STATE OF SOUTH DAKOTA
Richard Kneip, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Report of Investigations
No. 103

HYDROLOGY OF LAKE KAMPESKA

by
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for

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Dingell-Johnson
F-19-R Completion Report

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ABSTRACT

Lake Kampeska is located northwest of Watertown in Codington County, South Dakota. Results of test hole drilling in the area indicate that an aquifer, located northeast of Lake Kampeska, hydraulically connects the Big Sioux River, Gravel Creek and the lake. Also, there is a direct connection between the Big Sioux River and the lake through the inlet-outlet channel.

Direct precipitation adds 20.52 inches of water annually to the surface of Lake Kampeska. Surface-water and ground-water recharge the lake when the lake has a lower water level than the river and the aquifer northeast of the lake.

Discharge from Lake Kampeska occurs in the form of evaporation, which removes 33 inches of water annually, and artificial discharge. The city of Watertown pumps approximately 3.2 inches of water from the lake annually for municipal purposes. In addition, ground water and surface water leave the lake through the inlet-outlet channel and the aquifer when the lake has a higher water level than the aquifer and the river.

During flooding a large quantity of water high in nutrients enters Lake Kampeska through the inlet-outlet channel. Sand and gravel deposits northeast of the lake and the low relief of this area prevent construction of an effective structure, on the inlet-outlet channel, to stop floodwater from reaching the lake. Even if such a structure could function, the flood damage in Watertown would increase substantially.

It is recommended that the floodwater be stored north of the study area to reduce the flood damage around the lake and in the city of Watertown. Water will gradually discharge from such a storage area, and there will be more water in the river and the aquifer northeast of the lake during summer and fall. This increase in water will induce recharge or at least decrease discharge from Lake Kampeska, as a result, lake-level fluctuation will be reduced. A storage area will also reduce the amount of silt carried into the lake.

It is recommended that soil conservation practices be employed north of the lake and around the lake to reduce the amount of nutrients entering Lake Kampeska. Construction of a sewage system is also imperative to eliminate the influx of nutrients from residences around the lake.

INTRODUCTION

Purpose and Scope

Study of the factors influencing the water level at Lake Kampeska was initiated in 1966. The objectives of the project were to identify the sources of water recharging and discharging the lake, determine their quality and quantity, study the uses of the water, and relate the above factors as to the possible cause of lake-level fluctuation. One final objective was to recommend any method by which a more stable lake level could be achieved.

Location and Extent of the Area

Lake Kampeska is located in Codington County in northeastern South Dakota. Included in the study area are approximately 80 square miles in the Coteau des Prairies division of the Central Lowlands physiographic province (fig. 1).

Previous Investigations

The first report discussing water supplies and geology of Lake Kampeska was prepared by the South Dakota Geological Survey (Rothrock, 1933). This report described the geology and origin of the lake. Flint (1955) made a reconnaissance study of the glacial geology of eastern South Dakota. Steece (1958a) mapped the geology of the Watertown quadrangle, and in another report concerning ground-water resources (1958b) included the Lake Kampeska area. Tipton (1958) mapped the geology of the Henry quadrangle which borders the study area. Rukstad and Hedges (1964) described the ground-water supply for the city of Watertown. A report entitled, "Report on Water Supply Facilities and Proposed Improvements for the City of Watertown," was prepared by J. T. Banner and Associates, Inc. (1965).

Methods and Procedures

During this investigation the surficial geology of the area was reviewed and the geologic map modified. Data obtained from all test holes drilled in the area since 1933 were analyzed, and additional test holes were drilled in areas having scattered or insufficient information. Seventeen observation wells were installed in the area to study the ground-water fluctuation. Data on recharge and discharge of water to the lake were analyzed, and 51 water samples were collected for chemical analyses.

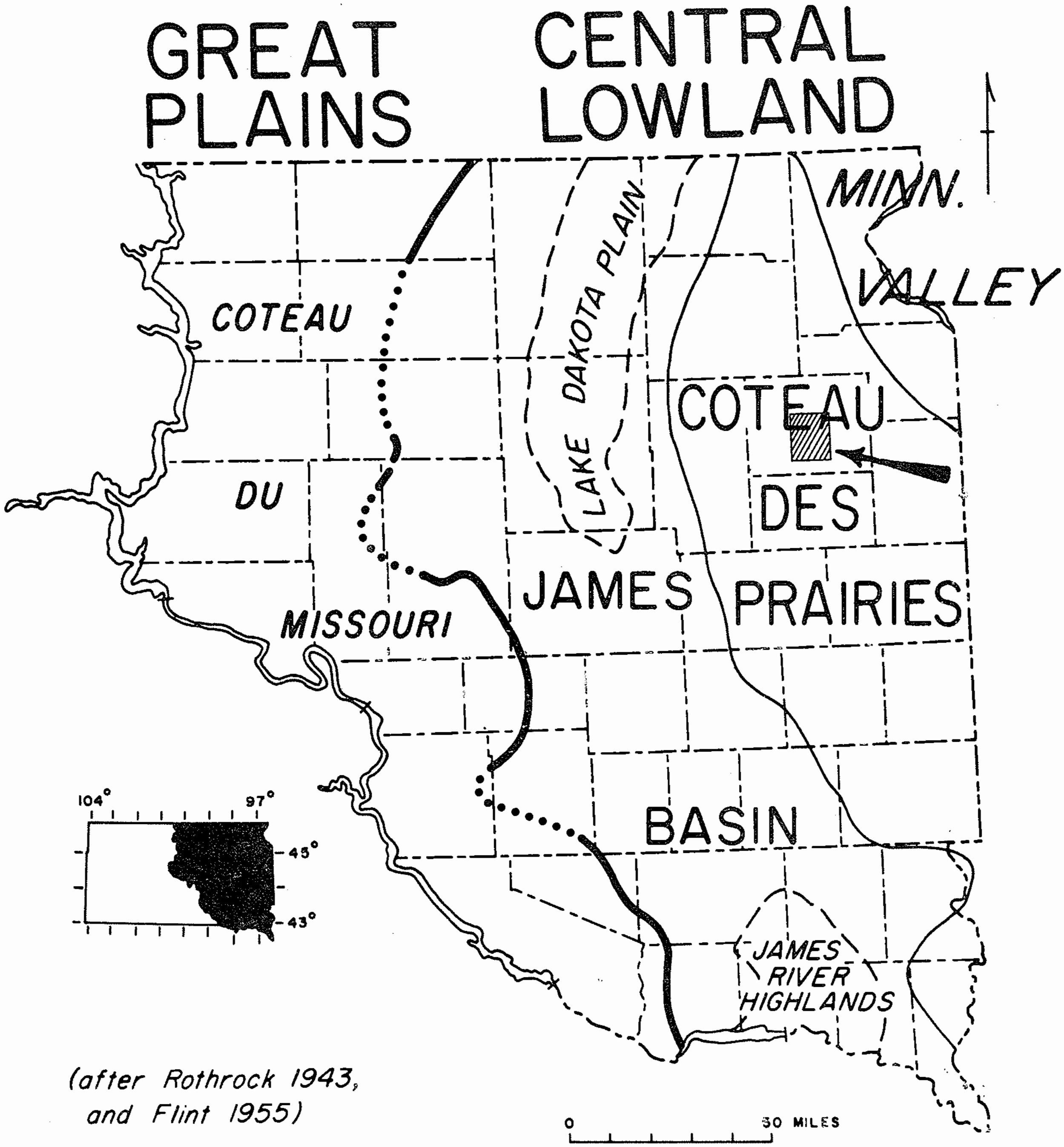
Acknowledgements

The project was financed by the South Dakota Department of Game, Fish and Parks (Dingell-Johnson Project F-19-R). The study was conducted under the direction of Duncan J. McGregor, State Geologist, with equipment provided by the South Dakota Geological Survey. Several water samples were analyzed by the Survey; the remainder of the samples were analyzed by the South Dakota Chemical Laboratory.

Assistance of the employees of the South Dakota Department of Game, Fish, and Parks in Pierre and Watertown, especially Robert Hanten and Harold Lundie, is appreciated. Also, the help of the East Dakota Conservancy Sub-District is acknowledged. Cooperation of the residents in the study area is appreciated, and special thanks are due to John Babcock, Watertown City Engineer, for his assistance.

Climate

The climate of the area is characterized by large fluctuations in temperature. Average daily temperature is 43.0 degrees Fahrenheit, and the average annual precipitation is 20.52 inches at the U. S. Weather Bureau Station at Watertown Airport, one-half mile east of Lake Kampeska.



Lake Kampeska area

Figure 1. Major physiographic divisions of eastern South Dakota and location of the Lake Kampeska study area.

Topography and Drainage

The topography of the Lake Kampeska area ranges from nearly flat, well drained, and gently undulating to rugged, poorly drained knob and kettle topography. Maximum relief in the study area is 150 feet with land elevations ranging from 1860 feet northwest of the study area to 1710 feet southeast of the study area (pl. 1).

The main stream in the area is the Big Sioux River which controls both surface and shallow ground-water movement. Gravel Creek (Mud Creek) and Willow Creek are tributaries to the Big Sioux River.

Origin and History of Lake Kampeska

Lake Kampeska is a natural lake of glacial origin. Its existence is due to the action of glacial ice which covered this section of the State in the geologic past. The lake is ellipsoidal in shape with an extension at the southwest end. It is about 2½ miles wide and 5 miles long covering approximately 4,800 acres (fig. 2).

Lake Kampeska has been used for commercial and recreational purposes since early settlement. "The marvelous purity of its water at once attracts the attention of the visitor. There are no marshes or muddy banks" (City of Watertown Directory, 1886-1887, p. 12). "In a commercial way Lake Kampeska is a valuable asset to Watertown. It furnishes the city with the purest of water, some of which is bottled and sold throughout the northwest. Over 30,000 tons of ice are cut from its surface each year" (Pictorial Review of Watertown, S. D., 1916).

In 1887 a pump house was built on the lake shore and a pipeline constructed to Watertown. Since then the city has obtained most of its water from the lake.

Since the late nineteenth century several structures have been constructed northeast of the lake. In 1888 a mill dam was erected on the Big Sioux River downstream from the lake's inlet-outlet channel (located northeast of the lake, see A in fig. 3). In 1928 several structures were built in location B (fig. 3). These structures consisted of a concrete weir equipped with a swinging grill, a dike, and a dam. The purpose of these structures was to increase the water flow into the lake, decrease the discharge from the lake, and prevent the fish from leaving the lake. An ice jam considerably damaged the structures the following spring. Efforts to repair the construction failed and the system was abandoned. Figure 4 shows remains of the concrete weir.

In 1932 a rock dam was constructed on the Big Sioux River downstream from the lake on or near to the old mill dam (see A, fig. 3). In 1933 a diversion ditch (see E, fig. 3) was dug to connect Gravel Creek to the Big Sioux River. A dam was also constructed on the old Gravel Creek channel to block the water from flowing in old Gravel Creek channel. The purpose of this project was to increase the recharge into the lake.

A sheet piling dam was constructed across the Big Sioux River in 1941 (see C, fig. 3, and fig. 5). The purpose of this dam was to raise the water level in the lake; however, late one night the top of the dam was mysteriously cut to lower the lake level.

The flood of 1969 raised the lake level and flooded several cottages around Lake Kampeska. Consequently, the dam on the old Gravel Creek channel was blasted out to divert water from the lake and lower the lake level. Later a dam was placed in the diversion ditch (see G, fig. 3) to stop the discharge of lake water through this channel, and thereby stop the lake-level decline.

GENERAL GEOLOGY

Surficial Deposits

Surficial deposits in the Lake Kampeska study area can be divided into two main groups—(1) glacial deposits and (2) stream deposits.

Glacial Deposits

During the Pleistocene Epoch of geologic time, ice moved into the Lake Kampeska area

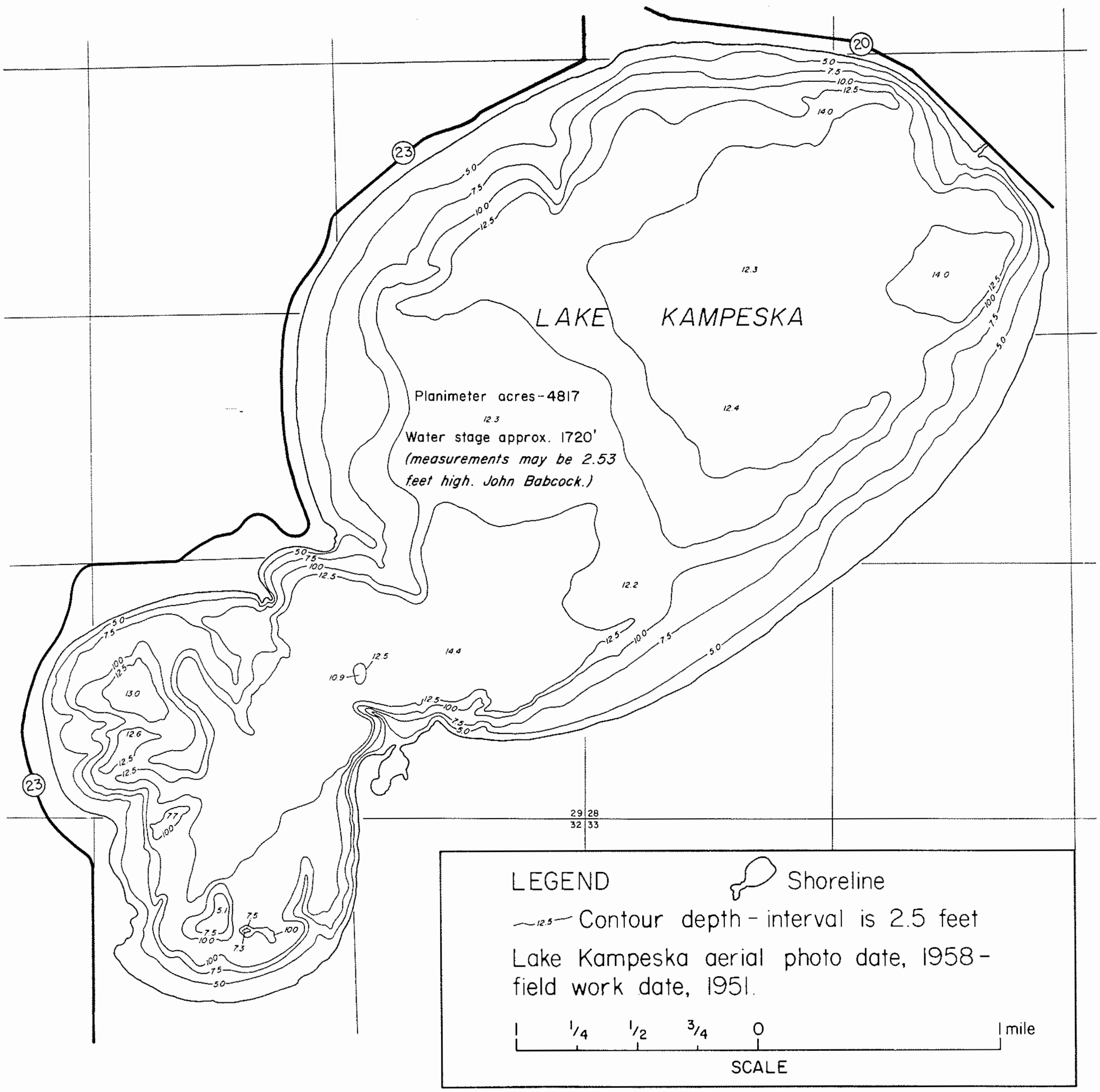


Figure 2. Depth contour map of Lake Kampeska.
(from S.D. Dept. of Game, Fish, and Parks)

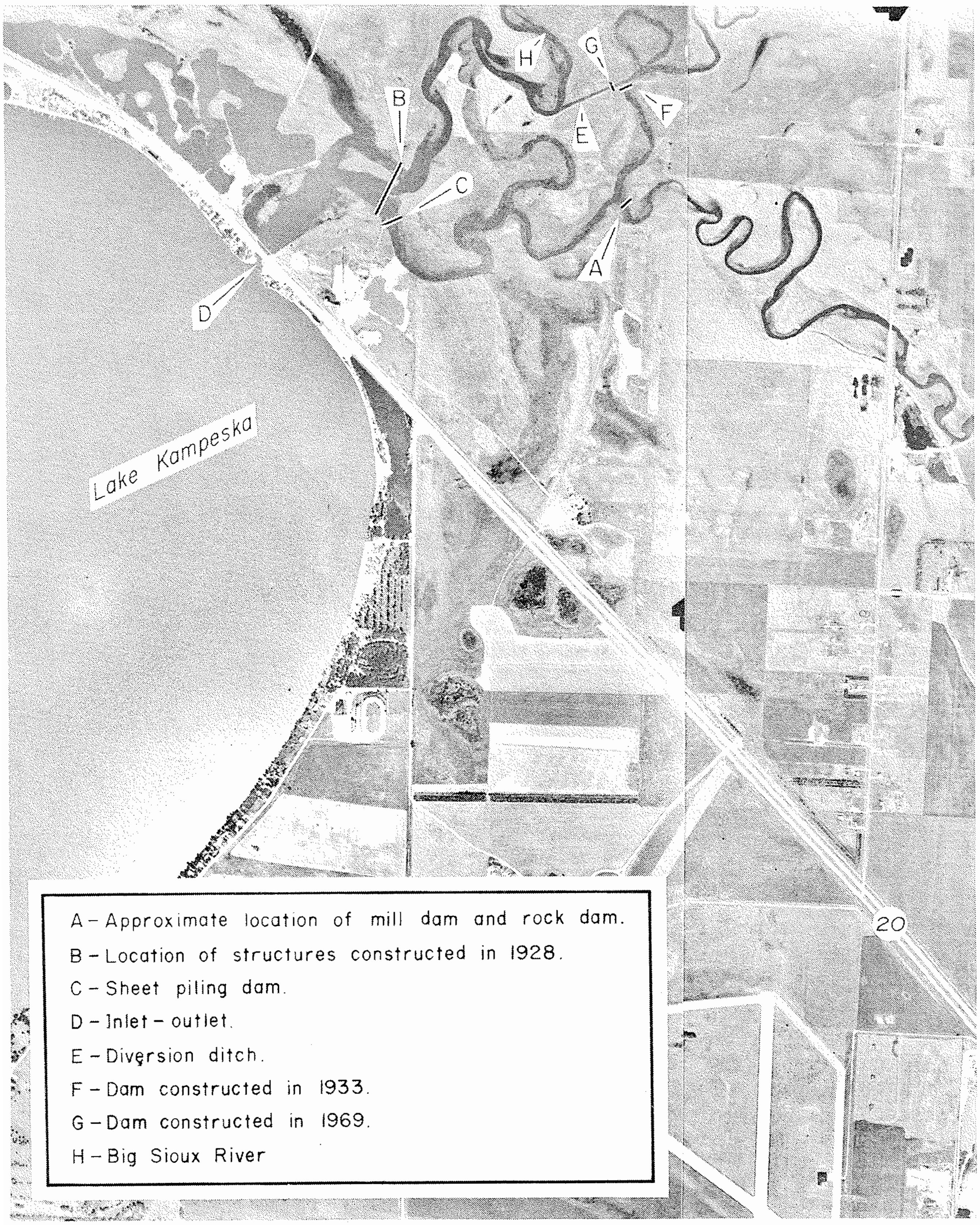


Figure 3. Vertical aerial photo northeast of Lake Kampeska showing the locations of structures. *(Photo courtesy of Soil Conservation Service – Photo date 7-14-65)*

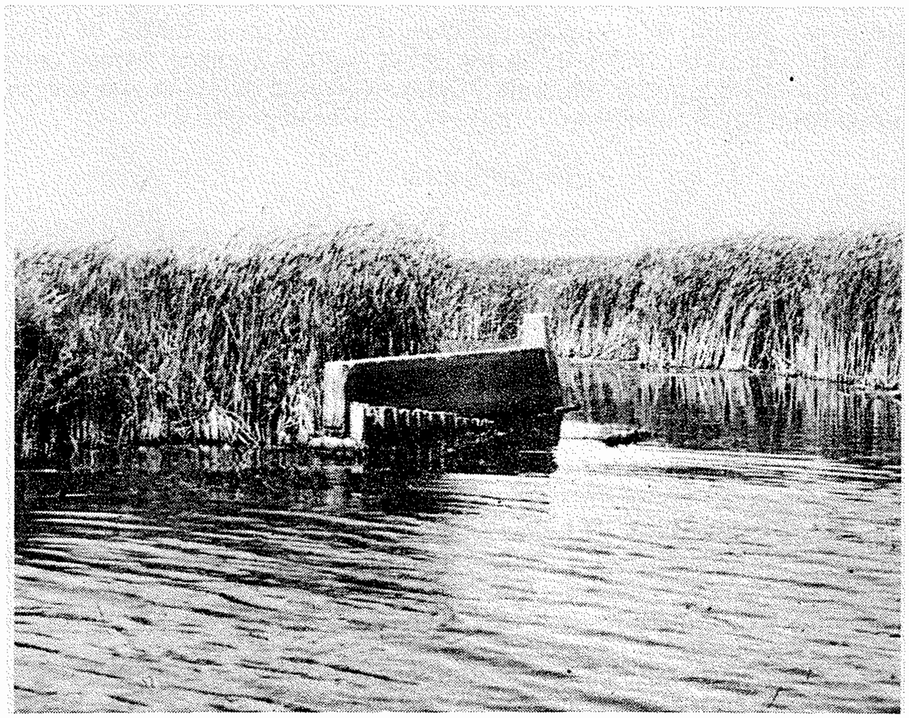


Figure 4. Photograph showing the remains of a concrete weir constructed in 1928.

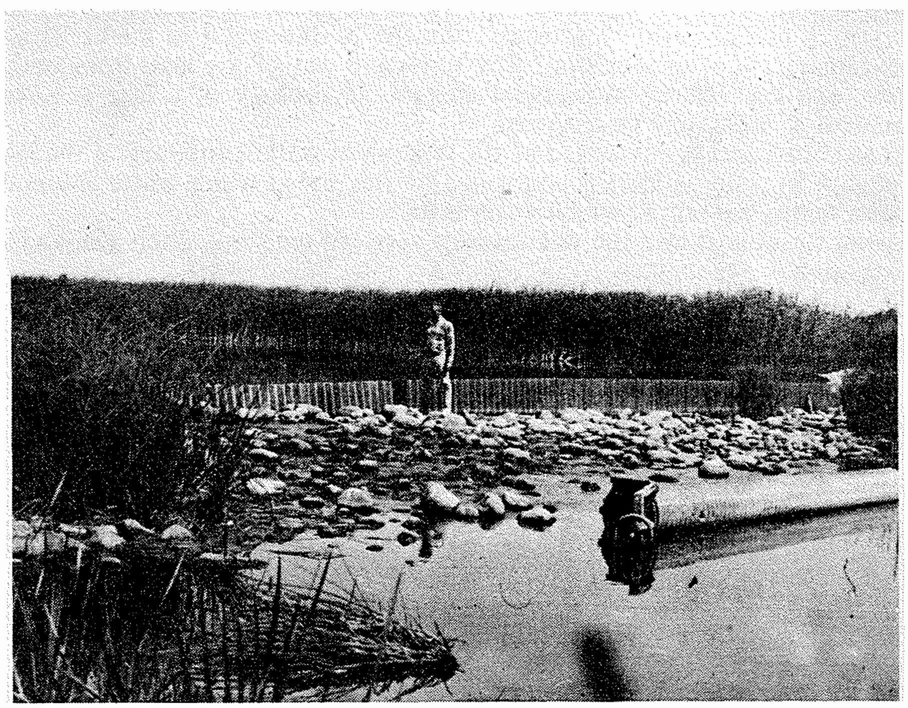


Figure 5. Photograph showing the remains of a dam constructed in 1941.

and deposited glacial drift. Drift can be divided into till and outwash deposits. Till consists of a heterogeneous mixture of boulders, pebbles, and sand in a matrix of clay directly deposited by the ice. Outwash material, on the other hand, is a sorted deposit consisting of mostly sand and gravel with minor amounts of clay deposited by meltwater streams issuing from the ice. Figures 6 and 7 show the distribution of these deposits.

