Hydrogeology of

Camp Grafton South

Eddy County

North Dakota

By

Allen E. Comeskey

North Dakota Ground-Water Studies
Number 88
North Dakota State Water Commission

1989

Hydrogeology of

Camp Grafton South

Eddy County
North Dakota

North Dakota Ground-Water Studies
Number 88

By
Allen E. Comeskey

Published By
North Dakota State Water Commission
State Office Building
900 East Boulevard
Bismarck, North Dakota 58505

1989

TABLE OF CONTENTS

Introduction

Camp Grafton South, a training facility under development by the North Dakota Army National Guard, overlies a portion of the Cherry Lake aquifer (Trapp, 1968). Prior to this investigation, information on the aquifer was limited to the surface geology and one test hole. The subsurface geology of the camp area had not been explored. A better understanding of the nature of the aquifer is needed for developing water supplies and safeguarding the aquifer. The purpose of this investigation is to provide a preliminary reconnaissance of the subsurface geology of the glacial drift, identify hydrologic units within the aquifer, determine water levels and flow directions, document water quality, and identify areas requiring additional study. The Cretaceous Pierre Formation, which subcrops below the drift, is not included in this investigation due to its low permeabilities and yields and less desirable quality of water.

Location

Camp Grafton South is located in southeastern Eddy County about 22 miles east of New Rockford (fig. 1). It has an area of about twelve square miles and includes all or portions of Sections 1, 2, 3, 4, 10, and 11 of township 148 North, Range 63 West; Sections 19, 30, 31, and 32, Township 149 North, Range 62 West; and Sections 13, 14, 23, 24, 25, 26, 27, 34, 35, and 36, Township 149 North, Range 63 West (fig. 2).

Previous Investigations

The area of this report has been included in earlier reports. Simpson (1929) described the general geology, drainage, and occurrence of groundwater of Eddy County as a part of his study of the geology and groundwater of North Dakota. Chemical quality of

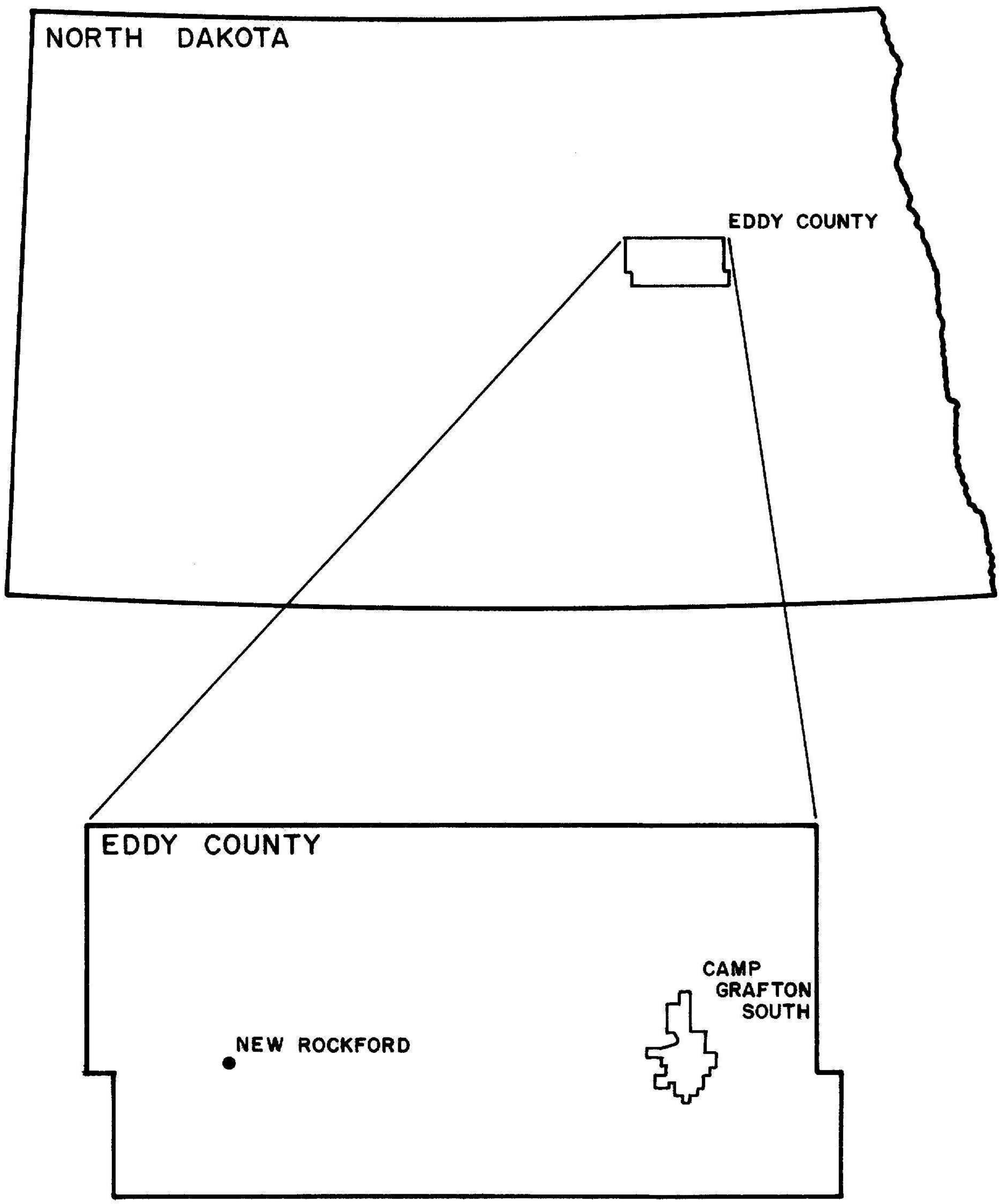


FIG. 1 -Study area location

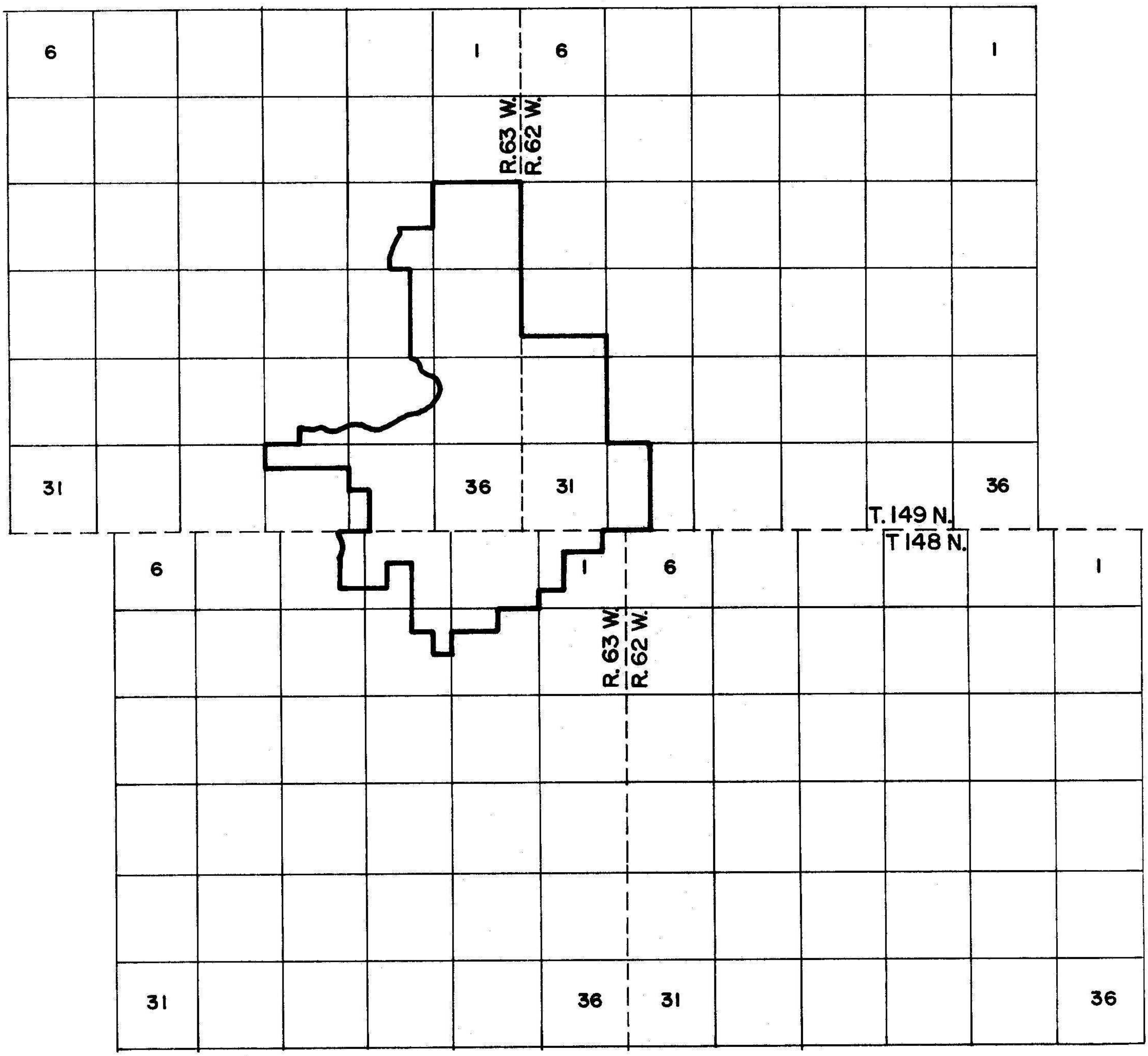


FIG. 2 - Area included in Camp Grafton South

water from four wells of the New Rockford municipal supply and one spring are described.

Bluemle (1965) describes the preglacial and glacial geology and geologic history of Eddy and Foster Counties. He specifically describes the nature and origin of the McHenry end moraine and associated outwash within the study area.

Trapp (1968) describes the occurrence of groundwater in both consolidated rocks and glacial sediments. Specific aquifers and chemical analyses of water samples from them are discussed. The Cherry Lake aquifer is described.

Geologic Setting

Camp Grafton South is located within the Central Lowlands Physiographic Province. Eddy County is an area of local unintegrated drainage except for the James and Sheyenne Rivers (Simpson 1929). The Continental Divide lies within Camp Grafton South (fig. 3). Areas north of the divide are part of the Sheyenne River drainage basin and ultimately drain to Hudson Bay. Areas south of the divide are part of the James River drainage basin and ultimately drain to the Gulf of Mexico. The camp area appears to be a non–contributing area of both basins. Local drainage is towards numerous small lakes. Lake Coe and South Washington Lake are adjacent to the western border of the camp (fig. 2) and are termini of some of the local drainage.

Underlying the glacial drift is the Pierre Formation of Cretaceous age. It is a dark gray to black marine shale with occasional bentonitic zones. Chemical analyses of water samples obtained from the aquifer adjacent to the bedrock suggest that flow from the Pierre Formation to the Cherry Lake aquifer does occur. Permeabilities of the Pierre Formation are generally low, even where fractured. Flow from the Pierre Formation to the aquifer is considered insignificant and, therefore, the Pierre Formation will not be included in this study of the aquifer.

