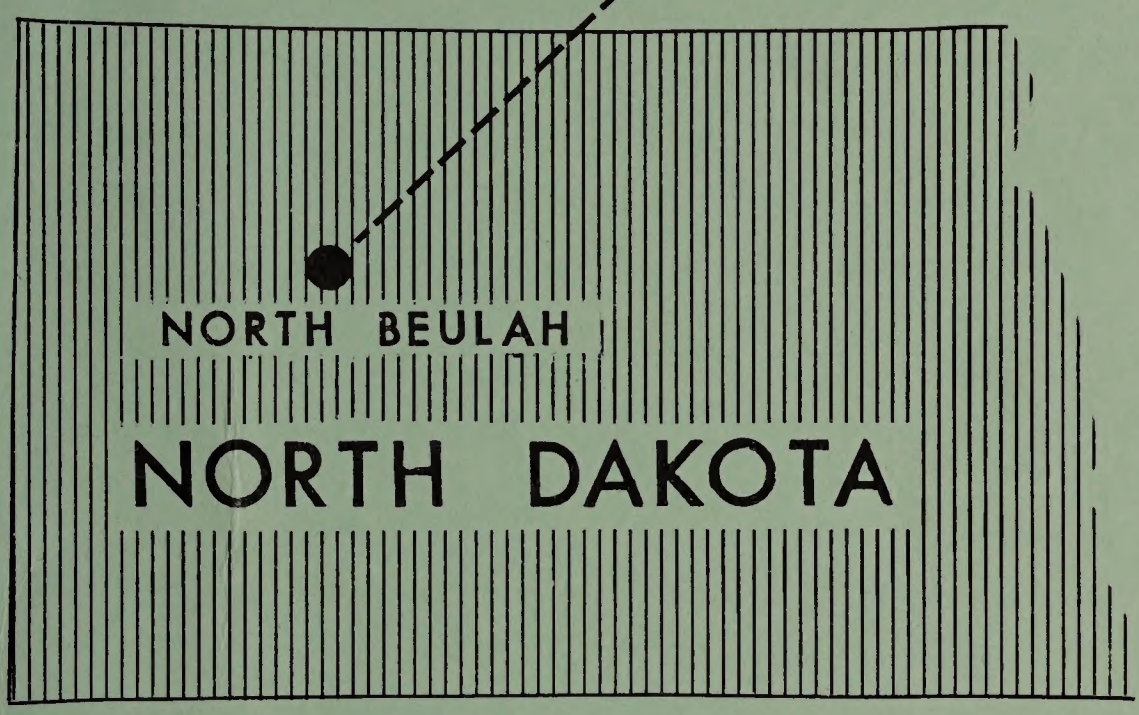
North Beulah Study Area Report



RESOURCE & POTENTIAL RECLAMATION EVALUATION

North Beulah Study Area Report

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

"North Beulah" Study Area Report was prepared through the efforts of the U.S. Department of Interior, principally the Bureau of Land Management and Bureau of Reclamation. The study effort began in 1979 and was concluded in 1981 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Editor's Note: In order to more closely associate the EMRIA program with the Federal Coal Management Program, the name "EMRIA" was officially dropped from use in May 1981. The responsibilities of the EMRIA program now come under "Technical Investigations in support of the Federal Coal Management Program."

Limited copies of this report are available from:

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16. Abstract (Limit: 200 words) The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The data consisted of geology, overburden, climate, and physiography. Geologic investigations in the study area consisted of drilling three core holes. Samples collected from stratigraphic units were analyzed in the laboratory to determine suitability of overburden materials for use as supplementary plant media in reconstructed profiles. A land classification survey was not performed in this study area. However, soils are assumed to be similar to those investigated in the adjacent Beulah Trench Study Area. As such, most soils should yield a minimum of 12 inches of good quality topsoil that is nonsaline, nonsodic, and permeable. Subsoil material should, in most cases, be of adequate quantity and quality for reconstructing a desirable root zone. The climatic regime in this area appears conducive to the production of native grasses and small grains. The moisture available to plants from snowmelt and spring precipitation is usually adequate for germination and establishment. In general, the potential for restoring surface-mined land in the North Beulah Study Area to a condition capable of supporting the present uses (rangeland, hayland, cropland) appears good to excellent.

17. Document Analysis a. Descriptors

0510 Environmental Surveys
0807 Coal Deposits
1407 Reclamation

b. Identifiers/Open-Ended Terms

Evaluation of Reclamation Potential of Surface-Mined Land, North Beulah Deposit, North Dakota, Mercer County

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(Formerly NTIS-35)
Department of Commerce

NORTH BEULAH STUDY AREA
NORTH BEULAH DEPOSIT
NORTH DAKOTA

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INTRODUCTION

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

PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements.

AUTHORITY

This report is prepared in accordance with Section 4 of the Agreement between the Bureau of Land Management and the Water and Power Resources Service 1/ dated May 7, 1974, and Work Order Number YA-515-IA9-3 dated January 22, 1979.

RESPONSIBILITY

BUREAU OF LAND MANAGEMENT

1. Selection of the study area.

2. Determination of the extent of the study.

3. Procuring easements and rights-of-entry.

WATER AND POWER RESOURCES SERVICE

1. Drilling three core holes through potential surface mineable coalbeds in the study area.

1/ Formerly the Bureau of Reclamation

2. Evaluation of core materials for their suitability in a reconstructed profile.

3. Providing the Bureau of Land Management with a final report of all investigations.

LOCATION

The North Beulah Study Area is located in Mercer County, about 2 miles northwest of Beulah, North Dakota (Plate 1). The study area lies within Township 144 North and Range 88 West. It includes the south ½ of section 10, the southwest ¼ of section 14 and all of section 22.

PRESENT LAND USES

Most of the study area is being used for livestock grazing with smaller portions being utilized for hay and small grain production.

POSTMINING LAND USES

Postmining land uses are expected to be similar to the present uses.

CLIMATE

The North Beulah Study Area has a continental-type climate characterized by warm summers, harsh cold winters, long periods of sunshine, and a moderate amount of precipitation during the growing season. Data obtained from a recording station in Beulah, North Dakota (about 2 miles southeast of the study area) were used to evaluate temperature, precipitation, and related climatic factors for the study area.

TEMPERATURE

Based on data recorded at Beulah between 1955 and 1974, temperature extremes of 104° F. in summer and -39° F. in winter may occur in this area. Average monthly temperatures and probable extremes for the area are listed in Table 1.

Frontal systems pass through this area frequently throughout the year and can cause large temperature changes within a 24-hour period. Several large, rapid fluctuations in temperature can occur over a 1 to 2 week period.

○ NORTH BEULAH STUDY AREA

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

EMRIA STUDY AREAS
NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERAL LOCATION MAP

DESIGNED V. LINSSEN	SUBMITTED
DRAWN V. LINSSEN	RECOMMENDED
CHECKED G. J. T.	APPROVED
BILLINGS, MONTANA MARCH 1976	1305-600-194

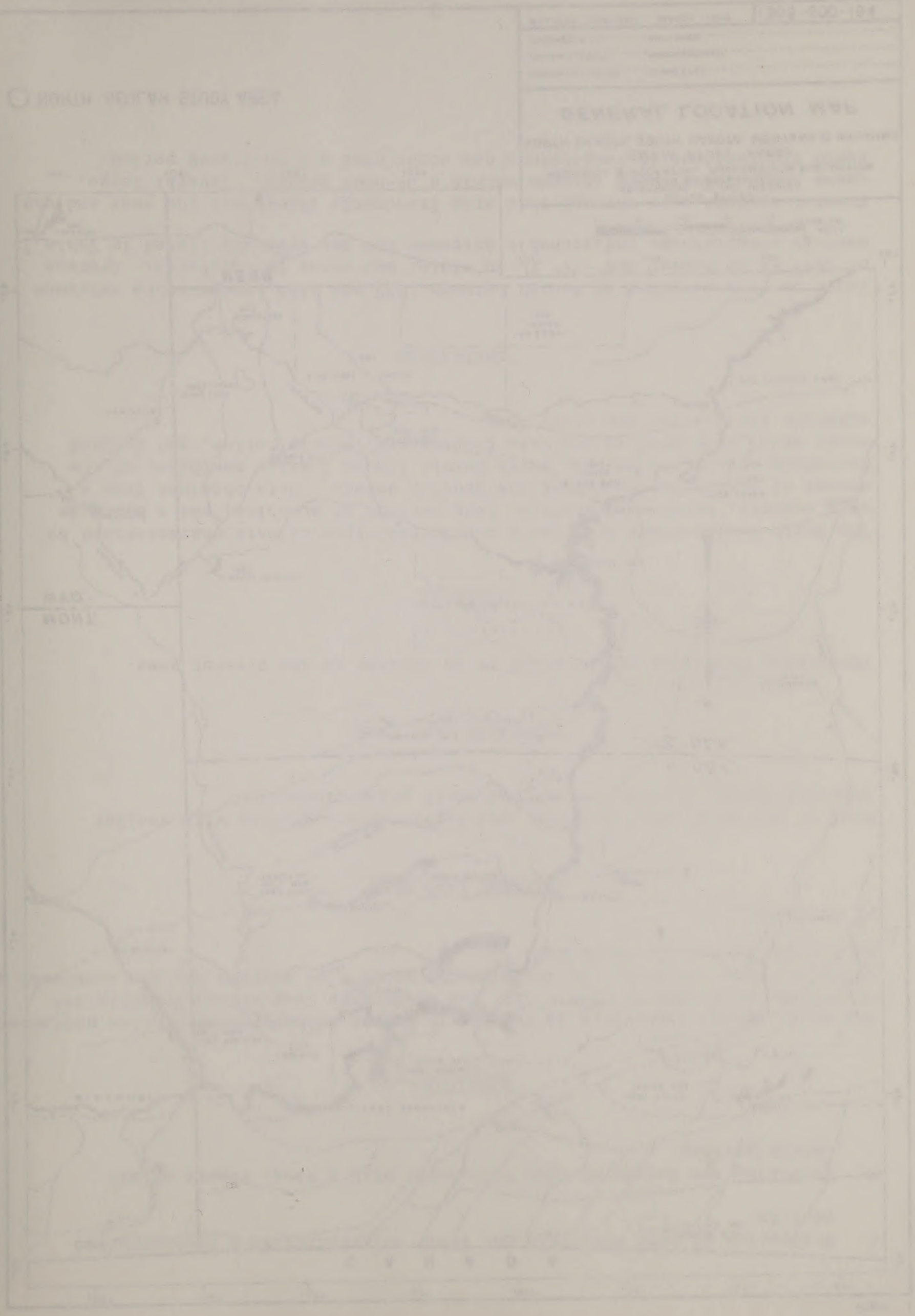

Table 1 - Temperature and Precipitation Data - Mercer County, North Dakota*

Month	Temperature[1]						Precipitation[1]				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have-- Maximum temperature higher than--	2 years in 10 will have-- Minimum temperature lower than--	Average number of growing degree days[2]	Average	2 years in 10 will have-- Less than--	2 years in 10 will have-- More than--	Average number of days with 0.10 inch or more	Average snowfall
	°F	°F	°F	°F	°F	Units	In	In	In		In
January----	18.8	-3.7	7.6	48	-37	0	.36	.11	.55	1	4.5
February---	24.7	1.2	13.0	52	-31	0	.32	.07	.51	1	4.2
March------	37.3	14.6	26.0	73	-23	63	.41	.13	.62	1	4.2
April------	53.6	28.3	41.0	85	9	124	1.72	.52	2.67	4	3.5
May--------	67.6	39.7	53.7	94	21	425	2.72	1.28	3.90	6	.5
June-------	77.0	49.9	63.5	97	34	705	3.35	1.79	4.61	7	.0
July-------	84.2	54.3	69.2	101	41	905	2.79	1.07	4.16	5	.0
August-----	84.5	52.5	68.5	104	37	884	1.65	.51	2.55	3	.0
September--	71.0	40.6	55.8	98	21	474	1.27	.48	1.90	3	.2
October----	60.4	31.0	45.7	89	13	230	.65	.13	1.05	2	.5
November---	38.9	16.5	27.7	69	-12	34	.57	.12	.92	2	4.6
December---	25.8	4.2	15.0	56	-31	17	.32	.12	.48	1	4.8
Year-----	53.7	27.4	40.6	104	-39	3,861	16.13	12.80	19.29	36	27.0

1/ Recorded between 1955-74 at Beulah, North Dakota.

