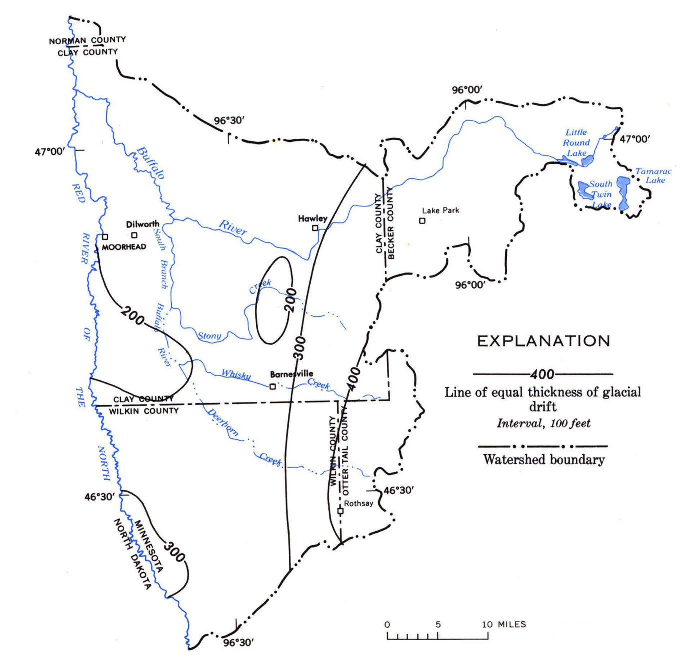
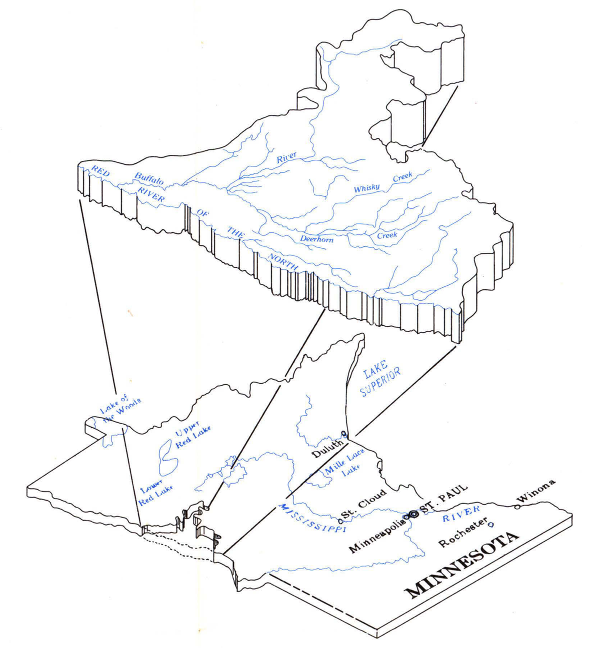
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS AND MINERALS