Stream Deposits

The Big Sioux River and some of its tributaries have deposited alluvium in their channels (fig. 6). Alluvium in the study area consists of sand, gravel, and clay.

Subsurface Bedrock

No bedrock is exposed in the Lake Kampeska study area. Data obtained from well logs in this area reveal that Cretaceous sedimentary rocks underlie the glacial drift. These deposits in descending order are the Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation.

Pierre Shale underlies approximately 500 feet of glacial drift, and consists of approximately 240 feet of light- to dark-gray shale.

Niobrara Marl consists of light- to medium-gray chalk with shaly layers and numerous microscopic white specks. These deposits have an average thickness of 90 feet.

Carlile Shale is chiefly light-gray to black shale with thin silt and sand layers, and is approximately 200 feet thick.

Greenhorn Limestone is composed of about 30 feet of hard, gray limestone.

Graneros Shale is siliceous and has an average thickness of approximately 150 feet.

A sequence of alternating sand, sandstone, and shale beds approximately 80 feet thick makes up the Dakota Formation. Beneath the Dakota Formation are rocks of Precambrian age, usually quartzite and granite.

HYDROLOGY OF LAKE KAMPESKA

Hydrology of a lake may be defined as the study of factors controlling the quality and processes governing the depletion and replenishment of the water in a lake. It takes into consideration precipitation, evaporation, flow into and out of the lake from both surface and subsurface, and the effects of artificial control. Hydrology of a lake is a science by which the behavior of lakes may be analyzed.

The water level of a lake is a function of the volume of water contained in the lake basin. The rate of change of water volume is controlled by the rate at which water enters the basin from all sources, minus the rate at which water is lost.

The following formula shows the relationship between recharge, discharge, and resulting lake-level fluctuation:

$$\Delta h\,(A + \Delta A) = \Delta V = \text{Recharge - Discharge}$$

where

Δh is the change of water level in the lake,
A is the surface area of the lake,
ΔA is the change of the surface area of the lake due to fluctuation of the lake level, and
ΔV is the change in volume of water in the lake.

The following is the analysis of these factors with presently available data.

Recharge

Recharge to the lake includes water from all sources, and may be divided into three major categories: (1) direct precipitation, (2) ground-water recharge, and (3) surface-water recharge.

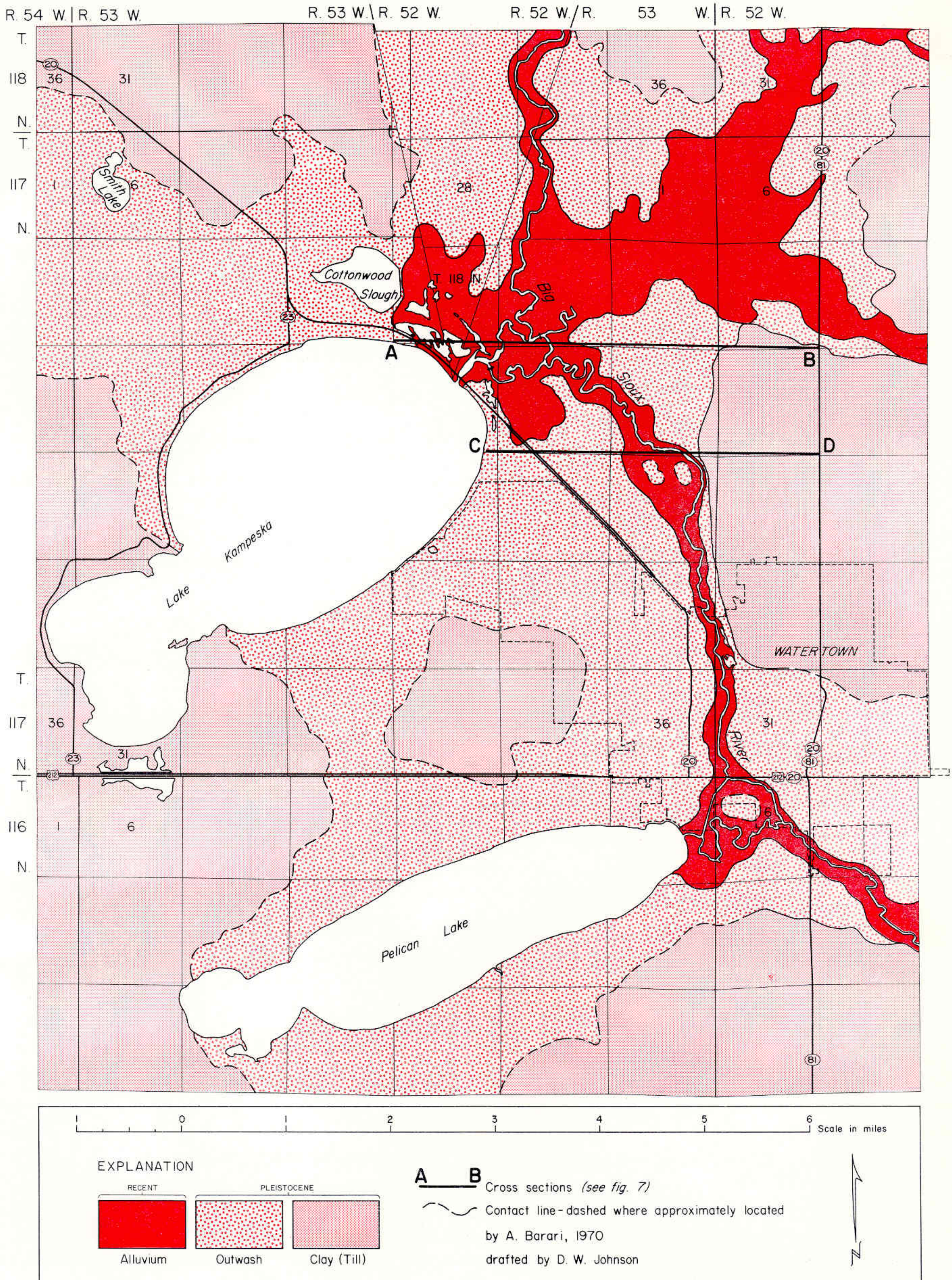


Figure 6. Generalized geologic map of the Lake Kampeska study area, *(modified from F. V. Steece, 1958 a - and M. J. Tipton, 1958).*

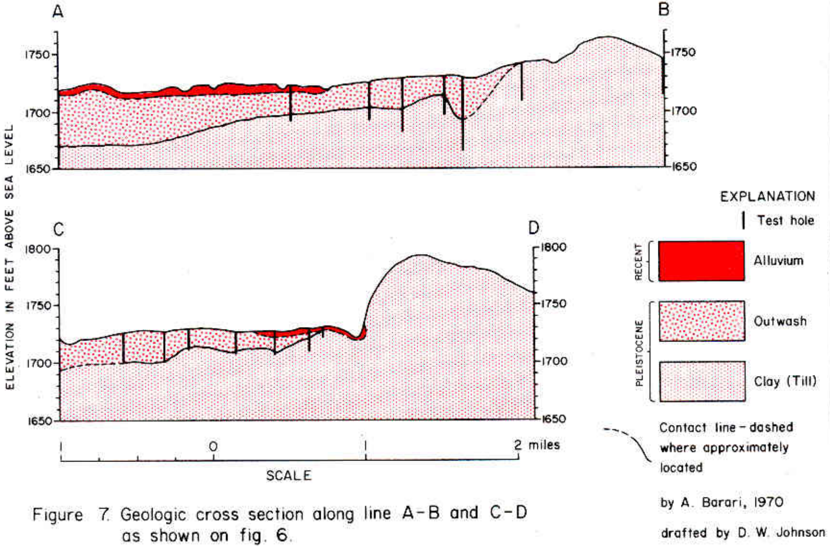


Figure 7. Geologic cross section along line A-B and C-D as shown on fig. 6.

Direct Precipitation

The term precipitation, as used in hydrology, is a general term for all forms of water derived from atmospheric vapor deposited on the lake surface.

Precipitation received in this area is measured at the U. S. Weather Bureau Station at the Watertown Airport, one-half mile east of the lake. The records show that the average annual precipitation at this station is 20.52 inches.

Appendix A is a table of monthly and annual precipitation for the Lake Kampeska area from 1898 through 1970. Figure 8 is a graph showing monthly precipitation from 1889 to 1945, and figure 9 shows the monthly precipitation and lake-level hydrograph at Lake Kampeska from 1945 through 1970.

Ground-Water Recharge

Occurrence of Ground Water

Ground water is defined as water contained in the voids or openings of rocks or sediments below the water table. The water table is the upper surface of the zone of saturation which is under atmospheric pressure. Practically all the pores of permeable rocks that lie below the water table are filled with water. Rocks (including the soil) that lie above the water table are in the zone of aeration. Some of the interstices in this zone are also filled with water, but the water is either held by molecular attraction or is moving downward toward the zone of saturation. Water in the ground moves downward through the unsaturated zone under the influence of gravity, whereas in the saturated zone it moves in a direction determined by the hydraulic gradient.

Nearly all ground water is derived from precipitation in the form of rain, melting snow, or ice. Water from these sources either evaporates, percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the lakes or ocean by streams, or percolates downward into the rocks.

Recharge is the addition of water to an aquifer (a formation having structures that permit appreciable amounts of water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral flow of ground water into the area, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge of ground water from an aquifer is accomplished in four main ways: (1) by evaporation from free-water surfaces and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water out of the area, and (4) by pumping from wells, which constitutes the major artificial discharge of ground water.

Definitions

The porosity of a rock or soil is a measure of the contained open spaces and is expressed as the percentage of these open spaces to the total volume of the rock.

$$\alpha = \frac{100W}{V}$$

where

α is the porosity,
W is the volume of water required to fill all of the pore space, and
V is the total volume of the rock or deposit.

The porosity of a sedimentary deposit depends mainly on (1) the shape and arrangement

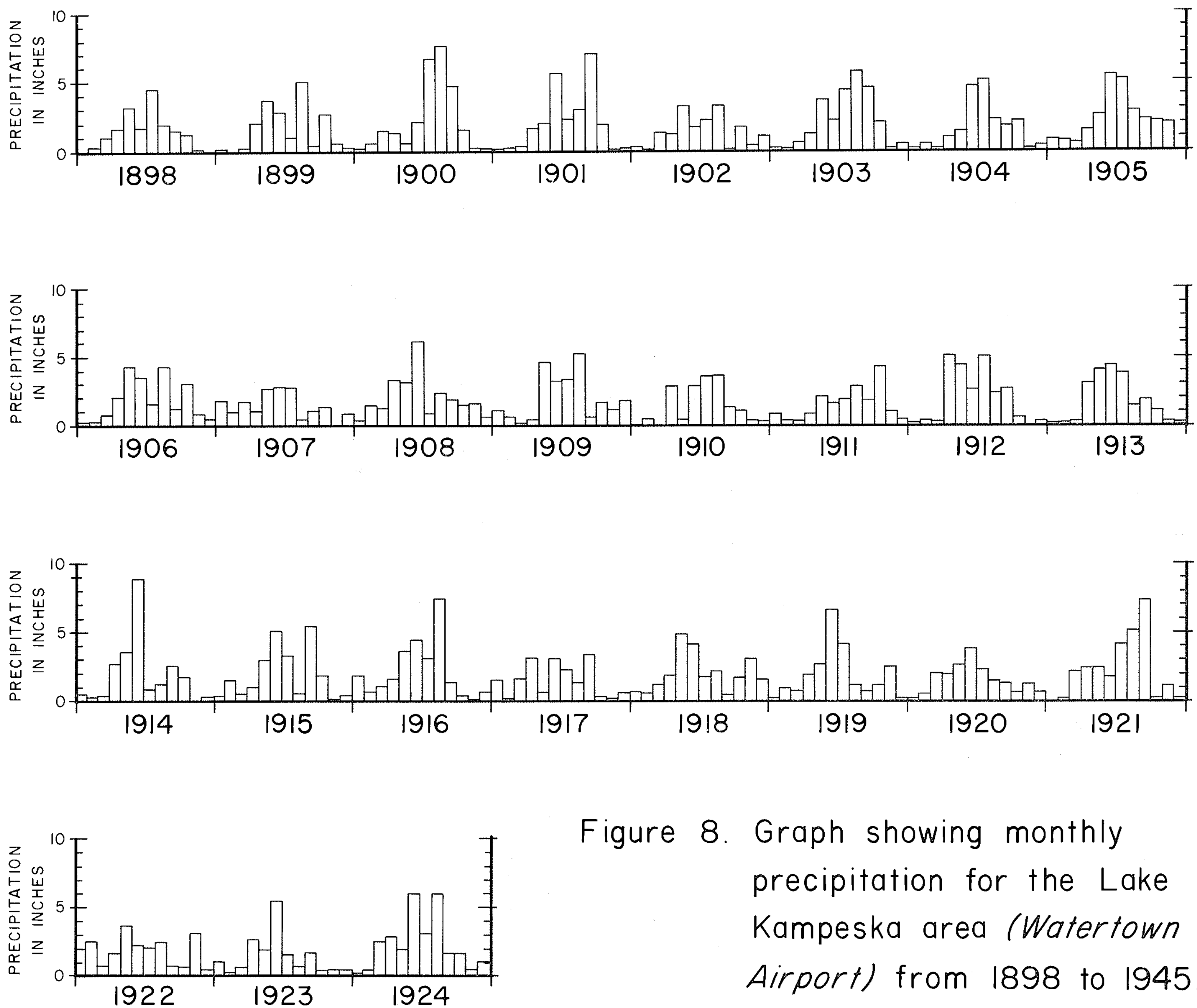


Figure 8. Graph showing monthly precipitation for the Lake Kampeska area *(Watertown Airport)* from 1898 to 1945.

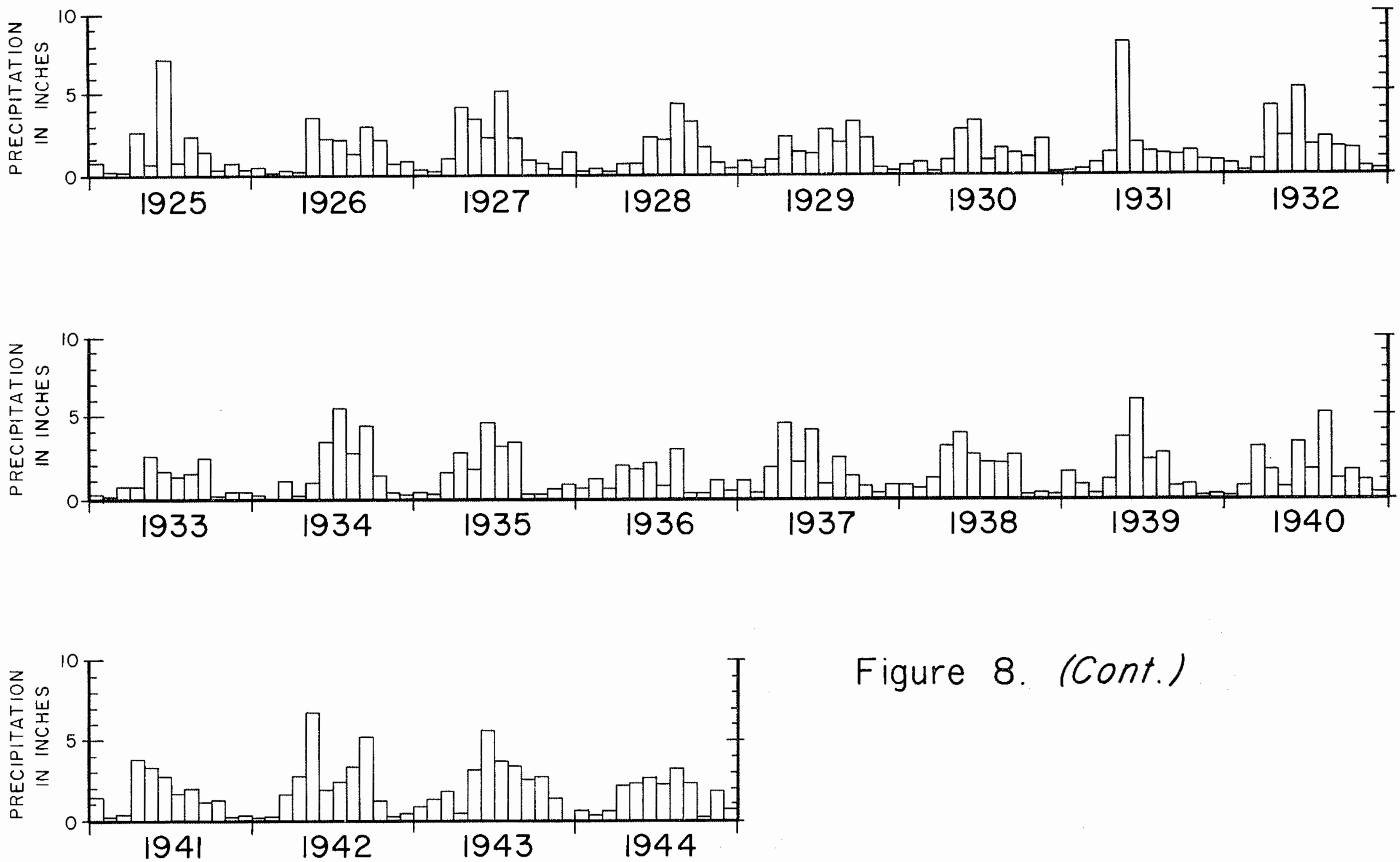


Figure 8. *(Cont.)*

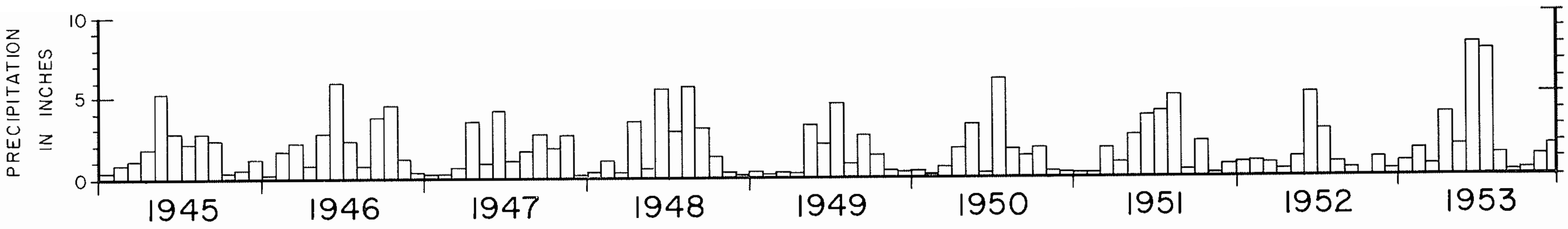


Figure 9. Graph showing monthly precipitation and lake-level hydrograph* for Lake Kampeska from 1945 through 1970.

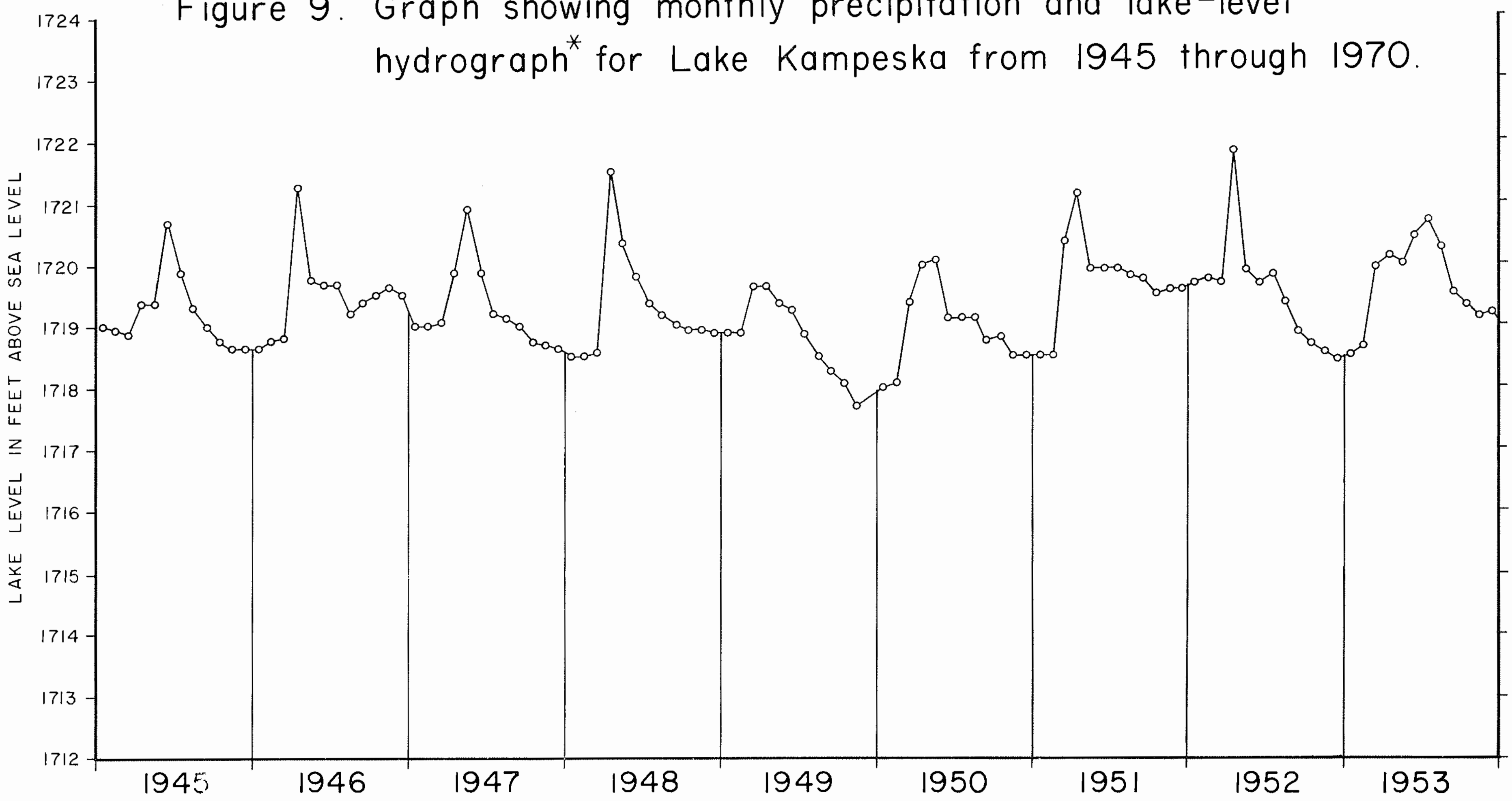
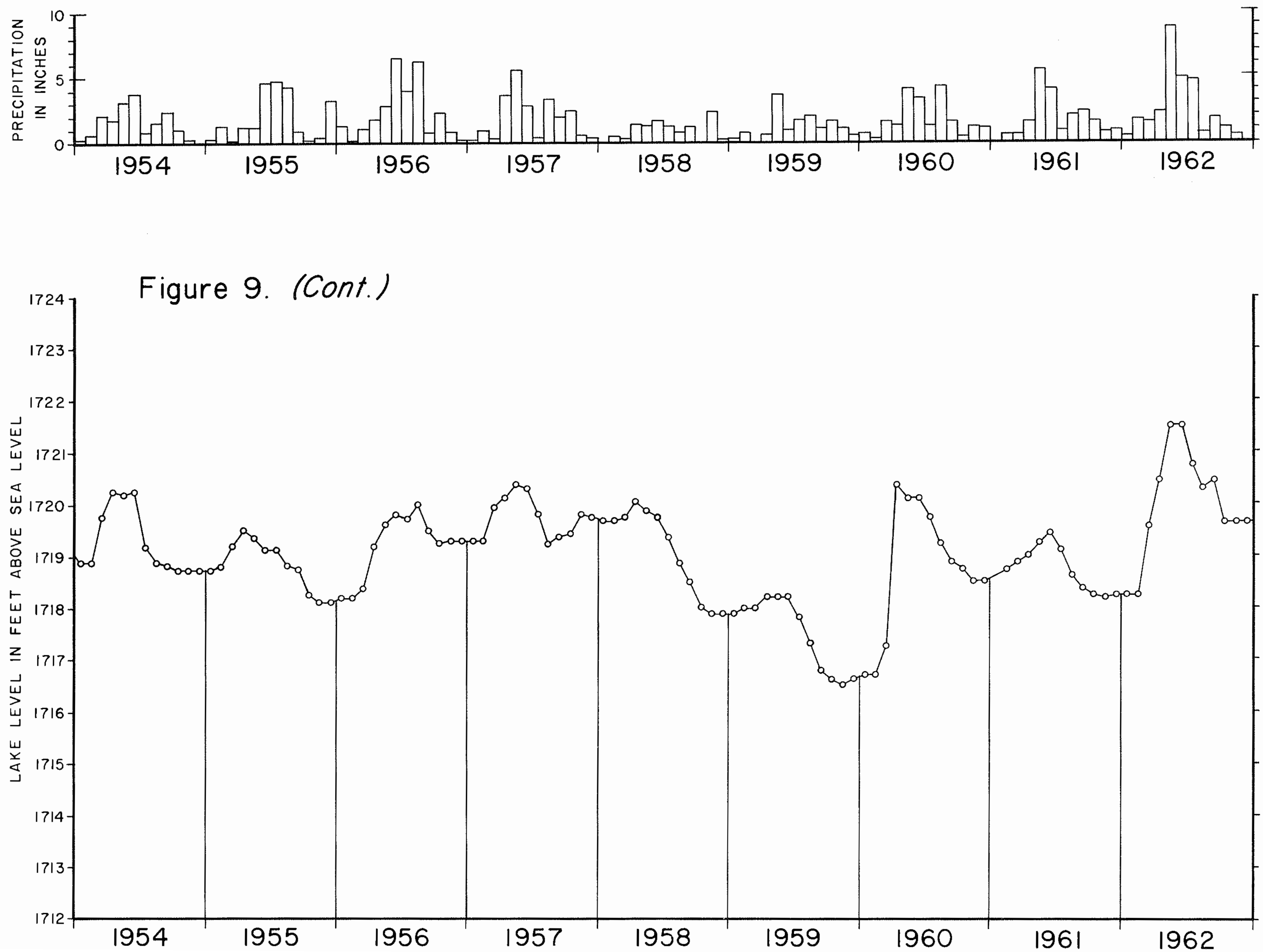