2/ A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by two, and subtracting the temperature below which growth is minimal for the principal crops in the area (40° F).

* This table is taken from: Soil Survey of Mercer County, North Dakota; U.S.D.A. - Soil Conservation Service, 1978.

The average growing season for hardy crops is estimated at 134 days between mid-May and mid- to late September. 2/ Tables 2 and 3, respectively, describe the probable growing season lengths and freeze dates in spring and fall. Typically, native range plants and small grains deplete the available soil moisture by mid-July and mature or become dormant. Tables 4 and 5 (Appendix) record the estimated moisture reserve at the beginning of the growing season and the approximate date that the moisture is depleted by native grasses and small grains.

PRECIPITATION

The average annual precipitation in this area is about 16.13 inches, with nearly 75 percent of this amount occurring during the growing season (May through September). June is the wettest month, averaging 3.35 inches. Average monthly precipitation values are included in Table 1.

Average snowfall for the area is about 27 inches, with almost 96 percent of this value falling between November and April (see Table 1). Effective precipitation from snowfall is considered to be 80 percent of the total snowfall.

A map showing precipitation deviation at selected locations within a 40-mile radius of Beulah, North Dakota, is included as Figure 1 in the Appendix.

OTHER CLIMATIC FACTORS

The prevailing wind direction is west-northwesterly, except in May, June, July, and August, when it is easterly. The windiest month is April, during which the wind speed averages about 13 miles per hour.

June and July are the months most susceptible to hail activity. Hail damage to native range plants is generally minimal; however, damage to small grains may be severe.

The interaction of climate and aspect generally does not limit crop or range productivity in this area. The surface relief is relatively subdued and, although the south facing slopes are more droughty, the reduction in plant productivity is minimal.

Thunderstorms occur on about 35 days in an average year. In at least 1 year in 5, the following rainfall intensities may be expected: 1.1 inches in 30 minutes, 1.5 inches in an hour, 1.8 inches in 3 hours, 1.9 inches in 6 hours, 2.3 inches in 12 hours, and 2.7 inches in 24 hours.

Annual evaporation from both Class A pans and lakes in this area is estimated at 36 inches.

2/ Includes days when the minimum temperature exceeds 28° F.

The area receives about 60 percent of the sunshine that could possibly occur each year.

EFFECT OF CLIMATE ON REVEGETATION

Most climatic factors in the North Beulah Study Area appear favorable for revegetation of surface-mined land. Spring is the most favorable planting time since soil moisture is relatively high during the early part of the growing season. The spring rains usually provide moisture to the soil in excess of the plant moisture requirement. With favorable moisture conditions, seedlings will grow rapidly and become established before the available moisture is depleted in about mid-July.

Climatic factors that may adversely affect revegetation efforts in this study area include: (1) below normal or uneven distribution of precipitation, especially during the growing season; (2) severe thunderstorms and/or strong winds that result in surface erosion; (3) late spring freezes; and (4) depletion of soil moisture by wind.

PHYSIOGRAPHY AND DRAINAGE

The North Beulah Study Area lies in the glaciated portion of the Great Plains Physiographic Province. Topography of the area is characterized by rolling hills bordered on the north by a wide, flat Pleistocene meltwater channel and on the south by the valley of Spring Creek.

Maximum relief for the immediate area is about 340 feet, ranging from an elevation of approximately 2,120 feet at the crest of a hill in section 15 to approximately 1,780 feet along Spring Creek. Surface gradients range from nearly flat in the buried channel to about 12 percent on steeper hillsides.

Drainage is accomplished through a dendritic system tributary to Spring Creek and the Pleistocene meltwater channel that joins it. Spring Creek is, in turn, tributary to the Knife River and joins it about 1 mile southwest of the town of Beulah.

GEOLOGY

REGIONAL GEOLOGY

The North Beulah Lignite Deposit is located in the Williston Basin in west-central 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.

Table 2
Growing Season Length (Mercer County, North Dakota)*

Probability	Daily minimum temperature during growing season[1]		
	Higher than 24° F	Higher than 28° F	Higher than 32° F
	Days	Days	Days
9 years in 10	134	117	99
8 years in 10	142	122	104
5 years in 10	156	134	115
2 years in 10	170	145	126
1 year in 10	178	151	131

Table 3
Freeze Dates in Spring and Fall (Mercer County, North Dakota)*

Probability	Temperature[1]		
	24° F or lower	28° F or lower	32° F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	May 16	May 31	June 4
2 years in 10 later than--	May 11	May 24	May 31
5 years in 10 later than--	May 1	May 12	May 23
First freezing temperature in fall:			
1 year in 10 earlier than--	September 17	September 7	September 2
2 years in 10 earlier than--	September 23	September 13	September 6
5 years in 10 earlier than--	October 5	September 23	September 16

1/ Recorded between 1955-74 at Beulah, North Dakota

* These tables are taken from: Soil Survey of Mercer County, North Dakota; U.S.D.A. - Soil Conservation Service, 1978.

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 unlifting 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, and sandstones of Cretaceous and Tertiary age cover the western part of North Dakota. Pleistocene and Holocene glacial, aeolian, and alluvial deposits mantle the bedrock in much of the area. Plate 2 is a generalized bedrock geologic map showing the southern limits of glaciation.

SITE GEOLOGY

Investigations

Previous investigations were conducted in the surrounding area by the U.S. Geological Survey and the Water and Power Resources Service. The Geological Survey results are documented in Open-File Report 77-481 and the Geologic Map of the Beulah Quadrangle. Water and Power Resources Service investigations are presented in EMRIA Report Number 10. Both reports are referenced in the Bibliography.

Geologic investigations for this report were conducted during August of 1979. The Water and Power Resources Service drill crew completed three core holes ranging in depth from 123.7 to 313.8 feet. The holes were drilled with a Failing Model 1500 rotary drill using an "H" series wireline core barrel. Drill fluid consisted of water from the Knife River and an organic polymer - "Revert." All overburden core was tested for suitability in reconstructed profiles by the Water and Power Resources Service Soils Laboratory in Bismarck, North Dakota. Test results are graphically shown on the geologic logs (Plates 3, 4, and and 5 in the Appendix). Coal samples were collected and shipped to

the U.S. Geological Survey Coal Resources Laboratory in Denver, Colorado. The samples were for their information and test results are not included in this report.

Plate 6 is a map showing where drill holes were completed by the Water and Power Resources Service. The map also shows the generalized surface geology in and around the study area.

Stratigraphy

Stratigraphic units exposed in and near the study area range in age from Paleocene to Holocene. The Paleocene is represented by the Sentinel Butte Member of the Fort Union Formation. The Pleistocene is represented by three different depositional units. Recent deposition is represented by Holocene alluvium. A brief description of each unit follows:

Paleocene

Fort Union Formation - Sentinel Butte Member - an alternating sequence of sandstones, siltstones, shales, carbonaceous shales, and lignites with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and weakly cemented. Shales vary from soft, plastic clay-shale to moderately indurated claystone. Shale and siltstone zones readily break down and form slopes below sandstone ledges. Correlation of clastic sediments over even short distances is difficult due to facies changes, channeling and variation in bedding thickness. Laboratory analyses of core samples indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are generally pale olive or yellowish-gray in color, while fresh core samples vary from light brown 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. Lignite zones serve as excellent marker beds as they can generally be traced over wide areas. This formation is about 500 feet thick.

Striking features in the Sentinel Butte Member are resistant clinker zones, locally called "scoria," that cap knobs or armor valley walls. The clinker is a fused or baked rock 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 rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented and baked to a brick-red or orange color. Alteration of the overlying material is roughly proportional to the original thickness of lignite that has burned. The clinker is permeable and locally supplies water for springs and wells.

Clinker outcrops are not prominent in the North Beulah Study Area because of the soil cover. They are, however, quite conspicuous a short distance to the north, near the south end of the Beulah Trench Study Area.

UNITED STATES
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RESOURCE & POTENTIAL RECLAMATION EVALUATION

EMRIA STUDY AREAS

NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERALIZED REGIONAL GEOLOGIC MAP

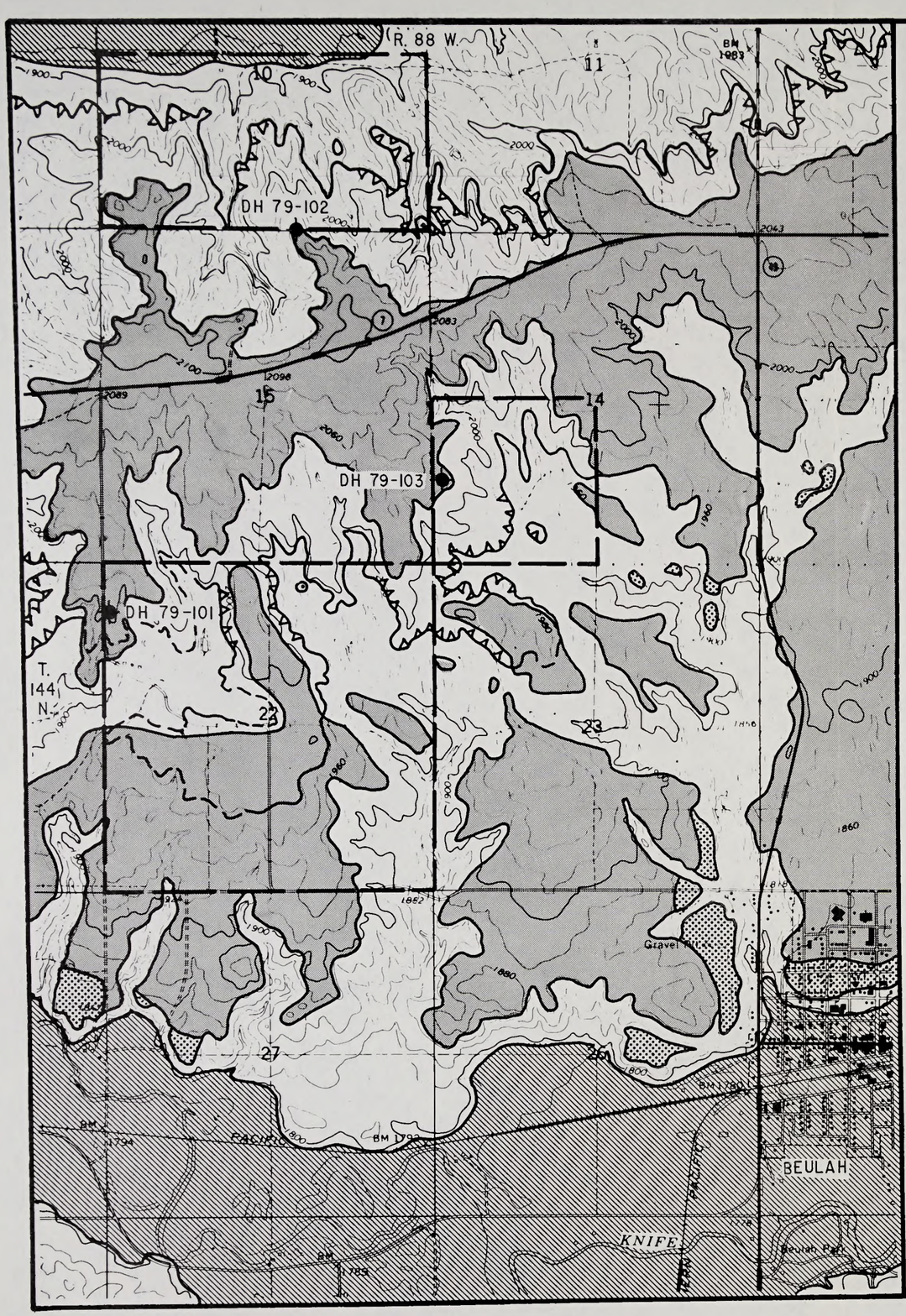
DESIGNED V. LINSSEN G. TAUCHER — SUBMITTED

DRAWN V. LINSSEN — RECOMMENDED

CHECKED G. J. T. — APPROVED

BILLINGS, MONTANA MARCH 1976

1305-600-195



EXPLANATION

HOLOCENE		ALLUVIUM – Unconsolidated clay, silt, sand and gravel up to 30 feet thick. Covers a buried channel along the Knife River that may be up to 150 feet deep.
PLEISTOCENE		TERRACE – Unconsolidated sand and gravel deposited by glacial meltwater. Up to 30 feet thick.
PLEISTOCENE		GLACIAL TILL – Heterogeneous mixture of clay, silt, sand, gravel, cobbles and boulders deposited by a Wisconsin Age ice sheet. It generally covers bedrock along the topographic highs where it has not been removed by erosion.
PALEOCENE		SENTINEL BUTTE MEMBER (Ft. Union Formation) – Sandstone, siltstone, shale and coal up to 500 feet thick.
		Base of Beulah-Zap Coalbed. Sawtooth where burned at the surface and dashed where inferred. Shown on map as it would occur if projected to ground surface.
	DH 79-101	Water and Power Resources Service Drill Holes 79-101 through 79-103.
		Limits of Study Area. Includes the S 1/2 of Section 10, SW 1/4 of Section 14 and all of Section 22, T. 144 N., R. 88 W.