The study area occupies a portion of the McHenry end moraine and a portion of an associated meltwater channel (fig. 3). Outwash occupies the meltwater channel. Also included in the study area are lacustrine sediments (Bluemle 1965). The end moraine is

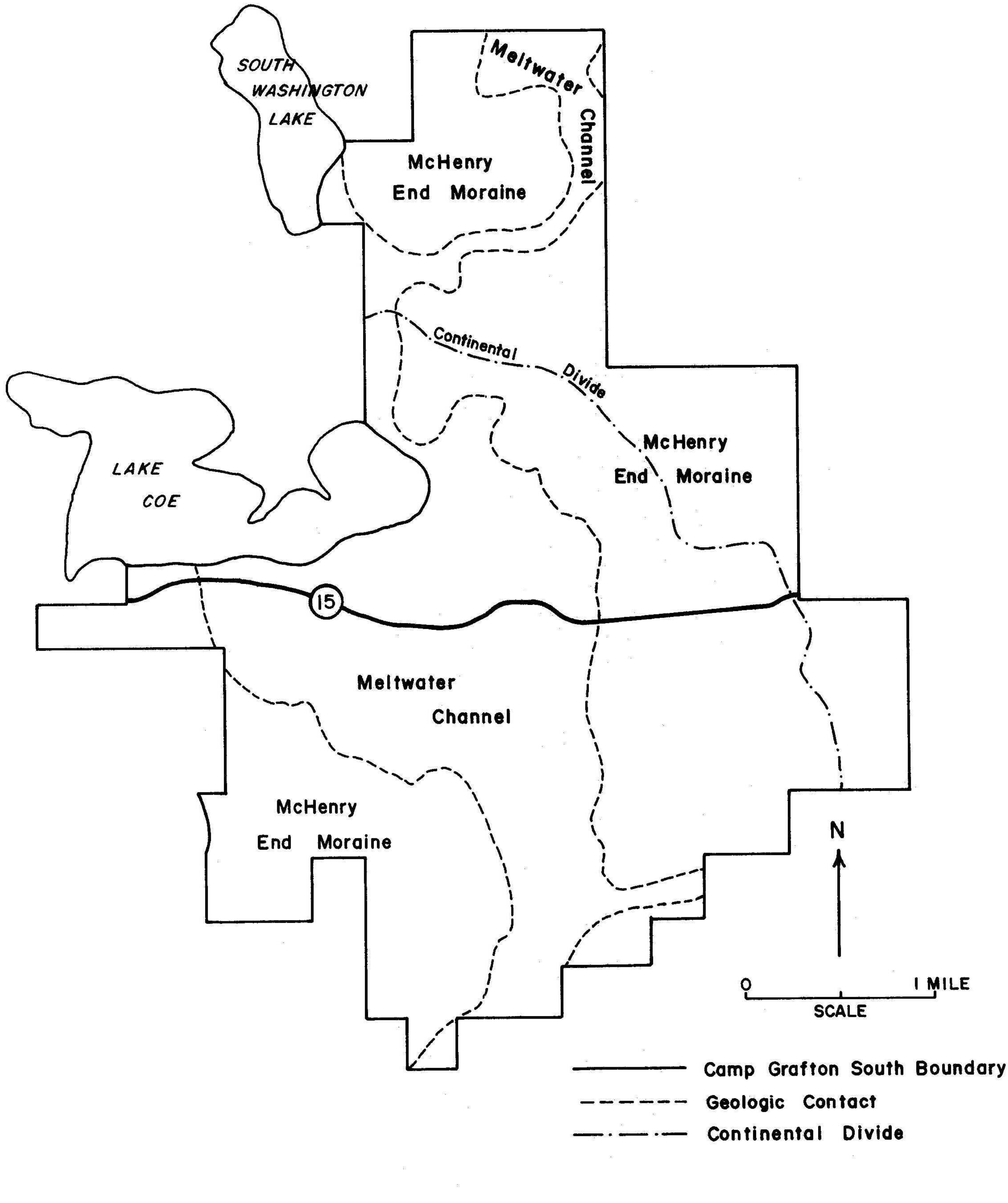


FIG. 3 - Geologic map of Camp Grafton South, modified from Blumle, 1965.

described as being composed of silty glacial drift. The outwash is described as being composed of medium to coarse clean sand with a reddish stain.

The source of the outwash was meltwater from the ice that formed the Viking end moraine five miles north of the Eddy County line. This outwash forms a broad plain north of the study area in the vicinity of Warwick. This meltwater and outwash was funneled into the channel that bisects the camp area (Bluemle, 1965).

Location numbering Systems

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township North and Range West of the 5th Principal Meridian and base line (fig. 4). The third number indicates the Section. The letters A, B, C, and D designate respectively the northeast, northwest, southwest, and southeast quarter Section (160 acre tract), quarter–quarter Section (40 acre tract) and quarter–quarter–quarter Section (10 acre tract). Therefore a well denoted by 148–063–36DDB would be located in the NW1/4 SE1/4 SE1/4 of Section 36, Township 148 North, Range 63 West. Consecutive terminal numbers are added if more than one well is located in a 10 acre tract, for example, 148–063–36DDB_1 and 148–063–36DDB_2.

Methods

The study was accomplished by means of: 1) test drilling, which includes the recording of lithologic logs and piezometer construction, 2) water sample collection and analysis, and 3) water level monitoring.

Test drilling was conducted from July 27 to August 25, 1987 in Section 1, Township 148 North, Range 63 West; Sections 31 and 32, Township 149 North, Range 62 West; and Sections 13, 14, 23, 24, 25, 26, 27, 34, 35, and 36, Township 149 North, Range 63 West. Fifteen locations were drilled totaling 5,208 feet (fig. 5). Twenty seven piezometers were constructed. Two piezometers would not pump to yield water samples for chemical

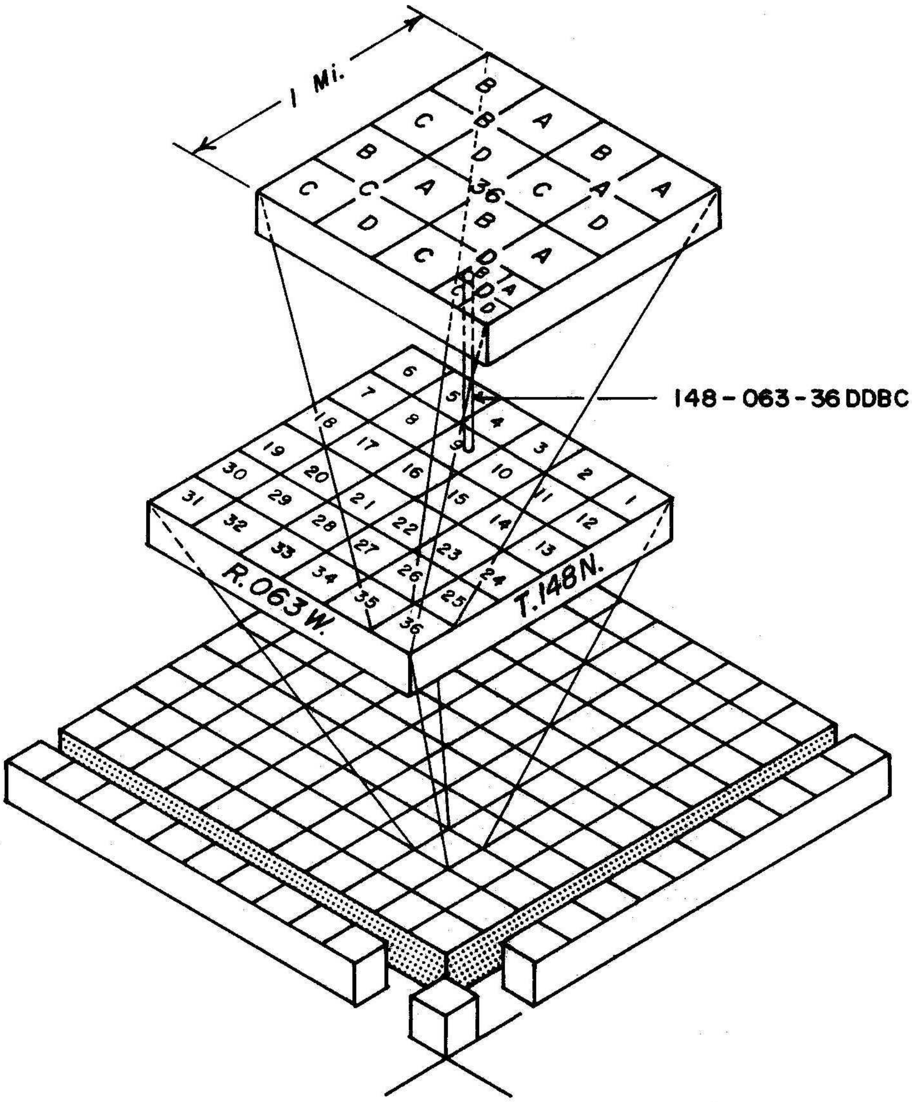


FIG. 4 - Location numbering system

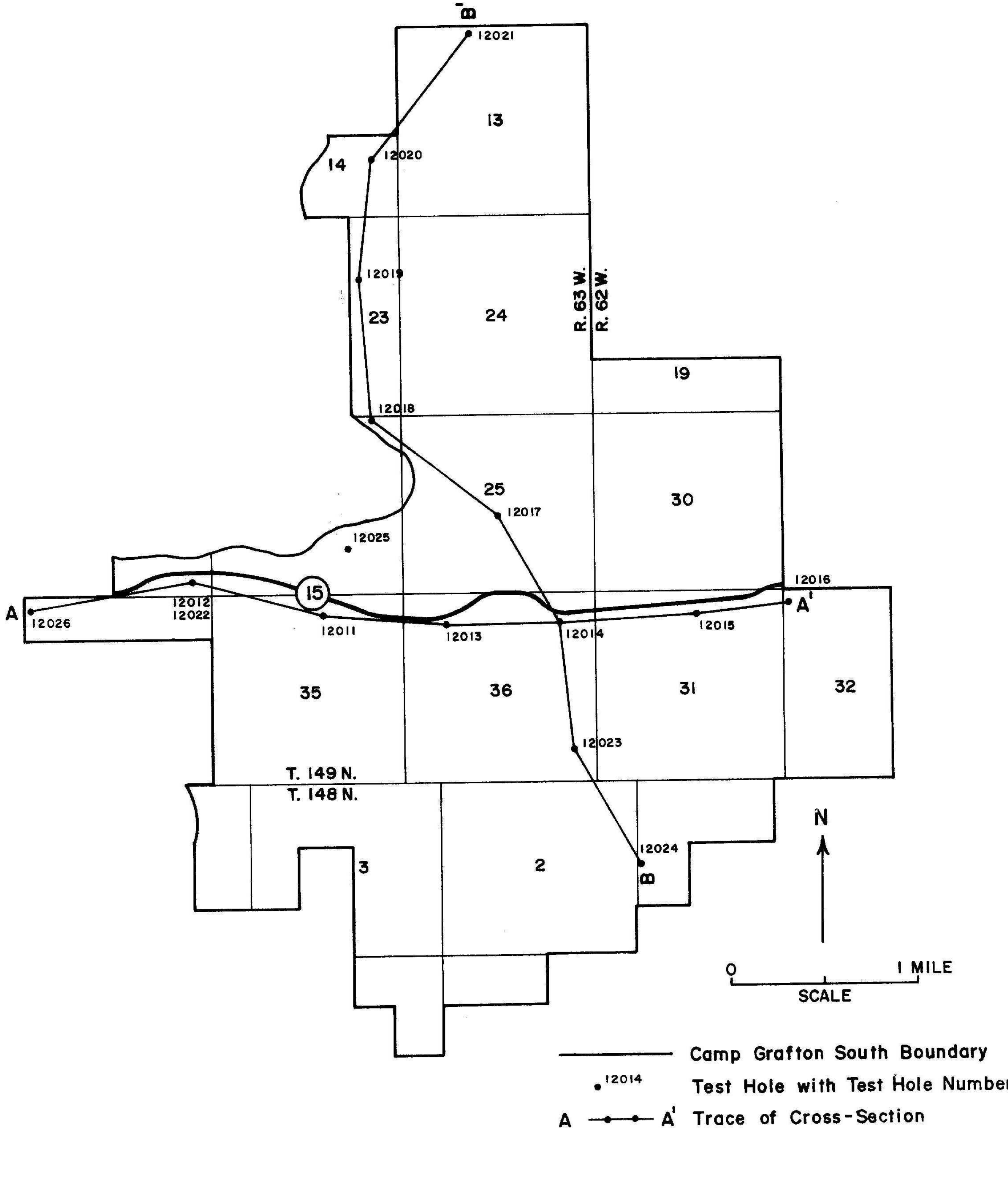


FIG. 5 - Location of test holes and cross-sections.

analysis. Twenty–five water samples were collected from the remaining piezometers on September 1 and 2, 1987. Seven additional samples were collected from the area lakes and springs.

Test drilling was accomplished by the forward mud rotary method generally using a 4 3/4 inch bit. Lithologic logs are written records of the materials encountered by the drill and are based on samples obtained from the drilling mud. These are recorded by the geologist. The lithologic logs have been included in Appendix A. Piezometers provide access to the water contained in the aquifer by means of 1 1/4 inch pvc pipe and 1 1/4 inch pvc well screen of various slot sizes. The screen is sand packed and the annulus above the sand pack filled with grout. Water samples are obtained by air lifting the water from wells with air lines inserted into the wells and connected to portable air compressors. These samples are sent to the State Water Commission Laboratory for analysis. Trace elements were included in the analysis. Results of the analysis are found in Appendix B. Water levels are measured by inserting a steel surveyor's tape into the well and measuring depth to water. The water level data is included in Appendix C.

Hydrogeology

Trapp (1968) considered the outwash of which the Cherry Lake aquifer is composed to be one hydrologic unit. He drilled one test hole in the outwash south of the study area at 148–063–11 ccb. Seven feet of surficial outwash, 14 feet of till, and 25 feet of coarse to very coarse sand were encountered.

Additional test drilling for this study revealed that the Cherry Lake aquifer is a sequence of interbedded very fine to coarse glaciofluvial sediments, glaciolacustrine sediments, and glacial till. The aquifer is associated with parallel channels incised into bedrock on the distal side of the end moraine (Plate 1). One channel attains an unknown depth greater than 400 feet below land surface at the western margin of the study area (test hole 12026).