Figure 9. *(Cont.)*



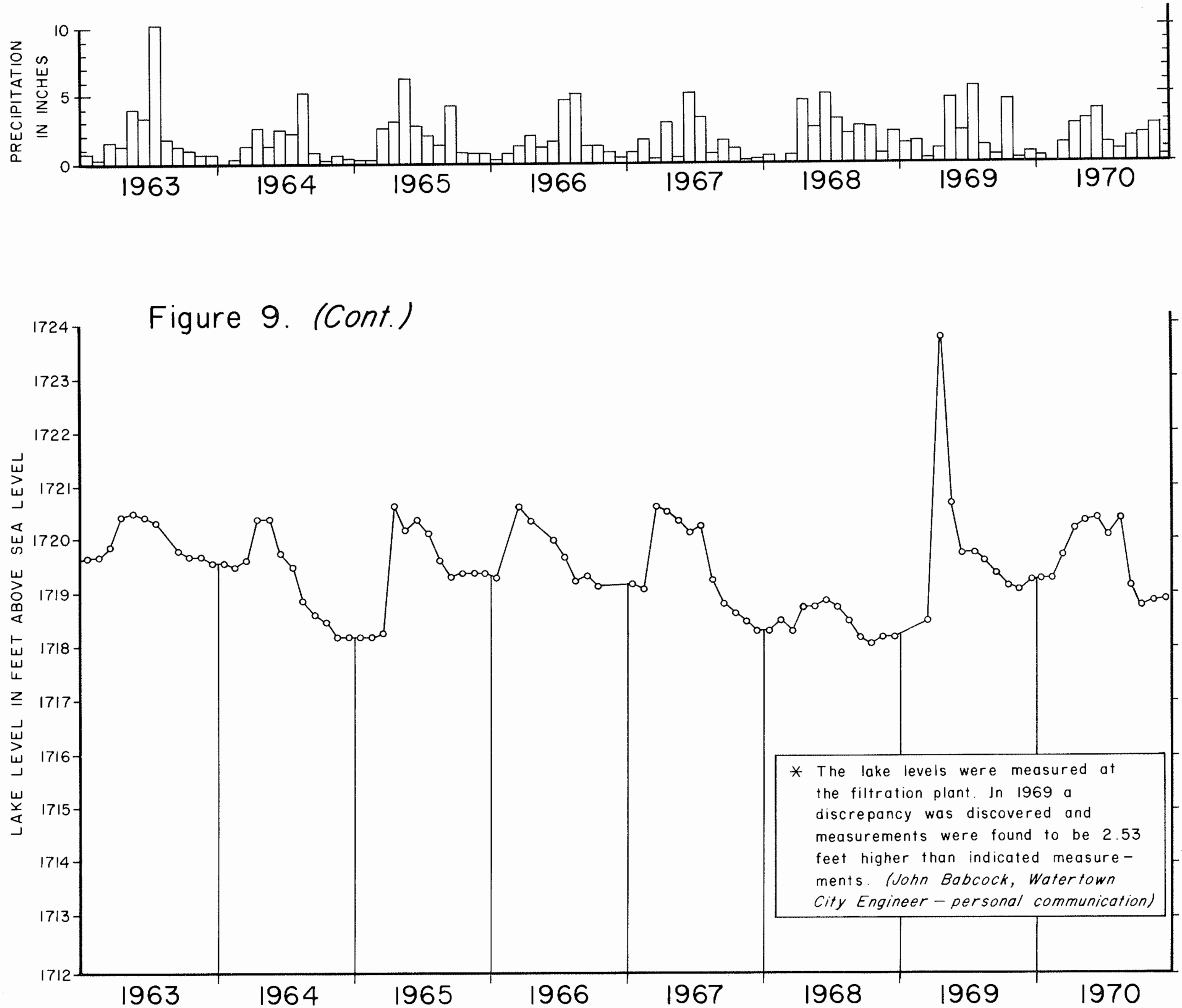


Figure 9. *(Cont.)*

of its constituent particles, (2) the degree of sorting of its particles, (3) the cementation and compaction to which the sediments have been subjected since deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Thus, the size of the material has little or no effect on porosity providing all other factors are equal. Porosities of rocks range from near zero to more than fifty percent, depending upon the above factors.

Permeability or hydraulic conductivity of a rock is its capacity for transmitting a fluid. The coefficient of permeability (K) is defined as the rate of flow of water in gallons per day through a cross-sectional area of one square foot under a unit hydraulic gradient. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores, even if the latter material has a high porosity. Therefore, permeability and porosity are not synonymous terms.

Coefficient of transmissibility (T) is expressed as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide extending the full saturated thickness of an aquifer under a hydraulic gradient of 100 percent. The relation between the coefficient of permeability and transmissibility is shown by the following equation:

$$T=Km$$

where

T is the coefficient of transmissibility,
K is the coefficient of permeability, or hydraulic conductivity, and
m is the thickness of the saturated deposits.

The coefficient of storage (S) of an aquifer is the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Specific yield is the ratio of the volume of water that a rock or soil will yield by gravity to the total volume of rock.

$$Sy = \frac{100\ Wy}{V}$$

where

Sy is the specific yield,
Wy is the volume of water yielded, and
V is the total volume of the rock or soil.

Coefficient of storage of a water-table aquifer is essentially equal to the specific yield; however, for an artesian aquifer the coefficient of storage is generally much smaller than the specific yield.

All of the water contained in the ground can not be removed by pumping from a well or under the influence of gravity; thus, retained water is held against gravity by surface tension and other means. The specific retention of a rock or soil is expressed as the percentage of the volume of water an aquifer holds against the force of gravity to the total volume of the deposits.

$$Sr = \frac{100\ Wr}{V}$$

where

Sr is the specific retention,
Wr is the volume of water retained, and
V is the total volume of the deposits.

Extent of the Shallow Aquifer

Logs of test holes drilled in the area since 1933 were used to define the extent of the shallow aquifer in the study area. During the study additional test holes were drilled in the areas of limited information. Figure 10 shows the location of test holes in the study area. Because of discrepancies in the data some of the old test holes were not plotted on this map. To facilitate finding the location of test holes a new number starting from the top of the map is assigned to each test hole or observation well. Appendix B, in addition to giving the logs of all test holes and observation wells, shows the new and old numbers.

Results from test holes in the area indicate that an extensive sand and gravel deposit northeast of the lake hydraulically connects the Big Sioux River and Gravel Creek to Lake Kampeska. Figure 11 shows the thickness of saturated sand and gravel in the study area.

Aquifer Tests

Three aquifer tests were conducted in the area by the South Dakota Geological Survey and United States Geological Survey during a study by J. T. Banner in 1964-65. The test conducted northeast of Lake Kampeska in sec. 14, T. 117 N., R. 53 W. (see fig. 10) is discussed below. The test was started on April 20, 1965, and continued for 72 hours at an average rate of 260 gallons per minute. Results of the test were calculated by personnel from the U. S. Geological Survey (written communication, May 28, 1965), and indicate the average transmissibility under field conditions to be $T = 5.0 \times 10^4$ gal/day/ft, with an average thickness of saturated sand of approximately 23 feet. The permeability was $K = 2.2 \times 10^3$ gal/day/ft^2.

Quantity of Ground-Water Recharge

Figure 12 is a water-table map of the study area for July 30, 1970 (see app. C for water-level measurements). This figure shows that ground water was moving toward the northeast of Lake Kampeska in two main gravel deposits along the Big Sioux River and Gravel Creek. Rates of these flows can be calculated by applying the following equation:

$$Q = KA\frac{dh}{dl} \qquad [1]$$

where

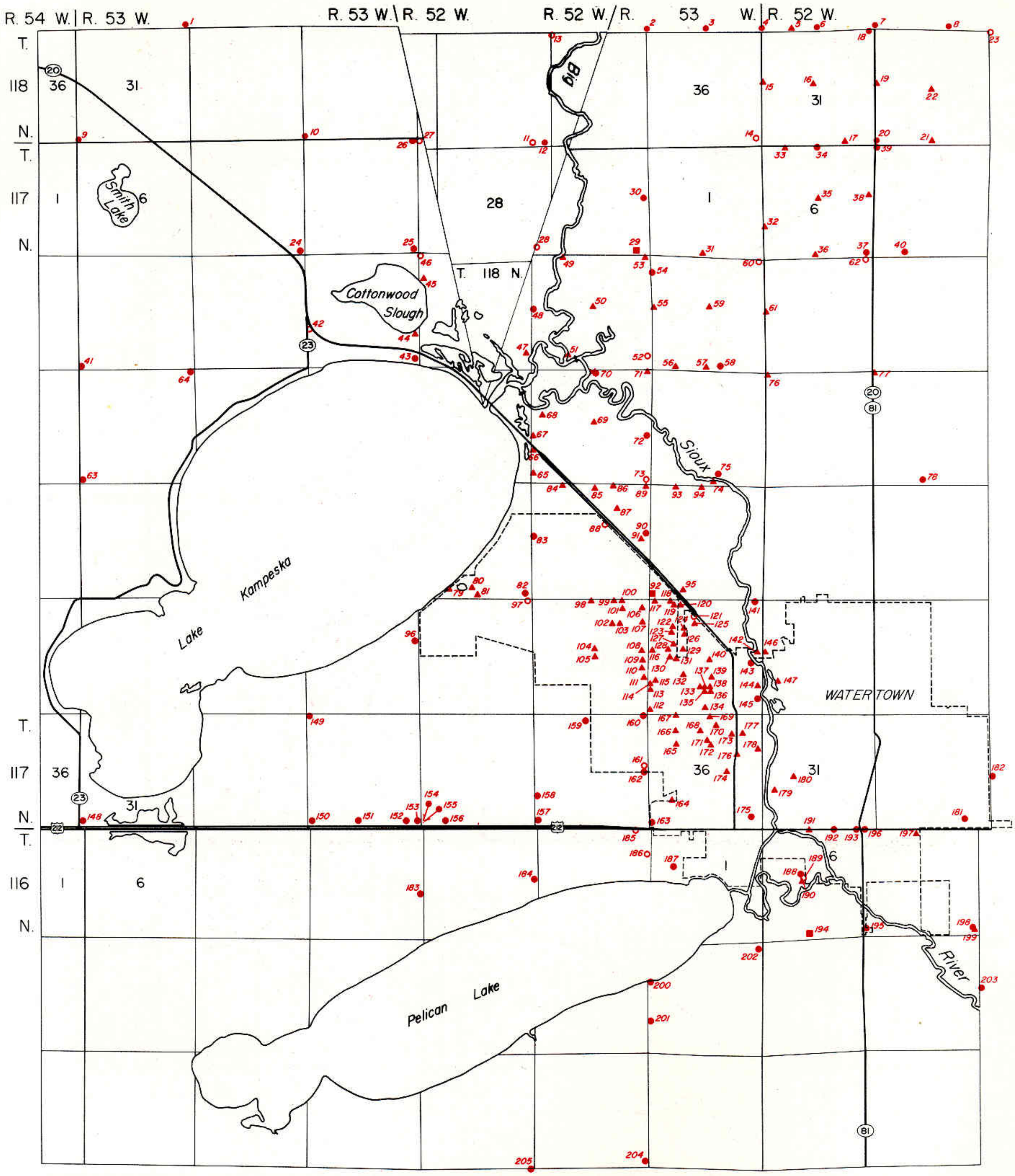
Q is the discharge per unit time (in gallons per day)
K is the coefficient of permeability or hydraulic conductivity of the aquifer in gallons per day per square foot.
A is the cross-sectional area of the aquifer,
$\frac{dh}{dl}$ is the hydraulic gradient (dh is the change of hydraulic head-dl is the change of horizontal distance).

Ground water flow from a cross section of the aquifer along the Big Sioux River, 2 miles north of the inlet-outlet was calculated by applying equation [1] and using the sand and gravel thickness along with the water-table map. The results indicate that 3.3×10^5 gal/day of water was flowing along the Big Sioux River 2 miles north of the inlet-outlet.

Ground-water flow in the aquifer along Gravel Creek was calculated 2 miles northeast of the inlet-outlet and was 4.0×10^5 gal/day.

The above flow rates do not include the water flow in the Big Sioux River and Gravel Creek.

Because of an extensive connection between the surface and ground water northeast of the lake and the lack of a stream gage upstream from the lake, the quantity of ground-water and surface-water recharge could not be differentiated with present data.



Scale in miles

EXPLANATION

73○ Observation well – S. D. Geological Survey

104▲ Test hole – City of Watertown

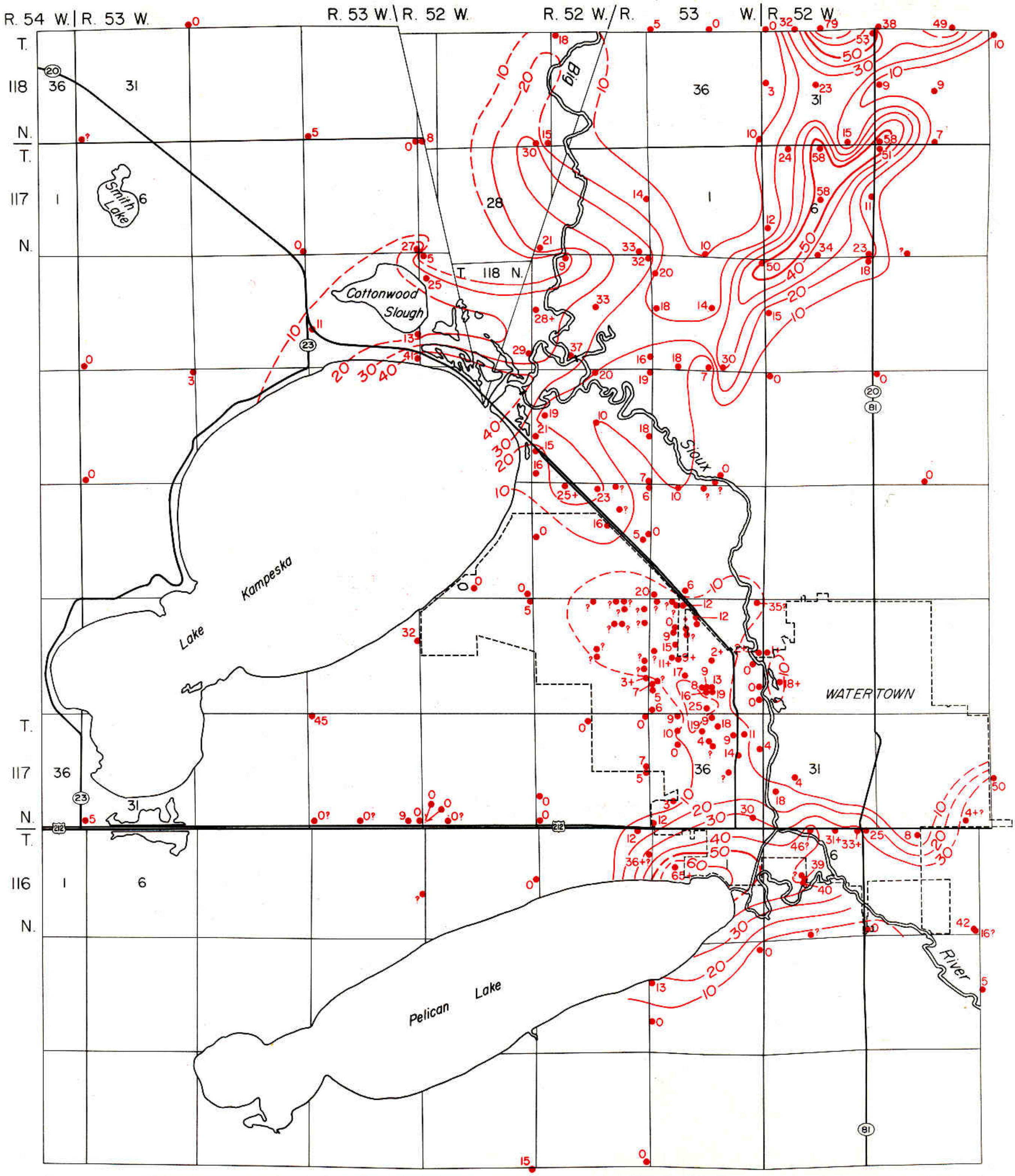
181● Test hole – S. D. Geological Survey

29■ Observation well – Water Resource Commission

× Pump test location

by A. Barari, 1970 drafted by D. W. Johnson

Figure 10. Map showing the location of test holes, observation wells, and pump test site in the Lake Kampeska study area.



Scale in miles: 1 0 1 2 3 4 5 6

EXPLANATION

Lines connect points of equal thickness of saturated sand and gravel *(dashed where approximately located, contour interval = 10 feet).*

Test hole, number indicates thickness of saturated sand; a "?" indicates that full thickness of saturated sand and gravel was not penetrated or water table was not measured.

by A. Barari, 1970

Figure 11. Map showing thickness of saturated sand and gravel in the Lake Kampeska study area.

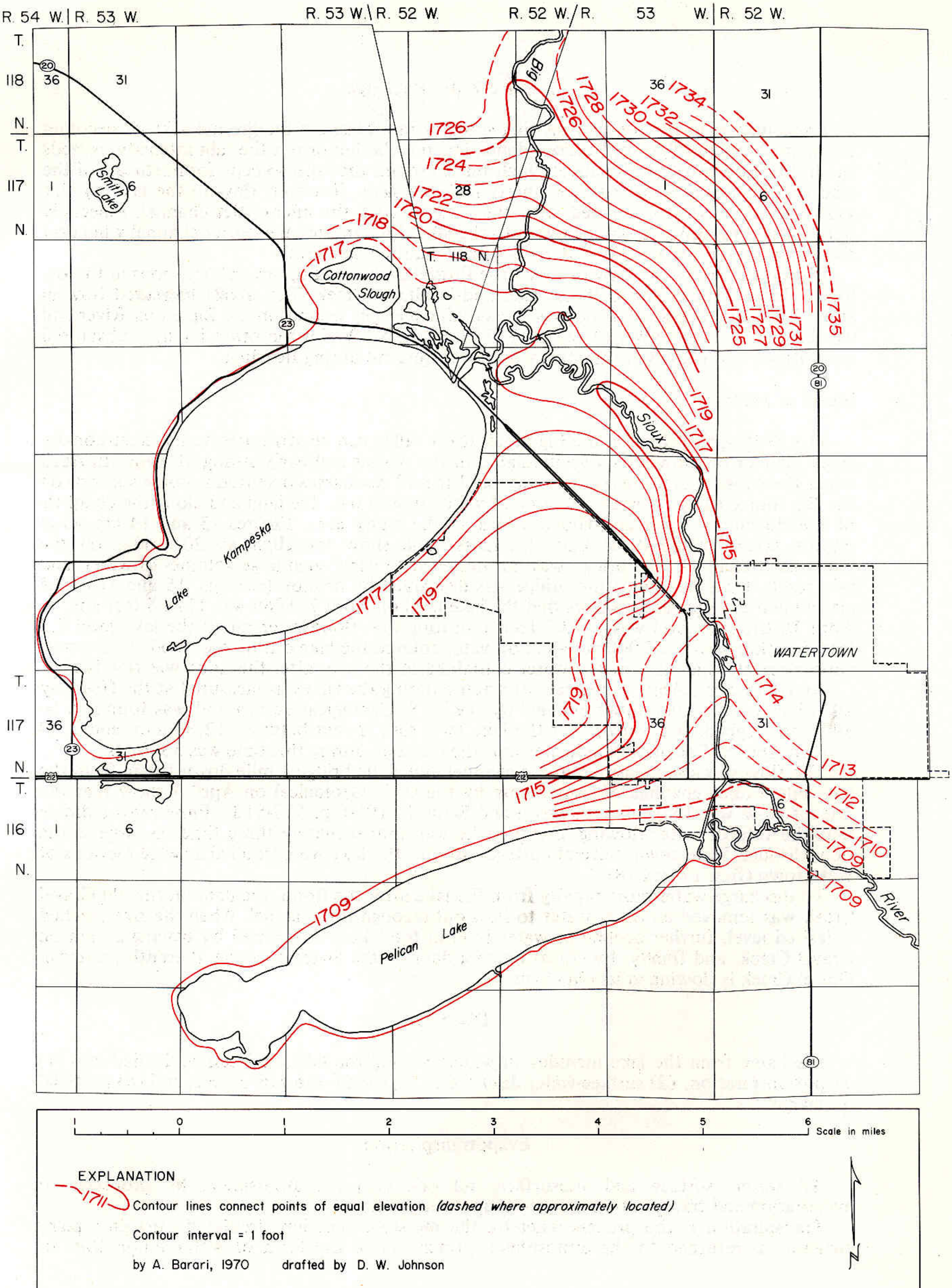


Figure 12. Water-table map of the Lake Kampeska study area for June 30, 1970.

Surface-Water Recharge

Precipitation in the form of melting snow or rain reaching the ground surface becomes either surface runoff or infiltration, depending on whether or not the rain intensity exceeds the infiltration capacity. Relatively high relief around the lake, except for northeast of the lake (pl. 1), causes some surface runoff into the lake. However, flow to the lake by this source is small when compared with the flow through the inlet-outlet channel, especially during flooding. Surface water flows into the lake through the inlet-outlet channel whenever the water level in the Big Sioux River is higher than the lake level.

