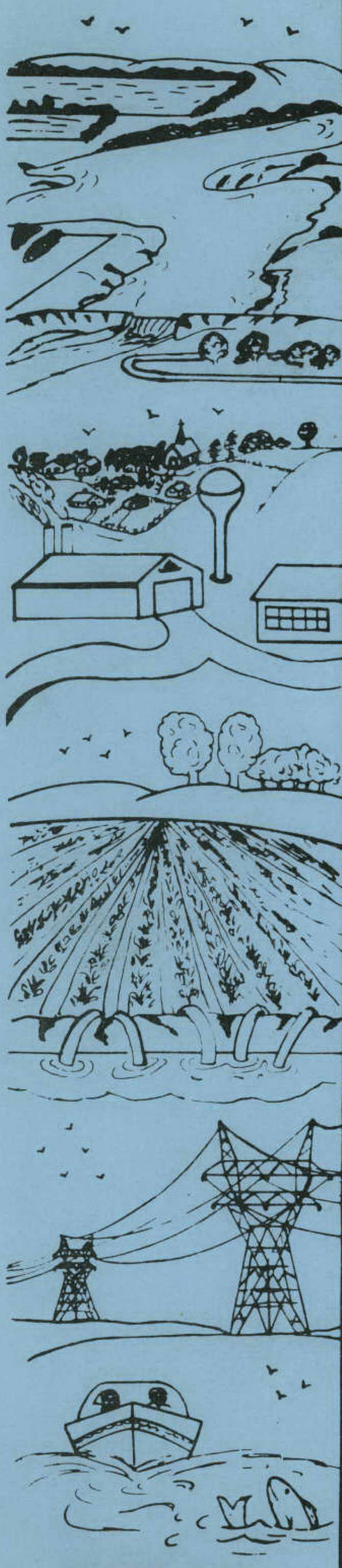

"BUY NORTH DAKOTA PRODUCTS"

Ground-Water Resources of the Oberon Area

Benson County, North Dakota

North Dakota Ground-Water Studies
No. 83

By

Charles E. Naplin

Ground-Water Hydrologist

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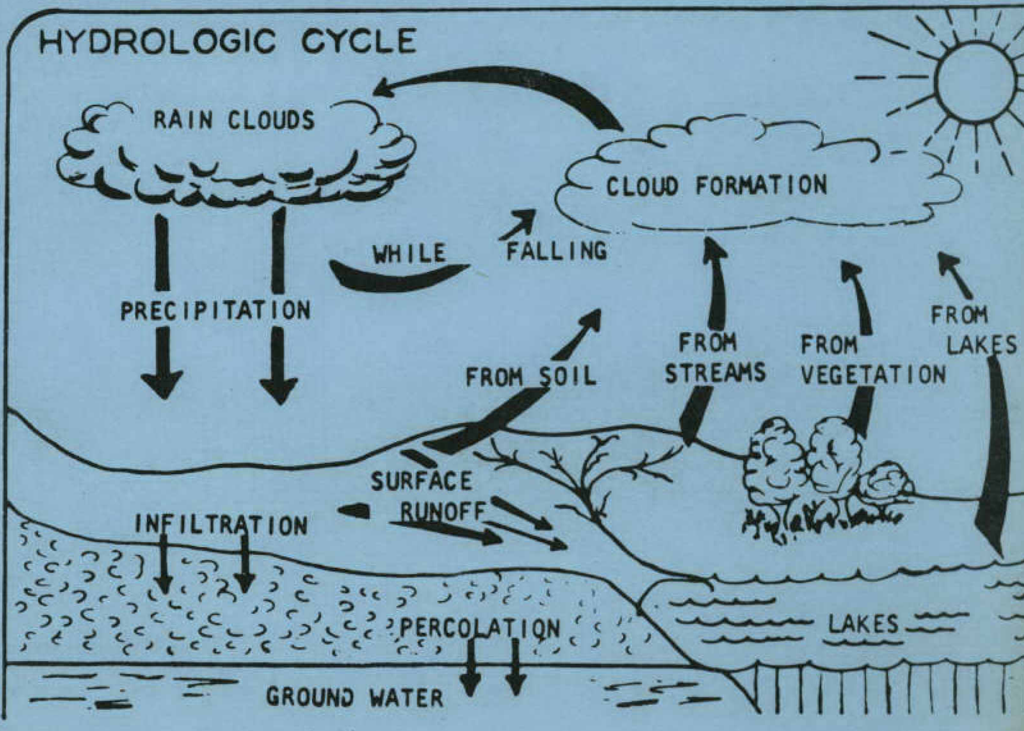

GROUND-WATER RESOURCES OF THE OBERON AREA

BENSON COUNTY, NORTH DAKOTA

NORTH DAKOTA GROUND-WATER STUDIES NO. 83

By
Charles E. Naplin, Ground-Water Geologist
North Dakota State Water Commission

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By
Charles E. Naplin
Ground-Water Geologist

INTRODUCTION

PURPOSE AND SCOPE

The Oberon City Council passed a resolution on December 7, 1972, requesting that the North Dakota State Water Commission conduct a ground-water survey for the City. An agreement was approved by the Commission on January 2, 1973, and the study was conducted during July of that year.

Geohydrologic data on ground-water conditions in the area was gathered by test drilling, installing observation wells, collecting water samples for chemical analysis, water-level measurements and a well inventory of selected private wells. Previous reports on the geology of the area provided additional information that contributed to the compilation of this report.

ACKNOWLEDGEMENTS

Test drilling was accomplished by Lewis Knutson and Jim Zidow using the State-owned forward rotary drilling machine. All field work was under direct supervision of the author. The chemical analyses were performed by Garvin Muri, State Water Commission chemist, at the North Dakota State Laboratories Department in Bismarck. Special acknowledgement is extended to Mayor Lawrence Keller, and Don Drummond, Auditor, for their cooperation and assistance during this investigation.

LOCATION AND GENERAL FEATURES

The Oberon area is located in southcentral Benson County and is in the drift

Prairie division of the Central Lowland physiographic province of North Dakota (fig. 1). This report describes a 16 square mile area in portions of Tps. 151 and 152 N., R. 67 W.

The climate is a subhumid continental type characterized by cold snowy winters and warm summer days with cool nights. According to the National Weather Service (1971) the mean annual temperature at Devils Lake is 38.4°F., based on a 67-year period of record. The mean annual precipitation recorded over a 96-year period of record is 16.26 inches.

The topography is gently rolling to hilly and is poorly drained. Surface elevations range from less than 1,515 feet southwest of town to slightly more than 1,620 feet at Oberon.

Oberon (1970 population 151) is an agricultural community and is served by a branch line of the Burlington Northern railroad. The City does not have a municipal water system and the residents rely on private wells for their water supply. The City installed a municipal sewer system in 1973.

PREVIOUS INVESTIGATIONS

Simpson (1929) described in general terms the glacial and bedrock geology of Benson County and briefly mentioned the Oberon outwash plain. He included an inventory of selected private and municipal wells and listed chemical analyses from a few city wells. Wells inventoried by Simpson near Oberon were listed as being completed in shallow glacial outwash deposits at depths less than 30 feet or completed in Pierre shale at depths exceeding 200 feet.