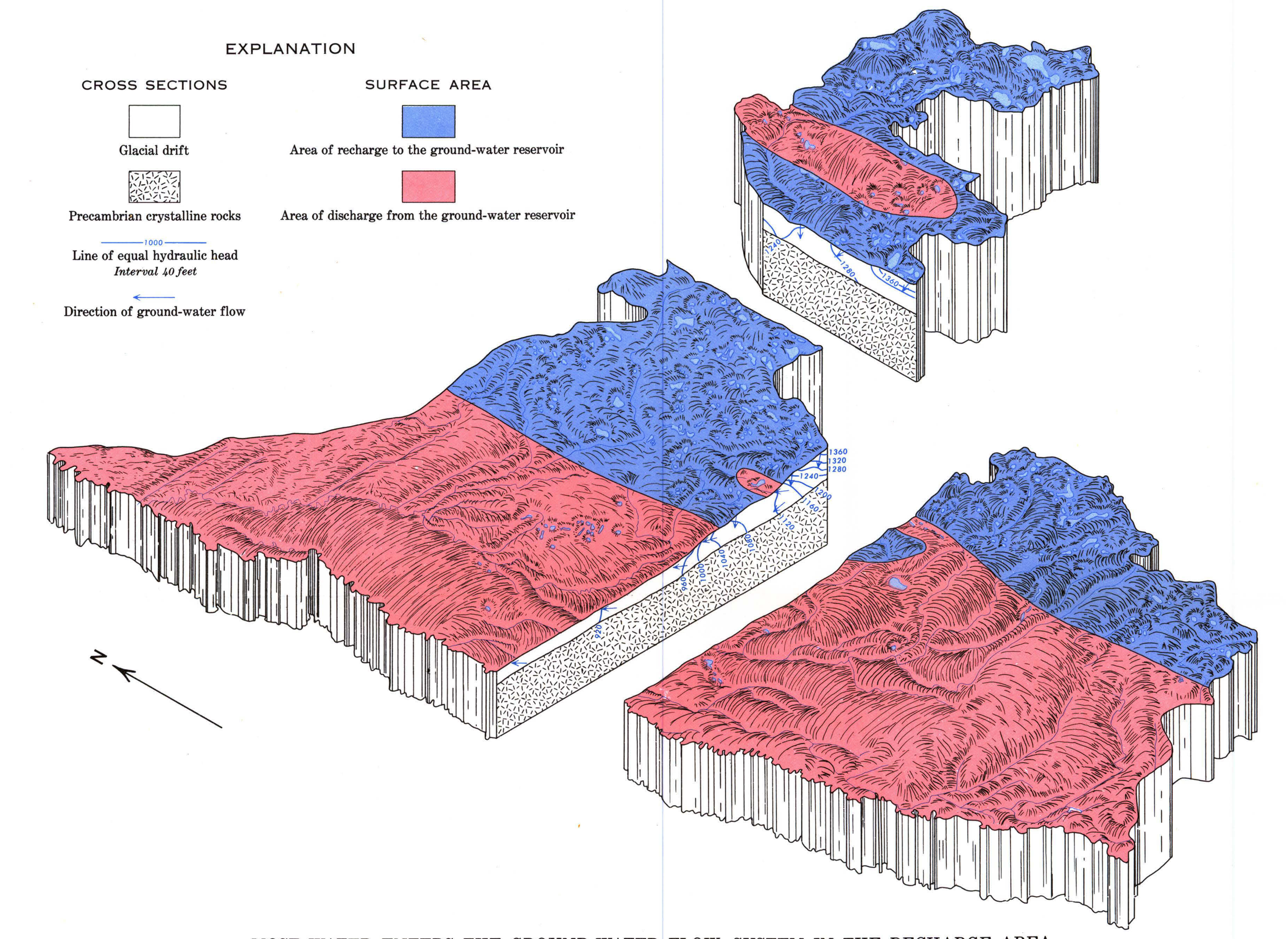
GROUND WATER



THE GLACIAL DRIFT IS THICKEST IN THE EASTERN PART OF THE WATERSHED BECAUSE OF THE MORAINE THAT OCCURS IN THIS AREA. *Variations in the drift thickness in the Lake Plain is an indication of the variation of the bedrock surface (the bottom of the glacial drift) because the land surface is flat and slopes uniformly to the west (the top of the glacial drift). This can be seen in the southeastern part of the watershed where the area of greater than 200-feet thickness coincides with the depression in the bedrock shown on the bedrock-topographic map below.*



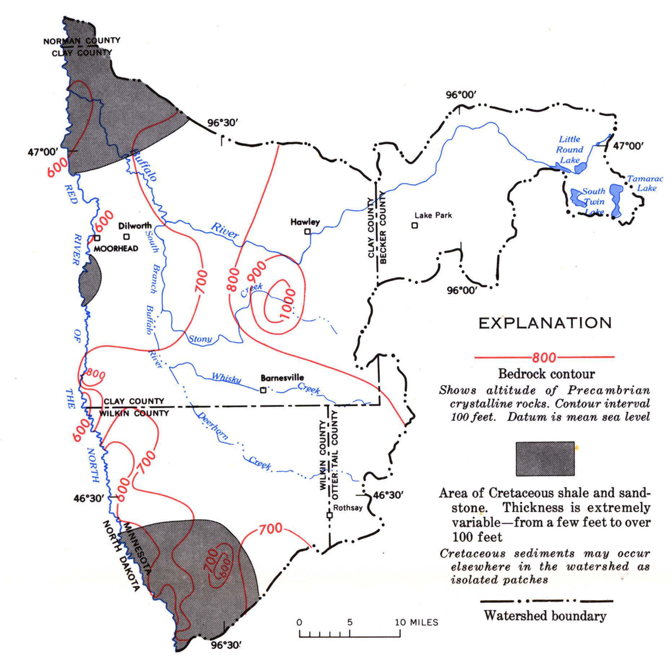
AREAL LOCATION OF BLOCK DIAGRAM



MOST WATER ENTERS THE GROUND-WATER FLOW SYSTEM IN THE RECHARGE AREA LYING WITHIN THE HUMMOCKY MORAINE

Within the moraine ground water moves downward from the higher lands to the deeper part of the ground-water reservoir and toward the valleys and depressions where it is discharged by means of springs, seeps, and evapotranspiration. Much of the water moving from the moraine leaves the ground-water reservoir in the area along the base of the moraine. The remainder of the water continues to move slowly westward through the deeper part of the reservoir to the area near the Red River of the North where it moves upward and is discharged. Within the lake plain the water table, which is the upper surface of the ground-water reservoir, fluctuates in response to recharge from precipitation, however, the recharge water does not enter the deeper part of the ground-water reservoir.

Where the Cretaceous rocks (see bedrock geology map) in the watershed are continuous with those in North Dakota, the hydraulic head is generally greater than that in the overlying drift causing the water to move upward and mix with water in the drift.