During the study, no flow or very little flow was observed on several occasions in the Big Sioux River 2 miles north of the lake and in Gravel Creek. The largest measured flow in June, July and August of 1968 was 2 cfs (cubic feet per second) in the Big Sioux River and was measured in the NW¼ of sec. 2, T. 117 N., R. 53 W. On the other hand, a substantial quantity of water flows in this stream and over the land during flooding.

Flood of 1969

The 1969 spring flood in the Big Sioux River valley can be attributed to an exceptionally thick blanket of snow which accumulated in the winter and early spring of 1969. In April when the snow melted, maximum stage and record discharges occurred in some stations on the Big Sioux River. A large quantity of water flowed over the land and along the channels of the Big Sioux River and Gravel Creek in the study area. Figures 13 and 14 are aerial photos taken northeast of Lake Kampeska and show the Highway 20 Bridge on the inlet-outlet channel. The bridge was not designed to carry such large volumes of water, and as a result, the east side of the bridge was destroyed by erosion (see figs. 15 and 16). The attachment to appendix E shows that the lake level on April 7, 1969 was 1718.5 feet and on April 10 the lake level was 1723.7 feet indicating that floodwater raised the lake level 5.2 feet. In other words, 26,000 acre-feet of water entered the lake during the flood. As a result, approximately one-third of the water contained in the lake after the flood was floodwater.

At 10:15 a.m., April 9, the rate of water entering the lake was measured at the Highway 20 Bridge on the inlet-outlet channel by the U. S. Geological Survey and was found to be 3900 cfs. Appendix E shows that the lake level rose .2 feet between 12:30 a.m. and 2:30 a.m. on April 9. Calculation indicates that the recharge during this time was 5800 cfs.

The flow was also measured in the channel under the bridge 1 mile downstream from the lake inlet-outlet channel. Measurements by the U. S. Geological on April 9 show that the rate of flow was 1550 cfs (Anderson and Schwab, 1970, p. 517-518). Flow rates indicate that the rate of water flowing into the lake was approximately three times as large as the flow through Watertown. Several cottages around the lake were flooded as were sections of Watertown (figs. 17 and 18).

To discharge water more rapidly from the lake after the flood, the dam on the old Gravel Creek was removed allowing water to flow out through this channel. When the lake reached a desired level, further decline of water level in the lake was stopped by placing a dam on Gravel Creek, and finally, by constructing a dam on the diversion ditch. Presently, water in Gravel Creek is flowing in its old channel.

Discharge

Discharge from the lake includes all waters leaving the lake, and can be divided into (1) evapotranspiration, (2) surface-water discharge, (3) ground-water discharge, and (4) artificial discharge.

Evapotranspiration

All water, surface and subsurface, released into the atmosphere by processes of evaporation and transpiration is called evapotranspiration.

Transpiration is the process whereby the moisture that has circulated through a plant structure is returned to the atmosphere, principally in the form of water vapor. Rate of

Figure 13. Aerial photo taken northeast of Lake Kampeska during the flood of 1969.

Figure 14. Aerial photo of Lake Kampeska showing the floodwater during the flood of 1969.

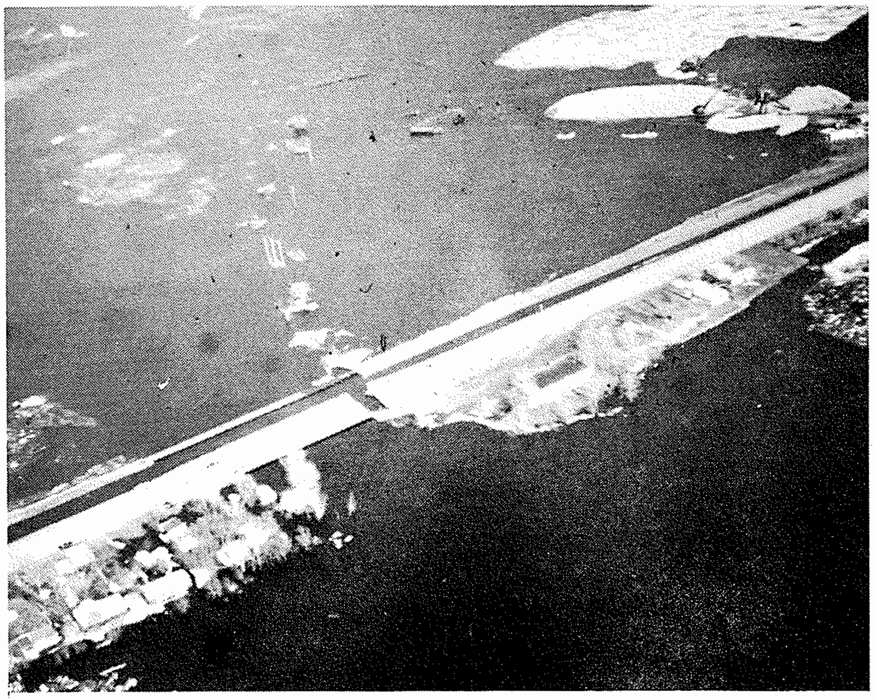


Figure 15. Aerial photo showing Highway 20 and erosion on the east side of the bridge (April 10, 1969).

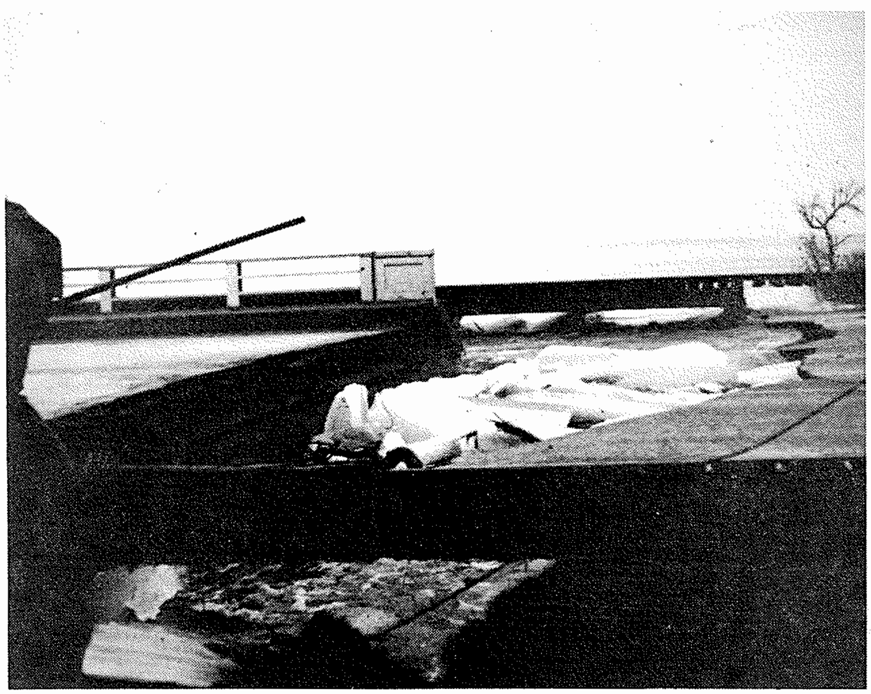


Figure 16. Photograph showing erosion on the east side of Highway 20 Bridge on the inlet-outlet channel (April 10, 1969).

Figure 17. Photograph showing flooded cottages around Lake Kampeska (April 10, 1969).

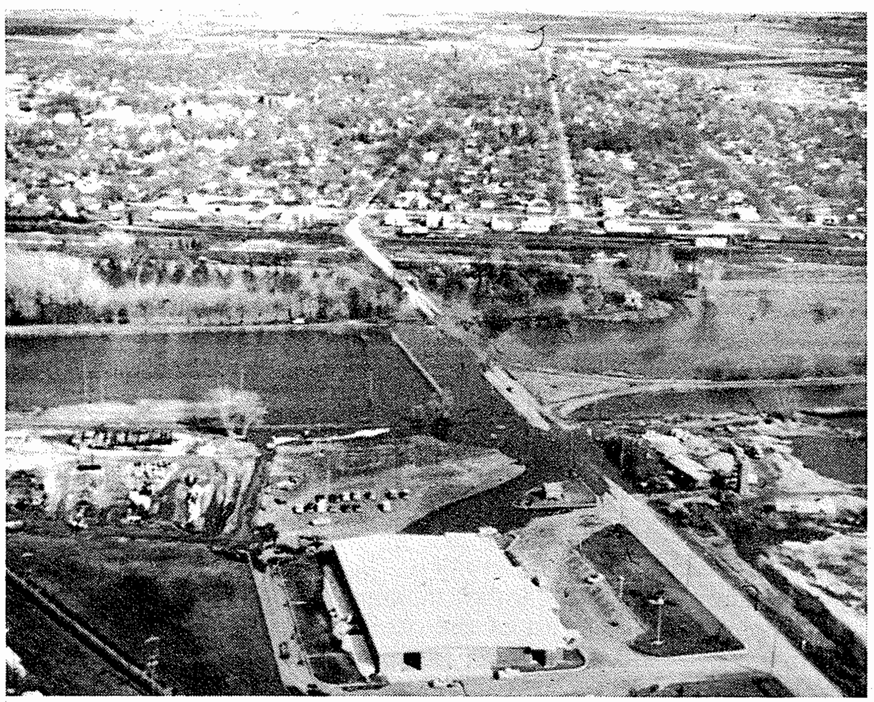


Figure 18. Aerial photo showing the floodwaters in Watertown, (April 10, 1969).

transpiration depends on climate and type of vegetation.

Evaporation is the process by which a liquid (water) is changed into vapor. The evaporation process occurs from the surface of land, lakes, ponds, and streams. Depth has a pronounced influence upon the rate of evaporation from any body of water. Likewise, water from a soil surface will evaporate initially at quite a high rate, but as soon as a thin layer of soil dries out the rate of evaporation is considerably reduced. Evaporation from the surface of a lake in this area is 33 inches per year (Kohler and others, 1959). At this rate Lake Kampeska loses 13,500 acre-feet of water per year.

Surface-Water Discharge

The only surface-water discharge from the lake is by the inlet-outlet channel through which water flows to the Big Sioux River when the lake elevation is higher than the water level in the river northeast of the lake.

Ground-Water Discharge

The main ground-water discharge takes place through the sand and gravel deposits northeast of the lake. Figure 12 is a water-table map of the Lake Kampeska study area for July 30, 1970. This map indicates that ground water was being discharged through the sand and gravel northeast of the lake. Because of the exchange between ground water and surface water in this location, the quantity of each flow could not be estimated accurately with the available data.

Artificial Discharge

Water is discharged directly from the lake by the city of Watertown. Seventy-two percent of the city's total water from 1944 through 1970 (app. F) was obtained from Lake Kampeska. During 1970 the city of Watertown removed 3.2 inches of water from the lake.

In addition, water is presently being pumped from the sand and gravel by domestic wells around the lake. However, the quantity of water pumped by domestic wells around the lake is small when compared with the water pumped from the lake by the city. Most of the water pumped for private use around the lake is directly or indirectly returned to the lake or to the aquifer around the lake.

Chemical Quality of Water

Ground water and surface water always contain dissolved chemical substances in various amounts. Contained chemicals are derived (1) from the atmosphere as water vapor condenses and falls, (2) from soil and underlying deposits as the water moves over the land and downward to the water table, and (3) from rocks below the water table where the water is moving. In general, the more chemical substances that a water contains, the poorer its quality, the suitability of water being determined by the purpose for which it is used. A certain quality of water may be suitable for one purpose and unsuitable for another.

Table 1 shows the quality of water samples collected from the Lake Kampeska area during the study, along with drinking water standard limits recommended by the U. S. Department of Public Health (sample W-Z). All W-B samples were collected from the inlet-outlet channel; all W-F samples and W-L samples were collected from the Big Sioux River north of the lake; all W-H samples and sample W-G were collected from Gravel Creek; and all W-K samples were collected from the lake at the filtration plant. For locations of these and other samples collected during the study see figure 19.

Except for high iron and manganese content in some of the samples and low fluoride in all samples (except sample W-B_3), the rest of the chemicals are within the limits set by the South Dakota Department of Health for drinking water standards.

Because this section of the report is concerned with the water quality of the lake, concentration of the chemicals in the following quotations from the Federal Water Pollution Control Administration (MacKenthun and Ingram, 1967) are used to compare the quality of

Table 1. Chemical analyses of water samples from the Lake Kampeska Area

(Concentrations are given in parts per million)

Sample	Date	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrogen	Soluble Phosphorus	Fluoride	Alkalinity Methyl-orange	Hardness as $CaCO_3$	Total Solids
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
W-A	7-1-67	92		22	0	183	0.06						320	486
W-B$_1$	7-1-67	40		36	Tr.	55	0.08						190	326
W-B$_2$	10-28-67	44	10	27	0.6	61	0.4	0.3	0.84		0.6	183	222	286
W-B$_3$	9-15-68	28	13	42	0	92	0.2	0.4	0.1		1.2	196	242	384
W-B$_4$	10-13-68	49	13	38	6	104	0	0	1.2		0.4	187	280	464
W-B$_5$	11-10-68	43	12	42	2	104	0.1	0	<0.1		0.4	200	278	364
W-B$_6$	4-8-69	13	Tr.	10	0	18	1.4	0.4	1.5			61	72	98
W-C	7-1-67	87		16	0	Tr.	0.07						280	397
W-D	7-1-67	61		18	0	0	Tr.						225	409
W-E	7-1-67	106		33	20	60	0.08						400	573
W-F$_1$	10-28-67	63	13	34	2	91	0	0.2	0.33		0.8	220	296	370
W-F$_2$	3-26-68	47	11	24	3	72	0.8	0.2	0.3		0.4	156	215	250
W-F$_3$	4-27-68	72	18	35	0.2	110	0	0	0.3		0	240	326	436
W-F$_4$	9-15-68	36	13	40	3	66	0.2	0	0.2		0.6	194	253	366
W-F$_5$	10-13-68	57	16	39	5	116	0	0	0.6		0.2	210	302	488
W-F$_6$	11-10-68	44	17	48	3	92	1.1	0	<0.1		0.4	240	306	404
W-F$_7$	5-3-69	46	11	44	0	56	0.04	0	<0.1		0.4	249	296	350
W-F$_8$	10-3-69	46	14	43	4	98	1.0	0	<0.1		0.2	203	290	348
W-F$_9$	10-19-69	45	16	44	6	104	0.3		0.6		0.2	196	293	348
W-F$_{10}$	11-23-69	63	17	50	6	98	0.3	0	0.5		0.4	277	364	499
W-F$_{11}$	3-7-70	21	2	13		22	1.1				0.2	93	105	138
W-F$_{12}$	4-4-70	37	5	26	2	30	0.7		0.4		0.2	164	199	254
W-F$_{13}$	4-24-70	41	10	34		62	0.3		2	0.2	0.4	176	241	308
W-F$_{14}$	5-10-70	61	10	49	2	68					0.2	290	355	422
W-F$_{15}$	5-28-70	58	13	51	0	64	1.4	0	<0.1	<0.1	0.4	277	356	394
W-G	3-26-68	74	11		3	118	0.4	0.4	0.7		0.4	190	307	396
W-H$_1$	4-27-68	94	12	39	3	156	0.78	0	0.2		0.4	240	396	556
W-H$_2$	10-13-68	85	10	18	6	148	0	0	1.4		0.2	233		530
W-H$_3$	4-8-69	7	Tr.	7	0	10	0.2	0	1.8	0.5	0.4	33	44	66
W-H$_4$	4-10-69	5	3	5		24	0.5		1.6	0.4	0.2	51	77	118
W-H$_5$	5-3-69	64	11	56	0	120	0	0	Tr.		0.4	262	392	464

Continued on next page.

Table 1--continued.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
W-H_6	3-7-70	8	3	16		30	0.8				0.2	68	86	120
W-H_7	4-4-70	62	7	7	2	102	0.2				0	186	182	370
W-H_8	4-24-70	70	11	45	2	120	0.3				0.2	234	362	466
W-H_9	5-10-70	83	9	39	2	116	0.2				0.2	289	368	492
W-H_{10}	5-28-70	70	9	41	1	106	0	0	<0.1	<0.1	0.2	240	344	420
W-I_1	4-27-68	50	76	65	47	256	0.12	0	<0.1		0.6	238	392	708
W-I_2	4-10-69			11		12	0.5		0.5			34	45	66
W-K_1	4-27-68	44	9	26	0.8	66	0.22	0	0.25		0.4	184	218	308
W-K_2	5-3-69	26	14	25	0.2	46	0	0	0.7		0.2	131	168	216
W-K_3	10-3-69	28	9	29	4	66	0.1	0	<0.1		0.2	144	191	240
W-K_4	10-19-69	41	13	34	8	72	0.3	3.9	2		0.2	168	240	290
W-K_5	11-23-69	21	10	34	6	56	0.6	0	2.7		0.2	142	194	298
W-K_6	3-7-70	38	10	37	4	82					0.2	174	246	318
W-K_7	4-4-70	35	10	35	5	58	0.3			0.5		174	230	304
W-K_8	4-24-70	27	9	55	2	46	0.3			0.5	0.2	140	295	240
W-K_9	5-10-70	30	7	27	5	54	0.2			0.5	0.2	154	187	258
W-K_{10}	5-28-70	29	8	28	2	60	0	0	<0.1	<0.1	0	148	189	220
W-L	4-9-69	8	Tr.	6	0	12	0.9	0	2.1		0.2	41	45	68
W-M	5-3-69	48	12	43	7.6	60	0	0			0.2	244	297	360
W-N	5-10-70	44	80	42	98	180	1.6		1.3	1.1	0.8	235	285	626
W-Z					250	500[1]	0.3	0.005[1]	10.0		0.9-[2] 1.7			1000[1]

W-Z. Drinking water standards, U. S. Public Health Service (1962).

Samples W-A, W-B_1, W-C, W-D, and W-E were analyzed by the South Dakota Geological Survey. All other samples were analyzed by the South Dakota Chemical Laboratory.

[1] Modified for South Dakota by the Department of Health (Written communication, Water Sanitation Section, March 20, 1968).

[2] 1.2 is optimum for South Dakota.

Location of water samples in table 1.

(For map location see fig. 19.)

W-A. NE¼SW¼SW¼ sec 12, T. 117 N., R. 53 W., irrigation pond.

W-B. All samples collected from SW¼NE¼ sec. 15, T. 117 N., R. 53 W., Lake Kampeska.

W-C. NE¼SW¼ sec. 25, T. 117 N., R. 53 W., City Well 3.

W-D. NW¼NW¼NW¼ sec. 31, T. 117 N., R. 52 W., Big Sioux River.

W-E. NW¼NE¼NE¼ sec. 12, T. 116 N., R. 53 W., 30 foot deep well.

W-F. All samples collected from SW¼SW¼ sec. 35, T. 118 N., R. 53 W., Big Sioux River.

W-G. SW¼SW¼ sec. 31, T. 118 N., R. 52 W., Gravel Creek.

W-H. NW¼NW¼ sec. 12, T. 117 N., R. 53 W., Gravel Creek.

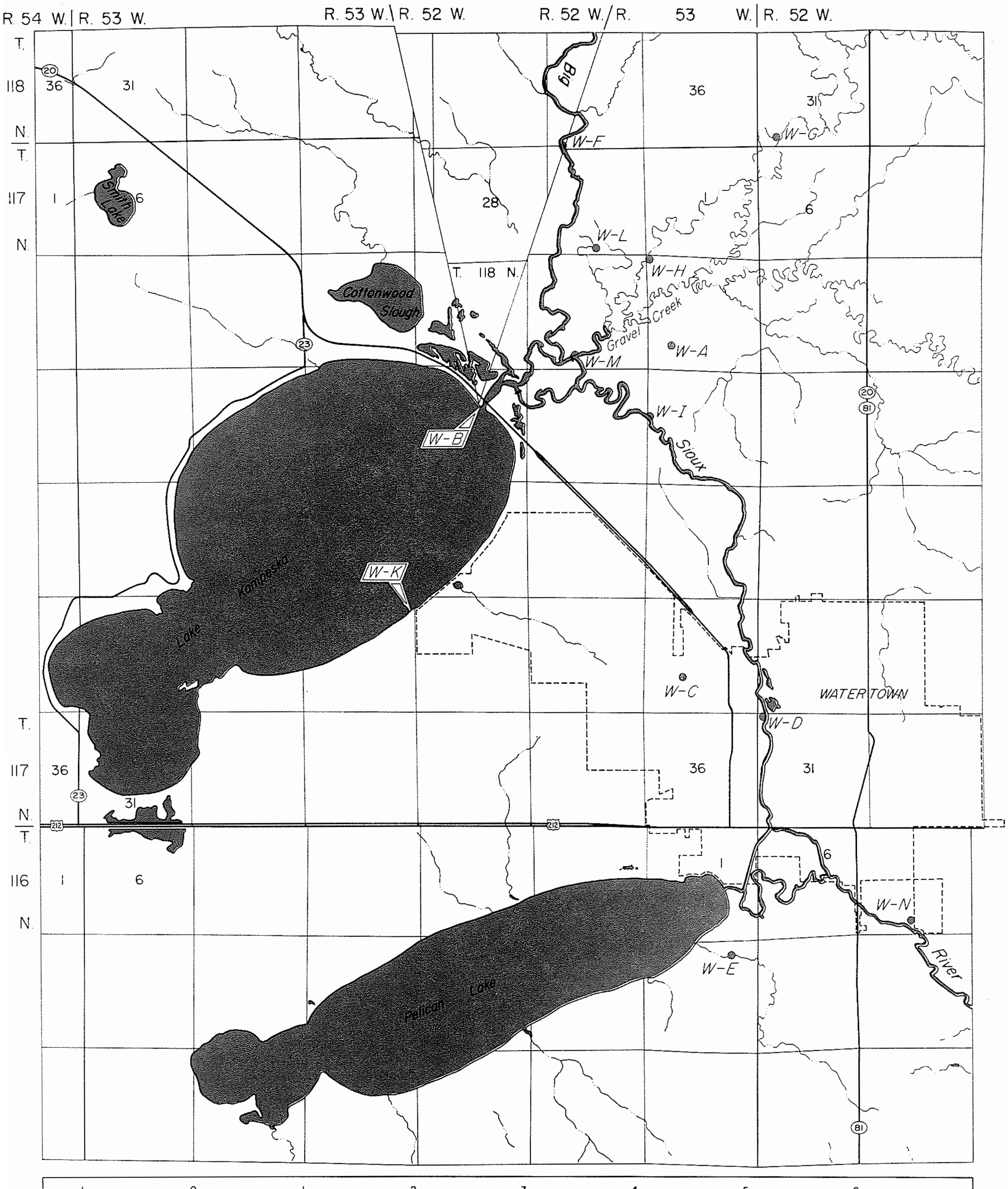
W-I. All samples collected from SW¼NW¼ sec. 13, T. 117 N., R. 53 W., Big Sioux River.

W-K. All samples collected from NE¼NE¼ sec. 28, T. 117 N., R. 53 W., Lake Kampeska next to filtration plant.

W-L. SE¼ sec. 2, T. 117 N., R. 53 W., Big Sioux River floodwater.

W-M. SW¼ sec. 11, T. 117 N., R. 53 W., diversion channel.

W-N. SE¼ sec. 5, T. 116 N., R. 52 W., flow from sewage pond into Big Sioux River.



EXPLANATION

W-B ● Location of water samples *(letters correspond to water samples listed in table 1.)*

Intermittent stream

by A. Barari, 1970 drafted by D. W. Johnson

Figure 19. Map showing location of water samples collected from the Lake Kampeska study area.

water samples listed in table 1. Extensive discussion of the biological aspect of the lake water is beyond the scope of this report.

Eutrophication is a term used to mean enrichment of waters by nutrients.