A report titled the Geology of the Oberon Quadrangle by Tetrick (1946)

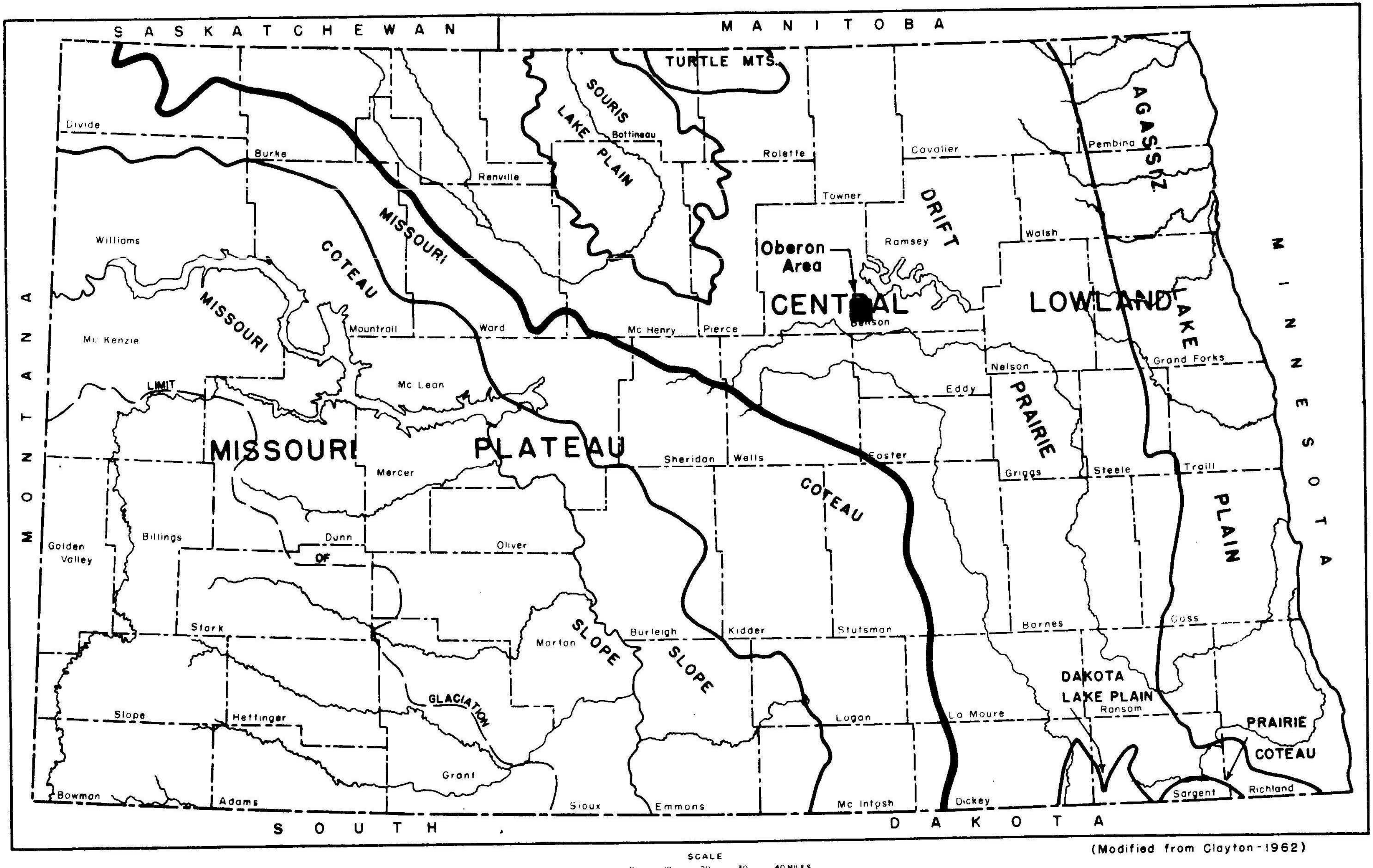


FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE OBERON AREA describes glacial stratigraphy and landforms in southcentral Benson and northwestern Eddy Counties. Tetrick cited outwash deposits, a buried valley in Crow Hill Coulee, and the terrace and floodplain sands and gravels along the Sheyenne River as important sources of ground water near Oberon.

Aronow and others (1953) studied the geology and ground-water resources of the Minnewaukan area and described outwash deposits extending into the vicinity of Oberon. Paulson and Akin (1964) conducted a regional geohydrologic survey of the Devils Lake area describing the geology and ground-water potential of outwash, buried channel, and bedrock aquifers. Their report includes an inventory of shallow wells ranging in depth from 8 to 44 feet that are completed in sand and gravel deposits comprising the Oberon outwash.

Two publications by Randich (1971, 1972) are the completed portion of a study of the geology and ground-water resources of Benson and Pierce Counties that was begun in 1967 and completed in 1971. The report will be complete upon publication of Part 1--Geology and Part 3--Ground-water Resources. The study was a cooperative effort between the North Dakota State Water Commission, U. S. Geological Survey, North Dakota Geological Survey, and the County Commissioners. It presents a general picture of the county's ground-water resources.

WELL-NUMBERING SYSTEM

The wells and test holes listed in Table 3 are numbered according to a system based on the location in the public land classification of the United States Bureau of Land Management (fig. 2). The first numeral denotes the township north of a base line, the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section,

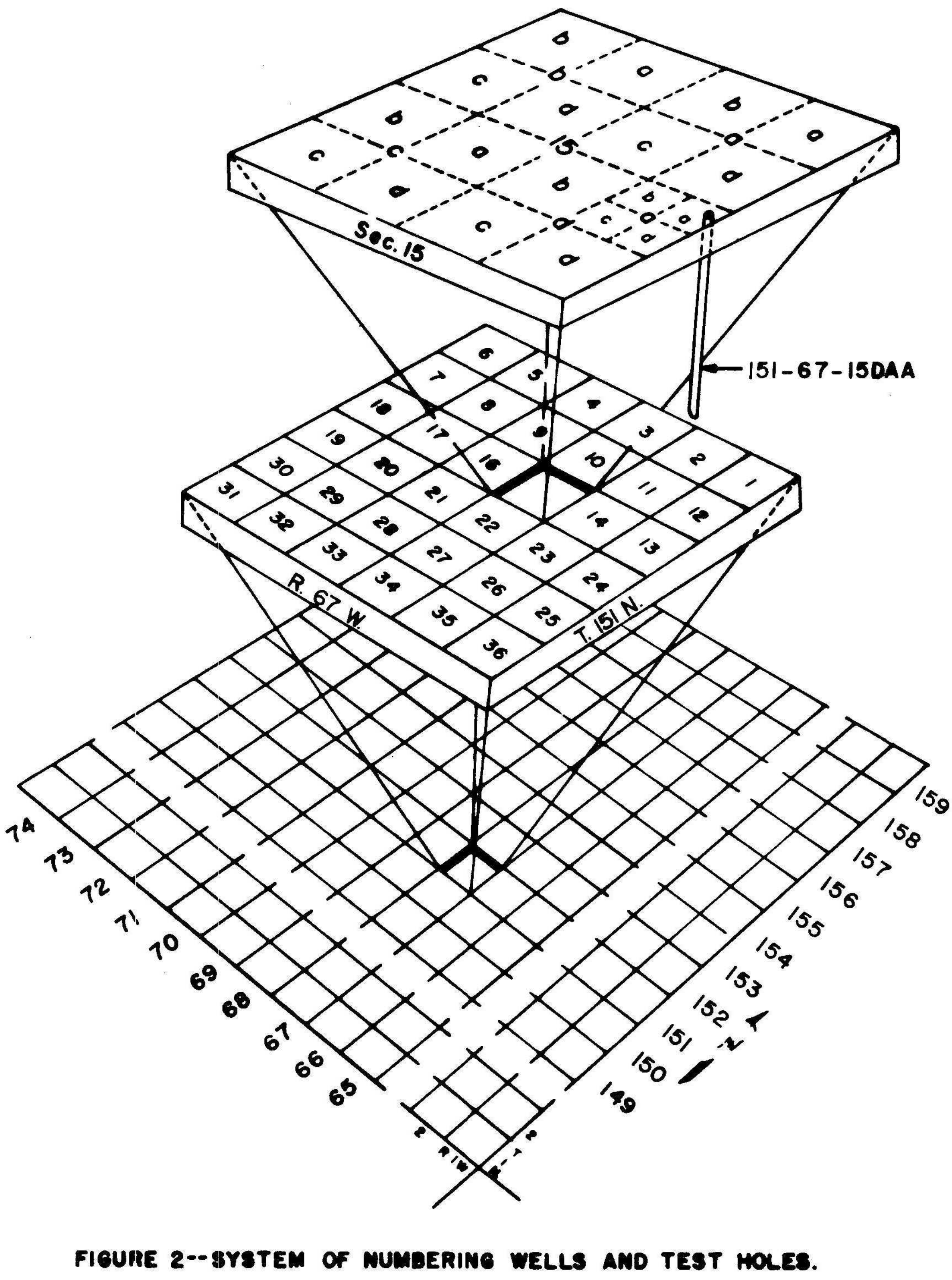


FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

and quarter-quarter-quarter section (10-acre tract). For example, well 151-67-15DAA is in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 15, T.151 N., R.67 W. Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

DEFINITION OF SELECTED TERMS

Aquifer--A permeable, water-bearing deposit that will yield significant quantities of water to wells.

Bedrock--Semi-consolidated rock underlying glacial and alluvial deposits of Pleistocene and/or Holocene age.

Discharge--The removal or loss of water from an aquifer or the flow of water into a stream.