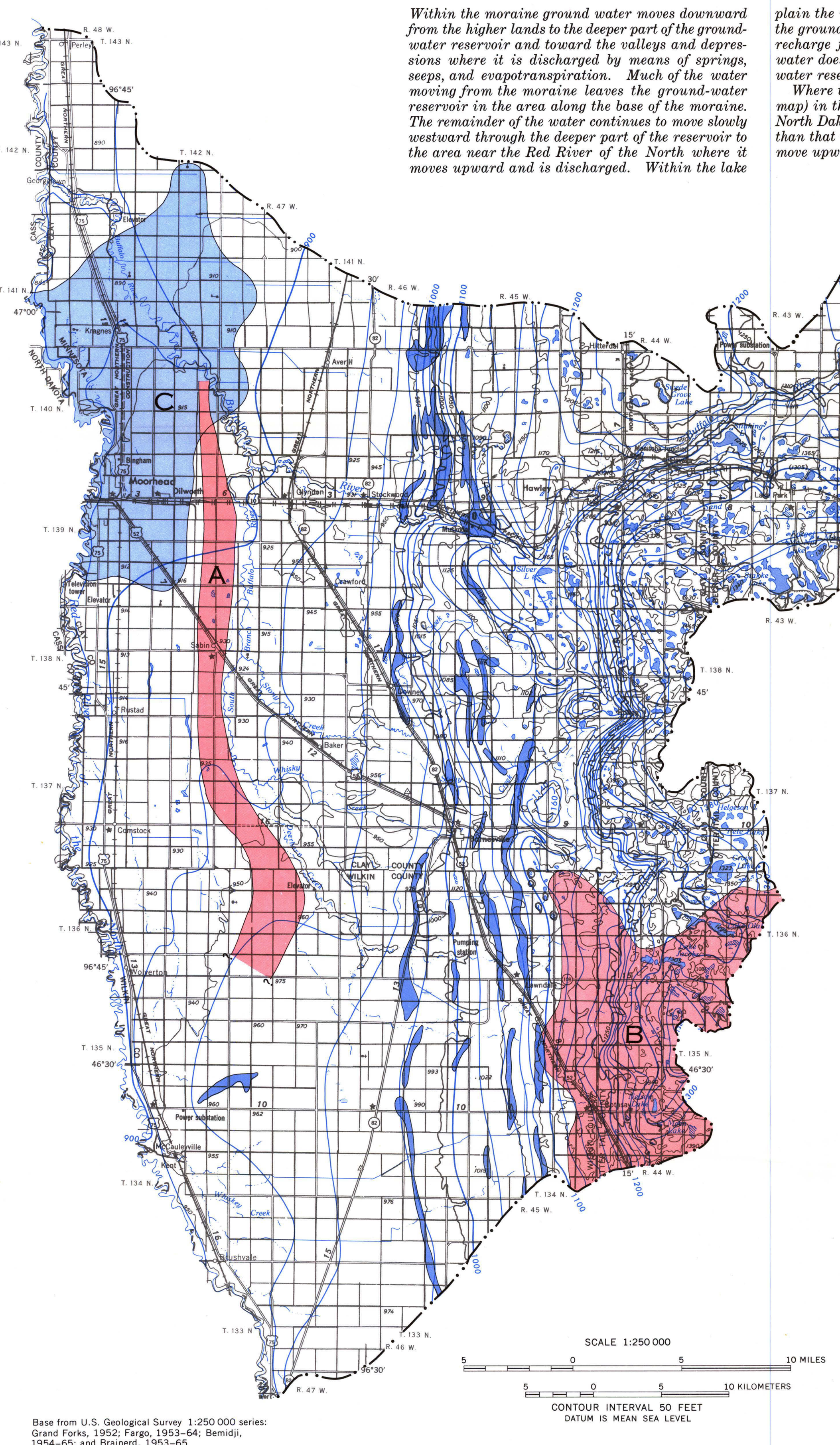
CRETACEOUS SEDIMENTS OCCUR MAINLY IN THE EXTREME WESTERN PART OF THE WATERSHED.—*These deposits may be found in other areas, but only as small local occurrences.*

The Cretaceous sediments consist largely of shale with sand lenses. The sand is generally fine to medium grained and is moderately permeable. Yields of wells tapping sand lenses are usually less than 50 gpm.

The surface of the Precambrian crystalline rocks has a general westward slope. However, the local relief is probably highly variable as shown in the western part of Wilkin County which contains the greatest concentration of bedrock control.

COMMUNITY WATER SUPPLIES

Community	Well characteristics: Depth (feet)	Diameter (inches)	Operating rate (gpm)	Depth to static water level (feet)	Specific capacity (gpm/ft)	Water quality (ppm): Total dissolved solids	Hardness	Iron	Sulfate	Remarks
Barnesville Well 5	72	20	300	27	21	473	382	1.7	55	Several other abandoned wells in town. Well 7 is a standby well.
Well 7	73	6	60-70	—	—	—	—	1.8	—	
Callaway Well 1	100	8	40	—	—	—	—	—	—	Well 2 was tested at 100 gpm.
Well 2	110	6	40	—	—	—	530	1.2	260	
Dilworth Well 4	155	8	65	118	3.6	—	137	1.5	144	
Well 5	178	12	100	109-115	5.25	600	119	0.61	144	
Northern Pacific R.R. Well	265	12	310	113	3	495	288	0.62	87	
Hawley Well 5	142	12	127	22	—	—	—	—	—	Well 5 tested 300 gpm.
Well 6	142	12	100	20	—	—	545	—	170	
Kent	137	4	50-100	—	—	1800	710	3.0	750	Three former city wells were greater than 400 feet deep. They were abandoned because of low yield, less than 10 gpm.
Lake Park	380	8	100	78	18	760	540	2.6	200	Several abandoned wells in town have approximately same depth.
Moorhead Well 5	265	20	500	166	72	648	189	0.63	164	Wells 5, 6, and 6-A are in town near U.S. Highway 75. They have been test pumped at 1,000 gpm.
Well 6	273	20	500	166	—	642	210	0.4	168	
Well 6-A	277	24	500	166	87	—	—	—	—	
Well 7	116	16	200	26	5	420	368	1.0	80	Wells 7, 8, 10 and 11 are about 1 mile east of Dilworth. Well 10 has been tested at 2,800 gpm for 24 hours. Well 7 not used.
Well 8	122	16	1400	26	60	—	—	—	—	
Well 10	114	16	1400	26	60	518	286	0.26	104	
Well 11	124	16	—	26	—	—	—	—	—	
Perley Well 1	185	6	50	—	—	99	—	0.76	—	
Well 2	190	6	50	—	—	—	—	—	—	
Rothsay Well 1	192	8	200	105	—	—	720	5.6	280	
Well 2	235	8	200	100	28	—	—	—	—	
Wolverton	160	8	15	—	—	—	300	1.6	200	



Base from U.S. Geological Survey 1:250 000 series: Grand Forks, 1952; Fargo, 1953–64; Bemidji, 1954–65; and Brainerd, 1953–65

