' W, of N.E. Corner Sec. 12, T. 156 N., R. 102 W. GROUND ELEV. 2180.0' ± DIP (ANGLE FROM HORIZ.) Vertical  
 BEGUN 10-8-82 FINISHED 10-11-82 DEPTH OF OVERBURDEN 0' TOTAL DEPTH 263.0 ft. BEARING  
 \*Westman 0.0-10.0 ft. LOGGED BY Botdorf 10.0-263.0 ft. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Blockoil	100					1978.0	202.0	<p>1946.0</p> <p>204.0</p> <p>205.5</p> <p>210.0</p> <p>210.0</p> <p>220.0</p> <p>230.0</p> <p>233.0</p> <p>240.0</p> <p>250.0</p> <p>254.0</p> <p>263.0</p> <p>270.0</p> <p>280.0</p> <p>290.0</p>		
	210	#15	210.0	233.0		1947.0	233.0			
	233.0	#16	233.0	254.0		1926.0	254.0			
	254.0					1917.0	263.0			
	263.0									
	263.0									
	263.0									
	263.0									
	263.0									
	263.0									

**EXPLANATION**

\* Westman - Soil Scientist  
 Botdorf - Geologist

Type of hole: D = Diamond, H = Hydrastelle, S = Shot, C = Churn  
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FEATURE Sand Creek Study Area PROJECT BLM-BR Coop. Agreement STATE North Dakota SHEET 3 OF 3 HOLE NO. DH 82-108

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

**GEOLOGIC LOG OF DH 82-108**

GEOLOGY C. BOTOORE FIELD APPROVAL  
 DRAWN S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-400

Depth in logs in feet.  
 Multiply feet by 0.3048 to obtain meters



Revised 9/82 1-1237 (8-84) Bureau of Reclamation GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 450' N., S. 25' E. of S.W. Corner Sec. 6, T. 155 N., R. 102 W. GROUND ELEV. 2320.0' ± DIP (ANGLE FROM HORIZ) Vertical

Table with columns: TYPE AND SIZE OF MOLE, CORE RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLER FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic data and descriptions of soil layers.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged by inch breaks. \*\*\* All soil colors moist.

Bureau of Reclamation GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 450' N., S. 25' E. of S.W. Corner Sec. 6, T. 155 N., R. 102 W. GROUND ELEV. 2320.0' ± DIP (ANGLE FROM HORIZ) Vertical

Table with columns: TYPE AND SIZE OF MOLE, CORE RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLER FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic data and descriptions of soil layers.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged by inch breaks. \*\*\* All soil colors moist.

Bureau of Reclamation GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 450' N., S. 25' E. of S.W. Corner Sec. 6, T. 155 N., R. 102 W. GROUND ELEV. 2320.0' ± DIP (ANGLE FROM HORIZ) Vertical

Table with columns: TYPE AND SIZE OF MOLE, CORE RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLER FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic data and descriptions of soil layers.

EXPLANATION \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 ft. logged by inch breaks. \*\*\* All soil colors moist.

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NDRTH DAKOTA GEOLOGIC LOG OF DH 82-109

Depth on logs in feet Multiply feet by 0.3048 to obtain meters



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota... HOLE NO. DH81-110 LOCATION 50' N. & 50' E. of SW Corner Sec. 9, T. 155 N., R. 101 W. GROUND ELEV. 2215.0'... BEGUN 8-29-81 FINISHED 9-2-81 DEPTH OF OVERBURDEN 252.0' BEARING... LOGGED BY Parish 10-0-81 LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic descriptions and data points.

EXPLANATION: \*X-Ray diffraction samples listed on page 3. \*Westman - Soil Scientist Parish - Geologist. \*\*Top 10 feet logged using inch breaks. Type of hole: D = Diamond, M = Mezzellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 1 OF 3 HOLE NO. DH81-110

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota... HOLE NO. DH81-110 LOCATION 50' N. & 50' E. of SW Corner Sec. 9, T. 155 N., R. 101 W. GROUND ELEV. 2215.0'... BEGUN 8-29-81 FINISHED 9-2-81 DEPTH OF OVERBURDEN 252.0' BEARING... LOGGED BY Parish 10-0-81 LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic descriptions and data points.

EXPLANATION: \*X-Ray diffraction samples listed on page 3. \*Westman - Soil Scientist Parish - Geologist. \*\*Top 10 feet logged using inch breaks. Type of hole: D = Diamond, M = Mezzellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 2 OF 3 HOLE NO. DH81-110

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota... HOLE NO. DH81-110 LOCATION 50' N. & 50' E. of SW Corner Sec. 9, T. 155 N., R. 101 W. GROUND ELEV. 2215.0'... BEGUN 8-29-81 FINISHED 9-2-81 DEPTH OF OVERBURDEN 252.0' BEARING... LOGGED BY Parish 10-0-81 LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed stratigraphic descriptions and data points.

EXPLANATION: \*X-Ray diffraction samples listed on page 3. \*Westman - Soil Scientist Parish - Geologist. \*\*Top 10 feet logged using inch breaks. Type of hole: D = Diamond, M = Mezzellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 3 OF 3 HOLE NO. DH81-110

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 81-110

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



**GEOLOGIC LOG OF DRILL HOLE**

SHEET 1 OF 3

FEATURE		PROJECT		STATE					
Sand Creek Study Area		BLM-BR Cooperative Agreement		North Dakota					
NOLE NO		LOCATION		DIP (ANGLE FROM HORIZ)					
DH81-111		60' N. & 60' W. of SE Corner Sec. 33, T. 155 N., R. 102 W. GROUND ELEV. 2227.2		Vertical					
BEGUN		FINISHED		DEPTH OF OVERBURDEN					
9-13-81		9-16-81		227.0'					
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		LOGGED BY		LOG REVIEWED BY					
See Notes		Parish, 10, 9-227.0'							
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE		ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY				UNSUITABLE
Drill OAMCO Model 1250 truckmounted. Driller N.N. Hermanson Method Bx casing drive samples 0-21'. Hq wireline core 21-33.5'. Rockbit 33.5-35'. Hq wireline core 35-227'. Water used as drill fluid. Losses noted below: Depth Loss (ppm) 22-33.5' 15 37' 8 Casing Record Set Hq casing to prevent caving and water loss. Depth Date 0-20' 9-13-81 20-31' 9-14-81 Pulled casing on 9-15-81. Progress Record Depth Date 0-33.5' 9-13-81 33.5-103' 9-14-81 103-217.5' 9-15-81 217.5-227' 9-16-81 Hole Completion Pulled casing and backfilled hole with sand-cement slurry. Water Levels Not stabilized. Depth Date 23.0' 9-14-81 23.6' 9-15-81	Bx	0.0	1.0				0 to 10 feet (all colors moist) Parent Material - Glacial till 0-12 inches - Loam; very slightly calcareous; 10 YR 3/2. 12-48 inches - Clay loam; strongly calcareous; 2.5 Y 5/2. 48-120 inches - Sandy clay loam; slightly calcareous; 2.5 Y 4/2. Notes - Sample #3 contains entire 6 ft. till zone due to poor core recovery; distinct calcic zone 12-48"; >12". 5-10% gravel of mostly small size. 10.0-19.0' SANDY CLAY (GLACIAL TILL): approx. 70% low plasticity fines; 25% fine to coarse sand; 5% subangular to subrounded gravel to 1/4"; damp to moist crumbly to firm; strong HCl reaction; brown. (CL)		
		100	0.0	1.0				19.0	
		100	1.0	4.0				19.0	
		100	4.0	10.0				19.0	
		100	11.0	13.0				19.0	
		100	27.5	29.5				2199.5	27.5
		100	31.5	33.5				2190.0	37.0
		100	37.0	42.0				2185.0	42.0
		100	46.1	46.1				2180.9	46.1
		100	52.0	52.0				2175.0	52.0
		100	55.0	55.0				2172.0	55.0
	100	59.2	59.2				2164.5	59.2	
	100	71.6	71.6				2155.0	72.0	
	100	83.0	83.0				2141.0	86.0	
	100	92.0	92.0				2134.7	92.0	
	100	93.0	93.0				2134.0	93.0	

**EXPLANATION**

\*Westman - Soil Scientist Parish - Geologist  
 \*Top 10' logged using inch breaks.  
 Type of hole: D = Diamond, H = Hydrastillite, S = Shot, C = Churn  
 Hole sealed: P = Packed, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"  
 Approx. size of casing (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

**GEOLOGIC LOG OF DRILL HOLE**

SHEET 2 OF 3

FEATURE		PROJECT		STATE					
Sand Creek Study Area		BLM-BR Cooperative Agreement		North Dakota					
NOLE NO		LOCATION		DIP (ANGLE FROM HORIZ)					
DH81-111		60' N. & 60' W. of SE Corner Sec. 33, T. 155 N., R. 102 W. GROUND ELEV. 2227.2		Vertical					
BEGUN		FINISHED		DEPTH OF OVERBURDEN					
9-13-81		9-16-81		227.0'					
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		LOGGED BY		LOG REVIEWED BY					
See Notes		Parish, 10, 9-227.0'							
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE		ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY				UNSUITABLE
86.0-92.3' SHALE: gray; moist; cuts easily with knife; moderate HCl reaction; bedding not discernible; core lengths to 18". 92.3-93.0' COAL: black; moist; brittle 93.0-114.3' SHALE: gray; moist; cuts easily with knife; moderate HCl reaction; bedding not discernible; core lengths to 36". 114.0-114.3' Carbonaceous: black; plastic. 114.3-114.6' COAL: black; moist; brittle. 114.6-114.8' CARBONACEOUS SHALE: black; moist; plastic. 114.8-123.5' COAL: black; moist; brittle. 123.5-124.2' SHALE: gray; moist; plastic; cuts easily with knife; air slakes; weak HCl reaction; bedding not discernible; core lengths to 4". 124.2-124.8' COAL: black; moist; brittle. 124.8-129.5' SHALE: gray; moist; cuts easily with knife; plastic; air slakes; moderate HCl reaction; bedding not discernible; core lengths to 18". 129.5-130.4' SANDSTONE: no recovery; driller reported soft, gray sandstone that washed away during drilling. 130.4-140.0' SHALE: gray; moist; cuts easily with knife; weak HCl reaction; bedding not discernible; core lengths to 18". 140.0-197.0' CLAYEY SANDSTONE: gray; moist; crumbly; fine grained; weak HCl reaction; bedding not discernible; core lengths to 30". 197.0-199.4' COAL: black; moist; brittle. 199.4-206.0' SHALE: medium to dark gray; moist; plastic; air slakes; cuts with some difficulty; carbonaceous near top and bottom; weak HCl reaction; tan concretions at 205.0'; bedding nearly horizontal; core lengths to 15". 206.0-211.0' COAL: black; moist; brittle. 211.0-212.4' CARBONACEOUS SHALE: dark gray; moist; cuts with some difficulty; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 12". 212.4-214.0' COAL: black; moist; brittle. 214.0-217.0' CARBONACEOUS SHALE: dark gray; moist; cuts with some difficulty; no HCl reaction; plastic; air slakes; bedding not discernible; thin coal layers near top of unit; core lengths to 20". 217.0-217.3' COAL: black; shaley; brittle. 217.3-227.0' SHALE: gray; moist; cuts easily with knife; weak HCl reaction; bedding not discernible; core lengths to 18".	Bx	104.0	106.0				104.0		
		100	106.0	106.0				106.0	
		100	131.0	133.0				131.0	
		100	137.0	139.0				137.0	
		100	161.0	163.0				161.0	
		100	174.6	176.0				174.6	
		100	176.0	176.0				176.0	
		100	197.0	197.0				197.0	
		100	199.4	199.4				199.4	

**EXPLANATION**

\*Westman - Soil Scientist Parish - Geologist  
 \*Top 10' logged using inch breaks.  
 Type of hole: D = Diamond, H = Hydrastillite, S = Shot, C = Churn  
 Hole sealed: P = Packed, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"  
 Approx. size of casing (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

**GEOLOGIC LOG OF DRILL HOLE**

SHEET 3 OF 3

FEATURE		PROJECT		STATE					
Sand Creek Study Area		BLM-BR Cooperative Agreement		North Dakota					
NOLE NO		LOCATION		DIP (ANGLE FROM HORIZ)					
DH81-111		60' N. & 60' W. of SE Corner Sec. 33, T. 155 N., R. 102 W. GROUND ELEV. 2227.2		Vertical					
BEGUN		FINISHED		DEPTH OF OVERBURDEN					
9-13-81		9-16-81		227.0'					
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		LOGGED BY		LOG REVIEWED BY					
See Notes		Parish, 10, 9-227.0'							
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE		SUITABILITY FOR RECONSTRUCTED PROFILE		ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY				UNSUITABLE
201.9-203.9' Avoca 203.9-216.3' Avoca 216.3-219.5' Avoca 219.5-221.5' Avoca 221.5-227.0' Avoca	Bx	201.9	203.9				201.9		
		100	203.9	203.9				203.9	
		100	216.3	216.3				216.3	
		100	219.5	219.5				219.5	
		100	221.5	221.5				221.5	
		100	227.0	227.0				227.0	

**EXPLANATION**

\*Westman - Soil Scientist Parish - Geologist  
 \*Top 10' logged using inch breaks.  
 Type of hole: D = Diamond, H = Hydrastillite, S = Shot, C = Churn  
 Hole sealed: P = Packed, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"  
 Approx. size of casing (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

**GEOLOGIC LOG OF DH 81-111**

GEOLOGY: L. PARISH FIELD APPROVAL  
 DRAWN: S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED: APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-403

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



**GEOLOGIC LOG OF DRILL HOLE** SHEET 1 OF 2

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota

HOLE NO. DH81-112 LOCATION 1500' N. & 98' W. of SE Corner Sec. 20, T. 154 N., R. 102 W. GROUND ELEV. 2160' ± OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9/3/81 FINISHED 9/13/81 DEPTH OF OVERBURDEN 181.2' TOTAL DEPTH 181.2' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED. See Notes. LOGGED BY Westman 0-10.0' Botdorf 10.0-181.2' LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Drill DAMCO 1250 truck-mounted Driller M.M. Herrmannson 9/3/81 Set up rig on site. 9/9/81 Finished rig set up. BxCs drive samples from 0.0 to 10.0'. Rotation drive from 10.0 to 23.0'. Used fish-tail bit to clean hole and water below 10.0'. 5" Cs set @ 2.5'. 9/10/81 Hole is at 23.0'. W.L. at 6.0'. BxCa rotation drive samples 23.0 to 42.0'. Attempted Hq wireline 4 1/2" Cs set to 24.0'. Rockbit 42.0 to 46.0'. BxCs rotation drive from 46.0 to 53.0'. Hq wireline 53.0 to 56.0'. 9/11/81 Hole is at 56.0'. W.L. at 0.0'. 4 1/2" Cs at 21.0'. Hq wireline 56.0 to 113.0'. Water loss (10 to 15 gpm) at 70.0'. 9/12/81 Hole is at 113.0'. W.L. at 55.2'. 4 1/2" Cs at 21.0'. Hq wireline 113.0 to 162.0' water loss at 5-10 gpm. 9/13/81 Hole is at 162.0'. 4 1/2" Cs at 21.0'. Hq wireline from 162.0 to 181.2' with little water loss below 162.0'. Pulled 4 1/2" Cs. Backfilled hole with sand and slurry to 3.0'. Backfilled 3.0 to 0.0' with clay. Drill water was sterilized as per N.D. Water Commission requirement.	Bx	100	#1	0.0	2.0				2158.0	2.0	0 to 10 feet (all colors moist)
	100	#2	2.0	5.2				2154.8	5.2	Parent Material - Glacial Till	
	100	#3	5.2	7.5				2152.5	7.5	0-24 inches - Sandy loam; noncalcareous 10 YR 3/2.	
	100	#4	7.5	10.0				2150.0	10.0	24-62 inches - Heavy sandy loam; strongly calcareous; 2.5 Y 5/2.	
	100	#5	10.0	27.2					27.2	62-90 inches - Heavy sandy loam; slightly calcareous; 2.5 Y 5/2.	
	100	#6	27.2	42.0					42.0	90-120 inches - Sandy clay loam; slightly calcareous; 2.5 Y 5/2.	
	100	#7	42.0	55.2					55.2	Notes--Lime disseminated through matrix in 24-62" zone; sand in 24-120" zone are mainly medium to moderately coarse in size; >24" - 5-10% angular gravel of mostly small size.	
	100	#8	55.2	80.0					80.0	10.0-27.2 SANDY CLAY (GLACIAL TILL): medium and earthy brown; oxidized; moist; slight HCl reaction; 55% medium plasticity fines; 40% fine to coarse subrounded sand; 5% fine subrounded gravel to 1/4"; firm; trims with difficulty; core lengths to 4.0'. (CL)	
	100	#9	80.0	98.5					98.5	PALEOCENE-FORT UNION FORMATION-SENTINEL BUTTE MEMBER	
	100	#10	98.5	107.5					107.5	27.2-42.0 CLAYEY SANDSTONE-SANDY CLAYSTONE: brown; oxidized; moist; very slight HCl reaction; alternating bands of medium plastic shale and uncemented fine grained sandstone; horizontal bedding; firm; hard to crush between fingers; occasional nodules of sugar textured gypsum to 1/4"; core lengths to 4.5'; soft blue shale from 41.3 to 41.5.	
	100	#11	107.5	110.5					110.5	42.0-46.0 SILTSTONE: brown to gray; moist; large amount of fine sand; non-plastic; uncemented; weak HCl reaction; core washed away during drilling.	
	100	#12	110.5	113.0					113.0	46.0-53.0 SILTY GRAY SHALE: alternating tan and medium gray bands; moist slight HCl reaction; low plasticity; silty; poor core recovery; core lengths to 1.0.	
	100	#13	113.0	115.0					115.0	53.0-53.8 SHALY COAL: gray and black; moist; shaly; no HCl reaction; hard; poor lignite.	
	100	#14	115.0	117.0					117.0	53.8-55.2 SHALE: blue gray; moist; slight HCl reaction; compact; firm; trims with knife leaving a waxy sheen; core lengths to 1.4'.	
	100	#15	117.0	119.0					119.0	55.2-63.5 COAL: black; moist; very firm; sampled and bagged in field, not available for inspection.	
	100	#16	119.0	121.0					121.0	63.5-64.8 COAL: black to dark brown; shaly; crumbly; poor lignite; core lengths to 0.4'.	
	100	#17	121.0	123.0					123.0	64.8-98.5 SHALE: medium gray; moist; slight HCl reaction; horizontal bedding with occasional leaf thin, dark brown carbonaceous partings; firm; shaves easily with knife; iron sulfide nodules up to 1/4" in size from 65.0 to 65.8'.	
	100	#18	123.0	125.0					125.0	98.5-107.5 SANDSTONE: medium gray; moist; very slight HCl reaction; fine sand; weakly cemented; near horizontal bedding; core lengths to 2.2'.	

**EXPLANATION** (Continued from page 1)

100 CORE LOSS

100 CORE RECOVERY

Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"  
 Approx. size of core (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

\*Westman - Soil Scientist  
 Botdorf - Geologist

\*\* Top 10 feet logged by inch breaks

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 1 OF 2 HOLE NO. DH81-112

**GEOLOGIC LOG OF DRILL HOLE** SHEET 2 OF 2

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota

HOLE NO. DH81-112 LOCATION 1500' N. & 98' W. of SE Corner Sec. 20, T. 154 N., R. 102 W. GROUND ELEV. 2160' ± OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9/3/81 FINISHED 9/13/81 DEPTH OF OVERBURDEN 181.2' TOTAL DEPTH 181.2' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED. See Notes. LOGGED BY Westman 0-10.0' Botdorf 10.0-181.2' LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Drill DAMCO 1250 truck-mounted Driller M.M. Herrmannson 9/3/81 Set up rig on site. 9/9/81 Finished rig set up. BxCs drive samples from 0.0 to 10.0'. Rotation drive from 10.0 to 23.0'. Used fish-tail bit to clean hole and water below 10.0'. 5" Cs set @ 2.5'. 9/10/81 Hole is at 23.0'. W.L. at 6.0'. BxCa rotation drive samples 23.0 to 42.0'. Attempted Hq wireline 4 1/2" Cs set to 24.0'. Rockbit 42.0 to 46.0'. BxCs rotation drive from 46.0 to 53.0'. Hq wireline 53.0 to 56.0'. 9/11/81 Hole is at 56.0'. W.L. at 0.0'. 4 1/2" Cs at 21.0'. Hq wireline 56.0 to 113.0'. Water loss (10 to 15 gpm) at 70.0'. 9/12/81 Hole is at 113.0'. W.L. at 55.2'. 4 1/2" Cs at 21.0'. Hq wireline 113.0 to 162.0' water loss at 5-10 gpm. 9/13/81 Hole is at 162.0'. 4 1/2" Cs at 21.0'. Hq wireline from 162.0 to 181.2' with little water loss below 162.0'. Pulled 4 1/2" Cs. Backfilled hole with sand and slurry to 3.0'. Backfilled 3.0 to 0.0' with clay. Drill water was sterilized as per N.D. Water Commission requirement.	Bx	100	#10	98.5	107.5				2053.0	107.0	98.5-107.0 SANDSTONE: medium gray; moist; very slight HCl reaction; fine sand; weakly cemented; near horizontal bedding; core lengths to 2.2'.
	100	#11	107.5	110.5				2049.5	110.5	107.0-110.5 COAL: black; moist; hard; chunky; broken; core lengths to 1.7'.	
	100	#12	110.5	113.0				2049.5	113.0	110.5-125.0 SANDY SHALE-SHALY SANDSTONE: gray; moist; slight HCl reaction; firm; weakly cemented; fine sand; horizontal bedding; laminated by light and dark gray; core lengths to 1.7'.	
	100	#13	113.0	125.0				2035.0	125.0	125.0-132.5 SANDY SHALE: olive green; moist; slight HCl reaction; firm; fine sand; shaves easily with knife; core lengths to 3.5'.	
	100	#14	125.0	132.5				2027.5	132.5	132.5-134.3 COAL: black; moist; hard and solid core lengths to 0.5'.	
	100	#15	132.5	134.3				2025.7	134.3	134.3-150.2 SHALE: light to medium gray; moist; slight HCl reaction; firm; horizontal bedding with occasional thin lignite partings mostly along bedding planes; plastic; slick and soft from 134.3 to 142.6'; 50 slickenside at 145.9'; core lengths to 2.0'; black; platy, brittle lignite 145.4-145.6.	
	100	#16	134.3	150.2				2009.8	150.2	150.2-157.9 SANDSTONE: gray; moist; slight HCl reaction; horizontal bedding; fine sand; trims easily with knife; weakly cemented; core lengths to 2.6'.	
	100	#17	150.2	157.9				2002.1	157.9	157.9-160.0 SILTY SHALE: buff gray; moist; weak HCl reaction; horizontal bedding; trims easily with knife, leaving a waxy sheen; core lengths to 1.9'.	
	100	#18	157.9	160.0				2000.0	160.0	160.0-163.4 COAL: black; compact; moist; sampled and bagged in field, not available for inspection.	
	100	#19	160.0	163.4				1996.6	163.4	163.4-174.2 SANDY CLAYEY SILTSTONE: medium gray; moist; slight HCl reaction; laminated light and dark gray; horizontal to crossbedded; fine uniform sand; clayey; shaves easily with knife; core lengths to 3.3'; sandy shale 173.5-173.9'; light gray, hard, cemented (scratches with knife) silty sandstone 173.9 to 174.2'.	
	100	#20	163.4	174.2				1985.8	174.2	174.2-175.5 COAL: black; moist; platy; crumbles in hand.	
	100	#21	174.2	175.5				1984.5	175.5	175.5-181.2 SHALE: light gray and olive mottled; moist; weak HCl reaction; occasional thin buff bands; firm but shaves easily with knife; core lengths to 3.0' brown to black, chunky, lignite that breaks between fingers 180.0 to 180.5.	
	100	#22	175.5	181.2				1978.8	181.2		

**EXPLANATION** (Continued from page 1)

100 CORE LOSS

100 CORE RECOVERY

Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"  
 Approx. size of core (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

\*Westman - Soil Scientist  
 Botdorf - Geologist

FEATURE Sand Creek Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 2 OF 2 HOLE NO. DH81-112

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

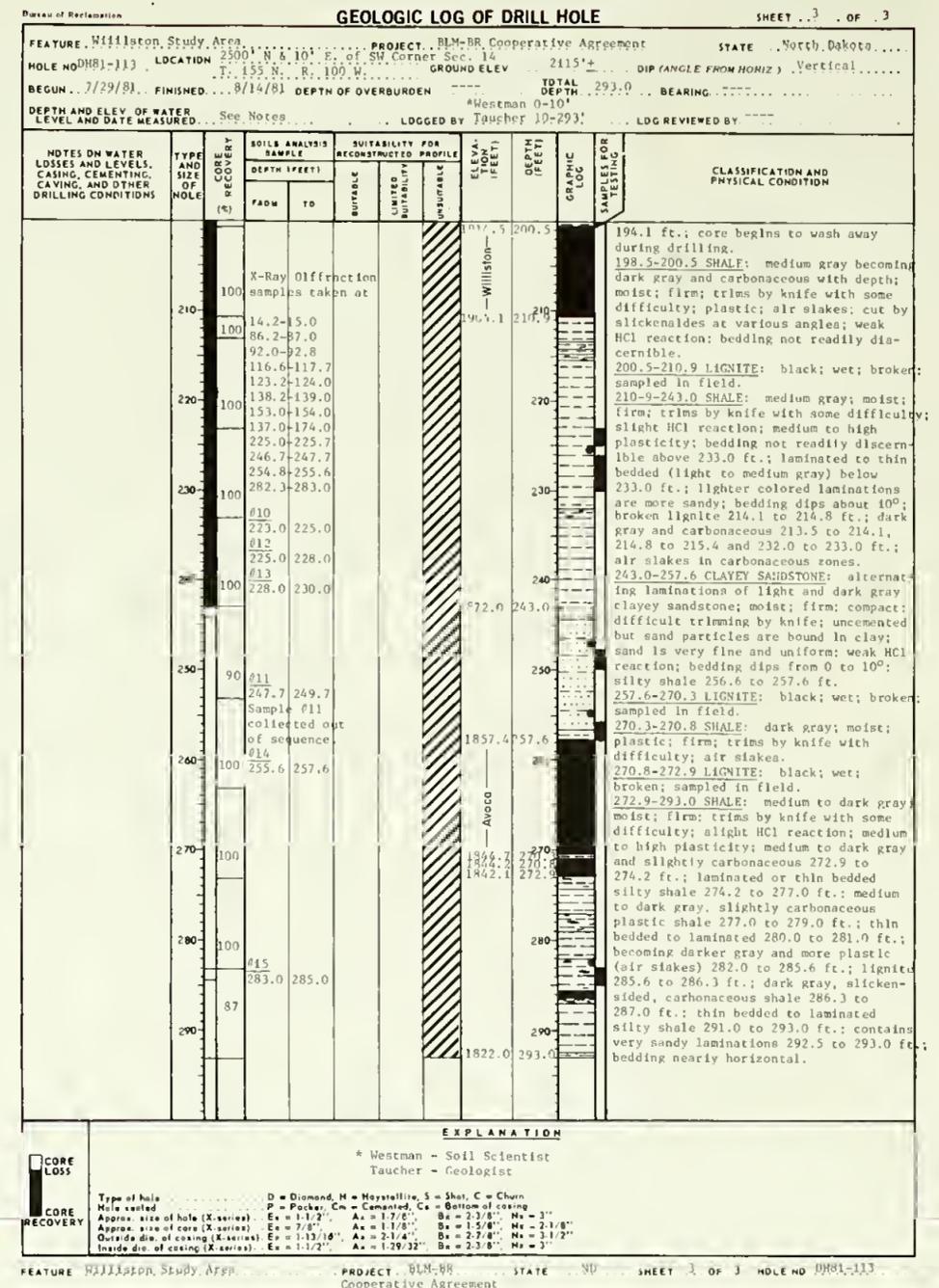
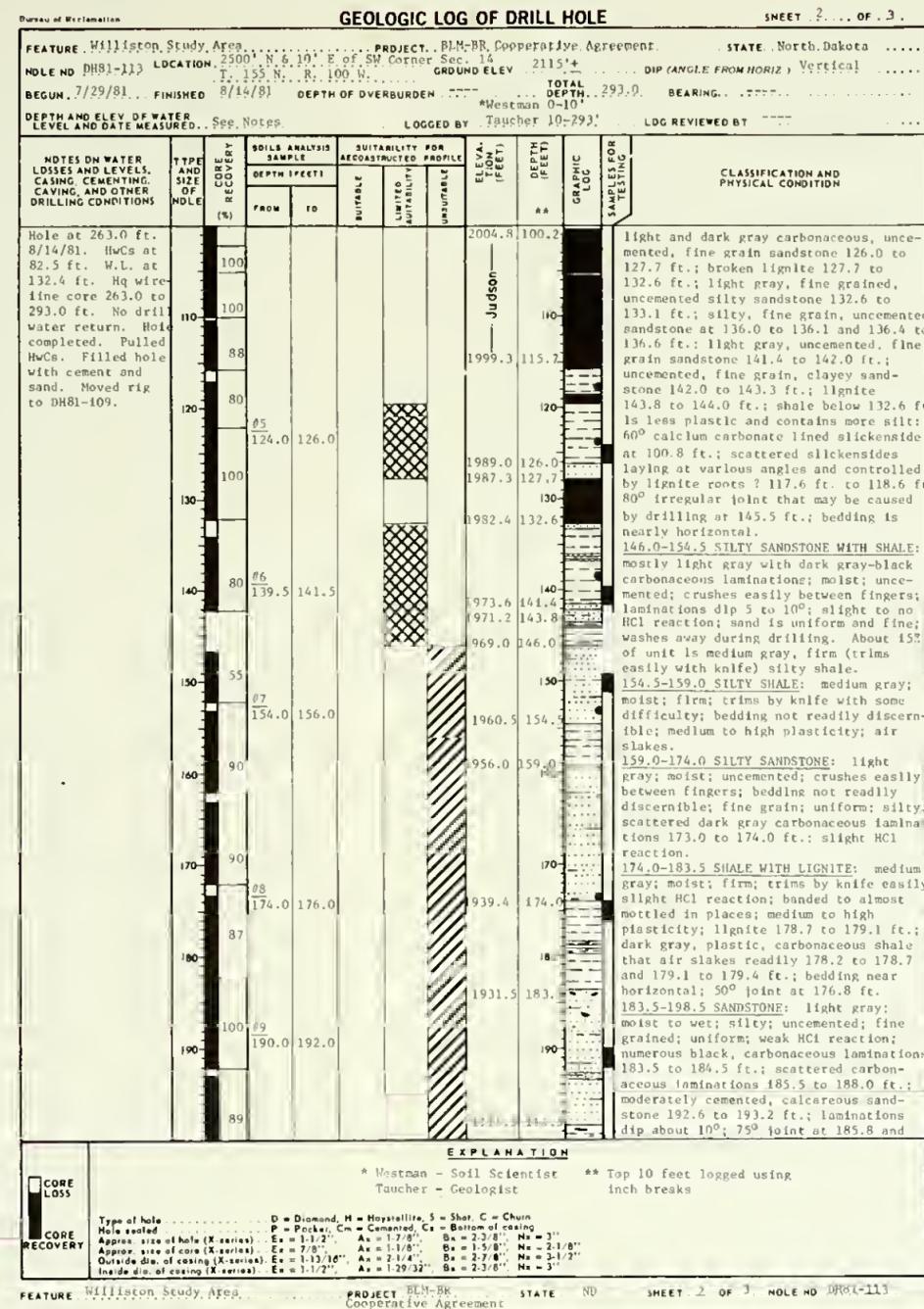
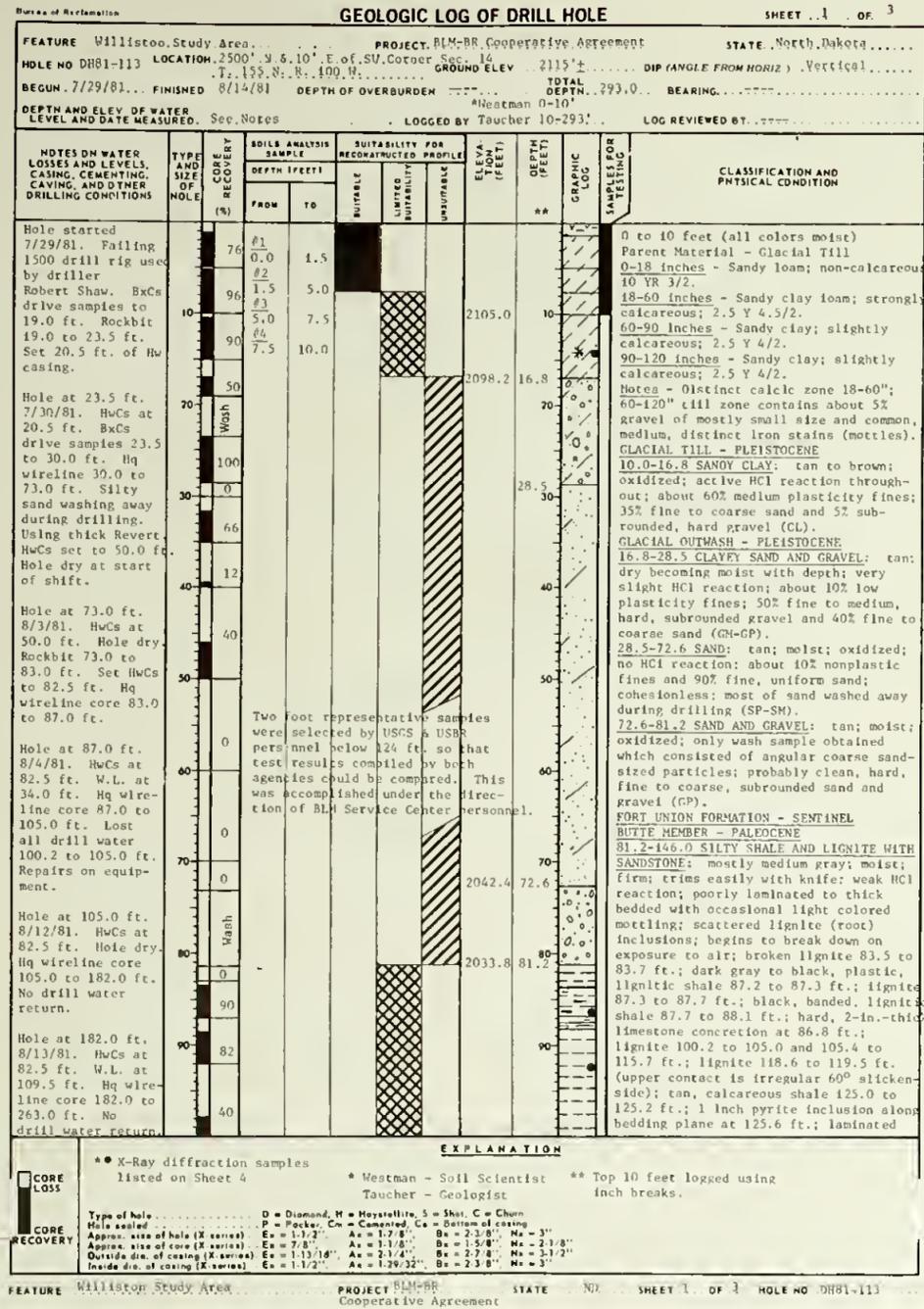
**GEOLOGIC LOG OF DH 81-112**

GEOLOGY C. BOTDORF FIELD APPROVAL  
 DRAWN S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-404

Depth on logs in feet.  
 Multiply feet by 0.3048 to obtain meters.





UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

**GEOLOGIC LOG OF DH 81-113**

GEOLOGY G. TAUCHER FIELD APPROVAL  
 DRAWN S. STARCEVIC TECHNICAL APPROVAL  
 CHECKED ARRIVED

BILLINGS, MONTANA JUNE 1983 1305-600-405

Depth on logs in feet  
 Multiply feet by 0.3048 to obtain meters



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 4

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 250° E & 375' N of SW Corner Sec. 11, T. 154 N., R. 100 W., S. 100 V. GROUND ELEV 2160.0±... DIP (ANGLE FROM HORIZ) Vertical... HOLE NO. DH81-114... DEPTH OF OVERBURDEN 10-260'... BEARING... LOGGED BY Calcasno & Schock... LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 260 feet depth.

EXPLANATION: \* X-Ray diffraction samples listed on page 4. \* Westman - Soil Scientist Calcasno & Schock - Geologists. \*\* Top 10 feet logged using inch breaks. Type of hole: D = Diamond, H = Hydrill, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing.

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 1 OF 4... HOLE NO. DH81-114

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 4

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 250° E & 375' N of SW Corner Sec. 11, T. 154 N., R. 100 W., S. 100 V. GROUND ELEV 2160.0±... DIP (ANGLE FROM HORIZ) Vertical... HOLE NO. DH81-114... DEPTH OF OVERBURDEN 10-260'... BEARING... LOGGED BY Calcasno & Schock... LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 260 feet depth.

EXPLANATION: \* Westman - Soil Scientist Calcasno & Schock - Geologists. Type of hole: D = Diamond, H = Hydrill, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing.

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 2 OF 4... HOLE NO. DH81-114

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 4

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 250° E & 375' N of SW Corner Sec. 11, T. 154 N., R. 100 W., S. 100 V. GROUND ELEV 2160.0±... DIP (ANGLE FROM HORIZ) Vertical... HOLE NO. DH81-114... DEPTH OF OVERBURDEN 10-260'... BEARING... LOGGED BY Calcasno & Schock... LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 260 feet depth.

EXPLANATION: \* Westman - Soil Scientist Calcasno & Schock - Geologists. Type of hole: D = Diamond, H = Hydrill, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing.

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 3 OF 4... HOLE NO. DH81-114

GEOLOGIC LOG OF DRILL HOLE SHEET 4 OF 4

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 250° E & 375' N of SW Corner Sec. 11, T. 154 N., R. 100 W., S. 100 V. GROUND ELEV 2160.0±... DIP (ANGLE FROM HORIZ) Vertical... HOLE NO. DH81-114... DEPTH OF OVERBURDEN 10-260'... BEARING... LOGGED BY Calcasno & Schock... LOG REVIEWED BY...

Table with columns: TYPE AND SIZE OF NOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 260 feet depth.

EXPLANATION: \* Westman - Soil Scientist Calcasno & Schock - Geologists. Type of hole: D = Diamond, H = Hydrill, S = Shot, C = Churn. Hole sealed: P = Packers, Cn = Cemented, Ca = Bottom of casing.

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE ND... SHEET 4 OF 4... HOLE NO. DH81-114

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 81-114

Drawn on logs in feet. Multiply feet by 0.3048 to obtain meters.

BILLINGS, MONTANA JUNE 1983 1305-600-406



GEOLOGIC LOG OF DRILL HOLE

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: North Dakota... LOCATION: 850' S, 6 1/2 1825' W of NE Corner Sec. 26... HOLE NO. DH81-115... GROUND ELEV. 2405.0'±... DIP (ANGLE FROM HORIZ): Vertical... BEGUN: 8-30-81... FINISHED: 9-1-81... DEPTH OF OVERBURDEN: 10.0'... TOTAL DEPTH: 180.0'... BEARING: ... LOGGED BY: Schock 10.0-180.0'... LOG REVIEWED BY: ...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS; TYPE AND SIZE OF HOLE; SOIL ANALYSIS SAMPLE; SUITABILITY FOR RECONSTRUCTED PROFILE; ELEVATION (FEET); DEPTH (FEET); GRAPHIC LOG; SAMPLES FOR TESTING; CLASSIFICATION AND PHYSICAL CONDITION. Includes data for core recovery percentages and detailed lithological descriptions.

EXPLANATION: \* Westman - Soil Scientist, Schock - Geologist. \*\* Top 10 feet logged by inch breaks. Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing. Approx. size of hole (X-series): Ex = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3".

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: ND... SHEET: 1 OF 2... HOLE NO. DH81-115

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: North Dakota... LOCATION: 850' S, 6 1/2 1825' W of NE Corner Sec. 26... HOLE NO. DH81-115... GROUND ELEV. 2405.0'±... DIP (ANGLE FROM HORIZ): Vertical... BEGUN: 8-30-81... FINISHED: 9-1-81... DEPTH OF OVERBURDEN: 10.0'... TOTAL DEPTH: 180.0'... BEARING: ... LOGGED BY: Schock 10.0-180.0'... LOG REVIEWED BY: ...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS; TYPE AND SIZE OF HOLE; SOIL ANALYSIS SAMPLE; SUITABILITY FOR RECONSTRUCTED PROFILE; ELEVATION (FEET); DEPTH (FEET); GRAPHIC LOG; SAMPLES FOR TESTING; CLASSIFICATION AND PHYSICAL CONDITION. Includes data for core recovery percentages and detailed lithological descriptions.

EXPLANATION: \* Westman - Soil Scientist, Schock - Geologist. \*\* Top 10 feet logged by inch breaks. Type of hole: D = Diamond, H = Hyattellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing. Approx. size of hole (X-series): Ex = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3".

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: ND... SHEET: 2 OF 2... HOLE NO. DH81-115

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH-81-115 GEOLOGY: C. SCHOCK FIELD APPROVAL DRAWN: S. STARGEVICH TECHNICAL APPROVAL CHECKED: APPROVED BILLINGS, MONTANA JUNE 1983 1305-600-407

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



**GEOLOGIC LOG OF DRILL HOLE** SHEET 1 OF 2

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 30' W. & 70' S. of NE Corner GROUND ELEV. 2271.0 ft. ± DIP (ANGLE FROM HORIZ.) Vertical  
 HOLE NO. 081-116 Sec. 18, T. 156 N., R. 96 W.  
 BEGUN 6-4-81 FINISHED 6-8-81 DEPTH OF OVERBURDEN TOTAL DEPTH 203.0 ft. BEARING  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-203.0' LOG REVIEWED BY Westman 0-10.0'

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEV. (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Drill OAMCO 1250 truckmounted. Driller M.M. Hermanson 6/4/81 moved in equipment and set up on site. Bx Cs drive samples 0.0 to 5.0 feet set 5 inch Cs at 2.0 ft. Washed out Cs with 4 in. drag bit. Continued Bx Cs rotation drive at 5.0 ft. interval, washed, and reamed out at 5.0 ft. Intervals using sterilized recirculated water to clean hole.		100	0.0	0.5				2261.0	0-10.0'		PLEISTOCENE 0 to 10 feet: Parent Material - Glacial Till
6/5/81 Hole at 51.9 ft. W.L. at 6.3 ft. Cs 5 in. at 3 ft. Bx Cs drive 51.9 to 53.5. Revert in hole. Hq wireline from 53.5 ft. to 103.0 ft. 50 gpm revert loss at 58.0 ft. and continued to try to keep mud to 83.6 ft. At 83.6 ft. switched to water 50 gpm loss continues to 103.0 ft. At 103.0 ft. ripped out, inner barrel jammed. Hole reamed to 70.0. Mixed bentonite and reamed to 83.0 ft. with partial circulation.		100	24.0	51.9			2247.0	24.0	10-24.0'		0-6 inches - Loam; noncalcareous; peaty. 6-42 inches - Clay Loam; noncalcareous. 42-60 inches - Sandy Clay Loam; strongly calcareous; 5 percent gravel. 60-120 inches - Sandy Clay Loam; strongly calcareous; 5 percent gravel. 10.0-24.0' SANDY CLAY (GLACIAL TILL): tan; moist; weak HCl reaction; 65 percent low plasticity fines; plasticity increases slightly with depth; 30 percent fine to coarse subangular sand; 5 percent subangular gravel to 1 inch; scattered lignite debris; core lengths to 2.0 ft. (CL). 24.0 - 51.9' SANDY CLAY (GLACIAL TILL): dark gray; moist; moderate HCl reaction; 75 percent medium plasticity fines; 20 percent fine to medium sand; 5 percent subrounded gravel to 1/2 in.; scattered lignite debris; core lengths to 2.5 ft. (CL-CH). 51.9-55.0' GRAVELLY SAND (OUTWASH): tan; dry; moderate HCl reaction; 80 percent fine sand; 10 percent non-plasticity fines; 10 percent fine subangular gravel to 1/2 in. (SP-SM). 52.9-53.5 Calcareous, oxidized zone with sharply contrasting rust coloration; breaks with difficulty in hands.
6/7/81 Hole at 132.3 ft. W.L. at 97.0 ft. Hq Cs to 61.5 ft. Hq wireline to 142.6 ft. changed bits. Hq wireline to 203.0. Fast drilling and lost water at 10 gpm.		100	73.9	93.0			2219.1	51.9	50-55.0'		PALEOCENE - FORT UNION FORMATION - SENTINEL BUTTE MEMBER 55.0-95.8' SILTSTONE: tan; medium gray from 63.6 to 83.6 ft.; moist; weak HCl reaction that becomes moderately reactive with depth; shaves easily with knife; firm; occasionally sandy and crumbly; bedding is not discernible and infrequently fragments of carbonized plant material lie in a horizontal depositional plane; core lengths to 1.4 ft. 56.4 ft. Slickensides dip 60°. 87.6 ft. Iron sulfide nodules. 95.8-145.8' SANDY SILTSTONE: medium gray; moist; weak to moderate HCl reaction; firm; weakly cemented; bedding is not readily discernible; core lengths to 1.3 ft. that break along thin laminations of fine sand. 97.6-99.6' Coal: black; moist; soft and crumbly. 102.0-103.0' Coal: gray; dry; a borderline carbonaceous shale with low specific gravity; core lengths to 0.3 ft.

EXPLANATION \* Westman - Soil Scientist  
 Botdorf - Geologist  
 \*\* Top 10 feet logged by inch breaks.  
 Type of hole: D = Diamond, H = Hyattalite, S = Shot, C = Churn  
 Note sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Ns = 3"  
 Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Ns = 3"

FEATURE Williston Study Area PROJECT BLM-BR Coop. Agr. STATE North Dakota SHEET 1 OF 2 HOLE NO. 081-116

**GEOLOGIC LOG OF DRILL HOLE** SHEET 2 OF 2

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 30' W. & 70' S. of NE Corner GROUND ELEV. 2271.0 ft. ± DIP (ANGLE FROM HORIZ.) Vertical  
 HOLE NO. 081-116 Sec. 18, T. 156 N., R. 96 W.  
 BEGUN 6-4-81 FINISHED 6-8-81 DEPTH OF OVERBURDEN TOTAL DEPTH 203.0 ft. BEARING  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-203.0' LOG REVIEWED BY Westman 0-10.0'

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF NOLE	RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEV. (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
6/8/81 Hole at 203.0' W.L. at 55.0'. Hq Cs at 61.5 is pulled. Hole is backfilled with sand and cement. 2.0 to 0.0 ft. backfilled with cuttings. Drill water was sterilized as per North Dakota Water Commission requirement.		100	95.8	125.0			2168.0	102.0	100-102.0'		109.6-111.6' Coal: black; moist; hard; with thin bedding planes. 114.0-115.0' Coal-Lignite Shale: black; moist; carbonaceous sandy mud; no HCl reaction; slight plasticity, tackily molds with fingers. 145.8-151.4' SILTY SHALE: light gray; moist; moderate HCl reaction; firm; horizontal bedding; some fine grained sand; becomes carbonaceous below 151.0'; core lengths to 3.0'. 151.4-154.2' COAL: black; dry; platy; breaks firmly in hands; core lengths to 4.0'. 154.2-160.0' SANDY SILTSTONE: medium gray; moist; no HCl reaction; gritty; fine grained sand; weakly cemented; firm; bedding is not discernible; infrequent fragments of carbonized plant material that lie in horizontal plane; core lengths to 1.3'. 160.0-163.0' CARBONACEOUS SANDSTONE: black water returned from hole and core sample washed away. 163.0-168.5' COAL: black; moist; firm; core lengths to 0.5'. 168.5-203.0' SANDY SILTSTONE: gray; large content of fine sand; soft and uncemented; gray water returned and core washed away.
		100	103.0	103.0			2159.4	111.6	100-103.0'		
		100	109.6	109.6			2157.0	114.0	100-109.6'		
		100	111.6	111.6			2156.0	115.0	100-111.6'		
		100	115.0	115.0					100-115.0'		
		100	120.0	120.0					100-120.0'		
		100	125.0	125.0					100-125.0'		
		100	130.0	130.0					100-130.0'		
		100	135.0	135.0					100-135.0'		
		100	140.0	140.0					100-140.0'		
		100	145.8	145.8					100-145.8'		
		100	151.4	151.4					100-151.4'		
		100	154.2	154.2					100-154.2'		
		100	160.0	160.0					100-160.0'		
		100	163.0	163.0					100-163.0'		
		100	168.5	168.5					100-168.5'		
		100	170.0	170.0					100-170.0'		
		100	175.0	175.0					100-175.0'		
		100	180.0	180.0					100-180.0'		
		100	185.0	185.0					100-185.0'		
		100	190.0	190.0					100-190.0'		
		100	195.0	195.0					100-195.0'		
		100	200.0	200.0					100-200.0'		
		100	203.0	203.0					100-203.0'		

EXPLANATION \* Westman - Soil Scientist  
 Botdorf - Geologist  
 Type of hole: D = Diamond, H = Hyattalite, S = Shot, C = Churn  
 Note sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Ns = 3"  
 Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Ns = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Ns = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Ns = 3"

FEATURE Williston Study Area PROJECT BLM-BR Coop. Agr. STATE North Dakota SHEET 2 OF 2 HOLE NO. 081-116

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

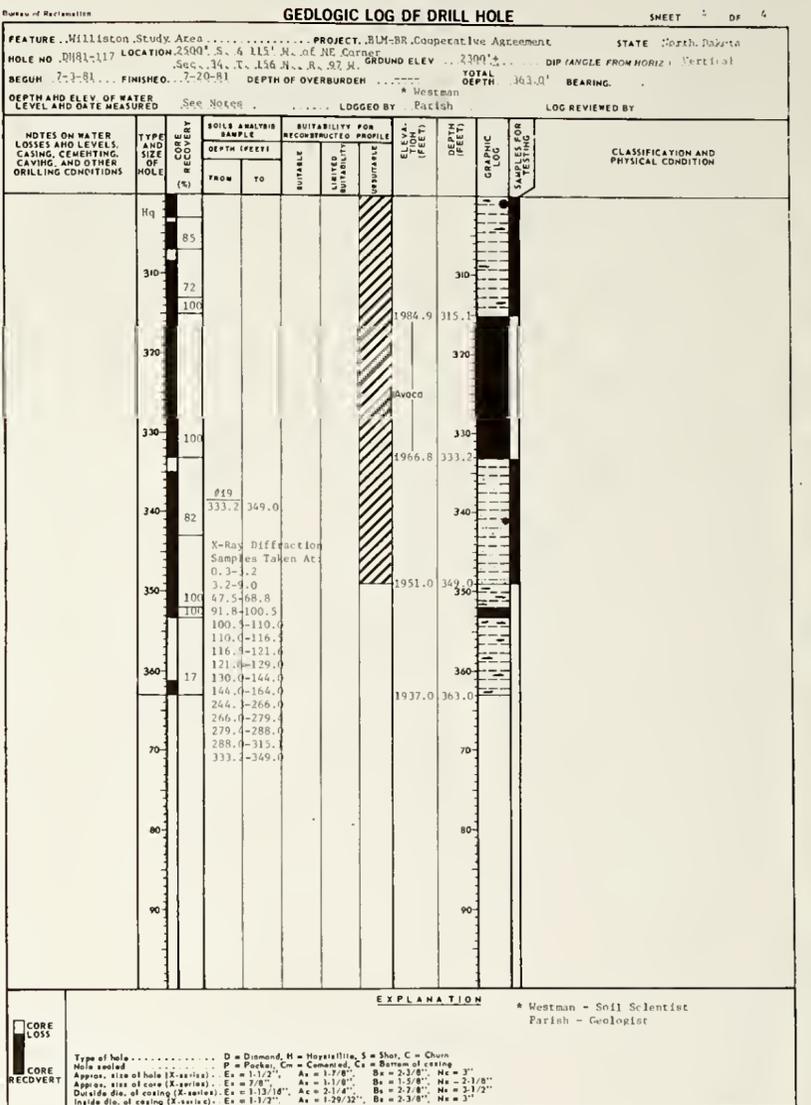
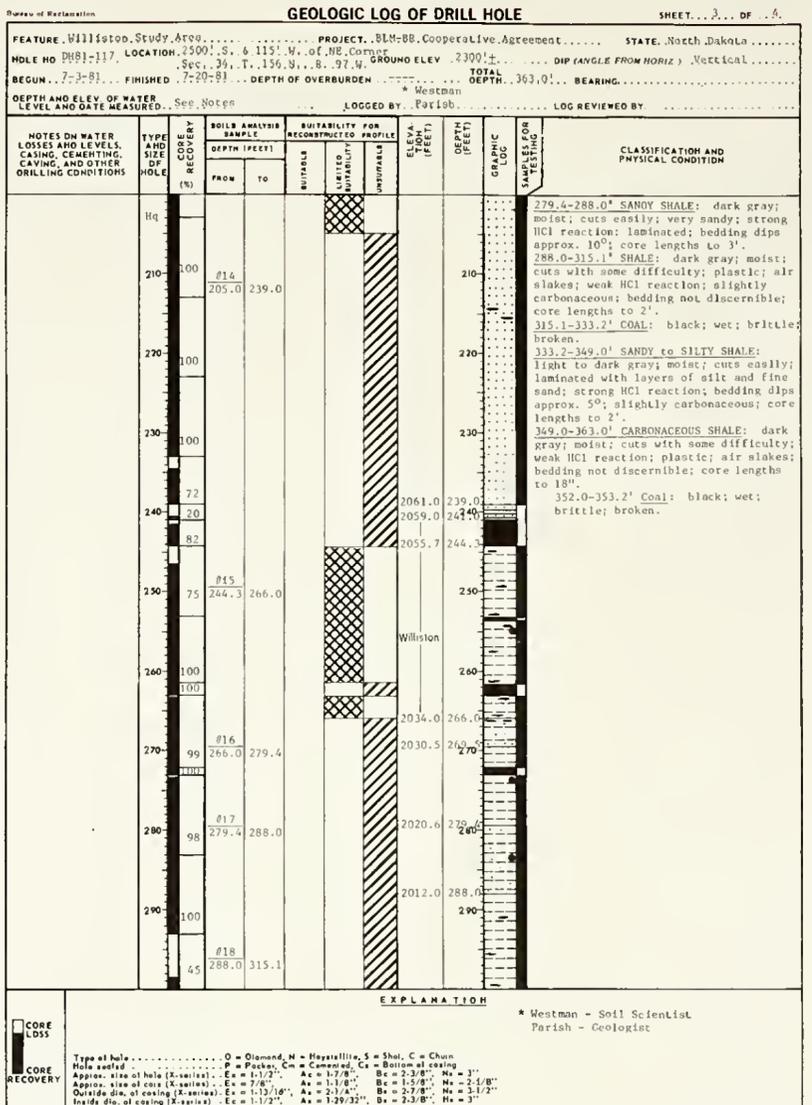
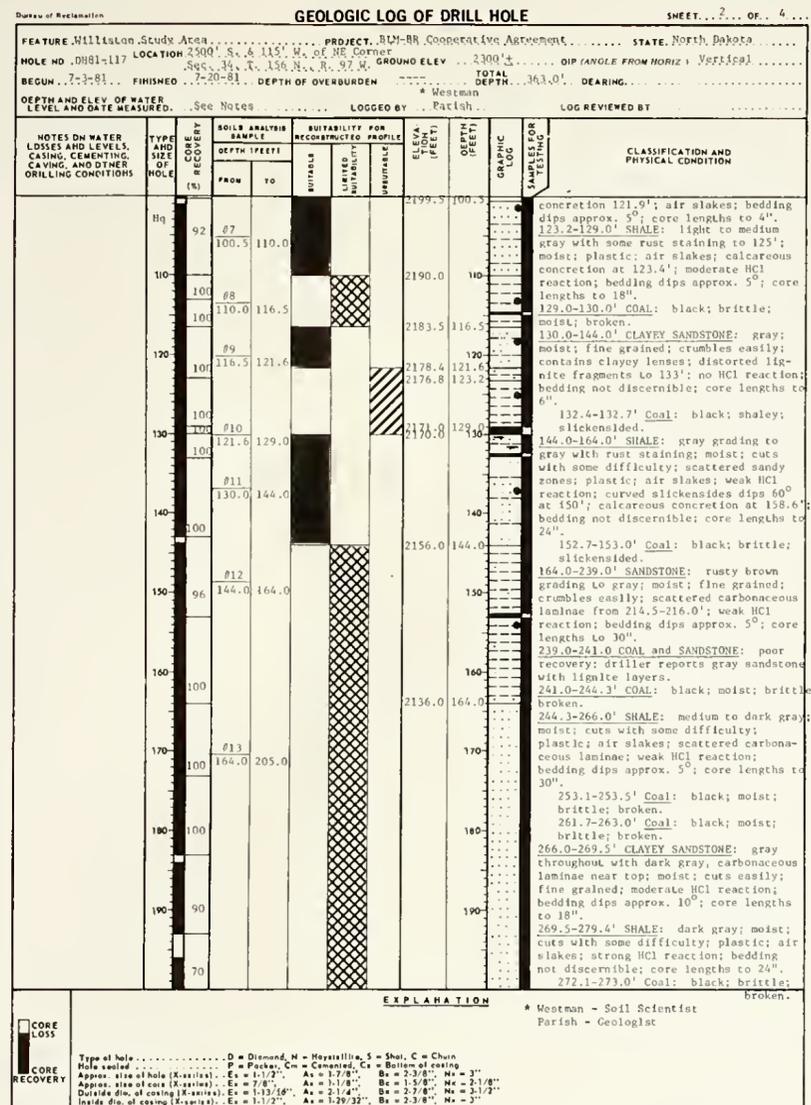
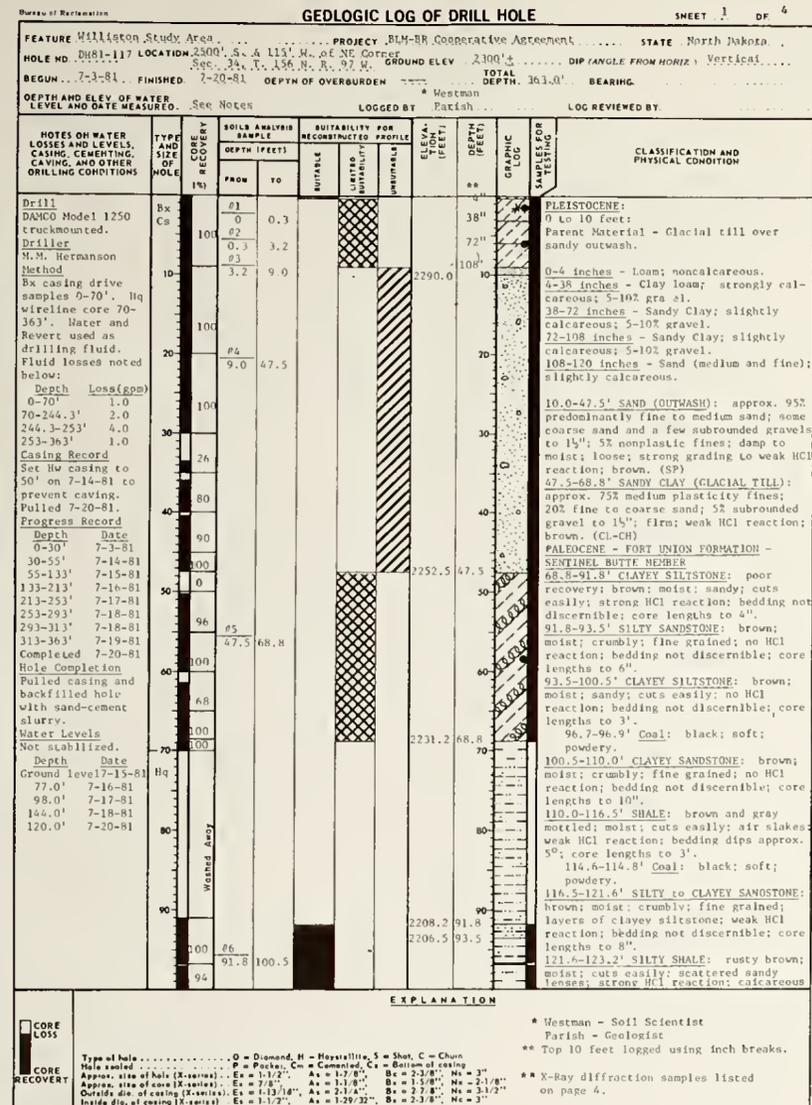
**GEOLOGIC LOG OF DH 81-116**

GEOLOGY C. BOTDORF FIELD APPROVAL  
 DRAWN S. STARCEVIC TECHNICAL APPROVAL  
 CHECKED APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-408

Depth on logs in feet.  
 Multiply feet by 0.3048 to obtain meters





UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA

**GEOLOGIC LOG OF DH 81-117**

GEOLOGY: L. PARISH FIELD APPROVAL

DRAWN: S. STARCEVICH TECHNICAL APPROVAL

CHECKED: APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-409

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.







FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 1200' W. & 50' N. of SE Corner HOLE NO. DH81-119...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION.

EXPLANATION: \* Westman - Soil Scientist Botdorf - Geologist \*\* Top 11 feet logged with breaks measured in inches.

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 1200' W. & 50' N. of SE Corner HOLE NO. DH81-119...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION.

EXPLANATION: \* G. Westman - Soil Scientist C. Botdorf - Geologist

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota LOCATION 1200' W. & 50' N. of SE Corner HOLE NO. DH81-119...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION.

EXPLANATION: \* G. Westman - Soil Scientist C. Botdorf - Geologist

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 81-119

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota... LOCATION 1200' W. & 50' N. of SE Corner... GROUND ELEV. 2400.0'±... DEPTH OF OVERBURDEN 0.0-11.0'

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for Pleistocene and Paleocene formations.

EXPLANATION \* Westman - Soil Scientist Bortdorf - Geologist \*\* Top 11 feet logged with breaks measured in inches. Type of hole... Hole sealed... Approx. size of hole... Outside dia. of casing... Inside dia. of casing...

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: N. Dakota. SHEET 1 OF 3. HOLE NO. DH81-119

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota... LOCATION 1200' W. & 50' N. of SE Corner... GROUND ELEV. 2400.0'±... DEPTH OF OVERBURDEN 0.0-11.0'

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for Paleocene and Pleistocene formations.

EXPLANATION \* C. Westman - Soil Scientist C. Bortdorf - Geologist Type of hole... Hole sealed... Approx. size of hole... Outside dia. of casing... Inside dia. of casing...

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: N. Dakota. SHEET 2 OF 3. HOLE NO. DH81-119

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota... LOCATION 1200' W. & 50' N. of SE Corner... GROUND ELEV. 2400.0'±... DEPTH OF OVERBURDEN 0.0-11.0'

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for Pleistocene and Paleocene formations.

EXPLANATION \* C. Westman - Soil Scientist C. Bortdorf - Geologist Type of hole... Hole sealed... Approx. size of hole... Outside dia. of casing... Inside dia. of casing...

FEATURE: Williston Study Area PROJECT: BLM-BR Cooperative Agreement STATE: N. Dakota. SHEET 3 OF 3. HOLE NO. DH81-119

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 81-119

Depth in logs in feet. Multiply feet by 0.3048 to obtain meters.



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: North Dakota... LOCATION: 2133' N. & 1900' S. of NE Corner... HOLE NO. DH81-120... GROUND ELEV. 2210.0 ft... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY: Bortdorf, 10.0-225.5' LOG REVIEWED BY: Westman

Table with columns: TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for Pleistocene, Paleocene - Fort Union Formation - Sentinel Butte Member, and various sandstone and shale layers.

EXPLANATION: \* Westman - Soil Scientist Bortdorf - Geologist. Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Williston Study Area... PROJECT: BLM-BR Coop. Agrmt... STATE: N. Dakota... SHEET 1 OF 3 HOLE NO. DH81-120

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: North Dakota... LOCATION: 2133' N. & 1900' S. of NE Corner... HOLE NO. DH81-120... GROUND ELEV. 2210.0 ft... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY: Bortdorf, 10.0-225.5' LOG REVIEWED BY: Westman

Table with columns: TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for 118.0-121.0 SANDY SILTSTONE, 121.0-122.0 COAL, 122.0-127.0 SHALE, 127.0-133.0 SANDY SHALE, 133.0-136.5 SHALE, 136.5-140.6 SANDY SILTSTONE, 140.6-142.7 SHALE, 142.7-143.7 COAL, 143.7-145.2 SHALE, 145.2-148.5 SHALE, 148.5-151.6 SANDSTONE, 151.6-159.0 SHALE, 159.0-159.4 CARBONACEOUS SHALE, 159.4-159.7 COAL, 159.7-162.0 SHALE.

EXPLANATION: \* Westman - Soil Scientist Bortdorf - Geologist. Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Williston Study Area... PROJECT: BLM-BR Coop. Agrmt... STATE: N. Dakota... SHEET 2 OF 3 HOLE NO. DH81-120

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE: Williston Study Area... PROJECT: BLM-BR Cooperative Agreement... STATE: North Dakota... LOCATION: 2133' N. & 1900' S. of NE Corner... HOLE NO. DH81-120... GROUND ELEV. 2210.0 ft... DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED... LOGGED BY: Bortdorf, 10.0-225.5' LOG REVIEWED BY: Westman

Table with columns: TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries for 162.0-162.2 CARBONACEOUS SHALE, 162.2-164.0 SANDY SHALE, 164.0-167.0 SHALE, 167.0-197.0 SANDSTONE, 197.0-200.2 SANDSTONE, 200.2-204.8 SANDSTONE, 204.8-220.5 SANDSTONE, 220.5-225.5 SHALE.

EXPLANATION: \* Westman - Soil Scientist Bortdorf - Geologist. Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Williston Study Area... PROJECT: BLM-BR Coop. Agrmt... STATE: N. Dakota... SHEET 3 OF 3 HOLE NO. DH81-120

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 81-120. Includes field approval and technical approval lines.

Depth in logs in feet Multiply feet by 0.3048 to obtain meters



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota HOLE NO. DH81-121 LOCATION T. 6 S. 25 N. of SW Corner of Sec. 22, T. 155 N. R. 96 W. GROUND ELEV. 2065.0' DIP (ANGLE FROM HORIZ) Vertical BEGUN 8/19/81 FINISHED 8/29/81 DEPTH OF OVERBURDEN 0-10.0' TOTAL DEPTH 172.0' BEARING \*\*\*\*\* LOGGED BY Botdorf 10.0-172.0' LOG REVIEWED BY \*\*\*\*\*

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 172 feet depth.

EXPLANATION \*X-Ray Diffraction Samples Listed on Page 3. \*Westman - Soil Scientist Botdorf - Geologist \*\* Top 10 feet logged using inch breaks. Type of hole: D = Diamond, H = Hydrastir, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 1 OF 3 HOLE NO DH81-121

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota HOLE NO. DH81-121 LOCATION T. 6 S. 25 N. of SW Corner of Sec. 22, T. 155 N. R. 96 W. GROUND ELEV. 2065.0' DIP (ANGLE FROM HORIZ) Vertical BEGUN 8/19/81 FINISHED 8/29/81 DEPTH OF OVERBURDEN 0-10.0' TOTAL DEPTH 172.0' BEARING \*\*\*\*\* LOGGED BY Botdorf 10.0-172.0' LOG REVIEWED BY \*\*\*\*\*

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 172 to 1992.0 feet depth.

EXPLANATION \*Westman - Soil Scientist Botdorf - Geologist. Type of hole: D = Diamond, H = Hydrastir, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 2 OF 3 HOLE NO DH81-121

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota HOLE NO. DH81-121 LOCATION T. 6 S. 25 N. of SW Corner of Sec. 22, T. 155 N. R. 96 W. GROUND ELEV. 2065.0' DIP (ANGLE FROM HORIZ) Vertical BEGUN 8/19/81 FINISHED 8/29/81 DEPTH OF OVERBURDEN 0-10.0' TOTAL DEPTH 172.0' BEARING \*\*\*\*\* LOGGED BY Botdorf 10.0-172.0' LOG REVIEWED BY \*\*\*\*\*

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 1992.0 to 2031.2 feet depth.

EXPLANATION \*Westman - Soil Scientist Botdorf - Geologist. Type of hole: D = Diamond, H = Hydrastir, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 3 OF 3 HOLE NO DH81-121

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NDRTH DAKOTA GEOLOGIC LOG OF DH 81-121 GEOLOGY C. BOTDORF FIELD APPROVAL DRAWN S. STARGEVICH TECHNICAL APPROVAL CHECKED APPROVED BILLINGS, MONTANA JUNE 1983 1305-600-413



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO. 0881-122 LOCATION 400' E & 1075' S of NW Corner Sec. 32 T. 155 N. R. 97 W. GROUND ELEV. 2255.0'± DIP (ANGLE FROM HORIZ.) Vertical
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Westman 0-10.0 LOG REVIEWED BY

Table with columns: TYPE AND SIZE OF HOLE, RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed notes on water losses, casing, and drilling conditions.

EXPLANATION
\* - X-Ray Diffraction Samples on Page 3.
\* Westman - Soil Scientist
\*\* Top 10 feet logged using inch breaks
Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn
Hole sealed: P = Pecker, Cm = Cemented, Cs = Bottom of casing

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 1 OF 3 HOLE NO 0881-122

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO. 0881-122 LOCATION 400' E & 1075' S of NW Corner Sec. 32 T. 155 N. R. 97 W. GROUND ELEV. 2255.0'± DIP (ANGLE FROM HORIZ.) Vertical
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Westman 0-10.0 LOG REVIEWED BY

Table with columns: TYPE AND SIZE OF HOLE, RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed notes on water losses, casing, and drilling conditions.

EXPLANATION
\* Westman - Soil Scientist
Boddorf - Geologist
Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn
Hole sealed: P = Pecker, Cm = Cemented, Cs = Bottom of casing

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 2 OF 3 HOLE NO 0881-122

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 3

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO. 0881-122 LOCATION 400' E & 1075' S of NW Corner Sec. 32 T. 155 N. R. 97 W. GROUND ELEV. 2255.0'± DIP (ANGLE FROM HORIZ.) Vertical
DEPTN AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Westman 0-10.0 LOG REVIEWED BY

Table with columns: TYPE AND SIZE OF HOLE, RECOVERY (%), SOIL ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, SAMPLES FOR TESTING, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed notes on water losses, casing, and drilling conditions.

EXPLANATION
\* Westman - Soil Scientist
Boddorf - Geologist
Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn
Hole sealed: P = Pecker, Cm = Cemented, Cs = Bottom of casing

FEATURE Williston Study Area PROJECT BLM-BR Cooperative Agreement STATE ND SHEET 3 OF 3 HOLE NO 0881-122

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
WILLIAMS AND MCKENZIE COUNTIES STUDY
NORTH DAKOTA

GEOLOGIC LOG OF DH 81-122

GEOLOGY C. BODDORF FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-414

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 2750' S., A 150' E. of NW Corner... GROUND ELEV 2150'±... OIP (ANGLE FROM HORIZ) Vertical... BEGUN 7-20-81... FINISHED 8-2-81... DEPTH OF OVERBURDEN 271.0'... BEARING Westman 0-10'... LOGGED BY Parish 10-271'... LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes data for DANCO Model 1250 truckmounted Driller, casing drive samples, and various soil types like Pleistocene, Silty Sandstone, and Silty Shale.

EXPLANATION: 106.0' Slickensides dip 60°. \* Westman - Soil Scientist Parish - Geologist. \*\* X-Ray diffraction samples listed on page 3. \*\* Top 10 feet logged using inch breaks.

FEATURE Williston Study Area... PROJECT BLM-BR Coop. Agreement... STATE N. Dakota... SHEET 1 OF 3... HOLE NO DH81-123

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 2750' S., A 150' E. of NW Corner... GROUND ELEV 2150'±... OIP (ANGLE FROM HORIZ) Vertical... BEGUN 7-20-81... FINISHED 8-2-81... DEPTH OF OVERBURDEN 271.0'... BEARING Westman 0-10'... LOGGED BY Parish 10-271'... LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes data for 107.5-130.6' Sandstone, 130.6-134.1' Coal, 134.1-135.4' Shale, and 135.4-168.0' Shale.

EXPLANATION: \* Westman - Soil Scientist Parish - Geologist. \*\* Top 10 feet logged using inch breaks.

FEATURE Williston Study Area... PROJECT BLM-BR Coop. Agreement... STATE N. Dakota... SHEET 2 OF 3... HOLE NO DH81-123

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Williston Study Area... PROJECT BLM-BR Cooperative Agreement... STATE North Dakota... LOCATION 2750' S., A 150' E. of NW Corner... GROUND ELEV 2150'±... OIP (ANGLE FROM HORIZ) Vertical... BEGUN 7-20-81... FINISHED 8-3-81... DEPTH OF OVERBURDEN 271.0'... BEARING Westman 0-10'... LOGGED BY Parish 10-271'... LOG REVIEWED BY...

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF NOLE, SOILS ANALYSIS SAMPLE DEPTH (FEET), SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION (FEET), DEPTH (FEET), GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes data for 168.0-171.8' Sandy Shale, 171.8-187.8' Clayey Sandstone, 187.8-191.6' Coal, and 191.6-192.8' Carbonaceous Shale.

EXPLANATION: \* Westman - Soil Scientist Parish - Geologist. \*\* Top 10 feet logged using inch breaks.

FEATURE Williston Study Area... PROJECT BLM-BR Coop. Agreement... STATE N. Dakota... SHEET 3 OF 3... HOLE NO DH81-123

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NDRTH DAKOTA GEOLOGIC LOG OF DH 81-123

Depth in logs in feet. Multiply feet by 0.3048 to obtain meters.



FEATURE: Tobacco Gardens Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota  
 HOLE NO. DH 82-124 LOCATION: 2640' N., 6 10' W. of S.E. Corner Sec. 17, T. 153 N., R. 97 W. GROUND ELEV. 2073.0' ± DIP (ANGLE FROM HORIZ.) Vertical.  
 BEGUN 10-22-82 FINISHED 10-24-82 DEPTH OF OVERBURDEN 0.0-10.0 ft. TOTAL DEPTH 216.0 ft. BEARING: Westman 0.0-10.0 ft.  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes LOGGED BY: Botdorf, 10-9-216.0 ft. LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOIL ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Drill Falling 1500 truckmounted. Driller R. V. Shaw Method 10/22/82 Moved in equipment and set up on site. Rock bit from 0.0 to 2.5 ft. Bx Cs drive samples from 2.5 to 28.0 ft. Rock bit from 28.0 to 30.0 ft. Bx Cs drive samples to 40.0. Set Hw Cs to 40.5 ft. Driller reports 100 percent water loss through coal. 10/23/82 Hole at 40.0 ft. No W.L. reported. Hw Cs at 40.5 ft. Hq wireline from 40.0 to 143.0 ft. Poor sample recovery, with repeated attempts. 10/24/82 Hole at 143.0 ft. W.L. at 100.0 ft. Hw Cs at 40.5 ft. Continued Hq wireline from 143.0 to 216.0 ft. Pulled tools and casing. Finished hole. Drill waters were sterilized as per North Dakota Water Commission requirements.	0	01	2.5	4.2			2070.5	2.5	<p>PLUPTOGENE</p> <p>0 to 10 feet***</p> <p>Parent Material - Glacial till.</p> <p>30-50 inches - loam; 2.5 Y 5/2; strong effervescence (30-42"); slight effervescence (42-50").</p> <p>50-54 inches - Heavy clay loam; 2.5 Y 4/2; slight effervescence.</p> <p>84-120 inches - Sandy clay to clay; 2.5 Y 4/2; slight effervescence.</p> <p>Notes - No sample recovered from 0-30"; 30-50" zone is weathered and friable till; 50-120" - massive till with about 5" small and medium sized gravel, numerous iron stains, and salt masses concentrated along fractures. R4-120" may not contain enough sand to make SC.</p> <p>10.0-27.8' SANDY CLAY (GLACIAL TILL): approx. 30% fine and medium with trace coarse sand; approx. 60% fines with medium plasticity, medium to high dry strength, medium toughness, approx. 10% fine, subrounded, weathered hard gravel; maximum size, 30 mm; hard; dense chips of lignite; gypsum crystals; dry to moist; tan to brown; moderate reaction with HCl. (Cl.)</p> <p>PALEOCENE - FORT UNION FORMATION - SENTINEL BUTTE MEMBER</p> <p>27.8-31.8' COAL: poor lignite, bedding not discernible, peaty; black; soft, crumbly; highly weathered; core lengths to 0.4 ft.; poor recovery; moist.</p> <p>31.8-35.0' SHALE: waxy when cut, non-calcareous, bedding not discernible, mottled; tan to brown; medium hardness, breaks with moderate manual pressure; lightly weathered; core lengths to 0.3 ft.; moist.</p> <p>35.0-43.0' CLAYEY SILTSTONE: uncemented, noncalcareous, laminated; tan; soft, crushes with light manual pressure; poor core recovery; moist.</p> <p>43.0-44.0' COAL: black; medium to moderately hard, breaks along horizontal planes with heavy manual pressure; lengths to 0.1 ft, badly broken; dry.</p> <p>44.0-64.0' SILTY SANDSTONE: fine grain sand, clayey to silty, moderately calcareous, laminated, horizontal and cross laminated, shaley 44.0 to 44.6 ft; gray; weakly cemented, crushes with light manual pressure; pressure along horizontal bedding; driller reported very</p>		
	10	01	7.0	10.0			2063.0	10			
	20	01	10.0	27.8			2045.2	27.8			
	30	01	35.0	40.5			2041.7	35.0			
	40	01	64.0				2030.0	43.0			
	50	01					2029.0	44.0			
	60	01					2009.0	64.0			
	70	01						70			
	80	01						80			
	90	01						90			

**EXPLANATION**  
 \* Westman - Soil Scientist  
 Botdorf - Geologist  
 \*\* Top 10 ft. logged in inch breaks.  
 \*\*\* All soil colors moist.

**CORE LOSS**  
 Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cn = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"  
 Approx. size of core (X-series): Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Tobacco Gardens Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota  
 HOLE NO. DH 82-124 LOCATION: 2640' N., 6 10' W. of S.E. Corner Sec. 17, T. 153 N., R. 97 W. GROUND ELEV. 2073.0' ± DIP (ANGLE FROM HORIZ.) Vertical.  
 BEGUN 10/22/82 FINISHED 10/24/82 DEPTH OF OVERBURDEN 0.0-10.0 ft. TOTAL DEPTH 216.0 ft. BEARING: Westman 0.0-10.0 ft.  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes LOGGED BY: Botdorf, 10-9-216.0 ft. LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOIL ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
soft below 63.0 ft.; core lengths to 1.0 ft.; moist. 64-94.0' SANDY SILTSTONE: noncalcareous horizontal bedding; buff to tan; uncemented fine sand and nonplastic silt; crushes easily with light manual pressure; driller reported that material was very soft; moist. 94.0-114.5' SANDY SILTSTONE: silty with very fine sand, moderately calcareous, laminated, horizontal bedding; light gray; uncemented, crushes easily with light manual pressure; moist. 114.5-135.0' SANDSTONE: mostly fine sand, silty, weakly calcareous, laminated, horizontal bedding, thin lignitic stringers; gray; uncemented, crushes easily with light manual pressure; driller reported very soft; moist. 135.0-171.7' SHALE: shaley, waxy when cut, noncalcareous, horizontal bedding, occasionally small pyritic concretions; gray; medium hardness, breaking with moderate manual pressure along bedding planes; core lengths to 1.9 ft.; 45° closed joint at 149.2 ft.; moist. Coal: 139.9 to 148.7, 159.1 to 163.0 and 164.7 to 167.5 ft.; most of coal sampled and bagged in the field; black; moist; platy and brittle 139.9 to 143.0 ft., hard and chunky 143.0 to 148.7 ft.; black; moist; platy and brittle 159.1 to 163.0 and 164.7 to 167.5 ft. 171.7-196.0' SANDSTONE: fine grain sand, noncalcareous, laminated, horizontal to cross laminated; clayey sandstone becoming sandstone below 173.0 ft.; gray; soft to medium hardness, crushes with light manual pressure; moist. 196.0-216.0' SANDSTONE?: no recovery; fine sand; uncemented; driller reported very soft.	13	07	96.0	114.5			1958.5	114.5	<p>1958.5</p> <p>114.5</p> <p>135.0</p> <p>1938.0</p> <p>135.0</p> <p>1933.1</p> <p>139.9</p> <p>1924.3</p> <p>148.7</p> <p>159.1</p> <p>1913.9</p> <p>159.1</p> <p>1910.0</p> <p>163.0</p> <p>1908.3</p> <p>164.7</p> <p>1905.5</p> <p>167.5</p> <p>1901.3</p> <p>171.7</p> <p>196.0</p> <p>171.7</p> <p>196.0</p> <p>1877.0</p> <p>196.0</p>		
	110	07					110				
	120	07					120				
	130	07					130				
	140	07					140				
	150	07					150				
	160	07					160				
	170	07					170				
	180	07					180				
	190	07					190				

**EXPLANATION**  
 \* Westman - Soil Scientist  
 Botdorf - Geologist

**CORE LOSS**  
 Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cn = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"  
 Approx. size of core (X-series): Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Tobacco Gardens Study Area PROJECT: BLM-BR Cooperative Agreement STATE: North Dakota  
 HOLE NO. DH 82-124 LOCATION: 2640' N., 6 10' W. of S.E. Corner Sec. 17, T. 153 N., R. 97 W. GROUND ELEV. 2073.0' ± DIP (ANGLE FROM HORIZ.) Vertical.  
 BEGUN 10-22-82 FINISHED 10-24-82 DEPTH OF OVERBURDEN 0.0-10.0 ft. TOTAL DEPTH 216.0 ft. BEARING: Westman 0.0-10.0 ft.  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes LOGGED BY: Botdorf, 10-9-216.0 ft. LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOIL ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
			FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE				
Unable to recover core from 196.0 to 216.0 ft. Encemented sand washing away.	Hq wireline	0					1857.0	216.0	<p>210</p> <p>220</p> <p>230</p> <p>240</p> <p>250</p> <p>260</p> <p>270</p> <p>280</p> <p>290</p>		
	210						210				
	220						220				
	230						230				
	240						240				
	250						250				
	260						260				
	270						270				
	280						280				
	290						290				

**EXPLANATION**  
 \* Westman - Soil Scientist  
 Botdorf - Geologist

**CORE LOSS**  
 Type of hole: D = Diamond, H = Hydrastite, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cn = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X-series): Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"  
 Approx. size of core (X-series): Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"  
 Outside dia. of casing (X-series): Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"  
 Inside dia. of casing (X-series): Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

**GEOLOGIC LOG OF DH 82-124**

GEOLOGY: C. BOTDORF FIELD APPROVAL  
 DRAWN: S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED: APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-416

Depth on logs in feet  
 Multiply feet by 0.3048 to obtain meters



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 4

Geologic log for well D882-125, Sheet 1 of 4. Includes project details, well location, and a detailed log of soil and rock samples from 0 to 102.0 feet depth. Includes soil analysis data and an explanation of symbols.

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 4

Geologic log for well D882-125, Sheet 2 of 4. Continuation of the log from Sheet 1, covering depths from 102.0 to 209.5 feet. Includes soil analysis data and an explanation of symbols.

GEOLOGIC LOG OF DRILL HOLE SHEET 3 OF 4

Geologic log for well D882-125, Sheet 3 of 4. Continuation of the log from Sheet 2, covering depths from 209.5 to 271.3 feet. Includes soil analysis data and an explanation of symbols.

GEOLOGIC LOG OF DRILL HOLE SHEET 4 OF 4

Geologic log for well D882-125, Sheet 4 of 4. Final section of the log, covering depths from 271.3 to 335.2 feet. Includes soil analysis data and an explanation of symbols.

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION RESOURCE AND POTENTIAL RECLAMATION EVALUATION WILLIAMS AND MCKENZIE COUNTIES STUDY NORTH DAKOTA GEOLOGIC LOG OF DH 82-125



FEATURE Tobacco Garden Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 HOLE NO. DH82-126 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 BEGUN 3-3-82 FINISHED 3-15-82 DEPTH OF OVERBURDEN 10.2' TOTAL DEPTH 261.5' BEARING.....  
 0-10.0' G. Westman 1/ 0-10.0' G. Westman 1/  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY 10.0-261.5' F. Calcagno LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			APPROXIMATE ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
ORILL RIG Failing 314C truck-mounted. DRILLER R.V. Shaw METHOD Bx drive from 0 to 42.0'. Hq from 42.0' to 261.5'. DRILLER'S COMMENTS Dropped 4.0' of core from 52.0 to 62.0'; picked it up on run from 62.0-68.0'. Coal bag sample #1 from 43.8 to 48.7'. Noted sandstone was soft and wet at 116.7'. Dropped core from 138.0 to 148.0'; picked it up on run from 148.0 to 152.0 and chewed some up. Dropped some core from 171.0 to 178.0. Coal bag sample #2 from 182.0 to 187.9. Coal bag sample #3 from 233.4 to 237.0. Coal bag sample #4 from 237.0 to 240.6. Water losses noted below: Depth Loss 24.0-29.0 100 240.0-261.5 50 CASING RECORD Bx to 32.5' to prevent caving and water loss. Pulled casing upon completion of hole. Depth (Ft.) Date ('82) 0-32.5 3-10 Pulled 3-15 PROGRESS RECORD Depth (Ft.) Date ('82) Set Up 3-3 0-42.0 3-10 42.0-103.0 3-11 103.0-152.0 3-12 152.0-202.7 3-13 202.7-261.5 3-14 Hole Compl. 3-15 HOLE COMPLETION Pulled casing, back-filled hole with sand and bentonite, cemented top 2.0 ft.	Bx	#1	0.0	0.9						0 to 10 Feet*: Parent Material - Glacial outwash/till. 0-11 inches - Loam; noncalcareous; 10 YR 3/2. 11-52 inches - Coarse sandy loam; strongly calcareous; 10 YR 4/3. 52-120 inches - Light clay loam; slightly calcareous; 10 YR 4/2. Notes: Plentiful roots of medium to very fine size in 0-11" zone; about 15% medium and fine-sized gravel in 11-52" outwash layer; glacial till below 52" contains about 5% gravel of varying size, numerous iron stains and lignite fragments, and salts (gypsum?) concentrated along fracture planes.	
			#2	0.9	4.3			2189.8	10.20		
			#3	4.3	10.0						
			#4	10.0	22.4						
			#5	22.4	35.6						
			#6	35.6	43.8						
			#7	51.4	65.8						
			#8	65.8	85.0						
			#9	85.0	100.8						
			#10	100.8	114.9						
		#11	114.9	127.6							
		#12	127.6	147.0							
		#13	147.0	164.0							
		#14	164.0	182.9							
		#15	182.9	199.8							

**EXPLANATION**  
 1/ Soil Scientist  
 2/ Geologist  
 \* logged in inches; all soil colors are moist  
 Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X series): Ex = 1 1/2", Aa = 1 7/8", Ba = 2 3/8", Na = 3"  
 Approx. size of core (X series): Ex = 7/8", Aa = 1 1/8", Ba = 1 5/8", Na = 2 1/8"  
 Outside dia. of casing (X series): Ex = 1 13/16", Aa = 2 1/4", Ba = 2 7/8", Na = 3 1/2"  
 Inside dia. of casing (X series): Ex = 1 1/2", Aa = 1 29/32", Ba = 2 3/8", Na = 3"

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 HOLE NO. DH82-126 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 BEGUN 3-3-82 FINISHED 3-15-82 DEPTH OF OVERBURDEN 10.2' TOTAL DEPTH 261.5' BEARING.....  
 0-10.0' G. Westman 1/ 0-10.0' G. Westman 1/  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY 10.0-261.5' F. Calcagno LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			APPROXIMATE ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
WATER LEVELS Depth (Ft.) Date ('82) 13.5 3-11 22.0 3-12 27.0 3-13 18.0 3-14 X-Ray Samples 1. 19.0-19.8 2. 28.7-29.6 3. 42.0-43.0 4. 57.0-58.0 5. 78.5-79.5 6. 93.0-94.0 7. 107.3-108.0 8. 123.0-124.0 9. 139.0-139.8 10. 152.0-152.9 11. 173.2-173.8 12. 196.9-197.8 13. 253.5-254.4	Hq									51.4-65.8' - SHALE: Medium to light gray; moist; firm (cuts with moderate knife pressure). Locally contains prominent, thin, variously oriented lignite stringers throughout. Waxy lustre when cut. Becomes sandier toward base. Core lengths to 12". Weak HCl reaction. 65.8-100.8' - CLAYEY SANDSTONE WITH SHALE INTERBEDS: Gray; moist; firm (cuts easily). Approx. 75% clayey sandstone; 20% interbedded plastic (waxy) shale; and 5% fine-grained sandstone. Faint horizontal bedding with occasional prominent black, variously oriented lignitic laminations (especially from 91 to 98"). Core lengths to 10". Very weak HCl reaction. 100.8-114.9' - SANDY SHALE: Gray; moist; firm to hard (cuts with moderate to heavy knife pressure). Very faint, sandy, horizontal laminations throughout. Occasional, thin, discontinuous lignite stringers present. Locally contains sandstone interbeds up to 0.3' thick. Core lengths to 11". No HCl reaction. 108.0-109.2' SILTY LIMESTONE: Gray; moist; hard (scratches with knife); calcareous; contains lignitic leaf impressions. Strong HCl reaction. CONCRETION. 114.9-127.6' - CLAYEY SANDSTONE: Gray; moist; soft to firm (cuts easily). Locally very sandy and locally lignitic. Very faint horizontal bedding present. Occasional shale interlayers (up to 20% by volume shale). Core lengths to 14". Very weak to no HCl reaction. 127.6-131.3' - COAL: Black; moist; hard (blocky). Gray shale interbed from 129.3-130.4'. Shale has prominent, multiple faceted slickensides. 131.3-182.9' - SHALE: Gray; moist; firm to hard (locally very difficult to cut). Locally very sandy - at places showing sandy laminations. Very faint horizontal bedding to laminated (locally nearly varved). Well developed pyrite cubes present, especially at 157.8'. Core lengths to 20". No HCl reaction. 181.5-181.9' - COAL: Black; moist; brittle. 182.5-182.7' - COAL: Black; moist; brittle; "dirty". 182.9-191.8' - COAL: Black; moist (wet and shattered from 187.4 to 188.0'); blocky. Horizontal slickensides present. Light gray shale interbed from 188.0 to 189.1' and from 190.0-190.6'.	
			#10	100.8	114.9						
			#11	114.9	127.6						
			#12	127.6	147.0						
			#13	147.0	164.0						
			#14	164.0	182.9						
			#15	182.9	199.8						

**EXPLANATION**  
 1/ Soil Scientist  
 2/ Geologist  
 \* logged in inches; all soil colors are moist  
 Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X series): Ex = 1 1/2", Aa = 1 7/8", Ba = 2 3/8", Na = 3"  
 Approx. size of core (X series): Ex = 7/8", Aa = 1 1/8", Ba = 1 5/8", Na = 2 1/8"  
 Outside dia. of casing (X series): Ex = 1 13/16", Aa = 2 1/4", Ba = 2 7/8", Na = 3 1/2"  
 Inside dia. of casing (X series): Ex = 1 1/2", Aa = 1 29/32", Ba = 2 3/8", Na = 3"

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota  
 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 HOLE NO. DH82-126 LOCATION 2590' S. & 450' E. of NW Corner Sec. 20 T. 152 N., R. 98 W. GROUND ELEV. 2200'± OIP (ANGLE FROM HORIZ.) 90°  
 BEGUN 3-3-82 FINISHED 3-15-82 DEPTH OF OVERBURDEN 10.2' TOTAL DEPTH 261.5' BEARING.....  
 0-10.0' G. Westman 1/ 0-10.0' G. Westman 1/  
 DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY 10.0-261.5' F. Calcagno LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	SOILS ANALYSIS SAMPLE DEPTH (FEET)		SUITABILITY FOR RECONSTRUCTED PROFILE			APPROXIMATE ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION	
		FROM	TO	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
191.8-203.8' - SANDY SHALE WITH CLAYEY SANDSTONE INTERBEDS: Gray; moist; firm (cuts with easy to moderate knife pressure). Approx. 80% sandy shale and 20% clayey sandstone. Occasional cross-bedded lignitic laminations. Core lengths to 20". No HCl reaction. 203.8-232.4' - SANDSTONE: Gray (locally yellow-gray); moist; soft to firm (cuts very easily); medium to fine-grained. Locally has "salt and pepper" appearance (biotite). Occasional 30°, thin, black lignite stringers throughout. Hard, yellow, clayey zones at 227.0', 228.3 to 228.7', and 229.7'. Core lengths vary from 4 to 30". Very weak to moderate HCl reaction. 232.4-233.4' - SHALE: Gray; moist; firm (cuts with difficulty); waxy-smooth lustre when cut. No HCl reaction. 233.4-242.0' - COAL: Black; moist; hard (blocky). Dark gray carbonaceous shale interbed from 240.6-241.3'. 242.0-250.5' - COAL WITH SHALE: Approx. 30% hard, black, moist coal and 70% firm to hard, gray, moist carbonaceous shale. Core lengths to 6". No HCl reaction. 250.5-255.2' - SHALE: Gray; moist; firm to hard (cuts with difficulty). Very faint horizontal bedding with occasional faint, horizontal to 20° lignitic laminations. Pyritic near the base. Gradational (sandy) lower contact. Core lengths to 14". No HCl reaction. 255.2-261.5' - CLAYEY SANDSTONE: Gray; moist; firm (cuts with moderate knife pressure). Occasional 20° lignitic laminations. Core lengths to 8". Very weak to weak HCl reaction. Bottom of hole at 261.5'.	Hq										
			#16	203.8	217.0						
			#17	217.0	233.4						
			#18	242.0	250.5						
			#19	250.5	255.2						

**EXPLANATION**  
 1/ Soil Scientist  
 2/ Geologist  
 \* logged in inches; all soil colors are moist  
 Type of hole: D = Diamond, H = Haystack, S = Shot, C = Churn  
 Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing  
 Approx. size of hole (X series): Ex = 1 1/2", Aa = 1 7/8", Ba = 2 3/8", Na = 3"  
 Approx. size of core (X series): Ex = 7/8", Aa = 1 1/8", Ba = 1 5/8", Na = 2 1/8"  
 Outside dia. of casing (X series): Ex = 1 13/16", Aa = 2 1/4", Ba = 2 7/8", Na = 3 1/2"  
 Inside dia. of casing (X series): Ex = 1 1/2", Aa = 1 29/32", Ba = 2 3/8", Na = 3"

UNITED STATES  
 DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
 RESOURCE AND POTENTIAL RECLAMATION EVALUATION  
 WILLIAMS AND MCKENZIE COUNTIES STUDY  
 NORTH DAKOTA

**GEOLOGIC LOG OF DH 82-126**

GEOLOGY F. CALCAGNO FIELD APPROVAL  
 DRAWN S. STARCEVICH TECHNICAL APPROVAL  
 CHECKED APPROVED

BILLINGS, MONTANA JUNE 1983 1305-600-418

Depth on logs in feet  
 Multiply feet by 0.3048 to obtain meters



GEOLOGIC LOG OF DRILL HOLE SHEET 1 OF 2

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO DH82-127 LOCATION 2624.0' N, 6 1274.0' W. of SE Corner
Section 31, T. 152 N., R. 97 GROUND ELEV. 2150'± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 2/28/82 FINISHED 3/11/82 DEPTH OF OVERBURDEN 10.0' TOTAL DEPTH 158.7' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-158.7' LOG REVIEWED BY

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, CORE RECOVERY, SOILS ANALYSIS SAMPLE DEPTH, SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION, DEPTH, GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 0 to 158.7 feet depth.

EXPLANATION
\* = X-Ray Samples
\* Westman - Soil Scientist - (Top 10 feet logged by Botdorf - Geologist)
Type of hole: D = Diamond, M = Moystellite, S = Shot, C = Churn
Mole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"
Approx. size of core (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"
Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"
Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Coop. Agreement STATE ND SHEET 1 OF 2 HOLE NO DH82-127

GEOLOGIC LOG OF DRILL HOLE SHEET 2 OF 2

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Cooperative Agreement STATE North Dakota
HOLE NO DH82-127 LOCATION 2624.0' N, 6 1274.0' W. of SE Corner
Section 31, T. 152 N., R. 97 GROUND ELEV. 2150'± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 2/28/82 FINISHED 3/11/82 DEPTH OF OVERBURDEN 10.0' TOTAL DEPTH 158.7' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf 10.0-158.7' LOG REVIEWED BY

Table with columns: NOTES ON WATER LOSSES AND LEVELS, TYPE AND SIZE OF HOLE, CORE RECOVERY, SOILS ANALYSIS SAMPLE DEPTH, SUITABILITY FOR RECONSTRUCTED PROFILE, ELEVATION, DEPTH, GRAPHIC LOG, CLASSIFICATION AND PHYSICAL CONDITION. Includes detailed log entries from 10.0 to 158.7 feet depth.

EXPLANATION
Type of hole: D = Diamond, M = Moystellite, S = Shot, C = Churn
Mole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"
Approx. size of core (X-series): Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"
Outside dia. of casing (X-series): Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"
Inside dia. of casing (X-series): Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

FEATURE Tobacco Garden Study Area PROJECT BLM-BR Coop. Agreement STATE ND SHEET 2 OF 2 HOLE NO DH82-127

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
WILLIAMS AND MCKENZIE COUNTIES STUDY
NORTH DAKOTA
GEOLOGIC LOG OF DH 82-127
GEOLOGY C. BOTDORF FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA JUNE 1983 1305-600-419

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.



Table 2  
Sheet 1

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-101  
Location: 105' E. & 224' S. of NW Corner, Sec. 7, T. 159 N., R. 101 W.  
Logged by: C. Botdorf  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,356	4,357	4,358	4,359	4,360	4,361
SACK NUMBER	101-1	101-2	101-3	101-4	101-5	101-6
DEPTH (FT)	0-0.7	0.7-4.0	4.0-6.5	6.5-10.0	10-31.5	31.5-53.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	2.0	1.9	2.1	1.7	1.5	0.8
Coarse Sand (1.0-0.5 mm)	3.6	3.4	4.3	3.6	2.4	1.2
Medium Sand (0.5-0.25 mm)	6.4	4.3	13.0	7.2	5.0	2.8
Fine Sand (0.25-0.10 mm)	8.5	11.2	14.6	9.6	12.3	11.1
TOTAL SAND (2.0-0.05 mm)	32.3	31.0	43.9	33.9	34.4	26.3
SILT (0.05-0.002 mm)	52.1	39.4	34.9	60.9	32.8	27.0
CLAY (0.002 mm)	15.6	29.6	21.2	5.2	32.8	27.0
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	CL	L	SIL	CL	CL-L
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	1.14	0.08	0.20	0.08	0.04	0.00
24th Hr.	2.05	0.06	0.22	0.08	0.02	0.02
<u>SETTLING VOLUME</u> (ml)	26.0	24.0	21.0	23.0	25.0	29.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	29.0	27.7	19.3	26.2	25.7	28.0
15 bar	11.9	12.2	9.1	12.7	12.9	14.1
<u>SOIL REACTION-pH</u>						
Paste	7.4	8.3	7.9	7.8	7.7	7.7
1:5 H <sub>2</sub> O	8.2	9.4	8.6	8.3	8.6	8.8
1:2 U.O1 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSTUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATIUN EXTRACT</u>						
Saturation Percentage	53.6	53.5	41.9	53.7	48.6	56.7
EC <sub>e</sub> @25°C (mmhos/cm)	1.24	1.04	8.4	8.0	5.5	3.1
Ca++ (me/l)	-	1.0	15.0	21.4	23.3	8.9
Mg++ (me/l)	-	3.6	76.4	61.9	29.6	10.1
Na++ (me/l)	1.5	5.6	32.2	33.1	20.3	15.7
K+ (me/l)	-	0.2	0.8	1.2	0.9	0.8
CO <sub>3</sub> - (me/l)	-	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> - (me/l)	-	4.1	2.2	1.9	2.0	4.3
Cl- (me/l)	-	0.9	3.7	3.6	1.5	0.8
SO <sub>4</sub> - (me/l)	-	4.9	120.0	112.0	72.0	30.5
NO <sub>3</sub> - (me/l)	-	<0.1	0.4	0.4	0.3	<0.1
SAR (me/l)	-	3.7	4.8	5.1	4.0	5.1
Na (me/100g)	0.1	0.3	1.3	1.8	1.0	0.9
Ca+Mg (me/100g)	-	0.2	3.8	5.0	2.6	1.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.20	0.20	1.5	2.2	0.86	0.46
Ca+Mg (me/l)	1.8	1.2	12.8	20.6	5.4	1.8
<u>EXCHANGEABLE SUDIUM</u> (percent)	1.5	4.2	24.2	7.0	5.2	5.1
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	22.1	21.2	15.3	23.1	22.9	23.3
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	<0.1	<0.1
BORON (B) (ppm)	-	-	-	-	0.60	0.70
CADMIUM (Cd) (ppm)	-	-	-	-	<0.1	0.22
COPPER (Cu) (ppm)	-	-	-	-	3.0	6.6
IRON (Fe) (ppm)	-	-	-	-	22.1	78.5
MERCURY (Hg) (ppm)	-	-	-	-	0.10	0.15
MANGANESE (Mn) (ppm)	-	-	-	-	30.0	49.8
MOLYBDENUM (Mo) (ppm)	-	-	-	-	0.3	0.6
NICKEL (Ni) (ppm)	-	-	-	-	1.5	2.3
LEAD (Pb) (ppm)	-	-	-	-	2.1	3.0
SELENIUM (Se) (ppm)	-	-	-	-	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	-	2.5	2.2

\*Insufficient Sample

Table 2  
Sheet 2

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-101 (cont'd)  
Location: 105' E. & 224' S. of NW Corner, Sec. 7, T. 154 N., R. 101 W.  
Logged by: C. Boddorf  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,362	4,363	4,364	4,365	4,366	4,367
SACK NUMBER	101-7	101-8	101-9	101-10	101-11	101-12
DEPTH (FT)	53-63	63-82	82-98.5	98.5-110.8	110.8-128	128-137.2
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.2	0.0	0.2	0.1	0.0
Coarse Sand (1.0-0.5 mm)	0.0	0.0	0.0	0.1	0.2	0.1
Medium Sand (0.5-0.25 mm)	0.5	0.0	0.0	0.4	0.1	0.0
Fine Sand (0.25-0.10 mm)	8.0	0.9	0.1	0.9	0.1	0.1
Very Fine Sand (0.10-0.05 mm)	10.8	10.4	1.0	12.6	7.5	1.0
TOTAL SAND (2.0-0.05 mm)	19.3	11.5	1.1	14.2	8.0	1.2
SILT (0.05-0.002 mm)	61.4	65.3	61.3	62.2	66.0	59.2
CLAY (0.002 mm)	19.3	23.2	37.6	23.6	26.0	39.6
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	SIL	S1CL	SIL	SIL	S1CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	32.0	38.0	74.0	56.0	71.0	175.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	28.7	37.1	55.2	33.0	32.6	38.3
15 bar	10.7	14.2	24.5	12.4	11.0	17.0
<u>SOIL REACTION-pH</u>						
Paste	8.0	8.0	7.9	8.4	8.1	8.2
1:5 H <sub>2</sub> O	9.4	9.3	9.2	9.6	9.8	9.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	49.0	63.0	95.8	69.9	64.5	79.3
EC <sub>e</sub> @25°C (mmhos/cm)	1.68	1.80	1.42	1.70	2.10	1.98
Ca <sup>++</sup> (me/l)	2.0	2.7	1.4	1.0	0.8	0.6
Mg <sup>++</sup> (me/l)	1.8	2.1	1.0	0.9	0.7	0.5
Na <sup>++</sup> (me/l)	12.2	12.7	11.1	12.8	16.7	16.8
K <sup>+</sup> (me/l)	0.4	0.6	0.5	0.4	0.4	0.4
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.2	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.5	4.7	5.4	5.3	7.1	9.6
Cl <sup>-</sup> (me/l)	0.7	0.3	0.4	0.0	0.0	<0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	10.8	12.5	7.8	9.2	12.2	9.0
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SR	8.9	8.2	10.1	13.1	19.3	22.7
Na (me/100g)	0.6	0.8	1.1	0.9	1.1	1.3
Ca+Mg (me/100g)	0.2	0.3	0.2	0.1	0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.30	0.30	0.40	0.34	0.42	0.50
Ca+Mg (me/l)	0.9	0.2	0.2	0.1	0.0	0.1
<u>EXCHANGEABLE SODIUM</u> (percent)	10.0	10.9	12.9	13.3	15.1	27.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	21.0	24.6	33.9	23.2	20.3	17.6
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.58	0.54	0.46	0.42	0.46	0.46
CADMIUM (Cd) (ppm)	<0.1	0.27	0.29	<0.1	0.12	0.61
COPPER (Cu) (ppm)	8.2	8.9	12.6	4.1	3.9	5.0
IRON (Fe) (ppm)	85.4	60.4	85.1	61.9	140.0	234.0
MERCURY (Hg) (ppm)	0.15	0.20	0.15	0.20	0.25	0.30
MANCANESE (Mn) (ppm)	27.7	13.0	13.6	10.6	24.8	37.3
MOLYBDENUM (Mo) (ppm)	0.3	0.5	1.3	0.3	0.4	0.67
NICKEL (Ni) (ppm)	0.64	2.2	3.1	1.2	1.4	2.0
LEAD (Pb) (ppm)	3.4	4.4	8.9	4.20	3.9	3.6
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	2.5	5.0	4.3	3.5	3.4	5.5

