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PROGRESS REPORT ON THE GEOLOGY AND GROUND-WATER RESOURCES OF THE DEVILS LAKE AREA, N. DAK.

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During the past two years the Geological Survey has been studying the geology and ground-water conditions in the vicinity of Devils Lake, N. Dak. The investigation, being made through cooperative arrangements with the North Dakota State Water Conservation Commission and North Dakota Geological Survey, is an outgrowth of the serious problems facing the area in regard to obtaining suitable water supplies for domestic, municipal, and industrial purposes.

SOME BASIC IDEAS ON THE GEOLOGY AND GROUND-WATER SUPPLIES IN THE DEVILS LAKE AREA

The surface material in the area is the glacial drift which was deposited from the great ice sheet that covered the area in Pleistocene time. The drift rests upon a thick section of Cretaceous shale which is underlain in turn by a group of formations commonly referred to in North Dakota as the "Dakota sandstone."

There is no published information regarding the formations below the Dakota sandstone in this area at the present time. However, the log of a stratigraphic test hole recently drilled in the northern part of Ramsey County may be available in the near future.

The glacial drift is composed principally of till--a mixture of clay, sand, gravel, and boulders that is practically impervious and so does not yield water. However, bodies of water-sorted materials may be included in or associated with the till, and these may be of varying degrees of importance as sources of water, depending upon their extent, thickness, and the sizes of the particles composing them. Some of these bodies are covered and surrounded by the till and have small opportunity for replenishment of any water that may be taken from them through wells. Others of these bodies, such as the sand-and-gravel outwash from the last glacial advance and retreat, may be exposed at the land surface and may cover relatively large areas. Any water taken from such areas may be replenished seasonally by downward percolation of precipitation to the ground water; consequently, these bodies provide the most likely permanent sources for the development of ground-water supplies.

The thickness of the glacial drift varies considerably in the area, depending both on surface relief and on the configuration of the surface of the underlying shale bedrock. Where deep valleys occur in the shale bedrock surface the drift is likely to be much thicker than in adjacent areas.

In the Devils Lake area, many small water supplies are obtained from the upper part of the shale bedrock. The water-bearing beds are thin but may be rather extensive. The aquifers are not particularly productive, however, and the wells in shale generally yield less than 10 gallons a minute. The lower part of the shale generally does not contain water-bearing beds and, when any are found, the water obtained is generally too highly mineralized for most uses.

At Devils Lake, water is obtained from the Dakota sandstone at a depth of about 1,500 feet. The wells have a natural flow and will yield several hundred gallons a minute when pumped. The water is highly mineralized and is unfit for many domestic and industrial uses.

Because the Dakota sandstone is deeply buried beneath the drift and the thick shale it is not recharged locally, and it receives water only very slowly from adjacent areas. The water that is being taken from it thus is derived largely from local storage. Consequently, the artesian pressure (or water level) is constantly lowering and will continue to lower so long as water is withdrawn.

PRESENT WATER SUPPLY AT DEVILS LAKE

At the present time, the Devils Lake municipal water supply is obtained from two wells in the Dakota sandstone. The water from these wells, although soft, is highly mineralized with sodium chloride (table salt) and sodium sulfate (Glauber's salt) and is unfit for drinking, cooking, and many industrial purposes. Water for drinking, cooking, and some industrial purposes is obtained from shallow wells in the shale. These wells all have relatively small yields and one that will produce 15 gallons a minute for any considerable period of time is considered an exceptionally "strong" well. There are more than 125 privately owned wells in shale in the city, and they furnish the bulk of water required for drinking, cooking, and minor industrial uses. In addition, considerable "shale" water is delivered to hotels, restaurants, and many residents by water companies for drinking and cooking purposes, in much the same manner that milk is delivered in most towns and cities. In the evening, around suppertime, many city residents queue up with buckets and jars at a public "shale" well at the county courthouse to obtain potable water for drinking and cooking.

In addition to the "shale" wells in the city, there are a number of shallow dug wells that yield water from the glacial drift. Fewer than five drilled wells in the city are known to yield water from the drift.

Water for industrial use by the Otter Tail Power Co. and the Great Northern Railroad is obtained from Sweetwater Lake at a point about $5\frac{1}{2}$ miles north of the city.

The present use of water for municipal and industrial purposes, including the water obtained from Sweetwater Lake, probably averages nearly a million gallons a day, and the peak daily consumption during the summer may be nearly $1\frac{1}{2}$ million gallons. Consulting engineers believe that, if an adequate supply of good quality water were available, as much as 2 million gallons a day would be used and peak daily demands might run as high as 3 to 4 million gallons.