Evapotranspiration--The process by which water is returned to the atmosphere through direct evaporation from water or land surfaces and by transpiration of vegetation.

Glaciofluvial deposits--Sediments deposited by streams flowing from a glacier (outwash).

Ground water--Water in the zone of saturation.

Ground-water movement--The movement of ground water in the zone of saturation.

Infiltration--The movement of water from the surface towards the zone of saturation.

Observation well--A well from which hydrologic data are measured and recorded.

Permeable rock--A rock that has a texture permitting water to move through it under ordinary pressure differentials.

Recharge--The addition of water to the zone of saturation.

Storage--The quantity of water contained in openings in the zone of saturation.

Water table--The upper surface of the zone of saturation where the hydrostatic pressure is equal to atmospheric pressure. The configuration of the water table commonly is a subdued expression of the land surface.

Zone of saturation--the zone below the water table.

WATER QUALITY

All natural water occurring on the earth's surface or underground contains dissolved minerals. Precipitation begins to dissolve mineral matter as it falls to the surface and continues to dissolve minerals as it infiltrates into the ground. Dissolved minerals in ground water vary in type and concentration depending primarily upon the composition and solubility of rocks encountered, the length of time the water is in contact with the rocks, and the amount of carbon dioxide and soil acids in the water. Water that has been underground for a long time, or that has travelled a long distance from the recharge area, usually contains more dissolved mineral matter than water that has been underground for only a short time and is withdrawn close to a recharge area.

Dissolved mineral constituents are reported in milligrams per liter (mg/l). A milligram per liter is one thousandth (0.001) of a gram of dissolved material per liter of solution. Hardness is usually reported in milligrams per liter, but may be converted to grains per U. S. gallon (gr/gal) by dividing milligrams per liter by 17.12.

Table 1 gives the significance of the various chemical constituents of water for a domestic or municipal water supply in North Dakota. Results of chemical analyses for wells in the study area are listed in Table 2.

BASIC HYDROLOGIC CONCEPTS

All ground water of economic importance is derived from precipitation. After the precipitation falls on the earth's surface, part is returned to the atmosphere by evaporation, some runs into streams, and the remainder percolates into the ground. Much of the water that sinks into the ground is held temporarily in the soil and

TABLE 1 -- Dissolved chemical constituents in water -- their effects upon usability and recommended concentration limits for domestic and municipal water supplies in North Dakota.

Constituent or Parameter	Effects of dissolved constituents on water use	Significance for water supplies 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 0.3 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. Over 125 mg/l 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 useage 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 (cl)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologically harmful. Humans and animals may adapt to higher concentrations.		
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 depend on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Nitrate (NO_3)	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-softening 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 primarily for irrigation analyses.		

[1] Schmid, 1965.
[2] U.S. Public Health Service, 1962.

is returned to the atmosphere either by evaporation or by transpiration. The remainder infiltrates downward to the zone of saturation and becomes ground water.

Ground water moves under the influence of gravity from areas of recharge to areas of discharge. The movement of ground water is generally very slow and may be only a few feet per year. The rate of movement is governed by the permeability of the deposits through which the water moves and by the hydraulic gradient. Gravel and well-sorted medium to coarse sand are usually very permeable. Fine-grained materials such as silt, clay, and shale have low permeability, and act as confining barriers that restrict the free movement of ground water into or out of more permeable rocks.

The water level in a well fluctuates in response to recharge to and discharge from the aquifer. Land surface loadings and atmospheric pressure changes cause minor water level fluctuations in confined aquifers. Pumping a well causes its water level to be lowered and the water-level surface surrounding the well will resemble a cone referred to as the cone of depression. Water-level drawdown is the difference between static and pumping levels. The degree of drawdown is controlled by the hydraulic properties of the aquifer, the physical characteristics of the well, and the rate and duration of pumping. Continuous withdrawal of water from an aquifer by pumping may cause, 1) a decrease in the rate of natural discharge, 2) an increase in the rate of recharge, 3) a reduction in the volume of water in storage, or 4) any combination of these.

GROUND WATER IN THE PREGLACIAL ROCKS

The Oberon area is situated near the eastern edge of the Williston Basin and is underlain by more than 4,000 feet of westward-dipping sedimentary rocks (fig. 3). These rocks consist of alternating beds of limestone, dolostone, sandstone, and shale that were deposited millions of years ago in ancient seas. The Pierre

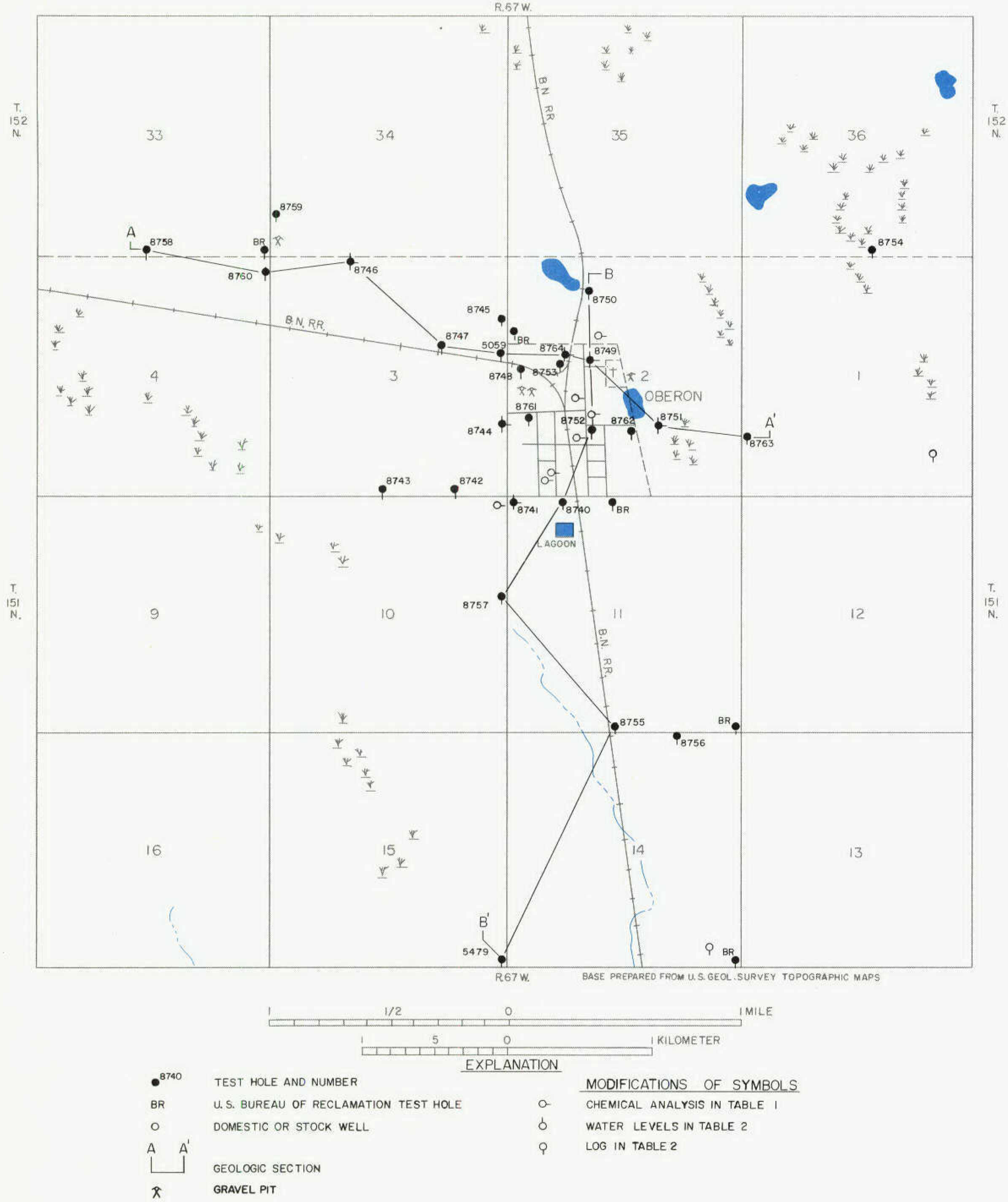


FIGURE 3--LOCATION OF WELLS, TEST HOLES, GEOLOGIC SECTIONS, AND RELATED FEATURES IN THE OBERON AREA

Formation directly underlies glacial drift in the Oberon area and is the only bedrock unit that is included in the scope of this study.