NOTE

Geology compiled using the Water and Power Resources Services' 1979 reconnaissance mapping data and the U.S. Geological Surveys' "Geologic Map of the Beulah Quadrangle, North Dakota; compiled in 1949.

N

2000 0 2000 4000 6000

SCALE OF FEET

NOTE

Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTH BEULAH STUDY AREA – NORTH DAKOTA

GENERALIZED GEOLOGIC INVESTIGATIONS MAP

GEOLOGY G TAUCHER	FIELD APPROVAL
DRAWN L E ALLSOP	TECH. APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA FEBRUARY, 1981 1305-600-196

Pleistocene

Glacial Till - a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by one or more continental glaciers. It occurs as a thin veneer or as remnant patches on the bedrock surface. Up to 50 feet thick.

Channel Deposits - mostly sand and gravel that fills buried channels up to 150 feet in depth beneath the Knife River Valley and the valley immediately north of the study area. Covered by Holocene alluvium.

Terrace Deposits - erosional remnants of sand and gravel that were deposited by glacial meltwater. These deposits occur along the valley walls of the Knife River. Up to 30 feet thick.

Holocene

Alluvium - unconsolidated clay, silt, sand, and gravel deposited by modern streams in valley floors. Up to 30 feet thick.

Lignite Beds

Four lignite beds or zones were penetrated by drilling in the North Beulah Study Area. These have been designated as A, B, C and D on the geologic logs (Appendix). Three of these beds can be reasonably correlated with surrounding coalbeds. The A Coalbed probably represents the Schoolhouse Bed. The B Coalbed is the bed of economic interest in this study area and is the Beulah-Zap Coalbed. The D Coalbed is a zone containing three beds and correlates with the Hazen Coalbed which crops out along the Knife River trench downstream from the town of Beulah.

At the request of the landowner, drill hole DH79-101 was moved about 750 feet south of its original location in the northwest corner of Section 22 (Plate 6). The hole was started at an elevation stratigraphically below the Schoolhouse Bed and above the Beulah-Zap Bed. Glacial till was encountered to a depth of 31 feet in the interval where the Beulah-Zap Bed was expected. The drill hole was then deepened to 313.8 feet to encounter the Hazen Coalbed which lies about 220 feet below the Beulah-Zap Bed.

Drill holes DH79-102 and -103 were drilled to 153.0 and 123.7 feet, respectively. Both holes penetrated the Schoolhouse and Beulah-Zap Coalbeds. Drill hole DH79-102 is located in the south half of Section 10 and drill hole DH79-103 is located in the southwest quarter of Section 14 (Plate 6).

Structure

The study area is located in the Williston Basin, but local sediments are essentially flat lying.

Small faults exist in the area as indicated by slickensides found in drill core samples. Evidence of movement is generally restricted to weak, plastic, carbonaceous shales immediately above or below lignite beds. Displacement along these fractures could not be determined, but probably does not exceed 5 feet.

Paleontology

Surface inspection 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 soil. Fossils found in drill core included calcareous shells and carbonaceous tree fragments. None were collected for identification.

Mineral Resources

Natural gas and oil are the only minerals, other than coal, that may be present in the North Beulah Study Area. Exploration holes have been drilled in the region in the past. Extensive new investigations in the Williston Basin to the west of the study area may extend into it and lead to new discoveries. At the present time, however, no producing wells are located within the study area boundaries.

ENGINEERING GEOLOGY

Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the North Beulah Study Area. The bedrock is somewhat softer, but physical property test results should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Much of the bedrock at the North Beulah Study Area consists of bentonitic shales which are susceptible to minor shrinking and swelling. 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, the North Beulah Study Area experiences no problems with land stability. Landslides do not occur because of the gentle slopes and subsidence is not a problem.

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 3/

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.

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

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 mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring 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, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter 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.

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 the 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.

Material Sources

Earth materials suitable for most construction can be found within or near the North Beulah Study Area. Material types and the local sources are noted below:

Impervious

Impervious material is clayey or silty borrow that can be used for construction of embankments or as canal or ditch lining. It is available from the glacial till that covers most of the uplands.

Pervious

Pervious material is a clean sand or gravel suitable for use in filters or other types of structures where free drainage is required. It can be found in the Pleistocene channel fill along the northwest edge of the study area.

Concrete Aggregate

Concrete aggregate is a clean sand or gravel similar to the pervious material noted before. It may also be available from nearby Pleistocene channel fill, but the nearest Water and Power Resources Service approved sources are located near the Missouri River approximately 20 to 35 miles southeast of the study area.

Clinker

Clinker or scoria is a thermally altered rock formed by heat from burning coalbeds. It is reasonably hard, brittle and crushes easily. It is frequently used for road fill and surfacing. Deposits are located in several places near the study area where the Beulah-Zap Coalbed has burned along its outcrop.

Riprap

Riprap is a durable, reasonably well-graded mixture of rock fragments generally ranging from about 6 inches to 3 feet in diameter. It is used for surface protection from running water. Ideally, individual fragments should be angular to remain stable on steep slopes. High quality riprap material is not available in the North Beulah Study Area. The bedrock is too soft, and although there are scattered glacial boulders in the area, gathering them would be very expensive and they are too rounded to remain stable on anything but gentle slopes. Probably the closest sources of suitable rock are the Black Hills of South Dakota or the granitic basement rocks of extreme eastern North Dakota.

Seismicity

The North Beulah Study Area lies 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, Nebraska, and Canada have been felt in the state. A list of earthquakes that have been recorded in North Dakota follows, but much of the information on exact location and intensity is unknown.

Date	Intensity (Modified Mercalli)	Distance From North Beulah	Located Near
Oct. 9, 1872	Unknown	420 miles	Sioux City, IA
Nov. 15, 1877	Unknown	Unknown	Iowa or Nebraska
May 15, 1909	Unknown	Unknown	SK, Canada
Oct. 26, 1946	IV	105 miles	Williston, ND
Aug. 17, 1959	IX	480 miles	Hebgen Lake, MT
July 8, 1968	IV	75 miles	Huff, ND
July 9, 1975	Unknown	235 miles	Morris, MN

OVERBURDEN SUITABILITY FOR REVEGETATION

SOIL MANTLE SUITABILITY

A soil boring was made immediately adjacent to three geologic drill holes: DH79-101, DH79-102, and DH79-103, in order to provide general information on topsoil/subsoil quality for revegetation.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger was then used to penetrate the soil to a depth of 10 feet, except for Point Site 1 adjacent to DH79-101, where cobble/boulders halted the boring at 7.5 feet. Soil texture, color, and other observable features of the exposed profiles were recorded. Samples were collected from each layer in the profiles for laboratory analysis.

Routine analyses including pH, hydraulic conductivity, settling volume, and electrical conductivity were performed on each sample. The results of these analyses (Tables 6 through 8, Appendix), together with notes from the field investigations, provided the basic data needed to determine soil suitability for revegetation. The criteria listed in Table 9 were used to place the soil materials in one of three classes: Suitable, Limited Suitability, and Unsuitable.

The results of the soil suitability determination for each Point Site profile are described briefly below. Because the type and quality of soils are highly diverse in the North Beulah Study Area, the physical and chemical properties important to their use as plant media cannot be projected accurately over a wide range of conditions. Therefore, the quality determination of the soil materials applies only to the specific site where each profile was excavated. No attempt is made herein to project the results to adjacent areas.

Point Site No. 1 - Table 6 (Appendix)

This soil developed in slightly to moderately calcareous glacial till. All samples from the profile were medium to moderately fine textured, nonsaline, and permeable.

All soil material in this profile, to a depth of 78 inches, was classed as Suitable for use as topsoiling material in the reconstructed profile. Below

Table 9

CRITERIA USED TO DETERMINE OVERBURDEN (SOIL AND BEDROCK) SUITABILITY FOR REVEGETATION [4]

FACTORS AFFECTING USE	DEGREE OF SUITABILITY: SUITABLE	LIMITED SUITABILITY	UNSUITABLE
EC (mmhos/cm)	<8	8-16	>16
SAR	<2	2-12	>12
ESP [5]	<2	2-15	>15
pH	5.0-8.5	3.5-5.0	<3.5; >8.5
Coarse Fragments over 3-inch diameter (percent by volume)	<15	15-35	>35
Intermediate Textural Group	medium moderately fine moderately coarse	fine	coarse
Available Water Capacity (inches/inch)	>.1	.1-.05	<.05
Depth to Bedrock or cemented pan	>40"	20-40"	<20"
Slope (%)	<8	8-15	>15

4/ EMRIA Handbook - Guidelines for Reclamation Study Areas; Bureau of Land Management, 1977.

5/ Rate 2:1 Clay texture poor if over 10; Sand texture if over 20.

When rating bedrock suitability, EC, SAR, pH, and texture are used from the table; slope and depth to bedrock are disregarded.

78 inches, the quantity and quality of soil material may be limited due to a high percentage of coarse fragments (cobble/boulders) present in the soil matrix.

Point Site No. 2 - Table 7 (Appendix)

This soil developed in slightly to moderately calcareous glacial till which extends to a depth of about 60 inches. The till mantle overlies a zone of highly weathered sandstone belonging to the Sentinel Butte Member of the Fort Union Formation.

The glacial soil material appears Suitable for use as plant media in the reconstructed profile. All samples to a depth of 66 inches were medium to moderately fine textured, nonsaline, and permeable. Samples from the underlying weathered sandstone were medium to moderately coarse textured, nonsaline to slightly saline, and permeable. This material appears Limited in suitability for use as topsoil due to its coarse texture, limited fertility, and low available water holding capacity. Replacement of this material in the subsoil zone (below the primary plant rooting zone) would be desirable.

Point Site No. 3 - Table 8 (Appendix)

This residual soil developed in weathered sandstone and sandy shale of the Sentinel Butte Member, Fort Union Formation. All samples between 0 and 52 inches were medium textured, nonsaline, and permeable. These materials appear highly Suitable for replacement as topsoil in the reconstructed profile.

Between 52 and 120 inches, all samples showed a marked increase in soluble salts, causing them to be placed in the Limited Suitability class. These materials appear best suited for replacement as subsoil. Because the texture and permeability of these materials are favorable, the soluble salts should leach readily if the materials are placed over spoils with good internal drainage.

BEDROCK SUITABILITY

Bedrock samples from drill holes DH79-101, DH79-102, and DH79-103 were evaluated as to their suitability for use as plant media. The results of laboratory analyses (Tables 10 through 12, Appendix) together with interpretations of the geologic logs (Plates 3 through 5, Appendix) provided the basic data required to make the evaluation. The criteria used for the suitability determination are listed in Table 9.

The bedrock materials were placed in one of three classes based on the quality of the material for use as revegetative media. These classes are: Suitable, Limited Suitability, and Unsuitable.

Table 13, Appendix, describes the suitability of each sample from drill holes DH79-101, DH79-102, and DH79-103. Deficiencies are indicated for the materials classified as Limited Suitability or Unsuitable.