NEED FOR STUDY

Several factors were involved in the development of concern over the city's water supply. In the first place, the industrial growth of the city is inhibited because of the poor quality of the municipal water supply from the deep wells. Also, late in the winter of 1948, one of the wells began producing muddy water and it was feared that this well might have to be abandoned, in which case the city would be short of water for fire protection and for operating the sanitary sewer system.

As a result, it was decided to drill a new artesian well immediately at a cost of approximately $35,000. For long-range planning, it was decided to investigate the possibility of obtaining an adequate supply of water of good quality in the area. Drilling of the new artesian well was begun in the fall of 1949 and the well was finished in the fall of 1950. However, because of failure of the water to "clear up," the well may be rejected. The muddy water from the old well is still being used in the water system.

POSSIBLE SOLUTIONS TO WATER-SUPPLY PROBLEM INVESTIGATED

Sweetwater Lake Area

One of the first solutions considered by the city was the development of a water supply from Sweetwater Lake. The lake contains water of low mineral content which would be entirely satisfactory for municipal and industrial uses. However, the development of a surface-water supply from that area would require the construction of an expensive plant for the removal of bacteria and suspended matter, as well as an expensive pipe line. Also, though the lake is full to overflowing at the present time, it was nearly dry during the drought years of the 1930's, and much of the area now under water was then cultivated.

It was believed, however, that if large-capacity wells could be developed from aquifers that would receive water from the lake when the wells were pumped, a suitable supply might be developed from such wells. The necessity for an expensive treatment plant would be eliminated and sufficient usable water could be obtained from ground-water storage during drought periods when the lake might be dry.

Accordingly, 55 test holes were drilled in the vicinity of the lake. The drilling failed to disclose any ground-water bodies that appear to be adequate for development by the city. One narrow buried channel deposit of gravel, which appears to run under the lake and to extend southward toward Devils Lake, was found. A pumping test on a well drilled in this channel failed to produce any indication of possible recharge to the water-bearing gravel in this channel from the surface water in the lake. The channel is so narrow and the transmissibility of the gravel fill so low that supplies adequate for the city could not be developed from wells in it unless recharge from the surface would be shown to occur in the immediate vicinity of the wells.

On the other hand, smaller supplies, say of the order of 50,000 to 100,000 gallons a day, probably could be developed at several places along the channel. The permanence of such developments would depend upon the rate of recharge to the gravels, which as yet is unknown; but even without recharge the water in underground storage would support the smaller developments for several years if the wells were spaced far enough apart along the channel.

A few other places near the lake where smaller developments probably could be undertaken were located, but none of these appear to be sufficiently important to be of interest to the city in its search for a dependable supply.

Another possibility considered was that of developing a combination supply--a surface-water supply from Sweetwater Lake which would be adequate during periods of excessive precipitation and runoff, and a supply from wells elsewhere in the area for supplemental use during periods of deficient rainfall and runoff.

Mauvais Coulee Area

One area that appeared favorable for the development of wells of this nature was along Mauvais Coulee, which extends from West Bay of Devils Lake to Lake Irwin (Lake Irwin is part of the Sweetwater chain of lakes north of the town of Churches Ferry.) Considerable surface flows occur in Mauvais Coulee during the spring break-up, and any shallow-lying aquifers in or adjacent to the coulee would be recharged directly from the surface flow or diversions of the surface flow could be made for the purpose of recharging the aquifers if runoff water did not reach them naturally.

Considerable test drilling was done along Mauvais Coulee, but only one hole penetrated a substantial thickness of sand and gravel--more than 80 feet. The hole was near the west bank of Mauvais Coulee on State Highway 19. The sand and gravel was not found in test holes a little more than a quarter of a mile east and west. However, if conditions were such that additional recharge to this body of sand and gravel could be induced by pumping from it, the aquifer might have potentialities as a source of a supplemental supply. Probably additional test drilling should be done in this vicinity in order to determine the actual extent of the aquifer.

West side of Creel Bay and Camp Grafton Area

Another area in which considerable test drilling was done is west of Creel Bay opposite Camp Grafton and about 6 miles southwest of Devils Lake. Information from the well inventory showed reasonable prospects for the occurrence of water-bearing gravel bodies of some magnitude in this area. The test drilling disclosed the presence of a channel of considerable width and depth which appears to run along the north shore of Devils Lake in this area. The channel contains abundant sand and gravel deposits in some places but in other places it contains only rather impermeable glacial till.

One test hole near the lake and immediately opposite the community of Lakewood penetrated about 130 feet of sand and gravel, and most of the other test holes in this area penetrated significant thicknesses of sorted materials. These sands and gravels are covered in this area by 50 to more than 100 feet of relatively impermeable till. However, it is believed that wells of large capacity could be developed in the area.