Test drilling indicates the Pierre consists of dark gray to grayish-black, hard, fissile, noncalcareous shale. The Pierre is overlain by more than 80 feet of glacial drift at Oberon but outcrops along the Sheyenne River valley about four miles south of the study area. The Pierre is weathered flakey, loose, and light gray when exposed in outcrops and often contains thin, bentonitic zones that have a popcorn-like appearance when dry, and an abundance of small, reddish-brown iron concretions.

The shale has very low permeability and is generally not an adequate source of water supply. Ground-water movement is restricted to openings along cleavage planes and poorly developed joint systems in the upper part of the formation. Ground water enters fractures in the shale by filtering down through the overlying glacial drift. Wells tapping fractured zones in the Pierre generally yield water that is high in dissolved solids and of the sodium sulfate or sodium chloride types. Chemical analyses of water from the Pierre were not obtained in the study area because nearly all private wells are completed in the Oberon outwash or lenses of sand and gravel within the till.

GROUND WATER IN THE GLACIAL DRIFT

The existing landforms in the Oberon area are the direct result of glaciation that occurred during Wisconsin time more than 12,000 years ago (Bluemle, 1965). Wisconsinan ice advanced southeastward over the area and then retreated depositing end moraine, ground moraine, and outwash. Figure 4 shows the glacial landforms in the Oberon area as revised from Tetrick (1946).

The North Viking end moraine forms a topographic high north and east of Oberon and consists of a series of prominent ridges, knobs, and kettles that are

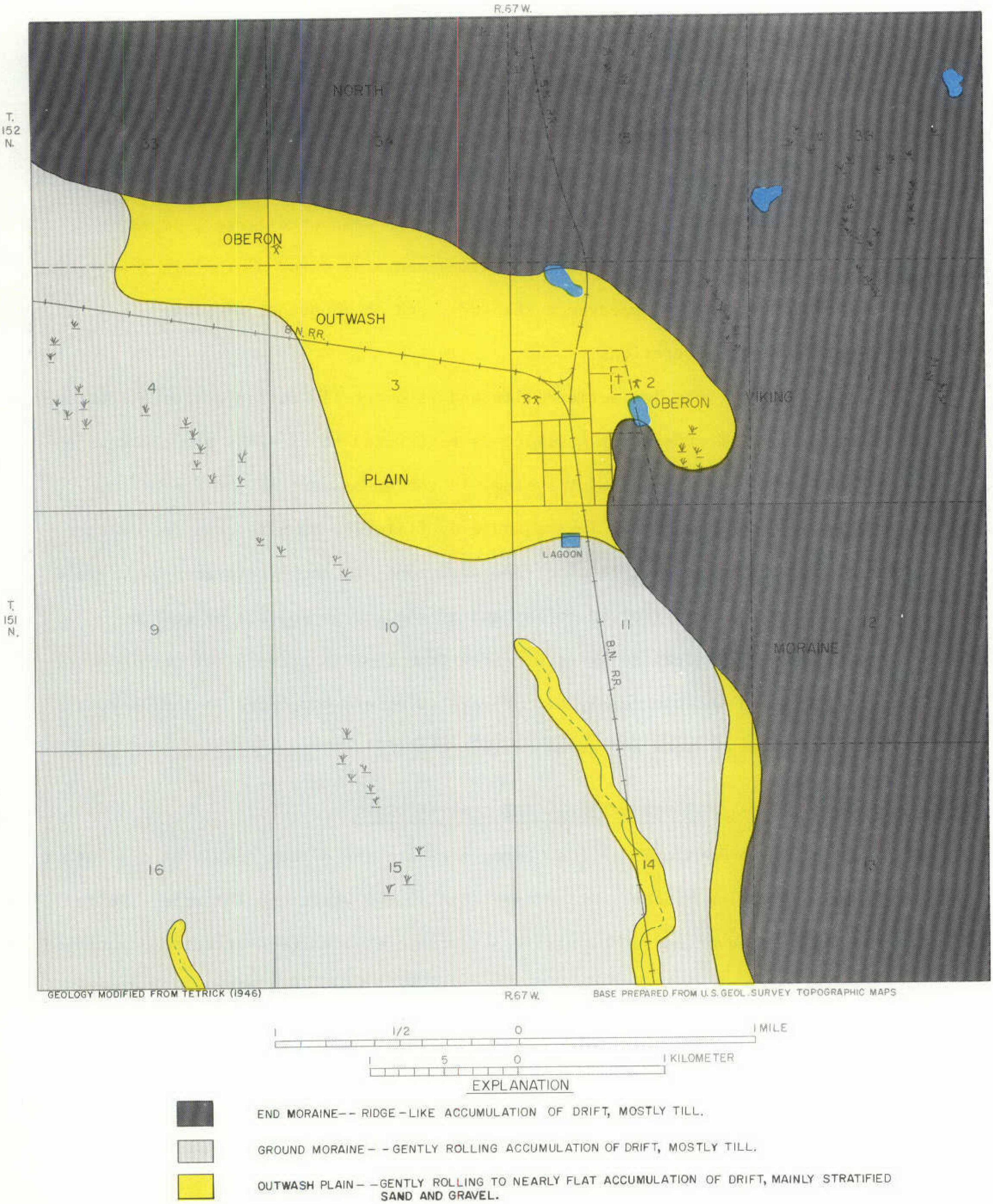


FIGURE 4 -- GLACIAL MAP OF THE OBERON AREA

characteristic of a terminal moraine. The end and ground moraines in the study area consist of till which is an unsorted mixture of clay, silt, sand, gravel, cobbles, and boulders. These features were formed as the ice front stagnated, melted, and let down an irregular accumulation of glacial debris.

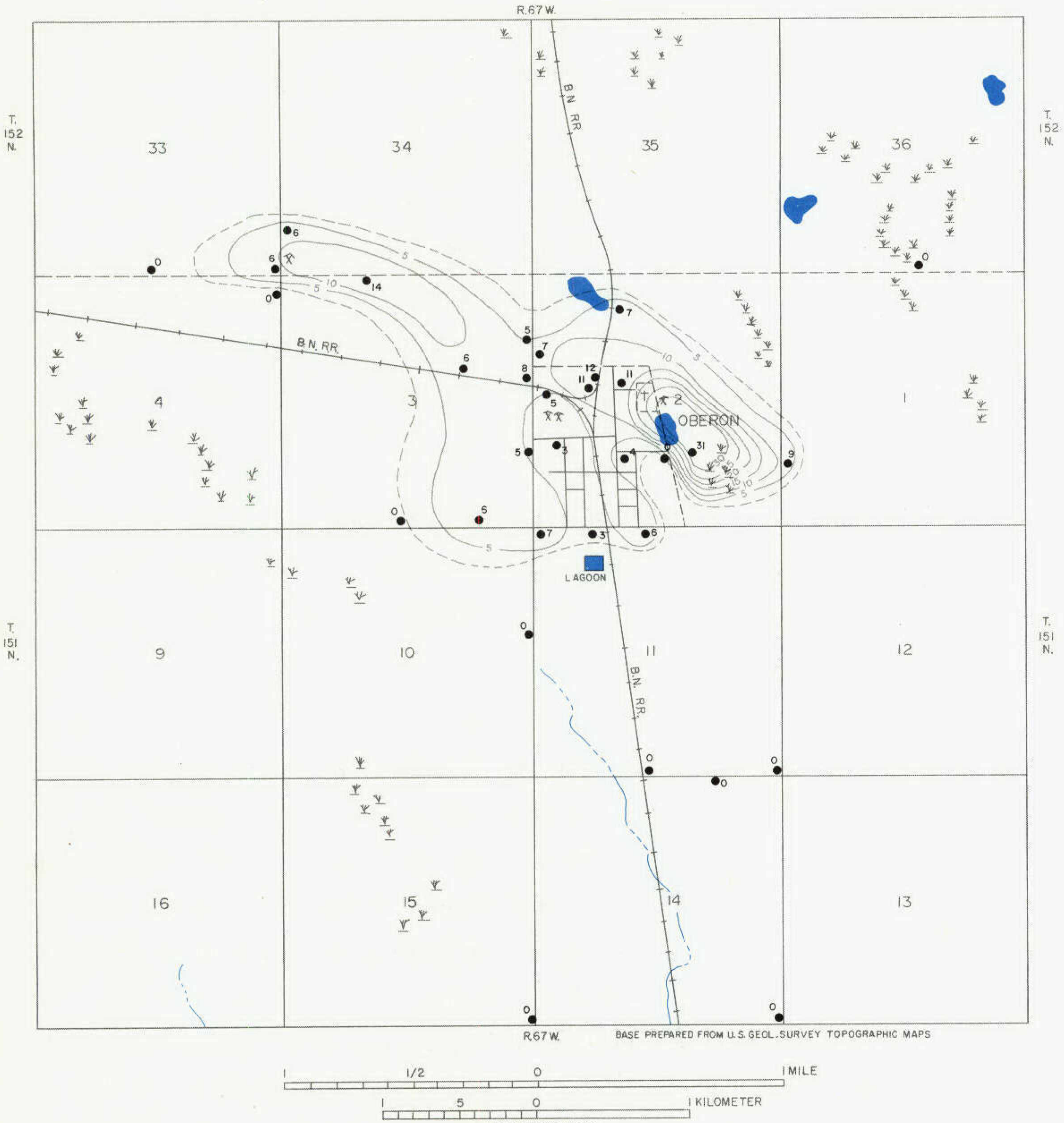
The Oberon outwash plain and several other isolated deposits of sand and gravel were formed as meltwater streams flowed southeastward along and parallel to the receding ice front. Outwash material at Oberson consists of stratified, poor to well-sorted, very fine sand to coarse gravel that often contains inter-bedded clay and silt. The Oberon outwash slopes gently to the southwest away from the North Viking moraine and directly overlies ground moraine in the study area (pl. 1).