The Cherry Lake aquifer is here divided into five distinct units based on stratigraphy and water levels; three major units and two less extensive units. There are also isolated sand and gravel deposits of unknown extent. The major units shown in figure 6 are: 1) a surficial unit (unit A), 2) a shallow confined unit, (unit B), and 3) a deep confined unit (unit C).

Surficial Unit

The surficial unit is composed of outwash which covers the floor of the meltwater channel and portions of the McHenry end moraine. Figure 6 is a map of the areal extent of the surficial unit. This map is based on the soil survey maps of Eddy County (Wright and Sweeney, 1977). Thickness of the outwash ranges from 0 to 29 feet. It is composed of poorly sorted and interbedded silt to coarse pebble gravel. Grain shape is from angular to rounded. The sediment is composed of about 70 percent quartz; the remainder is predominantly detrital igneous lithologies and feldspar with minor amounts of detrital shale. The occurrence of the outwash on the distal slopes of the McHenry end moraine suggests that the source of the outwash was meltwater from the ice that formed the end moraine, as well as meltwater from the ice that formed the Viking end moraine as described by Bluemle.

Shallow Confined Unit

Thickness of the shallow confined unit ranges from 0 to 27 feet. Depth to the top of the unit ranges from 18 to 25 feet. It trends roughly northwest to southeast. Width ranges from about 0.7 to greater than 2 miles and length is about 2.5 miles (fig. 7). The sediment is poorly sorted and ranges from fine sand to gravel, with grain shape ranging from angular to rounded. The composition of the sediment was about equal proportions of detrital shale, limestone, and igneous lithologies. The shallow confined unit is generally overlain by till and occasionally by silt. The shallow confined unit overlies till and appears to grade laterally to lacustrine sediments. This may represent an outwash surface developed on till and overridden by a later advance of the ice.

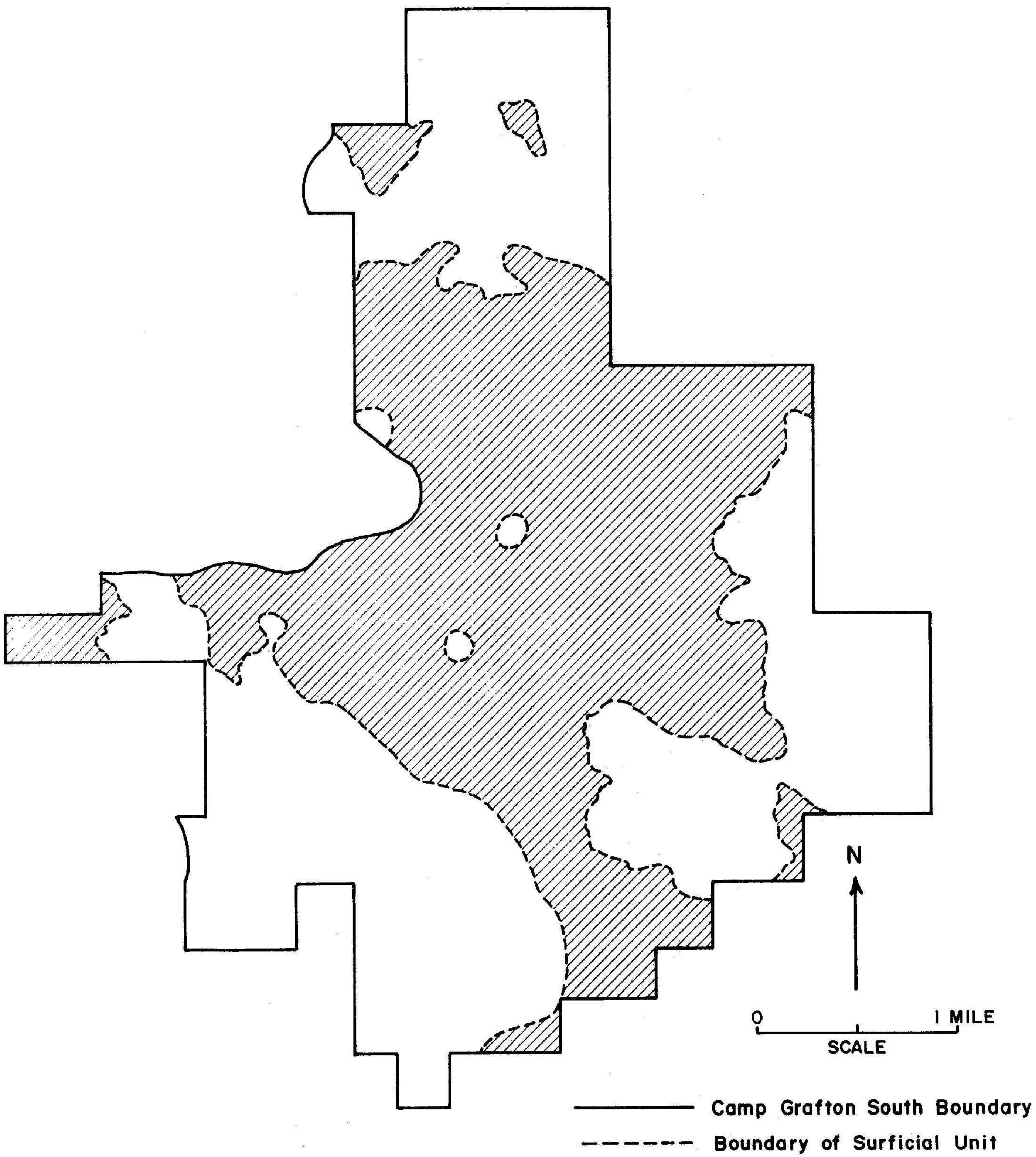


FIG. 6 - Map view showing Surfical Aquifer.

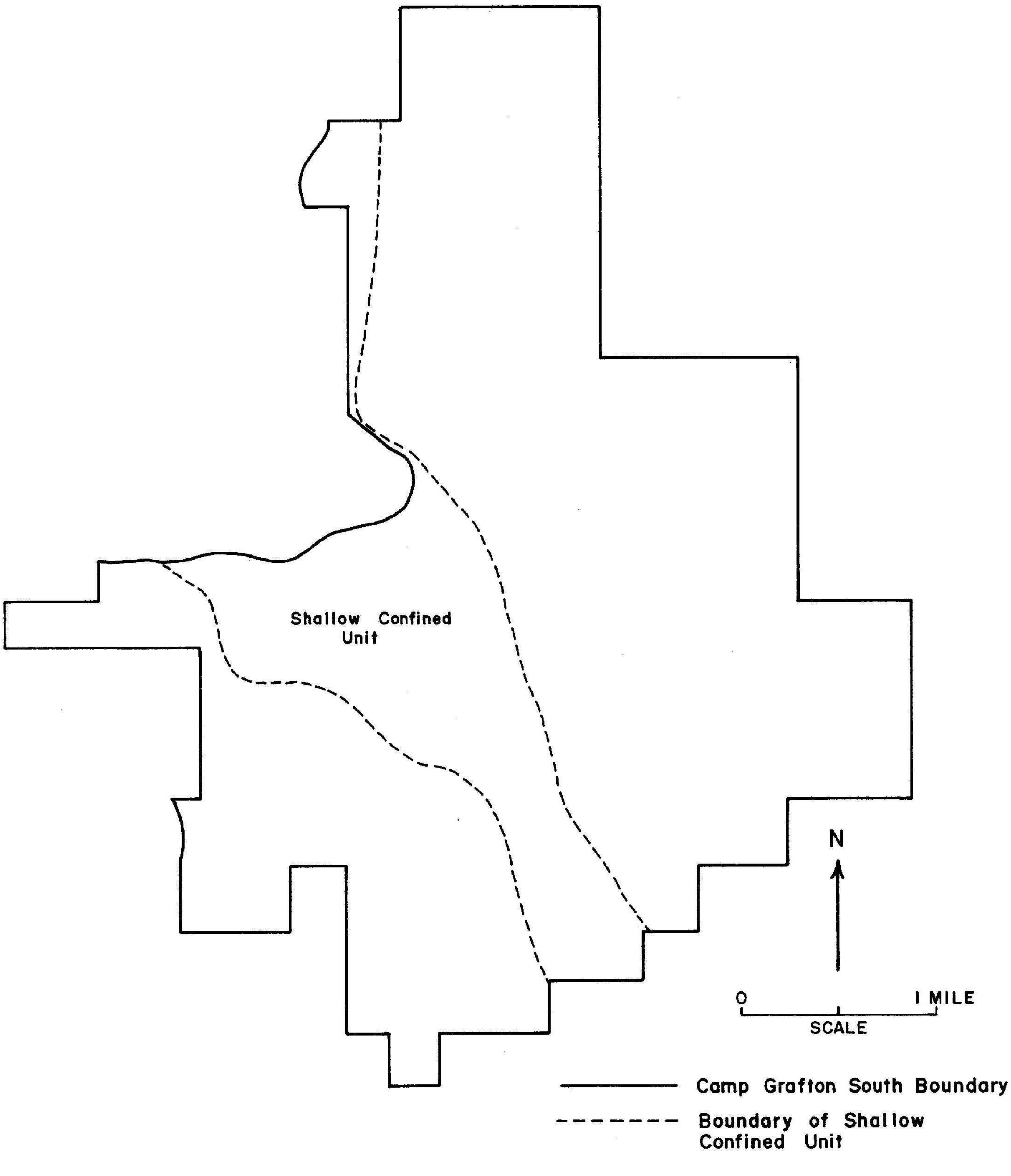


FIG. 7 - Map view showing Shallow Confined Unit.

Deep Confined Unit

Thickness of the deep confined unit ranges from 0 to 96 feet. It trends roughly north–south. It has a sinuous nature and occupies a trench in the bedrock on the distal side of the end moraine (fig. 8). Depth to the unit ranges from 126 to 182 feet. The sediment is moderately to poorly sorted and ranges from fine sand to pebbles with a predominance of coarse sand and granules. Grain shape ranges from angular to rounded. Sediment composition is equal proportions of shale, limestone, and igneous lithologies. This unit is overlain by till.

Minor Units

The areal extent of the minor units is not known. Fewer test holes encountered them and they were not related to some other feature, such as a trench in the bedrock. They may or may not be as extensive as the major units. Unit D (Plate 1) overlies till at about the same stratigraphic position as the shallow confined unit, but is considered separately due to different water levels. It is overlain predominantly by silt. Depth to unit D ranges from 48 to 51 feet. It is about 18 feet thick, about 0.6 miles long, and about 0.2 miles wide. The sediment is predominantly quartz with about 10 percent shale, limestone, and igneous lithologies. Unit E appears to occupy the same stratigraphic position as buried lacustrine clays and may be related to their formation. It is overlain by till. Depth to the unit ranges from 107 to 113 feet. Thickness ranges from 39 to 49 feet. The width is not known and length is about 0.8 miles. The sediment is composed of quartz sand and limestone and shale gravel.

Flow System

The termini of the local flow system are the lakes. At any location the lakes possess the lowest hydraulic head and flow is towards them. The lakes, which are windows into the water table, exhibit progressively lower elevations to the north, revealing a northward flow towards the regional sink of the Sheyenne River. Water enters the flow system through three sources; direct infiltration of precipitation on the McHenry end moraine and