The upper strata (approximately 0 to 50 feet) of drill holes DH79-101 and DH79-102 were determined to be Suitable for use as plant media. These strata consist of medium to moderately fine textured materials which are nonsaline, nonsodic, and moderately permeable. The remaining samples from DH79-101 and DH79-102, as well as all samples from DH79-103, were classified as Limited Suitability or Unsuitable. Notable deficiencies of these materials included: high salinity and/or sodicity, high pH, slow permeability, high clay percentage, and carbonaceous influence.

Because the type and quality of bedrock materials in the North Beulah Study Area are highly diverse, the physical and chemical properties important to their use as plant media cannot be projected accurately over a wide range of conditions. Therefore, the bedrock suitability determination applies only to the specific site where each core was drilled. No attempt is made in this report to project the data to adjacent areas. Also, the ease of separating and stockpiling bedrock materials for resurfacing was not considered in this suitability evaluation.

RECLAMATION POTENTIAL

Based on the resource data presented in this report and EMRIA Report No. 10 (Beulah Trench Study Area), the potential for restoring surface-mined land in the North Beulah Study Area to a condition capable of supporting the present uses (rangeland, hayland, and cropland) appears good to excellent. The two critical factors directly influencing revegetation are: (1) climate, and (2) availability of suitable plant growth material; both appear favorable in this study area.

The climatic regime in this area appears conducive to the production of native grasses and small grains. The moisture available to plants from snowmelt and spring precipitation is usually adequate for germination and establishment. Although the growing season in this area is estimated at 134 days between mid-May and mid to late September, the native grasses and small grains will typically mature or become dormant by about mid-July when the available soil moisture is depleted.

Although a land classification (soil) survey was not performed in the North Beulah Study Area, it is assumed that the glacial, residual, and alluvial/colluvial soils occurring in the area are similar to those investigated in the adjacent Beulah Trench Study Area. In general, most of these soils should yield about 12 inches of good quality topsoil that is nonsaline, nonsodic, and permeable. Given adequate moisture and a moderate amount of fertilization, this material should provide an excellent revegetative medium. The quantity and quality of subsoil material in the Beulah Trench Study Area was highly variable but, in most cases, appeared adequate for reconstructing a desirable root zone. The same will probably hold true for the North Beulah Study Area.

BIBLIOGRAPHY

Benson, W.E., and Lindvall, R.M., 1949, Geologic Map of the Beulah Quadrangle, North Dakota: U.S. Geological Survey Preliminary Map.

Groenewold, G.H., and Rehm, B.W., 1980, Instability of Contoured Surface-Mined Landscapes in the Northern Great Plains: Causes and Implications, 15 pp.

Law, Ronald, 1977, Preliminary Report on the Geology of the Near-Surface Coal Beds in the Knife River Area, North Dakota: U.S. Geological Survey, Open File Report 77-481.

United States Bureau of Reclamation, 1968, Region 6 Concrete Aggregate and Riprap Sources: Report No. C-1078-6A.

United States Department of the Interior, Bureau of Land Management, 1975, Otter Creek Study Site: EMRIA Report No. 1.

United States Department of the Interior, Bureau of Land Management, 1977, Beulah Trench Study Area: EMRIA Report No. 10.

United States Department of the Interior, Bureau of Land Management, 1977, Guidelines for Reclamation Study Areas: EMRIA Handbook.

APPENDIX

Table 4 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses[1/]

North Beulah Study Area

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F.)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches[3/]
May 11					+3.63[2/]		
	May 21	11	60.6	4.24		2.57	+1.96
June					+1.96		
	June 15	37	63.5	4.85		3.97	+1.08
July					+1.08		
	July 15	67	69.5	6.12		2.62	-2.42[4/]
August					-2.42		
	August 15	98	68.5	5.35		2.08	-5.69
Sept.					-5.69		
	Sept. 12	126	57.1	2.89		1.42	-7.16
Sept. 25		139		23.45			

1/ Computed by Blaney-Criddle Method using the Beulah Weather Station - Latitude 47°16'.
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 3.63 inches.
3/ Difference = Moisture reserve plus precipitation minus moisture use.
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, plants use available moisture by July 15 and mature and become dormant.

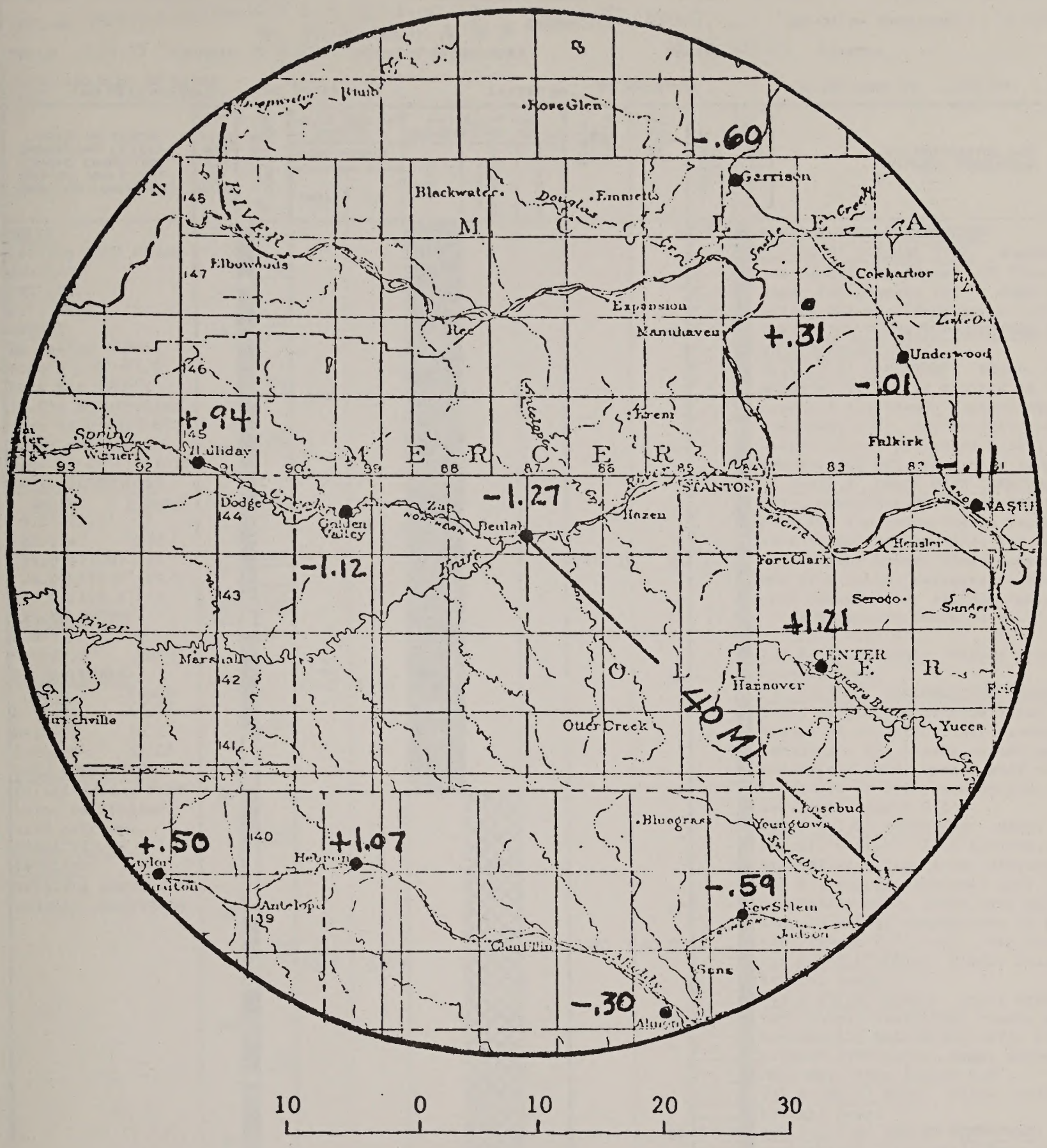
Table 5 - Potential Consumptive Use of Moisture and Available Moisture - Small Grains[1/]

North Beulah Study Area

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F.)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches[3/]
May 11					+3.63[2/]		
	May 21	11	60.6	1.92		2.57	+4.28
June					+4.28		
	June 15	37	63.5	4.48		3.97	+3.77
July					+3.77		
	July 15	67	69.5	8.58		2.62	-2.19[4/]
August					-2.19		
	August 15	98	68.5	5.99		2.08	-6.10
Sept.					-6.10		
	Sept. 12	126	57.1	.99		1.42	-5.67
Sept. 25		139		21.96			

1/ Computed by the Blaney-Criddle Method using the Beulah Weather Station - Latitude 47°16'
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 3.63 inches.
3/ Difference = Moisture reserve plus precipitation minus moisture use.
4/ Natural precipitation during most years is inadequate to meet potential moisture needs.

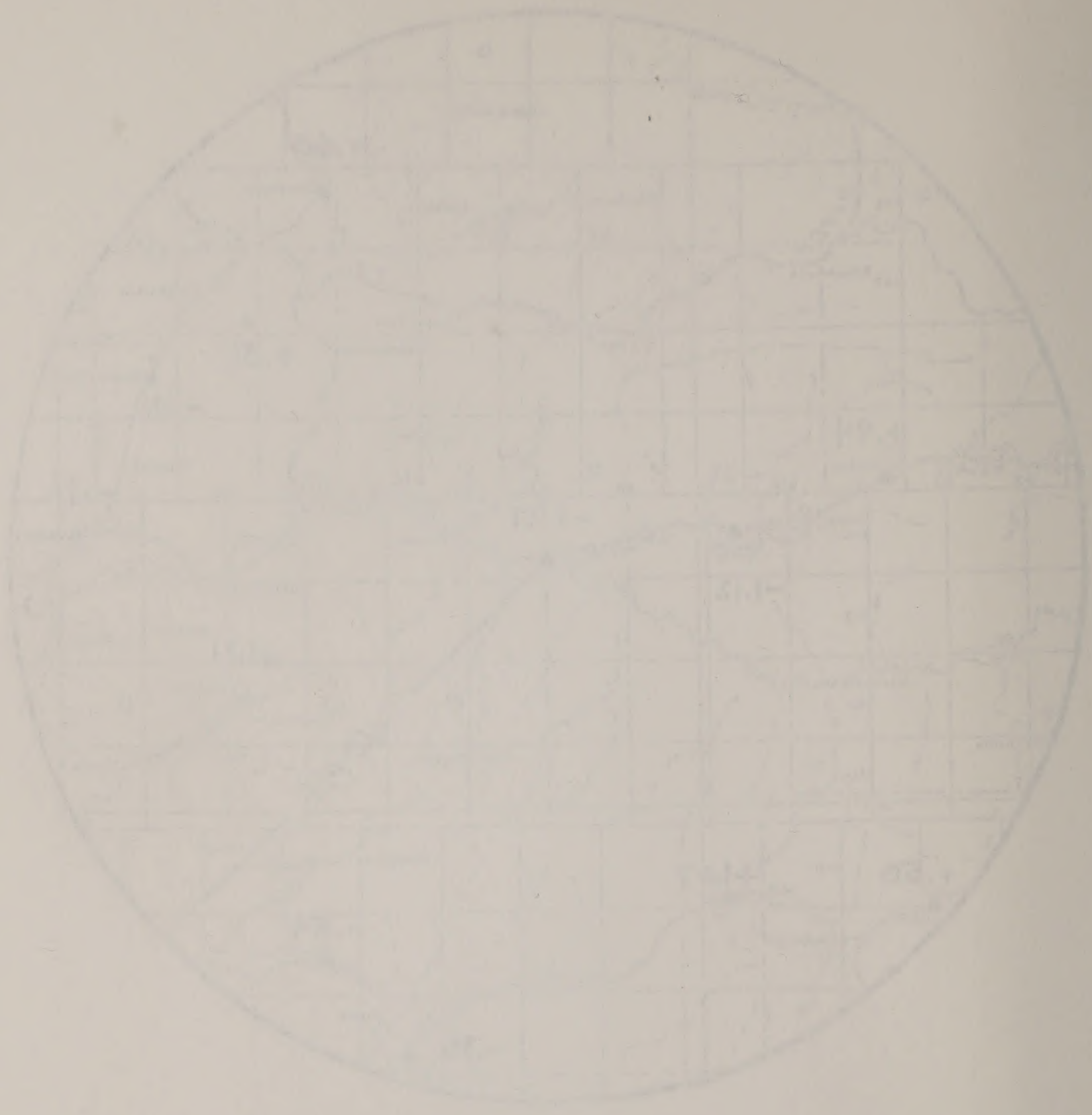
Figure 1



Precipitation Deviation at Selected Locations in the North Beulah Study Area.