Sand and gravel deposits comprising the Oberon outwash constitute the only significant glacial drift aquifer encountered during this investigation. Thin lenses of sand and gravel occur within the glacial till but these deposits are discontinuous and yield only small quantities of water to wells.

OBERON AQUIFER

Data collected during this study show that the Oberon aquifer underlies an area of about 1½ square miles. The outwash ranges in cumulative thickness from 4 feet in test hole 8758 (152-67-33CDD) to 37 feet in test hole 8764 ($157\text{-}67\text{-}2BDC_1$) but is not completely saturated with ground water. Therefore, by the definition of an aquifer as listed in this report, only the saturated portion of the outwash deposit constitutes the Oberon aquifer (fig. 5).

The aquifer's saturated thickness is directly related to the total thickness of sand and gravel and also reflects the subsurface geometry of the deposit. Geologic sections A-A' and B-B' (pl. 1) and the saturated thickness map (fig. 5) indicate this relationship. The area of greatest saturated thickness is located



EXPLANATION

CONTROL POINT--NUMBER INDICATES SATURATED AQUIFER THICKNESS IN FEET.

CONTOUR INTERVAL 5 FEET.

---AQUIFER BOUNDARY IS APPROXIMATE.

FIGURE 5 -- SATURATED THICKNESS OF THE OBERON AQUIFER

at test hole 8751 (151-67-2DBD) that penetrated 31 feet of water-bearing material from 26-40, 44-54 and 58-65 feet below land surface, respectively.

The Oberon aquifer is generally unconfined and the water-table fluctuates in response to the degree of seasonal precipitation. The hydrograph for a well at 151-67-2CDC in Oberon shows that the water-table is at a high level when rainfall is greatest and declines when precipitation is minimal (fig. 6).

The downward infiltration of precipitation is the primary source of recharge, but a small amount of seepage from the underlying and adjacent till may also enter the aquifer. Ground water is discharged by seepage to adjacent low areas by the evapotranspiration of vegetation, and by the pumping of wells.

About 2,000 acre-feet of ground water is stored in the Oberon aquifer assuming an areal extent of 1½ square miles (960 acres), an average saturated thickness of 7 feet, and a porosity of 30 percent for fine to medium sand. However, only about 50 percent of the water in storage or 1000 acre-feet, would be recoverable by wells. Yields exceeding 100 gpm (gallons per minute) may be possible from properly constructed wells.

Thirteen water samples (table 2) indicated the water is a calcium bicarbonate type. Dissolved solids ranged from 357 to 949 mg/l and average 654 mg/l. The water is hard and may contain excessive concentrations of iron and manganese. The presence of nitrate in concentrations ranging from 0.4 to 160 mg/l indicate local contamination of the aquifer, particularly within the city limits (fig. 7). The presence of nitrate reflects the downward infiltration of nitrogenous wastes into the aquifer from septic tanks in Oberon, that has occurred over a period of many years.

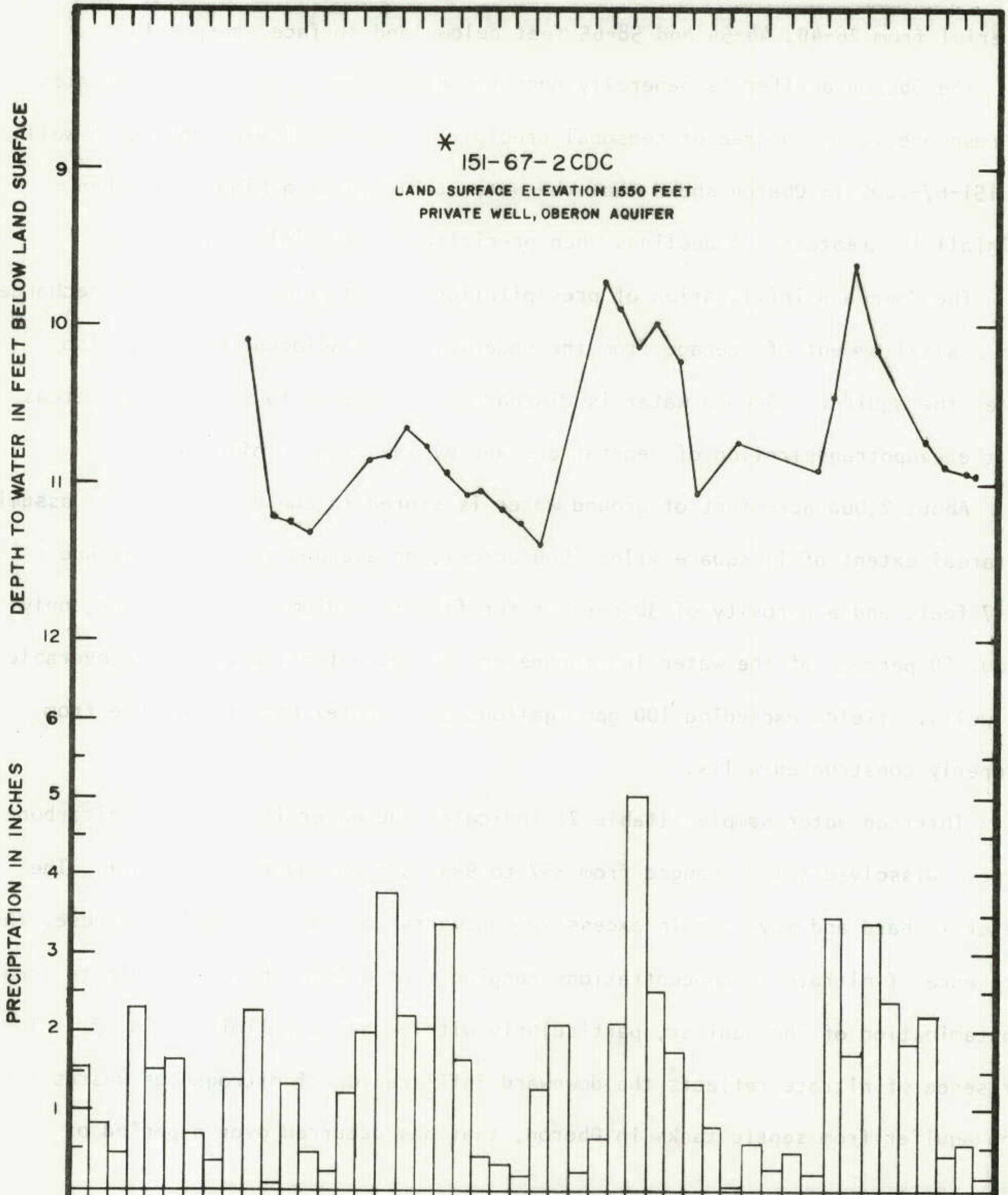
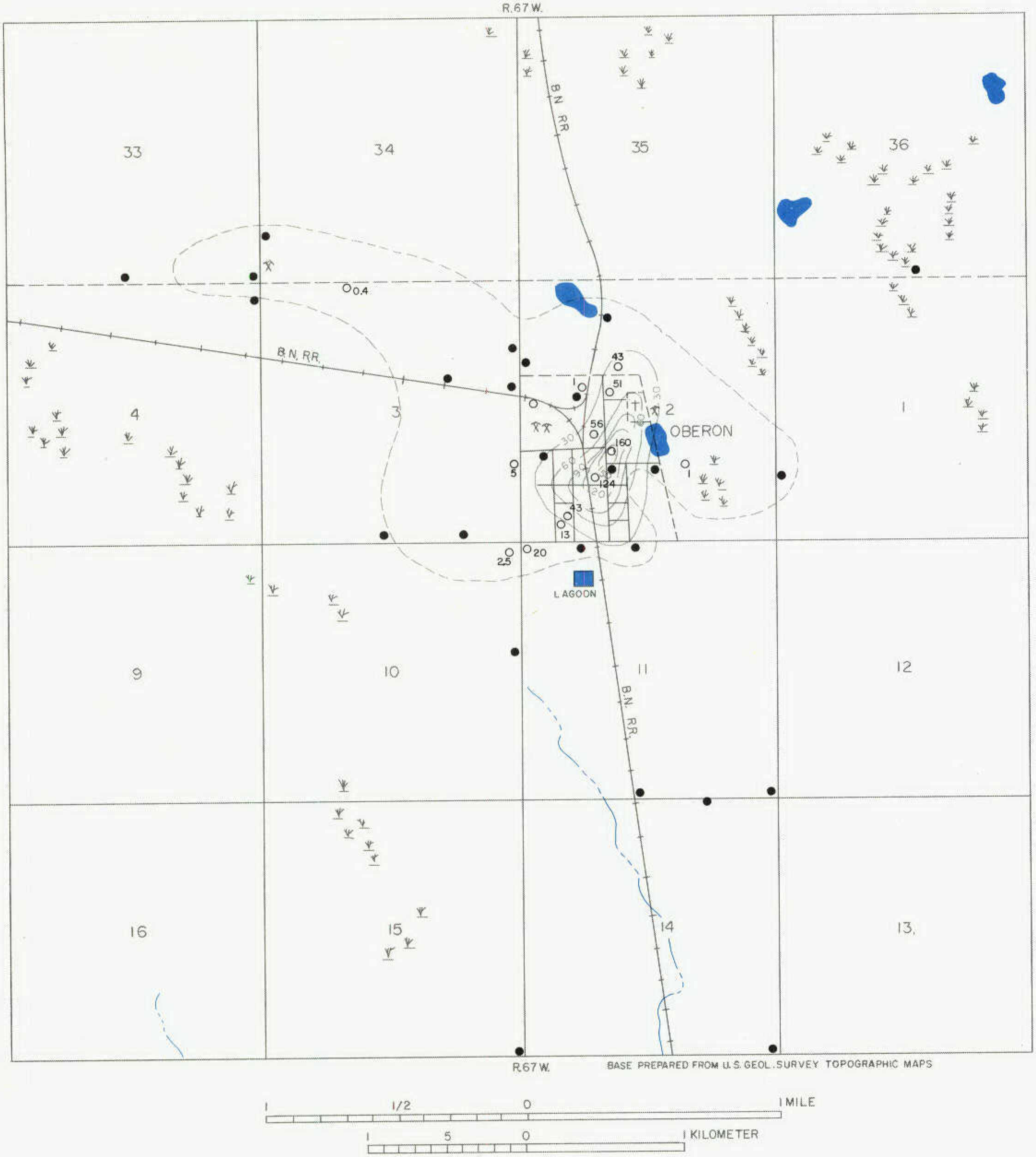