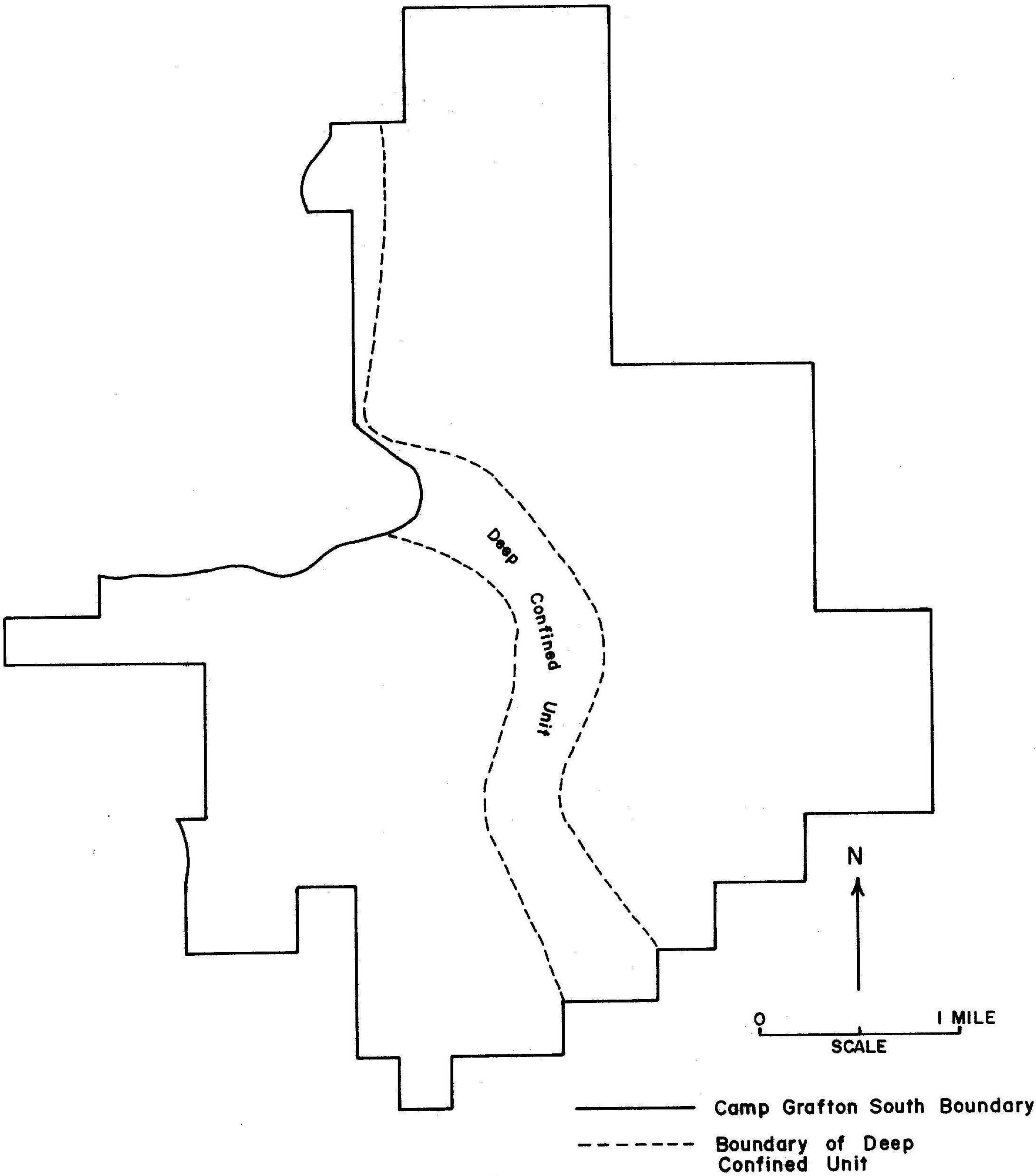


FIG. 8 - Map view showing Deep Confined Unit.

surficial aquifer; in flow through the confined units from sources outside the study area; and from bedrock.

Illustrated in figure 9 is a generalization of the topography, stratigraphy, and flow system of the study area. The McHenry end moraine lies to the east, the meltwater channel to the west of the moraine, and a lower moraine to the west of the meltwater channel A chain of lakes and marshes occupies the meltwater channel. The surficial unit, various confined units, and the deep unit incised into bedrock are represented.

The highest hydraulic heads are found in the McHenry end moraine. Runoff is concentrated in numerous undrained depressions where infiltration is enhanced. The high hydraulic heads result in strong downward gradients. Flow is downward through the moraine then laterally towards the lakes. Test holes 12015, 12019, and 12020 are located on the end moraine. Water levels measured in piezometer nests constructed at these sites reveal this downward gradient, even on the very margin of the moraine. Also, springs are found on the moraine where deep draws intersect the water table. Water from the springs then flows to the meltwater channel and lakes.

Precipitation and runoff infiltrates directly into the surficial unit. Water levels from observation wells in the surficial unit show that flow is laterally towards the lakes.

Water levels from observation wells in the confined units show that flow is northward and upward towards the lakes. An exception to this are found at the location of test holes 12014 and 12017. Hydraulic heads in minor unit D are higher than in the deeper unit and resulting in an upward and downward flow direction. The areal extent of unit D is not known, but it may extend sufficiently far into the McHenry end moraine or possess sufficient hydraulic connection with the end moraine to derive its hydraulic head from the moraine.

The surface drainage divide lies within the study area which places the study area in both the Sheyenne and James River drainage basins. The ground water appears to flow exclusively northward, which places the ground water divide somewhere south of the study

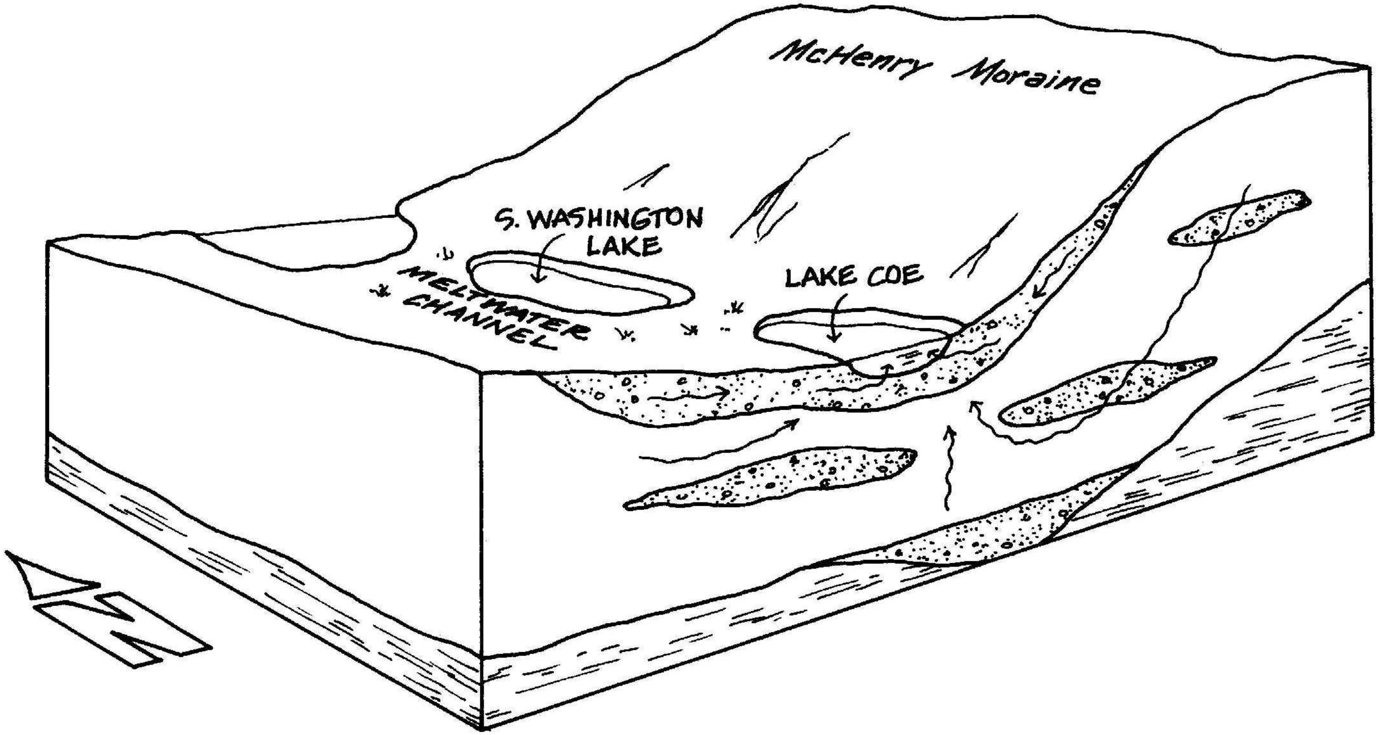


FIG. 9 - Generalized diagram of land features and flow system.

area.

Water Quality

Quality of the water available from the five units of the aquifer system is evaluated with regard to suitability for human consumption and irrigation. Two sets of standards apply to water provided for public water supplies. First, are mandatory standards adopted by the U.S. Environmental Protection Agency in 1976 for constituents known to be hazardous in small concentrations. These include arsenic, barium, cadnium, chromium, lead, mercury, nitrate, selenium, silver, and certain radioactive elements. Second, are non–mandatory standards adopted by the U.S. Public Health Service in 1962 for constituents with significance of an aesthetic nature. These may affect taste or color of the water, affect domestic applications such as cooking and laundry, or produce undesirable physiological effects. These constituents and their effects are presented in Appendix D.

The irrigation classification of a water can be obtained from the chart seen in Appendix E which was developed by the U. S. Salinity Laboratory. The chart is based on the specific conductivity of the water, which is a function of the dissolved solids concentration, and the sodium adsorption ratio (SAR). Appendix F discusses the soils upon which a water of a given classification may be safely used.

Analyses of water samples from units of the Cherry Lake aquifer and area lakes and springs are presented in Appendix B. Also analyzed for, but not listed, are arsenic, lead, lithium, mercury, molybdenum, and strontium. The U.S. Environmental Protection Agency mandatory standards are not exceeded by the constituents included in the analyses. The U.S. Public Health Service (USPHS) standards are exceeded in some cases. The concentration of these constituents, relative to U.S. Public Health Service standards, and the irrigation classification for samples obtained from each unit are discussed below.

Chemical analysis of two samples from the surficial aquifer (Unit A) indicate the water is very hard. Both samples were a calcium bicarbonate type. One sample exceeds the USPHS standards for manganese. All other constituents were within the standards.

Dissolved solids were 272 and 286 milligrams per liter and the sodium adsorption ratio was 0.1. The irrigation classification of the water is C2–S1.

Chemical analyses of five samples from the shallow confined aquifer (Unit B) indicate the water is very hard. One sample was a calcium bicarbonate type. Four samples contained calcium, magnesium, and sodium as the predominant cation and bicarbonate as the predominant anion. Two samples exceed the USPHS standards for total dissolved solids. Two exceed the standards for iron. All exceed the standards for manganese. Dissolved solids range from 294 to 610 milligrams per liter and the sodium adsorption ratio ranges from 0.2 to 2.5. The range of irrigation classifications of the five samples is C3–S1 and C2–S1.

Chemical analyses of five samples from the deep confined aquifer (Unit C) indicate the water ranges in hardness from soft to very hard. Four samples were a sodium bicarbonate type. One sample has sodium as the predominant cation and bicarbonate, sulfate, and chloride as the predominant anions. Four samples exceed the USPHS standards for total dissolved solids. One sample exceeds the standards for sulfate and chloride. All exceed the standards for manganese. Dissolved solids range from 347 to 1910 milligrams per liter and the sodium adsorption ratio ranges from 2.8 to 3.2. The irrigation classification of the five samples ranges from C2–S1 to C4–S4.

Chemical analyses of two samples from the minor unit D indicate the water is very hard. The two samples were a calcium bicarbonate type. Both samples exceed the USPHS standards for manganese but are within the standards for all other constituents. Dissolved solids are 303 and 348 milligrams per liter and the sodium adsorption ratio is 0.2. The irrigation classification is C2–S1.

Chemical analyses of three samples from the minor unit E indicate the water is moderately hard to very hard. Two samples were a sodium bicarbonate type. One sample calcium, magnesium, and sodium were the predominant cations and bicarbonate was the predominant anion. All samples exceed the USPHS standards for manganese but are within the standards for all other constituents. Dissolved solids range from 357 to 456 milligrams per liter and the sodium adsorption ratio is 1.9 to 5.4. The irrigation classification is C2–S1.

Summary and Conclusions

There are three major aquifer units within the Cherry Lake aquifer system. They are 1) a surficial unit, 2) a shallow confined unit, and 3) a deep confined unit.

The termini of the local flow system are the lakes. Regional flow is northward to the Sheyenne River. Water enters the flow system through the McHenry end moraine, through the surficial unit, from outside the study area through the confined units, and from bedrock. Flow is downward and laterally through the end moraine, laterally in the surficial unit, and upward and northward in the confined units..

Chemical analyses of samples from the aquifer units indicate the waters are generally very hard and within the limits recommended by the U.S. Environmental Protection Agency, U.S. Public Health Service for human consumption. An exception is manganese which usually exceeds recommended limits. Waters from the surficial and shallow confined unit are acceptable for irrigation on most soils. Water from the deep confined unit would generally not be acceptable for irrigation.

Additional test drilling could be performed to better define the areal extent of, and hydraulic connection between, the aquifer units. Also, additional drilling is needed to determine the depth, orientation, and nature of the sediments filling the deeply incised valley at the western margin of the study area.

Selected References

Bluemle, John P., 1965, Geology and Ground–Water Resources of Eddy and Foster Counties: Part I, Geology: North Dakota Geological Survey Bull. 44 and North Dakota State Water Commission County Ground–Water Studies 5.

Simpson, Howard E., 1929, Geology and Ground–Water Resources of North Dakota: United States Geological Survey Water–Supply Paper 598.

Trapp, Henry, Jr., 1966, Geology and Ground–Water Resources of Eddy and Foster Counties: Part II, Ground–Water Basic Data: North Dakota Geological Survey Bull. 44 and North Dakota State Water Commission County Ground–Water Studies 5.

Trapp, Henry, Jr., 1968, Geology and Ground–Water Resources of Eddy and Foster Counties: Part III, Ground–Water Resources: North Dakota Geological Survey Bull. 44 and North Dakota State Water Commission County Ground–Water Studies 5.