\*Insufficient Sample

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-101 (cont'd)  
Location: 105' E. & 224' S. of NW Corner, Sec. 7, T. 154 N., R. 101 W.  
Logged by: C. Botdorf  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION			
	Date			
LABORATORY NUMBER	4,368	4,369	4,370	4,371
SACK NUMBER	101-13	101-14	101-15	101-16
DEPTH (FT)	141-153	153-160.5	160.5-173.4	173.4-177.8
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	0.0	0.0
Coarse Sand (1.0-0.5 mm)	0.1	0.2	0.1	0.0
Medium Sand (0.5-0.25 mm)	0.1	0.1	0.1	0.0
Fine Sand (0.25-0.10 mm)	0.1	0.1	0.1	4.0
Very Fine Sand (0.10-0.05 mm)	2.6	4.5	0.3	24.0
TOTAL SAND (2.0-0.05 mm)	2.9	4.9	0.6	28.0
SILT (0.05-0.002 mm)	60.2	74.6	51.5	63.7
CLAY (0.002 mm)	36.9	20.5	47.9	8.3
GRAVEL (percent)	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	SIL	SIC	SIL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	245.0	145.0	310.0	35.0
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	48.9	37.6	53.1	21.0
15 bar	20.4	11.8	24.2	4.1
<u>SOIL REACTION-pH</u>				
Paste	8.6	8.8	8.8	8.5
1:5 H <sub>2</sub> O	10.2	10.1	9.8	9.9
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-
<u>CATIONIC REQUIREMENT</u> (me/100g)	-	-	-	-
<u>SATURATION EXTRACT</u>				
Saturation Percentage	89.5	65.8	101.1	44.1
EC <sub>e</sub> @25°C (mmhos/cm)	1.70	2.60	2.6	5.2
Ca <sup>++</sup> (me/l)	0.2	0.2	0.2	2.3
Mg <sup>++</sup> (me/l)	0.1	0.2	0.1	1.07
Na <sup>++</sup> (me/l)	15.2	23.4	23.6	47.5
K <sup>+</sup> (me/l)	0.2	0.2	0.2	0.5
CO <sub>3</sub> <sup>-</sup> (me/l)	1.4	1.5	1.5	0.4
HCO <sub>3</sub> <sup>-</sup> (me/l)	9.0	12.1	15.4	5.7
Cl <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	6.3	12.0	8.0	45.0
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	39.3	52.3	60.9	37.0
Na (me/100g)	1.4	1.5	2.4	2.1
Ca+Mg (me/100g)	<0.1	<0.1	<0.1	0.1
<u>1:5 EXTRACT</u>				
EC <sub>5</sub> @25°C (mmhos/cm)	0.54	0.60	0.70	0.60
Ca+Mg (me/l)	0.0	0.0	0.0	0.0
<u>EXCHANGEABLE SODIUM</u> (percent)	52.1	40.4	69.0	31.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	16.7	15.4	14.9	5.2
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.52	0.58	0.48	0.44
CADMIUM (Cd) (ppm)	0.17	<0.1	<0.1	0.15
COPPER (Cu) (ppm)	5.6	2.3	9.1	2.6
IRON (Fe) (ppm)	207.0	192.0	395.0	241.0
MERCURY (Hg) (ppm)	0.20	0.15	0.30	0.20
MANGANESE (Mn) (ppm)	34.5	28.4	46.3	23.9
MOLYBDENUM (Mo) (ppm)	0.3	0.4	0.5	0.4
NICKEL (Ni) (ppm)	2.5	3.1	1.2	0.80
LEAD (Pb) (ppm)	4.9	2.1	7.2	1.7
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	5.6	4.5	5.5	3.7

\*Insufficient Sample

Table 3  
Sheet 1

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-102  
Location: 400' N. & 25' W of SE Corner, Sec. 32, T. 159 N., R. 101 W.  
Logged by: C. Botdorf  
Date: October 1982

DETERMINATION LABORATORY NUMBER	LABORATORY DESCRIPTION					
	Data					
	78	79	80	81	82	83
SACK NUMBER	102-1	102-2	102-3	102-4	102-5	102-6
DEPTH (FT)	2.0-5.5	5.5-9.0	9.0-10.0	10.0-24.0	24.0-45.5	45.5-60.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	1.7	2.8	1.1
Coarse Sand (1.0-0.5 mm)	-	-	-	8.1	19.8	31.4
Medium Sand (0.5-0.25 mm)	-	-	-	39.4	46.3	44.2
Fine Sand (0.25-0.10 mm)	-	-	-	13.7	8.8	6.2
Very Fine Sand (0.10-0.05 mm)	-	-	-	12.1	6.3	5.3
TOTAL SAND (2.0-0.05 mm)	40.6	37.4	35.8	75.6	84.0	88.2
SILT (0.05-0.002 mm)	31.8	33.0	30.6	12.8	8.4	6.2
CLAY (0.002 mm)	27.6	29.6	33.6	11.6	7.6	5.6
GRAVEL (percent)	2.5	3.1	5.1	-	-	-
TEXTURAL CLASS (LAB)	CL	CL	CL	SL	LS	S
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.17	0.09	*	0.22	5.4	11.0
24th Hr.	0.19	0.08	*	0.36	7.4	11.0
SETTLING VOLUME (ml)	18.5	21.5	21.0	19.5	18.0	16.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	25.1	27.5	26.1	17.0	11.2	8.3
15 bar	14.0	13.4	13.5	9.0	3.8	2.8
<b>SOIL REACTION-pH</b>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.4	8.3	8.2	8.0	7.0	7.5
1:2 0.01 M CaCl <sub>2</sub>	7.7	7.4	7.2	7.2	6.8	6.8
GYPSUM REQUIREMENT (me/100g)	-3.6	+0.4	*	+4.6	+5.4	+7.4
<b>SATURATION EXTRACT</b>						
Saturation Percentage	46.9	53.2	50.7	38.6	37.9	35.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.960	1.558	2.065	1.068	0.832	0.688
Ca <sup>++</sup> (me/l)	0.90	2.10	3.90	3.80	3.50	3.00
Mg <sup>++</sup> (me/l)	3.61	5.74	7.87	2.79	1.97	2.46
Na <sup>++</sup> (me/l)	7.3	13.0	15.8	5.2	4.0	4.1
K <sup>+</sup> (me/l)	0.29	0.36	0.59	0.34	0.32	0.27
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	3.17	2.32	2.36	2.14	2.53	1.67
Cl <sup>-</sup> (me/l)	1.53	4.30	5.17	3.16	0.68	0.45
SO <sub>4</sub> <sup>-</sup> (me/l)	7.40	14.58	20.63	6.83	6.58	7.71
NO <sub>3</sub> <sup>-</sup> (me/l)	0.001	0.000	0.000	0.001	0.001	0.003
SAR (me/l)	4.9	6.6	6.5	2.9	2.4	2.5
Na (me/100g)	0.34	0.69	0.80	0.20	0.15	0.15
Ca+Mg (me/100g)	0.21	0.42	0.60	0.25	0.21	0.20
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	.229	.309	.395	.184	.121	.126
Ca+Mg (me/l)	0.88	1.09	1.40	0.79	0.51	0.56
<b>EXCHANGEABLE SODIUM (percent)</b>						
	3.9	4.4	4.1	2.1	1.2	1.7
<b>CATION EXCHANGE CAPACITY (me/100g)</b>						
NaOAc@pH 8.2	22.0	23.6	25.0	17.4	13.0	9.0
<b>Trace Elements (ppm)</b>						
SILVER (Ag)	-	-	-	-	-	-
BORON (B)	0.62	1.21	*	0.59	0.59	0.62
CADMIUM (Cd)	0.04	0.06	*	0.06	0.04	0.02
COPPER (Cu)	2.8	2.8	*	1.2	0.8	0.8
IRON (Fe)	139.0	130.6	*	87.0	84.4	83.4
MERCURY (Hg)	0.03	0.04	*	0.04	0.03	0.01
MANGANESE (Mn)	65.2	54.2	*	6.4	3.6	7.0
MOLYBDENUM (Mo)	0.1	0.7	*	0.4	0.3	0.3
NICKEL (Ni)	1.6	1.4	*	0.4	0.4	0.4
LEAD (Pb)	1.20	1.20	*	0.60	0.60	0.40
SELENIUM (Se)	<0.1	<0.1	*	<0.1	<0.1	<0.1
ZINC (Zn)	2.6a	10.9	*	24.2	2.0	4.5

\*Insufficient Sample

Table 3  
Sheet 2

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-102 (cont'd)  
 Location: 400' N. & 25' W of SE Corner, Sec. 32, T. 159 N., R. 101 W.  
 Logged by: C. Boddort  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
	84	85	86	87	88	89
<u>LABORATORY NUMBER</u>	102-7	102-8	102-9	102-10	102-11	102-12
<u>DEPTH (FT)</u>	60.0-78.0	78.0-95.0	95.0-111.4	111.4-123.8	123.8-137.9	148.1-154.7
<u>PARTICLE SIZE ANALYSIS</u>	(percent)					
Very Coarse Sand (2.0-1.0 mm)	1.2	0.8	0.5	-	-	-
Coarse Sand (1.0-0.5 mm)	34.6	15.8	16.7	-	-	-
Medium Sand (0.5-0.25 mm)	42.0	48.5	55.3	-	-	-
Fine Sand (0.25-0.10 mm)	5.9	12.5	8.8	-	-	-
Very Fine Sand (0.10-0.05 mm)	6.3	5.8	6.1	-	-	-
TOTAL SAND (2.0-0.05 mm)	30.0	83.4	88.4	20.4	6.2	11.0
SILT (0.05-0.002 mm)	4.4	9.0	7.0	44.0	39.2	54.4
CLAY (0.002 mm)	5.6	7.6	5.6	33.6	54.6	34.6
GRAVEL	(percent)					
	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S	LS	LS	CL	C	SiCL
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)					
6th Hr.	12.0	8.0	8.1	0.06	0.07	0.11
24th Hr.	13.0	8.1	8.1	0.04	0.06	0.19
<u>SETTLING VOLUME</u>	(ml)					
	15.0	14.5	15.5	28.0	33.0	31.0
<u>MOISTURE RETENTION</u>	(% )					
1/3 bar	7.8	9.5	8.6	43.7	47.4	43.2
15 bar	2.5	3.0	2.8	36.7	32.1	26.4
<u>SDIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	7.7	8.0	8.0	8.1	8.1	8.3
1:2 0.01 M CaCl <sub>2</sub>	6.9	7.3	7.4	7.6	7.7	7.8
<u>GYP SUM REQUIREMENT</u>	(me/100g)					
	+1.0	+0.4	+2.4	-0.2	-2.2	-6.4
<u>SATURATION EXTRACT</u>						
Saturation Percentage	35.9	41.3	36.0	76.7	86.0	85.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.802	0.627	0.867	0.741	1.001	0.838
Ca <sup>++</sup> (me/l)	2.30	1.65	2.30	1.38	1.90	1.00
Mg <sup>++</sup> (me/l)	2.13	1.80	2.46	2.05	2.46	1.23
Na <sup>++</sup> (me/l)	4.2	3.7	5.5	5.2	5.5	6.0
K <sup>+</sup> (me/l)	D.22	0.15	0.16	0.65	1.30	0.7D
CD <sub>3-</sub> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3-</sub> (me/l)	1.84	1.48	1.44	2.19	4.59	3.95
Cl <sup>-</sup> (me/l)	0.45	0.40	0.51	0.25	0.23	0.28
SO <sub>4-</sub> (me/l)	6.56	5.42	8.47	6.84	6.34	4.70
ND <sub>3-</sub> (me/l)	<0.001	0.000	0.000	0.001	0.000	0.000
SAR (me/l)	2.8	2.8	3.6	4.0	3.6	5.7
Na (me/100g)	0.15	0.15	0.20	0.40	0.47	0.52
Ca+Mg (me/100g)	0.16	0.14	0.17	0.26	0.38	0.19
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	.117	.144	.153	.286	.331	.303
Ca+Mg (me/l)	0.47	0.59	0.60	1.12	1.11	0.72
<u>EXCHANGEABLE SODIUM</u>	(percent)					
	1.9	2.4	2.5	2.4	3.9	4.3
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)					
NaDac@pH 8.2	8.8	12.0	10.4	35.8	28.4	31.2
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.56	0.79	0.46	0.59	0.72	0.92
CADMIUM (Cd) (ppm)	0.04	0.04	0.02	0.06	0.08	0.06
COPPER (Cu) (ppm)	0.6	0.6	0.6	12.0	12.0	8.0
IRON (Fe) (ppm)	76.8	86.6	70.6	67.6	134.8	91.4
MERCURY (Hg) (ppm)	0.01	0.00	0.01	0.08	0.04	0.07
MANGANESE (Mn) (ppm)	3.8	4.8	4.6	5.4	22.6	6.6
MOLYBDENUM (Mo) (ppm)	0.3	0.2	0.1	0.4	0.9	0.3
NICKEL (Ni) (ppm)	0.2	0.4	0.4	2.2	8.0	2.0
LEAD (Pb) (ppm)	0.40	0.40	0.60	8.20	5.80	7.20
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1	0.2	0.2
ZINC (Zn) (ppm)	2.4	1.4	1.3	3.9	5.8	3.8

\*Insufficient Sample

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-1D2 (cont'd)  
 Location: 400' N. & 25' W of SE Corner, Sec. 32, T. 159 N., R. 101 W.,  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION		LABORATORY DESCRIPTION	
		Data	
LABORATORY NUMBER		90	
SACK NUMBER		102-13	
DEPTH (FT)		154.7-170.0	
<u>PARTICLE SIZE ANALYSIS</u> (percent)			
Very Coarse Sand	(2.0-1.0 mm)	-	
Coarse Sand	(1.0-0.5 mm)	-	
Medium Sand	(0.5-0.25 mm)	-	
Fine Sand	(0.25-0.10 mm)	-	
Very Fine Sand	(0.10-0.05 mm)	-	
TOTAL SAND	(2.0-0.05 mm)	44.8	
SILT	(0.05-0.002 mm)	32.6	
CLAY	(0.002 mm)	22.6	
GRAVEL	(percent)	-	
<u>TEXTURAL CLASS (LAB)</u>		L	
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)			
6th Hr.		0.01	
24th Hr.		0.01	
<u>SETTLING VOLUME</u> (ml)		22.5	
<u>MOISTURE RETENTION</u> (%)			
1/3 bar		33.4	
15 bar		16.3	
<u>SOIL REACTION-pH</u>			
Paste		-	
1:5 H <sub>2</sub> O		8.7	
1:2 0.01 M CaCl <sub>2</sub>		7.8	
<u>GYPNUM REQUIREMENT</u> (me/100g)		-1.0	
<u>SATURATION EXTRACT</u>			
Saturation Percentage		59.1	
EC <sub>e</sub> @25°C	(mmhos/cm)	1.003	
Ca <sup>++</sup>	(me/l)	0.50	
Mg <sup>++</sup>	(me/l)	0.90	
Na <sup>++</sup>	(me/l)	10.0	
K <sup>+</sup>	(me/l)	0.40	
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.00	
HCO <sub>3</sub> <sup>-</sup>	(me/l)	4.38	
Cl <sup>-</sup>	(me/l)	0.28	
SO <sub>4</sub> <sup>-</sup>	(me/l)	7.14	
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.002	
SAR	(me/l)	11.9	
Na	(me/100g)	0.59	
Ca+Mg	(me/100g)	0.08	
<u>1:5 EXTRACT</u>			
EC <sub>5</sub> @25°C	(mmhos/cm)	0.297	
Ca+Mg	(me/l)	0.36	
<u>EXCHANGEABLE SODIUM</u> (percent)		8.1	
<u>CATION EXCHANGE CAPACITY</u> (me/100g)		28.4	
NaOAc@pH 8.2			
<u>SILVER (Ag)</u> (ppm) -			
<u>BARIUM (Ba)</u> (ppm) 0.95			
<u>CADMIUM (Cd)</u> (ppm) 0.02			
<u>COPPER (Cu)</u> (ppm) 3.2			
<u>IRON (Fe)</u> (ppm) 62.8			
<u>MERCURY (Hg)</u> (ppm) 0.03			
<u>MANGANESE (Mn)</u> (ppm) 3.4			
<u>MOLYBDENUM (Mo)</u> (ppm) 0.3			
<u>NICKEL (Ni)</u> (ppm) 1.6			
<u>LEAD (Pb)</u> (ppm) 4.40			
<u>SELENIUM (Se)</u> (ppm) <0.1			
<u>ZINC (Zn)</u> (ppm) 2.6			
*Insufficient Sample			

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-103  
 Location: 40' N. & 500' W. of SE Corner, Sec. 14, T. 158 N., R. 103  
 Logged by: C. Botdorf  
 Date: November 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	91	92	93	94	95	96
SACK NUMBER	103-1	103-2	103-3	103-4	103-5	103-6
DEPTH (FT)	0-1.4	1.4-5.0	5.0-10.0	10.0-13.8	13.8-31.5	31.5-44.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	30.8	53.0	75.0	32.8	29.8	6.0
SILT (0.05-0.002 mm)	43.8	27.4	16.4	35.0	50.0	38.8
CLAY (0.002 mm)	25.4	19.6	8.6	32.2	20.6	55.2
GRAVEL (percent)	2.4	1.7	54.8	3.4	-	-
TEXTURAL CLASS (LAB)	L	SL	SL	CL	L/S&L	C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.91	1.3	0.50	0.20	0.45	0.60
24th Hr.	1.5	2.7	1.3	0.20	0.52	1.00
SETTLING VOLUME (ml)	*	17.5	15.5	21.5	21.0	31.5
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	36.8	20.9	10.0	28.6	34.2	47.0
15 bar	18.4	9.0	7.2	7.1	6.9	6.8
<u>SOIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	6.4	6.1	7.9	7.7	8.1	7.4
1:2 0.01 M CaCl <sub>2</sub>	5.6	5.8	7.2	7.1	6.9	6.8
GYPSUM REQUIREMENT (me/100g)	+2.2	+2.8	+3.8	+3.0	+2.6	+2.4
<u>SATURATION EXTRACT</u>						
Saturation Percentage	74.1	36.0	22.2	54.2	57.7	83.5
EC <sub>e</sub> @25°C (mmhos/cm)	0.535	0.336	0.874	0.518	0.246	2.081
Ca <sup>++</sup> (me/l)	3.20	1.20	4.00	3.00	1.25	9.50
Mg <sup>++</sup> (me/l)	1.80	0.72	2.70	1.23	0.57	9.84
Na <sup>++</sup> (me/l)	0.70	0.63	2.1	0.54	0.38	6.5
K <sup>+</sup> (me/l)	0.29	0.16	0.30	0.24	0.17	1.50
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	3.47	0.69	1.95	2.53	1.67	5.36
Cl <sup>-</sup> (me/l)	0.56	0.78	3.22	1.72	0.28	0.40
SO <sub>4</sub> <sup>-</sup> (me/l)	1.96	1.24	3.93	0.76	0.42	21.58
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	0.023	<0.001	0.000	0.006	0.00
SAK (me/l)	0.44	0.64	1.1	0.37	0.40	2.1
Na (me/100g)	0.05	0.02	0.05	0.03	0.02	0.54
Ca+Mg (me/100g)	0.37	0.07	0.15	0.23	0.11	1.62
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	.130	.071	.155	.140	.122	.583
Ca+Mg (me/l)	0.90	0.31	1.82	1.01	0.87	3.51
EXCHANGEABLE SODIUM (percent)	.29	.55	1.7	.61	.69	1.8
CATION EXCHANGE CAPACITY (me/100g)	37.0	18.2	8.6	31.0	26.0	36.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.82	0.56	*	*	0.00	0.95
CADMIUM (Cd) (ppm)	0.24	0.08	*	*	0.06	0.26
COPPER (Cu) (ppm)	2.2	2.6	*	*	1.2	16.0
IRON (Fe) (ppm)	182.2	139.2	*	*	52.8	154.0
MERCURY (Hg) (ppm)	0.03	0.02	*	*	0.04	0.07
MANGANESE (Mn) (ppm)	39.6	40.2	*	*	7.4	36.0
MOLYBDENUM (Mo) (ppm)	0.1	0.1	*	*	0.2	1.2
NICKEL (Ni) (ppm)	2.8	2.8	*	*	0.4	10.0
LEAD (Pb) (ppm)	1.00	0.80	*	*	0.60	6.80
SELENIUM (Se) (ppm)	<0.1	<0.1	*	*	<0.1	0.5
ZINC (Zn) (ppm)	6.4	2.4	*	*	0.8	16.7

\*Insufficient Sample

Table 4  
Sheet 2

Hanka Study Area, North Dakota  
 Geologic Drill Hole: 82-103  
 Location: 40' N. & 500' W. of SE Corner, Sec. 14, T. 158 N., R. 103  
 Logged by: C. Botdorf  
 Date: November 1982

DETERMINATION	LABORATORY DESCRIPTION			
	Data			
LABORATORY NUMBER	97	98	99	100
SACK NUMBER	103-7	103-8	103-9	103-10
DEPTH (FT)	44.0-63.0	73.0-82.0	91.9-103.0	113.2-131.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	13.0	5.8	9.8	27.4
SILT (0.05-0.002 mm)	58.8	27.0	56.0	43.4
CLAY (0.002 mm)	28.2	67.2	34.2	29.2
GRAVEL (percent)	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiCL	C	SiCL	CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0.06	0.02	0	0
24th Hr.	0.08	0.06	0	0
<u>SETTLING VOLUME</u> (ml)	24.5	33.5	*	27.5
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	35.0	63.5	62.7	54.0
15 bar	16.7	32.5	39.3	30.0
<u>SOIL REACTION-pH</u>				
Paate	-	-	-	-
1:5 H <sub>2</sub> O	8.3	8.2	9.0	9.2
1:2 0.01 M CaCl <sub>2</sub>	7.6	7.7	7.8	7.9
<u>GYPSUM REQUIREMENT</u> (me/100g)	+3.6	+7.4	+11.2	+11.6
<u>SATURATION EXTRACT</u>				
Saturation Percentage	63.7	96.0	121.6	89.9
EC <sub>e</sub> @25°C (mmhoa/cm)	0.905	1.510	1.248	1.537
Ca <sup>++</sup> (me/l)	2.00	1.70	0.21	0.30
Mg <sup>++</sup> (me/l)	1.97	1.80	0.38	0.41
Na <sup>++</sup> (me/l)	6.0	15.0	15.3	18.1
K <sup>+</sup> (me/l)	0.61	0.90	0.38	0.35
CO <sub>3</sub> <sup>-</sup> (me/l)	0	0.34	0	0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.46	8.71	8.62	9.70
Cl <sup>-</sup> (me/l)	0.34	0.71	8.62	9.70
SO <sub>4</sub> <sup>-</sup> (me/l)	5.78	9.64	7.23	8.95
NO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00
SAR (me/l)	4.3	11.3	28.2	30.4
Na (me/100g)	0.38	1.44	1.86	1.63
Ca+Mg (me/100g)	0.25	0.34	0.07	0.06
<u>1:5 EXTRACT</u>				
EC <sub>s</sub> @25°C (mmhoa/cm)	.243	.376	.463	.466
Ca+Mg (me/l)	0.98	0.51	0.29	0.20
<u>EXCHANGEABLE SODIUM</u> (percent)	2.6	6.2	17.6	20.3
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	29.6	37.8	38.2	38.2
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	-	-	-	-
BORON (B) (ppm)	0.66	1.77	0.79	0.59
CADMIUM (Cd) (ppm)	0.10	0.22	0.14	0.10
COPPER (Cu) (ppm)	5.8	12.0	8.8	5.2
IRON (Fe) (ppm)	130.8	182.6	78.4	93.2
MERCURY (Hg) (ppm)	0.04	0.06	0.05	0.03
MANGANESE (Mn) (ppm)	11.2	14.6	6.4	9.2
MOLYBDENUM (Mo) (ppm)	0.5	0.6	0.4	0.4
NICKEL (Ni) (ppm)	3.8	6.0	4.0	3.4
LEAD (Pb) (ppm)	3.40	12.00	7.20	6.00
SELENIUM (Se) (ppm)	0.1	0.4	0.1	0.1
ZINC (Zn) (ppm)	7.1	20.6	10.7	7.5
*Insufficient Sample				

Table 5  
Sheet 1

Hanks Study Area North Dakota  
 Geologic Drill Hole: 82-104  
 Location: 75' N. & 150' W. of SE Corner, Sec. 19, T. 158 N., R. 102 W.  
 Logged by: F. Calcagno  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,590	21,591	21,592	21,593	21,594	21,595
SACK NUMBER	104-1	104-2	104-3	104-4	104-5	104-6
DEPTH (FT)	0.0-0.67	6.0-10.0	10.0-37.5	37.5-45.0	45.0-71.6	71.6-85.0
<u>PARTICLE SIZE ANALYSIS</u>	(percent)					
Very Coarse Sand (2.0-1.0 mm)	3.0	-	-	-	-	0.3
Coarse Sand (1.0-0.5 mm)	6.6	-	-	-	-	0.8
Medium Sand (0.5-0.25 mm)	10.1	-	-	-	-	17.3
Fine Sand (0.25-0.10 mm)	19.6	-	-	-	-	55.2
Very Fine Sand (0.10-0.05 mm)	20.2	-	-	-	-	5.4
TOTAL SAND (2.0-0.05 mm)	49.5	34.8	32.8	36.6	36.5	79.0
SILT (0.05-0.002 mm)	29.9	42.6	42.9	38.2	37.9	11.2
CLAY (0.002 mm)	20.6	22.6	24.3	25.2	25.6	9.8
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	L	L	L	L	L	FSL
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)					
6th Hr.	0.35	0.06	0.04	0.10	0.06	1.85
24th Hr.	0.32	0.06	0.04	0.12	0.06	1.89
<u>SETTLING VOLUME</u>	(ml)					
	21.0	26.0	24.0	24.0	25.0	20.0
<u>MOISTURE RETENTION</u>	(%)					
1/3 bar	-	-	-	-	-	-
15 bar	10.1	16.8	15.9	15.5	15.3	6.5
<u>SOIL REACTION-pH</u>						
Paste	-	8.3	7.6	8.1	8.1	8.1
1:5 H <sub>2</sub> O	8.4	8.6	8.1	*	7.9	8.5
1:2 0.01 M CaCl <sub>2</sub>	*	*	*	*	*	*
<u>GYPSUM REQUIREMENT</u>	(me/100g)					
	0.6	-7.0	-7.3	-2.1	0.6	0.7
<u>SATURATION EXTRACT</u>						
Saturation Percentage	39.0	46.5	45.0	45.4	51.8	39.9
EC <sub>e</sub> @25°C (mmhos/cm)	1.39	1.00	3.6	4.0	4.1	1.99
Ca++ + Mg++ (me/l)	12.7	5.6	44.1	49.9	53.6	17.2
Mg++ (me/l)	-	-	-	-	-	-
Na+ (me/l)	2.3	4.2	5.2	4.1	4.5	4.8
K+ (me/l)	0.9	0.2	0.7	0.7	0.8	0.5
CO <sub>3</sub> - (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> - (me/l)	11.2	4.5	2.5	2.3	3.4	3.2
Cl- (me/l)	0.8	0.3	1.4	1.0	0.6	1.2
SO <sub>4</sub> - (me/l)	3.3	2.5	45.5	50.0	54.0	17.0
NO <sub>3</sub> - (me/l)	<0.1	2.4	2.8	4.1	3.6	1.5
SAR (me/l)	0.9	2.5	1.1	0.8	0.9	1.6
Na (me/100g)	0.1	0.2	0.2	0.2	0.2	0.2
Ca+Mg (me/100g)	0.5	0.3	2.0	2.3	2.8	0.7
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.24	0.20	0.77	1.70	1.92	0.24
Ca+Mg (me/l)	1.8	1.2	7.1	17.2	20.7	1.4
<u>EXCHANGEABLE SODIUM</u>	(percent)					
	3.40	3.04	0.92	0.51	0.42	0.66
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)					
NaOAc@pH 8.2	19.45	18.26	17.93	20.97	19.56	12.39
SILVER (Ag) (ppm)	-	-	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	2.6	2.8	1.8	1.6
CADMIUM (Cd) (ppm)	-	-	<0.1	<0.1	<0.1	<0.1
COPPER (Cu) (ppm)	-	-	2.4	2.9	3.4	1.0
IRON (Fe) (ppm)	-	-	2.5	2.0	2.9	2.1
MERCURY (Hg) (ppm)	-	-	0.05	0.05	0.10	0.05
MANGANESE (Mn) (ppm)	-	-	8.5	13.9	18.2	7.0
MOLYBDENUM (Mo) (ppm)	-	-	0.5	0.1	0.2	0.1
NICKEL (Ni) (ppm)	-	-	0.6	1.8	2.5	0.4
LEAD (Pb) (ppm)	-	-	1.2	1.6	1.6	0.7
SELENIUM (Se) (ppm)	-	-	0.1	<0.1	0.1	<0.1
ZINC (Zn) (ppm)	-	-	2.1	1.5	2.5	4.7

\*Insufficient Sample

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-104 (cont'd)  
Location: 75' N. & 150' W. of SE Corner, Sec. 19, T. 158 N., R. 102 W.,  
Logged by: F. Calcagno  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,596	21,597	21,598	21,599	21,600	21,601
SACK NUMBER	104-7	104-8	104-9	104-10	104-11	104-12
DEPTH ( FT)	85.0-100.2	100.2-115.0	115.0-122.2	122.2-133.3	133.3-161.0	161.0-185.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.1	-	-	-	0.2	-
Coarse Sand (1.0-0.5 mm)	1.5	-	-	-	0.8	-
Medium Sand (0.5-0.25 mm)	25.1	-	-	-	10.8	-
Fine Sand (0.25-0.10 mm)	50.1	-	-	-	36.1	-
Very Fine Sand (0.10-0.05 mm)	6.9	-	-	-	28.8	-
TOTAL SAND (2.0-0.05 mm)	83.7	3.0	3.5	30.1	76.7	16.8
SILT (0.05-0.002 mm)	8.0	64.1	74.6	52.6	12.0	62.0
CLAY (0.002 mm)	8.3	32.9	22.9	17.3	11.3	21.2
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS ( LAB)</u>	LPS	SiCL	SIL	SIL	FSL	SiL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	2.60	Trace	Trace	0.08	1.16	0.02
24th Hr.	2.52	Trace	Trace	0.08	1.16	Trace
<u>SETTLING VOLUME</u> (ml)	19.0	34.0	32.0	25.0	20.0	26.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	-	-	-	-	-	-
15 bar	-	26.6	26.9	15.9	7.3	22.1
<u>SOIL REACTION-pH</u>						
Paste	7.7	7.2	8.0	8.1	7.7	7.9
1:5 H <sub>2</sub> O	8.4	7.5	7.3	-	8.0	8.3
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-3.3	-7.0	-0.2	1.4	0.6	2.2
<u>SATURATION EXTRACT</u>						
Saturation Percentage	37.0	74.7	70.7	53.7	42.1	67.9
EC <sub>e</sub> @25°C (mmhos/cm)	2.15	4.3	2.25	3.8	2.30	2.00
Ca <sup>++</sup> + Mg <sup>++</sup> (me/l)	19.1	52.8	21.9	47.4	19.9	8.6
Mg <sup>++</sup> (me/l)	-	-	-	-	-	-
Na <sup>+</sup> (me/l)	5.3	5.5	4.0	5.9	6.3	11.7
K <sup>+</sup> (me/l)	0.4	1.1	1.0	0.8	0.4	0.7
CD <sub>3-</sub> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3-</sub> (me/l)	3.3	2.9	3.2	3.1	2.8	4.9
Cl <sup>-</sup> (me/l)	1.9	0.3	0.2	0.4	1.4	0.2
SO <sub>4-</sub> (me/l)	19.0	56.0	24.5	50.0	23.0	15.6
NO <sub>3-</sub> (me/l)	1.3	0.8	0.2	0.3	0.3	0.3
SAR (me/l)	1.7	1.1	1.2	1.2	2.0	5.6
Na (me/100g)	0.2	0.4	0.3	0.3	0.3	0.8
Ca+Mg (me/100g)	0.7	3.9	1.5	2.5	0.8	0.6
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.23	2.11	0.61	1.15	0.35	0.53
Ca+Mg (me/l)	1.4	22.6	4.0	10.9	2.3	1.9
<u>EXCHANGEABLE SODIUM</u> (percent)	2.04	1.00	1.27	2.03	1.36	6.56
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	12.93	38.91	27.82	22.28	14.34	26.30
NaDac@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	1.2	1.4	0.8	1.4	1.5	1.1
CADMIUM (Cd) (ppm)	<0.1	<0.1	0.2	0.1	<0.1	<0.1
COPPER (Cu) (ppm)	0.7	6.9	7.2	2.4	1.1	5.7
IRON (Fe) (ppm)	1.6	3.7	3.7	3.7	1.8	7.9
MERCURY (Hg) (ppm)	0.05	0.20	0.20	0.10	0.05	0.20
MANGANESE (Mn) (ppm)	9.6	6.7	32.3	13.8	10.6	17.9
MOLYBDENUM (Mo) (ppm)	0.1	0.1	0.3	<0.1	<0.1	0.2
NICKEL (Ni) (ppm)	0.1	1.6	1.7	0.7	0.3	1.2
LEAD (Pb) (ppm)	0.6	2.4	3.6	1.1	0.9	5.5
SELENIUM (Se) (ppm)	<0.1	0.1	0.1	<0.1	<0.1	0.1
ZINC (Zn) (ppm)	5.8	2.6	3.9	1.6	4.7	4.5

\*Insufficient Sample

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-104 (cont'd)  
 Location: 75' N. & 150' W. of SE Corner, Sec. 19, T. 158 N., R. 102 W.  
 Logged by: F. Calcagno  
 Date: March 1982

DETERMINATION	LABORATORY NUMBER	LABORATORY DESCRIPTION					
		Data					
		21,602	21,603	21,604	21,605	21,606	21,607
SACK NUMBER		104-13	104-14	104-15	104-16	104-17	104-18
DEPTH (FT)		185.5-191.5	191.5-196.5	196.5-217.3	218.5-231.5	231.5-235.4	161.0-185.5
<b>PARTICLE SIZE ANALYSIS</b> (percent)							
Very Coarse Sand	(2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand	(1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand	(0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand	(0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand	(0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND	(2.0-0.05 mm)	25.2	14.2	34.8	9.7	1.4	1.6
SILT	(0.05-0.002 mm)	56.7	62.6	64.4	48.7	66.3	54.4
CLAY	(0.002 mm)	18.1	23.2	18.8	41.6	32.3	44.0
GRAVEL	(percent)	-	-	-	-	-	-
<b>TEXTURAL CLASS (LAB)</b>		SIL	SIL	L	SIC	SICL	SIC
<b>HYDRAULIC CONDUCTIVITY</b> (in/hr)							
6th Hr.		0.06	0.00	0.02	0.00	0.00	0.00
24th Hr.		0.04	0.00	0.02	0.00	0.00	0.00
<b>SETTLING VOLUME</b>	(ml)	26.0	31.0	24.0	36.0	42.0	62.0
<b>MOISTURE RETENTION</b> (%)							
1/3 bar		-	-	-	-	-	-
15 bar		15.9	23.4	15.0	28.9	30.5	32.5
<b>SOIL REACTION-pH</b>							
Paste		9.3	7.8	8.4	8.3	8.3	8.3
1:5 H <sub>2</sub> O		8.8	*	8.9	8.7	8.8	8.9
1:2 0.01 M CaCl <sub>2</sub>		-	-	-	-	-	-
<b>GYPNUM REQUIREMENT</b>	(me/100g)	2.2	5.4	5.8	7.8	7.8	11.6
<b>SATURATION EXTRACT</b>							
Saturation Percentage		54.0	59.7	45.8	62.6	72.6	88.6
EC <sub>e</sub> @25°C	(mmhos/cm)	1.85	1.60	1.81	3.0	2.41	2.55
Ca++ + Mg++	(me/l)	7.8	4.6	3.4	3.2	1.7	1.3
Mg++	(me/l)	-	-	-	-	-	-
Na++	(me/l)	9.6	10.9	14.0	27.7	22.1	24.3
K+	(me/l)	0.4	0.7	0.4	0.6	0.4	0.4
CO <sub>3</sub> -	(me/l)	0.0	0.0	0.1	0.1	0.0	0.2
HCO <sub>3</sub> -	(me/l)	3.0	6.5	5.0	11.9	9.2	11.4
Cl-	(me/l)	0.1	0.2	0.2	0.4	0.8	0.4
SO <sub>4</sub> -	(me/l)	14.0	9.4	12.4	18.5	14.0	14.0
NO <sub>3</sub> -	(me/l)	0.3	0.2	0.3	0.2	0.1	0.1
SAR	(me/l)	4.9	7.2	10.7	21.9	24.0	30.1
Na	(me/100g)	0.5	0.7	0.6	1.7	1.6	2.2
Ca+Mg	(me/100g)	0.4	0.3	0.2	0.2	0.1	0.1
<b>1:5 EXTRACT</b>							
EC <sub>5</sub> @25°C	(mmhos/cm)	0.46	0.40	0.32	0.63	0.62	0.75
Ca+Mg	(me/l)	1.7	0.9	0.2	0.4	0.2	0.2
<b>EXCHANGEABLE SODIUM</b>	(percent)	5.74	8.59	14.31	20.51	26.84	29.44
<b>CATION EXCHANGE CAPACITY</b>	(me/100g)	23.36	26.30	17.93	30.76	24.85	27.17
NaOAc@pH 8.2							
SILVER (Ag)	(ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B)	(ppm)	1.5	0.4	0.7	2.6	1.0	1.2
CADMIUM (Cd)	(ppm)	0.2	0.2	<0.1	0.2	<0.1	-/1
COPPER (Cu)	(ppm)	4.6	6.3	2.9	5.3	6.5	7.2
IRON (Fe)	(ppm)	2.6	9.7	4.1	7.6	12.7	13.6
MERCURY (Hg)	(ppm)	0.20	0.25	0.20	0.20	0.10	0.15
MANGANESE (Mn)	(ppm)	4.7	18.0	5.0	9.9	29.6	26.3
MOLYBDENUM (Mo)	(ppm)	0.3	0.4	0.5	0.8	1.0	0.7
NICKEL (Ni)	(ppm)	2.7	2.2	1.6	2.1	3.2	3.7
LEAD (Pb)	(ppm)	2.5	6.0	3.2	5.0	3.7	5.0
SELENIUM (Se)	(ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ZINC (Zn)	(ppm)	7.3	6.0	4.7	6.0	12.3	8.5

\*Insufficient Sample

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-104 (cont'd)  
 Location: 75' N. & 150' W. of SE Corner, Sec. 19, T. 158 N., R. 102 W.  
 Logged by: F. Calcagno  
 Date: March 1982

		LABORATORY DESCRIPTION				
		Data				
DETERMINATION		21,608	21,609	21,610	21,611	21,612
LABORATORY NUMBER		104-19	104-20	104-21	104-22	104-23
SACK NUMBER		245.9-263.2	263.2-267.9	267.9-284.6	284.6-308.8	308.8-332.5
DEPTH (FT)						
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand	(2.0-1.0 mm)	-	-	-	-	-
Coarse Sand	(1.0-0.5 mm)	-	-	-	-	-
Medium Sand	(0.5-0.25 mm)	-	-	-	-	-
Fine Sand	(0.25-0.10 mm)	-	-	-	-	-
Very Fine Sand	(0.10-0.05 mm)	-	-	-	-	-
TOTAL SAND	(2.0-0.05 mm)	32.1	1.4	10.3	5.4	0.6
SILT	(0.05-0.002 mm)	44.0	50.4	63.3	56.1	60.2
CLAY	(0.002 mm)	23.9	48.2	26.4	38.5	39.2
GRAVEL	(percent)	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>		L	SIC	SIL	SICL	SICL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u>	(ml)	72.0	80.0	98.0	147.0	214.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar		-	-	-	-	-
15 bar		38.9	35.3	39.8	34.2	40.7
<u>SOIL REACTION-pH</u>						
Paste		8.5	8.4	8.6	8.8	8.8
1:5 H <sub>2</sub> O		9.3	9.1	9.3	9.3	9.1
1:2 0.01 M CaCl <sub>2</sub>		-	-	-	-	-
<u>GYPNUM REQUIREMENT</u>	(me/100g)	10.1	11.3	17.3	9.8	16.9
<u>SATURATION EXTRACT</u>						
Saturation Percentage		90.9	105.9	86.9	98.5	138.0
EC <sub>e</sub> @25°C	(mmhos/cm)	2.02	2.25	2.25	2.40	1.84
Ca <sup>++</sup> + Mg <sup>++</sup>	(me/l)	0.7	0.4	0.5	0.4	0.4
Mg <sup>++</sup>	(me/l)	-	-	-	-	-
Na <sup>++</sup>	(me/l)	20.0	23.4	24.1	24.9	19.4
K <sup>+</sup>	(me/l)	0.3	0.3	0.3	0.3	0.2
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.4	0.3	0.2	0.3	0.1
HCO <sub>3</sub> <sup>-</sup>	(me/l)	11.4	13.7	13.5	13.8	14.3
Cl <sup>-</sup>	(me/l)	0.2	0.2	0.2	0.1	<0.1
SO <sub>4</sub> <sup>-</sup>	(me/l)	9.6	9.0	10.4	10.0	4.5
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.2	0.2	0.2	0.2	0.1
SAR	(me/l)	33.8	52.3	48.2	55.7	43.4
Na	(me/100g)	1.8	2.5	2.1	2.5	2.7
Ca+Mg	(me/100g)	0.1	<0.1	<0.1	<0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C	(mmhos/cm)	0.65	0.84	0.75	0.69	0.82
Ca+Mg	(me/l)	0.2	0.1	0.1	0.2	0.2
<u>EXCHANGEABLE SODIUM</u>	(percent)	40.79	44.43	47.59	26.51	56.89
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)	21.08	31.50	20.86	25.43	32.06
NaOAc@pH 8.2						
SILVER (Ag)	(ppm)	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B)	(ppm)	0.9	1.4	0.8	0.5	0.7
CADMIUM (Cd)	(ppm)	0.1	0.2	<0.1	0.2	<0.1
COPPER (Cu)	(ppm)	2.2	7.3	3.2	6.7	9.9
IRON (Fe)	(ppm)	7.9	10.1	9.3	13.4	10.1
MERCURY (Hg)	(ppm)	0.15	0.10	0.15	0.25	0.25
MANGANESE (Mn)	(ppm)	14.4	37.1	21.3	31.0	14.0
MOLYBDENUM (Mo)	(ppm)	0.3	0.7	0.6	1.0	0.5
NICKEL (Ni)	(ppm)	2.1	3.6	2.4	3.6	1.7
LEAD (Pb)	(ppm)	2.0	6.0	1.9	4.4	7.1
SELENIUM (Se)	(ppm)	<0.1	0.5	0.1	0.1	0.3
ZINC (Zn)	(ppm)	5.0	10.7	5.1	7.8	5.4

\*Insufficient Sample

Table 6  
Sheet 1

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-105  
 Location: 80' N. & 30' W. of SE Corner, Sec. 34, T. 158 N., R. 101 W.  
 Logged by: F. Calcagno  
 Date: February 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,568	21,569	21,570	21,571	21,572	21,573
SACK NUMBER	105-1	105-2	105-3	105-4	105-5	105-6
DEPTH (FT)	0.0-0.67	0.67-2.75	2.75-7.5	7.5-10.0	10.0-39.0	39.5-48.6
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	0.0	0.0	-
Coarse Sand (1.0-0.5 mm)	-	-	-	0.0	0.0	-
Medium Sand (0.5-0.25 mm)	-	-	-	25.7	21.9	-
Fine Sand (0.25-0.10 mm)	-	-	-	41.9	50.5	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	5.6	6.4	-
TOTAL SAND (2.0-0.05 mm)	35.4	41.2	31.8	74.0	79.7	10.4
SILT (0.05-0.002 mm)	33.0	31.1	39.3	16.8	13.1	78.6
CLAY (0.002 mm)	31.6	27.7	28.9	9.2	7.2	11.0
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	CL	CL	CL	FSL	LFS	SIL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.04	0.28	0.0	2.52	2.29	0.10
24th Hr.	0.02	0.20	Trace	2.56	2.21	0.10
SETTLING VOLUME (ml)	28.0	23.0	23.0	19.0	19.0	25.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	-	-	-	-	-	-
15 bar	12.0	13.3	15.7	5.2	4.8	13.9
<b>SOIL REACTION-pH</b>						
Paste	8.0	8.0	8.3	7.9	7.5	7.8
1:5 H <sub>2</sub> O	8.6	8.2	8.8	8.3	7.9	7.3
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	0.6	0.4	1.7	1.0	3.7	-0.2
<b>SATURATION EXTRACT</b>						
Saturation Percentage	48.5	45.9	51.4	31.6	32.1	57.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.62	0.96	0.70	2.75	3.9	2.70
Ca <sup>++</sup> + Mg <sup>++</sup> (me/l)	4.7	7.8	1.7	20.2	45.6	32.7
Mg <sup>++</sup> (me/l)	-	-	-	-	-	-
Na <sup>++</sup> (me/l)	1.3	1.2	5.2	11.0	6.3	2.2
K <sup>+</sup> (me/l)	0.3	0.4	0.2	0.5	0.8	0.6
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.2	4.6	4.8	3.2	2.2	4.7
Cl <sup>-</sup> (me/l)	0.2	1.1	0.4	0.4	2.0	1.1
SO <sub>4</sub> <sup>-</sup> (me/l)	1.4	1.7	1.5	28.5	47.0	30.5
NO <sub>3</sub> <sup>-</sup> (me/l)	0.5	2.0	0.3	0.4	0.2	0.2
SAR (me/l)	0.8	0.6	5.6	3.5	1.3	0.5
Na (me/100g)	0.1	0.1	0.3	0.3	0.2	0.1
Ca+Mg (me/100g)	0.2	0.4	0.1	0.6	1.5	1.9
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.35	0.20	0.18	0.29	1.32	0.50
Ca+Mg (me/l)	1.9	1.5	0.8	1.4	11.4	3.9
EXCHANGEABLE SODIUM (percent)	1.28	0.57	5.91	6.33	2.13	0.90
CATION EXCHANGE CAPACITY (me/100g)	19.55	23.47	19.45	10.10	9.34	22.50
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	<0.1	<0.1
BORON (B) (ppm)	-	-	-	-	1.6	2.3
CADMIUM (Cd) (ppm)	-	-	-	-	<0.1	<0.1
COPPER (Cu) (ppm)	-	-	-	-	0.4	4.2
IRON (Fe) (ppm)	-	-	-	-	2.1	10.6
MERCURY (Hg) (ppm)	-	-	-	-	0.05	0.20
MANGANESE (Mn) (ppm)	-	-	-	-	10.5	6.9
MOLYBDENUM (Mo) (ppm)	-	-	-	-	<0.1	<0.1
NICKEL (Ni) (ppm)	-	-	-	-	0.5	1.0
LEAD (Pb) (ppm)	-	-	-	-	0.9	1.7
SELENIUM (Se) (ppm)	-	-	-	-	<0.1	<0.1
ZINC (Zn) (ppm)	-	-	-	-	1.0	3.0

\*Inaufficient Sample

Table 6  
Sheet 2

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-105 (cont'd)  
 Location: 80' N. & 30' W. of SE Corner, Sec. 34, T. 15B N., R. 101 W.,  
 Logged by: F. Calcagno  
 Date: February 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,574	21,575	21,576	21,577	21,578	21,579
SACK NUMBER	105-7	105-8	105-9	105-10	105-11	105-12
DEPTH (FT)	58.0-78.0	78.0-93.0	93.0-98.0	101.5-118.0	118.0-136.0	138.0-146.2
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	0.0	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	0.2	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	11.9	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	34.3	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	24.3	-	-	-
TOTAL SAND (2.0-0.05 mm)	12.6	19.6	70.7	14.7	13.1	2.3
SILT (0.05-0.002 mm)	63.3	62.6	19.8	63.4	50.5	41.4
CLAY (0.002 mm)	24.1	17.8	9.5	21.9	36.4	56.3
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SIL	FSL	SIL	SiCL	SiC
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.00	0.03	0.63	0.00	0.00	0.00
24th Hr.	0.00	0.02	0.47	0.00	0.00	0.00
SETTLING VOLUME (mI)	29.0	25.0	19.0	27.0	75.0	142.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	-	-	-	-	-	-
15 bar	22.6	13.6	5.8	18.2	32.9	42.0
<b>SOIL REACTION-pH</b>						
Paste	7.7	7.8	8.1	8.0	8.3	8.3
1:5 H <sub>2</sub> O	8.5	8.6	9.2	9.1	9.4	9.4
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	4.2	6.9	-0.2	3.1	8.5	14.1
<b>SATURATION EXTRACT</b>						
Saturation Percentage	70.0	56.9	37.9	60.2	98.1	118.1
EC <sub>e</sub> @25°C (mmhos/cm)	1.92	2.00	1.90	1.77	1.98	2.40
Ca <sup>++</sup> + Mg <sup>++</sup> (me/l)	10.8	10.5	9.6	2.1	0.5	0.6
Mg <sup>++</sup> (me/l)	-	-	-	-	-	-
Na <sup>+</sup> (me/l)	8.4	10.3	10.0	14.4	19.6	23.8
K <sup>+</sup> (me/l)	0.9	0.8	0.6	0.5	0.3	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	2.8	5.2	3.3	6.0	11.4	12.1
Cl <sup>-</sup> (me/l)	0.1	0.3	0.5	0.3	<0.1	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	17.0	16.2	15.8	10.6	8.8	11.6
NO <sub>3</sub> <sup>-</sup> (me/l)	0.2	0.3	0.3	0.1	0.1	0.1
SAR (me/l)	3.6	4.5	4.6	14.1	39.2	43.5
Na (me/100g)	0.6	0.6	0.4	0.9	1.9	2.8
Ca+Mg (me/100g)	0.8	0.6	0.4	0.1	<0.1	0.1
<b>1:5 EXTRACT</b>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.51	0.35	0.31	0.40	0.63	0.96
Ca+Mg (me/l)	2.1	1.4	1.2	0.5	0.4	0.3
EXCHANGEABLE SODIUM (percent)	4.52	5.51	5.12	14.56	32.33	39.04
CATION EXCHANGE CAPACITY (me/100g)	26.30	20.65	11.19	21.03	25.54	31.52
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	2.1	2.3	1.3	1.1	0.4	1.6
CADMIUM (Cd) (ppm)	<0.1	<0.1	<0.1	<0.1	0.2	0.2
COPPER (Cu) (ppm)	6.6	3.2	1.8	1.5	5.4	9.7
IRON (Fe) (ppm)	4.7	5.0	2.3	2.7	11.6	10.0
MERCURY (Hg) (ppm)	0.75	0.25	0.15	0.20	0.30	0.25
MANGANESE (Mn) (ppm)	12.6	13.0	3.3	11.9	28.7	20.9
MOLYBDENUM (Mo) (ppm)	0.7	0.7	0.4	0.7	0.6	1.1
NICKEL (Ni) (ppm)	1.3	1.6	0.7	0.2	3.8	3.4
LEAD (Pb) (ppm)	5.9	3.4	1.5	1.8	3.7	8.2
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ZINC (Zn) (ppm)	3.8	3.2	3.3	1.2	6.3	8.4

\*Insufficient Sample

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-105 (cont'd)  
Location: 80' N. & 30' W. of SE Corner, Sec. 34, T. 158 N., R. 101 W.  
Logged by: F. Calcagno  
Date: February 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,580	21,581	21,582	21,583	21,584	21,585
SACK NUMBER	105-13	105-14	105-15	105-16	105-17	105-18
DEPTH (FT)	146.7-156.3	156.6-172.0	172.0-176.6	181.7-195.0	203.2-213.3	213.3-234.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	3.8	1.4	15.1	11.0	1.9	15.8
SILT (0.05-0.002 mm)	69.1	41.6	53.7	58.5	66.7	56.1
CLAY (0.002 mm)	27.1	57.0	31.2	30.5	31.4	28.1
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S1CL	S1C	S1CL	S1CL	S1CL	S1CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	100.0	138.0	42.0	93.0	257.0	140.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	-	-	-	-	-	-
15 bar	37.5	34.3	34.9	59.5	48.2	35.2
<u>SOIL REACTION-pH</u>						
Paste	8.6	8.6	8.4	8.9	9.0	8.9
1:5 H <sub>2</sub> O	9.6	9.4	8.5	9.4	9.5	9.8
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	9.8	13.7	14.5	21.6	17.3	10.5
<u>SATURATION EXTRACT</u>						
Saturation Percentage	86.1	113.9	74.5	126.2	135.5	83.6
EC <sub>e</sub> @25°C (mmhos/cm)	2.42	2.75	5.5	2.55	2.05	2.01
Ca <sup>++</sup> + Mg <sup>++</sup> (me/l)	0.4	0.4	1.2	0.3	0.4	0.3
Mg <sup>++</sup> (me/l)	-	-	-	-	-	-
Na <sup>++</sup> (me/l)	24.6	28.3	58.3	26.4	22.1	21.9
K <sup>+</sup> (me/l)	0.3	0.3	0.4	0.2	0.2	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	0.1	0.2	1.4	1.3	0.0	1.1
HCO <sub>3</sub> <sup>-</sup> (me/l)	12.3	14.3	18.4	16.7	14.8	15.7
Cl <sup>-</sup> (me/l)	0.1	<0.1	0.2	<0.1	<0.1	<0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	12.0	13.2	37.5	7.8	6.7	5.0
NO <sub>3</sub> <sup>-</sup> (me/l)	0.1	0.1	0.2	0.3	0.1	<0.1
SAR (me/l)	55.0	63.3	75.3	68.2	49.4	56.5
Na (me/100g)	2.1	3.2	4.3	3.3	3.0	1.8
Ca+Mg (me/100g)	<0.1	<0.1	0.1	<0.1	0.1	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.70	1.00	0.89	1.04	0.90	0.63
Ca+Mg (me/l)	0.4	0.4	0.4	0.2	0.4	0.2
<u>EXCHANGEABLE SODIUM</u> (percent)	37.17	46.52	44.90	64.02	46.21	45.98
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	23.80	27.06	30.00	34.02	30.86	17.39
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.7	0.9	2.7	1.0	0.5	<0.1
CADMIUM (Cd) (ppm)	0.1	0.1	0.1	<0.1	0.1	<0.1
COPPER (Cu) (ppm)	4.3	9.9	5.3	4.9	4.7	3.3
IRON (Fe) (ppm)	8.1	10.5	6.0	5.6	11.0	8.1
MERCURY (Hg) (ppm)	0.25	0.30	0.25	0.25	0.25	0.15
MANGANESE (Mn) (ppm)	28.8	20.2	5.1	5.3	18.2	19.2
MOLYBDENUM (Mo) (ppm)	0.4	1.3	0.7	1.8	0.6	0.2
NICKEL (Ni) (ppm)	2.1	6.2	3.3	1.2	2.4	0.9
LEAD (Pb) (ppm)	2.7	7.4	6.7	5.2	3.4	3.0
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	0.2	0.1	<0.1
ZINC (Zn) (ppm)	6.4	10.6	5.8	5.6	7.1	4.2