EXPLANATION

Glacial till

A heterogeneous mixture consisting mainly of silt and clay, but containing sand, gravel, and boulders. The till extends from the surface to bedrock in the morainal area, but in the Lake Plain it is overlain by glacial lake sediments. Lenses of silt, sorted sand, and gravel are scattered throughout the till and are the main sources of ground water in most of the area. Yields to individual wells from most sand lenses are generally less than 20 gpm (gallons per minute), but wells tapping large sand and gravel lenses can often be pumped at rates of several hundred gpm

The upper 10 to 50 feet of till is oxidized and is therefore usually slightly more permeable than the underlying unweathered gray till. In the western part of the watershed older glacial lake deposits may occur within the till

Beach ridge aquifers

Predominantly fine to medium sand, containing much coarse sand and some fine to medium gravel. The deposits range from less than 10 to more than 30 feet in thickness at their highest point. The ridges are tens of miles long and their width ranges from a few hundred feet to more than a mile. They are saturated in the lower half to two-thirds and the larger deposits can yield more than 20 gpm to individual wells. The lower beach ridges are unreliable as a source of ground water because wells commonly go dry in late summer and fall

A

Buried sand ridge aquifer

Fine to medium, grading to very fine sand and silt toward the edges. The sand unit is interfingered with, or grades into, lake clays both to the east and to the west along its entire length. The thickest part of the unit, along its axis, is generally from 100 to 120 feet thick. The deposit is more than 25 miles long and ranges from less than one to two miles wide. Nearly the entire aquifer is overlain by lake clay of varying thickness—from a few feet to more than 20 feet. Individual wells in the aquifer yield up to 350 gpm

B

Buried sand and gravel aquifer

Largely medium sand, but containing much coarse sand to fine gravel. The thickness of the deposit is not well known, but one test hole penetrated 107 feet of the sand and gravel. It is overlain in all but a few local places by till from a few feet to more than 100 feet thick. The extent of the deposit was determined on the basis of completion altitudes of wells. Most wells in the area are completed within the altitude range of the sand and gravel penetrated by the test holes—the majority being from 1,075 to 1,130 feet above mean sea level

Well drillers report that pumping wells at rates up to 30 gpm does not draw down the water level. A test hole one mile east of Lawndale yielded 750 gpm for 24 hours with less than 5 feet of drawdown

C

Sand aquifer within till
(See detailed analysis below)

The characteristics of the aquifer materials are largely unknown because of the lack of drill logs, except in the Moorhead area. However, the area was outlined because the majority of the wells in the area are completed at a similar altitude (710–740 feet above mean sea level), indicating the possibility of an aquifer at this position. Test holes and wells drilled by the city of Moorhead show sand and gravel within the altitude range indicated and provide the only information on yields to large capacity wells from the aquifer. In this area the aquifer has been pumped at rates of 500 gpm

Watershed boundary

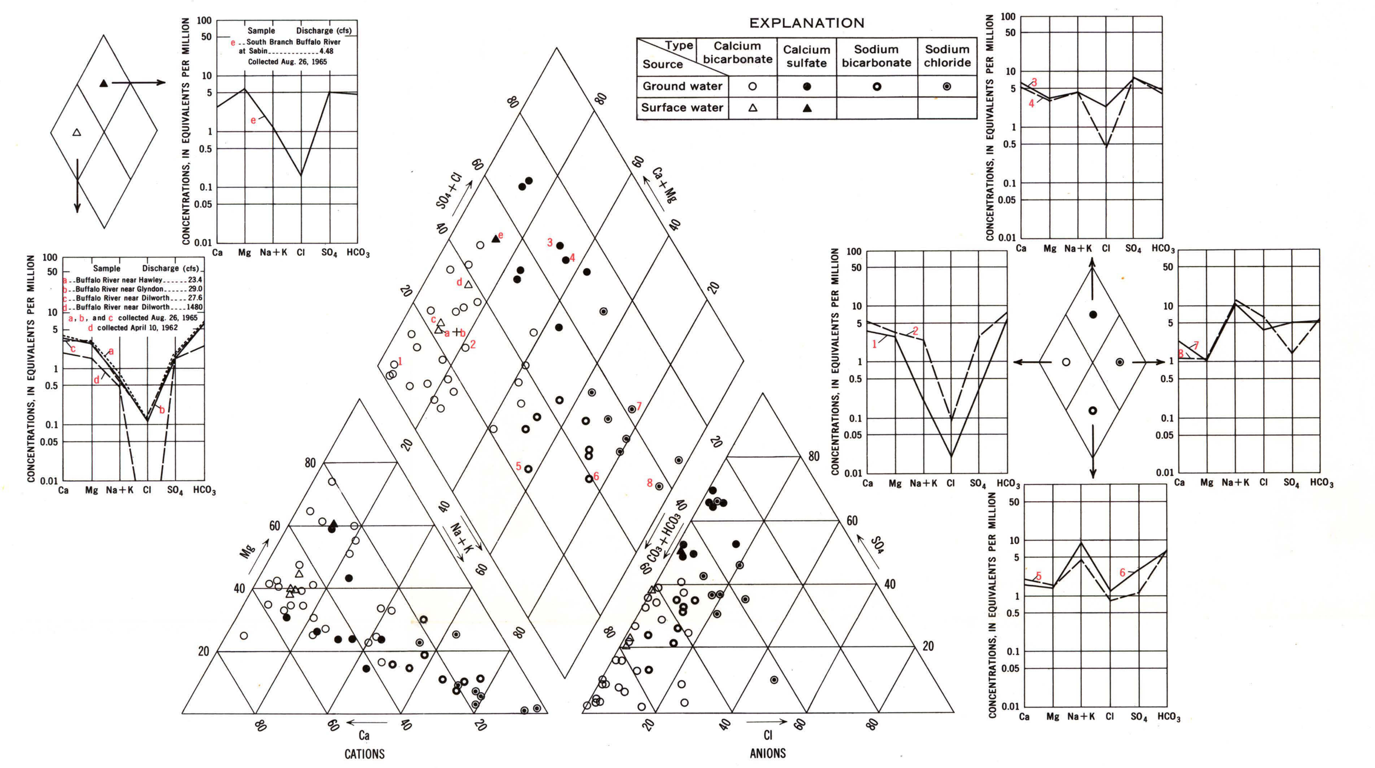
Aquifer boundary

Water-table contour
Shows altitude of water table. Contour interval 20 feet. Datum is mean sea level