> "Present knowledge indicates that the fertilizing elements contributing most to lake eutrophication are nitrogen and phosphorus. Iron and certain 'trace' elements are also important . . . As nutrient concentrations increase, the number of algal cells increase . . . Reservoirs or lakes are the settling basins of drainage areas. The potential productivity of a body of water is determined to a great extent by the natural fertility of the land over which the runoff drains and by the contributions of civilization. Biological activity within the lake influences such chemical characteristics as dissolved oxygen, pH, carbon dioxide, hardness, alkalinity, iron, manganese, phosphorus, and nitrogen; it is varied through temperature fluctuation and stimulated by nutrient variations (e.g., phosphorus and nitrogen). A lake's basin gives dimension to biological activity and may, because of unique physical characteristics, concentrate the nutrients it receives as well as the developing biomass. Sawyer (1947) studied the southern Wisconsin lakes and concluded that a 0.30 mg/l concentration of inorganic nitrogen (N) and a 0.01 mg/l concentration of soluble phosphorus (P) at the start of the active growing season could produce nuisance algal blooms . . . A continued high rate of nutrient supply is not necessary for continued algal production. After an initial stimulus, the recycling of nutrients within the lake basin may be sufficient to promote algal blooms for a number of years without substantial inflow from contributing sources." (MacKenthun and Ingram, 1967, p. 103-133).

The nutrient level of the lake water and waters recharging the lake vary seasonally. For example, floodwater introduces a high concentration of nutrients. Samples collected from the northeast of the lake during the flood of 1969 show that floodwater had as high as 2.1 ppm nitrogen and 0.5 ppm soluble phosphorus. The concentration of these chemicals are higher than the figures referred to in the above quotations. Even if the lake water did not have any phosphorus and nitrogen before flooding, the concentration of these chemicals after flooding would be raised to a level higher than the concentration needed to produce algal blooms. (After the flood of 1969 approximately one-third of the water contained in the lake was floodwater, [see page 22]).

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

The Big Sioux River is directly connected to Lake Kampeska through the inlet-outlet channel northeast of the lake. In addition, an aquifer northeast of the lake hydraulically connects the Big Sioux River and Gravel Creek to the lake. These two mediums of exchange, i.e., the inlet-outlet channel and the aquifer, are the primary avenues of surface and ground-water recharge and discharge for Lake Kampeska.

Recharge to Lake Kampeska includes direct precipitation, which adds 20.52 inches of water annually, runoff, and recharge through the inlet-outlet channel and through the aquifer northeast of the lake. Surface runoff from the area around the lake is small when compared with the flow from the northeast.

Discharge from the lake includes evaporation, which removes 33 inches of water from the surface of the lake annually, artificial discharge by the city of Watertown, which removes approximately 3.2 inches annually by pumping for municipal use, and discharge through the aquifer and inlet-outlet channel.

The change in the balance between the total recharge and discharge is reflected as fluctuation in lake level. When the water level in the Big Sioux River and the aquifer is higher than the lake level, water recharges the lake. When the water level in the lake is higher than the river and the water table in the aquifer, water is discharged from the lake.

During flooding a large quantity of water reaches Lake Kampeska through the inlet-outlet channel. The flood of 1969 caused the lake level to rise 5.2 feet indicating that

26,000 acre-feet of water was recharged into the lake. The rate of flow into the lake through the inlet-outlet channel was approximately 3 times greater than the rate of flow through Watertown.

A construction on the inlet-outlet channel to block the flow of floodwaters to the lake without controlling the quantity of water reaching the study area will not function during flooding. Either the sand and gravel deposits on the sides of such a construction will be eroded (see fig. 16) and the structure destroyed (see origin and history of Lake Kampeska, this report), or the water will flow over the construction. (See fig. 11 showing the location and thickness of sand and gravel deposits, and pl. 1 showing the very low relief of this area.) Even if the floodwater could be diverted from the lake during flooding, without construction of a deep wide channel through Watertown flood damages in Watertown would increase substantially.

Several plans have been proposed for flood control around Lake Kampeska and the city of Watertown. One proposal suggests construction of a channel between Lake Kampeska and Pelican Lake which would bypass the city and thus decrease flood damage there; unfortunately, such a project would also increase siltation and nutrient recharge to the lake. Dredging out the Big Sioux River downstream from Gravel Creek will reduce flooding in Watertown if dredging is deep enough, but this will induce increased ground-water discharge from the lake in dry seasons and, consequently, lower the lake level. Another alternative incorporates a design for a deep concrete channel along the Big Sioux River south of Gravel Creek through Watertown. This plan requires construction of a gate at the north end of the concrete channel to control the flow of water through the channel, and dredging of the river downstream. Thus, remedies for reducing flood damage and loss of lake water through the channel during dry seasons are embodied in this proposal; however, they will be very costly.

It is recommended that any management plan for Lake Kampeska should include provisions for the following major factors: There should be provisions for quality and quantity of water recharging the lake, both during low precipitation and high precipitation (flooding) periods, and there should be a provision made for the quantity of discharge passing through the inlet-outlet channel and through the gravel northeast of the lake. Taking the above factors into consideration, it is recommended that the floodwater be contained upstream from the study area. A reconnaissance study for the storage of floodwater north of Lake Kampeska was made by the Soil Conservation Service, and presently, engineering studies are being conducted under contract with the East Dakota Conservancy Sub-District. Such a storage area will reduce the flood damage around the lake and in Watertown, because stored water will gradually flow through the sand and gravel and in the river, thus increasing the flow during summer and fall when there is little or no flow in the river. Additional water in the aquifer and in the river northeast of the lake will also increase water flow into the lake or at least decrease the discharge of water from the lake. As a result, lake-level fluctuation will decrease, and siltation of the lake will be reduced.

Phosphorus and nitrogen content of the water is of primary importance to the biological aspect of the lake (see p. 31). Nutrient content of the lake and streams recharging the lake fluctuates seasonally, being especially high during flooding (see p. 31). Retaining water upstream will probably reduce some of the nutrient in the water reaching the lake, but it is recommended that soil conservation practices be employed to reduce the nutrient in the waters reaching the lake from the north and from areas around the lake. A sewage system should be constructed as soon as possible to eliminate the flow of nutrients introduced to the lake directly or indirectly (through the gravel) by residences around the lake.

Because the problems associated with the quantity and quality of lake water are inter-related, the total water management of the lake requires the cooperation of several government agencies. Furthermore, it is recommended that the public be fully informed about the problems, in order to gain their cooperation and support. Without public support not many projects can be implemented.

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APPENDIX A

Table of monthly and annual precipitation for
the Lake Kampeska area (Watertown Airport)
from 1898 through 1970*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1898	.00	.35	1.10	1.72	3.25	1.65	4.54	1.93	1.53	1.32	.15	.00	17.54
1899	.19	.00	.30	2.02	3.79	2.85	.95	5.03	.45	2.75	.53	.25	19.11
1900	.15	.52	1.45	1.30	.56	2.17	6.73	7.67	4.74	1.45	.12	.10	26.96
1901	.13	.25	.38	1.63	1.98	5.61	2.27	2.89	7.00	1.87	.08	.14	24.23
1902	.25	.07	1.29	1.28	3.25	1.70	2.35	3.34	.13	1.75	.44	1.05	16.90
1903	.15	.13	.53	1.20	3.73	2.26	4.48	5.76	4.52	1.91	.14	.43	25.24
1904	.20	.46	.10	.93	1.34	4.60	5.08	2.27	1.87	2.24	.01	.34	19.44
1905	.77	.72	.59	1.46	2.53	5.46	5.12	2.86	2.17	2.02	1.97	.00	25.67
1906	.26	.30	.78	2.12	4.30	3.44	1.63	4.25	1.25	3.07	.75	.47	22.62
1907	1.85	.93	1.74	.56	2.71	2.79	2.80	.39	.96	1.36	.00	.80	16.67
1908	.25	1.40	1.20	3.25	3.06	6.12	.88	2.37	1.82	1.48	1.50	.47	23.80
1909	1.09	.67	.10	.35	4.56	3.23	3.38	5.26	.50	1.65	1.14	1.72	23.65
1910	.00	.40	.00	2.75	.39	2.78	3.16	3.17	1.20	1.05	.30	.20	15.40
1911	.80	.31	.30	.85	2.14	1.51	1.87	2.82	1.85	4.24	.96	.34	17.99
1912	.10	.35	.22	5.16	4.30	2.55	5.01	2.29	2.61	.41	.00	.30	23.30
1913	.10	.10	.21	3.04	3.86	4.30	3.77	1.39	2.28	1.13	.27	.13	20.58
1914	.52	.38	.42	2.72	3.69	8.99	.95	1.30	2.64	1.84	.00	.30	23.75
1915	.40	1.64	.55	1.11	3.01	5.20	3.38	.57	5.49	1.80	.10	.41	23.66
1916	1.85	.69	1.09	1.53	3.62	4.40	3.06	7.40	1.25	.37	.02	.65	25.93
1917	1.43	.18	1.55	3.03	.46	2.94	2.21	1.21	3.28	.20	.08	.44	17.01
1918	.52	.40	1.12	1.70	4.73	3.95	1.62	2.00	.35	1.53	2.97	1.40	22.29
1919	.05	.84	.60	1.75	2.64	6.50	4.10	1.08	.53	1.18	2.47	.02	21.76
1920	.15	.32	1.92	1.81	2.58	3.72	2.20	1.42	1.28	.52	1.20	.54	17.66
1921	.00	.18	2.05	2.22	2.27	1.64	4.18	5.10	7.22	.15	.90	.16	26.07
1922	1.87	2.28	.56	1.56	3.49	2.03	1.82	2.39	.67	.52	2.93	.35	20.47
1923	.91	.15	.48	2.65	1.77	5.29	1.41	.63	1.67	.23	.31	.38	15.88
1924	.13	.32	2.46	2.72	1.72	5.86	2.96	5.83	1.52	1.50	.32	.07	26.31
1925	.77	.13	.08	2.73	.68	7.27	1.75	2.44	1.44	.29	.57	.37	18.52
1926	.49	.06	.27	.19	3.58	2.24	2.19	1.25	2.99	2.06	.57	.73	16.62
1927	.24	.16	.90	4.19	3.49	2.29	5.11	2.30	.97	.56	.39	1.48	22.08
1928	.18	.38	.05	.61	.60	2.33	2.09	4.41	3.22	1.58	.70	.26	16.41
1929	.85	.45	.93	2.31	1.35	1.27	2.77	1.91	3.17	2.10	.45	.20	17.76
1930	.54	.63	.17	.94	2.93	3.42	.88	1.54	1.28	1.09	2.13	.02	15.57
1931	.03	.31	.58	1.38	8.16	1.91	1.37	1.19	1.16	1.48	.88	.82	19.27
1932	.60	.02	.76	4.21	2.37	5.31	1.74	2.47	1.66	1.57	.47	.38	21.56
1933	.11	.00	.70	.70	2.65	1.67	1.33	1.99	2.49	.03	.31	.34	12.32
1934	.19	.04	1.02	.17	.99	3.51	5.65	2.81	4.53	1.43	.39	.20	20.93
1935	.40	.34	1.58	2.91	1.83	4.61	3.26	3.56	.17	.22	.54	.92	20.34
1936	.57	1.21	.53	2.02	1.81	2.29	.88	3.06	.30	.35	1.05	.49	14.56
1937	1.00	.36	1.91	4.62	2.30	4.40	.92	2.54	1.44	.73	.39	.83	21.44
1938	.81	.57	1.20	3.36	4.05	2.72	2.28	2.23	2.63	.12	.38	.29	20.64
1939	1.68	.85	.24	1.17	3.91	6.11	2.46	2.79	.73	.87	.02	.10	20.93
1940	.12	.70	3.16	1.77	.60	3.50	1.84	5.40	1.19	1.62	1.15	.47	21.52
1941	1.45	.09	.40	3.88	3.36	2.66	1.52	1.95	1.54	1.65	.14	.24	18.88
1942	.02	.08	1.56	2.83	6.80	1.91	2.46	3.39	5.20	1.08	.14	.37	25.84
1943	.92	1.35	1.98	.48	3.15	5.65	3.69	3.48	2.51	2.69	1.42	.00	27.32
1944	.58	.32	.52	2.16	2.25	2.57	2.24	3.21	2.28	.11	1.79	.68	18.71
1945	.41	.95	1.12	1.89	5.22	2.86	2.12	2.76	2.41	.32	.50	1.10	21.66

*Climatological summary, Climatography of the U.S., No. 20-39; and South Dakota annual summary, 1967, 1968, 1969, and monthly climatological summary for 1970.

Appendix A--continued.

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1946	.07	1.67	2.23	.67	2.74	6.00	2.37	.68	3.86	4.53	1.14	.36	26.32
1947	.31	.27	.68	3.50	.99	4.18	1.00	1.65	2.80	1.98	2.64	.03	20.03
1948	.26	1.04	.38	3.60	.51	5.52	2.88	5.63	3.11	1.26	.31	.07	24.57
1949	.54	.01	.41	.36	3.31	2.09	4.55	.79	2.55	1.42	.97	.82	17.82
1950	.41	.03	.65	1.85	3.21	.33	6.14	1.71	1.37	1.83	.42	.26	18.21
1951	.20	.21	1.85	.83	2.55	3.82	4.08	5.00	.40	2.24	.08	.80	22.06
1952	.77	.91	.73	.31	1.15	5.10	2.92	.82	.47	.00	1.10	.27	14.55
1953	.88	1.64	.50	3.86	1.77	8.15	7.77	1.19	.12	.32	1.07	1.85	29.12
1954	.37	.65	2.13	1.74	3.10	3.74	.88	1.67	2.42	1.09	.23	.02	18.04
1955	.26	1.39	.17	1.26	1.23	4.65	4.74	4.35	.94	.16	.46	3.36	22.97
1956	1.33	.20	1.04	1.80	2.88	6.56	4.02	6.25	.70	2.44	.97	.16	28.35
1957	.21	.99	.44	3.67	5.68	2.75	.46	3.47	1.98	2.42	.51	.42	23.00
1958	.10	.49	.44	1.46	1.34	1.73	1.35	.77	1.28	.10	2.53	.24	11.83
1959	.39	.74	.06	.64	3.77	.96	1.74	2.20	1.20	1.79	1.14	.56	15.19
1960	.68	.26	.87	2.64	2.49	3.81	1.29	4.40	1.59	.46	1.13	1.08	20.70
1961	.05	.50	.49	1.53	5.58	4.05	.79	2.03	2.31	1.50	.63	.73	20.19
1962	.42	1.67	1.49	2.36	8.75	4.71	4.62	.62	1.84	1.04	.42	.02	27.96
1963	.74	.28	1.65	1.34	4.18	3.48	10.36	1.89	1.39	1.11	.61	.61	27.64
1964	.05	.38	1.22	2.61	1.28	2.57	2.28	5.24	.77	.09	.53	.40	17.42
1965	.29	.29	2.67	3.14	6.41	2.89	2.02	1.39	4.36	.84	.78	.69	25.77
1966	.24	.77	1.33	2.02	1.10	1.63	4.67	5.13	1.37	1.37	.79	.28	20.70
1967	.85	1.75	.25	3.00	.41	5.19	3.41	.65	1.69	1.02	.12	.35	17.62
1968	.50	.01	.64	4.52	2.67	5.06	3.33	2.07	2.71	2.62	.58	2.40	27.11
1969	1.47	1.53	.23	1.02	4.77	2.47	6.67	1.26	.60	4.59	.25	.70	25.56
1970	.32	.08	1.46	2.69	3.12	3.96	1.37	.75	1.84	2.01	2.88	.32	20.80
Normal	.50	.59	.99	2.06	2.87	3.70	2.67	2.78	1.83	1.21	.81	.51	20.52

APPENDIX B

Logs of test holes and observation wells in the Lake Kampeska study area

(For location see fig. 10.)

Abbreviations used in appendix B:
South Dakota Geological Survey, SDGS; City of Watertown, CW; Water Resources Commission, WRC.

Number following the date of drilling is the previous test hole number.

Test Hole 1, SDGS, 1957, No. 31
Location: SE¼SE¼ sec. 30, T. 118 N., R. 53 W.
Surface elevation: 1805 feet
Static water elevation: not measured

0- 1	Topsoil, black
1-30	Till, yellow-brown

* * *

Test Hole 2, SDGS, 1957, No. 22
Location: SW¼SW¼ sec. 25, T. 118 N., R. 53 W.
Surface elevation: 1743 feet
Static water elevation: 1718 feet

0- 5	Topsoil
5- 7	Clay
7-30	Sand, coarse; water
30-37	Silt, brown; sand
37-65	Silt, brown; clay

* * *

Test Hole 3, SDGS, 1957, No. 32
Location: SW¼SE¼ sec. 25, T. 118 N., R. 53 W.
Surface elevation: 1761 feet
Static water elevation: not measured

0- 1	Topsoil, black
1-30	Till, yellow-brown

* * *

Test Hole 4, SDGS, 1963, No. 9
Surface elevation: not taken
Depth to water: 12 feet

0-19	Clay, brown; some sand and gravel
19-29	Till, brown
29-64	Clay, blue

* * *

Test Hole 5, CW, 1964-65, No. 21
Location: SW¼SE¼SW¼ sec. 30, T. 118 N., R. 52 W.
Surface elevation: 1755.90
Static water elevation: 1747.48

0- 2	Road bed
2- 5	Clay, sandy
5-17	Sand and gravel, medium to coarse; boulders; 4" mud loss
17-19	Clay, gray
19-42	Sand and gravel, medium to coarse; 6" mud loss
42-56	Clay, gray

* * *

Test Hole 6, SDGS, 1963, No. 10
Surface elevation: 1727 feet
Depth to water: 10 feet

0- 9	Gravel, red
9-29	Sand, medium to coarse; some clay
29-89	Sand, medium to coarse; less clay
89-99	Clay, blue

* * *

Test Hole 7, SDGS, 1963, No. 11
Surface elevation: 1734 feet
Depth to water: 4 feet

0-11	Clay, brown; gravel; unsorted
11-29	Gravel, coarse; some clay
29-44	Gravel; less clay
44-49	Gravel; more clay
49-54	Clay, blue

* * *

Test Hole 8, SDGS, 1963, No. 12
Surface elevation: 1739 feet
Depth to water: 15 feet

0-14	Clay; sand; gravel; poorly sorted
14-54	Sand, coarse; gravel, fine
54-64	Sand and gravel; more silty

* * *

Test Hole 9, SDGS, 1957, No. 48
Location: SW¼SW¼ sec. 31, T. 118 N., R. 53 W.
Surface elevation: 1748 feet
Static water elevation: not measured

0- 3	Topsoil
3- 4	Sand, clean, medium
4-13	Gravel, medium-fine
13-15	Gravel, medium-coarse; rocks

* * *

Test Hole 10, SDGS, 1963, No. 14
Surface elevation: 1765 feet
Depth to water: 18 feet

0-19	Sand, brown, medium; clay
19-24	Sand, fine; clay
24-29	Till, blue

* * *

Observation Well 11, SDGS, 1967-70
Location: SW¼SE¼SE¼ sec. 21, T. 118 N., R. 52 W.
Top of observation well: 1739.18 feet
Depth to water: 10 feet

0- 1	Topsoil
1- 3	Sand, fine
3- 5	Clay, gray
5-10	Sand and gravel
10-15	Gravel; some sand
15-30	Sand
30-40	Sand, coarse

* * *

Test Hole 12, SDGS, 1963, No. 16
Surface elevation: 1748 feet
Depth to water: 9 feet

0- 9	Clay, brown; some sand and gravel
9-24	Sand; some clay
24-59	Clay, blue; some sand

* * *

Observation Well 13, SDGS, 1967-70, No. 10
Location: NE¼NW¼NW¼NW¼ sec. 22, T. 118 N., R. 52 W.
Top of observation well: 1740 feet
Depth to water: 16 feet

0- 1	Topsoil
1-33	Sand, coarse; some pebbles
33-44	Clay, dark-gray; pebbly, (till)
44-49	Clay; some sand
49-74	Clay, blue

* * *

Observation Well 14, SDGS, 1967-70, No. 3
Location: SE¼SE¼SE¼SE¼ sec. 36, T. 118 N., R. 53 W.
Top of observation well: 1738.51 feet
Depth to water: 6 feet

0- 2	Topsoil
2- 6	Clay, dark-gray
6-16	Sand; some gravel

Observation Well 14--continued.

16-29	Clay, dark-gray; pebbly, (till)

* * *

Test Hole 15, CW, 1964-65, No. 22
Location: SW¼SW¼NW¼ sec. 31, T. 118 N., R. 52 W.
Surface elevation: 1749.15
Static water elevation: 1740.15

0- 2	Topsoil, clay
2-12	Medium to very coarse sand and gravel, 3" mud loss
12-18	Yellow clay
18-33	Gray clay

* * *

Test Hole 16, CW, 1964-65, No. 34
Location: SE¼SE¼NW¼ sec. 31, T. 118 N., R. 52 W.
Surface elevation: 1753.27
Static water elevation: 1742.02

0- 1	Topsoil
1- 3	Sandy clay
3-28	Medium to very coarse sand and gravel, 6" mud loss
28-31	Gray clay
31-37	Medium to very coarse sand and gravel, 6" mud loss
37-48	Gray clay

* * *

Test Hole 17, CW, 1964-65, No. 33
Location: SE¼SW¼SE¼ sec. 31, T. 118 N., R. 52 W.
Surface elevation: 1741.06
Static water elevation: 1736.23

0- 1	Topsoil
1- 3	Sandy clay
3-20	Medium to very coarse sand and gravel, 6" mud loss
20-33	Gray, clay

* * *

Test Hole 18, SDGS, 1957, No. 21
Location: NE¼NE¼ sec. 31, T. 118 N., R. 52 W.
Surface elevation: 1747 feet
Static water elevation: 1735 feet

0- 7	Topsoil
7-12	Sand, tan; silt; water
12-18	Gravel, medium-brown; water
18-30	Sand, coarse; gravel, fine
30-40	Sand, coarse
40-45	Sand, medium to fine
45-65	Sand, fine

* * *

Test Hole 19, CW, 1964-65, No. 37
Location: SW¼SW¼NW¼ sec. 32, T. 118 N., R. 52 W.
Surface elevation: 1753.71
Static water elevation: 1742.71

0- 1	Topsoil
1- 4	Yellow clay
4-20	Medium to coarse sand and gravel, 4" mud loss
20-33	Brown clay and gray clay

* * *

Test Hole 20, SDGS, 1957, No. 50
Location: SW¼SW¼ sec. 32, T. 118 N., R. 52 W.
Surface elevation: 1747 feet
Static water elevation: 1740 feet

0- 3	Topsoil
3- 7	Gravel, medium; sand, coarse; water
7- 9	Sand, medium; gravel, fine
9-24	Sand, coarse
24-47	Sand, medium to fine
47-65	Sand, medium to fine

* * *

Test Hole 21, CW, 1964-65, No. 31
Location: SW¼SW¼SE¼ sec. 32, T. 118 N., R. 52 W.
Surface elevation: 1753.71
Static water elevation: 1742.71

0- 1	Topsoil
1- 3	Sandy clay
3-18	Medium to very coarse sand and gravel, 7" mud loss
18-33	Yellow clay

* * *

Test Hole 22, CW, 1964-65, No. 32
Location: NW¼NW¼SE¼ sec. 32, T. 118 N., R. 52 W.
Surface elevation: 1761.87
Static water elevation: 1747.87

0- 1	Topsoil
1- 4	Sandy clay
4-23	Medium to very coarse sand and gravel, 10" mud loss
23-33	Brown gray clay

* * *

Observation Well 23, SDGS 1967-70
Location: NW¼NW¼NW¼NW¼ sec. 33, T. 118 N., R. 52 W.
Top of observation well: 1767 feet
Depth to water: 12.47 feet

0- 2	Topsoil
2-23	Sand and gravel

Observation Well 23--continued.