\*Insufficient Sample

Table 6  
Sheet 4

Hanks Study Area, North Dakota  
 Geologic Drill Hole: 82-105 (cont'd)  
 Location: 80' N. & 30' W. of SE Corner, Sec. 34, T. 158 N., R. 101 W.  
 Logged by: F. Calcagno  
 Date: February 1982

DETERMINATION	LABORATORY DESCRIPTION			
	Data			
LABORATORY NUMBER	21,586	21,587	21,588	21,589
SACK NUMBER	105-19	105-20	105-21	105-22
DEPTH (FT)	234.5-245.3	245.3-258.3	258.3-273.0	273.0-291.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	4.7	24.7	2.3	1.9
SILT (0.05-0.002 mm)	69.5	52.4	59.5	67.9
CLAY (0.002 mm)	25.8	22.9	38.2	30.2
CRAVEL (percent)	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SIL	SICL	SICL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00
SETTLING VOLUME (ml)	136.0	158.0	186.0	136.0
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	-	-	-	-
15 bar	32.2	34.3	31.2	33.4
<u>SOIL REACTION-pH</u>				
Paste	9.0	8.8	9.0	8.9
1:5 H <sub>2</sub> O	9.8	9.7	9.7	9.6
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-
CYPSUM REQUIREMENT (me/100g)	10.1	11.7	12.3	0.6
<u>SATURATION EXTRACT</u>				
Saturation Percentage	78.6	88.2	88.3	68.1
EC <sub>e</sub> @25°C (mmhos/cm)	2.80	2.45	2.50	2.64
Ca++ + Mg++ (me/l)	0.3	0.3	0.2	0.3
Mg++ (me/l)	-	-	-	-
Na++ (me/l)	28.5	26.0	26.3	28.4
K+ (me/l)	0.3	0.2	0.2	0.2
CO <sub>3</sub> - (me/l)	0.1	1.0	2.3	0.9
HCO <sub>3</sub> - (me/l)	13.7	16.3	17.8	17.4
Cl- (me/l)	<0.1	<0.1	<0.1	<0.1
SO <sub>4</sub> - (me/l)	15.2	8.0	6.3	10.4
NO <sub>3</sub> - (me/l)	0.1	0.1	0.2	0.2
SAR (me/l)	73.6	67.1	83.2	73.3
Na (me/100g)	2.2	2.3	2.3	1.9
Ca+Mg (me/100g)	<0.1	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>				
EC <sub>e</sub> @25°C (mmhos/cm)	0.80	0.76	0.81	0.71
Ca+Mg (me/l)	0.2	0.3	0.2	0.4
EXCHANGEABLE SODIUM (percent)	36.29	41.11	24.50	20.11
CATION EXCHANGE CAPACITY (me/100g)	20.85	22.50	38.15	37.06
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	<0.1	<0.1	<0.1	<0.1
CADMIUM (Cd) (ppm)	<0.1	<0.1	<0.1	<0.1
COPPER (Cu) (ppm)	2.5	2.7	5.4	4.4
IRON (Fe) (ppm)	8.1	9.5	12.0	9.0
MERCURY (Hg) (ppm)	0.20	0.20	0.20	0.20
MANGANESE (Mn) (ppm)	21.8	20.7	24.1	21.4
MOLYBDENUM (Mo) (ppm)	0.6	0.3	0.4	0.5
NICKEL (Ni) (ppm)	1.2	2.7	1.4	0.9
LEAD (Pb) (ppm)	2.4	2.4	3.5	3.1
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1
ZINC (Zn) (ppm)	3.7	4.5	4.3	2.8

\*Insufficient Sample

Table 7  
Sheet 1

Hanka Study Area, North Dakota  
 Geologic Drill Hole: 82-106  
 Location: 85' N. & 2275' E. of SW Corner, Sec. 15, T. 157 N., R. 101 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	1	2	3	4	5	6
SACK NUMBER	106-1	106-2	106-3	106-4	106-5	106-6
DEPTH (FT)	0-0.92	0.92-2.33	2.33-5.0	5.0-10.0	10.0-14.0	14.0-23.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	38.6	32.4	32.6	36.8	36.8	34.4
SILT (0.05-0.002 mm)	32.0	30.4	32.2	32.0	33.8	34.4
CLAY (0.002 mm)	29.0	37.2	35.2	31.2	29.4	31.2
GRAVEL (percent)	9.0	1.0	2.8	3.9	3.9	3.4
<u>TEXTURAL CLASS (LAB)</u>	CL	CL	CL	CL	CL	CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	*	0.12	0.00	0.75	*	0.50
24th Hr.	*	0.13	0.00	0.75	*	0.54
<u>SETTLING VOLUME</u> (ml)	21.5	22.0	23.0	20.5	20.5	21.5
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	30.7	29.2	35.5	27.7	26.3	27.9
15 bar	15.0	14.2	13.7	14.3	13.9	14.2
<u>SOIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.1	8.8	8.8	7.9	8.0	8.2
1:2 0.01 M CaCl <sub>2</sub>	6.4	6.8	7.2	6.8	6.9	6.9
<u>GYPSUM REQUIREMENT</u> (me/100g)	+4.2	+3.1	+2.6	-2.8	+5.2	-1.2
<u>SATURATION EXTRACT</u>						
Saturation Percentage	58.9	57.5	69.8	54.6	57.6	52.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.612	0.792	3.008	7.855	6.898	6.365
Ca <sup>++</sup> (me/l)	3.90	1.10	0.95	23.50	22.00	23.00
Mg <sup>++</sup> (me/l)	1.97	3.28	8.52	51.23	26.22	22.95
Na <sup>++</sup> (me/l)	0.35	3.60	22.2	50.0	39.0	39.8
K <sup>+</sup> (me/l)	0.54	0.29	0.56	0.95	0.90	0.90
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.15	4.22	3.87	1.52	1.39	1.26
Cl <sup>-</sup> (me/l)	0.70	0.65	3.65	5.62	3.34	2.33
SO <sub>4</sub> <sup>-</sup> (me/l)	0.91	3.40	24.71	118.54	83.39	83.1
NO <sub>3</sub> <sup>-</sup> (me/l)	*	0.005	0.001	0.597	1.194	1.935
SAR (me/l)	0.20	2.4	10.2	8.2	7.9	8.3
Na (me/100g)	0.02	0.21	1.55	2.73	2.18	2.10
Ca+Mg (me/100g)	0.35	0.25	0.66	4.08	2.78	2.43
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.170	0.320	0.639	2.095	1.188	1.200
Ca+Mg (me/l)	1.25	1.77	1.31	18.4	5.42	5.73
<u>EXCHANGEABLE SODIUM</u> (percent)	0.6	2.5	8.7	7.6	8.5	8.9
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	31.0	28.0	30.4	30.0	26.0	25.8
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	1.31	1.24	1.24	2.13	1.67	0.69
CADMIUM (Cd) (ppm)	0.12	0.02	0.40	0.10	0.14	0.10
COPPER (Cu) (ppm)	3.6	3.2	3.2	2.2	2.6	2.2
IRON (Fe) (ppm)	189.2	120.8	215.2	184.4	207.0	107.2
MERCURY (Hg) (ppm)	0.01	0.00	0.00	0.00	0.00	0.00
MANGANESE (Mn) (ppm)	31.4	40.0	148.4	104.2	139.0	26.2
MOLYBDENUM (Mo) (ppm)	0.1	0.0	1.0	0.4	0.5	0.3
NICKEL (Ni) (ppm)	4.2	1.2	3.4	2.4	3.2	1.0
LEAD (Pb) (ppm)	2.00	0.80	1.60	1.60	1.60	1.20
SELENIUM (Se) (ppm)	<0.1	<0.1	0.3	0.6	0.3	0.2
ZINC (Zn) (ppm)	75.0	4.4	6.7	2.1	2.5	1.9

\*Insufficient Sample

Table 7  
Sheet 2

Hanks Study Area, North Dakota  
Geologic Drill Hole: 82-106 (cont'd)  
Location: 85' N. & 2275' E. of SW Corner, Sec. 15, T. 157 N., R. 101 W.  
Logged by: C. Botdorf  
Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	7	8	9	10	11	12
SACK NUMBER	106-7	106-8	106-9	106-10	106-11	106-12
DEPTH (FT)	23.0-40.7	40.7-55.0	55.0-71.8	74.0-82.5	82.0-88.3	90.0-114.8
<b>PARTICLE SIZE ANALYSIS</b> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	34.8	12.4	8.8	33.2	2.2	2.4
SILT (0.05-0.002 mm)	33.8	49.4	55.0	43.6	48.6	45.8
CLAY (0.002 mm)	31.4	38.2	36.2	23.2	49.2	51.8
GRAVEL (percent)	5.6	-	-	-	-	-
TEXTURAL CLASS (LAB)	CL	SiCL	SiCL	L	SiC	SiC
<b>HYDRAULIC CONDUCTIVITY</b> (in/hr)						
6th Hr.	0.20	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.20	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME (ml)	22.5	68.0	31.5	23.5	24.0	100.0
<b>MOISTURE RETENTION</b> (%)						
1/3 bar	28.1	62.1	57.0	39.3	75.1	86.8
15 bar	14.0	28.2	36.3	19.1	30.7	33.9
<b>SOIL REACTION-pH</b>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.2	8.9	8.8	8.8	8.8	9.1
1:2 0.01 M CaCl <sub>2</sub>	7.0	7.1	7.3	7.4	7.6	7.9
GYPSUM REQUIREMENT (me/100g)	-0.8	+6.4	+5.2	+0.6	+7.6	+13.8
<b>SATURATION EXTRACT</b>						
Saturation Percentage	53.7	131.0	104.2	73.1	150.6	157.5
EC <sub>e</sub> @25°C (mmhos/cm)	6.893	2.028	2.259	1.188	1.325	2.323
Ca <sup>++</sup> (me/l)	23.0	0.55	0.65	0.65	0.28	0.15
Mg <sup>++</sup> (me/l)	20.49	0.66	0.78	0.70	0.26	0.15
Na <sup>++</sup> (me/l)	48.0	19.3	21.0	10.8	14.0	25.0
K <sup>+</sup> (me/l)	1.15	0.40	0.78	0.41	0.42	0.38
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	1.35	3.37	1.89	7.22	9.78	20.50
Cl <sup>-</sup> (me/l)	1.83	0.50	0.31	0.36	0.22	0.22
SO <sub>4</sub> <sup>-</sup> (me/l)	89.5	17.04	12.0	4.98	4.96	4.96
NO <sub>3</sub> <sup>-</sup> (me/l)	1.532	0.323	0.012	0.013	0.000	0.001
SAK (me/l)	10.3	24.8	24.8	13.1	26.9	64.6
Na (me/100g)	2.58	2.50	2.19	0.79	2.11	3.94
Ca+Mg (me/100g)	2.34	0.16	0.15	0.10	0.08	0.05
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.796	0.586	0.661	0.422	0.699	0.774
Ca+Mg (me/l)	2.05	2.02	1.63	0.66	0.40	2.02
EXCHANGEABLE SODIUM (percent)	10.8	22.6	21.6	10.4	18.6	36.2
CATION EXCHANGE CAPACITY (me/100g)	28.0	35.0	26.0	25.0	38.0	40.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.59	0.36	0.33	0.13	0.13	0.59
CADMIUM (Cd) (ppm)	0.20	0.10	0.12	0.10	0.12	0.08
COPPER (Cu) (ppm)	3.2	4.8	8.0	3.4	12.0	12.0
IRON (Fe) (ppm)	211.8	95.0	121.8	67.2	123.6	243.4
MERCURY (Hg) (ppm)	0.00	0.03	0.00	0.00	0.01	0.01
MANGANESE (Mn) (ppm)	154.4	5.2	17.2	6.2	13.6	37.4
MOLYBDENUM (Mo) (ppm)	0.5	0.5	1.1	0.3	0.7	1.0
NICKEL (Ni) (ppm)	3.4	1.4	6.0	3.4	8.0	8.0
LEAD (Pb) (ppm)	1.40	2.60	5.00	3.20	7.40	4.60
SELENIUM (Se) (ppm)	0.1	<0.1	0.1	<0.1	0.1	<0.1
ZINC (Zn) (ppm)	2.4	2.8	5.7	5.3	8.7	9.3

\*Insufficient Sample

Hanks Study Area, North Dakota  
 Geology & Drill Hole: 82-106 (cont'd)  
 Location: 85' N. & 2275' E. of SW Corner, Sec. 15, T. 157 N., R. 101 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	13	14	15	16	17	18
SACK NUMBER	106-13	106-14	106-15	106-16	106-17	106-18
DEPTH (FT)	115.0-134.0	134.0-137.4 & 145.9-152.0	152.0-164.1	164.1-172.1	175.0-191.7	131.7-210.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	0.0
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	0.1
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	8.0
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	46.4
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	8.1
TOTAL SAND (2.0-0.05 mm)	8.2	5.2	2.4	19.4	8.6	62.6
SILT (0.05-0.002 mm)	56.2	62.0	52.0	46.0	55.8	29.6
CLAY (U.002 mm)	35.6	32.8	45.6	36.6	35.6	7.8
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SiCL	SiCL	SiC	SiCL	SiCL	SL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.16
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.20
SETTLING VOLUME (ml)	75.0	100.0	320.0	255.0	100.0	17.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	85.7	89.8	97.3	99.0	56.4	11.0
15 bar	35.4	37.7	30.5	31.3	29.5	3.9
<b>SOIL REACTION-pH</b>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	9.4	9.3	9.8	10.0	9.7	9.4
1:2 0.01 M CaCl <sub>2</sub>	8.1	8.0	9.3	8.6	7.6	7.1
GYPSUM REQUIREMENT (me/100g)	+17.0	+12.6	+18.8	+26.0	+10.4	0.0
<b>SATURATION EXTRACT</b>						
Saturation Percentage	148.8	172.3	218.0	272.8	98.9	38.9
EC <sub>e</sub> @25°C (mmhos/cm)	2.010	1.619	1.712	1.295	1.808	1.586
Ca <sup>++</sup> (me/l)	0.12	0.10	0.08	0.04	0.08	0.10
Mg <sup>++</sup> (me/l)	0.11	0.11	0.08	0.03	0.06	0.12
Na <sup>+</sup> (me/l)	21.0	17.9	18.8	13.9	20.0	16.3
K <sup>+</sup> (me/l)	0.36	0.28	0.27	0.14	0.28	0.27
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.61	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	15.44	12.63	15.17	10.44	17.91	6.52
Cl <sup>-</sup> (me/l)	0.28	0.28	0.22	0.17	0.36	0.56
SO <sub>4</sub> <sup>-</sup> (me/l)	5.87	5.48	3.82	2.89	2.15	9.71
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	0.001	<0.001	0.000	0.000	0.010
SAR (me/l)	61.9	55.2	71.1	74.3	75.6	49.1
Na (me/100g)	3.12	3.08	4.10	3.79	1.98	0.63
Ca+Mg (me/100g)	0.03	0.04	0.03	0.02	0.01	0.01
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	1.002	.789	.779	.928	.370	.358
Ca+Mg (me/l)	0.49	0.91	0.32	0.49	0.50	0.28
EXCHANGEABLE SODIUM (percent)	46.8	49.4	77.0	81.0	53.0	43.67
CATION EXCHANGE CAPACITY (me/100g)	32.2	31.8	37.0	40.0	20.4	3.6
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.46	0.00	0.23	0.25	0.29	0.59
CADMIUM (Cd) (ppm)	0.08	0.08	0.10	0.06	0.06	0.02
COPPER (Cu) (ppm)	7.8	5.8	10.4	5.4	5.2	1.4
IRON (Fe) (ppm)	148.0	108.2	162.8	64.0	166.2	74.6
MERCURY (Hg) (ppm)	0.00	0.02	0.02	0.01	0.01	0.00
MANGANESE (Mn) (ppm)	16.2	11.0	17.2	2.4	15.4	4.4
MOLYBDENUM (Mo) (ppm)	0.8	0.9	0.5	2.4	0.3	0.1
NICKEL (Ni) (ppm)	6.0	8.0	8.0	2.0	1.2	0.8
LEAD (Pb) (ppm)	4.20	3.80	5.20	5.40	4.60	1.60
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	.1	<0.1	0.3
ZINC (Zn) (ppm)	10.0	5.3	6.7	3.7	3.2	3.3

\*Insufficient Sample

Table 8  
Sheet 1

Sand Creek Study Area, North Dakota  
 Geologic Orill Hole: 82-107  
 Location: 1125' S. & 1180' E. of NW Corner, Sec. 11, T. 156 N., R. 103 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Oata					
LABORATORY NUMBER	19	20	21	22	23	24
SACK NUMBER	107-1	107-2	107-3	107-4	107-5	107-6
DEPTH (FT)	2.0-6.0	6.0-10.0	10.0-44.6	44.0-60.0	60.0-72.2	72.2-89.6
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	33.8	35.6	36.4	28.8	25.0	0.0
SILT (0.05-0.002 mm)	32.6	34.8	35.0	41.6	46.6	42.8
CLAY (0.002 mm)	33.6	29.6	28.6	29.6	28.4	57.2
GRAVEL (percent)	3.3	2.9	4.9	3.9	0.76	-
TEXTURAL CLASS (LAB)	CL	CL	CL	CL	L	S1C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.73	0.21	0.12	0.07	0.05	0.00
24th Hr.	0.89	0.32	0.11	0.05	0.05	0.00
SETTLING VOLUME (ml)	20.0	23.0	23.5	23.0	22.0	32.5
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	26.4	26.8	27.3	26.8	29.7	45.6
15 bar	13.1	12.7	13.3	13.9	13.8	27.4
<u>SOIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.0	7.9	7.9	8.1	8.1	8.2
1:2 0.01 M CaCl <sub>2</sub>	7.4	6.9	7.2	7.0	7.1	7.4
GYPSUM REQUIREMENT (me/100g)	-6.4	-3.2	-2.4	-2.4	-2.4	+1.2
<u>SATURATION EXTRACT</u>						
Saturation Percentage	52.6	53.0	51.9	54.1	51.9	83.9
EC <sub>e</sub> @25°C (mmhos/cm)	6.940	6.202	4.191	2.454	2.181	1.279
Ca <sup>++</sup> (me/l)	8.60	7.10	24.50	11.50	3.10	1.90
Mg <sup>++</sup> (me/l)	75.82	45.08	23.77	9.84	9.02	2.95
Na <sup>++</sup> (me/l)	17.9	20.6	10.8	7.5	8.0	7.5
K <sup>+</sup> (me/l)	0.51	0.76	0.85	0.83	1.10	0.79
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	1.67	1.85	1.35	3.30	4.06	3.46
Cl <sup>-</sup> (me/l)	2.14	1.29	0.70	0.56	0.45	0.31
SO <sub>4</sub> <sup>-</sup> (me/l)	99.02	70.40	57.87	25.81	21.71	9.37
NO <sub>3</sub> <sup>-</sup> (me/l)	0.001	0.000	0.000	0.000	<0.001	0.001
SAR (me/l)	2.8	4.0	2.2	2.3	2.7	4.8
Na (me/100g)	0.94	1.04	0.56	0.40	0.42	0.63
Ca+Mg (me/100g)	4.44	2.77	2.51	1.15	0.89	0.41
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	1.130	1.157	.863	.459	.477	.393
Ca+Mg (me/l)	9.54	6.69	6.63	2.43	2.58	1.77
EXCHANGEABLE SODIUM (percent)	2.8	5.5	2.4	2.1	2.8	4.9
CATION EXCHANGE CAPACITY (me/100g)	30.2	24.0	26.2	30.2	23.0	36.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	1.24	1.01	0.66	0.62	0.92	0.88
CADMIUM (Cd) (ppm)	0.06	0.06	0.14	0.06	0.04	0.08
COPPER (Cu) (ppm)	2.6	2.8	3.2	6.4	7.0	10.2
IRON (Fe) (ppm)	206.0	216.8	220.0	186.2	253.0	91.0
MERCURY (Hg) (ppm)	0.01	0.01	0.00	0.00	0.00	0.09
MANGANESE (Mn) (ppm)	133.8	132.2	125.4	31.8	14.4	9.0
MOLYBDENUM (Mo) (ppm)	0.3	1.3	0.4	0.3	0.8	1.1
NICKEL (Ni) (ppm)	3.4	3.4	3.0	1.6	1.6	8.0
LEAD (Pb) (ppm)	1.40	1.60	1.60	1.80	3.20	9.00
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
ZINC (Zn) (ppm)	8.2	3.0	3.0	2.8	2.9	6.4

\*Insufficient Sample

Table 8  
Sheet 2

Sand Creek Study Area, North Dakota  
Geologic Orill Hole: 82-107 (cont'd)  
Location: 1125° S. & 1180° E. of NW Corner, Sec. 11, T. 156 N., R. 103 W.  
Logged by: C. Botdorf  
Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	25	26	27	28	29	*Site 6
SACK NUMBER	107-7	107-8	107-9	107-10	107-11	107-12
DEPTH (FT)	93.5-113.0	113.0-134.1	134.1-151.1	151.1-163.0	163.0-183.0	183.0-195.3
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	1.6	0.6	3.6	9.6	36.8	20.8
SILT (0.05-0.002 mm)	70.2	52.2	67.2	74.2	48.0	57.0
CLAY (0.002 mm)	28.2	47.2	29.2	16.2	15.2	22.2
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>						
SiCL	SiCL	SiC	SiCL	SiL	L	SiL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)						
	28.0	33.0	27.5	23.5	21.5	50.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	47.6	51.5	48.0	40.5	34.1	70.6
15 bar	23.4	30.1	25.6	23.3	12.5	34.7
<u>SOIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.4	8.5	8.8	9.1	9.2	9.5
1:2 0.01 M CaCl <sub>2</sub>	7.6	7.5	7.7	7.8	8.0	8.5
<u>GYPSUM REQUIREMENT</u> (me/100g)						
	+8.6	+6.0	+3.2	+3.4	+1.8	+9.2
<u>SATURATION EXTRACT</u>						
Saturation Percentage	96.9	109.3	102.8	81.6	66.0	145.2
EC <sub>e</sub> @25°C (µmhos/cm)	1.514	1.581	1.732	1.951	2.405	1.644
Ca <sup>++</sup> (me/l)	1.50	1.50	0.42	0.30	0.07	0.14
Mg <sup>++</sup> (me/l)	3.11	1.31	0.72	0.52	0.13	0.09
Na <sup>+</sup> (me/l)	10.5	13.9	18.0	19.5	24.0	17.9
K <sup>+</sup> (me/l)	0.77	0.63	0.60	0.42	0.42	0.26
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.65
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.19	5.94	5.24	7.76	9.68	10.28
Cl <sup>-</sup> (me/l)	0.28	0.45	0.98	0.45	0.50	0.42
SO <sub>4</sub> <sup>-</sup> (me/l)	11.41	10.95	9.52	12.83	14.45	7.04
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	0.000	0.003	0.012	0.011	0.000
SAR (me/l)	6.9	11.7	23.8	30.9	75.9	52.8
Na (me/100g)	1.02	1.52	1.85	1.62	1.58	2.60
Ca+Mg (me/100g)	0.45	0.31	0.12	0.07	0.01	0.03
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	.496	.544	.612	.627	.509	.615
Ca+Mg (me/l)	1.08	0.68	0.40	0.21	0.75	0.24
<u>EXCHANGEABLE SODIUM</u> (percent)						
	6.8	11.1	19.8	29.9	41.6	53.1
<u>CATION EXCHANGE CAPACITY</u> (me/100g)						
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.79	1.34	0.62	0.29	0.59	0.46
CADMIUM (Cd) (ppm)	0.10	0.10	0.08	0.08	0.10	0.10
COPPER (Cu) (ppm)	12.0	16.0	10.4	7.0	3.8	3.8
IRON (Fe) (ppm)	76.0	123.2	125.6	80.6	112.6	98.6
MERCURY (Hg) (ppm)	0.04	0.05	0.05	0.04	0.03	0.02
MANGANESE (Mn) (ppm)	6.8	18.8	16.8	6.8	8.2	4.4
MOLYBDENUM (Mo) (ppm)	0.5	0.4	0.6	0.2	0.2	0.5
NICKEL (Ni) (ppm)	10.0	10.0	6.0	2.2	4.0	0.4
LEAD (Pb) (ppm)	4.80	6.80	5.60	3.20	3.00	4.00
SELENIUM (Se) (ppm)	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
ZINC (Zn) (ppm)	4.8	7.3	5.9	5.3	4.7	9.6

\*Insufficient Sample

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-107 (cont'd)  
 Location: 1125' S. & 1180' E. of NW Corner, Sec. 11, T. 156 N., R. 103 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION	
	Data	*Site 6
LABORATORY NUMBER	31	
SACK NUMBER	107-13	
DEPTH (FT)	218.2-235.0	
<u>PARTICLE SIZE ANALYSIS</u> (percent)		
Very Coarse Sand (2.0-1.0 mm)	-	
Coarse Sand (1.0-0.5 mm)	-	
Medium Sand (0.5-0.25 mm)	-	
Fine Sand (0.25-0.10 mm)	-	
Very Fine Sand (0.10-0.05 mm)	-	
TOTAL SAND (2.0-0.05 mm)	0.6	
SILT (0.05-0.002 mm)	34.2	
CLAY (0.002 mm)	65.2	
GRAVEL (percent)	-	
<u>TEXTURAL CLASS (LAB)</u>	C	
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)		
6th Hr.	0.00	
24th Hr.	0.00	
<u>SETTLING VOLUME</u> (ml)	133.0	
<u>MOISTURE RETENTION</u> (%)		
1/3 bar	86.0	
15 bar	33.1	
<u>SOIL REACTION-pH</u>		
Paste	-	
1:5 H <sub>2</sub> O	9.1	
1:2 0.01 M CaCl <sub>2</sub>	8.1	
<u>GYPNUM REQUIREMENT</u> (me/100g)	+14.4	
<u>SATURATION EXTRACT</u>		
Saturation Percentage	142.9	
EC <sub>e</sub> @25°C (mmhos/cm)	1.730	
Ca <sup>++</sup> (me/l)	0.20	
Mg <sup>++</sup> (me/l)	0.14	
Na <sup>++</sup> (me/l)	26.0	
K <sup>+</sup> (me/l)	0.25	
CO <sub>3</sub> <sup>-</sup> (me/l)	0.34	
HCO <sub>3</sub> <sup>-</sup> (me/l)	11.91	
Cl <sup>-</sup> (me/l)	0.85	
SO <sub>4</sub> <sup>-</sup> (me/l)	13.83	
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	
SAR (me/l)	63.0	
Na (me/100g)	3.72	
Ca+Mg (me/100g)	0.05	
<u>1:5 EXTRACT</u>		
EC <sub>5</sub> @25°C (mmhos/cm)	.843	
Ca+Mg (me/l)	2.02	
<u>EXCHANGEABLE SODIUM</u> (percent)	61.5	
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	39.2	
NaOAc@pH 8.2		
<u>SILVER (Ag) (ppm)</u>		
	-	
<u>BORON (B) (ppm)</u>		
	0.92	
<u>CADMIUM (Cd) (ppm)</u>		
	0.22	
<u>COPPER (Cu) (ppm)</u>		
	16.0	
<u>IRON (Fe) (ppm)</u>		
	130.2	
<u>MERCURY (Hg) (ppm)</u>		
	0.03	
<u>MANGANESE (Mn) (ppm)</u>		
	8.6	
<u>MOLYBDENUM (Mo) (ppm)</u>		
	1.3	
<u>NICKEL (Ni) (ppm)</u>		
	5.2	
<u>LEAD (Pb) (ppm)</u>		
	12.00	
<u>SELENIUM (Se) (ppm)</u>		
	0.4	
<u>ZINC (Zn) (ppm)</u>		
	10.7	
*Insufficient Sample		

Table 9  
Sheet 1

Sand Creek Study Area, North Dakota  
Geologic Drill Hole: 82-108  
Location: 2250' S. & 50' W. of NE Corner, Sec. 12, T. 156 N., R. 102 W.  
Logged by: C. Bortdorf  
Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
	32	33	34	35	36	37
LABORATORY NUMBER	108-1	108-2	108-3	108-4	108-5	108-6
SACK NUMBER						
DEPTH (FT)	2.0-5.0	5.0-10.0	10.0-30.6	30.6-33.0	33.0-49.0	49.0-59.4
PARTICLE SIZE ANALYSIS (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	37.6	39.8	36.4	28.8	9.2	4.0
SILT (0.05-0.002 mm)	30.2	30.0	33.4	33.0	54.6	70.8
CLAY (0.002 mm)	32.2	30.2	30.2	28.2	36.2	
GRAVEL (percent)	1.5	2.9	3.0	3.7	-	-
TEXTURAL CLASS (LAB)	CL	CL	CL	CL	SiCL	SiL
HYDRAULIC CONDUCTIVITY (in/hr)						
6th Hr.	0.30	0.35	0.42	0.10	0.06	0.19
24th Hr.	0.42	0.73	0.46	0.12	0.06	0.22
SETTLING VOLUME (ml)	22.5	21.0	21.5	21.5	30.0	25.5
MOISTURE RETENTION (%)						
1/3 bar	27.9	24.4	26.1	26.5	44.4	39.0
15 bar	12.5	12.3	13.8	18.4	20.8	13.2
SOIL REACTION-pH						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.4	7.9	7.6	7.9	7.9	8.1
1:2 0.01 M CaCl <sub>2</sub>	7.2	7.2	7.1	7.0	7.1	7.5
GYPSUM REQUIREMENT (me/100g)	-3.4	-3.0	-4.6	-1.4	+4.4	+2.6
SATURATION EXTRACT						
Saturation Percentage	47.5	56.4	56.6	51.6	67.6	65.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.597	3.101	5.477	1.851	1.358	0.834
Ca <sup>++</sup> (me/l)	0.70	7.50	26.50	8.00	5.00	2.70
Mg <sup>++</sup> (me/l)	2.13	22.95	34.43	7.05	6.48	3.44
Na <sup>++</sup> (me/l)	4.6	14.0	25.0	7.0	3.0	2.5
K <sup>+</sup> (me/l)	0.15	0.56	0.95	0.84	0.96	0.71
CO <sub>3</sub> <sup>-</sup> (me/l)	0	0	0	0	0	0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.41	1.84	1.39	3.72	4.45	3.66
Cl <sup>-</sup> (me/l)	0.34	0.28	0.73	0.51	0.34	0.28
SO <sub>4</sub> <sup>-</sup> (me/l)	2.83	42.89	84.76	18.66	10.65	5.41
NO <sub>3</sub> <sup>-</sup> (me/l)	0.005	0.000	0.001	0.000	0.000	0.06
SAR (me/l)	3.9	3.6	4.5	2.5	1.2	1.4
Na (me/100g)	0.22	0.79	1.42	0.36	0.20	0.16
Ca+Mg (me/100g)	0.13	1.72	3.45	0.78	0.78	0.40
1:5 EXTRACT						
EC <sub>5</sub> @25°C (mmhos/cm)	.228	.637	1.930	.368	.396	.297
Ca+Mg (me/l)	1.03	3.99	16.6	1.50	1.92	1.67
EXCHANGEABLE SOOIIUM (percent)	3.0	2.6	2.4	6.0	1.1	1.5
CATION EXCHANGE CAPACITY (me/100g)	22.0	22.4	22.2	25.0	29.6	21.8
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	0.52	0.79	0.88	0.66	0.29	0.52
CADMIUM (Cd) (ppm)	0.04	0.06	0.12	0.08	0.14	0.08
COPPER (Cu) (ppm)	3.4	3.4	3.2	6.6	12.0	5.8
IRON (Fe) (ppm)	193.2	168.0	176.2	271.6	225.2	104.2
MERCURY (Hg) (ppm)	0.01	0.01	0.02	0.00	0.01	0.02
MANGANESE (Mn) (ppm)	132.8	94.2	100.0	37.6	20.4	16.2
MOLYBDENUM (Mo) (ppm)	0.1	0.7	0.4	0.3	1.1	0.5
NICKEL (Ni) (ppm)	3.6	2.4	2.4	2.0	10.0	6.0
LEAD (Pb) (ppm)	1.20	1.40	1.40	1.80	7.00	5.20
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1	0.1	0.1
ZINC (Zn) (ppm)	4.2	4.5	4.4	6.0	7.9	5.4

\*Insufficient Sample

Table 9  
Sheet 2

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-108  
 Location: 2250' S. & 50' W. of NE Corner, Sec. 12, T. 156 N., R. 102 W.  
 Logged by: C. Boddorf  
 Date: October 1982

DETERMINATION	LABORATORY NUMBER	LABORATORY DESCRIPTION					
		Data					
		38	39	40	41	42	43
SACK NUMBER		108-7	108-8	108-9	108-10	108-11	108-12
DEPTH (FT)		65.0-78.5	78.5-104.0	104.0-124.8	124.8-131.2	131.2-140.1	115.3-168.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand	(1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand	(0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand	(0.25-0.10 mm)	-	-	-	-	-	-
Very Fioe Sand	(0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND	(2.0-0.05 mm)	11.0	17.0	4.0	47.0	5.0	4.6
SILT	(0.05-0.002 mm)	65.8	57.8	67.8	35.6	49.8	52.6
CLAY	(0.002 mm)	23.2	25.2	28.2	17.4	45.2	42.8
GRAVEL	(percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)		S1L	S1L	S1CL	L	S1C	S1C
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.02	0	0	0	0	0
24th Hr.		0.02	0	0	0	0	0
SETTLING VOLUME	(ml)	26.0	26.5	31.0	33.5	30.5	49.0
MOISTURE RETENTION	(%)						
1/3 bar		41.0	47.1	61.8	61.9	63.3	73.1
15 bar		13.6	24.5	27.5	31.6	26.6	41.2
SOIL REACTION-pH							
Paste		-	-	-	-	-	-
1:5 H <sub>2</sub> O		8.5	8.8	9.2	3.7	9.2	9.2
1:2 0.01 M CaCl <sub>2</sub>		7.6	7.6	7.8	8.3	8.0	8.1
GYPSUM REQUIREMENT	(me/100g)	-1.8	+5.0	+13.0	+5.0	+9.8	+15.2
SATURATION EXTRACT							
Saturation Percentage		63.7	76.8	95.2	116.2	111.1	135.4
EC <sub>e</sub> @25°C	(mmhos/cm)	1.106	2.052	2.118	1.472	1.860	1.332
Ca <sup>++</sup>	(me/l)	1.30	0.72	0.20	0.14	0.14	0.22
Mg <sup>++</sup>	(me/l)	1.64	0.74	0.24	0.10	0.33	0.10
Na <sup>++</sup>	(me/l)	11.0	28.0	33.0	18.5	24.0	18.0
K <sup>+</sup>	(me/l)	0.53	0.50	0.38	0.21	0.45	0.29
CO <sub>3</sub> <sup>-</sup>	(me/l)	0	0	2.78	0.98	1.03	0
HCO <sub>3</sub> <sup>-</sup>	(me/l)	5.84	10.33	13.32	8.70	11.16	10.52
Cl <sup>-</sup>	(me/l)	0.34	0.64	0.28	0.37	0.45	0.31
SO <sub>4</sub> <sup>-</sup>	(me/l)	8.29	18.99	17.44	8.50	12.28	7.78
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.002	0.000	0.000	0.003	0.000	0.000
SAR	(me/l)	9.1	32.8	70.4	53.4	49.5	45.0
Na	(me/100g)	0.70	2.15	3.14	2.15	2.67	2.44
Ca+Mg	(me/100g)	0.19	0.11	0.04	0.03	0.05	0.04
1:5 EXTRACT							
EC <sub>s</sub> @25°C	(mmhos/cm)	.371	.604	.674	.619	.719	.750
Ca+Mg	(me/l)	0.73	0.33	0.28	0.38	0.47	0.40
EXCHANGEABLE SODIUM	(percent)	8.4	20.1	35.2	37.9	24.0	35.8
CATION EXCHANGE CAPACITY	(me/100g)	22.6	27.0	28.0	17.0	35.6	31.8
NaOAc@pH 8.2							
SILVER (Ag)	(ppm)	-	-	-	-	-	-
BORON (B)	(ppm)	0.36	0.59	0.59	0.23	0.43	1.34
CADMIUM (Cd)	(ppm)	0.16	0.16	0.12	0.10	0.12	0.14
COPPER (Cu)	(ppm)	8.2	12.0	12.0	3.6	9.2	12.0
IRON (Fe)	(ppm)	90.6	96.6	145.2	48.8	74.2	78.2
MERCURY (Hg)	(ppm)	0.03	0.03	0.04	0.05	0.04	0.05
HANGANESE (Mn)	(ppm)	6.6	11.2	25.4	2.8	10.6	8.6
MOLYBDENUM (Mo)	(ppm)	0.4	0.8	0.7	0.5	1.6	0.5
NICKEL (Ni)	(ppm)	3.6	8.0	12.0	4.0	8.0	8.0
LEAD (Pb)	(ppm)	5.00	5.60	5.80	3.60	7.20	8.80
SELENIUM (Se)	(ppm)	<0.1	0.2	0.1	<0.1	0.1	0.2
ZINC (Zn)	(ppm)	5.3	10.4	6.6	6.2	7.5	7.1

\*Insufficient Sample

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-108 (cont'd)  
 Location: 2250' S. & 50' W. of NE Corner, Sec. 12, T. 156 N., R. 102 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION			
	Data			
LABORATORY NUMBER	44	45	46	47
SACK NUMBER	108-13	108-14	108-15	108-16
DEPTH (FT)	168.0-185.6	185.6-202.0	210.0-233.0	233.0-254.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	13.6	10.4	3.2	3.8
SILT (0.05-0.002 mm)	57.6	58.8	64.8	62.2
CLAY (0.002 mm)	28.8	30.8	32.0	34.0
GRAVEL (percent)	-	-	-	-
<u>TEXTURAL CLASS (LA8)</u>	S1CL	S1CL	S1CL	S1CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0	0	0	0
24th Hr.	0	0	0	0
<u>SETTLING VOLUME</u> (ml)	89.0	160.0	80.0	170.0
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	73.3	80.8	59.5	88.8
15 bar	31.2	29.7	29.1	37.0
<u>SOIL REACTION-pH</u>				
Paste	-	-	-	-
1:5 H <sub>2</sub> O	9.5	9.5	9.2	9.4
1:2 0.01 M CaCl <sub>2</sub>	8.6	8.7	8.1	8.6
<u>GYPSUM REQUIREMENT</u> (me/100g)	+11.0	+14.0	+9.8	+13.0
<u>SATURATION EXTRACT</u>				
Saturation Percentage	143.4	145.4	109.5	168.9
EC <sub>e</sub> @25°C (mmhos/cm)	1.441	1.506	1.297	1.512
Ca <sup>++</sup> (me/l)	0.06	0.06	0.49	0.08
Mg <sup>++</sup> (me/l)	0.06	0.04	0.74	0.09
Na <sup>++</sup> (me/l)	19.0	19.1	19.0	19.1
K <sup>+</sup> (me/l)	0.22	0.20	0.54	0.23
CO <sub>3</sub> <sup>-</sup> (me/l)	1.91	1.07	0.86	1.24
HCO <sub>3</sub> <sup>-</sup> (me/l)	9.62	11.64	12.19	11.78
Cl <sup>-</sup> (me/l)	0.56	1.13	0.85	0.34
SO <sub>4</sub> <sup>-</sup> (me/l)	7.45	5.56	6.87	6.14
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	0.000	0.000	0.000
SAR (me/l)	77.6	85.4	24.2	65.5
Na (me/100g)	2.72	2.78	2.08	3.22
Ca+Mg (me/100g)	0.02	0.01	0.13	0.03
<u>1:5 EXTRACT</u>				
EC <sub>5</sub> @25°C (mmhos/cm)	.810	.861	.600	.547
Ca+Mg (me/l)	0.34	0.26	1.11	2.02
<u>EXCHANGEABLE SODIUM</u> (percent)	55.9	49.3	46.3	81.8
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	22.0	28.0	21.8	34.0
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	-	-	-	-
BORON (B) (ppm)	0.00	0.10	0.62	3.41
CADMIUM (Cd) (ppm)	0.08	0.10	0.08	0.10
COPPER (Cu) (ppm)	7.4	7.6	5.8	12.0
IRON (Fe) (ppm)	104.2	136.4	70.8	111.4
MERCURY (Hg) (ppm)	0.04	0.04	0.04	0.04
MANGANESE (Mn) (ppm)	8.4	14.4	5.0	
MOLYBDENUM (Mo) (ppm)	0.5	0.6	0.2	0.6
NICKEL (Ni) (ppm)	6.0	8.0	0.4	8.0
LEAD (Pb) (ppm)	4.20	4.20	10.60	8.20
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	0.2
ZINC (Zn) (ppm)	5.7	6.8	4.6	5.9

\*Insufficient Sample

Table 10  
Sheet 1

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-109  
 Location: 450' N. & 25' E. of SW Corner, Sec. 6, T. 155 N., R. 102 W.,  
 Logged by: C. Botdorf  
 Date: November 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	48	49	50	51	52	53
SACK NUMBER	109-1	109-2	109-3	109-4	109-5	109-6
DEPTH (FT)	3.0-3.58	3.58-5.0	5.0-7.0	7.0-7.83	7.83-10.0	10.0-35.3
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	37.6	37.4	39.2	40.0	39.0	37.2
SILT (0.05-0.002 mm)	31.4	30.2	28.8	39.2	42.4	33.6
CLAY (0.002 mm)	31.0	32.4	37.0	20.8	18.6	29.2
GRAVEL (percent)	3.3	1.7	2.0	3.1	1.8	4.5
<u>TEXTURAL CLASS (LAB)</u>	CL	CL	CL	L	L	CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	*	0.21	0.43	0.74	0.38	0.22
24th Hr.	*	0.24	0.54	0.84	0.54	0.27
<u>SETTLING VOLUME</u> (ml)	-	20.5	20.0	18.5	21.5	22.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	26.8	26.3	24.9	22.8	24.0	26.2
15 bar	11.4	12.4	11.9	10.7	11.7	13.1
<u>SOIL REACTION-PH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.5	8.3	7.8	7.8	7.7	7.7
1:2 0.01 M CaCl <sub>2</sub>	6.8	7.5	7.1	7.2	7.1	7.1
<u>GYPSUM REQUIREMENT</u> (me/100g)	*	-0.2	-8.2	-8.6	-8.6	-7.0
<u>SATURATION EXTRACT</u>						
Saturation Percentage	46.2	47.3	50.4	46.0	52.3	53.9
EC <sub>e</sub> @25°C (mmhos/cm)	0.792	4.386	7.380	6.625	6.774	4.628
Ca <sup>++</sup> (me/l)	0.50	3.50	22.00	23.00	22.50	2.45
Mg <sup>++</sup> (me/l)	3.69	4.02	75.41	65.57	67.71	3.77
Na <sup>++</sup> (me/l)	5.5	23.0	30.0	26.0	25.0	12.0
K <sup>+</sup> (me/l)	0.23	0.50	0.80	0.80	0.70	0.85
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.24	2.57	1.20	1.07	0.96	1.39
Cl <sup>-</sup> (me/l)	0.51	0.68	0.90	1.41	1.02	1.19
SO <sub>4</sub> <sup>-</sup> (me/l)	4.17	27.77	126.11	112.89	113.43	16.49
NO <sub>3</sub> <sup>-</sup> (me/l)	0.011	0.000	0.002	0.000	0.000	0.000
SAR (me/l)	3.8	11.9	4.3	3.9	3.7	6.8
Na (me/100g)	0.25	1.09	1.51	1.20	1.31	0.65
Ca+Mg (me/100g)	0.19	0.36	0.37	4.07	4.69	0.34
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	.199	.799	2.034	2.182	2.873	1.472
Ca+Mg (me/l)	0.84	1.93	12.1	23.3	33.1	27.4
<u>EXCHANGEABLE SODIUM</u> (percent)	3.0	3.6	3.3	4.1	5.4	2.2
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	22.0	26.6	26.0	16.0	20.0	21.6
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	*	0.98	0.98	*	1.24	0.29
CADMIUM (Cd) (ppm)	*	0.04	0.08	*	0.08	0.14
COPPER (Cu) (ppm)	*	2.8	2.6	*	2.8	3.2
IRON (Fe) (ppm)	*	104.0	141.6	*	157.8	137.8
MERCURY (Hg) (ppm)	*	0.02	0.02	*	0.03	0.02
MANGANESE (Mn) (ppm)	*	31.8	56.6	*	62.4	60.2
MOLYBDENUM (Mo) (ppm)	*	0.6	1.0	*	0.4	0.4
NICKEL (Ni) (ppm)	*	0.8	1.4	*	1.6	1.4
LEAD (Pb) (ppm)	*	1.00	1.40	*	1.40	1.40
SELENIUM (Se) (ppm)	*	-	-	*	-	-
ZINC (Zn) (ppm)	*	4.4	11.0	*	5.7	18.9

\*Insufficient Sample

Table 10  
Sheet 2

Sand Creek Study Area, North Dakota  
Geologic Drill Hole: 82-109 (cont'd)  
Location: 450' N. & 25' E. of SW Corner, Sec. 6, T. 155 N., R. 102 W.  
Logged by: C. Botdorf  
Date: November 1982

DETERMINATION LABORATORY NUMBER	LABORATORY DESCRIPTION Data					
	54	55	56	57	58	59
<u>SACK NUMBER</u>	109-7	109-8	109-9	109-10	109-11	109-12
<u>DEPTH (PT)</u>	35.3-50.2	56.1-66.3	76.0-94.0	94.0-112.0	112.0-132.0	132.0-151.6
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	0.1	0.0	0.6	-
Coarse Sand (1.0-0.5 mm)	-	-	0.4	0.3	1.4	-
Medium Sand (0.5-0.25 mm)	-	-	14.7	29.2	16.7	-
Fine Sand (0.25-0.10 mm)	-	-	25.4	39.3	33.9	-
Very Fine Sand (0.10-0.05 mm)	-	-	10.2	5.2	10.0	-
TOTAL SAND (2.0-0.05 mm)	22.4	0.6	50.8	74.0	62.6	41.4
SILT (0.05-0.002 mm)	27.4	50.2	39.0	19.8	31.2	48.4
CLAY (0.002 mm)	50.2	49.2	10.2	6.2	6.2	10.2
GRAVEL (percent)	4.5	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	C	S1C	L	SL	SL	L
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.22	0.07	1.0	5.3	1.8	4.1
24th Hr.	0.27	0.22	0.08	2.5	2.1	4.4
<u>SETTLING VOLUME</u> (ml)	28.0	30.0	19.5	18.5	19.5	22.5
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	48.8	46.7	23.5	17.7	22.2	28.8
15 bar	13.1	26.9	25.9	11.5	7.0	14.0
<u>SOIL REACTION-pH</u>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	7.6	8.0	8.3	8.3	8.7	8.8
1:2 0.01 M CaCl <sub>2</sub>	7.1	7.1	7.6	7.5	7.5	7.7
<u>GYPSUM REQUIREMENT</u> (me/100g)	-6.4	+1.4	-2.6	+7.2	+8.0	-0.6
<u>SATURATION EXTRACT</u>						
Saturation Percentage	77.8	79.4	45.9	69.5	46.9	52.9
EC <sub>e</sub> @25°C (mmhos/cm)	3.251	1.653	1.475	1.746	2.100	1.609
Ca <sup>++</sup> (me/l)	16.00	3.70	2.30	2.05	1.10	0.25
Mg <sup>++</sup> (me/l)	19.67	5.08	3.28	3.36	2.21	1.15
Na <sup>++</sup> (me/l)	12.8	11.9	13.3	16.8	26.0	18.0
K <sup>+</sup> (me/l)	1.20	0.93	0.50	0.40	0.34	0.27
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.90	4.77	3.16	2.46	5.05	6.48
Cl <sup>-</sup> (me/l)	0.42	0.23	0.51	0.59	0.56	0.56
SO <sub>4</sub> <sup>-</sup> (me/l)	44.35	16.61	15.71	19.56	24.04	12.63
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.001	0.001	0.018	0.065	<0.001	0.000
SAR (me/l)	3.0	5.7	7.9	10.2	20.2	21.5
Na (me/100g)	0.99	0.94	0.61	1.17	1.22	0.95
Ca+Mg (me/100g)	2.78	0.70	0.26	0.38	0.16	0.07
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25°C (mmhos/cm)	0.760	0.444	0.310	0.307	.362	.421
Ca+Mg (me/l)	5.50	1.58	0.87	0.74	0.42	0.33
<u>EXCHANGEABLE SODIUM</u> (percent)	1.6	4.4	6.1	3.1	11.0	15.8
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	39.8	28.0	14.0	10.8	12.2	18.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	-
BORON (B) (ppm)	1.61	1.54	0.92	0.98	1.31	0.95
CADMIUM (Cd) (ppm)	0.30	0.14	0.08	0.06	0.08	0.08
COPPER (Cu) (ppm)	20.0	14.0	3.8	1.6	2.0	3.2
IRON (Fe) (ppm)	115.4	105.4	51.2	68.8	77.4	54.6
MERCURY (Hg) (ppm)	0.01	0.04	0.02	0.02	0.02	0.01
MANGANESE (Mn) (ppm)	14.8	20.0	4.0	5.0	4.8	4.2
MOLYBDENUM (Mo) (ppm)	2.2	0.9	0.0	0.0	0.1	0.3
NICKEL (Ni) (ppm)	10.0	8.0	1.2	1.6	3.6	4.0
LEAD (Pb) (ppm)	8.40	8.40	3.40	2.40	2.80	2.80
SELENIUM (Se) (ppm)	-	-	-	-	-	-
ZINC (Zn) (ppm)	12.2	11.1	4.0	2.9	3.4	4.4

\*Insufficient Sample

Table 10  
Sheet 3

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-109 (cont'd)  
 Location: 450' N. & 25' E. of SW Corner, Sec. 6, T. 155 N., R. 102 W.  
 Logged by: C. Botdorf  
 Date: November 1982

DETERMINATION LABORATORY NUMBER	LABORATORY DESCRIPTION					
	Data					
	60	61	62	63	64	65
SACK NUMBER	109-13	109-14	109-15	109-16	109-17	109-18
DEPTH (FT)	163.0-184.0	184.0-194.6	194.6-210.0	210.0-216.5	216.5-229.6	229.6-237.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	0.1	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	1.3	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	22.2	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	16.6	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	19.0	-
TOTAL SAND (2.0-0.05 mm)	5.2	27.0	3.0	21.4	59.2	5.0
SILT (0.05-0.002 mm)	46.6	49.6	47.6	37.6	20.8	46.0
CLAY (0.002 mm)	48.2	23.4	49.4	41.0	20.0	49.0
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SIC	SIL	SIC	C	SCL/SL	SIC
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME (ml)	30.0	23.5	21.5	33.5	30.0	50.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	47.0	39.6	63.9	66.5	47.0	74.8
15 bar	23.5	20.2	25.9	34.6	15.2	31.0
<b>SOIL REACTION-pH</b>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.7	9.1	8.9	9.1	9.4	9.0
1:2 0.01 M CaCl <sub>2</sub>	7.7	8.0	7.9	8.1	8.3	8.2
CYSPUM REQUIREMENT (me/100g)	+12.2	+8.2	+12.0	+14.0	+8.4	+12.2
<b>SATURATION EXTRACT</b>						
Saturation Percentage	90.6	67.7	100.8	106.9	84.7	143.3
EC <sub>e</sub> @25°C (mmhos/cm)	1.718	1.966	1.839	1.775	1.800	1.548
Ca <sup>++</sup> (me/l)	0.60	0.22	0.21	0.15	0.25	0.13
Mg <sup>++</sup> (me/l)	0.75	0.49	0.33	0.18	0.25	0.16
Na <sup>++</sup> (me/l)	30.0	25.0	24.0	23.8	22.0	19.6
K <sup>+</sup> (me/l)	0.68	0.34	0.44	0.35	0.30	0.32
CO <sub>3</sub> <sup>-</sup> (me/l)	2.14	0.86	0.86	0.43	0.00	0.47
HCO <sub>3</sub> <sup>-</sup> (me/l)	10.76	6.71	8.71	8.17	6.33	8.52
Cl <sup>-</sup> (me/l)	0.37	0.45	0.20	0.23	0.42	0.20
SO <sub>4</sub> <sup>-</sup> (me/l)	18.76	18.03	15.21	15.64	16.05	10.94
NO <sub>3</sub> <sup>-</sup> (me/l)	0.000	<0.001	0.002	0.005	<0.001	0.000
SAR (me/l)	36.5	41.9	46.2	58.6	44.0	51.5
Na (me/100g)	2.72	1.69	2.42	2.54	1.86	2.81
Ca+Mg (me/100g)	0.12	2.8	4.7	0.04	0.04	0.04
<b>1:5 EXTRACT</b>						
EC <sub>5</sub> @25°C (mmhos/cm)	.612	.539	.586	.707	.589	.707
Ca+Mg (me/l)	0.34	0.23	0.21	0.41	0.16	0.41
EXCHANGEABLE SODIUM (percent)	21.9	22.8	34.1	33.5	35.4	41.9
CATION EXCHANGE CAPACITY (me/100g)	32.4	25.0	27.6	30.0	22.4	26.2
NaOAc@pH 8.2						
<b>SILVER (Ag) (ppm)</b>						
SILVER (Ag)	-	-	-	-	-	-
<b>BORON (B) (ppm)</b>						
BORON (B)	1.24	0.66	0.98	0.69	0.00	1.15
<b>CADMIUM (Cd) (ppm)</b>						
CADMIUM (Cd)	0.20	0.06	0.16	0.10	0.08	0.20
<b>COPPER (Cu) (ppm)</b>						
COPPER (Cu)	14.0	4.0	14.0	10.0	2.8	16.0
<b>IRON (Fe) (ppm)</b>						
IRON (Fe)	78.6	39.0	117.6	69.2	67.6	136.8
<b>MERCURY (Hg) (ppm)</b>						
MERCURY (Hg)	0.08	0.04	0.06	0.07	0.03	0.06
<b>MANGANESE (Mn) (ppm)</b>						
MANGANESE (Mn)	4.6	1.6	14.2	1.8	1.6	12.8
<b>MOLYBDENUM (Mo) (ppm)</b>						
MOLYBDENUM (Mo)	1.9	0.5	0.9	0.3	0.3	0.5
<b>NICKEL (Ni) (ppm)</b>						
NICKEL (Ni)	8.0	2.6	6.0	2.0	2.2	6.0
<b>LEAD (Pb) (ppm)</b>						
LEAD (Pb)	8.40	3.60	8.00	5.20	3.20	8.40
<b>SELENIUM (Se) (ppm)</b>						
SELENIUM (Se)	-	-	-	-	-	-
<b>ZINC (Zn) (ppm)</b>						
ZINC (Zn)	7.2	3.4	10.8	4.7	3.8	9.0