Wright, Robert M. and Sweeney, Michael O. , 1977, Soil Survey of Eddy County and Parts of Benson and Nelson Counties, North Dakota: Soil Conservation Service.

Appendix A

TEST HOLE LOGS

Descriptions of materials penetrated by the drill and records of piezometers completed.

Explanation

Test Hole Number-	Indicates North Dakota State Water Commission as owner and test hole number, terminal letter indicates successive test holes or piezometers at same site.
Screened Interval-	Depth interval below land surface adjoining the well screen.
Casing Size and Type-	Number indicates inside diameter of casing. PVC - polyvinyl chloride.
Comments-	QW - chemical analysis of water samples available WL - water levels available.
Well Type-	Test Hole - no observation well completed. Piezometer - observation well with sand packed screen and annulus sealed with grout.
Source of Data-	SWC - North Dakota State Water Commission.

148–063–01CBBC$_1$
NDSWC 12024A

Date completed: 8/13/87

Depth drilled (ft.): 200

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u> Topsoil	3	0 – 3
Sand, gravelly, coarse sand to pebbles, .75" dia., 80% very coarse sand to fine granules, angular to rounded, equal proportions limestone, quartz, and shale, 15% pebbles, subangular to rounded, 5% coarse sand	9	3 –12
Silt, sandy, cohesive, oxidized to 16	13	12 –25
Sand, very fine to fine	2	25 –27
Silt, sandy, cohesive	5	27 –32
Clay, silty, sandy pebbly, soft, plastic, slightly oxidized (till)	9	32 –41
Sand, clayey, soft, cohesive, olive gray (lacustrine or fluvial)	9	41 –50
Clay, silty, sandy, pebbly, soft, plastic, olive gray (till)	15	50 –65
Clay, very silty, slightly sandy, soft, slightly plastic to slightly crumbly, interbedded clayey silt (till)	15	65 –80

Clay, silty, sandy, pebbly, soft, plastic, olive gray (till)	11	80 –91
Clay, very silty, slightly sandy, slightly pebbly, soft, slightly crumbly, interbedded gravel (till)	12	91 –113
Sand, fine to coarse, predominantly medium to coarse, interbedded very sandy clay, subangular to rounded	18	113–131
Gravel, fine granules to pebbles, interbedded very sandy clay, subangular to rounded	21	131–152
Masserated shale with shale pebbles (till)	11	152–163
Clay, slightly silty, sandy, pebbly, slightly firm, plastic (till)	19	163–182
Pierre Formation		
Shale, non–silty, waxy, interbedded bentonitic shale	18	182–200

148–063–01CBBC2
NDSWC 12024B

Date completed: 8/14/87

Depth drilled (ft.): 160

Screened interval (ft.): 151–156

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1566.46

Lithologic Log

Unit description	Thickness (ft)	Depth (ft.)
<u>Glacial Drift</u>		
Topsoil	2	0 – 2
Clay, very silty	3	2 – 5
Gravel, sandy, coarse sand to pebbles, predominantly fine graunules, 75% subangular to rounded granules, 15% very coarse sand, 10% pebbles	6	5 – 11
Clay, very silty, slightly sandy, soft, plastic, oxidized to 16 feet (till or fluvial)	10	11–21
Sand, fine to coarse, predominantly medium to coarse, subangular to rounded	5	21–26
Silt, clayey, soft, olive gray (fluvial lacustrine)	20	26–46
Clay, silty, sandy, pebbly, firm, olive gray (till)	25	46–71
Silt, very clayey, soft, crumbly, olive gray (fluvial or lacustrine)	14	71–85
Clay, silty, sandy, pebbly, soft, plastic, gravelly (till)	27	85–112
Clay, very sandy, soft, plastic (till or fluvial)	12	112–124
Clay, silty, sandy, pebbly, soft, plastic, olive gray, gravelly (till)	9	124–133

Gravel, sandy, very coarse sand to pebbles, interbedded clay	24	133–157
Clay, masserated shale with shale pebbles (till)	3	157–160

148–063–01CBBC3
NDSWC 12024C

Date completed: 8/14/87

Depth drilled (ft.): 17

Screened interval (ft.): 7–12

Casing size (in) & type: 2" pvc

Comments: WL

Well type: 12024C

Source of data: Piezometer

Principal aquifer: Cherry lake

Land surface altitude (ft): 1567.20

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–13BAAB1
NDSWC 12021A

Date completed: 8/12/87

Depth drilled (ft.): 160

Screened interval (ft.): 96–101

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1497.37

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Clay, very silty, soft, plastic	4	3 – 7
Sand, fine to coarse, predominantly medium to coarse	5	7 –12
Clay	1	12–13
Gravel, sandy, medium sand to pebbles, predominantly subangular to rounded granules	1	13–14
Clay, silty	7	14–21
Sand	2	21–23
Clay, silty	2	23–25
Sand	1	25–26
Clay, very silty, very sandy, pebbly, soft, slightly crumbly (till)	17	26–43
Gravel, rounded shale pebbles	2	43–45
Clay, slightly silty, slightly sandy, very pebbly, firm, waxy (till)	51	45–96
Gravel, very sandy, coarse sand to fine pebbles	5	96–101
Clay, till as above	23	101–124
Pierre Formation		

Shale, non–silty, waxy to fissile, poorly to moderately indurated	36	124–160

149–063–14DACD1
NDSWC 12020A

Date completed: 8/11/87

Depth drilled (ft.): 225

Screened interval (ft.): 212–217

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1528.56

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Gravel, sandy, very coarse sand to pebbles, 1.5 in. diameter, predominantly fine to coarse granules, angular to rounded	10	2 –12
Clay, silty, sandy, pebbly, soft, plastic, cohesive, oxidized (till)	11	12–23
Gravel, sandy, very coarse sand to coarse pebbles, 2 in. diameter, predominantly coarse granules to fine pebbles, sand and fine granules, are angular, coarser material is very rounded, predominantly rounded shale pebbles	22	23–45
Clay, very sandy	4	45–49
Clay, silty, tight, waxy (lacustrine)	3	49–52
Clay, silty, sandy, pebbly, soft, plastic, cohesive (till)	16	52–68
Clay, very silty, very sandy, pebbly, slightly firmer (till)	7	68–75
Clay, very silty, very sandy, pebble, soft, plastic,	6	75–81

cohesive (till)		
Gravel, very coarse pebles	4	81–85
Clay, with shale gravel (till)	5	85–90
Clay, silty, sandy, pebbly, firm, waxy, shale pebbles	4	90–94
Clay, very silty, very sandy, pebbly, slightly firm, slightly crumbly	32	94–126
Sand, gravelly, fine sand to fine pebbles, predominantly very coarse sand to granules, angular to rounded, interbedded clay	24	126–150
Clay, slightly sandy, slightly pebbly, maserated shale and shale pebbles	26	150–176
Clay, silty, sandy, pebbly, partially oxidized, soft, plastic (till)	6	176–182
Sand, gravelly, medium sand to pebbles, predominantly coarse to very coarse sand, angular to round, interbedded clay	24	182–206
Clay, silty, sandy, pebbly, firm, crumbly (till)	15	206–221
Pierre Formation		
Shale, non–silty, waxy	4	221–225

148–063–14DACD2
NDSWC 12020B

Date completed: 8/11/87

Depth drilled (ft.): 160

Screened interval (ft.): 151–156

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1528.50

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

148–063–14DACD3
NDSWC 12020C

Date completed: 8/12/87

Depth drilled (ft.): 44

Screened interval (ft.): 38–43

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1528.82

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–23ADBB1
NDSWC 12019A

Date completed: 8/7/87

Depth drilled (ft.): 240

Screened interval (ft.): 218–223

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1503.14

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	4	0 – 4
Sand, gravelly, medium sand to pebbles, predominantly very coarse sand to fine granules, angular to rounded	8	4– 12
Silt, also very fine sand, very clayey, cohesive	6	12– 18
Sand, fine to very coarse, predominantly medium to coarse, angular to rounded	20	18– 38
Silt, clayey	8	38 –46
Clay, silty, sandy, pebbly, soft, plastic, cohesive (till)	55	46–101
Clay, very silty, soft, crumbly	21	101–122
Sand	4	122–126
Clay	5	126–131
Sand, fine to very coarse, predominantly medium to coarse, angular to rounded, interbedded shale, gravel and clay	46	131–177
Sand, medium to fine granules, predominantly coarse to very coarse sand, angular	50	177–227

to rounded, much interbedded shale gravel		
<u>Pierre Formation</u> Shale, non-silty, waxy	13	227–240

149–063–23ADBB2
NDSWC 12019B

Date completed: 8/8/87

Depth drilled (ft.): 40

Screened interval (ft.): 32–37

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1503.12

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Clay, silty	2	3 – 5
Sand, gravelly, fine sand to granules, predominantly medium to coarse sand	8	5 – 13
Clay, very silty, soft, plastic	7	13–20
Sand, gravelly, fine sand to fine pebble, predominantly rounded, coarse sand	17	20–37
Clay	3	37–40

149–063–23ADBB3
NDSWC 12019C

Date completed: 8/8/87

Depth drilled (ft.): 20

Screened interval (ft.): 7–12

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1503.72

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–25BBBB
NDSWC 12018

Date completed: 8/7/87

Depth drilled (ft.): 300

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u> Topsoil	2	0 – 2
Sand, very fine to fine	7	2 – 9
Clay, very silty, soft, oxidized	12	9 –21
Sand, fine to coarse, predominantly medium, subangular to subrounded	42	21–63
Sand, very clayey, oxidized	20	63–83
Sand, fine to coarse, clean	6	83–89
Silt, clayey, soft, cohesive, oxidized to 93 feet	6	83–89
Clay, silty, sandy, slightly pebbly, soft, cohesive, plastic (till)	23	117–140
Clay, silty, very sandy, pebbly, soft, friable (till)	15	140–155
Clay, slightly silty, slightly sandy, slightly pebbly, firm, waxy (till)	6	155–161
Gravel, very coarse sand to coarse granules, interbedded sandy clay	6	161–167
Clay, silty, soft, cohesive, occasionally thinly laminated or varved, becomes less silty with depth (lacustrine)	79	167–246

Sand, clayey, slightly pebbly, slightly cohesive to friable (till)	18	246–264
Clay, maserated shale with shale pebbles	5	264–269
Pierre Formation		
Shale, non–silty, waxy, interbedded bentonite	31	269–300

149–063–25DBBC1
NDSWC 12017A

Date completed: 8/5/87

Depth drilled (ft.): 280

Screened interval (ft.): 263–268

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1534.70

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u>		
Topsoil	3	0 – 3
Clay, very silty, very soft, plastic, oxidized (fluvial)	5	3 – 8
Sand, very fine to fine	4	8 – 12
Clay, very silty to clayey, silt	10	12 – 22
Sand, fine to very coarse, predominantly coarse to very coarse	2	22– 24
Clay, silty, sandy, pebbly, soft, cohesive, plastic (till)	16	24– 40
Sand	8	40– 48
Gravel, fine granules to pebbles, subangular to rounded granules, rounded pebbles	10	48– 58
Clay, silty, sandy, pebbly, slightly firm, brittle and crumbly (till)	23	58– 81
Gravel, sandy, very coarse to pebbles	4	81– 85
Clay (till), as above	12	85– 97
Clay, silty, sandy, pebbly,	5	97–102

maserated shale		
Shale, non–silty, waxy (shore block)	25	102–127
Clay, very silty to slightly silty, interbedded gravel	55	127–182
Gravel, very coarse sand to granules, predominantly fine granules, angular to rounded, interbedded clay, appears coarse with depth	90	182–272
<u>Pierre Formation</u>		
Shale, non–silty, waxy	8	272–280

149–063–25DBBC2
NDSWC 12017B

Date completed: 8/6/87

Depth drilled (ft.): 89

Screened interval (ft.): 78–83

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1534.59

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Clay, silty, sandy, slightly firm, cohesive (till)	9	3 –12
Sand	1	12–13
Clay, very silty, soft	8	13–21
Sand, very fine to very coarse, predominantly medium to coarse, angular to rounded	5	21–36
Clay, silty, sandy, pebbly, soft to slightly firm, cohesive (till)	23	26–49
Gravel, sandy, very coarse sand to pebbles, predominantly fine to coarse granules	7	49–56
Clay, slightly to very silty	5	56–61
Clay, silty, sandy, pebbly, soft, cohesive (till)	18	61–79
Gravel, sandy, very coarse sand to pebbles	5	79–84
Clay	5	84–89