THE GROUND-WATER AVAILABILITY MAP SHOWS AREAS WHERE WATER CAN BE OBTAINED FROM KNOWN AQUIFERS WITHIN THE GLACIAL DEPOSITS

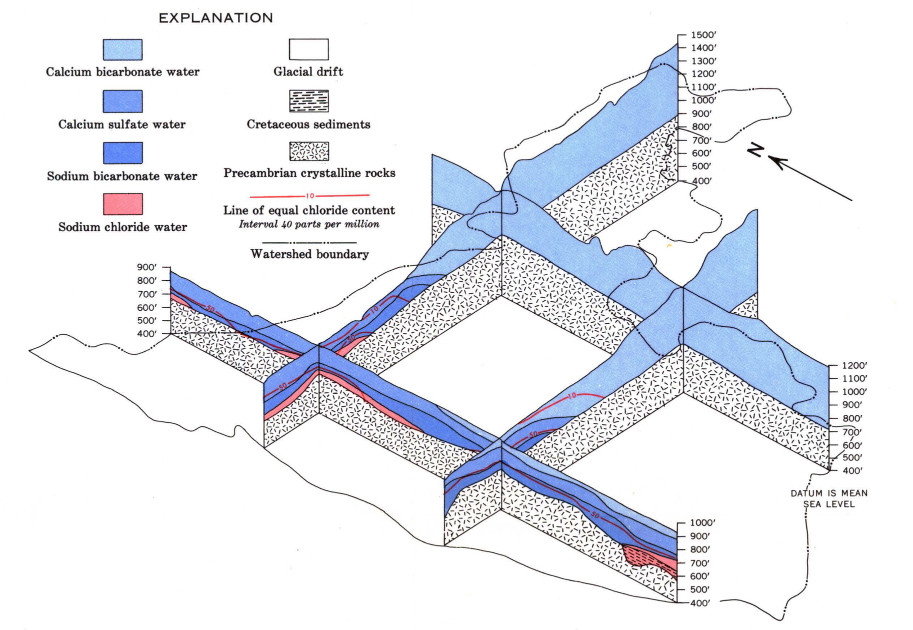
The water-table contours indicate that very little ground water is diverted to tributaries of the Red River of the North in the lake plain area. However, in the morainal area east of Hawley the ground water moves to the Buffalo River as indicated by the large upstream bends in the water-table contours.

WATER QUALITY

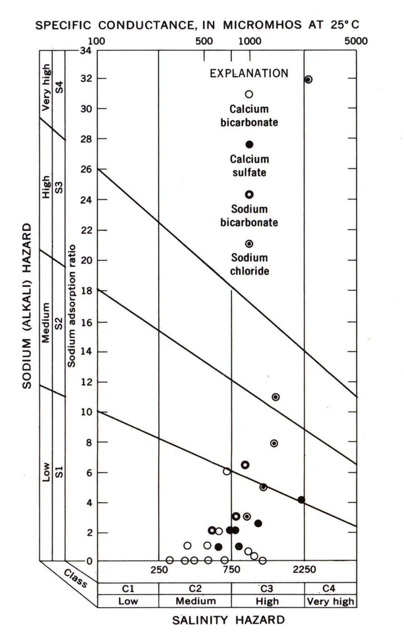


PERCENTAGE DISTRIBUTION OF THE SIX MAJOR IONS IN SOLUTION FOR GROUND AND SURFACE WATERS IN THE BUFFALO BASIN SHOW THAT GROUND WATER HAS A WIDE VARIABILITY IN WATER TYPE BUT THAT MOST SURFACE WATER IS THE CALCIUM BICARBONATE TYPE

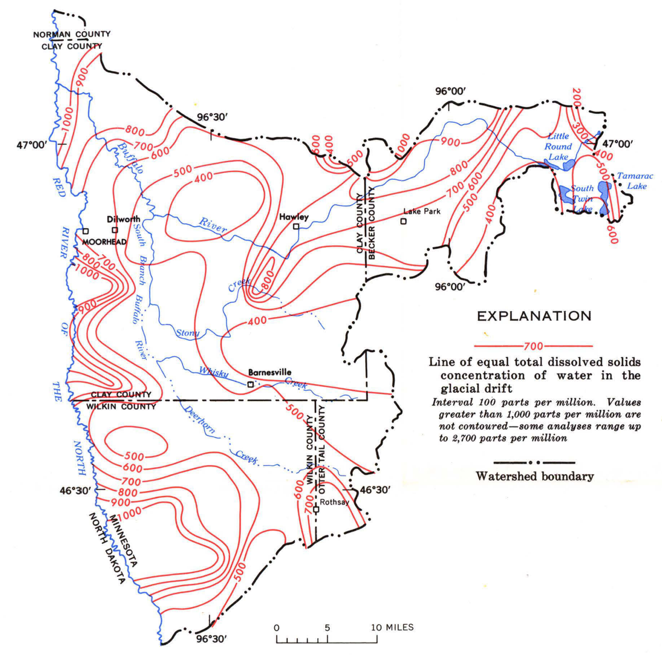
The water type is principally controlled by the solubility of the minerals within the ground-water reservoir, the time the water is in contact with these minerals, and the intermixing of water of different types. Softening of water, a decrease in calcium and magnesium ion concentration and an increase in sodium ion concentration, is indicated by the sodium bicarbonate type. The plots of ion concentration of ground waters show that the concentrations of the major ions generally range from 1 to about 10 equivalents per million except for chloride which is generally less than 1 equivalent per million. Concentration of dissolved solids in surface water from the Buffalo River during periods of low flow are similar to that in the ground water. At higher flows the surface water is less mineralized. Water from the South Branch Buffalo River at Sabin is generally more mineralized and contains a significantly greater concentration of sulfate than water from the Buffalo River near Dilworth.