23-29	Clay, dark-gray; pebbly, (till)

* * *

Test Hole 24, SDGS, 1963, No. 20
Surface elevation: 1750 feet
Depth to water: not measured

0-17	Gravel, fine to medium; some sand
17-44	Clay, brown
44-49	Clay, brown; some sand
49-54	Clay, blue

* * *

Test Hole 25, SDGS, 1963, No. 21
Surface elevation: 1747 feet
Depth to water: 22 feet

0-29	Clay, red; sand
29-39	Sand, brown; clay
39-49	Sand; more clay
49-59	Clay, gray

* * *

Test Hole 26, SDGS, 1963, No. 15
Surface elevation: 1721 feet
Depth to water: 17 feet

0- 9	Clay, brown; sand
9-24	Till, blue
24-49	Till, brown

* * *

Observation Well 27, SDGS, 1967-70
Location: NW¼NW¼NW¼NW¼ sec. 3, T. 117 N., R. 53 W.
Top of observation well: 1749.9 feet
Depth to water: 18 feet

0- 2	Topsoil
2-28	Sand and gravel
28-49	Clay, gray-blue; pebbly, (till)

* * *

Observation Well 28, SDGS, 1967-70
Location: SW¼SW¼SW¼SW¼ sec. 2, T. 117 N., R. 53 W.
Top of observation well: 1728.58 feet
Depth to water: 8 feet

0- 1	Topsoil
1-12	Sand and gravel, coarse
12-27	Gravel

Observation Well 28--continued.

27-39	Clay, dark-brown; pebbly, (till)

* * *

Observation Well 29, WRC, No. WA2
Location: SE¼SE¼SE¼SE¼ sec. 2, T. 117 N., R. 53 W.
Static water level: 3 feet

0- 6	Topsoil
6-39	Sand, gray, fine to coarse; some coal
39-50	Clay till, dark-gray

* * *

Test Hole 30, SDGS, 1963, No. 23
Surface elevation: not measured
Depth to water: 10 feet

0-14	Sand and gravel; some clay
14-19	Sand and gravel
19-24	Sand and gravel; more clay
24-29	Till, brown
29-37	Till, blue

* * *

Test Hole 31, CW, 1964-65, No. 13
Location: SE¼SE¼SW¼ sec. 1, T. 117 N., R. 53 W.
Surface elevation: 1726.59
Static water elevation: 1722.26

0- 1	Topsoil
1- 5	Gray clay
5- 7	Medium to very coarse sand and gravel
7- 8	Black clay
8-13	Brown clay
13-23	Medium to very coarse sand and gravel, boulders, 4" mud loss
23-28	Gray clay, gravel streaks
28-30	Medium to coarse sand and gravel, 1" mud loss
30-45	Gray clay

* * *

Test Hole 32, CW, 1964-65, No. 35
Location: SW¼NW¼SW¼ sec. 6, T. 117 N., R. 52 W.
Surface elevation: 1730.66
Static water elevation: 1725.66

0- 1	Topsoil
1- 8	Gray clay
8-20	Fine to coarse cemented sand, 4" mud loss
20-33	Gray clay

* * *

Test Hole 33, CW, 1964-65, No. 36
Location: NE¼NW¼NW¼ sec. 6, T. 117 N., R. 52 W.
Surface elevation: 1734.17
Static water elevation: 1732.67

0- 1	Topsoil
1- 3	Soft clay
3-10	Medium to very coarse sand and gravel, 4" mud loss
10-11	Gray clay, boulders
11-22	Medium to very coarse sand and gravel, 5" mud loss
22-32	Gray clay
32-38	Fine to coarse cemented sand and gravel, 4" mud loss
38-48	Gray clay

* * *

Test Hole 34, SDGS, 1963, No. 78
Surface elevation: 1736 feet
Depth to water: 4 feet

0- 6	Topsoil and clay
6-19	Sand, medium; gravel, fine
19-59	Sand; gravel
59-64	Sand; gravel; more clay
64-74	Clay, brown

* * *

Test Hole 35, CW, 1964-65, No. 20
Location: SW¼SW¼NE¼ sec. 6, T. 117 N., R. 52 W.
Surface elevation: 1738.23
Static water elevation: 1733.06

0- 1	Topsoil
1- 3	Gray clay
3-17	Fine to very coarse sand and gravel, boulders, 4" mud loss
17-20	Gray clay
20-63	Fine to coarse cemented sand and gravel, 6" mud loss
63-78	Gray clay

* * *

Test Hole 36, CW, 1964-65, No. 6
Location: SW¼SW¼SE¼ sec. 6, T. 117 N., R. 52 W.
Surface elevation: 1733.29
Static water elevation: 1727.79

0- 1	Topsoil
1-10	Gray clay
10-15	Fine to medium sand
15-18	Fine to coarse sand and gravel, boulders, 7" mud loss
18-31	Fine sand
31-42	Gray clay, sand streaks
42-55	Fine to medium cemented sand
55-63	Gray clay

* * *

Test Hole 37, SDGS, 1963, No. 25
Surface elevation: not taken
Depth to water: 6 feet

0- 9	Sand, fine to coarse; some clay
9-29	Sand; some clay
29-44	Till, blue

* * *

Test Hole 38, CW, 1964-65, No. 39
Location: SE¼SE¼NE¼ sec. 6, T. 117 N., R. 52 W.
Surface elevation: 1744.57
Static water elevation: 1735.40

0- 1	Topsoil
1- 5	Yellow clay
5-15	Medium to coarse sand and gravel, 5" mud loss
15-32	Brown clay
32-37	Fine to coarse sand, 3" mud loss
37-38	Gray and brown clay

* * *

Test Hole 39, SDGS, 1967-70
Location: NW¼NW¼NW¼NW¼ sec. 5, T. 117 N., R. 52 W.
Surface elevation: 1744 feet
Depth to water: 5 feet

0 - 2	Topsoil, black, organic
2 - 4½	Clay, gray, compact, dry
4½- 5½	Sand, gray-brown, fine, moist; some pebbles
5½-18	Sand, brown, medium to coarse, wet
18 -30	Sand, light grayish-brown, fine to medium
30 -56	Sand, brown, very coarse to pea-size gravel, clean; some rocks
56 -67	Clay, gray, gravelly, (till)

* * *

Test Hole 40, SDGS, 1957
Location: SE¼SW¼ sec. 5, T. 117 N., R. 52 W.
Surface elevation: 1746 feet
Static water elevation: not measured

0- 4	Gravel
4-10	Gravel with silt

* * *

Test Hole 41, SDGS, 1957
Location: SW¼SW¼ sec. 7, T. 117 N., R. 53 W.
Surface elevation: 1758 feet
Static water elevation: 1718 feet

0- 9	Topsoil
9-11	Sand, medium
11-27	Sand, medium; gravel

Test Hole 41–continued.

27-57	Silt, gray; sand, coarse
57-67	Silt, gray; sand, medium
67-71	Silt, gray; sand, fine
71-74	Clay, tan; rocks, (till)

* * *

Observation Well 42, SDGS, 1967-70
Location: NW¼SW¼NW¼SW¼ sec. 9, T. 117 N., R. 53 W.
Height of pipe above the ground: 2 feet
Depth to water from the top of the pipe: 12.19 feet

0- 2	Topsoil
2-23	Sand and gravel
23-29	Clay, pebbly, (till)

* * *

Test Hole 43, SDGS, 1957, No. 28
Location: SE¼SE¼ sec. 9, T. 117 N., R. 53 W.
Surface elevation: 1726 feet
Static water elevation: 1717 feet

0- 2	Topsoil
2- 7	Sand, black; (sand with black silt)
7- 9	Sand, medium; gravel; silt
9-50	Gravel, fine; sand, medium; clay
50-65	Till

* * *

Test Hole 44, CW, 1964-65, No. 17
Location: NE¼SE¼SE¼ sec. 9, T. 117 N., R. 53 W.
Surface elevation: 1721.48
Static water elevation: 1715.63

0- 3	Road bed
3-13	Fine to very coarse sand and gravel, 3" mud loss
13-14	Gray clay
14-20	Fine to coarse sand and gravel, 3" mud loss
20-33	Gray clay

* * *

Test Hole 45, CW, 1964-65, No. 18
Location: NW¼SW¼NW¼ sec. 10, T. 117 N., R. 53 W.
Surface elevation: 1721.68
Static water elevation: 1716.18

0- 5	Road bed (clay)
5-30	Fine to medium sand and gravel, 3" mud loss
30-40	Gray clay

* * *

Observation Well 46, SDGS, 1967-70
Location: NW¼NW¼NW¼NW¼ sec. 10, T. 117 N., R. 53 W.
Top of observation well: 1743.76 feet
Depth to water: 26 feet

0- 1	Topsoil
1- 7	Sand, coarse
7-24	Sand, brown, fine to coarse
24-31	Sand, coarse
31-39	Clay, olive-brown, pebbly, compact, (till)

* * *

Test Hole 47, CW, 1964-65, No. 9
Location: SE¼SE¼SE¼ sec. 10, T. 117 N., R. 53 W.
Surface elevation: 1718.94
Static water elevation: 1715.69

0- 1	Topsoil
1- 5	Gray clay
5-13	Medium to coarse sand and gravel, 4" mud loss
13-17	Gray clay, boulders
17-38	Medium to coarse sand and gravel, 4" mud loss
38-48	Gray clay

* * *

Test Hole 48, SDGS, 1963, No. 26
Surface elevation: 1724 feet (approximately)
Depth to water: 5 feet

0- 9	Clay, black, sandy
9-37	Gravel, fine to pea-size; hit rock, couldn't penetrate

* * *

Test Hole 49, CW, 1964-65, No. 23
Location: NW¼NE¼NW¼ sec. 11, T. 117 N., R. 53 W.
Surface elevation: 1724.86
Static water elevation: 1717.28

0- 1	Topsoil
1- 8	Gray clay
8-17	Medium to very coarse sand and gravel, 4" mud loss
17-20	Gray clay
20-33	Yellow clay

* * *

Test Hole 50, CW, 1964-65, No. 10
Location: SW¼SW¼NE¼ sec. 11, T. 117 N., R. 53 W.
Surface elevation: 1720.91
Static water elevation: 1716.24

0- 1	Topsoil
1- 8	Gray clay
8-28	Medium to coarse sand and gravel, 4" mud loss

Test Hole 50--continued.

28-30	Gray and brown clay, boulders
30-43	Fine to coarse sand and gravel, 4" mud loss
43-48	Gray clay

* * *

Test Hole 51, CW, 1964-65, No. 11
Location: SW¼SE¼SW¼ sec. 11, T. 117 N., R. 53 W.
Surface elevation: 1719.92
Static water elevation: 1715.50

0- 1	Topsoil
1- 7	Gray clay
7-28	Medium to very coarse sand and gravel, 8" mud loss
28-44	Fine to coarse sand and gravel
44-48	Gray clay

* * *

Observation Well 52, SDGS, 1967-70
Location: NE¼SE¼SE¼SE¼ sec. 11, T. 117 N., R. 53 W.
Top of observation well: 1721.04 feet
Depth to water: 4 feet

0- 1	Topsoil
1-20	Sand and gravel
20-29	Clay, dark-gray, pebbly, (till)

* * *

Test Hole 53, CW, 1964-65, No. 7
Location: NE¼NE¼NE¼ sec. 11, T. 117 N., R. 53 W.
Surface elevation: 1726.80
Static water elevation: 1720.38

0- 1	Road bed
1-10	Gray clay
10-20	Medium to very coarse sand and gravel, boulders, 6" mud loss
20-42	Fine to medium sand and gravel
42-48	Gray clay

* * *

Test Hole 54, SDGS, 1963, No. 27
Surface elevation: 1724 feet
Depth to water: 9 feet

0- 9	Clay, sandy
9-29	Sand; some clay
29-44	Till, blue

* * *

Test Hole 55, CW, 1964-65, No. 12
Location: SW¼SW¼NW¼ sec. 12, T. 117 N., R. 53 W.
Surface elevation: 1722.01
Static water elevation: 1719.01

0- 1	Topsoil
1- 7	Gray clay
7-23	Medium to very coarse sand and gravel, 4" mud loss
23-33	Gray clay
33-34	Medium to coarse sand and gravel
34-38	Gray clay

* * *

Test Hole 56, CW, 1964-65, No. 2
Location: SE¼SW¼SW¼ sec. 12, T. 117 N., R. 53 W.
Surface elevation: 1724.93
Static water elevation: 1717.93

0- 1	Road bed
1- 7	Clay
7-23	Medium to very coarse sand and gravel, 6" mud loss
23-26	Gray clay, boulders
26-28	Medium to very coarse sand and gravel, 2" mud loss
28-38	Brown clay
38-48	Gray clay

* * *

Test Hole 57, CW, 1964-65, No. 3
Location: SE¼SE¼SW¼ sec. 12, T. 117 N., R. 53 W.
Surface elevation: 1727.34
Static water elevation: 1719.34

0- 1	Topsoil
1- 3	Gray clay
3-15	Medium to very coarse sand and gravel, boulders, 4" mud loss
15-33	Gray clay

* * *

Test Hole 58, SDGS, 1963, No. 28
Surface elevation: 1726 feet
Depth to water: 9 feet

0- 9	Sand; gravel; some clay
9-39	Sand; gravel
39-64	Till, brown

* * *

Test Hole 59, CW, 1964-65, No. 14
Location: SW¼SW¼NE¼ sec. 12, T. 117 N., R. 53 W.
Surface elevation: 1728.82
Static water elevation: 1720.57

0- 1	Topsoil

Test Hole 59--continued.

1- 3	Gray clay
3-22	Medium to very coarse sand and gravel, 4" mud loss
22-33	Gray clay

* * *

Observation Well 60, SDGS, 1967-70
Location: NE¼NE¼NE¼NE¼ sec. 12, T. 117 N., R. 53 W.
Height of pipe above the ground: 2 feet
Depth to water from the top of pipe: 4 feet

0- 2	Topsoil
2- 7	Clay, sandy
7-15	Sand, light-gray, fine
15-42	Sand, fine to coarse
42-57	Sand, coarse
57-69	Clay, dark-gray, (till)

* * *

Test Hole 61, CW, 1964-65
Location: SW¼SW¼NW¼ sec. 7, T. 117 N., R. 52 W.
Surface elevation: 1729.65
Static water elevation: 1722.15

0- 1	Topsoil
1- 3	Sandy clay
3-22	Medium to very coarse sand and gravel, boulders, 5" mud loss
22-33	Gray clay

* * *

Observation Well 62, SDGS, 1967-70
Location: NE¼NE¼NE¼NE¼ sec. 7, T. 117 N., R. 52 W.
Top of observation well: 1742.24 feet
Depth to water: 4 feet

0- 1	Sand, clean, brown, coarse
1- 4	Sand, medium-brown, clean; scattered pea-sized gravel
4-13	Gravel, brown, pea-sized
13-19	Sand, coarse
19-26	Gravel, sandy with high clay content
26-29	Till, gray, unoxidized

* * *

Test Hole 63, SDGS, 1967-70
Location: SW¼SW¼SW¼SW¼ sec. 18, T. 117 N., R. 53 W.
Depth to water: dry

0- 1	Topsoil
1- 4	Sand and gravel
4-22	Clay, brown, compact
22-39	Clay and sand

* * *

Test Hole 64, SDGS, 1967-70
Location: NE¼NE¼NE¼NE¼ sec. 18, T. 117 N., R. 53 W.
Depth to water: 9 feet

0- 2	Topsoil
2-12	Sand and gravel
12-29	Clay, dark-brown, pebbly, (till)

* * *

Test Hole 65, CW, 1933-34
Location: SW¼SW¼SW¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1719.4
Static water elevation: 1711.6

0- 1	Topsoil
1-12	Fine to coarse sand and gravel
12-16	Coarse sand
16-18	Clay

* * *

Test Hole 66, CW, 1964-65
Location: SW¼NW¼SW¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1721.47
Static water elevation: 1715.40

0- 3	Sandy topsoil
3-21	Fine to very coarse sand and gravel, 6" mud loss
21-23	Black silt
23-33	Gray clay

* * *

Test Hole 67, CW, 1964-65
Location: NW¼NW¼SW¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1720.17
Static water elevation: 1715.17

0- 1	Topsoil
1- 2	Sandy clay
2-15	Medium to very coarse sand and gravel, 4" mud loss
15-18	Medium to coarse sand and gravel
18-26	Medium to coarse sand, boulders
26-28	Soft gray clay
28-45	Medium to coarse sand and gravel, 4" mud loss
45-63	Gray clay

* * *

Test Hole 68, CW, 1964-65
Location: SW¼SW¼NW¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1720
Static water elevation: 1715

0- 1	Topsoil

Test Hole 68--continued.

1-17	Fine to coarse sand and gravel, sea shells, 6" mud loss
17-24	Fine to medium black sand
24-40	Gray clay
40-42	Fine to coarse sand
42-48	Gray clay

* * *

Test Hole 69, CW, 1964-65
Location: SW¼SW¼NE¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1729.17
Static water elevation: 1719.34

0- 1	Topsoil
1- 2	Sandy clay
2-20	Medium to very coarse sand and gravel, 4" mud loss
20-30	Gray clay
30-48	Brown clay

* * *

Test Hole 70, CW, 1964-65
Location: NE¼NE¼NW¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1719.05
Static water elevation: 1715.25

0- 1	Topsoil
1- 5	Gray clay
5-25	Medium to very coarse sand and gravel, boulders, 5" mud loss
25-33	Brown clay

* * *

Test Hole 71, CW, 1964-65
Location: NE¼NE¼NE¼ sec. 14, T. 117 N., R. 53 W.
Surface elevation: 1720.92
Static water elevation: 1717.09

0- 6	Clay
6-25	Medium to coarse sand and gravel, 4" mud loss
25-35	Gray clay

* * *

Test Hole 72, SDGS, 1963
Surface elevation: 1720 feet
Depth to water: 4 feet

0- 4	Sand, coarse; some clay
4-22	Sand, coarse
22-64	Clay, blue
64-74	Clay, brown

* * *

Observation Well 73, SDGS, 1967-70
Location: SE¼SE¼SE¼SE¼ sec. 14, T. 117 N., R. 53 W.
Top of observation well: 1724.46 feet
Depth to water: 8 feet

0- 1	Topsoil
1-13	Sand and gravel
13-24	Clay, olive-brown, (till)

* * *

Test Hole 74, CW, 1933-34
Location: SE¼SW¼SE¼ sec. 13, T. 117 N., R. 53 W.
Surface elevation: 1718.2
Static water elevation: dry hole

0-2	Topsoil
2-3	Sand
3-8	Clay

* * *

Test Hole 75, SDGS, 1963
Surface elevation: not taken
Depth to water: 9 feet

0- 4	Topsoil; unsorted sand and gravel
4-12	Clay, gray, moist
12-39	Clay, blue

* * *

Test Hole 76, CW, 1964-65
Location: NW¼NW¼NW¼ sec. 18, T. 117 N., R. 52 W.
Surface elevation: 1739.56
Static water elevation: dry hole

0- 1	Road bed
1- 4	Sandy clay
4- 5	Medium to coarse sand and gravel
5-23	Brown clay
23-33	Gray clay

* * *

Test Hole 77, SDGS, 1957
Location: NW¼NW¼ sec. 17, T. 117 N., R. 52 W.
Surface elevation: 1743 feet
Static water elevation: not measured

0 - 4	Topsoil
4 - 4½	Gravel and clay
4½-25	Till

* * *

Test Hole 78, SDGS, 1957
Location: SE¼SW¼ sec. 17, T. 117 N., R. 52 W.
Surface elevation: 1762 feet
Static water elevation: not measured

0-30	Till, yellow-brown

* * *

Test Hole 79, CW, 1933-34, No. 48
Location: SW¼SE¼SW¼ sec. 22, T. 117 N., R. 53 W.

0- 2	Topsoil
2-10	Clay
10-17	Fine to coarse sand and gravel
17-22	Clay
22-23	Fine to coarse sand and gravel
23-	Clay

* * *

Test Hole 80, CW, 1933-34, No. 49
Location: SE¼SE¼SW¼ sec. 22, T. 117 N., R. 53 W.

0- 4	Topsoil
4-16	Fine blue sand
16-	Clay

* * *

Test Hole 81, CW, 1933-34, No. 50
Location: SW¼SW¼SE¼ sec. 22, T. 117 N., R. 53 W.

0- 3	Topsoil
3-14	Coarse yellow sand
14-	Clay

* * *

Test Hole 82, SDGS, 1963, No. 32
Surface elevation: not taken
Depth to water: dry

0-34	Clay, brown

* * *

Test Hole 83, SDGS, 1967-70
Location: SW¼SW¼NW¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1743 feet
Depth to water: 21 feet

0- 1	Topsoil
1- 6	Clay, sandy, dry
6-17	Sand and gravel, dry
17-39	Till

* * *

Test Hole 84, CW, 1933-34, No. 30
Location: NW¼NE¼NW¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1719.7
Static water elevation: 1712.4

0- 1	Topsoil
1- 8	Packed sand
8-15	Coarse sand
15-22	Fine to coarse sand and gravel
22-27	Coarse sand
27-38	Clay

* * *

Test Hole 85, CW, 1933-34, No. 18
Location: NW¼NW¼NE¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1719.5
Static water elevation: 1713.2

0- 3	Topsoil
3-10	Fine sand
10-20	Fine to coarse sand and gravel
20-26	Coarse sand
26-28	Clay

* * *

Test Hole 86, CW, 1933-34, No. 26
Location: NE¼NW¼NE¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1725.2
Static water elevation: not measured

0- 3	Topsoil
3-14	Packed sand
14-18	Clay

* * *

Test Hole 87, CW, 1933-34, No. 24
Location: SE¼NW¼NE¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1724.4
Static water elevation: not measured

0- 3	Topsoil
3-15	Fine to coarse sand and gravel
15-18	Clay

* * *

Observation Well 88, SDGS, 1967-70
Location: NW¼SW¼NE¼ sec. 23, T. 117 N., R. 53 W.
Top of observation well: 1732.61 feet
Depth to water: 14 feet

0- 1	Topsoil
1- 3	Clay, brown
3-28	Sand and gravel

Observation Well 88--continued.

28-48	Clay, pebbly

* * *

Test Hole 89, CW, 1933-34, No. 25
Location: NE¼NE¼NE¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1724.2
Static water elevation: 1714.6

0- 3	Topsoil
3-16	Packed sand
16-18	Clay

* * *

Test Hole 90, SDGS, 1963
Surface elevation: 1730 feet
Depth to water: 14 feet

0-14	Clay, dark-brown; some sand
14-44	Clay, dark-brown
44-54	Clay, blue
54-74	Clay, brown

* * *

Test Hole 91, CW, 1933-34, No. 17
Location: SE¼SE¼NE¼ sec. 23, T. 117 N., R. 53 W.
Surface elevation: 1723.2
Static water elevation: 1715.3

0- 2	Topsoil
2- 8	Coarse sand
8-13	Fine to coarse sand and gravel
13-18	Clay

* * *

Observation Well 92, WRC, No. S-4
Location: SW¼SW¼SW¼SW¼ sec. 24, T. 117 N., R. 52 W.
Surface elevation:
Static water elevation: 4.6 feet

0- 3	Topsoil
3-24	Sand, coarse
24-40	Clay, blue

* * *

Test Hole 93, CW, 1933-34, No. 27
Location: NE¼NW¼NW¼ sec. 24, T. 117 N., R. 53 W.
Surface elevation: 1725.3
Static water elevation: 1715.2

0- 1	Topsoil

Test Hole 93–continued.