\*Insufficient Sample

Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 82-109 (cont'd)  
 Location: 450' N. & 25' E. of SW Corner, Sec. 6, T. 155 N., R. 102 W.  
 Logged by: C. Botdorf  
 Date: November 1982

DETERMINATION		LABORATORY DESCRIPTION	
		Data	
<u>LABORATORY NUMBER</u>		66	
<u>SACK NUMBER</u>		109-19	
<u>DEPTH (FT)</u>		238.9-240.0	
<u>PARTICLE SIZE ANALYSIS</u>	(percent)		
Very Coarse Sand	(2.0-1.0 mm)	-	
Coarse Sand	(1.0-0.5 mm)	-	
Medium Sand	(0.5-0.25 mm)	-	
Fine Sand	(0.25-0.10 mm)	-	
Very Fine Sand	(0.10-0.05 mm)	-	
TOTAL SAND	(2.0-0.05 mm)	30.2	
SILT	(0.05-0.002 mm)	45.8	
CLAY	(0.002 mm)	24.0	
GRAVEL	(percent)	-	
<u>TEXTURAL CLASS (LAB)</u>		L	
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)		
6th Hr.		0.00	
24th Hr.		0.00	
<u>SETTLING VOLUME</u>	(ml)	35.5	
<u>MOISTURE RETENTION</u>	(%)		
1/3 bar		48.5	
15 bar		27.6	
<u>SOIL REACTION-pH</u>			
Paste		-	
1:5 H <sub>2</sub> O		8.9	
1:2 0.01 M CaCl <sub>2</sub>		7.6	
<u>GYPSUM REQUIREMENT</u>	(me/100g)	+8.4	
<u>SATURATION EXTRACT</u>			
Saturation Percentage		73.6	
EC <sub>e</sub> @25°C	(mmhos/cm)	1.729	
Ca <sup>++</sup>	(me/l)	0.62	
Mg <sup>++</sup>	(me/l)	0.41	
Na <sup>++</sup>	(me/l)	21.6	
K <sup>+</sup>	(me/l)	0.26	
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.51	
HCO <sub>3</sub> <sup>-</sup>	(me/l)	9.70	
Cl <sup>-</sup>	(me/l)	0.51	
SO <sub>4</sub> <sup>-</sup>	(me/l)	12.71	
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.000	
SAR	(me/l)	30.1	
Na	(me/100g)	1.72	
Ca+Mg	(me/100g)	0.08	
<u>1:5 EXTRACT</u>			
EC <sub>5</sub> @25°C	(mmhos/cm)	.510	
Ca+Mg	(me/l)	0.41	
<u>EXCHANGEABLE SODIUM</u>	(percent)	45.2	
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)	21.8	
NaOAc@pH 8.2			
SILVER (Ag)	(ppm)	-	
BORON (B)	(ppm)	0.75	
CADMIUM (Cd)	(ppm)	0.14	
COPPER (Cu)	(ppm)	6.6	
IRON (Fe)	(ppm)	269.0	
MERCURY (Hg)	(ppm)	0.03	
MANGANESE (Mn)	(ppm)	4.0	
MOLYBDENUM (Mo)	(ppm)	0.4	
NICKEL (Ni)	(ppm)	1.4	
LEAD (Pb)	(ppm)	5.00	
SELENIUM (Se)	(ppm)	-	
ZINC (Zn)	(ppm)	4.5	
*Insufficient Sample			

Table 11  
Sheet I

Sand Creek Study Area, North Dakota  
 Geologic Orill Hole: 81-110  
 Location: 50' N. & 50' E. of SW Corner, Sec. 9, T. 155 N., R. 101 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
	4,499	4,500	4,501	4,502	4,503	4,504
<u>LABORATORY NUMBER</u>	110-1	110-2	110-3	110-4	110-5	110-6
<u>DEPTH (FT)</u>	0-0.5	0.5-3.5	3.5-6.5	6.5-10.0	32.0-34.0	45.0-47.0
<u>PARTICLE SIZE ANALYSIS</u>	(percent)					
Very Coarse Sand (2.0-1.0 mm)	2.2	2.2	2.3	1.4	1.3	0.8
Coarse Sand (1.0-0.5 mm)	4.9	4.1	4.1	3.6	2.2	1.8
Medium Sand (0.5-0.25 mm)	7.8	7.8	7.0	7.5	4.7	5.3
Fine Sand (0.25-0.10 mm)	13.5	11.6	11.2	11.7	13.3	10.9
Very Fine Sand (0.10-0.05 mm)	13.1	9.0	11.2	11.5	12.0	10.7
TOTAL SAND (2.0-0.05 mm)	41.5	34.7	35.9	35.7	33.5	29.5
SILT (0.05-0.002 mm)	37.9	40.5	37.5	38.0	41.1	44.5
CLAY (0.002 mm)	20.6	24.8	26.6	26.3	25.4	26.0
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	L	L	L	L	L	L
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)					
6th Hr.	0.55	0.14	0.06	0.26	0.06	0.20
24th Hr.	0.47	0.14	0.04	0.24	0.04	0.16
<u>SETTLING VOLUME</u>	(ml)					
	23.0	23.0	30.0	24.0	28.0	27.0
<u>MOISTURE RETENTION</u>	(%)					
1/3 bar	25.5	25.6	23.5	25.0	25.3	24.7
15 bar	11.1	11.1	11.5	12.3	13.4	13.0
<u>SOIL REACTION-pH</u>						
Paste	7.7	7.9	8.1	7.9	7.5	7.5
1:5 H <sub>2</sub> O	8.4	8.9	9.0	-	-	-
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u>	(me/100g)					
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	56.6	51.0	55.1	56.5	56.0	53.6
EC <sub>e</sub> @25°C (mmhos/cm)	0.71	1.04	2.65	7.5	4.7	4.9
Ca <sup>++</sup> (me/l)	-	3.2	3.2	22.6	24.4	24.7
Mg <sup>++</sup> (me/l)	-	6.1	12.4	58.2	28.3	29.4
Na <sup>++</sup> (me/l)	1.12	2.4	14.4	31.8	11.3	11.6
K <sup>+</sup> (me/l)	-	0.4	0.5	0.8	1.0	1.1
CO <sub>3</sub> <sup>-</sup> (me/l)	-	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	-	4.5	2.7	1.5	2.1	3.1
Cl <sup>-</sup> (me/l)	-	0.1	0.1	2.9	0.9	0.3
SO <sub>4</sub> <sup>-</sup> (me/l)	-	7.1	26.8	109	60.0	52.5
NO <sub>3</sub> <sup>-</sup> (me/l)	-	<0.1	<0.1	<0.1	0.4	9.0
SAR (me/l)	-	1.1	5.2	5.0	2.2	2.2
Na (me/100g)	0.1	0.1	0.8	1.8	0.6	0.6
Ca+Mg (me/100g)	-	0.5	0.9	4.6	3.0	2.9
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.25	0.24	0.53	3.0	0.90	0.91
Ca+Mg (me/l)	2.04	1.77	2.28	28.3	7.58	6.75
<u>EXCHANGEABLE SODIUM</u>	(percent)					
	1.0	1.9	6.7	8.4	2.8	2.5
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)					
NaOAc@pH 8.2	19.2	15.8	16.4	15.4	17.8	16.3
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	0.94	0.68	0.52
CADMIUM (Cd) (ppm)	-	-	-	0.83	0.42	0.38
COPPER (Cu) (ppm)	-	-	-	2.3	4.2	4.3
IRON (Fe) (ppm)	-	-	-	30.8	62.2	32.0
MERCURY (Hg) (ppm)	-	-	-	0.10	0.10	0.15
MANGANESE (Mn) (ppm)	-	-	-	40.4	66.5	50.1
MOLYBDENUM (Mo) (ppm)	-	-	-	0.7	0.5	0.4
NICKEL (Ni) (ppm)	-	-	-	0.98	2.6	2.7
LEAD (Pb) (ppm)	-	-	-	1.5	1.3	1.8
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	1.8	1.2	1.4

\*Insufficient Sample

Table 11  
Sheet 2

EMRIA-Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 81-110 (cont'd)  
 Location: 50' N. & 50' E. of SW Corner, Sec. 9, T. 155 N., R. 101 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,505	4,506	4,507	4,508	4,509	4,510
SACK NUMBER	110-7	110-8	110-9	110-10	110-11	110-12
DEPTH (FT)	60.5-62.5	64.5-66.2	74.4-76.9	79.9-81.9	93.0-95.0	101.0-103.0
<u>PARTICLE SIZE ANALYSIS</u>	(percent)					
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	0.1	2.1	0.1	0.0
Coarse Sand (1.0-0.5 mm)	0.0	0.1	0.3	1.8	0.1	0.1
Medium Sand (0.5-0.25 mm)	0.2	0.2	0.3	1.0	0.1	0.1
Fine Sand (0.25-0.10 mm)	6.7	17.3	2.3	6.7	9.9	5.5
Very Fine Sand (0.10-0.05 mm)	13.1	26.9	12.3	24.3	33.1	20.0
TOTAL SAND (2.0-0.05 mm)	20.0	44.5	15.3	35.9	43.3	25.7
SILT (0.05-0.002 mm)	59.1	44.1	68.5	44.9	43.8	59.7
CLAY (0.002 mm)	20.9	11.4	16.2	19.2	12.9	14.6
CRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	L	SIL	L	L	SIL
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)					
6th Hr.	0.14	0.12	0.12	0.71	0.16	0.43
24th Hr.	0.12	0.12	0.14	0.67	0.16	0.39
<u>SETTLING VOLUME</u>	(ml)					
	24	19	18	25	22	21
<u>MOISTURE RETENTION</u>	(% )					
1/3 bar	21.9	17.2	22.2	23.7	20.5	23.6
15 bar	9.0	6.3	8.8	10.1	6.8	8.1
<u>SOIL REACTION-pH</u>						
Paste	7.8	7.7	7.6	7.7	7.7	7.8
1:5 H <sub>2</sub> O	8.7	8.7	8.4	8.8	9.0	8.8
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPNUM REQUIREMENT</u>	(me/100g)					
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	48.9	37.6	41.0	48.5	38.3	46.0
EC <sub>e</sub> @25°C (mmhos/cm)	2.75	4.5	5.0	2.42	2.20	2.41
Ca <sup>++</sup> (me/l)	8.7	15.7	24.5	6.1	5.1	6.8
Mg <sup>++</sup> (me/l)	11.3	21.5	25.1	7.5	6.0	6.8
Na <sup>++</sup> (me/l)	9.2	15.4	15.3	11.5	12.2	12.1
K <sup>+</sup> (me/l)	0.9	0.9	1.0	0.6	0.6	1.1
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	2.4	2.9	2.0	3.1	2.6	3.7
Cl <sup>-</sup> (me/l)	0.5	1.5	0.3	0.7	0.3	0.5
SO <sub>4</sub> <sup>-</sup> (me/l)	19.5	43.5	63.0	20.0	20.5	21.5
NO <sub>3</sub> <sup>-</sup> (me/l)	6.3	6.7	3.13	1.9	0.6	0.2
SAR (me/l)	2.9	3.6	3.1	4.4	5.2	4.7
Na (me/100g)	0.4	0.6	0.6	0.6	0.5	0.6
Ca+Mg (me/100g)	1.0	1.4	2.0	0.7	0.4	0.6
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25°C (mmhos/cm)	0.36	0.55	1.50	0.39	0.33	0.40
Ca+Mg (me/l)	2.31	4.59	14.5	1.77	1.27	1.50
<u>EXCHANGEABLE SODIUM</u>	(percent)					
	3.0	4.0	3.6	14.8	5.9	4.7
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)					
NaOAc@pH 8.2	13.5	10.1	14.0	10.8	10.2	10.7
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.80	0.76	0.88	0.78	0.60	0.70
CADMIUM (Cd) (ppm)	0.78	<0.1	0.17	<0.1	0.26	0.82
COPPER (Cu) (ppm)	3.3	2.2	3.5	0.93	3.9	7.9
IRON (Fe) (ppm)	31.1	35.3	44.3	18.8	15.0	60.3
MERCURY (Hg) (ppm)	0.10	0.20	0.20	0.15	0.15	0.20
MANCANESE (Mn) (ppm)	26.9	29.1	29.6	37.2	21.8	31.2
MOLYBDENUM (Mo) (ppm)	0.2	0.4	0.4	0.2	0.1	0.5
NICKEL (Ni) (ppm)	0.6	1.0	1.3	0.15	0.74	2.8
LEAD (Pb) (ppm)	1.8	1.3	1.7	0.4	1.1	2.9
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	1.2	2.1	1.6	1.3	1.8	7.9

\*Insufficient Sample

EMRIA-Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 81-110 (cont'd)  
 Location: 50' N. & 50' E. of SW Corner, Sec. 9, T. 155 N., R. 101 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,511	4,512	4,513	4,514	4,515	4,516
SACK NUMBER	110-13	110-14	110-15	110-16	110-17	110-18
DEPTH (FT)	126.0-128.0	160.5-162.5	177.0-179.0	186.5-188.5	197.0-199.0	217.0-219.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.1	0.2	0.3	0.0	0.0	0.3
Coarse Sand (1.0-.5 mm)	0.1	0.2	0.1	0.0	0.0	0.1
Medium Sand (.5-0.25 mm)	0.2	0.4	0.2	0.0	0.0	0.1
Fine Sand (.25-0.10 mm)	3.1	1.0	3.3	0.1	7.4	0.4
Very Fine Sand (.10-0.05 mm)	7.2	7.2	44.0	0.3	48.0	14.7
TOTAL SAND (2.0-0.05 mm)	10.7	9.0	47.9	0.4	55.4	15.6
SILT (.05-0.002 mm)	62.9	68.5	43.2	64.4	36.0	61.8
CLAY (.002 mm)	26.4	22.5	8.9	35.2	8.6	22.6
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	SIL	L	SICL	VFSL	SIL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	28	32	35	65	40	120
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	34.9	42.0	33.8	55.3	32.3	51.1
15 bar	15.2	17.7	11.0	24.0	8.4	26.9
<u>SOIL REACTION-pH</u>						
Paste	7.9	8.0	8.5	8.5	9.1	9.0
1:5 H <sub>2</sub> O	8.9	9.2	9.9	9.7	10.2	10.1
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYP SUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	56.5	67.8	52.7	87.5	47.0	74.5
EC <sub>e</sub> @25°C (mmhos/cm)	2.20	3.2	3.0	2.60	3.3	2.95
Ca <sup>++</sup> (me/l)	6.0	2.7	1.0	0.6	0.4	0.4
Mg <sup>++</sup> (me/l)	5.1	2.4	2.7	0.3	0.4	0.0
Na <sup>++</sup> (me/l)	12.5	28.1	29.0	25.0	32.6	28.4
K <sup>+</sup> (me/l)	0.9	0.7	0.3	0.3	0.4	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.5	0.5	1.0	1.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	6.0	6.8	9.9	9.1	7.5	0.4
Cl <sup>-</sup> (me/l)	0.2	0.3	0.3	0.2	0.6	0.4
SO <sub>4</sub> <sup>-</sup> (me/l)	17.5	25.5	19.0	16.5	24.0	17.5
NO <sub>3</sub> <sup>-</sup> (me/l)	1.3	1.1	2.3	0.2	0.3	2.4
SAR (me/l)	5.3	17.6	21.3	37.3	51.5	63.5
Na (me/100g)	0.7	1.9	1.5	2.2	1.5	2.1
Ca+Mg (me/100g)	0.6	0.3	0.2	0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25°C (mmhos/cm)	0.45	0.59	0.60	0.70	0.62	0.90
Ca+Mg (me/l)	1.04	0.46	0.42	0.21	0.23	0.32
<u>EXCHANGEABLE SODIUM</u> (percent)	10.4	30.0	44.4	54.0	56.4	65.0
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	13.5	16.8	12.6	16.3	10.1	16.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.80	1.00	0.78	0.80	0.56	0.58
CADMIUM (Cd) (ppm)	0.37	0.89	0.84	0.54	<0.1	0.58
COPPER (Cu) (ppm)	9.7	20.6	3.5	10.5	3.3	3.3
IRON (Fe) (ppm)	28.2	91.8	91.6	22.8	94.7	96.0
MERCURY (Hg) (ppm)	0.35	0.45	0.15	0.45	0.20	0.30
MANGANESE (Mn) (ppm)	11.1	32.8	19.7	49.2	13.5	13.9
MOLYBDENUM (Mo) (ppm)	0.6	2.0	0.5	0.7	0.7	0.5
NICKEL (Ni) (ppm)	6.6	6.4	3.4	6.3	5.3	5.3
LEAD (Pb) (ppm)	5.9	5.5	1.8	4.4	1.1	1.1
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	10.5	12.8	9.8	10.6	7.7	7.5

\*Inufficient Sample

EMRIA-Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 81-110 (cont'd)  
 Location: 50' N. & 50' E. of SW Corner, Sec. 9, T. 155 N., R. 101 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION	
	Data	
LABORATORY NUMBER		4,517
SACK NUMBER		110-19
DEPTH (FT)		234.0-240.0
<u>PARTICLE SIZE ANALYSIS</u>	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	0.0
Coarse Sand	(1.0-0.5 mm)	0.1
Medium Sand	(0.5-0.25 mm)	0.1
Fine Sand	(0.25-0.10 mm)	0.3
Very Fine Sand	(0.10-0.05 mm)	3.7
TOTAL SAND	(2.0-0.05 mm)	4.2
SILT	(0.05-0.002 mm)	63.9
CLAY	(0.002 mm)	31.9
GRAVEL	(percent)	-
<u>TEXTURAL CLASS (LAB)</u>		SiCL
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)	
6th Hr.		0.00
24th Hr.		0.00
<u>SETTLING VOLUME</u>	(ml)	210
<u>MOISTURE RETENTION</u>	(%)	
1/3 bar		61.8
15 bar		29.8
<u>SOIL REACTION-pH</u>		
Paste		9.2
1:5 H <sub>2</sub> O		10.0
1:2 0.01 M CaCl <sub>2</sub>		-
<u>GYPSUM REQUIREMENT</u>	(me/100g)	-
<u>SATURATION EXTRACT</u>		
Saturation Percentage		112.6
EC <sub>e</sub> @25°C	(mmhos/cm)	2.10
Ca <sup>++</sup>	(me/l)	0.3
Mg <sup>++</sup>	(me/l)	0.0
Na <sup>++</sup>	(me/l)	21.4
K <sup>+</sup>	(me/l)	0.2
CO <sub>3</sub> <sup>-</sup>	(me/l)	1.9
HCO <sub>3</sub> <sup>-</sup>	(me/l)	9.6
Cl <sup>-</sup>	(me/l)	0.4
SO <sub>4</sub> <sup>-</sup>	(me/l)	9.3
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.1
SAR	(me/l)	55.3
Na	(me/100g)	2.4
Ca+Mg	(me/100g)	<0.1
<u>1:5 EXTRACT</u>		
EC <sub>e</sub> @25°C	(mmhos/cm)	0.60
Ca+Mg	(me/l)	0.44
<u>EXCHANGEABLE SODIUM</u>	(percent)	<0.1
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)	21.0
NaOAc@pH 8.2		
SILVER (Ag)	(ppm)	<0.1
BORON (B)	(ppm)	0.60
CADMIUM (Cd)	(ppm)	0.46
COPPER (Cu)	(ppm)	13.7
IRON (Fe)	(ppm)	81.4
MERCURY (Hg)	(ppm)	0.40
MANGANESE (Mn)	(ppm)	14.8
MOLYBDENUM (Mo)	(ppm)	1.0
NICKEL (Ni)	(ppm)	4.2
LEAD (Pb)	(ppm)	7.2
SELENIUM (Se)	(ppm)	<0.05
ZINC (Zn)	(ppm)	12.0

\*Insufficient Sample

Table 12  
Sheet 1

EMRIA-Sand Creek Study Area, North Dakota  
Geologic Drill Hole: 81-111  
Location: 60' N. & 60' W. of SE Corner, Sec. 33, T. 155 N., R. 102 W.  
Logged by: L. Parish  
Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,533	4,534	4,535	4,536	4,537	4,538
SACK NUMBER	111-1	111-2	111-3	111-4	111-5	111-6
DEPTH (FT)	0-1.0	1.0-4.0	4.0-10.0	11.0-13.0	27.5-29.5	31.5-33.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	1.3	3.1	2.1	2.0	1.9	0.1
Coarse Sand (1.0-0.5 mm)	2.6	4.2	3.8	3.6	3.9	0.1
Medium Sand (0.5-0.25 mm)	6.0	6.8	8.1	5.5	2.9	0.1
Fine Sand (0.25-0.10 mm)	8.6	10.3	11.9	12.1	2.1	0.8
Very Fine Sand (0.10-0.05 mm)	0.2	9.9	11.3	11.5	3.8	8.7
TOTAL SAND (2.0-0.05 mm)	18.7	34.3	37.2	34.7	14.6	9.8
SILT (0.05-0.002 mm)	61.3	36.2	36.9	38.7	63.5	79.2
CLAY (0.002 mm)	20.0	29.5	25.9	26.6	21.9	11.0
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SIL	CL	L	L	SIL	SIL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.06	0.20	0.20	0.12	0.20	0.04
24th Hr.	0.04	0.16	0.18	0.08	0.16	0.02
<u>SETTLING VOLUME</u> (ml)	22	22	25	23	28	26
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	28.0	26.4	24.6	23.8	40.7	37.8
15 bar	10.9	11.7	11.1	11.5	19.3	14.2
<u>SOIL REACTION-pH</u>						
Paste	7.2	8.0	8.2	7.6	4.1	7.8
1:5 H <sub>2</sub> O	8.2	9.1	9.2	8.3	4.5	8.5
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)						
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	50.3	47.8	48.2	50.8	65.9	62.7
EC <sub>e</sub> @25°C (mmhos/cm)	1.67	0.65	0.58	3.8	2.3	1.42
Ca <sup>++</sup> (me/l)	9.6	1.8	0.7	26.0	6.9	6.2
Mg <sup>++</sup> (me/l)	5.2	3.3	2.9	17.4	12.0	7.3
Na <sup>++</sup> (me/l)	3.9	1.3	2.1	5.1	4.6	2.1
K <sup>+</sup> (me/l)	0.6	0.3	0.3	1.1	0.9	0.9
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.6	3.4	3.8	1.9	0.0	5.2
Cl <sup>-</sup> (me/l)	0.3	0.1	0.3	0.2	0.3	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	14.0	2.0	1.3	48.5	25.5	11.0
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	0.8	0.2	0.1	1.0	<0.1
SAR (me/l)	1.4	0.8	1.6	1.1	1.5	0.8
Na (me/100g)	0.2	0.1	0.1	0.3	0.3	0.1
Ca+Mg (me/100g)	0.7	0.2	0.2	2.2	1.2	0.8
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.39	0.20	0.20	1.45	0.55	0.36
Ca+Mg (me/l)	2.93	2.26	1.87	15.2	3.74	3.63
<u>EXCHANGEABLE SODIUM</u> (percent)						
	2.5	1.9	2.6	2.0	1.6	1.9
<u>CATION EXCHANGE CAPACITY</u> (me/100g)						
NaOAc@pH 8.2	20.1	15.8	15.2	15.3	30.6	21.5
<u>Trace Elements</u>						
SILVER (Ag) (ppm)	-	-	<0.1	<0.1	<0.1	<0.1
BARON (B) (ppm)	-	-	0.86	1.70	2.46	1.22
CADMIUM (Cd) (ppm)	-	-	<0.1	<0.1	0.18	0.40
COPPER (Cu) (ppm)	-	-	2.3	2.3	5.0	11.8
IRON (Fe) (ppm)	-	-	25.9	28.5	534.0	13.3
MERCURY (Hg) (ppm)	-	-	0.35	0.15	0.30	0.30
MANGANESE (Mn) (ppm)	-	-	28.6	30.5	17.8	11.9
MOLYBDENUM (Mo) (ppm)	-	-	1.0	0.6	0.6	0.5
NICKEL (Ni) (ppm)	-	-	0.56	0.62	0.54	6.2
LEAD (Pb) (ppm)	-	-	1.5	1.2	0.46	4.0
SELENIUM (Se) (ppm)	-	-	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	1.8	1.9	3.1	7.3

\*Insufficient Sample

EMRIA-Sand Creek Study Area, North Dakota  
 Geologic Orill Hole: 81-111 (cont'd)  
 Location: 60' N. & 60' W. of SE Corner, Sec. 33, T. 155 N., R. 102 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,539	4,540	4,541	4,542	4,543	4,544
SACK NUMBER	111-7	111-8	111-9	111-10	111-11	111-12
DEPTH (FT)	48.4-50.4	57.2-59.2	69.6-71.6	81.0-83.0	90.0-92.0	104.0-106.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	0.6	0.0	0.1	0.0	0.1	0.0
Coarse Sand (1.0-0.5 mm)	0.2	0.1	0.1	0.0	0.1	0.0
Medium Sand (0.5-0.25 mm)	0.3	0.1	0.0	0.4	0.1	0.0
Fine Sand (0.25-0.10 mm)	0.3	0.2	0.5	23.4	0.2	0.1
Very Fine Sand (0.10-0.05 mm)	0.7	0.2	1.5	46.2	1.9	0.3
TOTAL SAND (2.0-0.05 mm)	2.1	0.6	2.2	70.0	2.4	0.4
SILT (0.05-0.002 mm)	78.1	71.0	88.7	24.7	85.3	77.1
CLAY (0.002 mm)	19.8	28.4	9.1	5.3	12.3	22.5
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SICL	S1	YFSL	S1L	S1L
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.00	0.00	0.04	0.98	0.00	0.00
24th Hr.	0.00	0.02	0.02	0.91	0.00	0.00
SETTLING VOLUME (ml)	28	38	23	20	29	47
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	39.8	42.3	34.9	20.4	40.8	47.6
15 bar	14.3	19.0	9.9	8.6	11.8	17.2
<b>SOIL REACTION-pH</b>						
Paste	8.0	7.9	8.1	7.9	8.7	8.7
1:5 H <sub>2</sub> O	8.7	8.7	9.0	8.8	9.7	9.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<b>GYPNUM REQUIREMENT (me/100g)</b>						
	-	-	-	-	-	-
<b>SATURATION EXTRACT</b>						
Saturation Percentage	61.9	63.0	59.5	79.8	80.0	92.6
EC <sub>e</sub> @25°C (mmhos/cm)	2.4	2.8	2.6	3.3	3.0	2.4
Ca <sup>++</sup> (me/l)	4.7	4.2	2.3	5.8	0.6	0.4
Mg <sup>++</sup> (me/l)	5.4	4.7	2.9	6.5	0.7	0.6
Na <sup>++</sup> (me/l)	13.9	21.4	21.9	23.7	29.8	23.8
K <sup>+</sup> (me/l)	1.2	1.2	0.7	0.8	0.4	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	6.2	9.4	8.7	7.4	12.6	12.4
Cl <sup>-</sup> (me/l)	0.1	0.3	0.3	0.5	0.5	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	18.5	22.5	19.0	29.0	17.0	11.5
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	6.2	10.1	13.6	9.6	27.0	33.7
Na (me/100g)	0.9	1.3	1.3	1.9	2.4	2.2
Ca+Mg (me/100g)	0.6	0.6	0.3	1.0	0.1	0.1
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.51	0.64	0.58	0.60	0.78	0.89
Ca+Mg (me/l)	1.62	1.45	1.20	2.08	0.62	0.69
<b>EXCHANGEABLE SODIUM (percent)</b>						
	7.9	12.4	18.1	6.7	38.4	49.4
<b>CATION EXCHANGE CAPACITY (me/100g)</b>						
NaOAc@pH 8.2	17.7	20.1	14.9	14.9	15.1	17.0
<b>Trace Elements (ppm)</b>						
SILVER (Ag)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B)	0.96	1.20	1.06	1.68	0.68	1.16
CADMIUM (Cd)	0.10	0.71	0.29	0.49	<0.1	<0.1
COPPER (Cu)	6.7	11.6	5.4	4.3	4.7	8.0
IRON (Fe)	13.8	152.0	52.9	29.3	124.0	284.0
MERCURY (Hg)	0.30	0.30	0.15	0.10	0.20	0.20
MANGANESE (Mn)	3.6	45.2	10.8	7.9	23.2	54.9
MOLYBDENUM (Mo)	0.2	0.8	1.2	0.5	0.4	0.9
NICKEL (Ni)	0.53	3.9	5.0	12.2	3.5	4.4
LEAD (Pb)	6.6	6.4	3.7	3.4	3.2	3.4
SELENIUM (Se)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn)	6.0	10.1	7.5	7.0	6.9	9.4

\*Insufficient Sample

EMRIA-Sand Creek Study Area, North Dakota  
Geologic Orill Hole: 81-111 (cont'd)  
Location: 60' N. & 60' W. of SE Corner, Sec. 33, T. 155 N., R. 102 W.  
Logged by: L. Parish  
Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,545	4,546	4,547	4,548	4,549	4,550
SACK NUMBER	111-13	111-14	111-15	111-16	111-17	111-18
DEPTH (FT)	131.0-133.0	137.0-139.0	161.0-163.0	174.6-176.6	201.9-203.9	214.7-216.3
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.4	0.0	0.1	0.1	0.0	0.4
Coarse Sand (1.0-0.5 mm)	0.1	0.1	0.7	0.3	0.0	0.4
Medium Sand (0.5-0.25 mm)	0.1	0.1	1.1	9.2	0.0	0.2
Fine Sand (0.25-0.10 mm)	0.7	0.1	46.7	60.6	0.1	0.6
Very Fine Sand (0.10-0.05 mm)	21.2	3.1	30.4	8.2	0.1	0.1
TOTAL SAND (2.0-0.05 mm)	22.5	3.4	79.0	78.4	0.2	1.7
SILT (0.05-0.002 mm)	60.7	75.4	12.7	16.8	39.6	54.6
CLAY (0.002 mm)	16.8	21.2	8.3	4.8	60.2	43.7
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiL	SiL	LFS	LFS	C	SiC
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.02	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	50	52	36	31	300	225
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	49.2	53.5	28.9	17.8	70.2	61.0
15 bar	18.2	24.2	8.8	6.0	29.6	25.0
<u>SOIL REACTION-pH</u>						
Paste	9.0	9.0	9.4	9.5	9.3	9.0
1:5 H <sub>2</sub> O	10.0	9.8	10.1	10.2	9.7	9.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSSUM REQUIREMENT</u> (me/100g)						
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	80.0	92.6	47.1	36.1	165.2	118.2
EC <sub>e</sub> @25°C (mmhos/cm)	2.9	3.0	3.1	3.0	1.42	2.3
Ca <sup>++</sup> (me/l)	0.2	0.3	9.2	0.3	0.2	0.2
Mg <sup>++</sup> (me/l)	0.2	0.3	0.3	0.3	0.2	0.3
Na <sup>++</sup> (me/l)	29.1	20.4	31.3	30.6	14.1	22.6
K <sup>+</sup> (me/l)	0.4	0.4	0.3	0.3	0.2	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	1.1	2.3	1.9	3.0	1.0	0.7
HCO <sub>3</sub> <sup>-</sup> (me/l)	11.3	13.2	12.6	13.0	8.6	10.1
Cl <sup>-</sup> (me/l)	0.3	0.2	0.4	0.3	0.2	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	17.0	14.5	17.0	13.0	4.4	11.5
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	65.1	55.5	62.6	55.9	31.5	45.2
Na (me/100g)	2.3	2.8	1.5	1.1	2.3	2.7
Ca+Mg (me/100g)	<0.1	<0.1	<0.1	<0.1	0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25°C (mmhos/cm)	0.90	0.95	0.71	0.59	0.62	0.90
Ca+Mg (me/l)	0.42	0.58	0.23	0.37	0.64	1.04
<u>EXCHANGEABLE SODIUM</u> (percent)						
	61.9	60.9	66.4	74.4	70.7	61.5
<u>CATION EXCHANGE CAPACITY</u> (me/100g)						
NaOAc@pH 8.2	16.8	19.2	11.3	7.8	22.2	21.8
<u>SILVER (Ag)</u> (ppm)						
	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<u>BORON (B)</u> (ppm)						
	0.86	0.82	0.60	0.42	1.00	1.18
<u>CAESIUM (Cs)</u> (ppm)						
	0.43	0.35	<0.1	<0.1	0.46	0.10
<u>COPPER (Cu)</u> (ppm)						
	5.4	8.2	1.6	1.1	14.3	9.0
<u>IRON (Fe)</u> (ppm)						
	17.9	54.0	34.4	39.2	41.0	61.0
<u>MERCURY (Hg)</u> (ppm)						
	0.30	0.20	0.20	0.20	0.20	0.20
<u>MANGANESE (Mn)</u> (ppm)						
	3.4	8.6	6.3	3.9	2.2	11.5
<u>MOLYBDENUM (Mo)</u> (ppm)						
	0.6	1.1	0.2	0.7	0.4	0.5
<u>NICKEL (Ni)</u> (ppm)						
	3.8	0.25	1.0	0.72	1.3	2.4
<u>LEAD (Pb)</u> (ppm)						
	4.7	5.2	3.1	2.2	12.5	8.4
<u>SELENIUM (Se)</u> (ppm)						
	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<u>ZINC (Zn)</u> (ppm)						
	9.6	9.2	11.8	12.6	16.1	10.9

\*Insufficient Sample

EMRIA-Sand Creek Study Area, North Dakota  
 Geologic Drill Hole: 81-111 (cont'd)  
 Location: 60' N. & 60' W. of SE Corner, Sec. 33, T. 155 N., R. 102 W.  
 Logged by: L. Parish  
 Date: September 1981

DETERMINATION	LABORATORY DESCRIPTION	
	Data	
<u>LABORATORY NUMBER</u>		4,551
<u>SACK NUMBER</u>		111-19
<u>DEPTH (FT)</u>		219.5-221.5
<u>PARTICLE SIZE ANALYSIS</u>	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	0.0
Coarse Sand	(1.0-0.5 mm)	0.1
Medium Sand	(0.5-0.25 mm)	0.3
Fine Sand	(0.25-0.10 mm)	0.3
Very Fine Sand	(0.10-0.05 mm)	0.4
TOTAL SAND	(2.0-0.05 mm)	1.1
SILT	(0.05-0.002 mm)	60.6
CLAY	(0.002 mm)	38.3
GRAVEL	(percent)	-
<u>TEXTURAL CLASS (LAB)</u>		S1CL
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)	
6th Hr.		0.00
24th Hr.		0.00
<u>SETTLING VOLUME</u>	(ml)	140
<u>MOISTURE RETENTION</u>	(%)	
1/3 bar		47.1
15 bar		19.6
<u>SOIL REACTION-pH</u>		
Paste		7.9
1:5 H <sub>2</sub> O		8.9
1:2 0.01 M CaCl <sub>2</sub>		-
<u>GYPSPUM REQUIREMENT</u>	(me/100g)	-
<u>SATURATION EXTRACT</u>		
Saturation Percentage		115.2
EC <sub>e</sub> @25°C	(mmhos/cm)	8.5
Ca <sup>++</sup>	(me/l)	12.5
Mg <sup>++</sup>	(me/l)	7.0
Na <sup>++</sup>	(me/l)	78.1
K <sup>+</sup>	(me/l)	1.2
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.0
HCO <sub>3</sub> <sup>-</sup>	(me/l)	5.2
Cl <sup>-</sup>	(me/l)	0.3
SO <sub>4</sub> <sup>-</sup>	(me/l)	91.0
NO <sub>3</sub> <sup>-</sup>	(me/l)	<0.1
SAR	(me/l)	25.0
Na	(me/100g)	9.0
Ca+Mg	(me/100g)	2/2
<u>1:5 EXTRACT</u>		
EC <sub>5</sub> @25°C	(mmhos/cm)	2.42
Ca+Mg	(me/l)	2.70
<u>EXCHANGEABLE SODIUM</u>	(percent)	31.3
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)	19.5
NaOAc@pH 8.2		
SILVER (Ag)	(ppm)	<0.1
BORON (B)	(ppm)	1.00
CADMIUM (Cd)	(ppm)	0.18
COPPER (Cu)	(ppm)	12.2
IRON (Fe)	(ppm)	170.0
MERCURY (Hg)	(ppm)	0.30
MANGANESE (Mn)	(ppm)	63.6
MOLYBDENUM (Mo)	(ppm)	2.2
NICKEL (Ni)	(ppm)	3.8
LEAD (Pb)	(ppm)	2.9
SELENIUM (Se)	(ppm)	<0.05
ZINC (Zn)	(ppm)	15.7

\*Insufficient Sample

Table 13  
Sheet 1

Williston Study Area, North Dakota  
Geologic Drill Hole: 81-113  
Location: 2500' N. & 10' E. of SW Corner, Sec. 14, T. 155 N., R. 100 W.  
Logged by: G. Taucher  
Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,518	4,519	4,520	4,521	4,522	4,523
SACK NUMBER	113-1	113-2	113-3	113-4	113-5	113-6
DEPTH (FT)	0-1.5	1.5-5.0	5.0-7.5	7.5-10.0	124.0-126.0	139.5-141.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.7	2.3	2.7	0.1	1.1	2.3
Coarse Sand (1.0-0.5 mm)	3.4	3.6	5.3	0.0	0.6	3.5
Medium Sand (0.5-0.25 mm)	12.9	8.4	6.6	0.1	0.3	7.7
Fine Sand (0.25-0.10 mm)	18.9	16.3	14.8	0.2	0.3	11.8
Very Fine Sand (0.10-0.05 mm)	6.2	20.2	12.0	2.9	30.5	11.6
TOTAL SAND (2.0-0.05 mm)	42.1	30.8	41.4	3.3	32.8	36.9
SILT (0.05-0.002 mm)	44.3	46.6	35.8	67.5	70.3	38.3
CLAY (0.002 mm)	13.6	22.6	22.8	29.2	26.9	24.8
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	L	L	L	S1CL	S1L	L
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.79	0.31	0.06	0.20	0.06	0.02
24th Hr.	0.91	0.30	0.04	0.14	0.02	0.02
<u>SETTLING VOLUME</u> (ml)	21.0	20.0	28.0	25.0	31.0	30.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	21.1	21.9	23.0	24.8	38.8	38.8
15 bar	8.2	8.8	10.6	12.0	16.0	18.0
<u>SOIL REACTION-pH</u>						
Paste	6.9	7.9	8.2	8.3	7.8	8.0
1:5 H <sub>2</sub> O	7.5	9.0	9.4	8.8	8.4	8.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	41.6	41.1	42.0	47.8	63.6	70.1
EC <sub>e</sub> @25°C (mmhos/cm)	0.63	0.46	1.06	2.95	1.63	1.60
Ca <sup>++</sup> (me/l)	3.0	1.3	0.7	7.8	7.9	4.1
Mg <sup>++</sup> (me/l)	1.6	2.3	2.5	14.9	6.6	3.9
Na <sup>++</sup> (me/l)	1.3	0.8	7.1	12.7	2.7	7.5
K <sup>+</sup> (me/l)	0.5	0.2	0.3	0.9	1.5	1.2
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	3.9	3.0	4.3	2.3	4.5	5.3
Cl <sup>-</sup> (me/l)	0.2	0.7	0.7	0.8	0.2	0.2
SO <sub>4</sub> <sup>-</sup> (me/l)	1.7	0.4	15.5	32.3	13.5	10.0
NO <sub>3</sub> <sup>-</sup> (me/l)	0.3	<0.1	<0.1	<0.1	0.2	0.7
SAR (me/l)	0.9	0.5	5.6	3.8	1.0	3.8
Na (me/100g)	0.1	0.0	0.3	0.6	0.2	0.5
Ca+Mg (me/100g)	0.2	0.1	0.1	1.1	0.9	0.6
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.03	0.09	0.24	0.42	0.34	0.35
Ca+Mg (me/l)	0.71	1.27	1.06	2.28	2.53	2.08
<u>EXCHANGEABLE SODIUM</u> (percent)	0.7	1.5	9.2	6.6	3.2	5.8
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	15.3	13.1	13.0	15.2	12.6	17.3
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	1.24	0.82	0.52
CADMIUM (Cd) (ppm)	-	-	-	0.29	0.50	0.88
COPPER (Cu) (ppm)	-	-	-	2.2	15.5	12.5
IRON (Fe) (ppm)	-	-	-	30.0	136.0	137.0
MERCURY (Hg) (ppm)	-	-	-	0.20	0.30	0.40
MANGANESE (Mn) (ppm)	-	-	-	49.4	38.2	31.7
MOLYBDENUM (Mo) (ppm)	-	-	-	0.7	0.6	1.6
NICKEL (Ni) (ppm)	-	-	-	1.1	4.2	4.7
LEAD (Pb) (ppm)	-	-	-	0.80	4.3	3.2
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	32.6	10.2	9.4

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Orthil Hole: 81-113 (cont'd)  
 Location: 2500' N. & 10' E. of SW Corner, Sec. 14, T. 155 N., R. 100 W.  
 Logged by: G. Taucher  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,524	4,525	4,526	4,527	4,528	4,529
SACK NUMBER	113-7	113-8	113-9	113-10	113-11	113-12
DEPTH (FT)	154.0-156.0	174.0-176.0	190.0-192.0	223.0-225.0	247.7-249.7	226.0-228.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.1	0.3	0.0	0.1	0.0	0.1
Coarse Sand (1.0-0.5 mm)	0.0	0.3	0.0	0.1	0.0	0.0
Medium Sand (0.5-0.25 mm)	0.1	0.1	0.1	0.1	0.0	0.1
Fine Sand (0.25-0.10 mm)	0.5	0.2	16.6	0.2	0.1	0.2
Very Fine Sand (0.10-0.05 mm)	18.2	8.5	25.2	3.3	10.2	0.3
TOTAL SAND (2.0-0.05 mm)	18.9	9.4	41.9	3.8	10.3	0.7
SILT (0.05-0.002 mm)	62.6	66.0	46.5	61.2	66.5	57.3
CLAY (0.002 mm)	18.5	24.6	11.6	35.0	23.2	42.0
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S1L	S1L	L	S1CL	S1L	S1C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	38.0	128.0	180.0	325.0	450.0	440.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	41.6	53.7	38.7	54.4	58.2	61.2
15 bar	17.2	31.9	22.6	27.6	34.7	28.8
<u>SOIL REACTION-pH</u>						
Paste	8.4	8.6	9.2	8.8	9.3	8.8
1:5 H <sub>2</sub> O	9.4	9.6	10.0	9.8	9.8	9.9
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	74.1	102.4	85.5	114.7	153.1	123.2
EC <sub>e</sub> @25°C (mmhos/cm)	2.01	2.20	1.59	2.29	1.62	2.59
Ca++ (me/l)	1.0	0.3	0.1	0.1	0.1	0.4
Mg++ (me/l)	0.6	0.6	0.2	0.3	0.1	0.1
Na++ (me/l)	18.8	21.1	15.1	23.5	16.6	25.9
K+ (me/l)	0.5	0.5	0.2	0.3	0.2	0.3
CO <sub>3</sub> - (me/l)	0.4	0.5	0.9	0.7	1.2	0.5
HCO <sub>3</sub> - (me/l)	7.9	7.6	6.7	10.9	9.0	13.5
Cl- (me/l)	0.1	0.2	0.2	0.2	0.2	0.2
SO <sub>4</sub> - (me/l)	11.4	13.0	7.3	12.0	5.8	12.0
NO <sub>3</sub> - (me/l)	0.4	0.5	0.2	<0.1	16.2	<0.1
SAK (me/l)	21.0	31.5	39.0	52.5	52.5	51.8
Na (me/100g)	1.4	2.2	1.3	2.7	2.5	3.2
Ca+Mg (me/100g)	0.1	0.1	<0.1	<0.1	<0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.50	0.59	0.47	0.92	0.75	0.97
Ca+Mg (me/l)	0.35	0.21	0.21	0.77	1.20	0.85
<u>EXCHANGEABLE SODIUM</u> (percent)	28.1	43.3	58.7	63.6	66.0	60.1
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	16.0	15.7	9.2	18.4	20.3	20.3
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.50	0.30	0.28	0.26	0.22	0.26
CADMIUM (Cd) (ppm)	0.66	0.64	0.72	0.30	0.16	0.31
COPPER (Cu) (ppm)	5.2	4.7	1.1	9.8	4.2	12.0
IRON (Fe) (ppm)	136.0	114.0	63.1	231.0	162.0	311.0
MERCURY (Hg) (ppm)	0.30	0.30	0.15	0.40	0.25	0.50
MANGANESE (Mn) (ppm)	26.3	18.0	8.5	48.8	21.9	51.6
MOLYBDENUM (Mo) (ppm)	0.6	0.4	0.3	1.0	0.9	0.8
NICKEL (Ni) (ppm)	4.8	4.0	6.3	3.4	2.8	4.0
LEAD (Pb) (ppm)	1.8	1.6	0.51	1.6	0.91	2.3
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	7.4	7.3	4.5	7.6	6.3	8.6

\*Insufficient Sample

Williston Study Area, North Dakota  
Geologic Drill Hole: 81-113 (cont'd)  
Location: 2500' N. & 10' E. of SW Corner, Sec. 14, T. 155 N., R. 100 W.  
Logged by: G. Taucher  
Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION		
	Data		
LABORATORY NUMBER	4,530	4,531	4,532
SACK NUMBER	113-13	113-14	113-15
DEPTH (FT)	228.0-230.0	255.6-257.6	283.0-285.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)			
Very Coarse Sand (2.0-1.0 mm)	0.0	0.7	0.0
Coarse Sand (1.0-0.5 mm)	0.0	0.2	0.1
Medium Sand (0.5-0.25 mm)	0.0	0.1	0.1
Fine Sand (0.25-0.10 mm)	0.1	0.3	0.3
Very Fine Sand (0.10-0.05 mm)	5.2	4.0	0.3
TOTAL SAND (2.0-0.05 mm)	5.3	5.3	0.8
SILT (0.05-0.002 mm)	61.7	64.8	39.8
CLAY (0.002 mm)	33.0	29.9	59.4
GRAVEL (percent)	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiCL	SiCL	C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)			
6th Hr.	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	400.0	22.0	420.0
<u>MOISTURE RETENTION</u> (%)			
1/3 bar	55.7	52.1	66.6
15 bar	23.0	31.8	28.2
<u>SOIL REACTION-pH</u>			
Paste	9.0	9.0	8.5
1:5 H <sub>2</sub> O	9.8	9.3	9.6
1:2 0.01 M CaCl <sub>2</sub>	-	-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	-	-	-
<u>SATURATION EXTRACT</u>			
Saturation Percentage	128.4	133.4	151.2
EC <sub>e</sub> @25°C (mmhos/cm)	2.03	2.00	2.90
Ca <sup>++</sup> (me/l)	0.2	0.2	0.3
Mg <sup>++</sup> (me/l)	0.1	0.1	0.2
Na <sup>++</sup> (me/l)	21.0	19.9	28.5
K <sup>+</sup> (me/l)	0.2	0.2	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.9	0.7	0.1
HCO <sub>3</sub> <sup>-</sup> (me/l)	11.8	7.9	8.4
Cl <sup>-</sup> (me/l)	0.2	0.2	0.5
SO <sub>4</sub> <sup>-</sup> (me/l)	7.5	11.5	19.5
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1
SAR (me/l)	54.2	51.4	57.0
Na (me/100g)	2.7	2.7	4.3
Ca+Mg (me/100g)	<0.1	<0.1	0.1
<u>1:5 EXTRACT</u>			
EC <sub>s</sub> @25°C (mmhos/cm)	0.80	1.00	1.29
Ca+Mg (me/l)	1.25	0.66	1.00
<u>EXCHANGEABLE SODIUM</u> (percent)	61.0	62.6	62.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	20.0	19.8	23.6
NaOAc@pH 8.2			
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.24	0.22	0.28
CADMIUM (Cd) (ppm)	0.64	0.81	0.60
COPPER (Cu) (ppm)	8.5	5.5	21.5
IRON (Fe) (ppm)	295.0	138.0	204.0
MERCURY (Hg) (ppm)	0.20	0.15	0.40
MANGANESE (Mn) (ppm)	56.0	28.6	62.7
MOLYBDENUM (Mo) (ppm)	0.9	0.7	2.1
NICKEL (Ni) (ppm)	3.7	2.2	7.7
LEAD (Pb) (ppm)	1.8	1.2	5.7
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	8.5	9.3	17.5

\*Insufficient Sample

Table 14  
Sheet 1

Williston Study Area, North Dakota  
Geologic Drill Hole: 81-114  
Location: 250' E. & 375' N. of SW Corner, Sec. 11, T. 154 N., R. 100 W.  
Logged by: F. Calcagno  
Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,469	4,470	4,471	4,472	4,473	4,474
SACK NUMBER	114-1	114-2	114-3	114-4	114-5	114-6
DEPTH (FT)	0-0.6	0.6-3.8	3.8-7.0	7.0-10.0	16.0-18.0	24.5-26.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	8.0	1.2	11.6	1.5	2.1	0.0
Coarse Sand (1.0-0.5 mm)	8.0	3.3	2.9	2.8	3.4	0.1
Medium Sand (0.5-0.25 mm)	11.3	6.1	6.2	4.6	6.7	0.2
Fine Sand (0.25-0.10 mm)	15.1	11.1	10.8	11.1	10.7	0.2
Very Fine Sand (0.10-0.05 mm)	10.9	11.1	10.9	11.5	10.9	0.3
TOTAL SAND (2.0-0.05 mm)	53.3	32.8	32.4	31.5	33.8	0.8
SILT (0.05-0.002 mm)	36.0	40.6	45.1	46.5	39.8	58.4
CLAY (0.002 mm)	10.7	26.6	22.5	22.0	26.4	40.8
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	FSL	L	L	L	L	SIC
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.28	0.10	0.20	0.12	0.08	0.00
24th Hr.	0.22	0.12	0.24	0.08	0.08	0.04
SETTLING VOLUME (ml)	21.0	24.0	24.0	25.0	27.0	45.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	22.2	27.6	25.3	25.2	25.4	32.3
15 bar	9.4	11.9	12.3	12.3	12.6	14.7
<u>SOIL REACTION-pH</u>						
Paste	7.4	8.3	8.0	7.7	7.7	8.0
1:5 H <sub>2</sub> O	7.9	9.0	8.5	8.3	8.5	8.5
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	50.5	49.4	52.4	52.2	53.5	67.8
EC <sub>e</sub> @25°C (mmhos/cm)	1.70	0.90	8.2	7.4	6.4	6.0
Ca <sup>++</sup> (me/l)	-	2.1	22.4	23.1	25.9	21.0
Mg <sup>++</sup> (me/l)	-	2.1	64.7	50.8	36.7	26.1
Na <sup>++</sup> (me/l)	1.68	4.1	37.8	33.2	26.0	29.8
K <sup>+</sup> (me/l)	-	0.3	1.0	1.1	1.3	1.0
CO <sub>3</sub> <sup>-</sup> (me/l)	-	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	-	4.0	2.1	1.3	1.6	1.6
Cl <sup>-</sup> (me/l)	-	0.5	3.1	3.2	2.0	0.3
SO <sub>4</sub> <sup>-</sup> (me/l)	-	4.0	120.0	103.0	72.5	61.0
NO <sub>3</sub> <sup>-</sup> (me/l)	-	0.1	0.1	5.6	14.5	17.1
SAR (me/l)	-	2.8	5.4	5.5	4.7	6.1
Na (me/100g)	0.1	0.2	2.0	1.7	1.4	2.0
Ca+Mg (me/100g)	-	0.2	4.6	3.9	3.3	3.2
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.60	0.24	2.8	2.82	1.81	1.30
Ca+Mg (me/l)	3.74	2.07	27.8	33.7	13.0	6.06
EXCHANGEABLE SODIUM (percent)	0.6	0.5	9.0	8.0	21.6	7.2
CATION EXCHANGE CAPACITY (me/100g)	18.3	18.3	17.8	22.6	15.3	15.3
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	1.74	3.86	1.24
CADMIUM (Cd) (ppm)	-	-	-	0.52	0.32	0.27
COPPER (Cu) (ppm)	-	-	-	2.7	2.6	2.9
IRON (Fe) (ppm)	-	-	-	31.9	38.8	26.1
MERCURY (Hg) (ppm)	-	-	-	0.15	0.15	0.20
MANGANESE (Mn) (ppm)	-	-	-	44.9	54.3	53.8
MOLYBDENUM (Mo) (ppm)	-	-	-	0.6	0.3	0.4
NICKEL (Ni) (ppm)	-	-	-	0.95	1.3	1.00
LEAD (Pb) (ppm)	-	-	-	1.3	1.5	2.4
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	5.1	3.2	1.8