149–063–25DBBC3
NDSWC 12017C

Date completed: 8/7/87

Depth drilled (ft.): 60

Screened interval (ft.): 51–56

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1534.37

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u>		
Topsoil	3	0 – 3
Clay, silty, soft	18	3 –21
Sand, gravelly, fine sand to fine pebbles, predominantly coarse to very coarse sand	7	21–28
Clay, silty, sandy, pebbly, plastic (till)	15	28–43
Gravel, sandy	5	43–48
Clay	3	48–51
Gravel	5	51–56
Clay, till	4	56–60

149–063–25DBBB4
NDSWC 12017D

Date completed: 8/7/87

Depth drilled (ft.): 30

Screened interval (ft.): 23–25

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1534.27

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–26DCA
NDSWC 12025

Date completed: 8/17/87

Depth drilled (ft.): 105

Screened interval (ft.): 38–43

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1512.52

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, sandy, pebbly, soft, plastic, cohesive, interbedded silty clay, oxidized to 19 feet (till)	21	2 –23
Sand, very fine to medium, subangular to rounded	4	23 –27
Gravel, sandy, very coarse sand to pebbles, 80% fine granules, 10% pebbles	15	27 –42
Clay, silty, sandy, pebbly, soft, plastic, interbedded sand and silt (till)	38	42 –80
Clay, silty, sandy, pebbly, slightly firmer than above, some maserated shale	15	80 – 95
Gravel, fine granules to coarse pebbles, abandoned due to caving	10	95–105

149–063–27DDDC1&2
NDSWC 12012 & 12022

Date completed: 7/29/87

Depth drilled (ft.): 320

Screened interval (ft.): 158–163

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1567.05

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, sandy, slightly pebbly, soft, slightly plastic, cohesive (till)	38	2 –40
Clay, silty, sandy, pebbly, soft, plastic, cohesive, firmer than above	9	40–49
Clay, silty, sandy, pebbly, soft, plastic, cohesive	18	49–57
Sand, very fine, clayey	24	67–91
Clay, very silty, sandy, slightly pebbly, soft, plastic	55	91–146
Clay, slightly to very silty, soft, plastic	7	146–153
Gravel, sandy, very coarse sand to pebbles, predominantly granules, subangular to rounded	16	153–169
Clay	3	169–172
Gravel, very coarse	2	172–174
Clay, maserated shale and shale pebbles	6	174–180
Clay, slightly silty, very sandy, pebbly, soft, plastic, cohesive (till)	26	180–206

Clay, slightly silty, sandy, very pebbly, maserated shale and shale pebbles (till)	17	206–223
Interbedded till and gravel	27	223–250
Clay, slightly silty, very sandy, slightly pebbly, soft, plastic, cohesive (till)	56	250–306
Clay, slightly silty, non–sandy, non–pebbly, soft, plastic, cohesive	1	306–307
Clay, till, as above	2	307–309
Clay, maserated shale	2	309–311
<u>Pierre Formation</u> Shale, non–silty, waxy	9	311–320

149–062–31ABBC1

NDSWC 12015A

Date completed: 8/4/87

Depth drilled (ft): 300

Screened interval (ft): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Sand, very fine to fine	2	3 – 5
Silt, very clayey, slightly sandy, slightly pebbly, soft, slightly plastic, more crumbly	5	5 –10
Silt, very clayey, very sandy, slightly pebbly, thinly laminated	54	10 –64
Sand, very fine to fine, well sorted, subangular to rounded	20	64 –84
Clay, very silty, soft, cohesive, interbedded clayey silt	60	84–144
Clay, very silty, very sandy, pebbly, firm (till)	17	144–161
Gravel, very coarse sand to fine pebbles, predominantly granules	6	161–167
Interbedded gravel and till	20	167–187
Gravel, as above	8	187–195
Interbedded gravel and till	14	195–209
Clay, very silty, soft, plastic, blocky	7	209–216

Clay, silty, sandy, pebbly, much firmer than above (till)	22	216–238
Sand, coarse sand to granules	6	238–244
Clay till, as above, becomes siltier with depth	14	244–258
Clay, very silty, slightly pebbly, soft, cohesive, slightly laminated	17	258–275
Clay, maserated shale with shale pebbles (till)	7	275–282
<u>Pierre Formation</u>		
Shale, non–silty, waxy, bentonitic	18	282–300

149–063–31ABBC2
NDSWC 12015B

Date completed8X8/4/87

Depth drilled (ft.): 172

Screened interval (ft.): 162–167

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1621.69

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Sand, very fine to fine	3	3 – 6
Clay, very silty, very sandy, oxidized to 52 feet	55	6 –61
Sand, very fine to fine, well sorted, angular to subangular	23	61 –84
Clay, very silty	58	84–142
Clay, silty, sandy, pebbly, slightly firm (till)	21	142–163
Gravel, sandy, very coarse sand to pebbles, predominantly granules, some interbedded clay	4	163–167
Till, gravelly	5	167–172

149–062–31ABBC3
NDSWC 12015C

Date completed: 8/4/87

Depth drilled (ft.): 85

Screened interval (ft.): 78–83

Casing size (in) & type: 2.0" pvc

Comments: WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1621.96

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–32BBB
NDSWC 12016

Date completed: 8/5/87

Depth drilled (ft.): 295

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, very sandy, soft, cohesive (till)	7	2 – 9
Gravel, sandy, very coarse sand to pebbles, predominantly granules to fine pebbles	1	9 –10
Clay, silty, sandy, pebbly, soft, plastic, cohesive (till)	11	10–21
Clay, very silty, soft, plastic	48	21–69
Interbedded silty clay, till, and detrital lignite	19	69–88
Sand, very clayey, fine to coarse, predominantly medium to coarse	57	88–145
Silt, very clayey, very soft	92	145–237
Clay, silty, sandy, pebbly, plastic, cohesive (till)	4	237–241
Clay, silty, sandy, pebbly, firmer than above, many shale pebbles (till)	11	142–252
Clay, silty to sandy, soft, cohesive	13	252–265
Interbedded sandy clay and rounded shale gravel	16	265–281
Pierre Formation		
Shale, non–silty, waxy	14	281–295

149–063–34BBB1
NDSWC 12026A

Date completed: 8/25/87

Depth drilled (ft.): 400

Screened interval (ft.): 251–256

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1518.62

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drif</u>		
Topsoil	2	0 – 2
Sand, gravelly, medium sand to coarse granules and some fine pebbles, subangular to rounded	18	2 –20
Clay, silty	2	20–22
Gravel, sandy, very coarse sand to fine pebbles	4	22 –26
Clay, very silty, soft, plastic	6	26 –32
Clay, till	8	32 –40
Gravel, very coarse sand and granules, angular to rounded, becomes coarser with depth	8	40 –48
Clay, silty, sandy, pebbly, firm (till)	16	48 –64
Silt, very clayey, soft	4	64 –68
Clay, till as above, interbedded gravel	102	68–170
Clay, very silty, soft, slightly plastic, interbedded sandy clay	74	170–244
Gravel, sandy, very coarse sand to pebbles, 80% granules, 10% sand, 10% pebbles	16	244–260

Clay, slightly silty, slightly sandy, pebbly, firm, waxy, maserated shale and shale pebbles (till)	20	260–280
Clay, very sandy, soft, plastic, interbedded clayey sand, ran out of drill rods	120	280–400

149–063–34BBB2
NDSWC 12026B

Date completed: 8/25/87

Depth drilled (ft.): 40

Screened interval (ft.): 27–32

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1518.75

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

149–063–35ABBD1
NDSWC 12011A

Date completed: 7/27/87

Depth drilled (ft.): 170

Screened interval (ft.): None

Casing size (in) & type: None

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Sand, gravelly, fine sand to granules, predominantly medium to very coarse sand	3	2 – 5
Clay	4	5 – 9
Clay, very silty, sandy, pebbly, very soft, plastic, cohesive, oxidized to 21 feet	16	9 –25
Sand, fine to coarse, subrounded to rounded, interbedded clay	10	25 –35
Gravel, sandy, very coarse sand to fine pebbles, predominantly coarse granules, angular to rounded	7	35 –52
Clay, very silty, sandy, pebbly, soft, plastic, cohesive, gravelly (till)	26	52 –78
Clay, maserated shale with shale pebbles (till)	3	78 –81
Silt, very clayey, soft, plastic, cohesive	3	81 –84
Clay, very silty, very sandy, pebbly, soft, plastic, cohesive	46	84–130
Clay, silty, sandy, pebbly, firmer	27	130–157

than above (till)		
Pierre Formation		
Shale, non–silty, waxy	13	157–170

149–063–35ABBD2
NDSWC 12011B

Date completed: 7/28/87

Depth drilled (ft.) 60

Screened interval (ft.): 44.5–49.5

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1515.37

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, silty	3	2 – 5
Sand, fine	4	5 – 9
Clay, very silty, sandy, pebbly, soft, very plastic, cohesive (till)	19	9 –28
Sand, gravelly, medium sand to granules, predominantly very coarse sand to granules	21	28–49
Gravel, very coarse	2	49–51
Clay, till	9	51–60

149–063–36AACB1
NDSWC 12014A

Date completed: 7/30/87

Depth drilled (ft.): 280

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test Hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Sand, fine to medium, well sorted, angular to rounded	6	2 – 8
Gravel, sandy, very coarse sand to pebbles, predominantly coarse granules	1	8 – 9
Sand, gravelly, medium sand to fine granules, predominantly medium to very coarse sand, angular to rounded	20	9 – 29
Silt, very clayey, cohesive, plastic, very slightly pebbly, partially oxidized (till or fluvial)	32	29– 51
Sand, gravelly, fine to medium, angular to rounded, 10% rounded granules	9	51– 60
Gravel, sandy, fine to coarse granules, some fine pebbles, coarser with depth	9	60– 69
Clay, silty, sandy, pebbly, soft, plastic, cohesive (till)	20	69– 89
Till, as above, much interbedded sand and gravel	19	89–108
Clay, silty, very sandy, pebbly firmer than above (till)	6	108–114
Clay, slightly silty to silty, waxy, (lacustrine)	9	114–123

Clay, silty, sandy, pebbly (till)	22	123–145
Sand, gravelly, interbedded with till (fluvial)	7	145–152
Sand, very clayey, fine grain, well sorted	19	152–171
Gravel, sandy, very coarse sand to fine pebbles, predominantly granules, interbedded clay and maserated shale	35	171–206
Interbedded till and gravel	52	206–258
Pierre Formation		
Shale, non–silty, waxy	22	258–280

149–063–36AACB2
NDSWC 12014B

Date completed: 7/30/87

Depth drilled (ft.): 187

Screened interval (ft.): 181–186

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Sand, slightly gravelly, fine sand to granules, angular to rounded	7	2 – 9
Clay	2	9 – 11
Sand, fine sand to medium pebble	17	11 –28
Clay, very silty, slightly sandy, slightly pebbly, soft, cohesive, plastic (till)	20	28–48
Silt, clayey, slightly sandy, very soft, slightly cohesive, plastic (till)	8	48–56
Gravel, sandy, very coarse sand to pebbles, predominantly granules	16	56–72
Clay, very silty, very sandy, slightly pebbly, firmer than above (till)	8	72–80
Clay, very silty	5	80–85
Clay (till) as above	4	85–89
Gravel	4	89–93
Clay, till, more sand and pebbles, firmer than above	16	93–109
Clay, silty, plastic	38	109–147
Clay, very sandy, soft, cohesive	22	147–169

Gravel, sandy, very coarse sand to granules, angular to rounded, interbedded clay	18	169–187

149–063–36AACB3
NDSWC 12014C

Date completed: 7/31/87

Depth drilled (ft.): 75

Screened interval (ft.): 64–69

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1545.08

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Sand, fine to coarse, angular to rounded	12	2 –14
Clay, very silty, sandy, very soft, plastic, cohesive, oxidized	7	14–21
Sand, gravelly, fine sand to granules, predominantly coarse to very coarse sand, rounded	10	21–31
Clay, very silty, slightly sandy, slightly pebbly, soft, plastic, cohesive (till)	18	31–49
Sand	7	49–56
Gravel, sandy, very coarse sand to pebbles, predominantly granules, subangular to rounded, coarser with depth	13	56–69
Clay	6	69–75

149–063–36AACB4
NDSWC 12014D

Date completed: 8/3/87

Depth drilled (ft.): 34

Screened interval (ft.): 24–29

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1545.00

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u>		
Topsoil	2	0 – 2
Sand, very fine to fine, well sorted	7	2 – 9
Clay, very sandy, very silty, soft, cohesive, plastic	12	9– 21
Sand, gravelly, medium sand to granules, predominantly coarse to very coarse sand	10	21–31
Clay	3	31–34