Notes

The 40-mile circle around the North Beulah Study Area indicates an area in which average yearly precipitation is about 16.39 inches. Minus or plus (inside circle) indicates deviation from the 16.39 inch normal at selected stations.



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GEOLOGIC LOG OF DRILL HOLE

FEATURE North Beulah Study Area / North Beulah Deposit — PROJECT EMRIA — STATE North Dakota
HOLE NO. DH79-101 — LOCATION 775' S. & 100' E. of N.W. Corner of Sec. 22, T. 144 N., R. 88 W. — GROUND ELEV. 2005.0' — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8-21-79 — FINISHED 8-24-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 313.8' — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Failing 1500 truck-mounted.
DRILLER
R.V. Shaw
METHOD
Bx casing drive sample 0.0'-33.0'. Rock bit 33.0'-34.0'; Hq wireline core 34.0'-313.8'. Water and Revert used as drill fluid.
DRILL FLUID LOSS

Depth	% Loss
0.0'-22.2'	?
22.2'-?	100
36.0'-73.0'	50
73.0'-153.8'	40-0
153.8'-313.8'	0

CASING RECORD

0.0-3.5'	6"
0.0-22.0'	Hw

WATER LEVELS

Date	Depth
8-21-79	49.9'
8-23-79	50.2'
8-24-79	51.0'

HOLE COMPLETION
Pulled casing from hole; backfilled with concrete.
CHARACTER OF DRILLING
Drilling normal, no unusual conditions.

TYPE AND SIZE OF HOLE: Bx; RB; WS; Hq

CORE RECOVERY (%): 90, 80, 90, 100, 90, 100, 100, 68, 40, 30, 65, 90, 95

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

	FROM	TO
#1	0.0	25.0
#2	25.0	50.0
#3	50.0	75.0
#4	75.0	100.0

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE

ELEVATION (FEET): 1975.0; 1941.2

DEPTH (FEET): 10, 20, 30, 40, 50, 60, 63.8, 70, 80, 90

GRAPHIC LOG

SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

GLACIAL TILL-PLEISTOCENE
0.0-30.0' GLACIAL TILL: approx. 70% low plasticity fines; 20% fine to coarse sand; 10% gravels to 1"; damp to moist; strong HCl reaction; brown. (CL)
FORT UNION FORMATION-SENTINEL BUTTE MEMBER-PALEOCENE
30.0-63.8' SANDSTONE: brown; unweathered: massive; very fine grained to fine grained; all breaks mechanical; poorly cemented; soft, can be deformed with slight finger pressure; moist; slightly reactive to HCl; max. core length 0.4'.
63.8-127.8' SHALE WITH CARBONACEOUS ZONES: gray; unweathered; laminated; 1 joint dips 80° remaining breaks mechanical; soft to moderately hard, can be broken with slight hammer blow; damp to moist; non to slightly reactive to HCl; max. core length 1.6'; average core 0.6'.
Carbonaceous Zones at 94.0'-94.5'; 115.0'-127.8'.
127.8-131.0' COAL: black; brittle; broken; damp.
131.0-153.5' CARBONACEOUS SHALE: dark gray; slightly weathered areas with traces of oxidation; air slaked; laminated; all breaks appear mechanical; moderately hard; breaks with slight hammer blow; dry to damp; nonreactive to HCl; max. core length 0.5'.
153.5-241.0' SANDSTONE: gray; unweathered; appears massive; fine grained; all breaks mechanical except joint dipping 80° at 206.0'; poorly cemented; soft to moderately hard, trims with difficulty; damp to moist; nonreactive to HCl; max. core length 2.5'; avg. core length 1.0'.
241.0-245.6' COAL: black; brittle; broken; damp.
245.6-257.6' SHALE: gray; unweathered; very thinly laminated; breaks appear mechanical; moderately soft, trims without difficulty; damp; nonreactive to HCl; max. core length 0.8'.
257.6-260.5' COAL: black; brittle; broken; damp.
260.5-272.6' SHALEY SANDSTONE: gray; unweathered; thin shale beds throughout; all breaks appear mechanical; moderately soft, trims without difficulty; damp; nonreactive to HCl; max. core length 1.1'.
272.6-284.7' COAL: black; brittle; broken; damp.
284.7-313.8' CARBONACEOUS SHALE: dark gray; unweathered; laminated; air slakes moderately; all breaks mechanical; parting along bedding planes; moderately soft but brittle in some areas; slightly damp; nonreactive to HCl; max. core length 0.3'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diomond, H = Hoystellite, S = Shot, C = Churn
Hole seoled . . . . . P = Pocker, Cm = Cemented, Cs = Bottom of cosing
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 dio. of cosing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dio. of cosing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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Plate 3

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE North Beulah Study Area
North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-101 — LOCATION 775' S. & 100' E. of N.W. Corner of Sec. 22, T. 144 N., R. 88 W. — GROUND ELEV. 2005.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-21-79 — FINISHED 8-24-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 313.8' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

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) FROM	SOILS ANALYSIS SAMPLE DEPTH (FEET) TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Hq	95										
		100										
			#5									
			100.0	127.8								
		61										
		85						1877.2	127.8			
									C			
		100						1874.0	131.0			
		89	#6									
			131.0	153.5								
		68										
		100						1851.5	153.5			
			#7									
			153.5	175.0								
		100										
		100										
			#8									
		100	175.0	200.0								
		100										

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . . D = Diomond, H = Hoystellite, S = Shot, C = Churn
Hole seoled . . . . . P = Pocker, Cm = Cemented, Cs = Bottom of cosing
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 dio. of cosing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dio. of cosing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3".

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE North Beulah Study Area / North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-101 — LOCATION 775' S. & 100' E. of N.W. Corner of Sec. 22, T. 144 N., R. 88 W. — GROUND ELEV. 2005.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-21-79 — FINISHED 8-24-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 313.8' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

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) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100										
		100	#9 200.0	225.0								
		100										
		100	#10 225.0	241.1								
		100						1764.0	241.0			
		100	#11 245.6 Minus	272.6 Coal				1759.4	245.6			D Zone
		100						1747.4	257.6			
		100						1744.5	260.5			
		100						1732.4	272.6			
		100						1720.3	284.7			
		100										

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole	D = Diamond, H = Hoystellite, S = Shot, C = Churn			
Hole 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",	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"

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GEOLOGIC LOG OF DRILL HOLE

Plate 3
SHEET 4 OF 4

FEATURE North Beulah Study Area / North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-101 — LOCATION 775' S. & 100' E. of N.W. Corner of Sec. 22, T. 144 N., R. 88 W. — GROUND ELEV. 2005.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-21-79 — FINISHED 8-24-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 313.8' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

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) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Hq	100										
		100						1691.2	313.8			

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole	D = Diomond, H = Hoystellite, S = Shot, C = Churn			
Hole sealed	P = Pocker, Cm = Cemented, Cs = Bottom of cosing			
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 dio. of cosing (X-series)	Ex = 1-13/16''	Ax = 2-1/4''	Bx = 2-7/8''	Nx = 3-1/2''
Inside dio. of cosing (X-series)	Ex = 1-1/2''	Ax = 1-29/32''	Bx = 2-3/8''	Nx = 3''

7-1337 (9-69)
Bureau of Reclamation

Plate 4

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE North Beulah Study Area / North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-102 — LOCATION 2250'.W..&.150'.N..of.S..E..Corner of Sec..10,.T..144.N.,.R..88.W. — GROUND ELEV. 2050.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-27-79. FINISHED 8-28-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 153.0' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Failing 1500 truck-mounted.
DRILLER
R.V. Shaw
METHOD
Bx casing drive sample 0.0'-13.0'; Hq wireline core 13.0'-153.0'. Water used as drill fluid
DRILL FLUID LOSS

Depth	% Loss
0.0-58.0'	0
58.0-92.0'	100
92.0-153.0'	90

CASING RECORD
0.0'-3.5' 6" Cs
WATER LEVEL

Date	Depth
8-28-79	49.0'

HOLE COMPLETION
Pulled casing from hole; backfilled with concrete.
CHARACTER OF DRILLING
Large water loss from 58.0'-153.0'.

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING
Bx	100						2042.9	7.1		
	90							10		
Hq	100	#1 0.0	26.1							
	100							20		
	100	#2 26.1	48.4				2023.9	26.1		
	100							30		
	100							40		
	100						2001.6	48.4		
	100	#3 52.6	76.1				1997.4	A 50 52.6		
	100						1986.2	60 63.8		
	73							70		
	94	#4 76.1	107.6				1969.7	80.3 80		
	100							90		

GLACIAL TILL-PLEISTOCENE
0.0-7.1' GLACIAL TILL: approx. 70% low plasticity fines; 15% fine to coarse sand; 15% gravel to 2"; strong HCl reaction; damp to moist; brown. (CL)
FORT UNION FORMATION-SENTINEL BUTTE MEMBER-PALEOCENE
7.1-26.1' SANDSTONE: gray brown; slightly weathered; massive; fine grained; all breaks appear mechanical; poorly cemented; soft, can be deformed by slight finger pressure; moist; non-reactive to HCl; max. core length 0.7'; average core length 0.3'.
26.1-48.4' SHALE INTERFINGERED WITH SANDY SHALE: gray; unweathered; some thin gypsum seams; laminated; breaks appear mechanical, often along bedding planes; moderately soft, trims roughly; damp; one joint dips approx. 65° at 48.0'; slightly reactive to HCl; max. core length 1.8'; avg. core length 0.5'.
48.4-52.6' COAL: black; brittle; broken; damp.
52.6-63.8' CARBONACEOUS SHALE: black; unweathered; appears massive; slightly air slaked; breaks appear mechanical; soft, can be deformed by finger; non-reactive to HCl.
63.8-80.3' SHALEY, CARBONACEOUS SANDSTONE: dark gray; unweathered; very fine grained; massive; breaks appear mechanical; moderately cemented, can be trimmed by knife without difficulty; damp; nonreactive to HCl; max. core length 1.4'; avg. core length 0.5'.
80.3-107.6' SANDY SHALE: dark gray; unweathered; slightly carbonaceous; laminated; one joint dipping 75° at 80.6'; moderately hard, trims by knife with some difficulty; moist; non-reactive to HCl; max. core length 1.4'; avg. core length 0.5'.
107.6-119.0' COAL: black; brittle; broken; damp.
119.0-121.6' SHALE: dark gray; unweathered; laminated; moderately hard; damp; nonreactive to HCl; max. core length 1.2'.
121.6-126.5' COAL: black; brittle; broken; damp.
126.5-153.0' SANDSTONE: gray; unweathered; fine grained; massive; all breaks mechanical; poorly cemented; soft, can be deformed with finger pressure; moist; nonreactive to HCl; max. core length 0.8'; avg. core length 0.4'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Pocker, Cm = 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 dio. of cosing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dio. of cosing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

FEATURE North Beulah Study Area / North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-102 — LOCATION 2250' W. & 150' N. of S.E. Corner of Sec. 10, T. 144 N., R. 88 W. — GROUND ELEV. 2050.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-27-79 — FINISHED 8-28-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 153.0' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

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) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Hq	100										
		100										
								1942.4	107.6			
									110			
		100							B			
								1931.0	119.0			
									120			
		100						1928.4	121.6			
								1923.5	126.5			
									130			
		100	#5 126.5	153.0								
									140			
		50										
									150			
		90	Hole Completed					1897.0	153.0			
									60			
									70			
									80			
									90			

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole	D = Diomond, H = Hoystellite, S = Shot, C = Churn			
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of cosing			
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 cosing (X-series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8",	Nx = 3-1/2"
Inside dia. of cosing (X-series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8",	Nx = 3"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

Plate 5

SHEET 1 OF 2

FEATURE: North Beulah Study Area / North Beulah Deposit — PROJECT: EMRIA — STATE: North Dakota

HOLE NO.: DH79-103 — LOCATION: 1300' N. & 30' E. of S.W. Corner of Sec. 14, T. 144 N., R. 88 W. — GROUND ELEV.: 2030.0' — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 8-29-79 — FINISHED: 8-30-79 — DEPTH OF OVERBURDEN: — TOTAL DEPTH: 123.7' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: R. Wyborney — LOG REVIEWED BY: Parish

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Failing 1500 truck-mounted.
DRILLER
R.V. Shaw
METHOD
Bx drive sample 0.0'-10.0'; rockbit 10.0'-11.0'; Hq wireline core 11.0'-123.7'. Water used as drill fluid.
DRILL FLUID LOSS

Depth	% Loss
0.0-22.0'	0
22.0-100.7'	20
100.7-123.7'	30

CASING RECORD
0.0-3.5' 6" Cs
WATER LEVELS

Date	Depth
8-30-79	25.5'

HOLE COMPLETION
Pulled casing from hole; backfilled with concrete.
CHARACTER OF DRILLING
Drilling normal, no unusual conditions.