THE DISTRIBUTION OF WATER TYPES SHOWS THAT THE CALCIUM BICARBONATE TYPE OCCURS MAINLY IN THE RECHARGE AREA IN THE EASTERN PART OF THE WATERSHED.—*In the lake plain, the calcium sulfate type is the most common. Sodium chloride water occurs deep in the ground-water reservoir in the western part of the lake plain and is associated with the Cretaceous sediments. The sodium bicarbonate type is probably a result of water moving upward from the Cretaceous sediments and mixing with water in the glacial drift.*

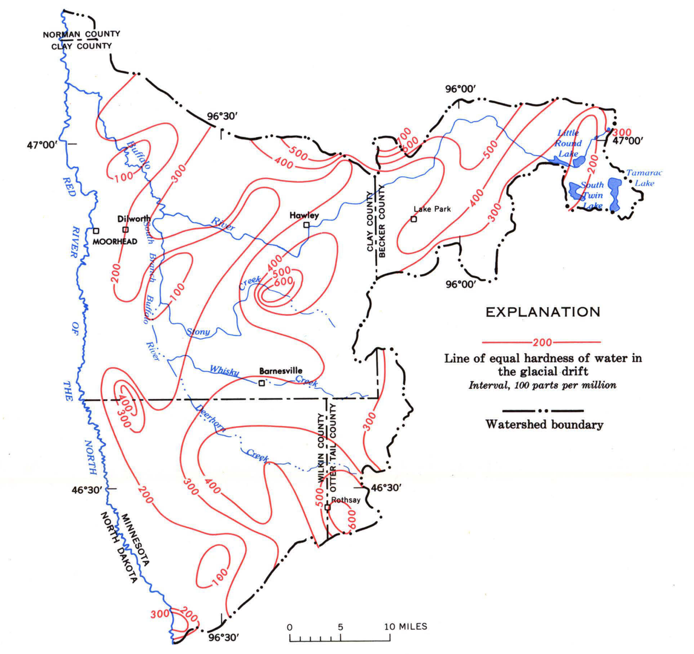


CALCIUM BICARBONATE AND CALCIUM SULFATE WATERS, THE MOST COMMON IN THE WATERSHED, HAVE LOW SODIUM HAZARD AND MEDIUM TO HIGH SALINITY HAZARD.—*These waters can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium; however, soils should be well drained to reduce effects of salinity. Sodium bicarbonate and sodium chloride water in the Buffalo River basin are generally not suitable for irrigation.*



DISSOLVED SOLIDS IN WATER OF THE GLACIAL DRIFT ARE HIGHER NEAR THE RED RIVER OF THE NORTH THAN IN THE EASTERN PART OF THE WATERSHED.—*The higher mineralization of water indicates that the water has been in contact with minerals in the ground-water reservoir for a longer period, and that water movement is probably slower than elsewhere in the watershed.*

Water containing dissolved solids of less than 1,000 parts per million is suitable for domestic and stock uses. Some water containing 1,000 parts per million or more of dissolved solids contains certain constituents which produce a noticeable taste.

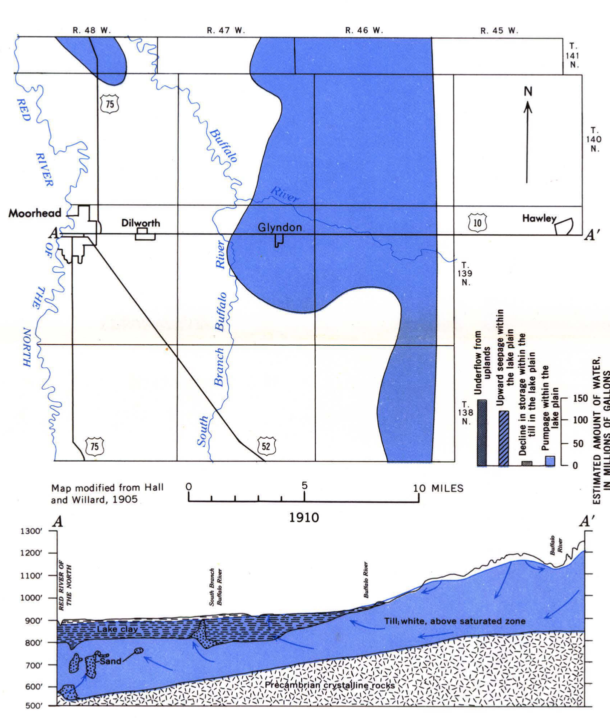


ALL GROUND WATER IN THE BUFFALO WATERSHED IS VERY HARD, BUT IN GENERAL, THE HARDNESS CONCENTRATION OF WATER IN THE LAKE PLAIN IS LOWER THAN IN THE MORAINAL AREA.—*The lower hardness in the Lake Plain is largely due to natural softening of ground water by base exchange.*