1-17	Packed sand
17-18	Boulders
18-20	Clay

* * *

Test Hole 94, CW, 1933-34, No. 28
Location: NE¼NE¼NW¼ sec. 24, T. 117 N., R. 53 W.
Surface elevation: 1722.7
Static water elevation: not measured

0- 1	Topsoil
1- 7	Packed sand
7-18	Clay

* * *

Test Hole 95, CW, 1933-34, No. 23
Location: SW¼SE¼SW¼ sec. 24, T. 117 N., R. 53 W.
Surface elevation: 1725.4
Static water elevation: 1713.4

0- 3	Topsoil
3-10	Packed sand
10-16	Coarse sand
16-18	Clay

* * *

Test Hole 96, SDGS, 1963, No. 33
Surface elevation: 1745 feet
Depth to water: 17 feet

0-29	Clay, brown; some sand
29-49	Sand; some clay
49-54	Till, brown

* * *

Observation Well 97, SDGS, 1967-70
Location: NE¼NE¼NE¼NE¼ sec. 27, T. 117 N., R. 53 W.
Top of observation well: 1732.78 feet
Depth to water: 8 feet

0- 2	Topsoil
2-12	Sand and gravel
12-24	Clay, grayish-tan, pebbly, (till)

* * *

Test Hole 98, CW, 1933-34, No. 53
Location: NW¼NW¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 3	Yellow sand
3-18	Blue sand

Test Hole 98–continued.

18-25	Yellow sand
25-	Clay

* * *

Test Hole 99, CW, 1933-34, No. 51
Location: NE¼NW¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2- 6	Clay
6-27	Blue sand
27-	Clay

* * *

Test Hole 100, CW, 1933-34, No. 52
Location: NW¼NE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2-22	Yellow sand
22-	Clay

* * *

Test Hole 101, CW, 1933-34, No. 54
Location: NW¼NE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0-23	Yellow sand
23-33	Blue sand
33-	Clay

* * *

Test Hole 102, CW, 1933-34, No. 56
Location: SE¼NW¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2-25	Yellow sand
25-	Clay

* * *

Test Hole 103, CW, 1933-34, No. 55
Location: SW¼NE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2-30	Fine yellow sand
30-	Clay

* * *

Test Hole 104, CW, 1933-34, No. 57
Location: SW¼SW¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil

Test Hole 104--continued.

2- 8	White sand
8-	Clay

* * *

Test Hole 105, CW, 1933-34, No. 5
Location: NW¼NW¼SE¼ sec. 26, T. 117 N., R. 53 W.
Surface elevation: 1719.3
Static water elevation: not measured

0- 4	Topsoil
4-11	Fine to coarse sand and gravel
11-28	Clay

* * *

Test Hole 106, CW, 1933-34, No. 39
Location: NE¼NE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 3	Topsoil
3-13	Fine yellow sand
13-	Clay

* * *

Test Hole 107, CW, 1933-34, No. 38
Location: SE¼NE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2-14	Fine yellow sand
14-	Clay

* * *

Test Hole 108, CW, 1933-34, No. 37
Location: SE¼SE¼NE¼ sec. 26, T. 117 N., R. 53 W.

0- 3	Topsoil
3-23	Fine yellow sand
23-	Clay

* * *

Test Hole 109, CW, 1933-34, No. 36
Location: NE¼NE¼SE¼ sec. 26, T. 117 N., R. 53 W.

0- 2	Topsoil
2-25	Fine yellow sand and rock
25-	Clay

* * *

Test Hole 110, CW, 1933-34, No. 55
Location: NE¼NE¼SE¼ sec. 26, T. 117 N., R. 53 W.

Test Hole 110--continued.

0- 3	Topsoil
3-34	Fine yellow sand and rock
34-	Clay

* * *

Test Hole 111, CW, 1933-34, No. 4
Location: SE¼NE¼SE¼ sec. 26, T. 117 N., R. 53 W.
Surface elevation: 1720.0
Static water elevation: 1714.0

0- 4	Topsoil
4- 9	Sand
9-28	Clay

* * *

Test Hole 112, CW, 1964-65, No. 68
Location: SW¼SW¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1731.5
Static water elevation: 1724.5

0- 1	Topsoil
1- 2	Brown clay
2-13	Fine to coarse sand and gravel, 6" mud loss
13-33	Brown clay

* * *

Test Hole 113, CW, 1933-34, No. 3
Location: NW¼SW¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1717.8
Static water elevation: 1714.0

0- 4	Topsoil
4- 9	Sand
9-28	Clay

* * *

Test Hole 114, CW, 1964-65, No. 64
Location: NW¼SW¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1730.2
Static water elevation: 1718.9

0- 1	Topsoil
1- 2	Brown clay
2-19	Fine to coarse sand and gravel, 1' mud loss
19-33	Brown clay

* * *

Test Hole 115, CW, 1933-34, No. 47
Location: SW¼NW¼SW¼ sec. 25, T. 117 N., R. 53 W.

Test Hole 115--continued.

0- 3	Topsoil
3-18	Coarse yellow sand
18-	Clay

* * *

Test Hole 116, CW, 1933-34, No. 42
Location: SW¼SW¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 3	Topsoil
3-17	Coarse yellow gravel
17-	Clay

* * *

Test Hole 117, CW, 1933-34, No. 58
Location: NW¼NW¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 3	Topsoil
3-25	Yellow sand
25-	Clay

* * *

Test Hole 118, CW, 1933-34, No. 59
Location: NE¼NW¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 3	Topsoil
3-13	Yellow sand
13-	Clay

* * *

Test Hole 119, CW, 1933-34, No. 60
Location: NE¼NW¼NW¼ sec. 25, T. 117 N., R. 52 W.

0 - 2	Topsoil
2 -18½	Yellow and blue sand
18½-	Clay

* * *

Test Hole 120, CW, 1933-34, No. 16
Location: NW¼NE¼NW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1721.3
Static water elevation: 1714.3

0- 2	Topsoil
2- 8	Coarse sand
8-15	Fine to coarse sand and gravel
15-19	Coarse sand
19-25	Clay

* * *

Observation Well 121, SDGS, 1967-70
Location: SE¼NE¼NW¼ sec. 25, T. 117 N., R. 53 W.
Top of observation well: 1723.49 feet
Depth to water: 6 feet

0- 2	Topsoil
2-17	Sand and gravel
17-24	Clay, dark-brown, pebbly, (till)

* * *

Test Hole 122, CW, 1933-34, No. 14
Location: NE¼SW¼NW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1720.9
Static water elevation: dry hole

0-2	Topsoil
2-5	Sand
5-8	Clay

* * *

Test Hole 123, CW, 1933-34, No. 15
Location: NE¼SW¼NW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1720.1
Static water elevation: 1713.6

0- 3	Topsoil
3- 7	Sand
7-16	Fine to coarse sand and gravel
16-18	Clay

* * *

Test Hole 124, CW, 1933-34, No. 46
Location: NW¼SE¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 2	Topsoil
2-20	Yellow and blue sand, coarse gravel
20-	Clay

* * *

Test Hole 125, CW, 1933-34, No. 45
Location: SE¼NE¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 2	Topsoil
2-15	Yellow and blue sand
15-	Clay

* * *

Test Hole 126, CW, 1933-34, No. 44
Location: NW¼SE¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 3	Topsoil
3-20	Yellow and blue sand

Test Hole 126--continued.

20-	Clay

* * *

Test Hole 127, CW, 1964-65, No. 50
Location: SE¼SW¼NW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1727.4
Static water elevation: 1719.4

0- 1	Sandy topsoil, brown silt streak ?
1-23	Fine to very coarse sand and gravel, 1" mud loss
23-33	Brown clay

* * *

Test Hole 128, CW, 1933-34, No. 41
Location: SE¼SW¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 2	Topsoil
2-32	Very fine yellow and blue sand, some gravel
32-	Clay

* * *

Test Hole 129, CW, 1933-34, No. 43
Location: SW¼SE¼NW¼ sec. 25, T. 117 N., R. 53 W.

0- 2	Topsoil
2-23	Coarse yellow sand
23-	Clay

* * *

Test Hole 130, CW, 1933-34, No. 13
Location: NE¼NW¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1718.4
Static water elevation: 1714.1

0- 2	Topsoil
2- 8	Fine sand
8-15	Fine to coarse sand and gravel
15-18	Clay

* * *

Test Hole 131, CW, 1933-34, No. 12
Location: NW¼NE¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1718.7
Static water elevation: 1714.6

0- 3	Topsoil
3-13	Fine to coarse sand and gravel
13-18	Clay

* * *

Test Hole 132, CW, 1933-34, No. 11
Location: SW¼NE¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1718.3
Static water elevation: 1714.0

0- 3	Topsoil
3- 8	Fine to coarse sand and gravel
8-11	Fine sand
11-21	Fine to coarse sand and gravel
21-28	Clay

* * *

Test Hole 133, CW, 1933-34, No. 20
Location: NE¼SE¼SW¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1720.1
Static water elevation: 1713.6

0- 2	Topsoil
2-15	Fine to coarse sand and gravel, packed
15-18	Clay

* * *

Test Hole 134, CW, 1964-65, No. 58
Location: SW¼SW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1721.6
Static water elevation: 1713.6

0- 2	Topsoil
2-35	Fine to coarse sand and gravel, 1' 16" mud loss
35-48	Brown clay

* * *

Test Hole 135, CW, 1933-34, No. 2
Location: NW¼SW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1717.4
Static water elevation: 1713.5

0- 3	Topsoil
3- 8	Fine sand
8-15	Fine to coarse sand and gravel
15-18	Fine sand
18-19	Boulders
19-23	Clay

* * *

Test Hole 136, CW, 1933-34, No. 21
Location: NW¼SW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1719.4
Static water elevation: 1712.9

0- 2	Topsoil
2- 8	Fine to coarse sand and gravel
8-18	Coarse sand

Test Hole 136--continued.

18-22	Gravel
22-26	Sand
26-28	Clay

* * *

Test Hole 137, CW, 1933-34, No. 22
Location: NW¼SW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1722.0
Static water elevation: not measured

0- 2	Topsoil
2-15	Packed sand
15-20	Clay

* * *

Test Hole 138, CW, 1933-34, No. 1
Location: NW¼SW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1717.3
Static water elevation: 1713.5

0- 3	Topsoil
3- 17	Fine to coarse sand and gravel
17-108	Clay

* * *

Test Hole 139, CW, 1933-34, No. 19
Location: SW¼NW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1718.0
Static water elevation: 1713.5

0- 3	Topsoil
3-13	Fine to coarse sand and gravel
13-16	Fine sand
16-18	Clay

* * *

Test Hole 140, CW, 1933-34, No. 10
Location: NW¼NW¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1725.7
Static water elevation: 1715.3

0- 2	Topsoil
2-12	Fine to coarse sand and gravel
12-23	Clay

* * *

Test Hole 141, SDGS, 1963, No. 34
Surface elevation: 1721 feet
Depth to water: 4 feet

Test Hole 141--continued.

0-17	Sand; clay, poorly sorted
17-39	Sand; some clay
39-59	Clay, gray, sandy
59-64	Clay, blue
64-69	Till, brown

* * *

Test Hole 142, CW, 1933-34, No. 8
Location: SE¼SE¼NE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1712.8
Static water elevation: 1707.7

0- 2	Topsoil
2- 7	Fine to coarse sand and gravel
7-18	Clay

* * *

Test Hole 143, SDGS, 1967-70
Location: SW¼NE¼NE¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1720 feet
Depth to water: 3 feet

0- 2	Topsoil
2- 5	Sand, coarse
5-40	Clay, pebbly, (till)

* * *

Test Hole 144, CW, 1964-65, No. 59
Location: NE¼SE¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1717.0
Static water elevation: dry hole

0- 1	Topsoil
1- 3	Fine to very coarse sand and gravel
3- 4	Boulders
4-18	Brown clay

* * *

Test Hole 145, SDGS, 1967-70
Location: NE¼SE¼SE¼SE¼ sec. 25, T. 117 N., R. 53 W.
Surface elevation: 1718 feet
Depth to water: 3 feet

0- 1	Topsoil
1-42	Clay, pebbly, (till)

* * *

Test Hole 146, CW, 1933-34, No. 7
Location: SW¼SW¼NW¼ sec. 30, T. 117 N., R. 52 W.
Surface elevation: 1718.8
Static water elevation: 1708.4

Test Hole 146–continued.

0- 2	Topsoil
2-11	Fine to coarse sand and gravel
11-28	Clay

* * *

Test Hole 147, CW, 1933-34, No. 6
Location: SE¼NW¼SW¼ sec. 30, T. 117 N., R. 52 W.
Surface elevation: 1721.4
Static water elevation: 1713.9

0- 2	Topsoil
2-26	Fine to coarse sand and gravel-packed
26-29	Clay
29-30	Boulders
30-33	Clay

* * *

Test Hole 148, SDGS, 1967-70
Location: SW¼SW¼SW¼SW¼ sec. 31, T. 117 N., R. 53 W.
Surface elevation: 1729 feet
Depth to water: 19 feet

0- 3	Roadbed
3- 7	Clay, dark-gray
7-19	Clay, dark-brown
19-24	Sand and gravel
24-34	Clay, dark-gray, pebbly, (till)

* * *

Test Hole 149, SDGS, 1967-70
Location: NW¼NW¼NW¼NW¼ sec. 33, T. 117 N., R. 53 W.
Surface elevation: 1722 feet
Depth to water: 6 feet

0- 2	Roadbed
2-11	Clay, dark-gray
11-17	Sand, fine to coarse; some gravel
17-47	Sand, coarse; gravel
47-55	Clay
55-63	Sand and gravel
63-71	Clay
71-73	Sand and gravel
73-84	Clay, dark-gray, pebbly, (till)

* * *

Test Hole 150, SDGS, 1957, No. 10
Location: SW¼SW¼ sec. 33, T. 117 N., R. 53 W.
Surface elevation: 1770 feet
Static water elevation: not measured

0- 3	Topsoil and till

Test Hole 150--continued.

3-20	Silt; some sand, (till)

* * *

Test Hole 151, SDGS, 1967-70
Location: SE¼SE¼SE¼SW¼ sec. 33, T. 117 N., R. 53 W.
Surface elevation: 1750 feet
Depth to water: dry

0- 2	Topsoil
2-25	Sand, fine to coarse
25-39	Clay, dark-brown, compact, pebbly, (till)

* * *

Test Hole 152, SDGS, 1967-70
Location: SW¼SE¼SE¼SE¼ sec. 33, T. 117 N., R. 53 W.
Surface elevation: 1740 feet
Depth to water: 22 feet

0- 2	Topsoil
2-31	Sand, coarse; gravel
31-49	Clay, dark-gray, compact, (till)

* * *

Test Hole 153, SDGS, 1957, No. 11
Location: SE¼SE¼ sec. 33, T. 117 N., R. 53 W.
Surface elevation: 1740? feet
Static water elevation: 1666 feet

0- 1	Topsoil
1-20	Gravel; sand; silt mixture
20-21	Pea gravel
21-25	Silt and pea gravel
25-27	Clay and sand, (dry)
27-44	Dry silt and occasional sand grains
44-55	Clay with sand grains, (water)

* * *

Test Hole 154, SDGS, 1967-70
Location: SW¼SW¼SW¼SW¼ sec. 34, T. 117 N., R. 53 W.
Surface elevation: 1746 feet
Depth to water: dry? (not measured)

0- 1	Topsoil
1-14	Sand and gravel
14-24	Clay, dark-brown, (till)

* * *

Test Hole 155, SDGS, 1963, No. 40
Surface elevation: 1746 feet
Depth to water: 35 feet

Test Hole 155--continued.

0-19	Sand, brown; gravel; some clay
19-29	Till, brown
29-44	Till, blue
44-54	Clay, buff
54-59	Till, blue

* * *

Test Hole 156, SDGS, 1957, No. 49
Location: SW¼SW¼ sec. 34, T. 117 N., R. 53 W.
Surface elevation: 1752 feet
Static water elevation: 1743 feet

0- 9	Topsoil
9-10	Silt, tan; sand; water
10-23	Till, clay, blue

* * *

Test Hole 157, SDGS, 1963, No. 41
Surface elevation: 1739 feet
Depth to water: not measured

0- 4	Topsoil
4-74	Till, brown; poor cuttings

* * *

Test Hole 158, SDGS, 1957, No. 12
Location: NW¼SW¼ sec. 35, T. 117 N., R. 53 W.
Surface elevation: 1751 feet
Static water elevation: 1735 feet

0- 9	Topsoil
9-12	Sand
12-55	Silt, tan; sand grains, (water)
55-65	Silt with sand

* * *

Test Hole 159, SDGS, 1963, No. 35
Surface elevation: 1775 feet
Depth to water: dry

0-74	Clay, dark

* * *

Test Hole 160, SDGS, 1967-70
Location: NE¼NE¼NE¼NE¼ sec. 35, T. 117 N., R. 53 W.
Surface elevation: 1730 feet
Depth to water: dry

0- 1	Topsoil
1- 3	Sand, coarse

Test Hole 160--continued.

3-15	Sand; some gravel
15-39	Clay, gravelly

* * *

Observation Well 161, SDGS, 1967-70
Location: SE¼SE¼SE¼NE¼ sec. 35, T. 117 N., R. 53 W.
Top of observation well: 1730.34 feet
Depth to water: 8 feet

0- 1	Topsoil
1- 6	Sand, brown, medium
6- 8	Sand, coarse
8-13	Sand, medium
13-15	Gravel, coarse
15-25	Clay, pebbly, (till)

* * *

Test Hole 162, SDGS, 1963, No. 39
Surface elevation: 1732 feet
Depth to water: 9 feet

0-10	Sand; gravel; becoming silty
10-14	Sand; gravel; saturated
14-34	Clay, sandy
34-49	Sand, fine, silty

* * *

Test Hole 163, SDGS, 1957, No. 13
Location: SW¼SW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1717 feet
Static water elevation: 1709 feet

0- 2	Topsoil
2- 8	Sand, clean; medium
8-20	Sand; some silt
20-55	Clay, dark, hard, dry; occasional sand grains
55-65	Sand; much silt, (water)

* * *

Test Hole 164, CW, 1933-34, No. 33
Location: NE¼SW¼SW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1733.3
Static water elevation: 1708.3

0- 4	Topsoil
4-23	Packed sand
23-28	Fine sand
28-30	Clay
30-34	Fine sand
34-38	Clay

* * *

Test Hole 165, CW, 1964-65, No. 67
Location: NW¼SE¼NW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1729.8
Static water elevation: dry hole

0- 1	Topsoil
1- 4	Brown clay
4-14	Fine to coarse sand and gravel, 6" mud loss
14-16	Boulders, gray clay
16-25	Fine to coarse sand, 3" mud loss
25-33	Brown clay

* * *

Test Hole 166, CW, 1964-65, No. 66
Location: SW¼NE¼NW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1724.7
Static water elevation: 1717.6

0- 1	Fill
1- 2	Black dirt
2- 5	Brown clay
5-17	Fine to coarse sand and gravel, 1' mud loss
17-25	Boulders, gray clay

* * *

Test Hole 167, CW, 1964-65, No. 65
Location: NW¼NE¼NW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1721.9
Static water elevation: 1718.4

0- 1	Road bed
1-12	Fine to coarse sand and gravel, 6" mud loss
12-18	Brown clay

* * *

Test Hole 168, CW, 1964-65, No. 62
Location: SE¼NE¼NW¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1724.3
Static water elevation: 1713.6

0- 1	Topsoil
1-30	Fine to coarse sand and gravel, 1' mud loss
30-32	Boulders, gray clay
32-48	Brown clay

* * *

Test Hole 169, CW, 1964-65, No. 51
Location: NW¼NW¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1717.8
Static water elevation: 1712.6

0- 1	Road bed
1- 4	Brown clay

Test Hole 169--continued.

4-14	Medium to very coarse sand and gravel, 6" mud loss
14-15	Black silt and boulders
15-33	Brown clay

* * *

Test Hole 170, CW, 1964-65, No. 70
Location: NW¼NW¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1721.8
Static water elevation: 1715.8

0- 2	Black dirt
2- 4	Brown clay
4-13	Fine to coarse sand and gravel, 6" mud loss
13-14	Brown silt
14-25	Fine to coarse sand and gravel, 1" mud loss
25-33	Boulders and brown clay

* * *

Test Hole 171, CW, 1964-65, No. 61
Location: NW¼SW¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1722.1
Static water elevation: 1713.2

0- 1	Road fill
1- 2	Black dirt
2- 5	Brown clay
5-13	Fine to very coarse sand and gravel, 6" mud loss
13-16	Boulders, gray clay
16-33	Brown clay

* * *

Test Hole 172, CW, 1964-65, No. 69
Location: NW¼SW¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: not measured
Static water elevation: not measured

0- 1	Topsoil
1-11	Fine to coarse sand and gravel, 6" mud loss
11-13	Brown clay
13-18	Fine to medium sand
18-33	Brown clay

* * *

Test Hole 173, CW, 1964-65, No. 60
Location: SE¼NW¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1718.5
Static water elevation: 1712.7

0- 1	Road fill
1- 3	Black dirt
3- 5	Brown clay

Test Hole 173–continued.

5-17	Fine to coarse sand and gravel, 6" mud loss
17-33	Boulders, brown clay

* * *

Test Hole 174, CW, 1933-34, No. 32
Location: NE¼NW¼SE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1724.4
Static water elevation: not measured

0- 4	Topsoil
4-10	Coarse sand
10-23	Fine to coarse sand and gravel, packed
23-25	Clay

* * *

Test Hole 175, SDGS, 1963, No. 42
Surface elevation: 1717 feet
Depth to water: 4 feet

0- 4	Sand, medium
4-24	Sand, medium
24-34	Gravel, fine
34-44	No cuttings

* * *

Test Hole 176, CW, 1964-65, No. 57
Location: NE¼SE¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1717.4
Static water elevation: 1706.2

0- 2	Topsoil
2-21	Fine to very coarse sand and gravel
21-23	Boulders, mud loss 1'
23-33	Brown clay

* * *

Test Hole 177, CW, 1964-65, No. 71
Location: SW¼NE¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1714.0
Static water elevation: 1711.1

0- 1	Topsoil
1-14	Fine to coarse sand and gravel, 6" mud loss
14-16	Gray clay
16-18	Brown clay

* * *

Test Hole 178, CW, 1964-65, No. 49
Location: NE¼SE¼NE¼ sec. 36, T. 117 N., R. 53 W.
Surface elevation: 1714.1
Static water elevation: 1707.1

0- 2	Sandy topsoil, gravel mixed
2-11	Fine to very coarse sand and gravel, 6" mud loss
11-33	Hard brown silty clay

* * *

Test Hole 179, CW, 1964-65, No. 54
Location: SW¼NW¼SW¼ sec. 31, T. 117 N., R. 52 W.
Surface elevation: 1714.40
Static water elevation: 1708.15

0- 3	Fill
3-21	Fine to very coarse sand and gravel
21-24	Boulders
24-25	Black silt
25-33	Brown clay boulders

* * *

Test Hole 180, CW, 1964-65, No. 53
Location: NW¼NE¼SW¼ sec. 31, T. 117 N., R. 52 W.
Surface elevation: 1714.65
Static water elevation: 1708.7

0- 2	Topsoil
2- 6	Brown clay
6-10	Fine to coarse sand and gravel, sea shells
10-11	Brown silt
11-25	Gray clay

* * *

Test Hole 181, SDGS, 1963, No. 44
Surface elevation: 1727 feet
Depth to water: not measured

0-14	Gravel, poorly sorted; clay, brown
14-29	Gravel, coarse to fine; some clay
29-45	Gravel, poorly sorted; less clay
45-54	Gravel
54-74	Sand, fine; some clay
74-89	Clay, blue

* * *

Test Hole 182, SDGS, 1963, No. 45
Surface elevation: 1724 feet
Depth to water: 19 feet

0-24	Sand; gravel; clay
24-44	Gravel, medium; some clay
44-59	Gravel; some clay

Test Hole 182--continued.