\*Insufficient Sample

EMRIA-Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-114 (cont'd)  
 Location: 250' E. & 375' N. of SW Corner, Sec. 11, T. 154 N., R. 100 W.  
 Logged by: F. Calcagno  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABDRATORY NUMBER	4,475	4,476	4,477	4,478	4,479	4,480
SACK NUMBER	114-7	114-8	114-9	114-10	114-11	114-12
DEPTH (FT)	28.8-30.8	34.0-36.0	41.0-43.0	44.7-45.2	61.0-63.0	85.0-87.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	10.0	0.0	0.1	0.1
Coarse Sand (1.0-0.5 mm)	0.0	0.3	0.0	0.1	0.1	0.4
Medium Sand (0.5-0.25 mm)	0.1	0.3	0.1	0.2	0.1	0.1
Fine Sand (0.25-0.10 mm)	0.6	0.6	0.6	0.4	0.0	0.0
Very Fine Sand (0.10-0.05 mm)	30.3	1.1	11.8	1.1	0.1	0.2
TOTAL SAND (2.0-0.05 mm)	31.0	2.3	12.5	1.8	0.4	0.8
SILT (0.05-0.002 mm)	61.1	63.8	63.3	59.2	83.7	73.4
CLAY (0.002 mm)	7.9	33.9	24.2	39.0	15.9	25.8
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SiCL	SiL	SiCL	SiL	SiL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.14	0.08	0.20	0.00	0.00	0.00
24th Hr.	0.16	0.14	0.22	0.00	0.02	0.14
<u>SETTLING VOLUME</u> (ml)	20	38	30	45	34	36
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	17.6	34.2	33.4	-	31.9	32.2
15 bar	4.2	14.9	15.9	-	6.4	12.7
<u>SOIL REACTION-pH</u>						
Paste	8.5	7.7	7.6	7.5	8.4	7.9
1:5 H <sub>2</sub> O	9.0	8.2	7.9	8.0	9.2	8.5
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	45.3	61.0	56.6	60.9	53.1	58.4
EC <sub>e</sub> @25°C (mmhos/cm)	3.2	5.7	7.4	4.3	2.6	1.76
Ca <sup>++</sup> (me/l)	5.9	16.0	26.4	0.00	3.1	4.5
Mg <sup>++</sup> (me/l)	9.1	24.2	35.8	0.00	6.1	6.3
Na <sup>++</sup> (me/l)	20.5	30.7	36.5	26.9	19.5	8.3
K <sup>+</sup> (me/l)	0.7	1.2	1.1	0.00	0.7	1.2
CO <sub>3</sub> <sup>-</sup> (me/l)	0.4	0.0	0.0	0.00	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	2.0	4.0	3.1	0.00	2.4	5.4
Cl <sup>-</sup> (me/l)	0.0	<0.1	<0.1	0.00	0.4	0.0
SO <sub>4</sub> <sup>-</sup> (me/l)	25.7	51.4	80.0	0.00	23.5	13.2
NO <sub>3</sub> <sup>-</sup> (me/l)	6.9	17.9	20.3	0.00	1.5	0.1
SAR (me/l)	7.5	6.9	6.5	0.00	9.1	3.6
Na (me/100g)	0.9	1.9	2.1	1.6	1.0	0.5
Ca+Mg (me/100g)	0.7	2.5	3.5	0.00	0.5	0.6
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.61	1.15	1.84	0.75	0.41	0.42
Ca+Mg (me/l)	2.35	5.34	13.7	2.28	0.85	1.89
<u>EXCHANGEABLE SODIUM</u> (percent)	10.0	7.8	6.7	8.1	16.7	7.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	7.0	18.0	17.8	21.0	6.6	13.0
NaDac@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.92	1.64	2.22	0.58	0.64	0.76
CADMIUM (Cd) (ppm)	<0.1	0.66	1.05	0.67	0.33	0.51
COPPER (Cu) (ppm)	2.3	7.3	10.0	6.1	0.9	6.5
IRON (Fe) (ppm)	15.6	74.3	108.0	78.5	21.2	185.0
MERCURY (Hg) (ppm)	0.10	0.25	0.30	0.25	0.15	0.30
MANGANESE (Mn) (ppm)	13.4	32.8	20.9	1.0	20.5	47.7
MOLYBDENUM (Mo) (ppm)	0.1	0.4	0.3	0.2	0.2	0.5
NICKEL (Ni) (ppm)	0.32	2.7	3.8	0.61	0.15	3.1
LEAD (Pb) (ppm)	1.2	2.9	2.3	4.8	1.2	3.1
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	1.0	5.2	5.4	2.1	0.5	9.3

\*Insufficient Sample

Table 14  
Sheet 3

EMRIA-Williston Study Area, North Dakota  
Geologic Drill Hole: 81-114 (cont'd)  
Location: 250' E. & 375' N. of SW Corner, Sec. 11, T. 154 N., R. 100 W.  
Logged by: F. Calcagno  
Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,481	4,482	4,483	4,484	4,484	4,486
SACK NUMBER	114-13	114-14	114-15	114-16	114-17	114-18
DEPTH (FT)	94.0-96.0	99.0-101.0	110.0-112.0	114.7-116.7	130.0-132.0	153.0-155.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.2	0.1	0.1	0.5	0.2	0.1
Coarse Sand (1.0-0.5 mm)	0.4	0.4	0.1	0.5	0.0	0.0
Medium Sand (0.5-0.25 mm)	0.3	0.2	0.3	0.6	0.0	0.1
Fine Sand (0.25-0.10 mm)	0.8	0.1	0.4	0.4	0.0	0.1
Very Fine Sand (0.10-0.05 mm)	10.3	0.2	0.6	6.7	0.0	1.1
TOTAL SAND (2.0-0.05 mm)	12.0	1.0	1.5	10.7	0.2	1.4
SILT (0.05-0.002 mm)	71.6	66.5	68.5	81.5	64.7	58.6
CLAY (0.002 mm)	16.4	32.5	30.0	7.8	35.1	40.0
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAS)	SIL	SICL	SICL	S1	SICL	SICL-Sic
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.02	0.02	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	38	125	75	34	155	400
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	38.4	44.4	33.9	40.2	36.9	61.9
15 bar	15.7	23.7	13.6	14.7	17.4	32.4
<u>SOIL REACTION-pH</u>						
Paste	8.3	8.3	7.5	6.9	8.6	8.9
1:5 H <sub>2</sub> O	9.1	9.3	8.5	8.0	9.9	10.0
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	67.7	110.2	69.5	70.3	72.7	136.5
EC <sub>e</sub> @25°C (mmhos/cm)	2.0	1.95	8.9	11.3	2.90	2.05
Ca <sup>++</sup> (me/l)	1.5	0.8	20.5	19.5	0.5	0.6
Mg <sup>++</sup> (me/l)	0.5	0.5	13.3	20.30	0.2	0.3
Na <sup>++</sup> (me/l)	17.6	18.2	70.6	83.5	27.3	19.4
K <sup>+</sup> (me/l)	0.6	0.4	1.4	1.2	0.4	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.00	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	8.8	6.7	3.3	7.6	9.4	7.8
Cl <sup>-</sup> (me/l)	0.2	0.1	0.2	0.4	0.3	0.2
SO <sub>4</sub> <sup>-</sup> (me/l)	10.8	13.5	103.0	114.0	20.0	11.8
NO <sub>3</sub> <sup>-</sup> (me/l)	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	17.6	22.6	17.2	18.7	46.1	28.9
Na (me/100g)	1.2	2.0	4.9	5.9	2.0	2.6
Ca+Mg (me/100g)	0.1	0.1	2.3	2.8	0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.39	0.51	1.29	1.74	0.88	0.94
Ca+Mg (me/l)	0.52	0.46	2.08	3.95	0.37	0.37
<u>EXCHANGEABLE SODIUM</u> (percent)	20.7	31.3	24.2	30.6	54.6	66.2
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	17.9	17.9	12.4	21.6	9.3	19.8
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.48	0.48	1.00	2.98	0.50	0.52
CADMIUM (Cd) (ppm)	0.16	0.78	0.43	0.74	0.45	0.41
COPPER (Cu) (ppm)	6.3	7.7	9.3	6.5	6.4	13.7
IRON (Fe) (ppm)	239.0	283.0	89.3	160.0	254.0	202.0
MERCURY (Hg) (ppm)	0.25	0.20	0.30	0.50	0.30	0.25
MANGANESE (Mn) (ppm)	45.4	61.2	62.8	22.5	64.3	33.1
MOLYBDENUM (Mo) (ppm)	0.5	0.5	0.3	1.4	0.3	0.8
NICKEL (Ni) (ppm)	3.2	1.3	3.2	4.5	1.7	6.0
LEAD (Pb) (ppm)	2.4	1.4	2.8	2.0	3.4	6.9
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	9.6	6.1	12.8	19.3	6.5	9.4

\*Insufficient Sample

Table 14  
Sheet 4

Williston Study Area, North Dakota  
Geologic Drill Hole: 81-114 (cont'd)  
Location: 250' E. & 375' N. of SW Corner, Sec. 11, T. 154 N., R. 100 W.  
Logged by: F. Calcagno  
Date: August 1981

	LABORATORY DESCRIPTION					
	OaTa					
LABORATORY NUMBER	4,487	4,488	4,489	4,490	4,491	4,492
SACK NUMBER	114-19	114-20	114-21	114-22	114-23	114-24
DEPTH (FI)	164.5-166.1	169.3-171.3	182.1-184.1	186.0-187.2	193.0-195.0	202.0-204.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.1	4.5	0.0	Hard	0.6	0.0
Coarse Sand (1.0-0.5 mm)	0.1	0.6	0.0	Sample	0.3	0.1
Medium Sand (0.5-0.25 mm)	0.1	0.2	0.0	Not	0.5	0.1
Fine Sand (0.25-0.10 mm)	12.5	0.4	0.1	Analyzed	0.6	0.0
Very Fine Sand (0.10-0.05 mm)	41.3	3.2	4.9		0.6	0.0
TOTAL SAND (2.0-0.05 mm)	54.1	8.9	5.0		2.6	0.3
SILT (0.05-0.002 mm)	28.9	65.4	75.4		48.8	62.1
CLAY (0.002 mm)	17.0	25.7	19.6		48.6	37.6
GRAVEL (percent)	-	-	-		-	-
<u>TEXTURAL CLASS (LAB)</u>	VFSL	SIL	SIL		SIC	SiCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00		0.00	0.00
24th Hr.	0.00	0.00	0.00		0.00	0.00
<u>SETTLING VOLUME</u> (ml)	275.0	400.0	275.0		340.0	350.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	53.0	61.5	50.2		53.8	47.2
15 bar	33.8	32.7	33.6		25.3	31.0
<u>SOIL REACTION-pH</u>						
Paste	9.5	9.0	8.9		7.8	8.8
1:5 H <sub>2</sub> O	10.3	9.9	9.8		9.4	9.9
1:2 0.01 M CaCl <sub>2</sub>	-	-	-		-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	-	-	-		-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	128.8	154.3	113.4		148.2	136.6
EC <sub>e</sub> @25°C (mmhos/cm)	1.39	1.80	1.88		4.1	1.90
Ca <sup>++</sup> (me/l)	0.2	0.2	0.3		1.1	0.2
Mg <sup>++</sup> (me/l)	<0.1	0.1	<0.1		1.1	0.1
Na <sup>++</sup> (me/l)	13.6	17.4	18.5		40.4	18.4
K <sup>+</sup> (me/l)	0.2	0.1	0.2		0.6	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	4.1	1.2	1.2		0.0	0.8
HCO <sub>3</sub> <sup>-</sup> (me/l)	15.6	7.7	7.7		8.9	8.5
Cl <sup>-</sup> (me/l)	0.2	0.1	0.1		0.2	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	3.0	9.3	9.3		35.0	9.5
NO <sub>3</sub> <sup>-</sup> (me/l)	1.1	<0.1	<0.1		<0.1	<0.1
SAR (me/l)	43.0	44.9	47.8		38.5	47.5
Na (me/100g)	1.8	2.7	2.1		6.0	2.5
Ca+Mg (me/100g)	<0.1	<0.1	<0.1		0.3	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.77	0.95	0.89		0.98	0.88
Ca+Mg (me/l)	0.17	0.08	0.21		0.85	0.31
<u>EXCHANGEABLE SODIUM</u> (percent)	72.4	62.2	60.0		44.4	59.9
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	15.6	21.4	18.5		21.4	16.2
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1		<0.1	<0.1
BORON (B) (ppm)	0.48	0.20	0.50		0.36	0.22
CADMIUM (Cd) (ppm)	0.52	0.60	0.22		0.72	<0.1
COPPER (Cu) (ppm)	2.5	8.7	7.4		18.9	6.4
IRON (Fe) (ppm)	50.1	181.0	198.0		402.0	229.0
MERCURY (Hg) (ppm)	0.20	0.35	0.25		0.35	0.30
MANGANESE (Mn) (ppm)	9.3	29.3	40.3		55.1	55.7
MOLYBDENUM (Mo) (ppm)	0.3	0.9	0.6		1.4	0.9
NICKEL (Ni) (ppm)	1.1	5.6	5.6		6.5	1.6
LEAD (Pb) (ppm)	1.8	3.2	5.6		6.5	1.6
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05		<0.05	<0.05
ZINC (Zn) (ppm)	9.6	9.9	8.5		10.8	6.5

\*Insufficient Sample

Table 14  
Sheet 5

EMRIA-Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-114 (cont'd)  
 Location: 250' E. & 375' N. of SW Corner, Sec. 11, T. 154 N., R. 100 W.  
 Logged by: F. Calcagno  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	4,493	4,494	4,495	4,496	4,497
SACK NUMBER	114-25	114-26	114-27	114-28	114-29
DEPTH (FT)	207.0-209.0	213.0-215.0	243.3-245.3	253-244	258-259
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand (2.0-1.0 mm)	Hard	1.3	0.7	0.1	0.0
Coarse Sand (1.0-0.5 mm)	Sample	0.5	1.1	0.0	0.0
Medium Sand (0.5-0.25 mm)	Not	0.2	0.7	0.0	0.0
Fine Sand (0.25-0.10 mm)	Analyzed	0.4	0.5	0.1	0.6
Very Fine Sand (0.10-0.05 mm)		20.7	0.2	7.2	30.7
TOTAL SAND (2.0-0.05 mm)		23.1	3.2	7.4	31.3
SILT (0.05-0.002 mm)		56.1	59.8	58.6	46.7
CLAY (0.002 mm)		20.8	37.0	34.0	22.0
GRAVEL (percent)		-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>					
		SIL	StCL	SICL	L
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.		0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)					
		340.	250.	325.	390.
<u>MOISTURE RETENTION</u> (%)					
1/3 bar		53.5	69.5	62.6	57.8
15 bar		34.1	30.4	32.9	36.1
<u>SOIL REACTION-pH</u>					
Paste		9.0	8.4	9.2	9.3
1:5 H <sub>2</sub> O		10.0	9.6	10.0	10.2
1:2 0.01 M CaCl <sub>2</sub>		-	-	-	-
<u>GYPSPUM REQUIREMENT</u> (me/100g)					
		-	-	-	-
<u>SATURATION EXTRACT</u>					
Saturation Percentage		141.4	150.0	146.7	141.0
EC <sub>e</sub> @25°C (mmhos/cm)		1.48	2.21	1.72	1.88
Ca <sup>++</sup> (me/l)		0.2	0.4	0.3	0.2
Mg <sup>++</sup> (me/l)		0.1	<0.1	<0.1	0.1
Na <sup>++</sup> (me/l)		14.3	22.2	17.3	17.4
K <sup>+</sup> (me/l)		0.1	0.3	0.2	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)		0.9	0.5	2.6	1.9
HCO <sub>3</sub> <sup>-</sup> (me/l)		7.4	11.0	8.8	5.9
Cl <sup>-</sup> (me/l)		0.1	0.2	0.1	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)		6.5	11.0	6.3	9.5
NO <sub>3</sub> <sup>-</sup> (me/l)		0.2	<0.1	<0.1	0.3
SAR (me/l)		36.9	49.6	44.7	44.9
Na (me/100g)		2.0	3.3	2.5	2.5
Ca+Mg (me/100g)		<0.1	0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>					
EC <sub>s</sub> @25°C (mmhos/cm)		0.89	0.79	0.90	0.86
Ca+Mg (me/l)		0.42	0.48	0.42	0.64
<u>EXCHANGEABLE SODIUM</u> (percent)					
		77.3	65.1	68.6	66.0
<u>CATION EXCHANGE CAPACITY</u> (me/100g)					
NaOAc@pH 8.2		15.4	25.8	23.6	19.4
<u>SILVER (Ag) (ppm)</u>					
		<0.1	<0.1	<0.1	<0.1
<u>BORON (B) (ppm)</u>					
		0.38	0.90	0.28	0.28
<u>CADMIUM (Cd) (ppm)</u>					
		0.57	<0.1	0.53	0.73
<u>COPPER (Cu) (ppm)</u>					
		6.9	16.2	12.4	5.2
<u>IRON (Fe) (ppm)</u>					
		188.0	66.4	55.2	77.7
<u>MERCURY (Hg) (ppm)</u>					
		0.25	0.35	0.35	0.25
<u>MANGANESE (Mn) (ppm)</u>					
		31.0	2.6	12.5	15.3
<u>MOLYBDENUM (Mo) (ppm)</u>					
		0.6	0.2	0.6	1.3
<u>NICKEL (Ni) (ppm)</u>					
		4.4	0.92	2.7	1.8
<u>LEAD (Pb) (ppm)</u>					
		2.7	9.7	8.4	2.5
<u>SELENIUM (Se) (ppm)</u>					
		<0.05	<0.05	<0.05	<0.05
<u>ZINC (Zn) (ppm)</u>					
		11.4	14.2	13.1	14.2

\*Insufficient Sample

Table 15  
Sheet 1

Williston Study Area, North Dakota  
Geologic Drill Hole: 81-117  
Location: 2500' S. & 115' W. of NE Corner, Sec. 34, T. 156 N., R. 97 W.,  
Logged by: L. Parish  
Date: July 1981

	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	21,236	21,237	21,238	21,239	21,240
SACK NUMBER	117-1	117-2	117-3	117-4	117-5
DEPTH (FT)	0.0-0.33	0.33-3.2	3.2-9.0	9.0-47.5	47.5-68.8
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand (2.0-1.0 mm)			11.3		
Coarse Sand (1.0-0.5 mm)			15.1		
Medium Sand (0.5-0.25 mm)			15.6		
Fine Sand (0.25-0.10 mm)			32.2		
Very Fine Sand (0.10-0.05 mm)			10.5		
TOTAL SAND (2.0-0.05 mm)	38.1	23.3	34.7	84.7	18.6
SILT (0.05-0.002 mm)	36.5	36.4	36.9	11.1	50.1
CLAY (0.002 mm)	25.4	29.3	28.4	4.2	31.3
GRAVEL (percent)	-	-	14.2	-	-
<u>TEXTURAL CLASS (LAB)</u>	L	CL	CL	LCOS	SlCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.	*	0.04	0.04	0.47	0.04
24th Hr.	*	0.04	0.04	0.51	0.04
<u>SETTLING VOLUME</u> (ml)	28	25	26	16	28
<u>MOISTURE RETENTION</u> (%)					
1/3 bar	-	-	-	-	-
15 bar	*	14.0	13.8	2.5	16.0
<u>SOIL REACTION-pH</u>					
Paste					
1:5 H <sub>2</sub> O	8.6	9.1	8.9	9.1	8.6
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	-1.39	-0.48	+7.6	-0.39	-0.21
<u>SATURATION EXTRACT</u>					
Saturation Percentage	44.1	49.7	50.0	20.7	58.8
EC <sub>e</sub> @25°C (mmhos/cm)	1.02	0.65	0.71	1.61	0.77
Ca <sup>++</sup> (me/l)	7.25	1.59	1.04	10.09	4.89
Mg <sup>++</sup> (me/l)	3.53	3.71	1.99	4.16	2.26
Na <sup>++</sup> (me/l)	1.53	1.39	4.45	3.54	0.96
K <sup>+</sup> (me/l)	0.05	0.04	0.05	0.07	0.07
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	6.75	3.94	3.85	2.19	4.27
Cl <sup>-</sup> (me/l)	0.44	0.94	0.31	1.75	0.23
SO <sub>4</sub> <sup>-</sup> (me/l)	2.54	0.66	1.59	12.74	1.98
NO <sub>3</sub> <sup>-</sup> (me/l)	1.00	0.44	0.36	0.26	0.18
SAR (me/l)	0.66	0.85	3.60	1.30	0.51
Na (me/100g)	0.07	0.06	0.20	0.16	0.06
Ca+Mg (me/100g)	0.48	0.23	0.13	0.63	0.42
<u>1:5 EXTRACT</u>					
EC <sub>5</sub> @25°C (mmhos/cm)	0.14	0.17	0.20	0.15	0.20
Ca+Mg (me/l)	1.14	1.27	0.91	0.94	2.40
<u>EXCHANGEABLE SODIUM</u> (percent)	0.63	1.09	4.12	0.47	0.43
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	23.40	22.93	20.22	5.00	28.91
NaOAc@pH 8.2					
SILVER (Ag) (ppm)	-	-	-	-	-
BORON (B) (ppm)	0.39	0.79	1.56	0.79	0.25
CAESIUM (Cs) (ppm)	*	0.04	0.06	0.04	0.06
COPPER (Cu) (ppm)	*	2.8	2.4	1.2	7.8
IRON (Fe) (ppm)	*	32.0	32.6	28.6	51.4
MERCURY (Hg) (ppm)	*	0.04	0.04	0.03	0.05
MANGANESE (Mn) (ppm)	*	18.6	15.4	7.8	33.2
MOLYBDENUM (Mo) (ppm)	*	0.20	0.58	0.15	0.51
NICKEL (Ni) (ppm)	*	0.6	0.4	0.4	1.0
LEAD (Pb) (ppm)	*	1.0	0.8	0.6	2.8
SELENIUM (Se) (ppm)	-	-	-	-	-
ZINC (Zn) (ppm)	*	1.64	1.10	0.78	1.40

\*Insufficient Sample

Table 15  
Sheet 2

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-117 (cont'd)  
 Location: 2500' S. & 115' W. of NE Corner, Sec. 34, T. 156 N., R. 97 W.  
 Logged by: L. Parish  
 Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	21,241	21,242	21,243	21,244	21,245
SACK NUMBER	117-6	117-7	117-8	117-9	117-10
DEPTH (FT)	91.8-100.5	100.5-110.0	120.0-116.5	116.5-121.6	121.6-129.0
<b>PARTICLE SIZE ANALYSIS</b> (percent)					
Very Coarse Sand (2.0-1.0 mm)		0.2		0.4	
Coarse Sand (1.0-0.5 mm)		0.2		0.5	
Medium Sand (0.5-0.25 mm)		1.8		0.4	
Fine Sand (0.25-0.10 mm)		32.9		19.0	
Very Fine Sand (0.10-0.05 mm)		23.3		27.3	
TOTAL SAND (2.0-0.05 mm)	17.2	58.4	7.3	47.6	1.3
SILT (0.05-0.002 mm)	63.6	37.9	65.1	44.4	56.8
CLAY (0.002 mm)	19.2	3.7	27.6	8.0	41.9
GRAVEL (percent)	-	-	-	-	-
<b>TEXTURAL CLASS (LAB)</b>					
HYDRAULIC CONDUCTIVITY (in/hr)	S4L	FSL	S1CL	L	S1C
6th Hr.	0.08	0.37	0.04	0.24	0.04
24th Hr.	0.06	0.39	0.04	0.26	0.04
SETTLING VOLUME (ml)	26	21	35	22	40
<b>MOISTURE RETENTION</b> (%)					
1/3 bar	-	-	-	-	-
15 bar	14.8	9.0	21.1	11.0	25.6
<b>SOIL REACTION-pH</b>					
Paste					
1:5 H <sub>2</sub> O	8.4	8.9	9.0	8.9	8.4
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-
<b>GYPHUM REQUIREMENT</b> (me/100g)					
	-0.50	-0.80	+0.47	-0.11	-0.57
<b>SATURATION EXTRACT</b>					
Saturation Percentage	61.9	42.1	75.8	48.0	90.8
EC <sub>e</sub> @25°C (mmhos/cm)	0.47	0.57	0.42	0.51	0.84
Ca <sup>++</sup> (me/l)	1.87	2.25	1.54	1.92	3.62
Mg <sup>++</sup> (me/l)	1.81	2.26	1.54	1.72	3.08
Na <sup>++</sup> (me/l)	0.91	1.20	0.96	1.34	1.91
K <sup>+</sup> (me/l)	0.04	0.03	0.04	0.03	0.07
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	2.27	1.53	1.96	1.94	2.24
Cl <sup>-</sup> (me/l)	0.29	0.36	0.13	0.23	0.20
SO <sub>4</sub> <sup>-</sup> (me/l)	1.23	2.29	1.23	1.94	2.56
NO <sub>3</sub> <sup>-</sup> (me/l)	0.24	0.24	0.20	0.28	0.12
SAR (me/l)	0.67	0.80	0.77	0.99	1.00
Na (me/100g)	0.06	0.05	0.07	0.06	0.17
Ca+Mg (me/100g)	0.23	0.19	0.23	0.17	0.61
<b>1:5 EXTRACT</b>					
EC <sub>5</sub> @25°C (mmhos/cm)	0.14	0.10	0.14	0.12	0.26
Ca+Mg (me/l)	0.98	0.74	0.98	0.83	1.55
<b>EXCHANGEABLE SODIUM</b> (percent)					
	0.75	2.79	1.55	1.38	1.73
<b>CATION EXCHANGE CAPACITY</b> (me/100g)					
NaOAc@pH 8.2	25.98	17.50	30.11	21.30	27.93
<b>Trace Elements</b>					
SILVER (Ag) (ppm)	-	-	-	-	-
BORON (B) (ppm)	0.93	1.18	1.22	1.31	1.72
CADMIUM (Cd) (ppm)	0.04	0.04	0.04	0.04	0.10
COPPER (Cu) (ppm)	1.4	0.6	1.8	1.2	6.2
IRON (Fe) (ppm)	15.0	14.8	18.4	16.6	53.8
MERCURY (Hg) (ppm)	0.08	0.04	0.07	0.05	0.06
MANGANESE (Mn) (ppm)	3.4	9.2	8.4	2.0	19.6
MOLYBDENUM (Mo) (ppm)	0.07	0.00	0.07	0.13	0.57
NICKEL (Ni) (ppm)	0.2	0.4	0.4	0.4	3.2
LEAD (Pb) (ppm)	0.8	0.4	1.0	0.6	5.0
SELENIUM (Se) (ppm)	-	-	-	-	-
ZINC (Zn) (ppm)	0.50	0.46	0.74	0.74	4.66

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-117 (cont'd)  
 Location: 2500' S. & 115' W. of NE Corner, Sec. 34, T. 156 N., R. 97 W.  
 Logged by: L. Parish  
 Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	21,246	21,247	21,248	21,249	21,250
SACK NUMBER	117-11	117-12	117-13	117-14	117-15
DEPTH (FT)	130.0-144.0	144.0-164.0	164.0-205.0	205.0-239.0	244.3-266.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand (2.0-1.0 mm)	0.2	-	0.1	0.1	-
Coarse Sand (1.0-0.5 mm)	0.3	-	1.0	1.6	-
Medium Sand (0.5-0.25 mm)	0.2	-	8.3	28.1	-
Fine Sand (0.25-0.10 mm)	7.8	-	56.1	45.5	-
Very Fine Sand (0.10-0.05 mm)	37.9	-	14.9	6.7	-
TOTAL SAND (2.0-0.05 mm)	46.4	2.2	80.4	82.0	2.0
SILT (0.05-0.002 mm)	46.2	69.0	11.4	13.9	63.7
CLAY (0.002 mm)	7.4	28.2	8.2	4.1	34.3
GRAVEL (percent)					
TEXTURAL CLASS (LAB)	L	SiCL	LFS	LS	SiCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.	0.08	0.04	0.79	0.71	0.00
24th Hr.	0.06	Tr.	0.79	0.67	0.00
<u>SETTLING VOLUME</u> (ml)	23	32	20	18	40
<u>MOISTURE RETENTION</u> (%)					
1/3 bar	-	-	-	-	-
15 bar	14.2	20.6	6.0	5.1	22.2
<u>SOIL REACTION-pH</u>					
Paste					
1:5 H <sub>2</sub> O	8.8	8.6	9.2	9.3	9.0
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	-0.84	-1.60	-0.40	+1.45	+3.22
<u>SATURATION EXTRACT</u>					
Saturation Percentage	48.6	68.2	37.5	32.3	79.9
EC <sub>e</sub> @25°C (mmhos/cm)	1.81	1.81	1.36	1.70	1.62
Ca <sup>++</sup> (me/l)	9.22	8.67	3.29	3.95	0.93
Mg <sup>++</sup> (me/l)	8.68	8.14	3.26	4.16	1.18
Na <sup>++</sup> (me/l)	3.11	3.35	7.84	9.52	13.97
K <sup>+</sup> (me/l)	0.09	0.11	0.05	0.08	0.07
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.05
HCO <sub>3</sub> <sup>-</sup> (me/l)	2.59	2.30	1.86	2.83	4.93
Cl <sup>-</sup> (me/l)	0.20	0.37	0.37	0.37	0.12
SO <sub>4</sub> <sup>-</sup> (me/l)	17.78	17.28	11.39	13.49	9.58
NO <sub>3</sub> <sup>-</sup> (me/l)	0.16	0.20	0.16	0.28	0.10
SAR (me/l)	1.00	1.20	4.30	4.70	14.00
Na (me/100g)	0.15	0.23	0.24	0.31	1.09
Ca+Mg (me/100g)	0.87	1.15	0.25	0.26	0.16
<u>1:5 EXTRACT</u>					
EC <sub>s</sub> @25°C (mmhos/cm)	0.29	0.39	0.21	0.20	0.41
Ca+Mg (me/l)	1.90	2.58	0.66	0.59	0.62
<u>EXCHANGEABLE SODIUM</u> (percent)	1.77	1.94	6.43	8.63	14.90
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	19.13	23.37	10.11	7.93	22.39
NaOAc@pH 8.2					
SILVER (Ag) (ppm)	-	-	-	-	-
BORON (B) (ppm)	1.25	1.22	1.25	1.09	2.79
CADMIUM (Cd) (ppm)	0.08	0.04	0.04	0.04	0.10
COPPER (Cu) (ppm)	1.0	2.6	1.8	4.6	8.8
IRON (Fe) (ppm)	22.4	40.4	47.2	58.2	35.8
MERCURY (Hg) (ppm)	0.06	0.08	0.05	0.05	0.09
MANGANESE (Mn) (ppm)	3.6	10.6	6.2	5.2	5.8
MOLYBDENUM (Mo) (ppm)	0.11	0.22	0.31	0.17	0.31
NICKEL (Ni) (ppm)	1.0	1.0	0.6	1.8	6.6
LEAD (Pb) (ppm)	1.8	3.0	0.8	2.4	6.8
SELENIUM (Se) (ppm)	-	-	-	-	-
ZINC (Zn) (ppm)	3.98	2.30	1.50	3.38	4.70

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-117 (cont'd)  
 Location: 2500' S. & 115' W. of NE Corner, Sec. 34, T. 156 N., R. 97 W.  
 Logged by: L. Parish  
 Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	21,251	21,252	21,253	21,254	
SACK NUMBER	117-16	117-17	117-18	117-19	
DEPTH (FT)	266.0-279.4	279.4-288.0	288.0-315.1	333.2-349.0	
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	4.4	16.1	1.3	5.8
SILT	(0.05-0.002 mm)	67.8	62.2	62.7	62.0
CLAY	(0.002 mm)	27.8	21.7	36.0	32.2
GRAVEL	(percent)	-	-	-	-
TEXTURAL CLASS (LAB)		SiCL	SiL	SiCL	SiCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.		0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	84	96	132	156
<u>MOISTURE RETENTION</u> (%)					
1/3 bar		-	-	-	-
15 bar		21.4	33.7	30.7	33.4
<u>SOIL REACTION-pH</u>					
Paste					
1:5 H <sub>2</sub> O		9.3	9.5	9.7	9.8
1:2 0.01 M CaCl <sub>2</sub>		-	-	-	-
GYPSUM REQUIREMENT	(me/100g)	+6.10	+8.20	+9.20	+9.10
<u>SATURATION EXTRACT</u>					
Saturation Percentage		101.7	94.3	93.7	67.5
EC <sub>e</sub> @25°C	(mmhos/cm)	1.62	1.50	1.95	2.50
Ca <sup>++</sup>	(me/l)	0.38	0.27	0.27	0.38
Mg <sup>++</sup>	(me/l)	0.36	0.27	0.27	0.18
Na <sup>++</sup>	(me/l)	15.88	15.35	20.37	27.02
K <sup>+</sup>	(me/l)	0.05	0.05	0.05	0.05
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.09	0.30	0.55	0.80
HCO <sub>3</sub> <sup>-</sup>	(me/l)	6.45	7.36	10.74	13.25
Cl <sup>-</sup>	(me/l)	0.15	0.17	0.19	0.42
SO <sub>4</sub> <sup>-</sup>	(me/l)	8.22	6.25	7.29	11.76
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.11	0.09	0.03	0.01
SAR	(me/l)	26.00	29.00	39.00	51.00
Na	(me/100g)	1.36	1.32	1.75	1.82
Ca+Mg	(me/100g)	0.06	0.05	0.05	0.04
<u>1:5 EXTRACT</u>					
EC <sub>5</sub> @25°C	(mmhos/cm)	0.53	0.51	0.64	0.69
Ca+Mg	(me/l)	1.59	1.07	1.28	0.99
EXCHANGEABLE SODIUM	(percent)	33.85	41.87	31.24	52.30
CATION EXCHANGE CAPACITY	(me/100g)	25.11	19.78	29.67	16.63
NaOAc@pH 8.2					
SILVER (Ag)	(ppm)	-	-	-	-
BORON (B)	(ppm)	1.88	1.79	1.31	1.81
CADMIUM (Cd)	(ppm)	0.10	0.06	0.12	0.08
COPPER (Cu)	(ppm)	7.8	5.0	7.8	3.4
IRON (Fe)	(ppm)	78.4	87.0	158.0	125.8
MERCURY (Hg)	(ppm)	0.07	0.07	0.06	0.08
MANGANESE (Mn)	(ppm)	12.8	8.8	19.0	27.8
MOLYBDENUM (Mo)	(ppm)	0.71	0.66	0.87	1.78
NICKEL (Ni)	(ppm)	6.6	4.0	6.6	3.8
LEAD (Pb)	(ppm)	4.4	2.4	3.6	3.8
SELENIUM (Se)	(ppm)	-	-	-	-
ZINC (Zn)	(ppm)	4.70	4.00	5.58	5.00

\*Insufficient Sample

Table 16  
Sheet 1

Williston Study Area North Dakota  
 Geologic Drill Hole: 81-121  
 Location: 76' E. & 25' N. of SW Corner, Sec. 22, T. 155 N., R. 96 W. ,  
 Logged by: C. Botdorf  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
	21,552	21,553	21,554	21,555	21,556	21,557
LABORATORY NUMBER	G-1	G-2	G-3	G-4	G-5	121-1
SACK NUMBER						
DEPTH ( FT)	0.0-1.2	1.2-2.5	2.5-5.0	5.0-7.5	7.5-10.0	10.0-12.5
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	9.7	12.0	7.6	6.4	11.6	-
Coarse Sand (1.0-0.5 mm)	12.8	14.6	12.5	11.3	20.0	-
Medium Sand (0.5-0.25 mm)	12.5	14.3	12.4	11.8	17.3	-
Fine Sand (0.25-0.10 mm)	23.1	26.1	24.7	25.8	21.3	-
Very Fine Sand (0.10-0.05 mm)	7.7	9.6	10.9	12.0	7.0	-
TOTAL SAND (2.0-0.05 mm)	65.8	76.6	68.1	67.3	77.2	1.5
SILT (0.05-0.002 mm)	22.1	14.5	18.9	19.5	15.6	65.0
CLAY (0.002 mm)	12.1	8.9	13.0	13.2	7.2	33.5
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SL	CoSL	SL	FSL	CoSL	SiCL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.10	0.08	0.20	0.26	0.33	Trace
24th Hr.	0.08	0.16	0.18	0.28	0.30	0.02
SETTLING VOLUME (ml)	17.0	16.0	18.0	18.0	16.0	43.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	-	-	-	-	-	-
15 bar	6.8	4.1	6.3	-	4.6	20.3
<b>SOIL REACTION-pH</b>						
Paste	7.9	8.1	8.1	8.3	8.2	8.1
1:5 H <sub>2</sub> O	8.1	8.8	9.1	9.0	8.9	8.9
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	0.3	-1.8	2.9	0.6	0.6	-1.0
<b>SATURATION EXTRACT</b>						
Saturation Percentage	19.1	13.9	17.1	19.2	13.4	61.0
EC <sub>e</sub> @25°C (mmhos/cm)	2.7	1.91	0.97	0.99	1.26	0.95
Ca++ + Mg++ (me/l)	30.6	20.8	8.8	8.0	10.1	2.4
Mg++ (me/l)	-	-	-	-	-	-
Na++ (me/l)	1.3	1.0	0.7	1.7	2.6	6.2
K+ (me/l)	0.7	0.5	0.4	0.3	0.3	0.2
CO <sub>3</sub> - (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> - (me/l)	7.2	4.8	4.6	4.4	6.1	2.6
Cl- (me/l)	1.2	1.1	0.9	0.6	2.3	0.6
SO <sub>4</sub> - (me/l)	20.0	16.0	2.9	3.0	3.4	5.2
NO <sub>3</sub> - (me/l)	5.7	1.7	1.4	1.9	1.0	0.5
SAR (me/l)	0.3	0.3	0.3	0.8	1.2	5.7
Na (me/100g)	<0.1	<0.1	<0.1	<0.1	<0.1	0.4
Ca+Mg (me/100g)	0.6	0.3	0.2	0.2	0.1	0.1
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.41	0.25	0.17	0.19	0.23	0.31
Ca+Mg (me/l)	3.2	1.7	1.4	1.3	1.3	1.0
EXCHANGEABLE SODIUM (percent)	0.09	0.00	0.00	0.57	2.08	7.39
CATION EXCHANGE CAPACITY (me/100g)	12.83	6.63	8.26	9.02	6.30	16.73
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	-	-	<0.1
BORON (B) (ppm)	-	-	-	-	-	2.2
CADMIUM (Cd) (ppm)	-	-	-	-	-	<0.1
COPPER (Cu) (ppm)	-	-	-	-	-	4.5
IRON (Fe) (ppm)	-	-	-	-	-	4.9
MERCURY (Hg) (ppm)	-	-	-	-	-	0.10
MANGANESE (Mn) (ppm)	-	-	-	-	-	9.5
MOLYBDENUM (Mo) (ppm)	-	-	-	-	-	-
NICKEL (Ni) (ppm)	-	-	-	-	-	1.5
LEAD (Pb) (ppm)	-	-	-	-	-	4.2
SELENIUM (Se) (ppm)	-	-	-	-	-	<0.1
ZINC (Zn) (ppm)	-	-	-	-	-	3.7

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-121 (cont'd)  
 Location: 76' E. & 25' N. of SW Corner, Sec. 22, T. 155 N., R. 96 W.  
 Logged by: C. Botdorf  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,558	21,559	21,560	21,561	21,662	21,663
SACK NUMBER	121-2	121-3	121-4	121-5	121-6	121-7
DEPTH (FT)	12.5-23.0	23.0-34.4	34.4-55.0	44.0-62.0	62.0-70.9	71.5-86.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	0.6	5.7	2.5	7.0	16.1	0.6
SILT (0.05-0.002 mm)	63.2	69.7	37.3	61.0	62.2	43.8
CLAY (0.002 mm)	36.2	24.6	60.2	32.0	21.7	55.6
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SICL	SIL	C	SICL	SIL	SIC
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	Trace	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	56.0	124.0	199.0	300.0	272.0	252.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	-	-	-	-	-	-
15 bar	19.0	20.7	26.1	35.5	28.5	24.6
<u>SOIL REACTION-pH</u>						
Paste	7.9	8.3	7.6	8.3	8.5	8.4
1:5 H <sub>2</sub> O	9.0	9.4	9.0	9.3	9.6	9.4
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYP SUM REQUIREMENT</u> (me/100g)	2.4	4.5	4.6	9.0	7.1	7.1
<u>SATURATION EXTRACT</u>						
Saturation Percentage	68.9	63.3	104.3	112.1	103.6	71.1
EC <sub>e</sub> @25°C (mmhos/cm)	1.37	1.25	3.65	2.40	1.68	2.05
Ca++ + Mg++ (me/l)	2.8	0.7	2.6	0.7	0.6	0.8
Mg++ (me/l)	-	-	-	-	-	-
Na++ (me/l)	9.8	10.6	35.3	23.1	16.7	23.5
K+ (me/l)	0.3	0.2	0.5	0.3	0.2	0.3
CO <sub>3</sub> - (me/l)	0.0	0.0	0.0	0.0	0.2	0.0
HCO <sub>3</sub> - (me/l)	3.0	4.5	13.2	9.6	9.1	16.9
Cl- (me/l)	0.3	0.3	0.4	0.1	0.2	0.4
SO <sub>4</sub> - (me/l)	9.8	6.8	24.5	13.2	6.9	6.0
NO <sub>3</sub> - (me/l)	0.2	0.2	<0.1	0.1	0.2	0.1
SAR (me/l)	8.3	17.9	31.0	39.0	30.5	37.2
Na (mc/100g)	0.7	0.7	3.7	2.6	1.7	1.7
Ca+Mg (me/100g)	0.2	<0.1	0.3	0.1	0.1	0.6
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.42	0.45	1.35	1.00	0.71	0.60
Ca+Mg (me/l)	0.9	0.4	0.5	0.3	0.4	0.4
<u>EXCHANGEABLE SODIUM</u> (percent)	9.44	10.55	21.56	39.21	31.28	24.92
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	17.00	16.63	24.67	18.69	16.30	19.89
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	2.4	0.8	2.4	1.0	0.6	1.3
CADMIUM (Cd) (ppm)	<0.1	<0.1	0.2	0.1	0.2	0.2
COPPER (Cu) (ppm)	2.3	1.0	7.9	4.2	2.3	6.5
IRON (Fe) (ppm)	3.3	2.0	11.2	8.7	6.7	16.5
MERCURY (Hg) (ppm)	0.10	0.10	0.30	0.25	0.20	0.30
MANGANESE (Mn) (ppm)	29.7	12.7	28.6	26.9	18.9	26.5
MOLYBDENUM (Mo) (ppm)	-	-	2.4	1.2	0.7	0.6
NICKEL (Ni) (ppm)	0.4	0.2	5.7	2.3	1.8	1.4
LEAD (Pb) (ppm)	1.7	1.3	4.2	1.2	1.6	5.7
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ZINC (Zn) (ppm)	1.6	1.3	9.8	6.3	4.4	6.7

\*Insufficient Sample

Williston Study Area North Dakota  
 Geologic Drill Hole: 81-121 (cont'd)  
 Location: 76' E. & 25' N. of SW Corner, Sec. 22, T. 155 N., R. 96 W.  
 Logged by: C. Bortdorf  
 Date: August 1981

DETERMINATION	LABORATORY DESCRIPTION			
	Data			
LABORATORY NUMBER	21,564	21,565	21,566	21,567
SACK NUMBER	121-8	121-9	121-10	121-11
DEPTH (FT)	89.3-93.5	93.5-113.0	113.0-125.0	140.0-162.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	31.3	1.1	0.3	0.7
SILT (0.05-0.002 mm)	58.9	60.9	46.9	68.0
CLAY (0.002 mm)	9.8	38.0	52.8	31.3
GRAVEL (percent)	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SiCL	SiC	SiCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0.00	0.00	0.00	0.00
24th Hr.	Trace	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	29.0	186.0	225.0	136.0
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	-	-	-	-
15 bar	5.1	22.8	23.8	24.1
<u>SOIL REACTION-pH</u>				
Paste	8.3	8.8	8.7	8.8
1:5 H <sub>2</sub> O	9.3	9.6	9.6	9.8
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	1.6	6.1	4.6	5.9
<u>SATURATION EXTRACT</u>				
Saturation Percentage	18.1	25.7	33.2	26.0
EC <sub>e</sub> @25°C (mmhos/cm)	3.65	2.69	3.5	2.98
Ca++ + Mg++ (me/l)	3.2	0.4	1.0	0.5
Mg++ (me/l)	-	-	-	-
Na++ (me/l)	33.9	28.7	35.6	30.8
K+ (me/l)	0.5	0.4	0.4	0.3
CO <sub>3</sub> - (me/l)	0.0	1.8	0.6	2.8
HCO <sub>3</sub> - (me/l)	7.3	16.9	18.1	16.7
Cl- (me/l)	1.9	0.9	0.5	0.3
SO <sub>4</sub> - (me/l)	25.5	7.9	17.8	11.4
NO <sub>3</sub> - (me/l)	1.0	0.1	0.6	0.2
SAR (me/l)	26.8	64.2	50.3	61.6
Na (me/100g)	0.6	0.7	1.2	0.8
Ca+Mg (me/100g)	0.1	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>				
EC <sub>5</sub> @25°C (mmhos/cm)	0.50	0.70	0.75	0.80
Ca+Mg (me/l)	0.6	1.0	0.4	0.3
<u>EXCHANGEABLE SODIUM</u> (percent)	33.47	33.85	33.16	41.75
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	4.13	10.54	10.86	10.86
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	1.3	0.4	0.9	0.9
CADMIUM (Cd) (ppm)	<0.1	<0.1	<0.1	0.2
COPPER (Cu) (ppm)	0.9	2.0	3.6	2.4
IRON (Fe) (ppm)	3.2	9.1	11.6	10.1
MERCURY (Hg) (ppm)	0.10	0.20	0.30	0.25
MANGANESE (Mn) (ppm)	6.3	30.1	31.2	19.4
MOLYBDENUM (Mo) (ppm)	0.3	0.5	0.7	<0.1
NICKEL (Ni) (ppm)	0.4	0.6	1.8	0.9
LEAD (Pb) (ppm)	1.0	2.6	3.1	2.0
SELENIUM (Se) (ppm)	<0.1	<0.1	<0.1	<0.1
ZINC (Zn) (ppm)	1.7	3.2	6.4	4.1

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-123  
 Location: 2750' S. & 115' E. of NW Corner, Sec. 9, T. 154 N., R. 97 W.  
 Logged by: L. Parish  
 Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	21,255	21,256	21,257	21,258	21,259	
SACK NUMBER	123-1	123-2	123-3	123-4	123-5	
DEPTH (FT)	0.0-0.5	0.5-3.2	3.2-12.0	14.3-26.8	26.8-41.0	
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	38.3	30.4	32.2	2.1	14.8
SILT	(0.05-0.002 mm)	39.5	37.3	37.9	53.6	53.2
CLAY	(0.002 mm)	22.2	32.3	29.9	44.3	32.0
<u>GRAVEL</u> (percent)						
TEXTURAL CLASS (LAB)	L	CL	CL	SiC	SiCL	
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.08	Tr.	Tr.	0.04	Tr.	
24th Hr.	0.06	Tr.	Tr.	0.06	Tr.	
SETTLING VOLUME	(ml)	27	26	26	35	35
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	-	-	-	-	-	
15 bar	13.1	15.2	16.2	20.8	14.4	
<u>SOIL REACTION-pH</u>						
Paste						
1:5 H <sub>2</sub> O	8.7	9.2	8.5	8.1	9.1	
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	
GYPSUM REQUIREMENT	(me/100g)	+3.4	+1.8	-1.6	-2.1	+0.66
<u>SATURATION EXTRACT</u>						
Saturation Percentage		48.3	52.2	52.8	70.7	58.5
EC <sub>e</sub> @25°C	(mmhos/cm)	1.03	0.87	6.50	6.80	6.30
Ca <sup>++</sup>	(me/l)	6.75	0.71	24.32	25.41	18.50
Mg <sup>++</sup>	(me/l)	3.53	2.89	49.75	54.73	22.80
Na <sup>++</sup>	(me/l)	1.63	5.88	29.13	26.02	46.49
K <sup>+</sup>	(me/l)	0.13	0.04	0.09	0.15	0.12
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	(me/l)	8.87	4.44	2.12	1.96	1.48
Cl <sup>-</sup>	(me/l)	0.39	1.47	4.86	0.48	0.23
SO <sub>4</sub> <sup>-</sup>	(me/l)	3.02	1.79	87.45	88.49	86.40
NO <sub>3</sub> <sup>-</sup>	(me/l)	0.00	0.38	3.55	13.36	0.66
SAR	(me/l)	0.72	4.40	4.80	4.10	10.00
Na	(me/100g)	0.08	0.31	1.54	1.84	2.72
Ca+Mg	(me/100g)	0.50	0.19	3.91	5.67	2.42
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C	(mmhos/cm)	0.20	0.23	1.31	2.40	1.35
Ca+Mg	(me/l)	1.52	0.93	9.98	23.97	6.63
EXCHANGEABLE SODIUM	(percent)	1.31	6.36	8.00	5.20	11.45
CATION EXCHANGE CAPACITY	(me/100g)	24.24	19.24	19.35	21.63	14.78
NaOAc@pH 8.2						
SILVER (Ag)	(ppm)	-	-	-	-	-
BORON (B)	(ppm)	1.83	1.88	1.40	3.44	1.31
CADMIUM (Cd)	(ppm)	0.14	0.02	0.08	0.08	0.06
COPPER (Cu)	(ppm)	2.4	4.2	3.2	5.4	6.4
IRON (Fe)	(ppm)	40.0	34.6	42.6	81.8	39.8
MERCURY (Hg)	(ppm)	0.04	0.03	0.04	0.05	0.04
MANGANESE (Mn)	(ppm)	40.8	19.4	14.6	11.2	4.4
MOLYBDENUM (Mo)	(ppm)	0.09	0.00	0.42	0.38	0.20
NICKEL (Ni)	(ppm)	2.0	0.8	0.6	0.6	0.4
LEAD (Pb)	(ppm)	1.4	1.0	1.0	2.4	2.6
SELENIUM (Se)	(ppm)	-	-	-	-	-
ZINC (Zn)	(ppm)	2.36	1.40	1.48	2.08	3.02

\*Insufficient Sample

Williston Study Area, North Dakota  
 Geologic Drill Hole: 81-123 (cont'd)  
 Location: 2750' S. & 115' E. of NW Corner, Sec. 9, T. 154 N., R. 97 W.,  
 Logged by: L. Parish  
 Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION				
	Data				
LABORATORY NUMBER	21,260	21,261	21,262	21,263	21,264
SACK NUMBER	123-6	123-7	123-8	123-9	123-10
DEPTH (FT)	41.0-56.7	56.7-70.0	70.0-97.8	105.5-130.6	135.4-168.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand (2.0-1.0 mm)				0.2	
Coarse Sand (1.0-0.5 mm)				0.1	
Medium Sand (0.5-0.25 mm)				0.4	
Fine Sand (0.25-0.10 mm)				39.4	
Very Fine Sand (0.10-0.05 mm)				14.1	
TOTAL SAND (2.0-0.05 mm)	2.0	20.4	2.0	54.2	1.0
SILT (0.05-0.002 mm)	62.7	60.6	54.3	29.9	65.2
CLAY (0.002 mm)	35.3	19.0	43.7	15.9	33.8
GRAVEL (percent)	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S1CL	S1L	S1C	FSL	S1CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	40	72	118	168	225
<u>MOISTURE RETENTION</u> (%)					
1/3 bar	-	-	-	-	-
15 bar	22.5	32.3	28.9	35.9	39.9
<u>SOIL REACTION-pH</u>					
Paste					
1:5 H <sub>2</sub> O	9.3	9.6	9.6	9.9	9.8
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	+0.66	+6.40	+9.80	+11.00	+14.10
<u>SATURATION EXTRACT</u>					
Saturation Percentage	65.2	74.4	103.0	86.9	123.0
EC <sub>e</sub> @25°C (mmhos/cm)	4.20	2.00	2.00	2.00	1.80
Ca <sup>++</sup> (me/l)	3.35	0.60	0.44	0.16	0.22
Mg <sup>++</sup> (me/l)	4.52	0.72	0.63	0.18	0.09
Na <sup>++</sup> (me/l)	42.66	21.28	22.14	21.71	20.33
K <sup>+</sup> (me/l)	0.12	0.05	0.05	0.04	0.04
CO <sub>3</sub> <sup>-</sup> (me/l)	0.06	0.00	0.68	0.31	0.71
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.65	5.68	11.65	6.14	10.92
Cl <sup>-</sup> (me/l)	0.17	0.14	0.19	0.27	0.22
SO <sub>4</sub> <sup>-</sup> (me/l)	39.98	14.60	8.56	13.26	6.87
NO <sub>3</sub> <sup>-</sup> (me/l)	0.22	0.14	0.05	0.09	0.01
SAR (me/l)	22.00	26.00	30.00	52.00	52.00
Na (me/100g)	2.78	1.58	2.29	1.41	2.36
Ca+Mg (me/100g)	0.51	0.10	0.11	0.02	0.04
<u>1:5 EXTRACT</u>					
EC <sub>e</sub> @25°C (mmhos/cm)	0.81	0.54	0.66	0.40	0.83
Ca+Mg (me/l)	0.51	1.04	0.85	0.62	1.18
<u>EXCHANGEABLE SODIUM</u> (percent)	25.48	36.77	43.06	69.13	70.86
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	19.02	18.59	22.17	15.65	23.59
NaOAc@pH 8.2					
SILVER (Ag) (ppm)	-	-	-	-	-
BORON (B) (ppm)	1.72	0.79	1.18	0.79	1.25
CAESIUM (Cs) (ppm)	0.08	0.04	0.08	0.08	0.12
COPPER (Cu) (ppm)	9.4	2.8	10.0	7.0	16.0
IRON (Fe) (ppm)	54.2	35.0	183.0	58.8	102.0
MERCURY (Hg) (ppm)	0.07	0.06	0.07	0.05	0.10
MANGANESE (Mn) (ppm)	20.4	4.0	30.8	2.8	14.0
MOLYBDENUM (Mo) (ppm)	0.36	0.44	0.46	0.78	0.37
NICKEL (Ni) (ppm)	2.8	2.2	4.4	2.4	6.6
LEAD (Pb) (ppm)	5.6	1.4	4.0	3.8	7.0
SELENIUM (Se) (ppm)	-	-	-	-	-
ZINC (Zn) (ppm)	3.04	1.94	6.28	6.40	7.78