149–063–36BBDA1
NDSWC 12013A

Date completed: 7/29/87

Depth drilled (ft.): 160

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, sandy, slightly pebbly, very soft, plastic, cohesive, oxidized to 11 feet (till)	19	2 – 21
Sand, gravelly, medium sand to granules, predominantly coarse sand, subangular to rounded, 70% quartz, 15% igneous, 15% carbonates	6	21– 27
Clay, very silty, very sandy, pebbly, firmer than above, much shale gravel (till)	48	27– 75
Gravel, sandy, very coarse sand to fine pebbles, predominantly fine pebbles, angular to rounded, interbedded clay	5	75– 80
Clay, as above (till)	65	80–145
Pierre Formation		
Shale, non–silty, waxy, poorly indurated	15	145–160

149–063–36BBDA2
NDSWC 12013B

Date completed: 7/29/87

Depth drilled (ft.): 35

Screened interval (ft.): 22–27

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1503.25

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u> Topsoil	2	0 – 2
Clay, very silty, very sandy, slightly pebbly, soft, plastic, oxidized to 11 feet (till)	19	2 –21
Sand, gravelly, very coarse sand to fine pebble, predominantly very coarse sand to fine granules	6	21– 27
Clay (till)	8	27– 35

149–063–36DDBC1
NDSWC 12023A

Date completed: 8/12/87

Depth drilled (ft.): 140

Screened interval (ft.): 131–136

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1530.49

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u>		
Sand, very fine to fine	3	0 – 3
Silt, clayey, oxidized	8	3 –11
Gravel	1	11–12
Clay, silty, plastic, oxidized (lacustrine or fluvial)	5	12–17
Clay, very silty, very sandy, pebbly, soft, plastic (till)	5	17–22
Sand, gravelly, fine sand to granules, 80% subangular to rounded, medium to coarse sand, 15% granules	30	22–52
Clay, silty, sandy, pebbly, slightly firm, plastic (till)	28	52–80
Gravel, sandy, coarse sand to pebbles, 80% subangular to rounded, very coarse sand and fine granules	20	80–100
Clay, very silty, soft (fluvial)	7	100–107
Gravel, sandy, very coarse sand to pebbles, 70% granules and pebbles	29	107–136
Clay, non–silty, tight, waxy, abandoned due to caving gravel	4	136–140

149–063–36DDBC2
NDSWC 12023B

Date completed: 8/13/87

Depth drilled (ft.): 95

Screened interval (ft.): 83–88

Casing size (in) & type: 1.25 pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1530.64

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, soft, plastic, oxidized	9	2 –11
Sand, very coarse to fine pebble	1	11–12
Clay, very silty, sandy, pebbly, soft, plastic (till)	13	12 –25
Sand, medium to coarse	9	25–43
Silty, very clayey	3	34–37
Sand, medium to coarse	6	37–43
Gravel, sandy, very coarse sand to pebbles, predominantly granules	9	43–52
Clay, very silty, sandy, pebbly, firm, brittle (till)	28	52–80
Gravel, sandy, very coarse sand to pebble, predominantly very coarse sand to fine granules, angular to rounded	15	80–95

149–063–36DDBC3
NDSWC 12023C

Date completed: 8/13/87

Depth drilled (ft.): 60

Screened interval (ft.): 46–51

Casing size (in) & type: 2" pvc

Comments: QW, WL

Well type: Piezometer

Source of data: SWC

Principal aquifer: Cherry Lake

Land surface altitude (ft): 1530.79

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
<u>Glacial Drift</u>		
Topsoil	2	0 – 2
Silt, very clayey	8	2 –10
Gravel, sandy, very coarse sand to pebbles	3	10–13
Interbedded gravel and clay	3	13–16
Clay, silty, sandy, pebbly, soft, plastic (till)	4	16–20
Sand, very fine to coarse silt, very clayey	23	20–43
Gravel, sandy, very coarse sand to pebbles	8	43–51
Clay	9	51–60

Appendix B

CHEMICAL ANALYSES OF WATER SAMPLES

Location	Well Depth (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (umho)	Temp (°C)	pH
			|<------	------	------	------	------	------	------	(milligrams	per liter)	------	------	------	------	------	------	------	------>|					
148-063-01CBBC2	156	09-02-87	30	0.01	0.79	40	11	75	8	339		40	5	0.3	2	0.27	379	150		51	2.7	590	11.0	
148-063-02DA	S	09-11-86	33	0.02	0.04	72	21	6	2	310		27	3	0.1		0.03	316	270	12	4	0.1	540	13.0	
148-063-11CCB		07-17-64	18	0.17		76	23	39	8	376		59	6	0.3	5		419	284		22	1.0		7.8	
149-062-31ABBC2	167	09-01-87	31	0.04	0.27	45	12	64	9	321		43	4	0.3	3	0.28	370	160		44	2.2	570	13.0	
149-063-13BAAB1	101	09-01-87	25	0.02	0.22	64	18	470	17	633		140	490	0.4	6	1.2	1540	230		80	13.0	3710	12.0	
149-063-13BD	S	09-11-86	30	0.03	0.13	79	25	17	7	365		31	4	0.2		0.06	374	300	1	11	0.4	620	14.0	
149-063-14BAD	S	10-23-64	23	0.15		72	27	14	7	337		44	5	0.5			358	292	16	9	0.4		11.1	
149-063-14CA	S-3	09-11-86	1	0.04		15	60	1000	280	737	400	930	360	0.1	1	2.7	3410	280		77	26.0	5400	15.0	
149-063-14DACD1	217	09-01-87	31	0.03	0.39	20	6	640	12	752		430	360	0.5	1	3.4	1870	75		94	32.0	3070	12.0	
149-063-14DACD2	156	09-01-87	31	0.01	0.22	14	4	310	8	659		200	20	0.7	1	1.1	915	52		92	19.0	1460	12.0	
149-063-14DACD3	43	09-01-87	32	0.01	0.06	73	23	18	7	341		35	4	0.2	2	0.06	362	280		12	0.5	580	12.0	
149-063-23ADBB1	223	09-01-87	30	0.09	0.43	41	10	76	7	322		19	21	0.2	3	0.15	367	140		52	2.8	590	12.0	
149-063-23ADBB2	37	09-01-87	28	0.21	0.44	74	21	7	4	298		40	2	0.2		0.04	323	270	27	5	0.2	515	11.0	
149-063-23ADBB3	12	09-01-87	38	0.11	0.33	77	18	4	2	287		16	1	0.2	3	0.05	301	270	31	3	0.1	585	14.0	
149-063-25DBBC1	268	09-01-87	30	0.01	0.24	19	5	240	8	444		100	99	0.4	1	0.65	721	66		87	13.0	1200	12.0	
149-063-25DBBC2	83	09-02-87	22	0.01	0.15	26	8	160	14	376		150	4	0.5	3	0.55	573	96		75	7.1	860	11.0	
149-063-25DBBC3	56	09-02-87	31	0.09	0.5	72	20	6	5	314		25	1	0.3		0.06	316	260	5	5	0.2	490	11.0	
149-063-25DBBC4	28	09-02-87	32	1.1	0.93	72	19	6	5	319		19	1	0.2	1	0.07	314	260		4	0.1	500	9.0	
149-063-26DA	S-4	09-11-86	8	0.14	0.01	15	40	1300	160	1230	200	980	540	0.1	1	3.7	3850	200		87	40.0	6000	15.0	
149-063-26DCA	43	09-01-87	28	0.61	0.34	71	46	83	12	444		170	14	0.3	2	0.26	647	370	2	32	1.9	975	11.0	
149-063-27CA	S-5	09-11-86	2	0.18	0.01	15	40	1400	180	1210	300	1100	580	0.2		4.8	4220	200		88	43.0	6400	14.0	
149-063-27DDDC2	163	09-01-87	10	0.15	0.24	29	9	3	14	161		61	2	0.1	1	0.07	207	110		4	0.1	241	13.0	
149-063-34BBB1	256	09-01-87	27	0.03	0.68	47	23	120	14	428		110	23	0.5	1	0.28	577	210		53	3.6			
149-063-34BBB2	32	09-01-87	27	0.01	0.34	74	25	28	5	298		89	9	0.2	1	0.1	405	290	44	17	0.7	670	11.0	
149-063-35ABBD2	50	09-01-87	29	0.76	0.29	68	25	93	10	422		120	9	0.2	2	0.3	564	270		42	2.5	880	10.0	
149-063-36AACB2	186	09-02-87	31	0.03	1.1	63	13	140	10	452		110	32	0.2	3	0.5	626	210		58	4.2	950	10.0	
149-063-36AACB3	69	09-02-87	32	0.18	0.81	110	30	11	7	401		57	3	0.2		0.06	450	400	70	6	0.2	740	10.0	
149-063-36AACB4	29	09-02-87	29	0.02	0.03	79	23	6	4	305		29	3	0.2	3	0.03	325	290	42	4	0.1	540	12.0	
149-063-36BBDA2	27	09-01-87	31	0.01	0.11	59	22	47	8	358		43	8	0.3	1	0.23	395	240		29	1.3	620	14.0	
149-063-36DDBC1	136	09-02-87	31	0.02	0.93	30	8	130	8	399		49	18	0.5	2	0.38	474	110		71	5.4	720	11.0	
149-063-36DDBC2	88	09-02-87	32	0.01	1.4	55	15	61	8	353		38	9	0.3		0.22	394	200		39	1.9	620	10.0	
149-063-36DDBC3	51	09-02-87	30	0.4	0.32	77	22	8	4	329		28	3	0.2	1	0.08	336	280	13	6	0.2	540	10.0	

Appendix C

WATER LEVELS

148-063-01CBBC2
Cherry Lake aquifer — LS Elev (msl,ft)= 1566.46 — SI (ft)= 151-156

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
09/02/87	43.81	1522.65	11/16/87	43.95	1522.51
11/05/87	44.07	1522.39			

148-063-01CBBC3
Cherry Lake aquifer — LS Elev (msl,ft)= 1567.20 — SI (ft)= 7-12

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	0.00	1567.20			

149-062-31ABBC2
Cherry Lake aquifer — LS Elev (msl,ft)= 1621.69 — SI (ft)= 162-167

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	94.74	1526.95	11/05/87	94.87	1526.82
09/01/87	94.68	1527.01			

149-062-31ABBC3
Cherry Lake aquifer — LS Elev (msl,ft)= 1621.96 — SI (ft)= 78-83

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	61.63	1560.33	11/05/87	61.51	1560.45
09/01/87	61.50	1560.46			

149-063-13BAAB1
Cherry Lake aquifer — LS Elev (msl,ft)= 1497.37 — SI (ft)= 96-101

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
09/01/87	10.14	1487.23	11/05/87	6.75	1490.62

149-063-14DACD1
Cherry Lake aquifer — LS Elev (msl,ft)= 1528.56 — SI (ft)= 212-217

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	43.75	1484.81	11/05/87	40.54	1488.02
09/01/87	41.57	1486.99	11/16/87	40.32	1488.24

149-063-14DACD2

Cherry Lake aquifer LS Elev (msl,ft)= 1528.50 SI (ft)= 151-156

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	35.56	1492.94	11/05/87	34.17	1494.33
09/01/87	34.94	1493.56	11/16/87	34.04	1494.46

149-063-14DACD3

Cherry Lake aquifer LS Elev (msl,ft)= 1528.82 SI (ft)= 38-43

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	22.64	1506.18	11/05/87	24.03	1504.79
09/01/87	23.53	1505.29	11/16/87	24.00	1504.82

149-063-23ADBB1

Cherry Lake aquifer LS Elev (msl,ft)= 1503.14 SI (ft)= 218-223

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	7.95	1495.19	11/05/87	8.42	1494.72
09/01/87	7.99	1495.15	11/16/87	8.39	1494.75

149-063-23ADBB2

Cherry Lake aquifer LS Elev (msl,ft)= 1503.12 SI (ft)= 32-37

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	4.33	1498.79	11/05/87	4.54	1498.58
09/01/87	4.23	1498.89	11/16/87	4.40	1498.72

149-063-23ADBB3

Cherry Lake aquifer LS Elev (msl,ft)= 1503.72 SI (ft)= 7-12

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	4.43	1499.29	11/05/87	4.59	1499.13
09/01/87	4.29	1499.43	11/16/87	4.56	1499.16

149-063-25DBBC1

Cherry Lake aquifer LS Elev (msl,ft)= 1534.70 SI (ft)= 263-268

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	39.49	1495.21	11/05/87	39.76	1494.94
09/01/87	39.48	1495.22	11/16/87	39.20	1495.50

149-063-25DBBC2

Cherry Lake aquifer — LS Elev (msl,ft)= 1534.59 — SI (ft)= 78-83

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	5.20	1529.39	11/05/87	5.29	1529.30
09/02/87	5.17	1529.42	11/16/87	5.34	1529.25

149-063-25DBBC3

Cherry Lake aquifer — LS Elev (msl,ft)= 1534.37 — SI (ft)= 51-56

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	3.23	1531.14	11/05/87	3.28	1531.09
09/02/87	3.04	1531.33	11/16/87	3.24	1531.13