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING
Bx	60						2024.5	5.5		
RB	36							10		
Hq	0	#1 0.0	21.4							
	100						2008.6	21.4		A
	81	#2 26.5	43.6				2003.5	26.5		
	100							30		
	85	#3 43.6	55.0				1986.4	43.6		
	100						1975.0	55.0		
	85	#4 55.0	71.7							
	95						1958.3	71.7		B
	100	#5 83.2 Minus Coal	110.9				1946.8	83.2		
							1944.9	85.1		
	100						1941.1	88.9		

CLASSIFICATION AND PHYSICAL CONDITION

GLACIAL TILL-PLEISTOCENE

0.0-5.5' GLACIAL TILL: approx. 70% low plasticity fines; 20% fine to coarse sand; 10% gravel to 1'; strong HCl reaction; damp; brown. (CL)

FORT UNION FORMATION-SENTINEL BUTTE MEMBER-PALEOCENE

5.5-21.4' SANDY SHALE: gray brown; slightly weathered; appears massive; all breaks mechanical; moderately soft, trims easily with knife; damp to moist; slightly reactive to HCl; max. core length 0.6'; avg. core length 0.4'.

21.4-26.5' COAL: black; broken; brittle; damp.

26.5-43.6' CARBONACEOUS SHALE: dark gray; unweathered; laminated; slightly air slaked; breaks mechanical along bedding planes; moderately hard, trims with some difficulty; damp; nonreactive to HCl; max. core length 2.6'.

43.6-55.0' SANDSTONE: gray; unweathered; massive; fine grained; slightly silty; all breaks appear mechanical; poorly cemented; soft, can be deformed by moderate finger pressure; moist; non-reactive to HCl; max. core length 0.5'.

55.0-71.7' SHALE: gray; unweathered; laminated; all breaks mechanical, partings usually along bedding planes; moderately hard; trims with difficulty; damp; nonreactive to HCl; max. core length 8.3'.

71.7-83.2' COAL: black; broken; brittle; damp.

83.2-85.1' SHALE: gray; unweathered; thin laminations; all breaks mechanical; moderately hard, trims with difficulty; damp; nonreactive to HCl.

85.1-88.9' COAL: black; broken; brittle; damp.

88.9-110.9' SANDY SHALE: gray; unweathered; laminated; all breaks mechanical; moderately soft, trims easily with knife; slightly damp; nonreactive to HCl; max. core length 1.1'.

110.9-123.7' SANDSTONE: gray; unweathered; massive; fine grained; all breaks appear mechanical; poorly cemented; soft, can be deformed with moderate finger pressure; moist; nonreactive to HCl; max. core length 0.7'. Carbonaceous Shale Zone at 111.0-112.0'.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole 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", 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"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE North Beulah Study Area
North Beulah Deposit — PROJECT EMRIA — STATE North Dakota

HOLE NO. DH79-103 — LOCATION 1300' N. & 30' E. of S.W. Corner of Sec. 14, T. 144 N., R. 88 W. — GROUND ELEV. 2030.0' — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8-29-79 — FINISHED 8-30-79 — DEPTH OF OVERBURDEN — TOTAL DEPTH 123.7' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY R. Wyborney — LOG REVIEWED BY Parish

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) FROM	SOILS ANALYSIS SAMPLE DEPTH (FEET) TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Hq	100										
		95						1919.3	110.9			
		100	#6 110.9	123.7								
		60	Hole Completed					1906.3	123.7			

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole	D = Diomond, H = Hoystellite, S = Shot, C = Churn			
Hole 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",	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"

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: North Beulah, North Dakota
Location. Sec. 22 Twp. 144 N. Range 88 W.
Soil Boring Adjacent to DH-79-101
Climate: Continental
Land Use: Rangeland
Point Site Number: 1

Relief:
Elevation: 2005'
Slope: Aspect: Undulating; 3-8%; SW
Vegetation: Blue grama; Needleandthread; Threeawn; scattered forbs/sedges

Stoniness:
Drainage:
Ground Water:
Land Form: Upper side slope

Parent Material: Glacial till

Profile Description By: T. Casey Date: 8/5/80
Correlated By: Date:

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION*
18,530	0-3	Very dark grayish brown (10 YR 3/2) loam; moist; noncalcareous; matted root features.
18,531	3-10	Dark brown (10 YR 3/3) loam-moist; moderate prismatic structure; noncalcareous.
18,532	10-34	Dark brown to pale brown (10 YR 3/3 to 6/3) light clay loam; moderately to strongly calcareous; scattered gravel.
18,533	34-66	Brown to pale brown (10 YR 4/3 to 6/3) loam to clay loam; slightly calcareous.
18,534	66-78	Brown (10 YR 4/3) light clay loam; slightly careous.
	78+	Boring stopped due to cobble/boulder.

* All colors are for dry soil unless otherwise noted.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		18,530	18,531	18,532	18,533	18,534
DEPTH	(in)	0-3	3-10	10-34	34-66	66-78
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0mm)					
Coarse Sand	(1.0-0.5mm)					
Medium Sand	(0.5-0.25mm)					
Fine Sand	(0.25-0.10mm)					
Very Fine Sand	(0.10-0.05mm)					
Total Sand	(2.0-0.05mm)					
Silt	(0.05-0.002mm)					
Clay	(<0.002mm)					
TEXTURAL CLASS (LAB.)						
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th hr		0.75	1.25	0.62	0.71	0.79
24th hr		0.79	1.25	0.58	0.67	0.75
SETTLING VOLUME	(ml)	25	25	26	24	25
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O		7.4	8.1	8.9	9.1	9.1
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage						
EC_e @ 25°C	(mmhos/cm)	0.68	1.20	2.40	0.61	1.10
Ca^{++}	(me/l)					
Mg^{++}	(me/l)					
Na^{+}	(me/l)					
K^{+}	(me/l)					
CO_3^{-}	(me/l)					
HCO_3^{-}	(me/l)					
Cl^{-}	(me/l)					
SO_4^{-}	(me/l)					
NO_3^{-}	(me/l)					
SAR	(me/l)					
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)					
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)					
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)					
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 6

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: North Beulah, North Dakota
Location. Sec. 10 Twp. 144 N. Range 88 W.
Soil Boring Adjacent to DH-79-102
Climate: Continental
Land Use: Rangeland
Point Site Number: 2

Relief:
Elevation: 2050'
Slope: Aspect: Hilly; 12-30%; N-NE
Vegetation: Blue grama; Needleandthread; Prairie junegrass; Threadleaf sedge

Stoniness:
Drainage:
Ground Water:
Land Form: Side slope

Parent Material: Glacial till

Profile Description By: T. Casey Date: 8/5/80
Correlated By: Date:

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION*
18,506	0-3	Dark grayish brown (10 YR 4/2) loam-moist.
18,507	3-12	Grayish brown to light grayish brown (10 YR 5/2 to 6/2) loam-moist; lime mottling.
18,508	12-20	Brown to pale brown (10 YR 5/3 to 6/3) light clay loam; strong lime.
18,509	20-28	Light brownish gray (10 YR 6/2) clay loam; strong lime.
18,510	28-36	Brown (10 YR 5/3) clay loam; moderate lime.
18,511	36-44	Yellowish brown (10 YR 5/4) loam; slight lime.
18,512	44-56	Yellowish brown (10 YR 5/4) loam; slight lime.
18,513	56-66	Yellowish brown (10 YR 5/4) sandy clay loam; slight lime.
18,514	66-70	Yellowish brown (10 YR 5/4) weathered sandstone.
18,515	70-76	Yellowish brown (10 YR 5/4) sandy loam.
18,516	76-108	Yellowish brown (10 YR 5/4) loamy sand - slightly moist.
18,517	108-120	Brownish yellow (10 YR 6/6) sand to loamy sand-moist.

* All colors are for dry soil unless otherwise noted.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		18,506	18,507	18,508	18,509	18,510	18,511
DEPTH	(in)	0-3	3-12	12-20	20-28	28-36	36-44
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)						
Coarse Sand	(1.0-0.5mm)						
Medium Sand	(0.5-0.25mm)						
Fine Sand	(0.25-0.10mm)						
Very Fine Sand	(0.10-0.05mm)						
Total Sand	(2.0-0.05mm)						
Silt	(0.05-0.002mm)						
Clay	(<0.002mm)						
TEXTURAL CLASS (LAB.)							
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		1.04	0.46	0.42	0.12	0.12	0.21
24th hr		1.21	0.42	0.35	0.12	0.12	0.19
SETTLING VOLUME	(ml)	26	25	25	26	25	26
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.5	9.0	9.2	9.4	9.5	9.5
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.51	0.42	0.45	0.72	0.95	1.20
Ca^{++}	(me/l)						
Mg^{++}	(me/l)						
Na^{+}	(me/l)						
K^{+}	(me/l)						
CO_3^{-}	(me/l)						
HCO_3^{-}	(me/l)						
Cl^{-}	(me/l)						
SO_4^{-}	(me/l)						
NO_3^{-}	(me/l)						
SAR	(me/l)						
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
1N KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 7
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: _____ Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. ____ Range ____ Elevation: _____ _____

_____ Slope: Aspect: _____ Drainage: _____

Climate: _____ Vegetation: _____ Ground Water: _____

Land Use: _____ _____ Land Form: _____ Profile Description By: _____ Date: _____

Point Site Number: 2 (continued) Correlated By: _____ Date: _____

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		18,512	18,513	18,514	18,515	18,516	18,517
DEPTH	(in)	44-56	56-66	66-70	70-76	76-108	108-120
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)					1.3	
Coarse Sand	(1.0-0.5 mm)					6.8	
Medium Sand	(0.5-0.25 mm)					22.7	
Fine Sand	(0.25-0.10 mm)					39.5	
Very Fine Sand	(0.10-0.05 mm)					9.1	
Total Sand	(2.0-0.05 mm)	29.6				79.4	
Silt	(0.05-0.002 mm)	40.7				11.0	
Clay	(<0.002 mm)	29.7				9.6	
TEXTURAL CLASS (LAB.)		CL				SL	
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.12	0.17	0.08	0.46	1.66	2.00
24th hr		0.10	0.15	0.06	0.42	1.37	1.58
SETTLING VOLUME	(ml)	27	26	24	23	18	19
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.4	9.1	8.4	8.9	9.1	8.6
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	1.90	2.50	5.50	4.10	3.30	2.60
Ca^{++}	(me/l)						
Mg^{++}	(me/l)						
Na^{+}	(me/l)						
K^{+}	(me/l)						
CO_3^{-}	(me/l)						
HCO_3^{-}	(me/l)						
Cl^{-}	(me/l)						
SO_4^{-}	(me/l)						
NO_3^{-}	(me/l)						
SAR	(me/l)						
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)			1.68			
Ca+Mg	(me/l)			18.66			
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 7
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: North Beulah, North Dakota
Location. Sec. 14 Twp. 144 N. Range 88 W.
Soil Boring Adjacent to DH-79-103
Climate: Continental
Land Use: Rangeland
Point Site Number: 3

Relief:
Elevation: 2030'
Slope: Aspect: Slightly Undulating; 3-8%; SE
Vegetation: Needleandthread; Western wheatgrass; Smooth brome

Stoniness:
Drainage:
Ground Water:
Land Form: Side slope

Parent Material: Sandstone/shale - Sentinel Butte Member, Fort Union Formation

Profile Description By: T. Casey Date: 8/5/80
Correlated By: Date:

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION*
18,518	0-3	Very dark grayish brown (10 YR 3/2) loam-moist; noncalcareous; matted root features.
18,519	3-10	Very dark grayish brown (10 YR 3/2) sandy loam to fine sandy loam-moist; noncalcareous.
18,520	10-24	Light brownish gray (10 YR 6/2) loam; moderate lime accumulation.
18,521	24-36	Brown to light brownish gray (10 YR 5/3 to 6/2) loam; moderate strong lime.
18,522	36-48	Yellowish brown (10 YR 5/4) loam; moderate lime; shale and coal chips present.
18,523	48-52	Light olive brown (2.5 Y 5/4) loamy sand; slight lime.
18,524	52-60	Yellowish brown (10 YR 5/4) loam; soft shale and coal present.
18,525	60-84	Pale brown (10 YR 6/3) silt loam with soft sandstone chips.
18,526	84-104	Light brownish gray (2.5 Y 6/2) fine sandy loam.
18,527	104-108	Same as above horizon.
18,528	104-116	Yellowish brown (10 YR 5/6) sandy loam with decomposed sandstone present.
18,529	116-120	Light brownish gray (2.5 Y 6/2) very fine sandy loam.