\*Insufficient Sample

Williston Study Area, North Dakota  
Geologic Orill Hole: 81-123 (cont'd)  
Location: 2750' S. & 115' E. of NW Corner, Sec. 9, T. 154 N., R. 97 W.  
Logged by: L. Parish  
Date: July 1981

DETERMINATION	LABORATORY DESCRIPTION			
	Data			
LABORATORY NUMBER	21,265	21,266	21,267	21,268
SACK NUMBER	123-11	123-12	123-13	123-14
DEPTH (FT)	168.0-187.8	196.2-215.6	217.1-243.3	253.7-261.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)				
Very Coarse Sand (2.0-1.0 mm)	0.1	-	-	0.1
Coarse Sand (1.0-0.5 mm)	0.1	-	-	0.1
Medium Sand (0.5-0.25 mm)	0.1	-	-	0.1
Fine Sand (0.25-0.10 mm)	9.4	-	-	22.0
Very Fine Sand (0.10-0.05 mm)	35.1	-	-	36.4
TOTAL SAND (2.0-0.05 mm)	44.8	9.4	0.6	58.7
SILT (0.05-0.002 mm)	37.0	61.4	57.0	25.3
CLAY (0.002 mm)	18.2	29.2	42.4	16.0
GRAVEL (percent)	-	-	-	-
TEXTURAL CLASS (LAB)	L	SiCL	SiC	VFSL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)				
6th Hr.	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00
SETTLING VOLUME (ml)	255	194	410	275
<u>MOISTURE RETENTION</u> (%)				
1/3 bar	-	-	-	-
15 bar	44.4	39.6	43.7	34.3
<u>SOIL REACTION-pH</u>				
Paste				
1:5 H <sub>2</sub> O	9.8	9.6	9.8	9.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	+12.60	+12.70	+16.90	+10.70
<u>SATURATION EXTRACT</u>				
Saturation Percentage	144.0	119.0	177.0	102.0
EC <sub>e</sub> @25°C (mmhos/cm)	1.18	1.90	1.31	0.95
Ca <sup>++</sup> (me/l)	0.11	0.27	0.11	0.05
Mg <sup>++</sup> (me/l)	0.18	0.27	0.09	0.18
Na <sup>++</sup> (me/l)	13.10	21.62	14.83	10.42
K <sup>+</sup> (me/l)	0.03	0.04	0.03	0.03
CO <sub>3</sub> <sup>-</sup> (me/l)	0.12	1.18	0.66	0.22
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.84	10.63	9.19	6.59
Cl <sup>-</sup> (me/l)	0.22	0.23	0.23	0.22
SO <sub>4</sub> <sup>-</sup> (me/l)	6.02	7.95	3.54	2.77
NO <sub>3</sub> <sup>-</sup> (me/l)	0.11	0.01	0.01	0.06
SAR (me/l)	34.00	41.00	47.00	30.00
Na (me/100g)	1.47	2.51	2.52	1.06
Ca+Mg (me/100g)	0.03	0.06	0.03	0.02
<u>1:5 EXTRACT</u>				
EC <sub>s</sub> @25°C (mmhos/cm)	0.73	0.80	0.81	0.42
Ca+Mg (me/l)	2.11	1.60	3.24	1.58
EXCHANGEABLE SODIUM (percent)	79.56	61.84	50.03	73.69
CATION EXCHANGE CAPACITY (me/100g)	25.76	28.70	35.54	20.86
NaOAc@pH 8.2				
SILVER (Ag) (ppm)	-	-	-	-
BORON (B) (ppm)	0.39	0.32	0.79	0.93
CADMIUM (Cd) (ppm)	0.06	0.08	0.10	0.06
COPPER (Cu) (ppm)	3.8	9.8	9.8	2.4
IRON (Fe) (ppm)	43.0	124.4	171.8	45.4
MERCURY (Hg) (ppm)	0.03	0.05	0.06	0.04
MANGANESE (Mn) (ppm)	2.2	15.2	22.6	2.4
MOLYBDENUM (Mo) (ppm)	0.37	0.45	0.87	0.18
NICKEL (Ni) (ppm)	3.4	4.4	6.6	0.8
LEAD (Pb) (ppm)	2.6	5.2	4.2	4.4
SELENIUM (Se) (ppm)	-	-	-	-
ZINC (Zn) (ppm)	4.96	4.74	8.96	3.44

\*Insufficient Sample

Table 18  
Sheet 1

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-124  
 Location: 2640' N. & 10'W of SE Corner, Sec. 17, T. 153 N., R. 97 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	67	68	69	70	71	72
SACK NUMBER	124-1	124-2	124-3	124-4	124-5	124-6
DEPTH (FT)	2.5-4.2	4.2-7.0	7.0-10.0	10.0-27.8	31.8-35.0	44.0-64.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	29.6	32.4	33.8	39.6	3.8	8.2
SILT (0.05-0.002 mm)	36.4	36.6	35.2	32.4	50.2	57.8
CLAY (0.002 mm)	34.0	31.0	31.0	28.0	46.0	34.0
GRAVEL (percent)	-	1.4	2.1	3.4	-	-
TEXTURAL CLASS (LAB)	CL	CL	CL	CL	SIC	SiCL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.59	0.06	0.37	0.62	0.12	0.00
24th Hr.	0.65	0.06	0.39	0.59	0.11	0.00
SETTLING VOLUME (ml)	21.0	22.0	22.0	21.0	28.5	31.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	28.2	29.4	27.1	26.4	48.0	52.8
15 bar	19.8	13.7	15.9	14.8	24.6	36.3
<b>SOIL REACTION-pH</b>						
Paste	-	-	-	-	-	-
1:5 H <sub>2</sub> O	8.3	8.4	7.9	7.7	4.9	9.0
1:2 0.01 M CaCl <sub>2</sub>	7.6	7.7	7.4	7.2	4.5	8.1
GYPSUM REQUIREMENT (me/100g)	-4.6	-3.8	-9.4	-7.4	-6.0	+2.6
<b>SATURATION EXTRACT</b>						
Saturation Percentage	50.2	61.6	53.8	53.8	80.9	110.4
EC <sub>e</sub> @25°C (mmhos/cm)	0.886	2.765	7.937	6.822	8.084	1.698
Ca <sup>++</sup> (me/l)	1.00	2.00	21.00	27.00	27.50	0.65
Mg <sup>++</sup> (me/l)	3.61	11.88	63.93	39.34	45.40	0.80
Na <sup>++</sup> (me/l)	6.3	22.0	47.0	34.0	59.0	23.6
K <sup>+</sup> (me/l)	0.20	0.30	0.80	1.10	2.00	0.58
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup> (me/l)	3.47	2.47	1.54	1.59	0.84	6.18
Cl <sup>-</sup> (me/l)	1.02	0.85	3.62	3.08	0.45	0.34
SO <sub>4</sub> <sup>-</sup> (me/l)	6.62	32.86	127.57	96.77	133.31	19.11
NO <sub>3</sub> <sup>-</sup> (me/l)	0.001	0.274	0.903	0.015	0.624	0.010
SAR (me/l)	4.2	8.3	7.2	5.9	9.7	27.7
Na (me/100g)	0.32	1.36	2.53	1.83	4.77	2.61
Ca+Mg (me/100g)	0.23	0.86	4.6	3.6	5.9	0.16
<b>1:5 EXTRACT</b>						
EC <sub>e</sub> @25°C (mmhos/cm)	.216	.481	1.491	1.614	1.324	.637
Ca+Mg (me/l)	1.01	1.57	12.3	14.2	6.40	0.28
EXCHANGEABLE SODIUM (percent)	3.0	6.6	4.7	3.9	1.8	20.7
<b>CATION EXCHANGE CAPACITY (me/100g)</b>						
NaOAc@pH 8.2	25.0	25.0	26.6	28.0	34.6	26.0
<b>SILVER (Ag) (ppm)</b>						
	-	-	-	-	-	-
<b>BORON (B) (ppm)</b>						
	0.49	1.54	1.28	1.87	5.18	1.28
<b>CADMIUM (Cd) (ppm)</b>						
	0.06	0.04	0.12	0.16	0.12	0.14
<b>COPPER (Cu) (ppm)</b>						
	2.4	2.2	2.2	2.4	14.0	9.4
<b>IRON (Fe) (ppm)</b>						
	100.0	119.2	125.8	131.4	396.0	70.2
<b>MERCURY (Hg) (ppm)</b>						
	0.02	0.02	0.08	0.04	0.09	0.06
<b>MANGANESE (Mn) (ppm)</b>						
	24.8	43.6	52.6	54.8	13.2	5.8
<b>MOLYBDENUM (Mo) (ppm)</b>						
	0.1	0.5	0.4	0.5	0.1	0.9
<b>NICKEL (Ni) (ppm)</b>						
	0.8	1.4	1.8	1.8	1.0	6.0
<b>LEAD (Pb) (ppm)</b>						
	1.20	1.40	1.60	1.40	2.80	5.60
<b>SELENIUM (Se) (ppm)</b>						
	<0.1	0.1	0.3	0.1	<0.1	0.1
<b>ZINC (Zn) (ppm)</b>						
	2.3	2.4	1.6	2.2	6.2	9.2

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-124 (cont'd)  
 Location: 2640' N. & 10'W of SE Corner, Sec. 17, T. 153 N., R. 97 W.  
 Logged by: C. Botdorf  
 Date: October 1982

DETERMINATION	LABORATORY DESCRIPTION				
	Oata				
LABORATORY NUMBER	73	74	75	76	77
SACK NUMBER	124-7	124-8	124-9	124-10	124-11
DEPTH (FT)	94.0-114.5	114.5-135.9	148.7-159.1	167.5-171.7	171.7-196.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)					
Very Coarse Sand (2.0-1.0 mm)	-	-	-	-	-
Coarse Sand (1.0-0.5 mm)	-	-	-	-	-
Medium Sand (0.5-0.25 mm)	-	-	-	-	-
Fine Sand (0.25-0.10 mm)	-	-	-	-	-
Very Fine Sand (0.10-0.05 mm)	-	-	-	-	-
TOTAL SAND (2.0-0.05 mm)	8.2	48.2	8.2	1.0	37.0
SILT (0.05-0.002 mm)	58.2	29.4	47.4	36.4	41.4
CLAY (0.002 mm)	33.6	22.4	44.4	62.6	21.6
GRAVEL (percent)	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiCL	L	SiC	C	L
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)					
6th Hr.	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	69.0	80.0	62.0	41.0	95.0
<u>MOISTURE RETENTION</u> (%)					
1/3 bar	74.0	73.1	81.7	91.9	73.4
15 bar	37.4	36.0	34.3	43.2	30.3
<u>SOIL REACTION-pH</u>					
Paste	-	-	-	-	-
1:5 H <sub>2</sub> O	9.4	9.6	9.3	9.1	9.5
1:2 U.O1 M CaCl <sub>2</sub>	8.5	8.9	8.6	8.5	8.6
<u>GYPNUM REQUIREMENT</u> (me/100g)	+11.2	+7.0	+8.4	+13.0	+7.2
<u>SATURATION EXTRACT</u>					
Saturation Percentage	142.5	150.1	165.1	166.9	139.6
EC <sub>s</sub> @25°C (mmhos/cm)	1.457	1.350	1.313	1.402	1.203
Ca++ (me/l)	0.10	0.07	0.08	0.55	0.20
Mg++ (me/l)	0.11	0.12	0.08	0.29	0.41
Na++ (me/l)	18.5	17.5	17.2	18.3	17.0
K+ (me/l)	0.23	0.15	0.21	0.30	0.20
CO <sub>3</sub> - (me/l)	0.34	2.23	1.50	0.60	0.86
HCO <sub>3</sub> - (me/l)	10.08	7.53	8.41	12.78	9.65
Cl- (me/l)	0.34	0.34	0.56	0.85	0.40
SO <sub>4</sub> - (me/l)	8.18	7.74	7.10	5.21	6.90
NO <sub>3</sub> - (me/l)	0.000	0.000	0.000	0.000	0.001
SAK (me/l)	57.1	56.8	60.8	28.2	30.8
Na (me/100g)	2.64	2.63	2.84	3.05	2.37
Ca+Mg (me/100g)	0.03	0.030	0.03	0.14	0.09
<u>1:5 EXTRACT</u>					
EC <sub>s</sub> @25°C (mmhos/cm)	.723	.707	.629	.720	.496
Ca+Mg (me/l)	0.18	0.39	0.29	1.43	0.25
<u>EXCHANGEABLE SODIUM</u> (percent)	46.4	47.4	53.8	8.2	47.4
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	26.2	24.4	28.2	37.2	22.0
NaOAc@pH 8.2					
SILVER (Ag) (ppm)	-	-	-	-	-
BORON (B) (ppm)	0.66	0.46	1.80	0.69	0.29
CADMIUM (Cd) (ppm)	0.16	0.10	-0.20	0.08	0.08
COPPER (Cu) (ppm)	5.0	1.6	8.4	10.0	3.80
IRON (Fe) (ppm)	147.0	53.0	58.2	108.0	69.4
MERCURY (Hg) (ppm)	0.04	0.03	0.05	0.13	0.03
MANGANESE (Mn) (ppm)	19.4	2.6	2.6	3.6	3.6
MOLYBDENUM (Mo) (ppm)	0.6	0.2	0.4	0.2	0.2
NICKEL (Ni) (ppm)	6.0	2.2	4.0	0.6	1.0
LEAD (Pb) (ppm)	4.20	3.80	9.40	14.00	4.60
SELENIUM (Se) (ppm)	<0.1	<0.1	0.3	0.6	0.1
ZINC (Zn) (ppm)	26.6	9.4	17.0	5.6	5.8

\*Insufficient Sample

Table 19  
Sheet 1

Tobacco Gardens Study Area, North Dakota  
Geologic Drill Hole: 82-125  
Location: 1795' N. & 1670' W. of SE Corner, Sec. 5, T. 152 N., R. 98 W.  
Logged by: C. Botdorf  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,406	4,407	4,408	4,409	4,410	4,411
SACK NUMBER	125-1	125-2	125-3	125-4	125-5	125-6
DEPTH (FT)	0-2.0	2.0-4.3	4.3-10.0	10.0-14.3	17.0-32.4	32.4-38.0
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	2.0	1.8	0.8	0.9	0.2	0.0
Coarse Sand (1.0-0.5 mm)	2.2	2.1	1.6	1.4	0.3	0.0
Medium Sand (0.5-0.25 mm)	5.6	5.1	5.3	4.4	0.2	0.0
Fine Sand (0.25-0.10 mm)	12.5	11.8	12.5	11.5	0.5	0.1
Very Fine Sand (0.10-0.05 mm)	12.2	11.3	12.4	14.4	12.0	2.5
TOTAL SAND (2.0-0.05 mm)	34.5	32.1	32.6	32.6	13.2	2.6
SILT (0.05-0.002 mm)	45.8	38.3	40.0	41.6	71.3	59.5
CLAY (0.002 mm)	19.7	29.6	27.4	25.8	15.5	37.9
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	L	CL	CL	L	SIL	SICL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	1.50	0.06	0.22	0.04	0.08	0.08
24th Hr.	1.61	0.08	0.20	0.02	0.06	0.06
SETTLING VOLUME (ml)	25.0	25.0	23.0	24.0	23.0	36.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	28.5	26.5	23.7	26.1	29.7	35.2
15 bar	12.3	11.5	11.8	12.5	8.3	16.5
<b>SOIL REACTION-pH</b>						
Paste	7.6	8.2	8.2	7.8	7.7	8.1
1:5 H <sub>2</sub> O	8.9	9.3	8.7	8.5	8.8	9.0
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSUM REQUIREMENT (me/100g)	-	-	-	-	-	-
<b>SATURATION EXTRACT</b>						
Saturation Percentage	55.3	55.9	55.9	56.6	63.0	80.4
EC <sub>e</sub> @25°C (mmhos/cm)	0.90	1.00	10.0	7.1	4.1	1.02
Ca <sup>++</sup> (me/l)	5.1	1.1	22.4	25.2	17.5	5.1
Mg <sup>++</sup> (me/l)	2.2	5.4	107.0	62.0	32.1	4.1
Na <sup>++</sup> (me/l)	0.7	2.5	21.4	12.3	3.0	2.3
K <sup>+</sup> (me/l)	0.6	0.3	0.9	0.9	0.6	0.6
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	4.9	3.5	1.8	1.3	1.6	1.9
Cl <sup>-</sup> (me/l)	0.4	0.8	4.9	3.5	0.5	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	1.5	5.0	144.0	91.0	51.0	9.8
NO <sub>3</sub> <sup>-</sup> (me/l)	0.8	<0.1	0.5	4.7	2.5	<0.1
SAR (me/l)	0.4	1.4	2.7	1.9	0.6	1.1
Na (me/100g)	<0.01	0.1	1.2	0.7	0.2	0.2
Ca+Mg (me/100g)	0.4	0.2	7.2	4.9	3.1	0.7
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.24	0.25	1.8	1.92	1.04	0.32
Ca+Mg (me/l)	1.8	1.2	23.1	35.9	5.2	1.7
EXCHANGEABLE SOOUM (percent)	0.7	2.8	3.9	1.9	1.1	0.6
CATION EXCHANGE CAPACITY (me/100g)	23.1	18.0	18.7	19.2	14.8	24.2
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	8.88	4.32	0.78
CADMIUM (Cd) (ppm)	-	-	-	0.57	<0.1	0.65
COPPER (Cu) (ppm)	-	-	-	3.0	2.4	2.4
IRON (Fe) (ppm)	-	-	-	38.5	32.2	16.4
MERCURY (Hg) (ppm)	-	-	-	0.05	0.10	0.10
MANGANESE (Mn) (ppm)	-	-	-	31.7	16.6	14.9
MOLYBDENUM (Mo) (ppm)	-	-	-	0.6	0.1	0.2
NICKEL (Ni) (ppm)	-	-	-	1.1	0.47	0.25
LEAD (Pb) (ppm)	-	-	-	2.2	1.5	3.1
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	1.2	0.7	1.9

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-125 (cont'd)  
 Location: 1795' N. & 1670' W. of SE Corner, Sec. 5, T. 152 N., R. 98 W.  
 Logged by: C. Bordorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,412	4,413	4,414	4,415	4,416	4,417
SACK NUMBER	125-7	125-8	125-9	125-10	125-11	125-12
DEPTH ( FT )	38.0-50.0	50.0-68.8	72.6-85.0	85.0-102.0	102.0-118.7	118.7-128.0
<u>PARTICLE SIZE ANALYSIS</u>	( percent )					
Very Coarse Sand ( 2.0-1.0 mm )	0.1	0.2	0.4	0.0	0.3	0.1
Coarse Sand ( 1.0-0.5 mm )	0.1	0.1	0.3	0.2	0.2	0.1
Medium Sand ( 0.5-0.25 mm )	0.1	0.2	0.2	0.2	0.2	0.1
Fine Sand ( 0.25-0.10 mm )	0.3	0.3	0.3	0.2	2.7	0.2
Very Fine Sand ( 0.10-0.05 mm )	9.6	2.9	2.5	23.2	42.5	2.3
TOTAL SAND ( 2.0-0.05 mm )	10.2	3.7	3.7	23.8	45.9	2.8
SILT ( 0.05-0.002 mm )	65.1	64.2	65.3	62.8	36.4	70.6
CLAY ( 0.002 mm )	24.7	32.1	31.0	13.4	17.7	26.6
GRAVEL ( percent )	-	-	-	-	-	-
<u>TEXTURAL CLASS ( LAB )</u>	SIL	SiCL	SiCL	SiCL	L	SIL
<u>HYDRAULIC CONDUCTIVITY</u>	( in/hr )					
6th Hr.	0.02	0.00	0.00	0.00	0.02	0.00
24th Hr.	0.02	0.02	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u>	( ml )					
	26.0	32.0	43.0	32.0	23.0	31.0
<u>MOISTURE RETENTION</u>	( % )					
1/3 bar	31.1	41.5	48.3	38.0	24.5	42.4
15 bar	11.19	16.5	23.1	11.0	7.5	15.8
<u>SOIL REACTION-pH</u>						
Paste	7.6	7.2	8.4	8.3	8.7	8.5
1:5 H <sub>2</sub> O	9.0	8.6	9.8	10.0	9.9	9.6
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u>	( me/100g )					
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	69.4	74.4	87.7	65.2	48.7	72.1
EC <sub>e</sub> @25° C ( mmhos/cm )	2.18	4.0	1.95	2.4	1.86	2.05
Ca <sup>++</sup> ( me/l )	11.2	15.1	1.5	1.5	1.0	1.6
Mg <sup>++</sup> ( me/l )	13.8	26.7	1.0	1.0	1.0	1.4
Na <sup>++</sup> ( me/l )	6.0	19.7	10.9	20.3	18.7	15.1
K <sup>+</sup> ( me/l )	0.8	1.5	0.5	0.6	0.5	0.5
CO <sub>3</sub> <sup>-</sup> ( me/l )	0.0	0.0	Trace	0.0	Trace	0.1
HCO <sub>3</sub> <sup>-</sup> ( me/l )	2.1	5.5	4.1	5.8	5.0	5.4
Cl <sup>-</sup> ( me/l )	1.2	0.5	0.1	0.4	0.6	0.6
SO <sub>4</sub> <sup>-</sup> ( me/l )	29.5	60.0	10.6	16.8	15.0	12.4
NO <sub>3</sub> <sup>-</sup> ( me/l )	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR ( me/l )	1.7	4.3	9.8	18.2	18.7	12.3
Na ( me/100g )	0.4	1.5	1.0	1.3	0.9	1.1
Ca+Mg ( me/100g )	1.7	3.1	0.2	0.2	0.1	0.2
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25° C ( mmhos/cm )	0.50	1.10	0.58	0.52	0.38	0.46
Ca+Mg ( me/l )	3.8	4.8	0.5	0.1	0.1	1.0
<u>EXCHANGEABLE SODIUM</u>	( percent )					
	2.2	4.1	20.0	21.7	19.6	13.9
<u>CATION EXCHANGE CAPACITY</u>	( me/100g )					
	19.7	23.5	25.1	19.5	14.4	20.6
NaDac@pH 8.2						
SILVER ( Ag ) ( ppm )	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON ( B ) ( ppm )	0.82	1.76	1.24	1.04	0.78	1.16
CADMIUM ( Cd ) ( ppm )	0.24	0.39	0.26	0.27	<0.1	0.21
COPPER ( Cu ) ( ppm )	4.8	12.9	11.2	8.5	2.5	7.1
IRON ( Fe ) ( ppm )	27.3	113.0	49.8	62.1	41.8	18.5
MERCURY ( Hg ) ( ppm )	0.05	0.35	0.25	0.20	0.10	0.20
MANGANESE ( Mn ) ( ppm )	2.5	31.6	12.8	16.1	9.5	12.2
MOLYBDENUM ( Mo ) ( ppm )	0.1	0.8	0.8	0.6	0.4	0.5
NICKEL ( Ni ) ( ppm )	0.39	5.9	4.0	3.9	1.5	2.4
LEAD ( Pb ) ( ppm )	1.4	6.6	7.8	5.2	3.0	8.0
SELENIUM ( Se ) ( ppm )	<0.05	<0.05	<0.05	<0.05	<0.054	<0.05
ZINC ( Zn ) ( ppm )	1.5	6.4	4.8	5.1	6.3	6.3

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole. 82-125 (cont'd)  
 Location: 1795' N. & 1670' W. of SE Corner, Sec. 5, T. 152 N., R. 98 W.  
 Logged by: C. Botdori  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,418	4,419	4,420	4,421	4,422	4,423
SACK NUMBER	125-13	125-14	125-15	125-16	125-17	125-18
DEPTH (FT)	128.0-137.2	137.2-142.0	146.5-148.5	148.5-163.0	163.0-178.0	178.0-193.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.1	0.0	0.0	0.0	0.2
Coarse Sand (1.0-0.5 mm)	0.0	0.4	0.1	0.0	0.0	0.8
Medium Sand (0.5-0.25 mm)	0.0	0.7	0.1	0.0	0.1	0.6
Fine Sand (0.25-0.10 mm)	0.1	2.2	0.1	19.7	0.1	0.6
Very Fine Sand (0.10-0.05 mm)	0.2	2.0	2.6	40.4	0.2	0.6
TOTAL SAND (2.0-0.05 mm)	0.3	5.4	2.9	60.1	0.4	2.8
SILT (0.05-0.002 mm)	70.0	59.7	73.6	23.2	73.1	72.0
CLAY (0.002 mm)	29.7	34.9	23.5	16.7	26.5	25.2
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiCL	SiCL	SiL	VFSL	SiL	SiL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.10	.22	0.00	0.00	0.00	0.00
24th Hr.	0.08	.24	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	51.0	30.0	36.0	31.0	70.0	51.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	34.7	44.8	41.5	35.9	51.1	46.6
15 bar	11.7	24.0	16.0	9.9	17.1	18.2
<u>SOIL REACTION-pH</u>						
Paste	7.8	7.0	8.3	9.0	8.8	8.5
1:5 H <sub>2</sub> O	9.0	7.9	9.2	10.3	10.0	9.6
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPNUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	66.7	70.7	77.0	55.8	78.4	68.6
EC <sub>e</sub> @25°C (mmhos/cm)	1.27	2.75	1.38	1.85	2.2	2.7
Ca <sup>++</sup> (me/l)	3.1	14.0	1.1	0.6	0.2	0.2
Mg <sup>++</sup> (me/l)	2.9	19.1	0.5	0.4	0.3	0.3
Na <sup>++</sup> (me/l)	8.0	14.5	14.0	20.5	21.2	13.5
K <sup>+</sup> (me/l)	0.8	0.8	0.5	0.2	0.2	0.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.00	0.00	0.00	0.2	Trace	1.5
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.3	6.6	5.1	6.8	12.3	12.6
Cl <sup>-</sup> (me/l)	0.3	0.3	0.5	0.5	0.2	0.5
SO <sub>4</sub> <sup>-</sup> (me/l)	9.8	34.0	10.4	13.8	8.5	9.1
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	4.6	3.6	15.7	29.0	42.4	27.0
Na (me/100g)	0.5	1.0	1.1	1.1	1.7	0.9
Ca+Mg (me/100g)	0.4	2.3	0.1	0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.28	0.76	0.44	0.52	0.78	0.80
Ca+Mg (me/l)	1.2	1.4	0.2	0.3	0.2	0.1
<u>EXCHANGEABLE SODIUM</u> (percent)	5.0	3.9	18.7	34.4	49.9	54.9
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	11.5	36.7	22.3	17.9	18.7	17.4
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	1.06	4.88	1.02	0.70	1.04	0.90
CADMIUM (Cd) (ppm)	0.43	0.54	0.73	0.42	0.39	0.47
COPPER (Cu) (ppm)	6.9	12.9	10.6	2.3	9.5	6.7
IRON (Fe) (ppm)	140.0	67.0	20.0	30.4	161.0	181.0
MERCURY (Hg) (ppm)	0.20	0.50	0.25	0.10	0.20	0.25
MANGANESE (Mn) (ppm)	54.0	16.1	3.3	5.2	52.7	66.2
MOLYBDENUM (Mo) (ppm)	0.4	1.0	0.2	0.3	0.5	1.1
NICKEL (Ni) (ppm)	2.1	11.6	0.30	1.6	2.5	3.3
LEAD (Pb) (ppm)	8.2	5.7	6.8	3.2	5.7	4.0
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	4.8	6.7	3.8	3.8	5.7	7.2

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Orill Hole: 82-125 (cont'd)  
 Location: 1795' N. & 1670' W. of SE Corner, Sec. 5, T. 152 N., R. 98 W.  
 Logged by: C. Botdorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Oata					
LABORATORY NUMBER	4,424	4,425	4,426	4,427	4,428	4,429
SACK NUMBER	125-19	125-20	125-21	125-22	125-23	125-24
DEPTH ( FT.)	193.0-216.3	216.3-230.6	230.6-243.0	254.0-271.3	271.3-276.0	276.0-287.5
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	0.5	0.0	0.1	0.0	0.0	0.0
Coarse Sand (1.0-0.5 mm)	0.9	0.0	0.0	0.0	0.0	0.0
Medium Sand (0.5-0.25 mm)	0.5	0.0	0.0	0.0	0.0	0.0
Fine Sand (0.25-0.10 mm)	0.5	0.3	0.0	0.1	1.8	0.1
Very Fine Sand (0.10-0.05 mm)	7.1	7.7	1.0	7.3	45.2	0.3
TOTAL SAND (2.0-0.05 mm)	9.5	8.0	1.1	7.4	47.0	0.4
SILT (0.05-0.002 mm)	66.4	58.3	54.0	69.0	35.0	66.2
CLAY (0.002 mm)	24.1	33.7	44.9	23.6	18.0	33.4
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	SIL	SICL	SIC	SIL	L	SICL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME (ml)	62.0	205.0	165.0	158.0	180.0	155.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	57.9	96.4	89.2	56.7	57.6	62.6
15 bar	30.8	53.9	37.8	28.0	29.7	26.4
<b>SOIL REACTION-pH</b>						
Paste	9.0	9.3	9.2	9.1	9.5	9.0
1:5 H <sub>2</sub> O	10.3	9.6	10.3	10.0	10.6	9.7
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<b>GYPSUM REQUIREMENT (me/100g)</b>						
	-	-	-	-	-	-
<b>SATURATION EXTRACT</b>						
Saturation Percentage	83.8	186.0	137.0	112.2	125.4	114.6
EC <sub>s</sub> @25°C (mmhos/cm)	2.5	1.26	1.75	1.70	1.42	1.86
Ca <sup>++</sup> (me/l)	0.2	0.2	0.2	0.2	0.1	0.2
Mg <sup>++</sup> (me/l)	0.3	0.1	0.2	0.1	0.1	0.3
Na <sup>++</sup> (me/l)	25.1	12.3	17.3	16.7	13.6	18.1
K <sup>+</sup> (me/l)	0.2	0.1	0.2	0.2	0.1	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	2.2	1.6	2.4	1.4	2.9	1.6
HCO <sub>3</sub> <sup>-</sup> (me/l)	11.4	7.6	10.8	9.4	7.0	10.5
Cl <sup>-</sup> (me/l)	0.6	0.1	0.2	0.1	0.2	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	10.1	2.8	3.7	5.7	4.2	6.0
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<.01	<0.1	<0.1	<0.1
SAR (me/l)	50.2	31.8	38.7	43.1	43.0	36.2
Na (me/100g)	2.1	2.3	2.4	1.9	1.7	2.1
Ca+Mg (me/100g)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<b>1:5 EXTRACT</b>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.88	0.90	0.90	0.80	0.74	0.88
Ca+Mg (me/l)	0.00	0.00	0.1	0.00	0.00	0.00
<b>EXCHANGEABLE SODIUM (percent)</b>						
	58.1	59.1	60.1	68.3	63.9	59.5
<b>CATION EXCHANGE CAPACITY (me/100g)</b>						
NaOAc@pH 8.2	26.6	36.2	40.9	17.6	17.7	21.6
<b>Trace Elements (ppm)</b>						
SILVER (Ag)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B)	0.72	0.64	0.74	0.54	0.44	0.42
CADMIUM (Cd)	<0.1	0.45	<0.1	0.19	<0.1	<0.1
COPPER (Cu)	10.9	4.3	8.2	6.0	2.1	9.0
IRON (Fe)	53.4	46.1	36.9	289.0	88.4	326.0
MERCURY (Hg)	0.30	0.15	0.15	0.15	0.10	0.20
MANGANESE (Mn)	17.4	8.5	12.9	38.4	7.6	44.3
MOLYBDENUM (Mo)	1.7	2.0	1.5	0.6	0.4	1.0
NICKEL (Ni)	4.9	4.7	4.6	3.4	1.5	4.9
LEAD (Pb)	6.0	8.7	9.6	3.4	3.7	4.7
SELENIUM (Se)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn)	7.2	4.4	6.3	6.4	6.4	7.4

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-125 (cont'd)  
 Location: 1795' N. & 1670' W. of SE Corner, Sec. 5, T. 152 N., R. 98 W;  
 Logged by: C. Botdorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION		
	Data		
LABORATORY NUMBER	4,430	4,431	4,432
SACK NUMBER	125-25	125-26	125-27
DEPTH ( FT)	287.5-298.5	308.9-311.0	313.0-335.2
<u>PARTICLE SIZE ANALYSIS</u> (percent)			
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	0.0
Coarse Sand (1.0-0.5 mm)	0.0	0.1	0.1
Medium Sand (0.5-0.25 mm)	0.0	0.2	0.1
Fine Sand (0.25-0.10 mm)	0.0	26.3	0.1
Very Fine Sand (0.10-0.05 mm)	0.4	31.2	1.2
TOTAL SAND (2.0-0.05 mm)	0.4	57.8	1.5
SILT (0.05-0.002 mm)	62.4	23.0	51.0
CLAY (0.002 mm)	37.2	19.2	47.5
GRAVEL (percent)	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S1CL	VFSL	S1C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)			
6th Hr.	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	305.0	240.0	270.0
<u>MOISTURE RETENTION</u> (%)			
1/3 bar	73.8	49.0	69.8
15 bar	31.2	20.8	28.8
<u>SOIL REACTION-pH</u>			
Paste	9.2	9.1	8.8
1:5 H <sub>2</sub> O	9.8	10.2	10.2
1:2 0.01 M CaCl <sub>2</sub>	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-
<u>SATURATION EXTRACT</u>			
Saturation Percentage	143.2	110.8	123.0
EC <sub>e</sub> @25°C (mmhos/cm)	1.50	1.26	2.1
Ca <sup>++</sup> (me/l)	.2	0.2	0.3
Mg <sup>++</sup> (me/l)	.1	0.1	0.2
Na <sup>++</sup> (me/l)	14.9	11.9	19.9
K <sup>+</sup> (me/l)	.2	0.1	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	1.6	0.6	0.2
HCO <sub>3</sub> <sup>-</sup> (me/l)	8.0	5.4	7.2
Cl <sup>-</sup> (me/l)	.2	0.4	0.2
SO <sub>4</sub> <sup>-</sup> (me/l)	5.2	5.8	12.5
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1
SAR (me/l)	38.5	30.7	39.8
Na (me/100g)	2.1	1.3	2.4
Ca+Mg (me/100g)	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>			
EC <sub>s</sub> @25°C (mmhos/cm)	.82	0.54	0.90
Ca+Mg (me/l)	.0	0.0	0.0
<u>EXCHANGEABLE SODIUM</u> (percent)	62.0	51.8	60.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	25.0	19.4	28.2
NaOAc@pH 8.2			
SILVER ( Ag) (ppm)	<0.1	<0.1	<0.1
BORON ( B) (ppm)	0.40	0.46	0.64
CADMIUM ( Cd) (ppm)	0.28	<0.1	0.63
COPPER ( Cu) (ppm)	7.2	4.3	19.1
IRON ( Fe) (ppm)	182.0	50.3	155.0
MERCURY ( Hg) (ppm)	0.20	0.15	0.15
MANGANESE ( Mn) (ppm)	27.4	1.7	24.8
MOLYBDENUM ( Mo) (ppm)	0.8	0.5	1.2
NICKEL ( Ni) (ppm)	6.1	1.5	4.2
LEAD ( Pb) (ppm)	7.3	6.2	5.7
SELENIUM ( Se) (ppm)	<0.05	<0.05	<0.05
ZINC ( Zn) (ppm)	5.7	9.3	9.6

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-126  
 Location: 2950' S. & 450' E. of NW Corner, Sec. 20, T. 152 N., R. 98 W.  
 Logged by: F. Calcagno  
 Date: March 1982

LABORATORY DESCRIPTION  
 Data

DETERMINATION	4,372	4,373	4,374	4,375	4,376	4,377
LABORATORY NUMBER	126-1	126-2	126-3	126-4	126-5	126-6
SACK NUMBER	0-0.9	0.9-4.3	4.3-10.0	10.0-22.4	22.4-35.6	35.6-43.8
DEPTH (FT)						
PARTICLE SIZE ANALYSIS (percent)						
Very Coarse Sand (2.0-1.0 mm)	2.4	12.4	0.8	0.5	0.3	0.0
Coarse Sand (1.0-0.5 mm)	2.6	9.1	0.7	0.5	0.5	0.0
Medium Sand (0.5-0.25 mm)	4.0	9.4	12.7	0.3	0.5	0.1
Fine Sand (0.25-0.10 mm)	5.7	13.0	17.9	0.3	0.8	0.1
TOTAL SAND (2.0-0.05 mm)	26.7	10.5	16.4	0.7	3.7	0.3
SILT (0.05-0.002 mm)	41.4	54.4	38.5	2.3	5.8	0.5
CLAY (0.002 mm)	42.7	31.9	38.2	71.6	61.0	69.1
GRAVEL (percent)	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	L	SL	L	S1L	S1CL	S1CCL
HYDRAULIC CONDUCTIVITY (in/hr)						
6th Hr.	2.83	3.54	0.22	0.08	0.14	0.00
24th Hr.	2.91	1.89	0.28	0.06	0.16	0.00
SETTLING VOLUME (ml)	25.0	20.0	23.0	30.0	33.0	39.0
MOISTURE RETENTION (%)						
1/3 bar	25.9	18.1	22.9	33.9	37.9	42.6
15 bar	10.8	7.8	10.4	14.8	18.2	17.4
SOIL REACTION-pH						
Paste	7.4	8.0	8.3	7.8	7.1	7.9
1:5 H <sub>2</sub> O	8.3	9.3	9.0	9.3	9.0	9.0
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
GYPSPUM REQUIREMENT (me/100g)	-	-	-	-	-	-
SATURATION EXTRACT						
Saturation Percentage	59.0	39.0	55.1	84.2	76.1	78.1
EC <sub>e</sub> @25°C (mmhos/cm)	1.14	0.74	5.1	4.8	6.2	2.9
Ca <sup>++</sup> (me/l)	8.2	3.7	10.6	10.7	23.1	4.5
Mg <sup>++</sup> (me/l)	3.9	2.7	38.6	31.9	39.8	6.9
Na <sup>++</sup> (me/l)	0.4	0.5	17.6	17.2	23.8	19.2
K <sup>+</sup> (me/l)	0.4	0.2	0.7	0.9	1.6	1.3
CO <sub>3</sub> <sup>-</sup> (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
HCO <sub>3</sub> <sup>-</sup> (me/l)	8.6	3.9	2.6	1.8	3.8	4.9
Cl <sup>-</sup> (me/l)	<0.1	<0.1	1.8	1.8	0.3	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	3.8	2.8	63.0	56.0	80.7	27.3
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	0.4	<0.1	1.9	4.1	<0.1
SAR (me/l)	0.2	0.3	3.6	3.7	4.2	8.0
Na (me/100g)	<0.1	<0.1	1.0	1.4	1.8	1.5
Ca+Mg (me/100g)	0.7	0.2	2.7	3.6	4.9	0.9
1:5 EXTRACT						
EC <sub>5</sub> @25°C (mmhos/cm)	0.15	0.12	0.80	1.00	1.3	0.60
Ca+Mg (me/l)	1.6	1.3	5.0	5.9	8.4	1.0
EXCHANGEABLE SODIUM (percent)	0.6	2.9	3.9	4.4	4.9	10.0
CATION EXCHANGE CAPACITY (me/100g)	25.1	14.0	21.1	24.7	26.6	27.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	2.04	4.06	2.18
CADMIUM (Cd) (ppm)	-	-	-	<0.1	0.86	<0.1
COPPER (Cu) (ppm)	-	-	-	1.4	10.3	9.9
IRON (Fe) (ppm)	-	-	-	25.4	115.0	126.0
MERCURY (Hg) (ppm)	-	-	-	0.15	0.20	0.25
MANGANESE (Mn) (ppm)	-	-	-	31.6	19.6	32.2
MOLYBDENUM (Mo) (ppm)	-	-	-	0.2	0.9	0.9
NICKEL (Ni) (ppm)	-	-	-	0.56	1.4	2.4
LEAD (Pb) (ppm)	-	-	-	2.6	4.0	8.2
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	2.8	4.1	6.7

\*Insufficient Sample

Table 20  
Sheet 2

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-126 (cont'd)  
 Location: 2950' S. & 450' E. of NW Corner, Sec. 20, T. 152 N., R. 98 W.  
 Logged by: F. Calcagno  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
	4,378	4,379	4,380	4,381	4,382	4,383
LABORATORY NUMBER	4,378	4,379	4,380	4,381	4,382	4,383
SACK NUMBER	126-7	126-8	126-9	126-10	126-11	126-12
DEPTH (FT)	51.4-65.8	65.8-85.0	85.0-100.8	100.8-114.9	114.9-127.6	131.3-147.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	0.0	0.0	0.4	0.2
Coarse Sand (1.0-0.5 mm)	0.0	0.0	0.0	0.0	0.3	0.2
Medium Sand (0.5-0.25 mm)	0.0	0.0	0.0	0.1	0.3	0.1
Fine Sand (0.25-0.10 mm)	0.2	0.4	0.3	0.6	2.6	9.1
Very Fine Sand (0.10-0.05 mm)	3.0	16.2	7.9	7.8	15.1	2.9
TOTAL SAND (2.0-0.05 mm)	3.2	16.6	8.2	8.5	18.7	3.5
SILT (0.05-0.002 mm)	61.5	54.1	61.0	65.9	63.5	65.1
CLAY (0.002 mm)	35.3	29.3	30.8	25.6	17.8	31.4
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SiCL	SiCL	SiCL	SiCL	SiL	SiCL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.02	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	54.0	72.0	220.0	31.0	28.0	45.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	39.9	50.9	64.6	37.7	38.2	52.2
15 bar	17.1	22.0	31.2	15.6	14.0	20.1
<u>SOIL REACTION-pH</u>						
Paste	8.3	8.8	9.1	8.2	8.0	8.7
1:5 H <sub>2</sub> O	9.4	9.6	9.5	9.8	9.7	10.1
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)						
	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	83.4	95.5	148.4	60.5	57.0	82.0
EC <sub>e</sub> @25°C (mmhos/cm)	2.0	1.8	1.4	2.0	2.9	2.3
Ca <sup>++</sup> (me/l)	1.2	0.4	0.2	0.5	1.1	0.4
Mg <sup>++</sup> (me/l)	0.8	0.2	0.1	0.5	1.1	0.4
Na <sup>+</sup> (me/l)	18.2	16.8	13.1	19.0	26.9	20.9
K <sup>+</sup> (me/l)	0.5	0.3	0.2	0.3	0.4	0.4
CO <sub>3</sub> <sup>-</sup> (me/l)	0.2	0.7	1.3	0.0	0.0	0.4
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.8	5.9	6.6	12.7	8.8	7.8
Cl <sup>-</sup> (me/l)	<0.1	0.1	0.1	<0.1	0.3	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	14.0	10.8	5.1	6.7	20.1	14.3
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	18.2	30.7	33.8	26.9	25.7	33.0
Na (me/100g)	1.5	1.6	1.9	1.1	1.5	1.7
Ca+Mg (me/100g)	0.2	0.1	<0.1	0.1	0.1	0.1
<u>1:5 EXTRACT</u>						
EC <sub>s</sub> @25°C (mmhos/cm)	0.44	0.58	0.66	0.50	0.58	0.64
Ca+Mg (me/l)	0.1	0.0	0.0	0.1	0.1	0.0
<u>EXCHANGEABLE SODIUM</u> (percent)						
	25.2	50.0	62.3	56.3	58.7	67.2
<u>CATION EXCHANGE CAPACITY</u> (me/100g)						
NaOAc@pH 8.2	20.4	19.3	25.2	22.4	25.4	28.5
<u>Trace Elements</u>						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	1.78	0.52	0.40	1.02	2.12	0.78
CADMIUM (Cd) (ppm)	0.57	0.31	0.18	0.11	0.65	0.28
COPPER (Cu) (ppm)	7.4	6.6	9.2	4.0	5.4	11.2
IRON (Fe) (ppm)	55.2	53.4	68.0	145.0	52.9	32.8
MERCURY (Hg) (ppm)	0.15	0.10	0.20	0.15	0.20	0.30
MANGANESE (Mn) (ppm)	17.2	13.1	19.0	63.8	22.4	8.0
MOLYBDENUM (Mo) (ppm)	0.3	0.4	1.7	0.5	0.5	1.3
NICKEL (Ni) (ppm)	1.0	1.7	5.0	3.1	6.4	4.4
LEAD (Pb) (ppm)	8.9	4.8	7.6	4.6	4.4	6.9
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	4.1	7.1	6.5	4.5	5.0	7.2

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
Geologic Drill Hole: 82-126 (cont'd)  
Location: 2950' S. & 450' E. of NW Corner, Sec. 20, T. 152 N., R. 98 W.  
Logged by: F. Calcagno  
Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,384	4,385	4,386	4,387	4,388	4,389
SACK NUMBER	126-13	126-14	126-15	126-16	126-17	126-18
DEPTH (FT)	147.0-164.0	164.0-182.9	191.8-203.8	203.8-217.0	217.0-233.4	242.0-252.5
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.5	0.0	0.0	0.2	3.4
Coarse Sand (1.0-0.5 mm)	0.0	0.7	0.2	0.3	0.1	1.7
Medium Sand (0.5-0.25 mm)	0.0	0.6	0.1	1.5	0.3	1.1
Fine Sand (0.25-0.10 mm)	0.0	0.6	0.4	34.1	24.3	1.4
Very Fine Sand (0.10-0.05 mm)	0.1	2.0	11.9	25.8	29.1	1.6
TOTAL SAND (2.0-0.05 mm)	0.1	4.4	12.6	61.7	54.0	9.2
SILT (0.05-0.002 mm)	59.5	38.8	59.0	21.5	29.1	47.2
CLAY (0.002 mm)	40.4	56.8	28.4	16.8	16.9	43.6
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	S1C	C	S1CL	FSL	VFSL	S1C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	235.0	205.0	255.0	145.0	170.0	195.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	75.5	105.5	58.5	48.8	40.7	61.9
15 bar	32.2	48.0	33.5	25.2	26.3	28.2
<u>SOIL REACTION-pH</u>						
Paste	8.9	9.2	9.3	9.2	9.5	8.7
1:5 H <sub>2</sub> O	10.3	10.4	10.4	10.0	10.1	10.1
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	175.0	226.6	150.3	115.6	115.8	140.4
EC <sub>e</sub> @25°C (mmhos/cm)	1.54	1.24	1.26	1.55	1.17	1.95
Ca <sup>++</sup> (me/l)	0.3	0.3	0.2	0.1	0.2	0.2
Mg <sup>++</sup> (me/l)	0.1	0.1	0.0	0.1	0.0	0.1
Na <sup>++</sup> (me/l)	15.2	13.0	12.4	15.1	10.7	19.2
K <sup>+</sup> (me/l)	0.2	0.2	0.1	0.1	0.1	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	0.5	1.3	1.4	1.1	1.5	0.7
HCO <sub>3</sub> <sup>-</sup> (me/l)	7.5	8.9	6.3	7.9	5.2	9.8
Cl <sup>-</sup> (me/l)	0.1	0.1	0.1	0.2	0.1	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	7.2	2.1	4.5	5.5	3.8	7.9
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	34.0	29.1	39.2	47.8	33.8	49.6
Na (me/100g)	2.7	2.9	1.9	1.7	1.2	2.7
Ca+Mg (me/100g)	0.1	0.1	<0.1	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>5</sub> @25°C (mmhos/cm)	0.70	0.92	0.65	0.58	0.52	0.69
Ca+Mg (me/l)	0.0	0.0	0.0	0.0	0.0	0.0
<u>EXCHANGEABLE SODIUM</u> (percent)	45.7	50.7	58.1	93.1	97.2	52.4
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	33.9	42.6	22.9	23.2	18.8	28.8
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	1.72	2.08	0.36	0.40	0.24	0.54
CAESIUM (Cs) (ppm)	0.15	<0.1	0.28	0.35	0.26	0.11
COPPER (Cu) (ppm)	8.0	6.8	6.1	2.6	0.63	9.3
IRON (Fe) (ppm)	67.3	50.6	40.2	121.0	36.0	193.0
MERCURY (Hg) (ppm)	0.25	0.25	0.25	0.15	0.10	0.30
MANGANESE (Mn) (ppm)	18.9	13.1	9.5	25.7	7.1	10.4
MOLYBDENUM (Mo) (ppm)	1.3	2.7	0.5	0.6	0.3	1.0
NICKEL (Ni) (ppm)	4.3	5.8	1.6	7.6	2.0	1.8
LEAD (Pb) (ppm)	8.0	11.0	7.4	3.9	2.6	9.2
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	7.5	7.8 6.6	7.2	2.5	6.8	

\*Insufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Orill Hole: 82-126 (cont'd)  
 Location: 2950' S. & 450' E. of NW Corner, Sec. 20, T. 152 N., R. 98 W.  
 Logged by: F. Calcagno  
 Date: March 1982

DETERMINATION		LABORATORY DESCRIPTION
		Oata
<u>LABORATORY NUMBER</u>		4,390
<u>SACK NUMBER</u>		126-19
<u>DEPTH (FT)</u>		252.5-255.2
<u>PARTICLE SIZE ANALYSIS</u>	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	0.0
Coarse Sand	(1.0-0.5 mm)	0.1
Medium Sand	(0.5-0.25 mm)	0.1
Fine Sand	(0.25-0.10 mm)	1.9
Very Fine Sand	(0.10-0.05 mm)	34.7
TOTAL SAND	(2.0-0.05 mm)	36.8
SILT	(0.05-0.002 mm)	47.2
CLAY	(0.002 mm)	16.0
GRAVEL	(percent)	-
<u>TEXTURAL CLASS (LAB)</u>		L
<u>HYDRAULIC CONDUCTIVITY</u>	(in/hr)	
6th Hr.		0.00
24th Hr.		0.00
<u>SETTLING VOLUME</u>	(ml)	28.0
<u>MOISTURE RETENTION</u>	(%)	
1/3 bar		32.4
15 bar		9.4
<u>SOIL REACTION-pH</u>		
Paste		8.7
1:5 H <sub>2</sub> O		9.9
1:2 0.01 M CaCl <sub>2</sub>		-
<u>GYPSUM REQUIREMENT</u>	(me/100g)	-
<u>SATURATION EXTRACT</u>		
Saturation Percentage		57.4
EC <sub>e</sub> @25°C	(mmhos/cm)	2.4
Ca <sup>++</sup>	(me/l)	0.5
Mg <sup>++</sup>	(me/l)	0.1
Na <sup>++</sup>	(me/l)	20.6
K <sup>+</sup>	(me/l)	0.3
CO <sub>3</sub> <sup>-</sup>	(me/l)	0.3
HCO <sub>3</sub> <sup>-</sup>	(me/l)	7.6
Cl <sup>-</sup>	(me/l)	0.1
SO <sub>4</sub> <sup>-</sup>	(me/l)	14.0
NO <sub>3</sub> <sup>-</sup>	(me/l)	<0.1
SAR	(me/l)	37.6
Na	(me/100g)	1.2
Ca+Mg	(me/100g)	<0.1
<u>1:5 EXTRACT</u>		
EC <sub>5</sub> @25°C	(mmhos/cm)	0.50
Ca+Mg	(me/l)	0.0
<u>EXCHANGEABLE SODIUM</u>	(percent)	80.4
<u>CATION EXCHANGE CAPACITY</u>	(me/100g)	13.3
NaOAc@pH 8.2		
SILVER (Ag)	(ppm)	<0.1
BORON (B)	(ppm)	0.68
CAESIUM (Cs)	(ppm)	<0.1
COPPER (Cu)	(ppm)	5.5
IRON (Fe)	(ppm)	55.2
MERCURY (Hg)	(ppm)	0.10
MANGANESE (Mn)	(ppm)	21.2
MOLYBDENUM (Mo)	(ppm)	0.3
NICKEL (Ni)	(ppm)	1.9
LEAD (Pb)	(ppm)	3.8
SELENIUM (Se)	(ppm)	<0.05
ZINC (Zn)	(ppm)	5.9