FIGURE 6—— WATER-LEVEL TRENDS IN THE OBERON AQUIFER AND PRECIPITATION AT SHEYENNE



EXPLANATION

o20 CONTROL POINT--NUMBER INDICATES NITRATE CONCENTRATION IN MILLIGRAMS PER LITER.

CONTOUR INTERVAL 30 MG/L.

---AQUIFER BOUNDARY IS APPROXIMATE.

FIGURE 7-- NITRATE CONCENTRATION IN THE OBERON AQUIFER

SUMMARY AND CONCLUSIONS

This study obtained and evaluated geohydrologic data that describe ground-water conditions within a 16-square mile area of Oberon in southcentral Benson County. The area is located within the Drift Prairie division of the Central Lowland physiographic province of North Dakota. Oberon's climate is subhumid continental and the average annual temperature and precipitation are 38.4°F and 16.26 inches, respectively.

More than 4,000 feet of sedimentary rocks, consisting of westward-dipping beds of limestone, dolostone, sandstone, and shale, underlie glacial drift in the area. The Pierre Formation, an impervious, dark-gray, hard, fissile, bentonitic shale, directly underlies the glacial drift, but does not yield adequate quantities of water to wells.

More than 80 feet of glacial drift overlies the Pierre shale at Oberon. The predominant glacial landforms were deposited more than 12,000 years ago and consist of end moraine, ground moraine, and outwash. The moraines are composed mostly of clayey, silty, pebbly, and bouldery till, that does not readily yield water to wells. Outwash deposits, consisting of up to 37 feet of stratified, clayey sand and gravel, yield water to many wells in the study area.

The Oberon aquifer was found to extend over an area of about 1½ square miles and contains up to 31 feet of saturated sand and gravel. About 1,000 acre-feet of recoverable ground water is stored in the aquifer and properly completed wells may yield more than 100 gpm. Ground water in the Oberon aquifer is a calcium bicarbonate type, averages 654 mg/l dissolved solids, and is contaminated with nitrate within the city limits.

This investigation determined that the Oberon aquifer is capable of providing the city with an adequate water supply. Selection of a municipal well site will depend on the aquifer's total available saturation and avoiding local contamination. Geohydrologic data suggest that the aquifer's greatest potential exists in the vicinity of test hole 8751 (151-67-2DBD) east of the city.

TABLE 2 -- CHEMICAL ANALYSES

(Analytical results are in milligrams per liter except where indicated)

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp (°F)	Date of Collection	(SiO_2)	(Fe)	(Mn)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total Dissolved Solids	Total Hardness as $CaCO_3$	Total Hardness Noncarbonate	Percent Sodium	SAR	Specific Conductance	pH
OBERON AQUIFER																									
C. Sorenson	151-67-2bda	35	46	7-27-73	26	0.31	0	130	46	17	7.2	334	0	250	19	0.2	43	2.30	686	510	230	7	0.3	1000	7.8
Test Hole 8749	151-67-2bdc$_1$	36	44	7-27-73	24	4.00	0.52	130	67	18	6.9	307	0	290	25	0.2	51	0.95	769	600	350	6	0.3	1110	8.1
Test Hole 8764	151-67-2bdc$_2$	38	45	7-27-73	25	13.00	1.60	80	36	20	6.9	295	0	110	0.3	0.1	1.0	0	417	300	58	12	0.5	663	8.1
Oberon Public School	151-67-2cab	44	46	7-27-73	27	0.21	0.01	120	58	15	6.9	362	0	190	38	0.1	56	1.5	686	540	250	6	0.3	1040	7.7
D. Drummond	151-67-2cac	28	48	7-18-73	26	0	0.08	110	86	71	8.5	438	0	190	79	0.3	160	0	949	630	270	19	1.2	1460	7.6
E. Buehler	151-67-2ccd$_1$	16	46	7-27-73	27	0.41	0	130	64	13	6.3	330	0	230	63	0.1	43	0.04	740	590	320	5	0.2	1120	7.7
E. Buehler	151-67-2ccd$_2$	17	46	7-27-73	25	0.41	0.04	160	72	17	6.9	341	0	330	66	0.1	13	0.13	849	670	390	5	0.3	1270	7.8
Farmers Union Elevator	151-67-2cdb	20	46	7-27-73	26	0.35	0	95	110	24	7.3	616	0	180	33	0.1	124	1.20	865	680	200	7	0.4	1300	7.7
Test Hole 8751	151-67-2dbd	53	46	7-19-73	28	0.45	0.57	160	41	86	7.0	330	0	160	18	0.2	1.0	0	524	420	150	5	0.2	821	8.1
Test Hole 8746	151-67-3bab	25	46	7-18-73	23	0.11	0.25	130	26	31	7.5	402	0	170	6.5	1.0	0.4	0	594	430	100	13	0.7	897	8.1
Test Hole 8744	151-67-3dad	17	46	7-18-73	24	0.29	0.21	71	25	16	6.2	273	0	69	5.6	0.3	5.0	0	357	280	56	11	0.4	572	8.2
L. Buehler	151-67-10aaa	10	46	7-27-73	25	0.31	0.01	67	32	15	3.8	296	0	68	20	0.1	2.5	022	380	300	57	10	0.4	633	7.9
Test Hole 8741	151-67-11bbb	14	46	7-17-73	22	0	0.44	120	58	26	7.8	333	0	230	47	0.3	20	0	696	540	270	9	0.5	1060	8.1

Table 3 -- Logs of Test

The following logs of test holes are a summary of data from driller's logs, geologist's sample descriptions and electric logs. Color descriptions are of wet samples and are based upon color standards of the National Research Council (Goddard and others, 1948). Grain-size classification is C. K. Wentworth's scale from Pettijohn (1957).