149-063-25DBBC4

Cherry Lake aquifer — LS Elev (msl,ft)= 1534.27 — SI (ft)= 23-28

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	6.45	1527.82	11/05/87	6.11	1528.16
09/02/87	6.13	1528.14	11/16/87	5.90	1528.37

149-063-26DCA

Cherry Lake aquifer — LS Elev (msl,ft)= 1512.52 — SI (ft)= 38-43

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
09/01/87	16.32	1496.20	11/16/87	16.37	1496.15
11/05/87	16.44	1496.08			

149-063-27DDDC2

Cherry Lake aquifer — LS Elev (msl,ft)= 1567.05 — SI (ft)= 158-163

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	21.40	1545.65	11/05/87	98.90	1468.15
09/01/87	22.52	1544.53			

149-063-34BBB1

Cherry Lake aquifer — LS Elev (msl,ft)= 1518.62 — SI (ft)= 251-256

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
09/01/87	25.00	1493.62	11/16/87	23.05	1495.57
11/05/87	23.10	1495.52			

149-063-34BBB2

Cherry Lake aquifer — LS Elev (msl,ft)= 1518.75 — SI (ft)= 27-32

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
09/01/87	21.46	1497.29	11/16/87	21.83	1496.92
11/05/87	21.81	1496.94			

149-063-35ABBD2

Cherry Lake aquifer — LS Elev (msl,ft)= 1515.37 — SI (ft)= 45-50

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	16.03	1499.34	11/05/87	16.38	1498.99
09/01/87	16.04	1499.33	11/16/87	16.34	1499.03

149-063-36AACB2

Cherry Lake aquifer — LS Elev (msl,ft)= — SI (ft)= 181-186

Date	Depth to Water (ft)	Date	Depth to Water (ft)	Date	Depth to Water (ft)
08/24/87	49.18	11/05/87	49.57	11/16/87	49.23
09/02/87	49.15				

149-063-36AACB3

Cherry Lake aquifer — LS Elev (msl,ft)= 1545.08 — SI (ft)= 64-69

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	11.31	1533.77	11/05/87	11.74	1533.34
09/02/87	11.36	1533.72	11/16/87	11.80	1533.28

149-063-36AACB4

Cherry Lake aquifer — LS Elev (msl,ft)= 1545.00 — SI (ft)= 24-29

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	12.24	1532.76	11/05/87	12.90	1532.10
09/02/87	12.31	1532.69	11/16/87	12.92	1532.08

149-063-36BBDA2

Cherry Lake aquifer — LS Elev (msl,ft)= 1503.25 — SI (ft)= 22-27

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	3.83	1499.42	11/05/87	4.16	1499.09
09/01/87	3.70	1499.55	11/16/87	4.10	1499.15

149-063-36DDBC1

Cherry Lake aquifer LS Elev (msl,ft)= 1530.49 SI (ft)= 131-136

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	10.41	1520.08	11/05/87	10.63	1519.86
09/02/87	10.36	1520.13	11/16/87	10.56	1519.93

149-063-36DDBC2

Cherry Lake aquifer LS Elev (msl,ft)= 1530.64 SI (ft)= 83-88

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	10.70	1519.94	11/05/87	10.89	1519.75
09/02/87	10.63	1520.01	11/16/87	10.82	1519.82

149-063-36DDBC3

Cherry Lake aquifer LS Elev (msl,ft)= 1530.79 SI (ft)= 46-51

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
08/24/87	14.82	1515.97	11/05/87	15.21	1515.58
09/02/87	14.84	1515.95	11/16/87	15.19	1515.60

Appendix D

SIGNIFICANCE OF CHEMICAL CONSTITUENTS

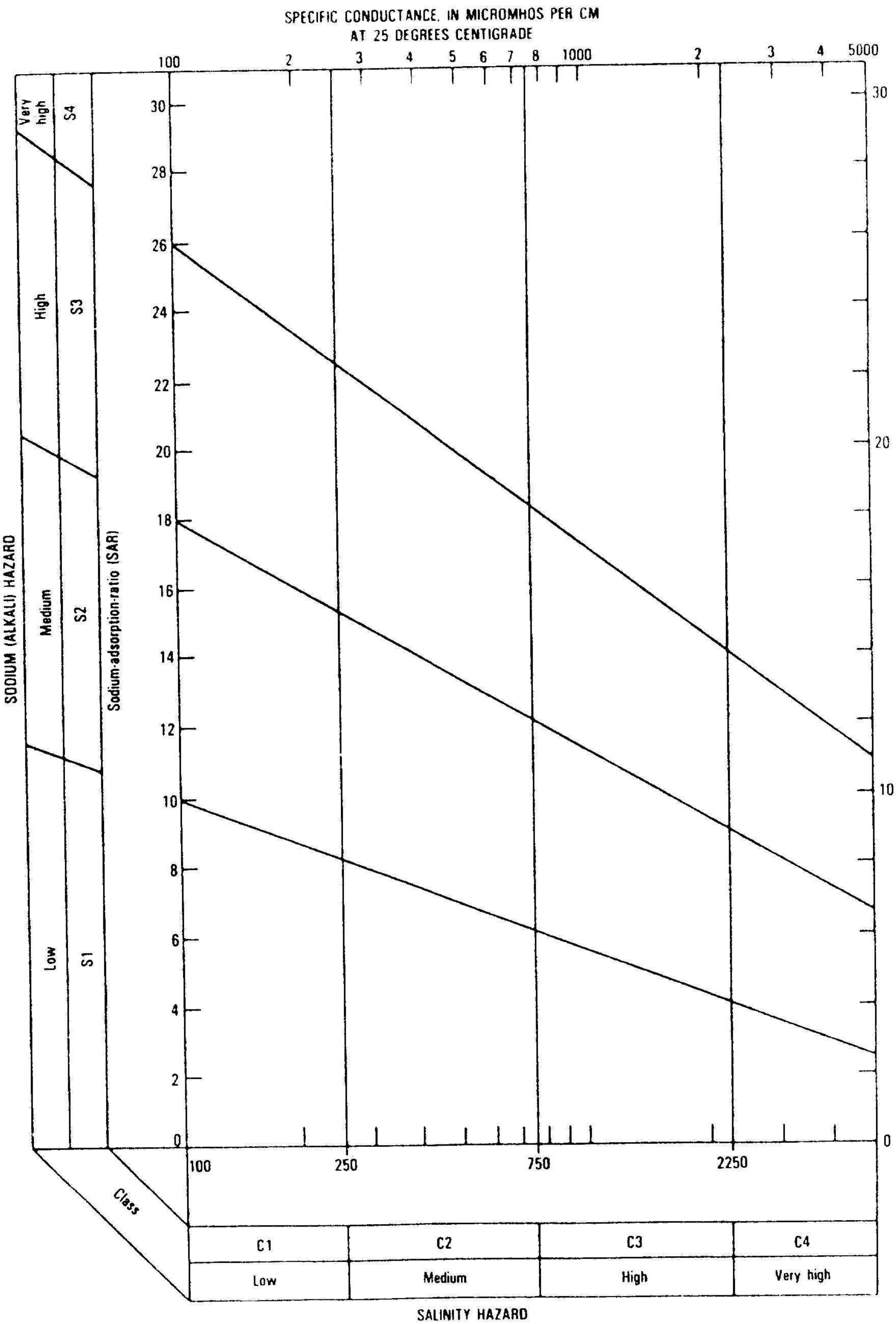
Constituent or Parameter	Effects of dissolved constituents on water use	Suggested limits for drinking water in North Dakota[1]	U.S. Public Health Service recommended limits for drinking water[2]
silica (SiO_2)	No physiological significance.		
Iron (Fe)	Concentrations over 0.1 mg/l will cause staining of fixtures. Over 0.5 mg/l may impart taste and colors to food and drink.		0.3 mg/l
Manganese (Mn)	Produces black staining when present in amounts exceeding 0.05 mg/l.		0.05 mg/l
Calcium (Ca) and Magnesium (Mg)	Calcium and magnesium are the primary causes of hardness. High concentrations may have a laxative effect on persons not accustomed to this type of water.		
Sodium (Na)	No physiological significance except for people on salt–free diets. Does have an effect on the irrigation usage of water.		
Potassium (K)	Small amounts of potassium are essential to plant and animal nutrition.		
Bicarbonate (HCO_3) and Carbonate (CO_3)	No definite significance, but high bicarbonate content will impart a flat taste to water.		
Sulfate (SO_4)	Combines with Calcium to form scale. More than 500 mg/l tastes bitter and may be a laxative.	0–300 mg/l – low 300–700 mg/l – high over – 700 mg/l very high	250 mg/l
Percent Sodium and Sodium Adsorption Ratio (SAR)	Indicate the sodium hazard of irrigation water.		
Chloride (c l)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologically harmful. Humans and animals may adapt to higher concentrations.		250 mg/l
Flouride (F)	Flouride helps prevent tooth decay within specified limits. Higher concentrations cause mottled teeth.	Limits of 0.9 mg/l to 1.5 mg/l	Recommended limits depends on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Nitrate	Over 45 mg/l can be toxic to infants. Larger concentrations can be tolerated by adults. More than 200 mg/l may have a deleterious effect on livestock health.		45 mg/l
Boron (B)	No physiological significance. Greater than 2.0 mg/l may be detrimental to many plants.		
Total dissolved solids	Persons may become accustomed to water containing 2,000 mg/l or more dissolved solids.	0–500 mg/l – low 500–1400 mg/l average 1400–2500 mg/l high over 2500 mg/l very high	500 mg/l
Hardness (as $CaCO_3$)	Increases soap consumption, but can be removed by a water–sofening system.	0–200 mg/l – low 200–300 mg/l average 300–450 mg/l high over 450 mg/l very high	
pH	Should be between 6.0 and 9.0 for domestic consumption.		
Specific Conductance	An electrical indication of total dissolved solids measured in micromhos per Centimeter at 25°C. Used primary for irrigation analyses.		

1. Schmid, R. W., 1965, Water Quality Explanation: North Dakota Water Commission, unpublished report, File No. 989.
2. U.S. Public Health Service, 1962, Public Health Service Drinking Water Standards: U.S. Public Health Service, Pub. No. 956, 61p.

Appendix E

IRRIGATION CLASSIFICATION

(from Hem, 1985 and the U. S. Salinity Laboratory, 1954)



SPECIFIC CONDUCTANCE, IN MICROMHOS PER CM
AT 25 DEGREES CENTIGRADE
100
2
3
4
5
6
7
8
1000
2
3
4
5000
SODIUM (ALKALI) HAZARD
Very high
S4
High
S3
Medium
S2
Low
S1
Sodium-adsorption-ratio (SAR)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
250
750
2250
Class
C1
C2
C3
C4
Low
Medium
High
Very high
SALINITY HAZARD

Appendix F

NORTH DAKOTA STATE WATER COMMISSION
IRRIGATION WATER QUALITY EXPLANATION

The following explanation* will give a general idea of the suitability of a water for irrigation purposes. The successful long–term use of any irrigation water depends more on rainfall, leaching, irrigation management, salt tolerances of crops and soil management practices than upon water quality itself. The determination of the suitability of water involves integrating the land and water factors. It is essential, therefore, to have a rather complete soil study made of the land to be irrigated. The County Agricultural Agent and Soil Conservation District Conservationist can assist in coordinating soil and water types.

The quality of irrigation water depends upon its salt constituents. The electrical conductivity and sodium–adsorption (SAR) of a water are used to classify irrigation water.

The salinity hazard of irrigation water is measured as electrical conductivity in terms of micromhos/cm at 25° C.

C–1 (0–250 micromhos): Low salinity water can be used for irrigation with little likelihood that soil salinity will develop.

C–2 (250–750 micromhos): Medium salinity water can be used for irrigation if a moderate amount of leaching occurs.

C–3 (750–2250 micromhos): High salinity water should be used only on soils of moderate to good permeability. Leaching is needed to prevent serious salinity.

C–4 (2250–5000 micromhos): Very high salinity water is generally undesirable for irrigation and should only be used occasionally on soils of good or high permeability where special leaching is provided to remove excess salt.

The sodium hazard of irrigation water is dependent on the SAR and the electrical conductivity of the water. For example, an SAR rating of 8 indicates a low sodium water within the conductivity range of 100 to 270 micromhos/cm, a medium sodium water within the 270 to 3000 micromhos/cm range, and a high sodium water over 3000 micromhos/cm.

S–1: Low sodium water can be used on almost all soils with little danger of accumulation of harmful amounts of exchangeable sodium.

S–2: Medium sodium water can be used on coarse textured soils with good permeability but is dangerous when used on fine textured soils.

S–3: High sodium water tends to cause harmful sodium accumulations and requires special soil management, good drainage, high leaching, and organic matter additions.

S–4: Very high sodium water is generally unsatisfactory for irrigation purposes.

*From "Diagnosis and Improvement of Saline and Alkali Soils" USDA Handbook #60, 1954.