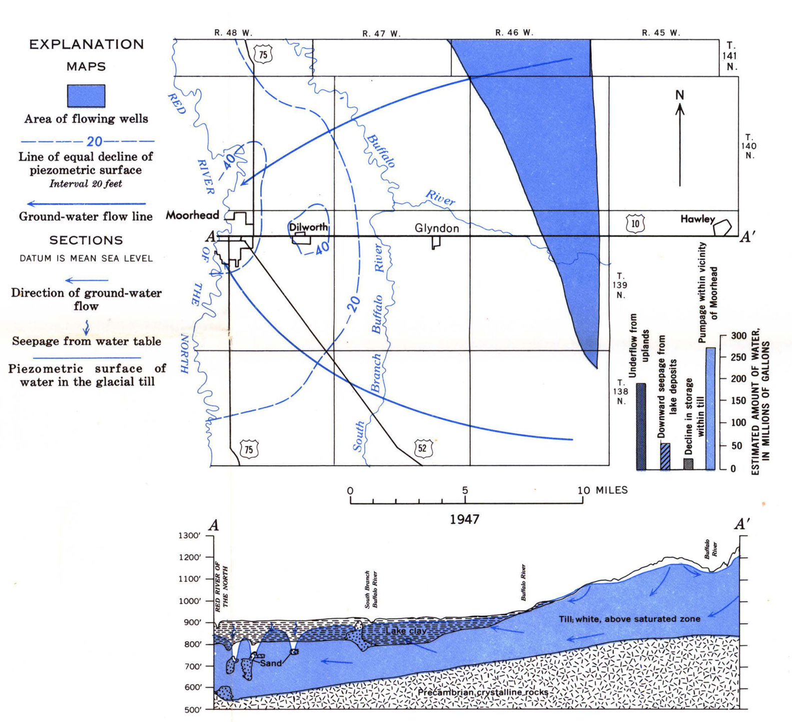
Hardness is due mainly to the presence of calcium and magnesium ions which react with soap to form insoluble products. Mineral salts of calcium and magnesium cause hardness and can form incrustation on well screens. Where hardness exceeds 500 parts per million, incrustation of well screens may be rapid in small diameter wells that are heavily pumped.

GROUND-WATER DEVELOPMENT IN THE MOORHEAD AREA

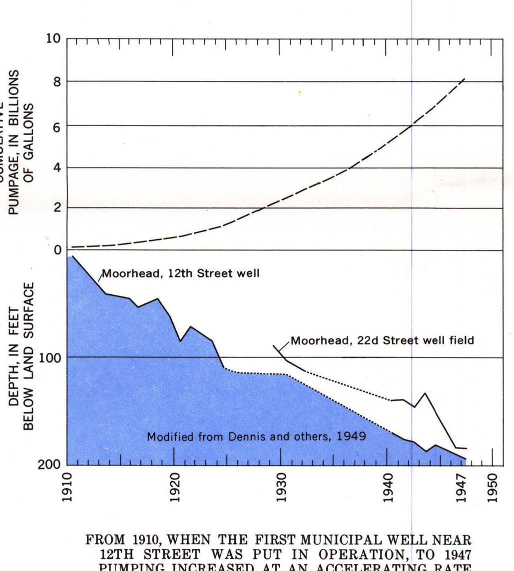
Ground-water development in the Moorhead area is one of the largest in the Red River Valley within Minnesota. Sustained yields are not large because the lake clay greatly reduces local recharge to the underlying drift aquifers in the Moorhead area. In other areas of the plain of Glacial Lake Agassiz similar geologic conditions will limit sustained yield.



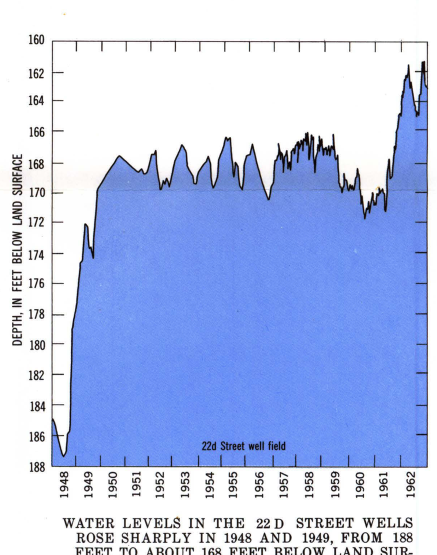
BEFORE 1910, FLOWING WELLS, OR WELLS HAVING STATIC LEVELS WITHIN A FEW FEET OF THE LAND SURFACE COULD BE OBTAINED AT ALMOST ANY PLACE WITHIN THE FLAT LAKE PLAIN EAST OF MOORHEAD.—*Recharge to the aquifers in the drift was principally from precipitation on the upland areas east of the lake plain and by some upward leakage from the Cretaceous rocks. Water from the upland moved laterally toward the valley and naturally discharged by upward percolation through the lake clay and the sand and gravel deposits near Dilworth. Pumpage resulted in a small decline in water stored within the till near Moorhead.*



BY 1947 THE DECLINE OF WATER LEVELS IN THE TILL DUE TO PUMPAGE RESULTED IN A DECREASE IN AREA OF THE FLOWING WELLS AND LOCAL LOWERING OF WATER LEVELS OF MORE THAN 40 FEET.—*The continued decline in water level shows that water was removed from storage within the till. Although the underflow moving into the valley from the uplands increased as hydraulic gradients increased due to the declining water levels, the gradients were not sufficient to transmit underflow through the poorly permeable till at a rate equal to discharge within the valley. The lowering of water levels within the till reversed the natural movement of water through the lake deposits in the vicinity of Moorhead. The thick cover of impermeable lake clay in this area greatly retards downward movement of water and therefore greatly limits recharge.*