Test holes are called observation wells when they have been completed with 1¼ inch diameter plastic casing and screened at the bottom. Well depths, screened producing intervals (S.I.) and water levels, with date of measurement, are so designated. Water levels are in feet below land surface. Elevations, based on mean sea level datum, were interpolated from topographic maps published by the U. S. Geological Survey.

The test holes listed in table 2 with numbers between 8740 and 8764 were drilled as part of this investigation. The other numbered test holes were drilled by the State Water Commission prior to this study. Test hole logs without numbers were provided by the individual or agency shown in the heading of the log.

151-67-1CCB
NDSWC 8763
Elevation 1555 Feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy loam, grayish-black--	1	1
	Clay, very silty,sandy,pebbly dusky yellow, oxidized (till)----------------------------	20	21
	Clay, silty, sandy, pebbly, olive gray,(till)	25	46
	Gravel, cobbles, boulders, poorly sorted, taking water------------------------------	9	55
	Clay,silty,sandy,pebbly,olive gray (till)--	5	60

151-67-1DD
(log from Schnell, Inc.)

	Topsoil------------------------------------	2	2
	Yellow sandy clay - gray clay at 2 ft.------	12	14
	Gravel and sand - rock at 17 ft.-----------	3	17
	Gray sandy clay - till--------------------	53	70
	Sand, gravel-------------------------------	3	73
	Clay---------------------------------------	3	76
	Gravel-------------------------------------	2	78
	Clay-till----------------------------------	2	80
	Gravel, clay-------------------------------	16	96
	Clay-till----------------------------------	15	111
	Hard clay----------------------------------	44	155
	Shale--------------------------------------	230	385

151-67-2BAC
NDSWC 8750
Elevation 1563 Feet

Glacial drift:			
	Clay, silty, sandy, pebbly, cobbles, boulders, dusky yellow, ixidized (till)-------------	18	18
	Clay, silty, sandy, pebbly, olive gray (till)	12	30
	Gravel, fine to coarse, about 40 percent sand, subrounded, poorly sorted, loose-----------	7	37
	Clay, silty, pebbly, olive gray (till)-----	3	40

151-67-2BCB
(Log from U.S. Bureau of Reclamation)

	Topsoil------------------------------------	0.7	0.7
	Sand, tan, silty, fine to medium, occasionally coarse, trace of clay, occasional gravel---	14.3	15
	Sand, brown, silty, fine to medium, zones of coarse sand and gravel--------------------	10	25

151-67-2BCC
NDSWC 8748

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, pebbly, dusky yellow, oxidized (till) ------------------------	2	2
	Sand, medium to coarse, about 20 percent gravel, subrounded, well-sorted, light brown, taking water --------------------	21	23
	Silt, clayey, medium gray ---------------	5	28
	Clay, silty, pebbly, olive gray (till) --	12	40

Observation Well
Depth 23 feet
S.I. 20-23 feet
Water level 17.85 feet
Measured 11-20-73

151-67-2BCD
NDSWC 8753
Elevation 1563 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy, gravelly loam, brown ----	1	1
	Sand, very fine to very coarse, about 25 percent gravel, subrounded, fair sorting, light brown, oxidized, taking water -----	32	33
	Clay, silty, sandy, pebbly, olive gray (till) -----------------------------------	7	40

151-67-2BDC$_1$

NDSWC 8749

Elevation 1565 feet

Glacial drift:		
Topsoil, sandy, gravelly loam, brown ----	1	1
Sand, fine to very coarse, mostly medium to coarse, about 40 percent gravel, subrounded, fair sorting, light brown, oxidized, taking water ------------------	35	36
Silt, clayey, medium gray ---------------	6	42
Sand, very fine to medium, subangular, well-sorted, lignitic ------------------	5	47
Clay, silty, sandy, pebbly, olive gray (till) ----------------------------------	13	60

Observation Well

Depth 36 feet

S.I. 33-36 feet

Water level 24.78 feet

Measured 11-20-73

151-67-2BDC$_2$

NDSWC 8764

Elevation 1565 feet

Glacial drift:		
Topsoil, silty, sandy loam, brownish black	1	1
Sand, very fine to very coarse, mostly coarse to very coarse, about 20 percent gravel, subangular, fair sorting, light brown, some clay, oxidized, taking water ---------------------	37	38
Clay, silty, pebbly, olive gray (till) ------	2	40

Observation Well

Depth 38 feet

S.I. 35-38 feet

Water level 26.01 feet

Measured 11-20-73

151-67-2CAC
NDSWC 8752
Elevation 1565 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, fine to very coarse, about 40 percent gravel, subrounded, light brown, oxidized, taking water----------------------------------	22	22
	Silt, clayey, medium gray-----------------	8	30
	Sand, fine to very coarse, subangular, well sorted-------------------------------------	4	34
	Clay, silty, gravelly, cobbles, boulders, olive gray (till)-----------------------	26	60

151-67-2CBC
NDSWC 8761
Elevation 1554 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy loam, brownish-black -	1	1
	Sand, very fine to very coarse, mostly coarse, about 30 percent gravel, subrounded, fair sorting, light brown, oxidized--------	18	19
	Silt, clayey, medium gray------------------	7	26
	Clay, silty, pebbly, olive gray (till)-----	14	40

151-67-2DBC
NDSWC 8762
Elevation 1563 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy loam, brownish-black-	1	1
	Sand, very fine to coarse, subangular, well-sorted, light brown, oxidized-------------	6	7
	Clay, silty, pebbly, yellowish-brown,oxidized (till)---------------------------------	13	20
	Clay, silty,pebbly, olive gray (till)------	19	39
	Gravel, sandy,poorly sorted----------------	1	40
	Clay, silty, sandy, pebbly, olive gray (till)	20	60

151-67-2DBD
NDSWC 8751
Elevation 1550 feet

Glacial drift:		
Clay, silty, sandy, pebbly, yellowish-brown oxidized (till)--------------------------	3	3
Sand, fine to very coarse, about 20 percent gravel, light brown, oxidized--------------	5	8
Clay, sandy, pebbly, dark-yellowish-brown, oxidized (till)--------------------------	4	12
Clay, silty, pebbly, olive gray (till)-----	14	26
Sand, fine to coarse, mostly medium, subrounded, well-sorted, clean---------------	14	40
Clay, silty, pebbly, olive gray (till)----	4	44
Sand, fine to very coarse, mostly coarse to very coarse, about 40 percent gravel, subrounded, moderately well-sorted, clean----	10	54
Clay, silty, pebbly, cobbles, olive gray (till)-----------------------------------	4	58
Cobbles, boulders, gravelly, poorly sorted-	7	65
Clay, silty, pebbly, olive gray (till)-----	15	80
Pierre Formation:		
Shale, siliceous, grayish-black, noncalcareous---------------------------------	20	100

Observation Well
Depth 53 feet
S.I. 47-53 feet
Water level 14.61 feet
Measured 11-20-73

151-67-3ADA
NDSWC 8745
Elevation 1557 feet

Glacial drift:		
Clay, silty, sandy, pebbly, boulders, yellowish-brown, oxidized (till)----------	5	5
Sand, medium to coarse, gravelly, subrounded, fair sorting, light brown, oxidized-------------------------------------	5	10
Clay, sandy, pebbly, cobbles, yellowish-brown, oxidized (till)---- --------------	5	15
Sand, fine to very coarse, mostly medium to coarse, subrounded, well-sorted, light brown, oxidized--------------------------------	7	22
Silt, clayey, medium gray-----------------	18	40