Short pumping tests made several years ago on the Camp Grafton supply wells indicate fairly permeable materials. Wells developed in the Camp Grafton area would yield water from the same source as wells developed west of Creel Bay, where the test drilling was done.

There are two objections to the development of large water supplies in the Creel Bay-Camp Grafton area. First, if the till overlying the sorted materials effectively seals them from surface recharge, then a large water supply developed there would be short-lived because the water pumped would come largely from ground-water storage that would not be replenished. Also, if there are areas under the present lake where recharge from the surface could reach these sorted materials, there is a possibility that the highly mineralized water from Devils Lake would be drawn to the wells when they were heavily pumped.

It appears that there is considerable ground water in storage in this area, probably enough to support developments of the magnitude required by the city of Devils Lake for many years without benefit of surface recharge. The possibility of immediate infiltration of the highly mineralized lake water to a well in this area probably could be ascertained from a pumping test on a developed well. However, if infiltration should occur by slow seepage, this condition might not be discovered until observations were made for months or perhaps several years under pumping conditions.

GLACIAL-OUTWASH AREAS NEAR WARWICK AND TOKIO SHOW GREATEST PROMISE

It became increasingly evident during the investigation that substantial water supplies of good quality and with good promise of being permanent, with a desirable excess of available water for future expansion, could not be obtained from any source within a relatively short distance of the city of Devils Lake. With this proposition in mind, some interest was indicated in developing supplies from more distant areas. For this reason two areas of glacial outwash were test-drilled. One of these outwash areas is near Warwick, about 20 miles southeast of Devils Lake. The outwash covers an area of more than 50 square miles. A six-hole section drilled across the outwash revealed thicknesses of sand and gravel of more than 100 feet. The sand and gravel extends to the surface, so that recharge occurs from precipitation. The water table ranges from the surface to about 15 feet below the surface in most of the area.

This area is the most favorable of any studied during the investigation for the development of large permanent ground-water supplies. The amount of ground water in storage is great, probably amounting to as much as 15,000 acre-feet per square mile or more in some parts of the area (15,000 acre-feet is about $6\frac{1}{2}$ billion gallons). It would be necessary to construct wells in the area and to pump them in order to determine what yields could be expected.

A smaller outwash area west of the village of Tokio and about 15 miles south of Devils Lake was test-drilled. Although the sand and gravel there is coarser and cleaner than that in the Warwick area, the total thickness of the outwash materials is much less, reaching a maximum of about 50 feet in the test holes; also, the depth to the water table is greater, so that less of the outwash material contains water. It is possible that fairly large supplies could be developed here, but on the basis of available information the area does not appear to be as favorable as the Warwick outwash area for the development of large supplies.

Development of irrigation with well water may be possible

Both the outwash areas may have potentialities for irrigation of substantial acreages using water from wells. It is unlikely that either of these areas will be considered for irrigation from surface-water supplies under the present Missouri Basin development plan. In any event, if wells of adequate capacity can be constructed, the use of well water for irrigation would have certain advantages over the use of surface water. Wells and necessary irrigation works could be contracted for by the individual landowners, and the expensive main canals required for the distribution of water from surface sources would not be necessary. The well water would be free of weed seeds and silt and would be available for use at the landowners' convenience.

The Warwick and parts of the Tokio outwash areas are relatively flat, so that not much leveling would be required to prepare a considerable part of the land for irrigation. Because of the very sandy nature of the soil and underlying materials, subsurface drainage over most of these areas is excellent and there would be little danger of waterlogging the land through the application of irrigation water. The suitability of the soil for irrigation agriculture was not considered, as that subject is outside the field of the Geological Survey.