59-69	Gravel, fine
69-74	Clay, dark-brown

* * *

Test Hole 183, SDGS, 1963, No. 49
Surface elevation: 1743 feet
Depth to water: not measured

0-14	Sand; gravel; clay; poorly sorted
14-29	Sand, fine, clean
29-44	Sand; some clay
44-69	Clay, brown; some sand
69-89	Till, blue

* * *

Test Hole 184, SDGS, 1963, No. 50
Surface elevation: 1725 feet
Depth to water: 34 feet

0- 4	Topsoil
4-36	Clay; sand; gravel, poorly sorted
36-79	Clay; sand and gravel
79-84	Clay, blue

* * *

Observation Well 185, SDGS, 1967-70
Location: NW¼NE¼NE¼NE¼ sec. 2, T. 116 N., R. 53 W.
Surface elevation: 1725 feet
Depth to water from the top of pipe: 16.6 feet

0- 2	Topsoil
2- 9	Sand and gravel
9-27	Sand, very fine, brown
27-39	Clay, brownish-gray, pebbly, (till)

* * *

Observation Well 186, SDGS, 1967-70
Location: SE¼SE¼NE¼NE¼ sec. 2, T. 116 N., R. 53 W.
Top of observation well: 1726.45 feet
Depth to water: 19 feet

0- 1	Topsoil
1-33	Sand, brown, fine
33-52	Gravel
52-55	Sand, coarse

* * *

Test Hole 187, SDGS, 1963, No. 51
Surface elevation: 1720 feet
Depth to water: 19 feet

Test Hole 187--continued.

0- 9	Clay, brown
9-14	Sand; some clay
14-20	Clay, sandy
20-39	Clay, sandy
39-84	Sand, coarse, silty

* * *

Test Hole 188, SDGS, 1963, No. 52
Surface elevation: 1718 feet
Depth to water: not measured

0-24	Gravel, fine
24-84	Gravel; sand; high clay content
84-99	Clay, sandy

* * *

Observation Well 189, SDGS, 1967-70
Location: SE¼SE¼SE¼NW¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation: 1712 feet (approximately)
Depth to water: 3 feet

0- 1	Topsoil
1- 2	Clay, sandy
2- 4	Gravel
4-42	Sand, coarse
42-46	Gravel
46-50	Clay, gray, (till)

* * *

Test Hole 190, CW, 1964-65, No. 55
Location: SE¼SE¼NW¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation: 1713.0
Static water elevation: 1708.24

0- 3	Road bed
3-35	Fine to very coarse sand and gravel, boulders, 1" mud loss
35-39	Gray clay
39-45	Fine to coarse sand, cemented, boulders, 3" mud loss
45-68	Gray clay
68-77	Coarse sand and gravel
77-83	Gray clay and boulders

* * *

Test Hole 191, CW, 1964-65, No. 45
Location: NW¼NW¼NE¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation: 1710.99
Static water elevation: 1706.39

0- 1	Topsoil
1- 5	Brown clay
5-15	Fine to very coarse sand and gravel, 1' mud loss

Test Hole 191--continued.

15-17	Brown clay
17-23	Fine to very coarse sand and gravel, 1' mud loss
23-27	Gray clay
27-35	Brown silty clay
35-40	Fine to coarse cemented sand, 3" mud loss
40-	Gray clay (hard)
-75	Very coarse sand and gravel, 6" mud loss
75-84	Gray clay with boulders

* * *

Test Hole 192, SDGS, 1957, No. 23
Location: NW¼NE¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation: 1720 feet
Static water elevation: 1707 feet

0- 5	Topsoil
5-25	Gravel, pea-size
25-45	Coarse sand; water
45-	Rock and gravel

* * *

Test Hole 193, SDGS, 1957, No. 24
Location: NE¼NE¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation: 1719 feet
Static water elevation: 1707 feet

0- 8	Topsoil
8-45	Sand and black silt
45-	Rocks

* * *

Observation Well 194, WRC, No. WA3
Location: SW¼SW¼SW¼SE¼ sec. 6, T. 116 N., R. 52 W.
Surface elevation:
Static water level: 10 feet

0- 2	Topsoil
2-10	Sand, brown, coarse, coarse gravel
10-50	Clay, sandy, some brown gravel

* * *

Test Hole 195, SDGS, 1963, No. 53
Surface elevation: 1720 feet
Depth to water: 9 feet

0- 9	Sand, poorly sorted, silty
9-34	Clay, buff, sandy
34-69	Till, dark-brown

* * *

Test Hole 196, SDGS, 1963, No. 43
Surface elevation: 1715 feet
Depth to water: 4 feet

0- 4	Topsoil
4- 29	Sand, dark, coarse; clay; gravel, poorly sorted
29-125	Clay, blue; some gravel
125-150	Clay, blue

* * *

Test Hole 197, CW, 1933-34, No. 34
Location: NE¼NE¼NW¼ sec. 5, T. 116 N., R. 52 W.
Surface elevation: 1714.9
Static water elevation: 1706.8

0- 3	Topsoil
3-16	Fine to coarse sand and gravel, packed
16-18	Clay

* * *

Test Hole 198, SDGS, 1957, No. 42
Location: SE¼SE¼ sec. 5, T. 116 N., R. 52 W.
Surface elevation: 1714 feet
Static water elevation: 1702 feet

0- 8	Topsoil
8-12	Gravel; sand, coarse
12-20	Sand, coarse; gravel, fine; water
20-22	Gravel, fine; sand, clean, coarse
22-32	Gravel, medium, clean, good for irrigation
32-42	Sand, clean, medium
42-54	Gravel, medium; silt, gray
54-60	Clay, blue; gravel, small, (till)

* * *

Test Hole 199, CW, 1964-65, No. 56
Location: SE¼SE¼SE¼ sec. 5, T. 116 N., R. 52 W.
Surface elevation: 1715.9
Static water elevation: 1708.19

0- 2	Black dirt
2- 5	Brown clay
5-23	Fine to coarse sand and gravel, 1' mud loss
23-33	Boulders and gray clay

* * *

Test Hole 200, SDGS, 1957, No. 47
Location: SW¼NW¼ sec. 12, T. 116 N., R. 53 W.
Surface elevation: 1721 feet
Static water elevation: 1709 feet

0- 8	Topsoil
8- 12	Gravel, fine; sand, coarse; silt

Test Hole 200--continued.

12- 25	Sand, coarse; silt; water
25- 55	Silt; sand, medium; water
55- 93	Silt, gray; sand, medium
93-100	Clay, blue, (till)

* * *

Test Hole 201, SDGS, 1963, No. 59
Surface elevation: 1735 feet
Depth to water: 21 feet

0-19	Clay; some sand
19-39	Clay, brown
39-49	Till, blue

* * *

Test Hole 202, SDGS, 1963, No. 56
Surface elevation: 1726 feet
Depth to water: 14 feet

0-39	Sand, medium; clay increases downward
39-44	Clay, brown; some sand
44-54	Drills like till
54-69	Clay; little sand
69-74	Clay, blue

* * *

Test Hole 203, SDGS, 1963, No. 57
Surface elevation: 1715 feet
Depth to water: 19 feet

0-19	Topsoil and clay
19-24	Gravel, fine, silty
24-84	Till, brown
84-94	Clay, buff
94-98	Clay, blue

* * *

Test Hole 204, SDGS, 1957, No. 15
Location: SE¼SE¼ sec. 14, T. 116 N., R. 53 W.
Surface elevation: 1763 feet
Static water elevation: not measured

0- 3	Topsoil
3-40	Silt; clay (dry); gravel, small and large stones intermixed, (till with quartz)

* * *

Test Hole 205, SDGS, 1957, No. 14
Location: NE¼NE¼ sec. 22, T. 116 N., R. 53 W.
Surface elevation: 1749 feet
Static water elevation: 1740 feet

Test Hole 205–continued.

0- 4	Topsoil
4- 6	Silt and clay mixed with gravel
6-14	Sand; gravel, wet
14-19	Mostly silt; some sand; some gravel
19-38	Clay, tan; silt with some sand
38-49	Sand
49-65	Silt, tan; clay

* * *

APPENDIX C

Water-level measurement for June 30, 1970
in the Lake Kampeska study area
(For map location, see fig. 12.)

Observation well number and location	Water level in feet above sea level
11. SW¼SE¼SE¼ sec. 21, T. 52 W., R. 118 N.	1725.13
13. NE¼NW¼NW¼NW¼ sec. 22, T. 118 N., R. 52 W.	1725.79
14. SE¼SE¼SE¼SE¼ sec. 36, T. 118 N., R. 53 W.	1732.45
23. NW¼NW¼NW¼NW¼ sec. 33, T. 118 N., R. 52 W.	1754
28. SW¼SW¼SW¼SW¼ sec. 2, T. 117 N., R. 53 W.	1720.17
52. NE¼SE¼SE¼SE¼ sec. 11, T. 117 N., R. 53 W.	1716.71
62 NE¼NE¼NE¼NE¼ sec. 7, T. 117 N., R. 52 W.	1734.62
Lake Kampeska inlet-outlet on Highway 20 Bridge	1716.91
73. SE¼SE¼SE¼SE¼ sec 14, T. 117 N., R. 53 W.	1717.06
97. NE¼NE¼NE¼NE¼ sec. 27, T. 117 N., R. 53 W.	1725.06
121. SE¼NE¼NW¼ sec. 25, T. 117 N., R. 53 W.	1719.63
161. SE¼SE¼SE¼SE¼ sec. 35, T. 117 N., R. 53 W.	1717.33
186. SE¼SE¼NE¼NE¼ sec. 2, T. 116 N., R. 53 W.	1710.70
Pelican Lake	1708

Some of the observation wells were destroyed by vehicles and construction of roads and are not included in this list.

APPENDIX D

Water levels for Lake Kampeska from 1928 to 1945

Measurement in feet above mean sea level*

Year	January	February	March	April	May	June	July	August	September	October	November	December
1928	1720.2	1720.5	1720.8	1720.5	1720.0	1719.5	1719.3	1719.2	1718.8	1718.7	1718.6	1718.5
1929	1718.5	1718.9	1721	1720.8	1720.3	1719.8	1719.1	1718.8	1718.4	1718.3	1718.3	1718.3
1930	1718.3	1718.5	1719.1	1719.1	1719.1	1719	1718.8	1718.3	1717.8	1717.5	1717.5	1717.5
1931	1717.5	1717.5	1717.3	1717.0	1718.7	1718.7	1718.6	1718.1	1717.5	1717.2	1717.1	1717.1
1932	1717.2	1717.2	1717.7	1717.9	1718.2	1718.3	1718.4	1718.4	1717.7	1717.5	1717.5	1717.5
1933	1717	1717	1717.2	1717	1716.1	1716.7	1716.5	1715.7	1715.5	1715	1714.7	1714.7
1934	1714.7	1714.7	1714.7								1712.9	1712.5
1935	1712.9	1712.9	1714.5	1715	1715.1	1715.3	1715.5	1715	1714.8	1714.2		1714
1936	1714		1714.1	1715	1715.7	1715.6	1715.1	1714.1	1713.5	1713.1	1712.9	1712.9
1937	1712.9		1713.4	1716.5	1720.6	1721.5	1720.8		1720.1	1719.7	1719.6	1719.6
1938	1719.6		1719.9	1721.1	1721.2	1720.8	1720.8	1720.6	1719.8	1719.7	1719.3	1719.2
1939												
1940						No reliable data						
1941												
1942			1718.4	1720.3		1720.5	1720.4			1720		1720
1943												
1944								1719.9	1719.6	1719.3	1719.2	1720

The data were obtained from several graphs and numerical tables; available from S. D. G. S. files, Dept. of Game, Fish, and Parks, and *Watertown Public Opinion* (see references cited).
These are approximate elevations.
*Measurements may be 2.53 feet higher than indicated elevations.

APPENDIX E

Water levels for Lake Kampeska from 1945 through 1970

(Measurements are in feet above mean sea level.)

Taken at City Water Plant
(Figures are 2.53 feet higher than indicated elevations.)[1]

Year	January	February	March	April	May	June	July	August	September	October	November	December
1945	1719’	1718’11”	1718’10”	1719’4”	1719’4”	1720’7”	1719’11”	1719’3”	1719’	1718’9”	1718’8”	1718’8”
1946	1718’8”	1718’9”	1718’10”	1721’2”	1719’9”	1719’7”	1719’8”	1719’2”	1719’4”	1719’6”	1719’7”	1719’5”
1947	1719’	1719’	1719’1”	1719’8”	1720’10”	1719’8”	1719’2”	1719’1”	1719’	1718’9”	1718’8”	1718’6”
1948	1718’6”	1718’6”	1718’7”	1721’6”	1720’4”	1719’8”	1719’4”	1719’2”	1719’	1718’11”	1718’11”	1718’10”
1949	1718’10”	1718’10”	1719’9”	1719’9”	1719’6”	1719’4”	1718’10”	1718’5”	1718’3”	1718’	1717’8”	
1950	1718’	1718’1”	1719’4”	1720’	1720’1”	1719’1”	1719’1”	1719’1”	1718’8”	1718’9”	1718’6”	1718’6”
1951	1718’6”	1718’6”	1720’4”	1721’1”	1719’11”	1719’11”	1719’11”	1719’10”	1719’8”	1719’5”	1719’6”	1719’6”
1952	1719’7”	1719’9”	1719’8”	1721’10”	1719’11”	1719’7”	1719’10”	1719’4”	1718’11”	1718’7”	1718’5”	1718’4”
1953	1718’5”	1718’6”	1719’10”	1720’1”	1720’	1720’5”	1720’8”	1720’3”	1719’6”	1719’4”	1719’2”	1719’3”
1954	1718’11”	1718’11”	1719’9”	1720’3”	1720’2¾”	1720’4”	1719’3½”	1718’10½”	1718’9¼”	1718’7½”	1718’7”	1718’7”
1955	1718’7”	1718’8”	1719’2”	1719’6”	1719’4”	1719’2”	1719’2”	1718’10”	1718’7”	1718’3”	1718’1”	1718’1”
1956	1718’2”	1718’2”	1718’4”	1719’2”	1719’7”	1719’9”	1719’8”	1720’	1719’6”	1719’3”	1719’3½”	1719’4”
1957	1719’4”	1719’4”	1719’11”	1720’1/3”	1720’4”	1720’3½”	1719’9”	1719’2½”	1719’4”	1719’5½”	1719’8½”	1719’8½”
1958	1719’7½”	1719’7”	1719’8”	1720’1”	1719’10”	1719’7”	1719’4”	1718’10”	1718’5½”	1718’	1717’10½”	1717’10½”
1959	1717’11”	1718’½”	1718’	1718’2”	1718’2”	1718’2”	1717’9”	1717’3¼”	1716’9”	1716’7”	1716’6¼”	1716’7”
1960	1716’8¼”	1716’8”	1717’3-1/3”	1720’4¾”	1720’1½”	1720’1.3”	1719’8¼”	1719’2½”	1718’11”	1718’8½”	1718’6½”	1718’6½”
1961		1718’8”	1718’11”	1719’	1719’3½”	1719’5”	1719’1¼”	1718’7”	1718’5”	1718’3½”	1718’2”	1718’2½”
1962[2]	1718.2’	1718.2’	1719.6’	1720.6’	1721.6’	1721.6’	1721’	1720.3’	1719.4’	1719.6’	1719.6’	1719.7’
1963	1719.7’	1719.7’	1719.9’	1720.4’	1720.5’	1720.4’	1720.3’		1719.8’	1719.8’	1719.8’	1719.7’
1964	1719.6’	1719.5’	1719.7’	1720.4’	1720.4’	1719.8’	1719.5’	1718.9’	1718.7’	1718.5’	1718.2’	1718.2’
1965	1718.2’	1718.2’	1718.3’	1720.6’	1721.2’	1720.4’	1720.2’	1719.6’	1719.3’	1719.5’	1719.4’	1719.4’
1966	1719.4’		1720.6’	1720.4’		1720’	1719.7’	1719.3’	1719.4’	1719.2’		
1967	1719.2’	1719.1’	1720.6’	1720.5’	1720.4’	1720.1’	1720.2’	1719.3’	1718.9’	1718.7’	1718.5’	1718.4’
1968	1718.4’	1718.5’	1718.4’	1718.7’	1718.7’	1718.8’	1718.7’	1718.5’	1718.2’	1718.1’	1718.2’	1718.3’
1969			1718.5’	*	1720.7’	1718.8’	1719.8’	1719.7’	1719.3’	1719.2’	1719.1’	1719.3’
1970	1719.3’	1719.3’	1719.7’	1720.2’	1720.4’	1720.4’	1720.1’	1720.4’	1719.1’	1718.8’	1718.9’	1718.9’

[1] John Babcock, personal communication, City of Watertown Engineer
[2] Years 1962-1970 measured to tenths of a foot.
*See attachment to appendix E.

ATTACHMENT TO APPENDIX E

Lake Levels

(Taken at Filtration Plant—Lake Kampeska)

April 1969

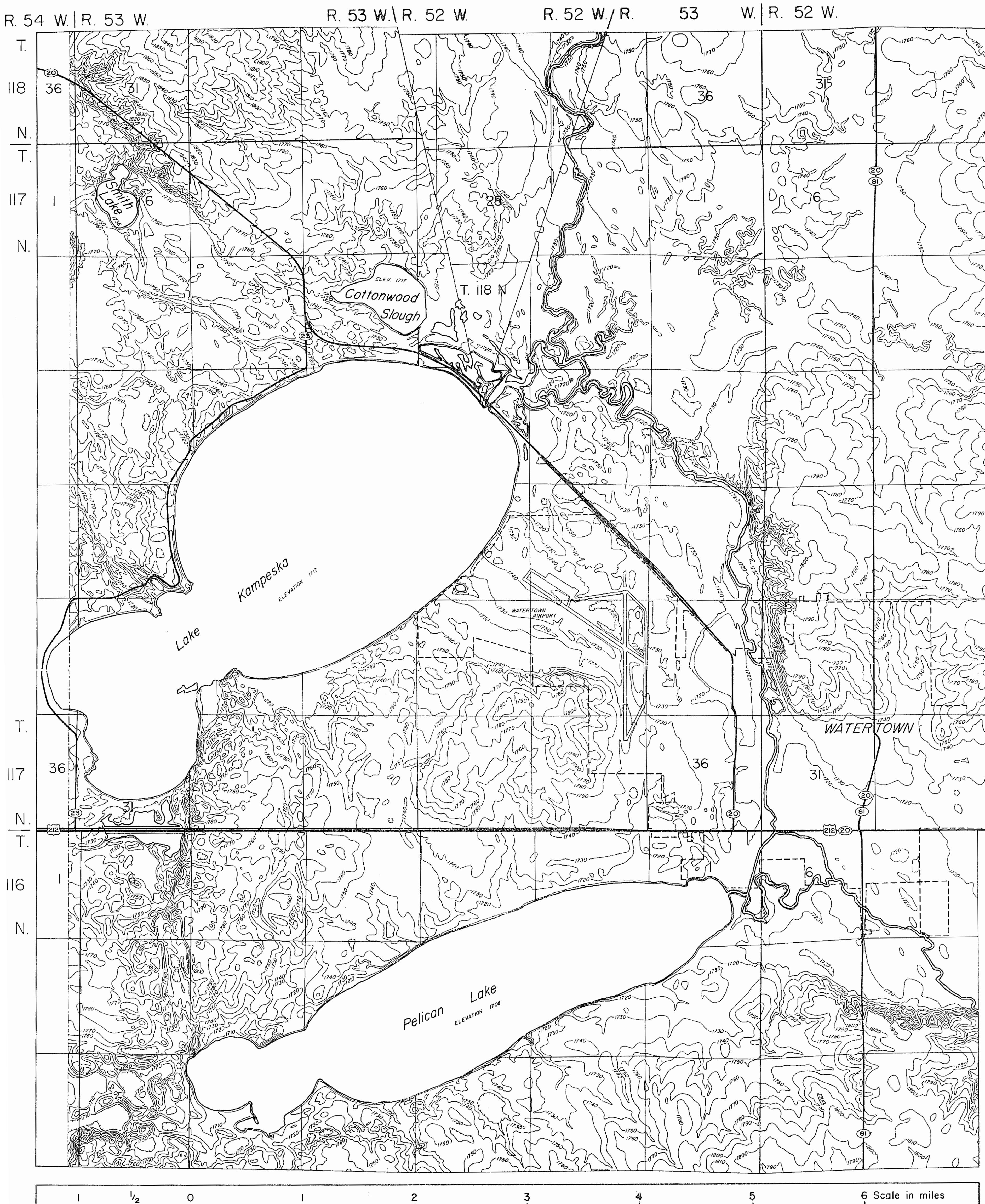
Date	Time	Lake Level *
April 5		1718.5
April 7		1718.5-1718.9
April 9	12:30 a.m.	1721.9
	2:30 a.m.	1722.1
	6:00 a.m.	1722.4
	3:30 p.m.	1723.2
	5:30 p.m.	1723.2
	7:30 p.m.	1723.3
	9:30 p.m.	1723.4
	11:30 p.m.	1723.5
April 10	1:30 a.m.	1723.6
	3:30 a.m.	1723.6
	5:30 a.m.	1723.6
	7:30 a.m.	1723.7
	9:30 a.m.	1723.7
	1:45 p.m.	1723.7
	4:30 p.m.	1723.7
	10:00 p.m.	1723.7
April 11	12:30 a.m.	1723.7
	3:30 a.m.	1723.7
	7:30 a.m.	1723.7
April 12	3:00 a.m.	1723.6
	6:00 a.m.	1723.5
	2:00 p.m.	1723.4
April 13	3:00 a.m.	1723.4
	5:30 a.m.	1723.3
	4:30 p.m.	1723.2
April 14	12:30 a.m.	1723.2
	5:30 a.m.	1723.1
April 15	12:00 a.m.	1723.0
	6:15 a.m.	1723.0
	4:30 p.m.	1722.8
April 16	8:15 a.m.	1722.6
April 17	10:30 a.m.	1722.4
April 18	12:30 a.m.	1722.3
	4:00 a.m.	1722.3
April 19	12:30 a.m.	1722.2
April 20	3:15 a.m.	1722.1
April 21	3:15 a.m.	1722.1
April 22	3:30 a.m.	1721.8
April 23	12:45 a.m.	1721.7
April 24	3:15 a.m.	1721.6
April 26	2:00 a.m.	1721.5
April 27	2:30 a.m.	1721.4
April 28	12:00 a.m.	1721.3
April 30		1721.2

*Measurements are 2.53 feet higher than indicated elevations.

APPENDIX F

Yearly water consumption by the city of Watertown

Year	Output Filtration Plant (in cubic feet)	Output Wells (in cubic feet)	Total Output (in cubic feet)
1944	48,755,600	7,793,600	56,549,200
1945	55,318,700	8,493,900	63,812,600
1946	38,013,200	29,910,700	67,923,900
1947	53,334,300	16,219,100	69,553,400
1948	55,467,700	17,431,700	72,899,400
1949	41,381,300	31,506,100	72,887,400
1950	47,900,700	16,427,000	64,327,700
1951	49,930,100	11,931,800	61,861,900
1952	52,079,200	17,910,700	69,989,900
1953	51,837,500	7,950,500	59,788,000
1954	53,110,100	4,893,600	58,003,700
1955	56,365,900	7,754,000	64,119,900
1956	54,855,300	8,846,600	63,710,900
1957	59,510,000	20,602,700	70,112,700
1958	58,203,400	20,269,100	78,472,500
1959	57,560,500	30,508,000	88,068,500
1960	60,231,000	16,975,000	77,206,000
1961	60,032,200	18,796,100	78,828,300
1962	57,501,700	11,462,700	68,964,400
1963	56,840,400	18,460,500	75,300,900
1964	58,467,400	34,550,800	93,018,200
1965	56,548,100	26,462,800	83,010,900
1966	55,615,900	33,771,400	89,387,300
1967	58,752,400	33,919,400	92,671,800
1968	53,962,100	35,576,900	89,539,000
1969	51,241,500	43,027,300	94,268,800
1970	56,312,300	32,909,400	89,221,700



1740 Contour line showing elevation above sea level, interval = 10 feet

Drafted by D. W. Johnson, 1971

Depression contour

Plate 1. Topographic map of the Lake Kampeska study area, *(from U. S. Geological Survey map).*