151-67-3ACD
NDSWC 8747
Elevation 1545 feet

Glacial drift:		
Clay, silty, sandy, pebbly, dusky yellow, oxidized (till)--------------------------	2	2
Sand, fine to very coarse, subrounded, well-sorted, clay layers----------------------	11	13
Silt, clayey, medium gray-----------------	12	25
Clay, silty, pebbly, olive gray (till)	15	40

151-67-3ADD
NDSWC 5059
Elevation 1553 feet

Glacial drift:		
Topsoil, sandy, brownish-black------------	1	1
Clay, sandy, yellowish-brown, oxidized (till)------------------------------------	2	3
Sand, fine to coarse, gravelly, subrounded, oxidized--------------------------------	22	25
Boulder, dolostone, yellowish-gray---------	2	27
Clay, silty, sandy, olive-gray, (till)-----	66	93
Pierre Formation:		
Shale, grayish-black, bentonitic-----------	27	120

151-67-3BAB
NDSWC 8746
Elevation 1560 feet

Glacial drift:		
Sand, fine to very coarse, mostly medium to coarse, about 20 percent gravel, subrounded, light brown, oxidized, taking water--------	27	27
Silt, clayey, medium gray------------------	12	39
Gravel, fine to coarse, sandy, poorly sorted loose--------------------------------------	2	41
Silt, clayey, light gray------------------	5	46
Clay, silty, pebbly, olive gray (till)-----	14	60

Observation Well
Depth 25 feet
S.I. 22-25 feet
Water Level 12.70 feet
Measured 11-20-73

151-67-3CDD
NDSWC 8743
Elevation 1536 feet

Glacial drift:		
Sand, medium to coarse, gravelly, cobbles, boulders, clayey, dusky yellow, poorly sorted, oxidized	5	5
Clay, sandy, pebbly, boulders, yellowish-brown, oxidized (till)	5	10
Clay, silty, pebbly, olive gray (till)	30	40

151-67-3DAD
NDSWC 8744
Elevation 1547 feet

Glacial drift:		
Sand, medium to very coarse, about 25 percent gravel, subrounded, well-sorted, light brown, oxidized, taking water	17	17
Silt, clayey, medium gray	6	23
Clay, silty, pebbly, cobbles, olive gray (till)	17	40

Observation Well
Depth 17 feet
S.I. 14-17 feet
Water level 11.79 feet
Measured 11-20-73

151-67-3DDC
NDSWC 8742
Elevation 1540 feet

Glacial drift:		
Sand, medium to very coarse, about 25 percent gravel, subangular, fair sorting, light brown, oxidized	11	11
Clay, silty, pebbly, cobbles, olive gray, (till)	29	40

151-67-4AAA
NDSWC 8760
Elevation 1555 feet

Glacial drift:		
Topsoil, silty, sandy loam, brownish-black	1	1
Sand, very fine to very coarse, about 10 percent gravel, subangular, light brown, oxidized	12	13
Silt, clayey, medium gray	7	20
Clay, silty, sandy, pebbly, olive gray (till)	20	40

151-67-10ADD
NDSWC 8757
Elevation 1535 feet

Glacial drift:			
	Clay, sandy, pebbly, yellowish-brown, oxidized (till)----------------------------	7	7
	Clay, sandy, pebbly, cobbles, boulders, olive gray (till)-------------------------------	33	40

151-67-11BAA
(Log from U.S. Bureau of Reclamation)
Elevation 1580 feet

Glacial drift:			
	Topsoil------------------------------------	0.8	0.8
	Clay, silty, sandy, light gray to tan, occasional fine gravel, (till)-------------	14.2	15
	Clay, silty, fine to medium gravel, occasional boulders, gray-brown, slightly oxidized, (till)------------------------------------	20	35
	Clay, silty, sandy, some gravel, slightly oxidized, gray and brown (till)------------	6.5	41.5
	Sand, silty, fine, uniform, gray-----------	8.5	50

151-67-11BBA
NDSWC 8740
Elevation 1544 feet

Glacial drift:			
	Sand, fine to very coarse, about 40 percent gravel, subrounded, fair sorting, light-brown, oxidized---------------------------	11	11
	Clay, silty, pebbly, olive gray (till)-----	18	29
	Clay, silty, sandy, pebbly, numerous cobbles, boulders, olive gray (till)----------------	11	40

151-67-11BBB
NDSWC 8741
Elevation 1543 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, medium to very coarse, about 30 percent gravel, subangular, fair sorting, light brown, oxidized, taking water ---------------------------------	14	14
	Clay, silty, pebbly, olive gray (till) -	26	40

Observation Well
Depth 14 feet
S.I. 11-14 feet
Water level 6.87 feet
Measured 11-20-73

151-67-11CDD
NDSWC 8755
Elevation 1535 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy loam, brownish-black ------	1	1
	Clay, sandy, pebbly, cobbles, yellowish-brown, oxidized (till) ------------------	17	18
	Clay, sandy, pebbly, olive gray (till) ---	6	24
	Gravel, sandy, subangular ---------------	4	28
	Clay, silty, pebbly, olive gray (till) ---	4	32
	Gravel, fine to medium, sandy, angular, loose ------------------------------------	2	34
	Clay, sandy, pebbly, olive gray (till)----	6	40

151-67-11DDD
(Log from U.S. Bureau of Reclamation)

Glacial drift:			
	Topsoil ----------------------------------	0.8	0.8
	Sand, silty, clayey, fine to medium, approximately 10 percent gravel, brown, oxidized --------------------------------	18.3	19.1
	Clay, silty, sandy, gravelly, olive gray, (till) ----------------------------------	5.9	25

151-67-14ABA
NDSWC 8756
Elevation 1545 feet

Glacial drift:			
	Clay, sandy, gravelly, yellowish-brown, oxidized (till) -------------------------	13	13
	Clay, sandy, pebbly, cobbles, olive gray, (till) ---------------------------------	27	40

151-67-14DDD5
(Log from Schnell, Inc.)
Elevation 1572 feet

Topsoil	2	2
Yellow clay with boulders	16	18
Sand	22	40
Clay	83	123
Shale	47	170

151-67-14DDD6
(Log from U.S. Bureau of Reclamation)

Topsoil	1	1
Sand, silty, clayey, gravelly, tan and brown	20	21
Sand, fine to medium, brown, clean	2	23
Clay, silty, sandy, gravelly, gray (till)	2	25

151-67-15DDD
NDSWC 5479
Elevation 1535 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy loam, brownish-black	1	1
	Clay, silty, sandy, yellowish-brown, oxidized (till)	21	22
	Clay, silty, olive gray (till)	45	67
Pierre Formation:			
	Shale, siliceous, grayish-black, bentonitic, noncalcareous	13	80

152-67-33CDD
NDSWC 8758
Elevation 1540 feet

Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	6	6
	Gravel, fine to coarse, sandy, poorly sorted, light brown, oxidized	2	8
	Clay, silty, pebbly, olive-gray with yellowish brown mottling (till)	8	16
	Gravel, fine to medium, sandy, poorly sorted	2	18
	Clay, silty, pebbly, olive gray (till)	22	40

152-67-33DDD
(Log from U.S. Bureau of Reclamation)

Topsoil--	0.8	0.8
Sand, silty, about 10 percent gravel, well-graded, light-gray to brown, clay zones----	19	19.8
Silt, clay laminae, fine sand, gravelly, gray--	5.2	25

152-67-34CCB
NDSWC 8759
Elevation 1558 feet

Glacial drift:		
Gravel, clayey, sandy, cobbles, boulders, brown--	3	3
Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)---------------------------	7	10
Gravel, sandy, clayey, poorly sorted, oxidized-------------------------------------	3	13
Clay, sandy, pebbly, olive gray (till)-----	7	20
Silt, clayey, medium gray------------------	16	36
Sand, fine to very coarse, gravelly, subrounded----------------------------------	4	40
Gravel, fine to coarse, cobbles, poorly sorted, loose-----------------------------	2	42
Clay, silty, pebbly, olive gray (till)-----	18	60

152-67-36DCC
NDSWC 8754
Elevation 1553 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, cobbles, boulders, yellowish-brown, oxidized (till)-----------	11	11
	Clay, silty, sandy, cobbles, olive gray (till)----------------------------------	9	20
	Sand, medium to very coarse, about 40 percent gravel, subangular, loose------------------	6	26
	Clay, silty, pebbly, olive gray (till)-----	34	60

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