HOW THE GEOLOGICAL SURVEY MADE THE INVESTIGATION

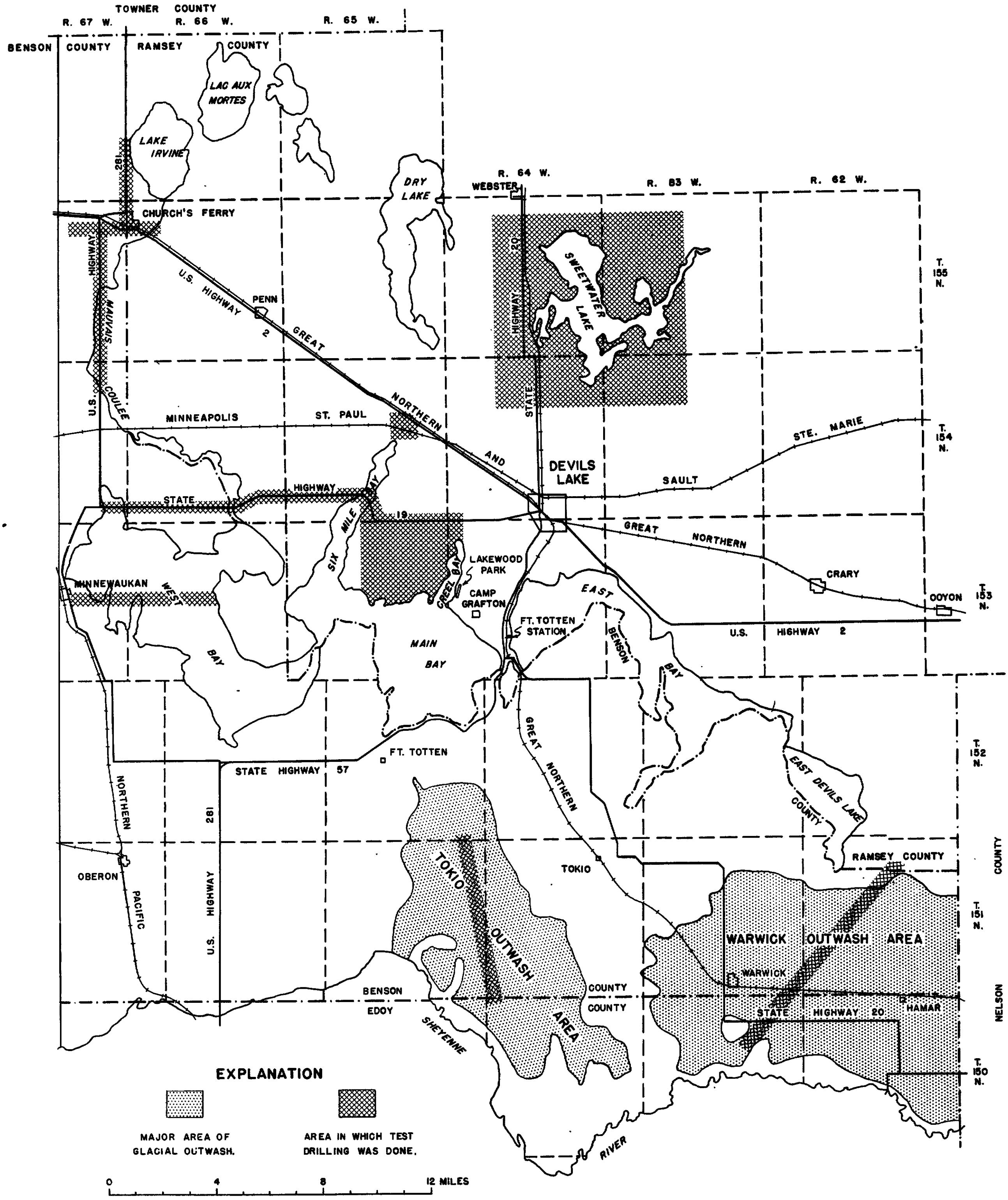
The area studied during the investigation covers parts of three counties and more than 1,000 square miles. During the investigation the general glacial geology of the entire area was mapped and detailed geologic mapping was done in a large part of the area. Records of most of the several thousand wells in the area were obtained and water-level measurements were made wherever possible. One hundred and two test holes were drilled, for a total of 11,276 feet of hole. Logs of many other test holes and wells in the area were gathered. Samples of water for chemical analysis were taken from many wells, lakes, and springs. A 3-day pumping test was made on the Great Northern Railroad wells near Sweetwater Lake, and the data and results from a pumping test on the Camp Grafton supply wells were already available.

A full report on the study is being prepared for publication. The report will include the factual data obtained plus geologic and ground-water maps. Also, it will present, as completely as possible, the relation between the geology and the occurrence of ground water in the area.

The factual data are on file in the Geology Building at the University of North Dakota, Grand Forks, and may be inspected by any interested persons who desire to do so before the full report is published.

ADDITIONAL WORK NEEDED TO COMPLETE INVESTIGATION OF AREA

Some additional work should be done in the area if funds can be available. As indicated previously, some additional test drilling probably should be done near Mauvais Coulee to outline the body of sand and gravel found near this stream on State Highway 19. Some test drilling should be done along State Highway 57 near Fort Totten Station and both north and south of the East Bay of Devils Lake in order to trace the buried valley test-drilled west of Creel Bay. Some test drilling should be done also in the area near Crary, as the well-inventory work indicated a possibility of the existence of deep drift aquifers in this area.



MAP SHOWING AREA OF GROUND-WATER RESOURCES STUDY AROUND DEVILS LAKE, NORTH DAKOTA.

(PREPARED BY U.S. GEOLOGICAL SURVEY)