* All colors are for dry soil unless otherwise noted.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		18,518	18,519	18,520	18,521	18,522	18,523
DEPTH	(in)	0-3	3-10	10-24	24-36	36-48	48-52
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)						1.2
Coarse Sand	(1.0-0.5mm)						2.3
Medium Sand	(0.5-0.25mm)						23.5
Fine Sand	(0.25-0.10mm)						39.7
Very Fine Sand	(0.10-0.05mm)						8.2
Total Sand	(2.0-0.05mm)						74.9
Silt	(0.05-0.002mm)						13.5
Clay	(<0.002mm)						11.6
TEXTURAL CLASS (LAB.)							FSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.96	0.62	0.59	0.37	0.46	1.62
24th hr		1.16	0.71	0.55	0.33	0.46	1.25
SETTLING VOLUME	(ml)	25	22	25	24	23	19
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.8	8.1	9.1	9.2	9.2	9.3
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.89	0.62	0.73	1.70	1.50	2.30
Ca^{++}	(me/l)						
Mg^{++}	(me/l)						
Na^{+}	(me/l)						
K^{+}	(me/l)						
CO_3^{-}	(me/l)						
HCO_3^{-}	(me/l)						
Cl^{-}	(me/l)						
SO_4^{-}	(me/l)						
NO_3^{-}	(me/l)						
SAR	(me/l)						
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 8
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: _____ Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. ____ Range ____ Elevation: _____ _____

_____ Slope: Aspect: _____ Drainage: _____

Climate: _____ Vegetation: _____ Ground Water: _____

Land Use: _____ _____ Land Form: _____ Profile Description By: _____ Date: _____

Point Site Number: 3 (continued) Correlated By: _____ Date: _____

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	LABORATORY DESCRIPTION						
			DETERMINATION		DATA				
			LABORATORY NUMBER		18,524	18,525	18,526	18,527	18,528	18,529
			DEPTH	(in)	52-60	60-84	84-104	104-108	108-116	116-120
			PARTICLE SIZE ANALYSIS	(percent)						
			Very Coarse Sand	(2.0-1.0mm)						
			Coarse Sand	(1.0-0.5mm)						
			Medium Sand	(0.5-0.25mm)						
			Fine Sand	(0.25-0.10mm)						
			Very Fine Sand	(0.10-0.05mm)						
			Total Sand	(2.0-0.05mm)						
			Silt	(0.05-0.002mm)						
			Clay	(<0.002mm)						
			TEXTURAL CLASS (LAB.)							
			BULK DENSITY	(g/cm^3)						
			HYDRAULIC CONDUCTIVITY	(in/hr)						
			6^{th} hr		0.12	0.37	0.87	1.26	0.33	0.67
			24^{th} hr		0.14	0.46	0.87	1.30	0.35	0.75
			SETTLING VOLUME	(ml)	30	24	22	23	23	23
			MOISTURE RETENTION	(percent)						
			1/10 bar							
			1/3 bar							
			15 bar							
			SOIL REACTION-pH							
			Paste							
			1:5 H_2O		8.7	8.5	8.5	7.6	7.5	7.6
			1:2 0.01 M $CaCl_2$							
			ORGANIC CARBON	(percent)						
			AVAILABLE PHOSPHORUS	(ppm)						
			$CaCO_3$ EQUIVALENT	(percent)						
			GYPSUM REQUIREMENT	(me/100g)						
			SATURATION EXTRACT							
			Saturation Percentage							
			EC_e @ 25°C	(mmhos/cm)	10.00	8.90	8.00	7.90	9.60	8.70
			Ca^{++}	(me/l)						
			Mg^{++}	(me/l)						
			Na^{+}	(me/l)						
			K^{+}	(me/l)						
			CO_3^{-}	(me/l)						
			HCO_3^{-}	(me/l)						
			Cl^{-}	(me/l)						
			SO_4^{-}	(me/l)						
			NO_3^{-}	(me/l)						
			SAR	(me/l)						
			Na	(me/100g)						
			Ca+Mg	(me/100g)						
			1:5 EXTRACT							
			EC_5 @ 25°C	(mmhos/cm)	2.31					
			Ca+Mg	(me/l)	23.67					
			EXCHANGEABLE SODIUM	(percent)						
			ACIDITY							
			IN KCl exchange acidity							
			Total	(me/100g)						
			Al^{+++}	(me/100g)						
			CATION EXCHANGE CAPACITY	(me/100g)						
			NaOAc@pH 8.2							
			BORON	(mg/l)						

Table 8
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
Drill Hole 79-101

Study Area: North Beulah, North Dakota | Relief: | Stoniness: | Parent Material: Sentinel Butte Member - Fort Union Formation

Location. Sec. 22 Twp. 144 N. Range 88 W. | Elevation: 2005.0' |

775' South & 100' East of NW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 8/79

DETERMINATION		DATA (ppm)					
Laboratory Number		16,995	16,996	16,997	16,998	16,999	17,000
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
Depth	(Ft)	0.0-23.0	25.0-50.0	50.0-75.0	75.0-100.0	100.0-127.8	131.0-153.5
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B						
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.08	0.06	0.34	0.20	0.16	0.18
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.6	3.0	15.2	12.2	7.8	11.0
IRON	Fe	90.8	94.6	155.0	192.0	215.0	129.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	23.4	21.6	13.2	17.6	18.2	4.4
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	6.2	9.4	12.8	6.6	5.8	9.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	3.3	3.0	15.0	12.3	9.2	7.0

LABORATORY DESCRIPTION							
DETERMINATION		DATA					
Laboratory Number		16,995	16,996	16,997	16,998	16,999	17,000
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
DEPTH	(Ft)	0.0-23.0	25.0-50.0	50.0-75.0	75.0-100.0	100.0-127.8	131.0-153.5
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)	39.5	24.3	6.8	0.7	8.7	14.3
SILT	(0.05-0.002 mm)	33.0	53.7	57.1	62.9	65.6	51.1
CLAY	(0.002 mm)	27.5	22.0	36.1	36.4	25.7	34.6
TEXTURAL CLASS (LAB)		CL	CL	SiCL	SiCL	SiL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.02	0.08	*	*1/2	*3/4	*1/2
24th Hr.		0.02	0.10	0.02	*3/4	*	*1/2
SETTLING VOLUME	(ml)	27	22	32	46	43	54
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		15.9	11.8	21.5	21.2	18.6	32.9
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.7	8.1	8.0	9.2	9.3	9.4
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-1.8	-1.5	-0.8	+1.0	+0.6	+4.4
SATURATION EXTRACT							
Saturation Percentage		52.6	41.3	63.4	78.5	67.9	83.1
EC_e@ 25°C	(mmhos/cm)	2.96	0.60	3.04	1.51	1.77	1.63
Ca++	(me/l)	18.44	3.35	16.58	0.93	1.21	0.44
Mg++	(me/l)	14.11	1.99	15.92	1.18	1.45	0.36
Na+	(me/l)	5.43	1.04	5.78	12.43	14.61	15.22
K+	(me/l)	0.56	0.20	1.00	0.57	0.57	0.29
CO_3-	(me/l)	0.00	0.00	0.00	0.22	0.15	0.60
HCO_3-	(me/l)	2.23	3.04	8.77	7.40	8.05	8.42
Cl-	(me/l)	2.31	0.25	0.18	0.09	0.49	0.13
SO_4-	(me/l)	33.31	2.60	31.23	8.33	9.79	7.58
NO_3-	(me/l)	0.78	0.03	0.03	0.03	0.03	0.03
SAR	(me/l)	1.4	0.6	1.4	12.0	13.0	24.0
Na	(me/100g)	0.29	0.04	0.37	0.96	0.99	1.26
Ca+Mg	(me/100g)	1.71	0.22	2.06	0.16	0.18	0.07
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.53	0.15	0.62	0.43	0.43	0.49
Ca+Mg	(me/l)	4.06	1.25	4.77	0.75	0.84	0.93
EXCHANGEABLE SODIUM	(percent)	2.1	1.1	1.5	13.0	20.0	30.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	16.1	15.6	22.7	16.3	15.0	17.1
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 10
Sheet 1 of 2

* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
Drill Hole 79-101 (cont.)

Study Area: _____ Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (ppm)					
Laboratory Number		17,001	17,016	17,002	17,003	17,004	17,005
Sack Number		101-7	101-8	101-9	101-10	101-11	101-12
Depth	(Ft)	153.5-175.0	175.0-200.0	200.0-225.0	225.0-241.1	245.6-262.6	284.7-313.8
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B						
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.08	0.08	0.08	0.06	0.12	0.14
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	1.6	1.6	1.6	1.4	4.8	9.8
IRON	Fe	142.0	130.0	257.0	243.0	159.0	196.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	5.6	6.6	10.4	9.4	11.2	13.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	2.8	3.6	4.2	3.0	3.0	5.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	5.2	4.6	3.7	3.8	9.3	10.5

LABORATORY DESCRIPTION							
DETERMINATION		DATA					
Laboratory Number		17,001	17,016	17,002	17,003	17,004	17,005
Sack Number		101-7	101-8	101-9	101-10	101-11	101-12
DEPTH	(Ft)	153.5-175.0	175.0-200.0	200.0-225.0	225.0-241.1	245.6-262.6	284.7-313.8
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.2	0.2	0.2	0.6	0.1	
Coarse Sand	(1.0-0.5 mm)	0.5	0.5	1.0	0.7	0.2	
Medium Sand	(0.5-0.25 mm)	24.2	5.6	17.4	10.8	0.3	
Fine Sand	(0.25-0.10 mm)	44.9	52.7	52.0	51.5	35.4	
Very Fine Sand	(0.10-0.05 mm)	10.0	12.6	9.2	12.8	18.9	
TOTAL SAND	(2.0-0.05 mm)	79.8	71.6	79.8	76.4	54.9	7.0
SILT	(0.05-0.002 mm)	7.9	17.2	8.9	10.3	26.6	59.3
CLAY	(0.002 mm)	12.3	11.2	11.3	13.3	18.5	33.7
TEXTURAL CLASS (LAB)		FSL	FSL	FSL	FSL	FSL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		*1/10	*1/10	*1/10	*1/10	*1/10	*1/10
24th Hr.		*1/4	*1/4	*1/4	*1/4	*1/4	*1/5
SETTLING VOLUME	(ml)	130	106	87	110	135	410
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		27.2	19.7	15.3	25.3	34.7	41.2
SOIL REACTION-pH							
Paste							
1:5 H_2O		10.1	10.2	10.2	10.2	10.0	10.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+4.1	+7.2	+6.3	+5.5	+9.1	+9.7
SATURATION EXTRACT							
Saturation Percentage		72.8	59.3	52.1	71.0	87.4	160.3
EC_e@ 25° C	(mmhos/cm)	1.76	1.73	1.86	1.95	2.28	1.22
Ca++	(me/1)	0.16	0.27	0.22	0.22	0.27	0.16
Mg++	(me/1)	0.09	0.18	0.09	0.18	0.27	0.09
Na+	(me/1)	16.87	17.04	18.26	18.57	21.57	11.83
K+	(me/1)	0.13	0.14	0.14	0.13	0.17	0.10
CO_3-	(me/1)	1.07	0.90	1.12	0.68	0.59	0.43
HCO_3-	(me/1)	7.31	8.58	o.77	7.71	10.41	7.71
Cl-	(me/1)	0.12	0.13	0.13	0.14	0.18	0.15
SO_4-	(me/1)	9.58	8.85	8.74	11.45	12.49	3.89
NO_3-	(me/1)	0.04	0.03	0.03	0.03	0.03	0.03
SAR	(me/1)	48.0	36.0	46.0	42.0	42.0	47.0
Na	(me/100g)	1.23	1.01	0.95	13.2	1.89	1.90
Ca+Mg	(me/100g)	0.02	0.03	0.02	0.03	0.04	0.04
1:5 EXTRACT							
EC_5@ 25° C	(mmhos/cm)	0.56	0.54	0.54	0.62	0.68	0.82
Ca+Mg	(me/1)	2.56	2.56	2.04	2.27	1.06	3.28
EXCHANGEABLE SODIUM	(percent)	58.0	59.0	61.0	54.0	53.0	62.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	9.2	8.7	8.3	9.1	13.2	19.0
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 10
Sheet 2 of 2

* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
Drill Hole 79-102

Study Area: North Beulah, North Dakota | Relief: | Stoniness: | Parent Material: Sentinel Butte Member - Fort Union Formation

Location. Sec. 10 Twp. 144 N. Range 88 W. | Elevation: 2050.0' | | |

2250' W & 150' N of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water: |

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 8/79

DETERMINATION		DATA (ppm)				
Laboratory Number		17,006	17,007	17,008	17,009	17,110
Sack Number		102-1	102-2	102-3	102-4	102-5
Depth	(Ft)	0.0-26.1	26.1-48.4	52.6-76.1	76.1-107.6	126.5-153.4
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B					
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.06	0.18	0.20	0.18	0.08
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	0.12	4.60	2.80	5.80	1.60
IRON	Fe	259.0	121.0	100.0	123.0	152.0
MERCURY	Hg					
LITHIUM	Li					
MANGANESE	Mn	17.0	13.6	5.8	7.8	7.4
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHOROUS	P					
LEAD	Pb	2.2	4.8	4.6	6.2	3.0
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	1.5	11.0	9.6	10.8	4.9

LABORATORY DESCRIPTION						
DETERMINATION		DATA				
Laboratory Number		17,006	17,007	17,008	17,009	17,110
Sack Number		102-1	102-2	102-3	102-4	102-5
DEPTH	(Ft)	0.0-26.1	26.1-48.4	52.6-76.1	76.1-104.6	126.5-153.4
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)	0.3				0.1
Coarse Sand	(1.0-0.5 mm)	2.2				0.8
Medium Sand	(0.5-0.25 mm)	16.8				21.1
Fine Sand	(0.25-0.10 mm)	45.4				50.6
Very Fine Sand	(0.10-0.05 mm)	6.8				8.3
TOTAL SAND	(2.0-0.05 mm)	71.5	23.4	24.8	33.9	80.9
SILT	(0.05-0.002 mm)	14.3	50.0	42.6	34.1	4.5
CLAY	(0.002 mm)	14.2	26.6	32.6	32.0	14.6
TEXTURAL CLASS (LAB)		FSL	L	CL	CL	FSL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		1.12	0.04	0.01	*1/10	*1/4
24th Hr.		1.29	0.04	0.01	*1/4	*1/3
SETTLING VOLUME	(ml)	22	27	28	110	64
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar			19.9	22.8	37.8	17.7
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.0	8.4	8.6	9.9	10.0
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-3.3	-1.1	+0.6	+8.8	+4.1
SATURATION EXTRACT						
Saturation Percentage		39.7	56.3	69.0	116.3	55.9
EC_e@ 25°C	(mmhos/cm)	3.83	1.50	2.40	2.03	5.83
Ca++	(me/l)	21.35	9.61	6.09	0.55	27.06
Mg++	(me/l)	18.00	6.78	7.15	0.54	46.77
Na+	(me/l)	11.52	0.89	12.96	18.61	13.35
K+	(me/l)	0.32	0.71	0.76	0.23	0.91
CO3-	(me/l)	0.00	0.00	0.00	0.31	0.00
HCO3-	(me/l)	9.38	4.18	5.31	6.73	5.96
Cl-	(me/l)	0.65	0.14	0.14	0.12	0.26
SO4-	(me/l)	41.64	14.30	21.76	13.33	80.16
NO3-	(me/l)	0.46	0.03	0.03	0.03	2.70
SAR	(me/l)	2.6	0.3	5.0	25.0	2.2
Na	(me/100g)	0.46	0.05	0.89	2.16	0.75
Ca+Mg	(me/100g)	1.55	0.92	0.71	0.12	4.12
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	0.62	0.34	0.48	0.77	0.49
Ca+Mg	(me/l)	5.84	2.75	1.68	1.11	2.14
EXCHANGEABLE SODIUM	(percent)					
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	15.8	17.3	20.3	21.5	10.2
NaOAc@pH 8.2						
BORON	(mg/l)					

* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 11

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

Drill Hole 79-103

Study Area: North Beulah, North Dakota | Relief: | Stoniness: | Parent Material: Sentinel Butte Member - Fort Union Formation

Location. Sec. 14 Twp. 144 N. Range 88 W. 1300' N and 30' of SW Corner | Elevation: 2030.0' | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 8/79

DETERMINATION		DATA (ppm)					
Laboratory Number		17,011	17,012	17,013	17,014	17,095	17,017
Sack Number		103-1	103-2	103-3	103-4	103-5	103-6
Depth	(Ft)	0.0-21.4	26.5-43.6	43.6-55.0	55.0-71.7	83.2-110.9	110.9-123.7
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B						
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.12	0.16	0.16	0.16	0.28	0.18
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	3.4	3.6	3.0	12.4	11.0	5.6
IRON	Fe	84.4	398.0	99.4	142.0	113.0	188.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	20.8	27.4	8.2	19.8	9.2	12.2
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	2.8	3.8	3.0	8.0	6.0	4.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	1.0	5.6	9.1	13.9	10.8	9.0

LABORATORY DESCRIPTION							
DETERMINATION		DATA					
Laboratory Number		17,011	17,012	17,013	17,014	17,015	17,016
Sack Number		103-1	103-2	103-3	103-4	103-5	103-6
DEPTH	(Ft)	0.0-21.4	26.5-43.6	43.6-55.0	55.0-71.7	83.2-110.9	110.9-123.7
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						0.3
Coarse Sand	(1.0-0.5 mm)						2.5
Medium Sand	(0.5-0.25 mm)						15.4
Fine Sand	(0.25-0.10 mm)						29.2
Very Fine Sand	(0.10-0.05 mm)						19.5
TOTAL SAND	(2.0-0.05 mm)	10.2	9.7	39.0	1.6	16.4	66.9
SILT	(0.05-0.002 mm)	52.8	65.5	37.0	48.0	61.4	17.8
CLAY	(0.002 mm)	37.0	24.8	24.0	50.4	22.2	15.3
TEXTURAL CLASS (LAB)		SiCL	SiL	L	SiC	SiL	FSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.02	0.04	0.02	*1/3	*1/5	*1/10
24th Hr.		0.04	0.06	0.02	*1/3	*1/3	*1/4
SETTLINC VOLUME	(ml)	23	25	70	70	98	116
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		24.4	20.6	17.9	31.3	30.1	27.9
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.1	6.2	9.1	9.4	9.8	9.8
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-23.0	-8.6	-0.3	+13.0	+5.7	+4.0
SATURATION EXTRACT							
Saturation Percentage		69.8	57.1	58.8	117.8	72.0	74.4
EC_e@ 25°C	(mmhos/cm)	8.48	2.71	2.94	1.90	1.64	1.90
Ca++	(me/1)	24.48	0.93	5.10	0.77	0.33	0.27
Mg++	(me/1)	109.50	1.45	7.60	2.08	0.27	0.27
Na+	(me/1)	9.70	23.96	18.96	16.70	16.00	18.78
K+	(me/1)	0.68	0.29	0.92	0.38	0.21	0.20
CO_3-	(me/1)	0.00	0.24	0.31	0.39	0.57	0.96
HCO_3-	(me/1)	0.74	6.64	5.75	7.68	8.43	8.43
Cl-	(me/1)	1.42	0.16	0.16	0.13	0.10	0.11
SO_4-	(me/1)	134.30	22.28	28.94	15.20	8.16	0.41
NO_3-	(me/1)	8.67	0.83	0.03	0.11	0.06	0.03
SAR	(me/1)	1.2	22.0	7.5	14.0	29.0	36.0
Na	(me/100g)	0.68	1.37	1.11	1.97	1.15	1.40
Ca+Mg	(me/100g)	9.35	0.13	0.75	0.34	0.04	0.04
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	3.90	2.54	0.56	0.70	0.44	0.51
Ca+Mg	(me/1)	56.15	32.24	1.25	1.13	0.99	1.00
EXCHANGEABLE SODIUM	(percent)	1.3	34.0	7.8	29.4	47.0	47.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	21.7	22.6	17.0	22.6	11.8	11.5
NaOAc@pH 8.2							
BORON	(mg/1)						

* Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 12

Suitability of Bedrock Material For Use As Plant Media in Revegetation -
North Beulah Study Area
Drill Hole 79-101

Depth (Ft)	Type	Suitability	Deficiency
0.0-23.0	StSs	Suitable	---
25.0-50.0	Ss	Suitable	---
50.0-75.0	Ss, Sh, CbSh	Limited	Slow Permeability, Carbonaceous
75.0-100.0	Ss, Sh, CbSh	Limited	Sodium, Slow Permeability, Carbonaceous
100.0-127.8	Ss, Sh, CbSh	Unsuitable	Sodium, Carbonaceous
131.0-153.5	CbSh	Unsuitable	Sodium, Slow Permeability
153.5-175.0	Ss	Unsuitable	Sodium, pH, Slow Permeability
175.0-200.0	Ss	Unsuitable	Sodium, pH, Slow Permeability
200.0-225.0	Ss	Unsuitable	Sodium, pH, Slow Permeability
225.0-241.1	Ss	Unsuitable	Sodium, pH, Slow Permeability
245.6-272.6	Sh, ShSs	Unsuitable	Sodium, pH, Slow Permeability
284.7-313.8	CbSh	Unsuitable	Sodium, pH, Carbonaceous

Legend

Ss - Sandstone
StSs - Silty Sandstone
ShSs - Clayey Sandstone
St - Siltstone
SsSt - Sandy Siltstone
ShSt - Clayey Siltstone
Sh - Shale
SsSh - Sandy Shale
StSh - Silty Shale
CbSh - Carbonaceous Shale
Ls - Limestone
SsLs - Sandy Limestone

Suitability of Bedrock Material For Use As Plant Media in Revegetation - North Beulah Study Area

Drill Hole 79-102

Depth (Ft)	Type	Suitability	Deficiency
0.0-26.1	Silty sand, Sh, Ss	Suitable	---
26.1-48.4	Sh, SsSh	Suitable	---
52.6-76.1	CbSh, ShSs	Unsuitable	Slow permeability, Carbonaceous
76.1-107.6	ShSs, SsSh	Unsuitable	Sodium, pH, Slow Permeability
126.5-153.4	Ss	Unsuitable	Sodium, pH, Slow Permeability

Suitability of Bedrock Material For Use As Plant Media in Revegetation - North Beulah Study Area

Drill Hole 79-103

Depth (Ft)	Type	Suitability	Deficiency
0.0-21.4	StSs, SsSt	Limited	Salinity, % Clay
26.5-43.6	CbSh	Unsuitable	Sodium, Carbonaceous
43.6-55.0	Ss	Limited	Sodium
55.0-71.7	Sh	Unsuitable	Sodium, % Clay
83.2-110.9 (minus coal)	Sh, SsSh	Unsuitable	Sodium, Slow Permeability, pH
110.9-123.7	Ss, CbSh	Unsuitable	Sodium, Slow Permeability, pH