\*Insufficient Sample

Table 21  
Sheet 1

Tobacco Gardena Study Area, North Dakota  
 Geologic Drill Hole: 82-127  
 Location: 2624' N. & 1274' W. of SE Corner, Sec. 31, T. 152 N., R. 97 W.  
 Logged by: C. Botdorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,391	4,392	4,393	4,394	4,395	4,396
SACK NUMBER	127-1	127-2	127-3	127-4	127-5	127-6
DEPTH (FT)	0-1.2	1.2-3.3	3.3-10.0	10.0-20.0	20.0-28.5	28.5-42.5
<b>PARTICLE SIZE ANALYSIS (percent)</b>						
Very Coarse Sand (2.0-1.0 mm)	0.7	10.7	0.2	3.3	0.0	0.0
Coarse Sand (1.0-0.5 mm)	1.2	0.9	0.0	1.4	0.0	0.0
Medium Sand (0.5-0.25 mm)	1.7	0.8	0.4	1.3	0.3	0.2
Fine Sand (0.25-0.10 mm)	4.5	15.3	41.7	60.2	20.9	32.0
Very Fine Sand (0.10-0.05 mm)	9.5	24.6	19.8	9.6	42.6	43.6
TOTAL SAND (2.0-0.05 mm)	17.6	32.3	62.1	75.8	63.8	75.8
SILT (0.05-0.002 mm)	51.1	48.0	25.4	16.1	19.4	13.0
CLAY (0.002 mm)	31.3	19.7	12.5	8.1	16.8	11.2
<b>GRAVEL (percent)</b>						
	-	-	-	-	-	-
TEXTURAL CLASS (LAB)	S1CL	L	FSL	FSL	VFSL	VFSL
<b>HYDRAULIC CONDUCTIVITY (in/hr)</b>						
6th Hr.	0.16	0.10	0.04	1.42	0.00	0.22
24th Hr.	0.18	0.12	0.02	.87	0.00	0.14
SETTLING VOLUME (ml)	27.0	23.0	48.0	21.0	100.0	20.0
<b>MOISTURE RETENTION (%)</b>						
1/3 bar	34.7	29.6	20.5	16.5	27.6	19.5
15 bar	15.6	12.2	8.1	7.5	10.7	7.8
<b>SOIL REACTION-pH</b>						
Paste	7.9	8.4	8.9	7.8	8.1	8.6
1:5 H <sub>2</sub> O	8.6	8.9	9.1	9.2	9.8	9.2
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<b>GYP SUM REQUIREMENT (me/100g)</b>						
	-	-	-	-	-	-
<b>SATURATION EXTRACT</b>						
Saturation Percentage	57.4	60.3	55.5	34.1	64.7	45.9
EC <sub>e</sub> @25°C (mmhos/cm)	8.0	12.0	7.1	5.0	1.60	1.35
Ca <sup>++</sup> (me/l)	*	22.7	14.5	*	1.6	1.7
Mg <sup>++</sup> (me/l)	*	65.5	28.2	*	1.4	1.2
Na <sup>+</sup> (me/l)	47.9	81.6	45.8	28.2	12.0	9.9
K <sup>+</sup> (me/l)	*	0.5	0.7	*	0.3	0.31
CO <sub>3</sub> <sup>-</sup> (me/l)	*	0.0	0.1	*	0.0	Trace
HCO <sub>3</sub> <sup>-</sup> (me/l)	*	1.7	2.0	*	2.5	4.0
Cl <sup>-</sup> (me/l)	*	1.0	0.7	*	0.2	0.4
SO <sub>4</sub> <sup>-</sup> (me/l)	*	164.0	88.0	*	13.6	9.0
NO <sub>3</sub> <sup>-</sup> (me/l)	*	0.24	<0.1	*	<0.1	0.1
SAK (me/l)	*	12.3	9.9	*	9.8	8.2
Na (me/100g)	2.7	4.9	2.5	1.0	0.8	0.5
Ca+Mg (me/100g)	*	5.3	2.4	*	0.2	0.1
<b>1:5 EXTRACT</b>						
EC <sub>5</sub> @25°C (mmhos/cm)	1.52	2.44	1.12	.50	0.30	0.25
Ca+Mg (me/l)	7.8	1.5	3.5	1.0	0.2	0.2
<b>EXCHANGEABLE SODIUM (percent)</b>						
	59.5	10.9	13.1	3.3	11.5	9.3
<b>CATION EXCHANGE CAPACITY (me/100g)</b>						
	12.1	23.5	15.5	28.0	19.8	13.0
NaOAc@pH 8.2						
SILVER (Ag) (ppm)	-	-	-	<0.1	<0.1	<0.1
BORON (B) (ppm)	-	-	-	0.76	0.26	0.58
CADMIUM (Cd) (ppm)	-	-	-	<0.1	<0.1	<0.1
COPPER (Cu) (ppm)	-	-	-	1.7	0.75	1.4
IRON (Fe) (ppm)	-	-	-	23.8	36.0	34.2
MERCURY (Hg) (ppm)	-	-	-	0.05	0.05	0.05
MANGANESE (Mn) (ppm)	-	-	-	22.1	29.8	8.7
MOLYBDENUM (Mo) (ppm)	-	-	-	0.7	0.2	0.4
NICKEL (Ni) (ppm)	-	-	-	1.2	1.1	1.4
LEAD (Pb) (ppm)	-	-	-	2.0	1.6	4.2
SELENIUM (Se) (ppm)	-	-	-	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	-	-	-	4.2	1.3	3.5

\*Inaufficient Sample

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-127 (cont'd)  
 Location: 2624' N. & 1274' W. of SE Corner, Sec. 31, T. 152 N., R. 97 W.  
 Logged by: C. Botdorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION					
	Data					
LABORATORY NUMBER	4,397	4,398	4,399	4,400	4,401	4,402
SACK NUMBER	127-7	127-8	127-9	127-10	127-11	127-12
DEPTH (FT)	42.5-53.5	63.4-71.0	71.0-83.5	83.5-98.0	107.1-121.0	121.0-125.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)						
Very Coarse Sand (2.0-1.0 mm)	0.0	0.0	0.1	0.2	0.3	0.2
Coarse Sand (1.0-0.5 mm)	0.3	0.0	0.2	0.1	0.3	0.1
Medium Sand (0.5-0.25 mm)	0.3	0.1	0.6	0.5	0.1	0.1
Fine Sand (0.25-0.10 mm)	0.3	0.1	50.3	47.8	0.2	0.0
Very Fine Sand (0.10-0.05 mm)	0.4	3.5	19.6	22.1	1.8	26.5
TOTAL SAND (2.0-0.05 mm)	1.3	3.7	70.8	70.7	2.7	26.9
SILT (0.05-0.002 mm)	64.1	52.9	14.2	15.2	47.3	38.9
CLAY (0.002 mm)	34.6	43.4	15.0	14.1	50.0	34.2
GRAVEL (percent)	-	-	-	-	-	-
<u>TEXTURAL CLASS (LAB)</u>	SICL	SIC	FSL	FSL	SIC	CL
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)						
6th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	47.0	71.0	85.0	180.0	175.0	180.0
<u>MOISTURE RETENTION</u> (%)						
1/3 bar	56.4	49.7	43.0	46.4	64.6	51.1
15 bar	27.9	20.6	13.5	25.0	27.0	23.1
<u>SOIL REACTION-pH</u>						
Paste	8.4	8.6	9.2	9.6	8.8	8.5
1:5 H <sub>2</sub> O	9.8	9.8	10.3	10.2	9.6	10.1
1:2 0.01 M CaCl <sub>2</sub>	-	-	-	-	-	-
<u>GYPSUM REQUIREMENT</u> (me/100g)	-	-	-	-	-	-
<u>SATURATION EXTRACT</u>						
Saturation Percentage	84.1	85.2	71.8	119.2	135.7	104.6
EC <sub>e</sub> @25°C (mmhos/cm)	1.72	1.92	2.4	1.5	2.0	2.6
Ca <sup>++</sup> (me/l)	0.8	0.5	0.6	0.1	0.2	0.1
Mg <sup>++</sup> (me/l)	0.6	0.4	0.2	0.1	0.1	0.2
Na <sup>++</sup> (me/l)	14.8	17.9	22.4	13.7	16.1	22.8
K <sup>+</sup> (me/l)	0.3	0.3	0.2	0.1	0.2	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	Trace	0.3	0.8	3.1	0.8	0.6
HCO <sub>3</sub> <sup>-</sup> (me/l)	5.7	9.0	9.1	5.3	8.0	10.5
Cl <sup>-</sup> (me/l)	0.3	0.3	0.3	0.2	<0.1	0.2
SO <sub>4</sub> <sup>-</sup> (me/l)	10.4	8.6	12.5	5.4	8.0	10.5
NO <sub>3</sub> <sup>-</sup> (me/l)	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAR (me/l)	17.7	26.7	35.4	43.3	41.6	58.9
Na (me/100g)	1.2	1.5	1.6	1.6	2.2	2.4
Ca+Mg (me/100g)	0.1	0.1	0.1	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>						
EC <sub>e</sub> @25°C (mmhos/cm)	0.52	0.60	0.64	0.60	0.92	0.88
Ca+Mg (me/l)	0.2	0.1	0.0	0.0	0.0	0.2
<u>EXCHANGEABLE SODIUM</u> (percent)	53.4	36.5	47.4	28.2	62.2	47.4
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	15.3	21.2	16.3	35.3	24.9	27.2
Na0Ac@pH 8.2						
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.60	0.64	0.66	0.48	0.48	0.90
CADMIUM (Cd) (ppm)	0.19	0.33	0.62	<0.1	0.50	0.18
COPPER (Cu) (ppm)	7.0	9.5	2.0	1.5	25.7	9.9
IRON (Fe) (ppm)	46.2	155.0	98.8	52.0	149.0	202.0
MERCURY (Hg) (ppm)	0.25	0.10	0.05	0.05	0.05	0.05
MANGANESE (Mn) (ppm)	13.4	33.8	15.1	7.0	24.4	57.6
MOLYBDENUM (Mo) (ppm)	0.8	0.6	0.5	0.2	1.0	0.7
NICKEL (Ni) (ppm)	2.8	3.7	2.8	1.5	3.3	7.0
LEAD (Pb) (ppm)	10.3	6.6	3.0	3.8	9.2	5.2
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	7.5	10.5	5.0	5.3	11.2	9.9

\*Insufficient, Sample

Table 21  
Sheet 3

Tobacco Gardens Study Area, North Dakota  
 Geologic Drill Hole: 82-127 (cont'd)  
 Location: 2624' N. & 1274' W. of SE Corner, Sec. 31, T. 152 N., R. 97 W.  
 Logged by: G. Botdorf  
 Date: March 1982

DETERMINATION	LABORATORY DESCRIPTION		
	Data		
LABORATORY NUMBER	4,403	4,404	4,405
SACK NUMBER	127-13	127-14	127-15
DEPTH (FT)	125.0-129.4	129.4-137.0	137.0-142.0
<u>PARTICLE SIZE ANALYSIS</u> (percent)			
Very Coarse Sand (2.0-1.0 mm)	0.0	0.1	0.0
Coarse Sand (1.0-0.5 mm)	0.0	0.2	0.0
Medium Sand (0.5-0.25 mm)	0.0	0.2	0.1
Fine Sand (0.25-0.10 mm)	0.2	0.0	0.1
Very Fine Sand (0.10-0.05 mm)	0.2	5.5	0.2
TOTAL SAND (2.0-0.05 mm)	0.4	6.0	0.4
SILT (0.05-0.002 mm)	33.2	56.4	31.3
CLAY (0.002 mm)	66.4	37.6	68.3
GRAVEL (percent)	-	-	-
TEXTURAL CLASS (LAB)	C	SICL	C
<u>HYDRAULIC CONDUCTIVITY</u> (in/hr)			
6th Hr.	0.00	0.00	0.00
24th Hr.	0.00	0.00	0.00
<u>SETTLING VOLUME</u> (ml)	430.0	270.0	440.0
<u>MOISTURE RETENTION</u> (%)			
1/3 bar	88.5	66.3	64.7
15 bar	31.3	28.1	27.4
<u>SOIL REACTION-pH</u>			
Paste	8.8	9.0	8.6
1:5 H <sub>2</sub> O	9.5	10.1	9.8
1:2 0.01 M CaCl <sub>2</sub>	-	-	-
<u>GYP SUM REQUIREMENT</u> (me/100g)	-	-	-
<u>SATURATION EXTRACT</u>			
Saturation Percentage	192.7	136.3	132.8
EC <sub>g</sub> @25°C (mmhos/cm)	2.0	1.82	1.92
Ca <sup>++</sup> (me/l)	0.1	0.2	0.4
Mg <sup>++</sup> (me/l)	0.1	0.1	0.2
Na <sup>++</sup> (me/l)	15.8	15.7	17.6
K <sup>+</sup> (me/l)	0.2	0.1	0.2
CO <sub>3</sub> <sup>-</sup> (me/l)	0.6	0.9	0.4
HCO <sub>3</sub> <sup>-</sup> (me/l)	6.0	6.6	8.6
Cl <sup>-</sup> (me/l)	0.1	0.1	0.1
SO <sub>4</sub> <sup>-</sup> (me/l)	10.1	8.7	7.3
NO <sub>3</sub> <sup>-</sup> (me/l)	<0.1	<0.1	<0.1
SAR (me/l)	53.1	40.5	32.1
Na (me/100g)	3.2	2.1	2.3
Ca+Mg (me/100g)	<0.1	<0.1	<0.1
<u>1:5 EXTRACT</u>			
EC <sub>5</sub> @25°C (mmhos/cm)	1.00	0.76	0.70
Ca+Mg (me/l)	0.0	0.1	0.4
<u>EXCHANGEABLE SODIUM</u> (percent)	62.1	71.5	57.7
<u>CATION EXCHANGE CAPACITY</u> (me/100g)	32.2	25.3	29.3
NaOAc@pH 8.2			
SILVER (Ag) (ppm)	<0.1	<0.1	<0.1
BORON (B) (ppm)	0.68	0.32	0.58
CADMIUM (Cd) (ppm)	0.22	0.15	<0.1
COPPER (Cu) (ppm)	13.0	7.2	11.2
IRON (Fe) (ppm)	128.0	41.6	142.0
MERCURY (Hg) (ppm)	0.25	0.15	0.35
MANGANESE (Mn) (ppm)	20.9	2.3	8.3
MOLYBDENUM (Mo) (ppm)	1.8	0.4	0.7
NICKEL (Ni) (ppm)	4.1	2.0	5.0
LEAD (Pb) (ppm)	11.1	7.7	9.0
SELENIUM (Se) (ppm)	<0.05	<0.05	<0.05
ZINC (Zn) (ppm)	11.2	6.4	13.9

\*Insufficient Sample

Criteria Used to Determine Suitability of Overburden Material  
For Use as Plant Media in Revegetation<sup>1/</sup>

<u>Parameter</u>	<u>Methodology</u>	<u>Suitable</u>	<u>Limited Suitability</u>	<u>Unsuitable</u>
Texture	Pipette method plus sand sieving	FSL, VFSL, L, SiL, SCL	LFS, SL, CL, SiCL, SC	S, LS, SiC, C
Electrical Conductivity (mmhos/cm)	Saturation extract/conductivity bridge	<4	4-12	>12
pH	Saturated paste/glass electrode	6.0 - 8.4	5.0 - 6.0; 8.4 - 9.0	<5.0; >9.0
Sodium Adsorption Ratio (SAR)	Calculate: $Na / \sqrt{(Ca+Mg)/2}$ ; Ca, Mg, and Na in meq/l	<6	6-9 heavy textures 6-12 medium and coarse textures	>9 - heavy textures >12 - medium and coarse textures
Exchangeable Sodium Percentage (ESP)	Ammonium acetate extraction; calculate: Na/CEC x 100%	<5	5-15	>15 <sup>2/</sup>
Boroo (mg/l)	Hot water extraction/ carminie method	<5		>5
Selenium (mg/l)	Hydride generation; flameless AA	<2		>2
Molybdenum (mg/l)	Ammonium oxalate extraction; flameless AA or N <sub>2</sub> O flame AA - 5000	<1		>1
Copper (mg/l)	DTPA extraction; AA	<u>3/</u>		<u>3/</u>
Manganeae (mg/l)	DTPA extraction; AA	<60		>60
Zinc (mg/l)	DTPA extraction; AA	<40		>40
Lead (mg/l)	DTPA extraction; AA	10-15 (pH <6) 15-20 (pH >6)		15 (pH <6) 20 (pH >6)
Cadmium (mg/l)	DTPA extraction; AA	<1		>1
Nickel (mg/l)	DTPA extraction; AA	2-3		>3
Mercury (mg/l)	Extraction by H <sub>2</sub> SO <sub>4</sub> ; flameless AA (quartz cell)	<0.5		>0.5
Iron (mg/l)	-		Not Established	
Nitrate-Nitrogen (mg/l)	-		Not Established	

<sup>1/</sup> Applicable only to reclamation study areas in Montana and North Dakota.

<sup>2/</sup> Rate 2:1 - Clay texture poor if >10, sand texture if >20.

<sup>3/</sup> Suspect level not established - an excessive consumption of molybdenum through ingestion of vegetation may be toxic to animals. This concern is directly related to the Cu:Mo ratio in the plant tissue.

Table 23

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-101

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.7	Loam	Suitable	-
0.7-4.0	Clay loam	Suitable	-
4.0-6.5	Loam till	Limited	Salinity
6.5-10.0	Loam till	Limited	Salinity
10.0-31.5	Loam till	Limited	Salinity, Texture
31.5-53.0	Loam till	Suitable	-
53.0-63.0	Ss	Limited	% Sodium
63.0-82.0	S Sist	Limited	% Sodium
82.0-98.5	Sh	Limited	Texture, % Sodium
98.5-110.8	SiSs	Limited	% Sodium
110.8-128.0	S Sist	Unsuitable	% Sodium
128.0-137.2	Sh	Unsuitable	% Sodium, Texture
141.0-153.0	Sh	Unsuitable	% Sodium, Texture
153.0-160.5	SiSs	Unsuitable	% Sodium, Nickel
160.5-173.4	Sh	Unsuitable	% Sodium, Texture
173.4-177.8	Ss	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-102

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
2.0-5.5	Loam till	Limited	Texture
5.5-9.0	Loam till	Limited	Texture
9.0-10.0	Loam till	Limited	Texture
10.0-24.0	Ss	Limited	Texture
24.0-42.5	Ss	Unsuitable	Texture
42.5-60.0	Ss	Unsuitable	Texture
60.0-78.0	Ss	Unsuitable	Texture
78.0-95.0	Ss	Unsuitable	Texture
95.0-111.4	Ss	Unsuitable	Texture
111.4-123.8	Sh	Limited	Texture
123.8-137.9	Sh	Unsuitable	Texture, Nickel
148.1-154.7	Ss, Sh	Limited	Texture
154.7-170.0	Ss	Suitable	-

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-103

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-1.4	Loam	Suitable	-
1.4-5.0	Sandy loam	Limited	Texture
5.0-10.0	Gravel/Sand	Unsuitable	Texture
10.0-13.8	Till	Limited	Texture
13.8-31.5	S Silt	Suitable	-
31.5-44.0	Sh	Unsuitable	Texture, Nickel
44.0-63.0	SiSs, Sh	Limited	Texture, Nickel
73.0-82.0	SiSs	Unsuitable	Texture, Nickel
91.9-103.0	Ssh	Limited	Texture, % Sodium
113.0-131.5	SiSs	Limited	Texture, % Sodium

Legend

Ss - Sandstone	C Silt - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Silt - Siltstone	Sish - Silty shale
S Silt - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-104

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.7	Loam	Suitable	-
6.0-10.0	Loam till	Suitable	-
10.0-37.5	Loam till	Suitable	-
37.5-45.0	Loam till	Suitable	-
45.0-71.6	Loam till	Limited	Salinity
71.6-85.0	Ss	Suitable	-
85.0-100.2	Ss	Limited	Texture
100.2-115.0	Sish	Limited	Texture, Salinity
115.0-122.2	Sh	Suitable	-
122.2-133.3	Css	Suitable	-
133.3-161.0	Ss	Suitable	-
161.0-185.5	Sh	Suitable	-
185.5-191.5	Css	Suitable	-
191.5-196.5	Sh	Suitable	-
196.5-217.3	Css	Limited	% Sodium
218.5-231.5	Sh	Unsuitable	Texture, % Sodium
231.5-235.4	Sish	Unsuitable	% Sodium
236.4-245.9	Sh	Unsuitable	Texture, % Sodium
245.9-263.2	Css	Unsuitable	% Sodium
263.2-267.9	Sh	Unsuitable	Texture, % Sodium
267.9-284.6	Css	Unsuitable	% Sodium
284.6-308.8	Sh	Unsuitable	% Sodium, Nickel
308.8-332.5	Sh	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 27

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-105

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.7	Clay loam	Limited	Texture
0.7-2.8	Clay loam	Limited	Texture
2.8-7.5	Till	Limited	Texture
7.5-10.0	Ss	Suitable	-
10.0-39.0	Ss	Limited	Texture
39.5-48.6	Sish	Suitable	-
58.0-78.0	Sh	Suitable	-
78.0-93.0	Sh	Suitable	-
93.0-98.0	Css	Suitable	-
101.5-118.0	Sish	Limited	% Sodium
118.0-136.6	Sish	Unsuitable	% Sodium, Nickel
138.0-146.2	Cbsh	Unsuitable	% Sodium, Texture
146.7-156.3	Sish	Unsuitable	% Sodium
156.6-172.0	Sh	Unsuitable	Texture, % Sodium
172.0-176.6	Cbsh	Unsuitable	% Sodium, Salinity
181.7-195.0	Sh	Unsuitable	% Sodium
203.2-213.3	Sh	Unsuitable	% Sodium
213.3-234.5	Sish	Unsuitable	% Sodium
234.5-245.3	Le St, Sh	Unsuitable	% Sodium
245.3-258.3	Css	Unsuitable	% Sodium
258.3-273.0	Sh	Unsuitable	% Sodium
273.0-291.5	Sh	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Hanks Study Area  
Drill Hole 82-106

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.9	Clay loam	Limited	Texture, Zinc
0.9-2.3	Clay loam	Limited	Texture
2.3-5.0	Till	Limited	Texture, Manganese
5.0-10.0	Till	Limited	Texture, Salinity
10.0-14.0	Till	Limited	Texture, Salinity
14.0-23.0	Till	Limited	Texture, Salinity
23.0-40.7	Till	Limited	Texture, Salinity
40.7-55.0	SiSs	Limited	Texture, % Sodium
55.0-71.8	Sh	Limited	Texture, % Sodium
74.0-82.5	SiSs	Suitable	-
82.5-88.3	Sh	Unsuitable	Texture, % Sodium
90.0-115.0	Sh	Unsuitable	Texture, % Sodium
115.0-134.0	Sh	Unsuitable	% Sodium, Nickel
134.0-152.0	SiSs	Unsuitable	% Sodium, Nickel
152.0-164.1	Sh	Unsuitable	Texture, % Sodium
164.1-172.1	Ss	Unsuitable	% Sodium, Texture
175.0-191.7	S Sist	Unsuitable	% Sodium, Texture
191.7-210.0	Ss	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 29

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
 Sand Creek Study Area  
 Drill Hole 82-107

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
2.0-60	Clay loam	Limited	Texture, Salinity
6.0-10.0	Till	Limited	Texture, Salinity
10.0-44.6	Till	Limited	Texture, Salinity
44.0-60.0	Till	Limited	Texture
60.0-72.2	Till	Suitable	-
72.2-89.6	Sish	Unsuitable	Texture, Nickel
93.5-113.5	Sh	Limited	Texture, Nickel
113.5-134.1	Sh	Unsuitable	Texture, Nickel
134.1-151.1	Sh	Unsuitable	Texture, % Sodium
151.1-163.0	S Sist	Unsuitable	% Sodium
163.0-183.0	Ss	Unsuitable	% Sodium, Nickel
183.0-195.7	Ss, Sh	Unsuitable	% Sodium
218.2-235.0	Sh	Unsuitable	Texture, % Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Sand Creek Study Area  
Drill Hole 82-108

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
2.0-5.0	Clay loam	Limited	Texture, Manganese
5.0-10.0	Till	Limited	Texture, Manganese
10.0-30.6	Till	Limited	Texture, Salinity
30.6-39.0	Till	Limited	Texture
39.0-49.0	Sish	Limited	Texture, Nickel
49.0-59.4	S Sist	Limited	Nickel
65.0-78.5	S Sist	Limited	Nickel
78.5-104.0	S Sist	Unsuitable	% Sodium, Nickel
104.0-124.8	Sh	Unsuitable	% Sodium, Nickel
124.8-131.2	Ss	Unsuitable	% Sodium, Nickel
131.2-137.4	Sh	Unsuitable	Texture, % Sodium
145.9-159.4/	Sh	Unsuitable	Texture, % Sodium
162.4-168.0			
168.0-185.6	Ss	Unsuitable	% Sodium, Nickel
185.6-202.0	S Sist	Unsuitable	% Sodium, Nickel
210.0-233.0	Sish	Unsuitable	% Sodium
233.0-254.0	Ssh	Unsuitable	% Sodium, Nickel

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 31

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Sand Creek Study Area  
Drill Hole 82-109

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
3.0-3.6	Clay loam	Limited	Texture
3.6-5.0	Till	Limited	Texture, Salinity
5.0-7.0	Till	Limited	Texture, Salinity
7.0-7.8	Till	Limited	Salinity
7.8-10.0	Till	Limited	Salinity, Manganese
10.0-35.3	Till	Limited	Texture, Manganese
35.3-50.2	S Sist, Sh	Unsuitable	Texture, Nickel
56.1-66.3	Sish	Unsuitable	Texture, Nickel
76.0-94.0	Ss	Suitable	-
94.0-112.0	Ss	Limited	Texture
112.0-132.0	Ss	Unsuitable	% Sodium, Texture
132.0-151.6	Ss	Unsuitable	% Sodium, Nickel
163.8-184.0	Sh	Unsuitable	Texture, % Sodium
184.0-194.6	SiSs	Unsuitable	% Sodium
194.6-210.0	Sish	Unsuitable	Texture, % Sodium
210.0-216.5	Ssh	Unsuitable	Texture, % Sodium
216.5-229.6	Ss	Unsuitable	% Sodium
229.6-237.0	Sh	Unsuitable	Texture, % Sodium
238.9-239.9	Ssh	Unsuitable	% Sodium

Legend

Ss - Sandstone  
SiSs - Silty sandstone  
Css - Clayey sandstone  
Sist - Siltstone  
S Sist - Sandy siltstone

C Sist - Clayey siltstone  
Sh - Shale  
Ssh - Sandy shale  
Sish - Silty shale  
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Sand Creek Study Area  
Drill Hole 82-110

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.5	Loam	Suitable	-
0.5-3.5	Loam	Suitable	-
3.5-6.5	Till	Suitable	-
6.5-10.0	Till	Limited	Salinity
32.0-34.0	Till	Limited	Salinity, Manganese
45.0-47.0	Till	Limited	Salinity
60.5-62.5	S Sist	Suitable	-
64.2-66.2	SiSs	Limited	Salinity
74.9-76.9	S Sist	Limited	Salinity
79.9-81.9	Sist	Limited	% Sodium
93.0-95.0	SiSs	Suitable	-
101.0-103.0	Ssh	Suitable	-
126.0-128.0	Sh	Limited	% Sodium, Nickel
160.5-162.5	Sh	Unsuitable	% Sodium, Nickel
177.0-179.0	Ssh	Unsuitable	% Sodium, Nickel
186.5-188.5	Sh	Unsuitable	% Sodium, Nickel
197.0-199.0	Css	Unsuitable	% Sodium, Nickel
217.0-219.0	Ssh	Unsuitable	% Sodium, Nickel
239.0-240.0/ 242.0-243.0	Ssh	Unsuitable	% Sodium, Nickel

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 33

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
 Sand Creek Study Area  
 Drill Hole 81-111

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-1.0	Silt loam	Suitable	-
1.0-4.0	Clay loam	Limited	Texture
4.0-10.0	Till	Suitable	-
11.0-13.0	Till	Suitable	-
27.5-29.5	Sh	Suitable	-
31.5-33.5	Sh	Limited	Nickel
48.4-50.4	Sh	Limited	% Sodium
57.2-59.2	Sh	Limited	Texture, % Sodium
69.6-71.6	Ssh	Limited	Silt %, % Sodium
81.0-83.0	Ss	Limited	Nickel
90.0-92.0	Sh	Unsuitable	% Sodium, Nickel
104.0-106.0	Sh	Unsuitable	% Sodium, Nickel
131.0-133.0	Sh	Unsuitable	% Sodium, Nickel
137.0-139.0	Sh	Unsuitable	% Sodium
161.0-163.0	Css	Unsuitable	% Sodium, Texture
174.6-176.0	Css	Unsuitable	% Sodium, Texture
201.9-203.9	Sh	Unsuitable	Texture, % Sodium
214.7-216.3	Cbsh	Unsuitable	Texture, % Sodium
219.5-221.5	Sh	Unsuitable	% Sodium, Manganese, Nickel

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 34

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
 Williston Study Area  
 Drill Hole 81-113

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-1.5	Loam	Suitable	-
1.5-5.0	Loam	Suitable	-
5.0-7.5	Till	Suitable	-
7.5-10.0	Till	Limited	Texture
124.0-126.0	Sish, Ss	Limited	Nickel
139.5-141.5	Sish, Ss	Limited	Nickel
154.0-156.0	Sish	Unsuitable	% Sodium, Nickel
174.0-176.0	Sh	Unsuitable	% Sodium, Nickel
190.0-192.0	Ss	Unsuitable	% Sodium, Nickel
223.0-225.0	Sh	Unsuitable	% Sodium, Nickel
225.0-228.0	Sh	Unsuitable	% Sodium
228.0-230.0	Sh	Unsuitable	Texture, % Sodium
247.7-249.7	Css	Unsuitable	% Sodium, Nickel
255.6-257.6	Css	Unsuitable	% Sodium, Texture
283.0-285.0	Sh	Unsuitable	Texture, % Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 35

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Williston Study Area  
Drill Hole 81-114

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.6	Loam	Suitable	-
0.6-3.8	Loam	Suitable	-
3.8-7.0	Till	Limited	Salinity
7.0-10.0	Till	Limited	Salinity
16.0-18.0	Till	Limited	Salinity, % Sodium
24.5-26.5	C Sist	Unsuitable	Texture, Salinity
28.8-30.8	C Sist	Limited	% Sodium
34.0-36.0	Sish	Limited	Texture, Salinity
41.0-43.0	C Sist	Limited	Salinity, Nickel
44.7-45.2	C Sist	Limited	Texture, Salinity
61.0-63.0	C Sist	Limited	% Sodium
85.0-87.0	Sh	Limited	Nickel
94.0-96.0	Css	Unsuitable	% Sodium, Nickel
99.0-101.0	Sh	Unsuitable	% Sodium, Manganese
110.0-112.0	Sh	Unsuitable	% Sodium, Salinity
114.7-116.7	Cbsh	Unsuitable	% Sodium, Salinity
130.0-132.0	Sh	Unsuitable	% Sodium, Manganese
153.0-155.0	Sh	Unsuitable	% Sodium, Texture
164.5-166.1	Css	Unsuitable	% Sodium
169.3-171.3	Sh	Unsuitable	% Sodium, Nickel
182.1-184.1	Ssh	Unsuitable	% Sodium, Nickel
186.0-187.2	Ssh	Unsuitable	Hard Rock (cemented)
193.0-195.0	Ssh	Unsuitable	Texture, % Sodium
202.0-204.0	Ssh	Unsuitable	% Sodium, Texture
207.0-209.0	Le St, Sh	Unsuitable	Hard Rock (cemented)
213.0-215.0	Ss	Unsuitable	% Sodium, Nickel
243.3-245.3	Sh	Unsuitable	% Sodium, Texture
253.0-255.0	Sh	Unsuitable	% Sodium, Texture
258.0-260.0	Css	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 36

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Williston Study Area  
Drill Hole 81-117

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.3	Loam	Suitable	-
0.3-3.2	Clay loam	Limited	Texture
3.2-9.0	Till	Limited	Texture
9.0-47.5	Sand/Outwash	Unsuitable	Texture
47.5-68.8	Till	Limited	Texture
91.8-100.5	SiSs, C Sist	Suitable	-
100.5-110.0	Css	Suitable	-
110.0-116.5	Sh	Limited	Texture
116.5-121.6	SiSs	Suitable	-
121.6-129.0	Sish, Sh	Unsuitable	Texture, Nickel
130.0-144.0	Css	Suitable	-
144.0-164.0	Sh	Limited	Texture
164.0-205.0	Ss	Limited	Texture
205.0-239.0	Ss	Unsuitable	Texture
244.3-266.0	Sh	Limited	Texture, % Sodium
266.0-279.4	Css, Sh	Unsuitable	% Sodium, Texture
279.4-288.0	Ssh	Unsuitable	% Sodium, Nickel
288.0-315.1	Sh	Unsuitable	% Sodium, Texture
332.0-349.0	Ssh	Unsuitable	% Sodium, Texture

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Williston Study Area  
Drill Hole 81-121

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-1.2	Sandy loam	Limited	Texture
1.2-2.5	Sandy loam	Limited	Texture
2.5-5.0	Sandy loam	Limited	Texture
5.0-7.5	Sandy loam	Suitable	(Fine sandy loam)
7.5-10.0	Sandy loam	Limited	Texture
10.0-12.5	Outwash	Limited	Texture
12.5-23.0	C Sist	Limited	Texture, % Sodium
23.0-34.4	S Sist	Unsuitable	% Sodium
34.4-55.0	Sish, Sh	Unsuitable	Texture, % Sodium
55.0-62.0	Css	Unsuitable	% Sodium, Texture
62.0-70.9	S Sist	Unsuitable	% Sodium
71.5-86.5	Sh	Unsuitable	Texture, % Sodium
89.3-93.5	Ss	Unsuitable	% Sodium
93.5-113.0	Sish	Unsuitable	% Sodium, Texture
113.0-125.0	Sh	Unsuitable	Texture, % Sodium
140.0-162.0	Cbsh, Sh	Unsuitable	% Sodium, Texture

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Williston Study Area  
Drill Hole 81-123

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.5	Loam	Suitable	-
0.5-3.2	Clay loam	Limited	Texture
3.2-12.0	Till	Limited	Texture
14.3-26.8	Sish	Unsuitable	Texture, Salinity
26.8-41.0	SiSs	Limited	Texture, Salinity
41.0-56.7	Sh	Unsuitable	% Sodium, Texture
56.7-70.0	Css	Unsuitable	% Sodium
70.0-97.8	Sh	Unsuitable	Texture, % Sodium
105.5-130.6	Sh, Ss	Unsuitable	% Sodium
135.4-168.0	Sh	Unsuitable	% Sodium, Texture
168.0-187.8	Ssh, Css	Unsuitable	% Sodium, Nickel
196.2-215.6	Ssh	Unsuitable	% Sodium, Texture
253.7-261.0	Css	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Table 39

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Tobacco Gardens Study Area  
Drill Hole 82-124

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
2.5-4.2	Clay loam	Limited	Texture
4.2-7.0	Till	Limited	Texture
7.0-10.0	Till	Limited	Texture, Salinity
10.0-27.8	Till	Limited	Texture, Salinity
31.8-35.0	Sh	Unsuitable	Texture, Salinity
44.0-64.0	SiSs	Unsuitable	Texture, % Sodium
94.0-114.5	S Sist	Unsuitable	% Sodium, Texture
114.5-135.9	Ss	Unsuitable	% Sodium
148.7-159.1	Sh	Unsuitable	Texture, % Sodium
167.5-171.7	Sh	Unsuitable	Texture, % Sodium
171.7-196.0	Ss	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Tobacco Gardens Study Area  
Drill Hole 82-125

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-2.0	Loam	Suitable	-
2.0-4.3	Clay loam	Limited	Texture
4.3-10.0	Till	Limited	Texture, Salinity
10.0-14.3	Till	Limited	Salinity, Boron
17.0-32.4	SiSs	Limited	Salinity
32.4-38.0	Ssh	Limited	Texture
38.0-50.0	SiSs	Suitable	-
50.0-68.0	Sh	Limited	Texture, Salinity
72.6-85.0	S Sist	Limited	Texture, Nickel
85.0-102.0	SiSs	Unsuitable	% Sodium, Texture
102.0-118.7	SiSs	Unsuitable	% Sodium
118.7-128.0	SiSh, Sh	Limited	% Sodium
128.0-137.2	SiSt	Limited	Texture
137.2-142.0	Sh	Limited	Texture, Nickel
146.5-148.5	Sh	Unsuitable	% Sodium
148.5-163.0	Ss	Unsuitable	% Sodium
163.0-178.0	Sh	Unsuitable	% Sodium
178.0-193.0	Sh	Unsuitable	% Sodium, Manganese
193.0-216.3	Sh	Unsuitable	% Sodium, Nickel
216.3-230.6	SiSs	Unsuitable	% Sodium, Nickel
230.6-243.0	Sh	Unsuitable	% Sodium, Texture
254.0-271.3	S Sist	Unsuitable	% Sodium, Nickel
271.3-276.0	Sh	Unsuitable	% Sodium
276.0-287.5	Ss	Unsuitable	% Sodium, Nickel
287.5-298.5	Sh	Unsuitable	% Sodium, Nickel
308.9-313.0	Ss	Unsuitable	% Sodium
313.0-335.2	Sh	Unsuitable	Texture, % Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Tobacco Gardens Study Area  
Drill Hole 82-126

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-0.9	Loam	Suitable	-
0.9-4.3	Outwash	Limited	Texture
4.3-10.0	Till	Limited	Salinity
10.0-22.4	SiSh	Limited	Salinity
22.4-35.6	Sh	Limited	Texture, Salinity
35.6-43.8	Ssh	Limited	Texture, % Sodium
51.4-65.8	Sh	Unsuitable	% Sodium, Texture
65.8-85.0	Css	Unsuitable	% Sodium, Texture
85.0-100.8	Css	Unsuitable	% Sodium, Texture
100.8-114.9	Ssh	Unsuitable	% Sodium, Texture
114.9-127.6	Css	Unsuitable	% Sodium, Nickel
131.3-147.0	Sh	Unsuitable	Texture, % Sodium
147.0-164.0	Sh	Unsuitable	Texture, % Sodium
164.0-182.9	Sh	Unsuitable	Texture, % Sodium
191.8-203.8	Ssh	Unsuitable	% Sodium, Texture
203.8-217.0	Ss	Unsuitable	% Sodium, Nickel
217.0-233.4	Ss	Unsuitable	% Sodium
242.0-250.5	Cbsh	Unsuitable	Texture, % Sodium
250.5-255.2	Sh	Unsuitable	% Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -  
Tobacco Gardens Study Area  
Drill Hole 82-127

<u>Depth (ft)</u>	<u>Type</u>	<u>Suitability</u>	<u>Limiting Factor(s)</u>
0.0-1.2	Clay loam	Limited	Texture, Salinity
1.2-3.3	Loam	Limited	Salinity, % Sodium
3.3-10.0	Ss	Limited	Salinity, % Sodium
10.0-20.0	Ss	Limited	Salinity
20.0-28.5	SiSs	Limited	% Sodium
28.5-42.5	Ss	Suitable	-
42.5-52.3	Sh	Unsuitable	% Sodium
63.4-71.0	Sh	Unsuitable	Texture, % Sodium
77.0-83.5	Ss	Unsuitable	% Sodium
83.5-98.0	Ss	Unsuitable	% Sodium
107.1-121.0	Sh	Unsuitable	Texture, % Sodium
121.0-125.0	Ssh	Unsuitable	% Sodium, Nickel
125.0-129.4	Sh	Unsuitable	Texture, % Sodium
129.4-137.0	Ssh	Unsuitable	% Sodium, Texture
137.0-147.0	Sh	Unsuitable	Texture, % Sodium

Legend

Ss - Sandstone	C Sist - Clayey siltstone
SiSs - Silty sandstone	Sh - Shale
Css - Clayey sandstone	Ssh - Sandy shale
Sist - Siltstone	Sish - Silty shale
S Sist - Sandy siltstone	Cbsh - Carbonaceous shale

Le St - Limestone

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Hanks  
 DRILL HOLE: 82-101

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
101-1	3%	14%	42%		41% (R)			
101-2	11%	4%	49%		56% (R)			
101-3	10%	4%	47%		37% (R)	2%		
101-4	3%	14%	40%		40% (R)	3%		
101-5		9%	29%		62% (R)			
101-6		9%	26%		65% (R)			
101-7	7%	4%	24%		65% (R)			
101-8	6%	10%	50%		32% (R)		2%	
101-9	6%	8%	64%		18% (R)	2%	2%	
101-10	4%	11%	58%		25% (R)	2%		
101-11	11%	8%	53%		23% (R)		3%	
101-12	9%	9%	56%		19% (R)	2%	5%	

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Hanks  
DRILL HOLE: 82-104

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
104-1	18%		52%		30% (R)			
104-2	16%		58%		26% (R)			
104-3	15%		49%		36% (R)			
104-4	trace		45%		55% (R)			
104-5	15%		23%		62% (R)			
104-6	6%		49%		45% (R)			
104-7	21%		5%		74% (R)			
104-8	8%	5%	21%		66% (R)			
104-9	14%		33%		53% (R)			
104-10	4%	7%	17%		72% (R)			
104-11	8%	12%	51%		29% (R)			
104-12	9%	11%	48%		32% (R)			
104-13	10%	10%	50%		30% (R)			
104-14	trace			100%				
104-15	12%	11%	41%		36% (R)			

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Hanks  
 DRILL HOLE: 82-104

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
104-16	6%	8%	28%		58% (R)			
104-17	11%	8%	57%		24% (R)			
104-18	10%	10%	25%		55% (R)			

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Hanks  
 DRILL HOLE: 82-105

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
105-1	1%	14%	33%		52% (R)			
105-2	6%	8%	36%		48% (R)	2%		
105-3	7%	10%	33%		50% (R)			
105-4	11%		17%		72% (R)			
105-5	7%	9%	53%		31% (R)			
105-6	9%	7%	62%		20% (R)	2%		
105-7	12%	12%	52%		24% (R)			
105-8	9%	10%	43%		38% (R)			
105-9	9%	0%	30%		61% (R)			
105-10	4%	8%	57%		27% (R)	2%	2%	
105-11	7%	8%	49%		34% (R)	2%		
105-12	4%	9%	64%		21% (R)	2%		
105-13	9%	7%	32%		42% (R)	5%		5%
105-14	6%	7%	64%		21% (R)	2%		

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Sand Creek  
 DRILL HOLE: 81-110

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
110-1	16%		43%		41% (R)			
110-2	5%	8%	49%		38% (R)			
110-3	4%		69%		27% (R)			trace
110-4	11%		46%		43% (R)			
110-5	10%	8%	64%		16% (R)	2%	trace	
110-6	14%	11%	38%		37% (R)			
110-7	9%	12%	52%		27% (R)			
110-8	11%	12%	47%		30% (R)			
110-9	8%	7%	33%		52% (R)			
110-10	3%			97%				
110-11	5%	11%	60%		24% (R)			
110-12		trace		100%				

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Sand Creek  
 DRILL HOLE: 81-111

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
111-1	13%	5%	41%		41% (R)			
111-2	15%		16%		69% (R)			
111-3	6%	10%	32%		52% (R)			
111-4	6%	10%	34%		50% (R)			
111-5	15%	8%	45%		32% (R)			
111-6	9%	11%	24%		56% (R)			
111-7	9%	9%	39%		43% (R)			
111-8	9%	10%	43%		38% (R)			
111-9	3%	13%	51%		33% (R)			
111-10	8%	6%	52%		34% (R)			
111-11	7%	13%	38%		42% (R)			
111-12	9%	15%	52%		24% (R)			
111-13	trace			100%				
111-14	15%	11%	53%		21% (R)			
111-15	12%	10%	58%		20% (R)			

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-113

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
113-1	16%	4%	45%		33% (R)	2%		
113-2	7%	7%	57%		27% (R)	2%		
113-3	15%	8%	43%		34% (R)			
113-4	11%	8%	49%		32% (R)			
113-5	12%	9%	48%		31% (R)			
113-6	5%	5%	19%		71% (R)			
113-7	9%	7%	36%		48% (R)			
113-8	10%	9%	41%		40% (R)			
113-9	12%	6%	54%		28% (R)			
113-10	9%		10%		81% (R)			
113-11	13%		12%		75% (R)			
113-12	9%	10%	38%		43% (R)			

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-114

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
114-1	16%		47%		37% (R)			
114-2	1%	5%	53%		41% (R)			
114-3	6%	6%	58%		30% (R)			
114-4	6%	8%	73%		11% (R)	2%		
114-5	6%	6%	54%		31% (R)	3%		
114-6	11%	8%	41%		38% (R)	2%		
114-7	11%	11%	46%		29% (R)	3%		
114-8	9%	8%	60%		23% (R)			
114-9	4%	11%	68%		17% (R)			
114-10	14%	10%	52%		24% (R)			
114-11	11%		25%		64% (R)			
114-12	11%	10%	56%		22% (R)			
114-13	10%		20%		70% (R)			
114-14	11%		14%		75% (R)			
114-15	8%	7%	50%		32% (R)	3%		

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston, North Dakota  
 DRILL HOLE: 81-117

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
117-2	12%		14%		63% (R)	3%	8%	
117-3	15%		15%		70% (R)	trace	trace	
117-5	16%		17%		63% (R)	4%		
117-6	6%		20%		72% (R)	2%		
117-7	11%		10%		75% (R)	4%		
117-8	13%		20%		63% (R)	4%		
117-9	trace		5%		95% (R)			
117-10	18%		25%		54% (R)	3%	trace	
117-11	12%		9%		73% (R)	6%		
117-12	trace		7%		93% (R)			
117-15	20%		20%		52% (R)	8%		
117-16	19%		18%		63% (R)	4%		
117-17	12%		33%		55% (R)			
117-18	13.5%	7.5%	46%		30% (R)	3%		
117-19	7%	7%	72%		12% (R)			

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-121

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
121-1	12%	18%	59%		19% (R)	2%		
121-2	8%	9%	61%		20% (R)	2%		
121-3	20%	7%	27%		46% (R)			
121-4	8%	8%	44%		40% (R)			
121-5	13%	11%	54%		21% (R)	1%		
121-6	18%	7%	27%		48% (R)			
121-7	40%	6%	32%		20% (R)	2%		
121-8	8%	5%	63%		22% (R)	2%		
121-9	39%	6%	44%		11% (R)			
121-10	9%	9%	61%		15% (R)	1%	5%	
121-11	11%	10%	52%		22% (R)		5%	
121-12	15%	7%	57%		18% (R)		3%	
121-13	12%	9%	52%		24% (R)	3%		

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-122

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
122-1	10%	7%	53%		28% (R)	2%		
122-2	9%	8%	63%		19% (R)	1%		
122-3	11%	5%	59%		23% (R)	2%		
122-4	5%	12%	59%		22% (R)	2%		
122-5	3%	9%	69%		16% (R)	3%		
122-6	11%	9%	55%		25% (R)			
122-7	9%	8%	43%		38% (R)	2%		
122-8	7%	8%	63%		18% (R)	2%	2%	
122-9	2%	11%	68%		17% (R)	2%		
122-10	4%	5%	28%		63% (R)			
122-11	8%		19%		73% (R)			trace
122-12	5%	9%	64%		21% (R)	1%	trace	
122-13	6%	11%	68%		9% (R)	3%	3%	
122-14	7%	8%	64%		20% (R)	1%	trace	trace
122-15	15%	7%	34%		44% (R)			

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-122

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
122-16	9%	9%	55%		27% (R)			
122-17	4%	7%	63%		21% (R)	1%	4%	
122-18	8%	6%	49%		35% (R)	2%		
122-19	2%	9%	15%		71% (R)	3%		
122-20	12%	10%	46%		28% (R)	2%		2%

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Williston  
 DRILL HOLE: 81-123

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
123-2	15%		30%		49% (R)	6%		
123-3	17%		40%		40% (R)	3%		
123-4	5%	9%	61%		23% (R)	2%		
123-5	6%	8%	56%		28% (R)	2%		
123-6	7%	9%	45%		35% (R)	4%		
123-7	8%	6%	27%		51% (R)	8%		
123-8	13%	6%	41%		35% (R)	5%		
123-10	8%	10%	38%		38% (R)	6%		
123-11	11%		16%		73% (R)			
123-12	10%	13%	23%		52% (R)	2%		
123-13	9%	5%	29%		52% (R)	5%		
123-14	26%		17%		57% (R)			

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Tobacco Gardens  
 DRILL HOLE: 82-125

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
125-1	6%	7%	53%		34% (R)			
125-2	trace	trace	37%		51% (R)	3%		7% (feldspar)
125-3	4%	11%	45%		31% (R)	4%		5% (feldspar)
125-4	3%	6%	31%		56% (R)			3% (feldspar)
125-5	7%	8%	33%		50% (R)	2%		
125-6	3%	8%	29%		60% (R)			
125-7		16%	57%		25% (R)	2%		
125-8		14%	69%		16% (R)	1%		
125-9	4%	11%	53%		29% (R)	2%		1%
125-10	17%	6%	49%		28% (R)			
125-11	2%	10%	64%		18% (R)	1%	5%	
125-12		9%	66%		18% (R)	2%	5%	
125-13	6%	11%	52%		24% (R)	2%		5% (feldspar)

\* R = Random type

RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Tobacco Gardens  
 DRILL HOLE: 82-125

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
125-14	4%	10%	27%		52% (R)	4%		3% (feldspar)
125-15	2%	12%	41%		36% (R)	4%		5% (feldspar)
125-16	6%	8%	32%		54% (R)			
125-17	6%	11%	65%		16% (R)	2%		
125-18	7%	11%	67%		31% (R)	4%		
125-19	9%	11%	62%		16% (R)	2%		
125-20	9%	5%	48%		36% (R)	2%		

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: Tobacco Gardens  
 DRILL HOLE: 82-126

<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
126-1	15%		29%		36% (R)			25% (feldspar)
126-2	5%	11%	63%		15% (R)	2%		4%
126-3	6%	11%	47%		36% (R)			
126-4	2%	13%	59%		24% (R)	2%		
126-5	5%	7%	37%		51% (R)			
126-6	3%	10%	53%		32% (R)	2%		
126-7	4%	8%	72%		14% (R)	2%		
126-8	5%	10%	64%		19% (R)	2%		
126-9		12%	35%		53% (R)			
126-10		12%	31%		57% (R)			
126-11	7%	8%	38%		42% (R)			5%
126-12	56%		9%		35% (R)			
126-13	8%	7%	33%		51% (R)	1%		

\* R = Random type

## RESULTS OF X-RAY DIFFRACTION ANALYSES

STUDY AREA: DRILL HOLE:	Tobacco Gardens 82-127							
<u>Sample</u>	<u>Kaolinite</u>	<u>Chlorite</u>	<u>Illite</u>	<u>Smectite</u>	<u>Mixed-Layer Clay*</u>	<u>Quartz</u>	<u>Carbonate</u>	<u>Other</u>
127-1	6%	13%	34%		47% (R)			
127-2	4%	15%	58%		24% (R)			
127-3	5%	14%	54%		25% (R)	2%		
127-4	8%	11%	40%		41% (R)			
127-5	20%		33%		47% (R)			
127-6	17%	17%	7%		58% (R)	1%		

\* R = Random type



Soils and Water Laboratory Procedures and References

I. Soil Characterization

A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvements of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).
2. Settling Volume, Imhoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).
3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).
4. Particle Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).
5. Bulk Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).
6. Moisture Retention is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).
7. Field Capacity - field determination.
8. Water holding capacity - determined by calculation: field capacity-wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with automated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater; Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical Analysis of Soils, 1964), and (Brown,

Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979, EPA-600 4-79-020, 365.1:365.1-1-365.1-9).
3. Nitrate-Nitrite are determined by phenoldisulfonic acid and by Automated cadmium reduction (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971, Thirteenth Edition, 133:233-237), (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7).
4. Sulfate is determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 375.2:375.2-1-375.2-4), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition, 156C: 334-336).
5. Sodium, Potassium, Calcium and Magnesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

#### C. Trace Metals

1. Trace Metals are determined by atomic absorption with flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 50-157), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition), and (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600-4-79-020).

#### D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook

No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical Analysis of Soils, 1964).

2. pH reading in  $\text{CaCl}_2$  Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).
3. Saturation Extract taken from saturated soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 2 and 3:84-88, 27:107 and 4:39-90), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical Analysis of Soils, 1964).
4. Exchangeable Sodium and Potassium are extracted by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 72-3:1033, 72-3.2.1:1034 and 57-1:891-895).
5. Exchangeable Sodium Percentage is determined by calculation relationship being  $\frac{\text{Na}}{\text{CEC}} \times 100$  (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).
6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).
7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).
8. Boron was determined by extraction with hot water (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).
9. Percent Organic Carbon is determined with Technicon Auto Analyzer II.
10. Total Carbonate expressed as % calcium carbonate, acid-neutralization, (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 23c:105-106).
11. SAR (sodium adsorption ratio) determined by calculation:  
$$\text{SAR} = \text{Na} / \sqrt{(\text{Ca} + \text{Mg})/2}$$
; Ca, Mg, and Na in meq/l.



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