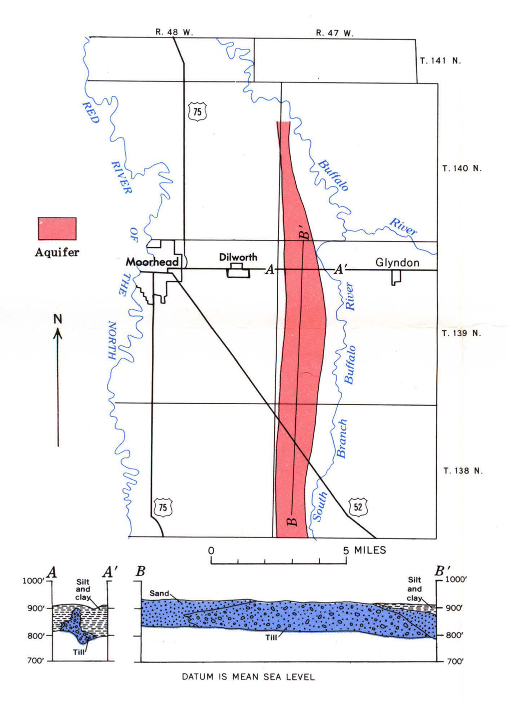


FROM 1910, WHEN THE FIRST MUNICIPAL WELL NEAR 12TH STREET WAS PUT IN OPERATION, TO 1947 PUMPING INCREASED AT AN ACCELERATING RATE WITH A RAPID DECLINE OF WATER LEVELS.—*The 12th Street well tapped a sand lens within the till which was inadequate to meet the pumping demands. Pumping from additional wells caused a continual decline of water levels resulting in decreased yields of the three city wells. By 1924 the city of Moorhead had begun looking for additional ground-water supplies. Between 1927 and 1932 three additional wells were located near 22d Street on the east edge of town. These wells tapped a separate sand aquifer within the till. In the succeeding years the demand for water continued to increase, water levels declined further, and the yield of the wells further decreased. By 1947 the average demand was about 1.2 million gallons a day (Dennis and others, 1949, p. 44). The pumping water level in one of the 12th Street wells was near the bottom and yields of the remaining wells had declined to the lowest for their period of operation.*



WATER LEVELS IN THE 22D STREET WELLS ROSE SHARPLY IN 1948 AND 1949, FROM 188 FEET TO ABOUT 168 FEET BELOW LAND SURFACE OWING TO REDUCTION IN PUMPAGE AT THE 22D STREET WELL FIELD.—*From 1950 to 1959, water levels fluctuated between 166 and 170 feet below land surface due to seasonal changes in pumpage rates, but no continued decline or rise in water levels occurred. Pumpage from the wells in town during this period average about one half million gallons per day. In 1960, a decline in water level of several feet resulted from increased pumpage. Water levels rose again in 1961 and 1962, when pumpage was again reduced at the well consequent to the city's use of the Red River of the North as the main source of supply.*

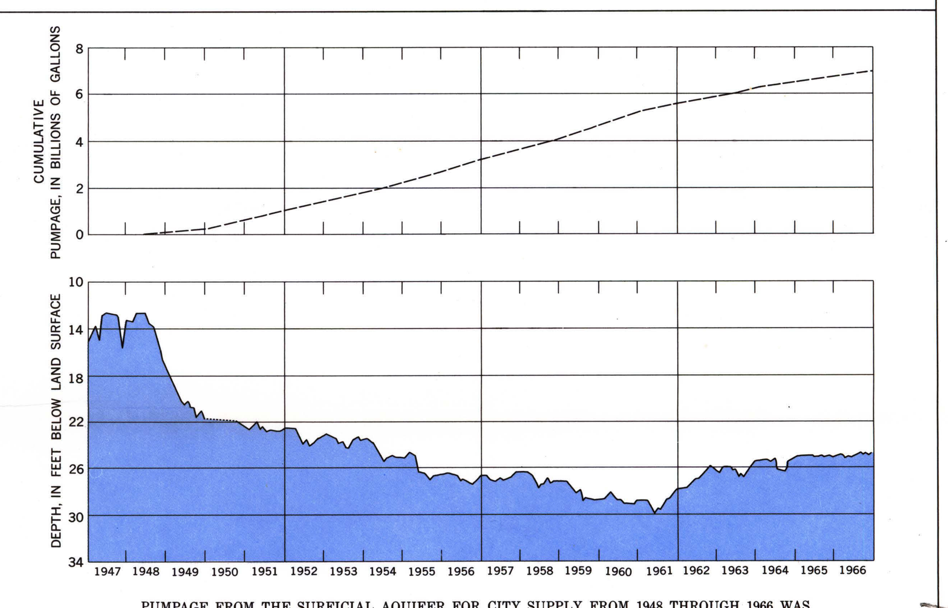
To meet the needs for additional water a gravel aquifer near Dilworth was located and mapped as a result of a test drilling program and supply wells were put into production.



THE LINEAR AQUIFER NEAR DILWORTH WAS DEVELOPED IN 1948 FOR A MUNICIPAL SUPPLY FOR MOORHEAD.—*Near the wells the aquifer consists of a gravel core about 0.5 mile wide and from 70 to 120 feet thick, grading laterally into sand and silt. The aquifer at the well field has an average coefficient of transmissibility of 300,000 gallons per day per foot and a storage coefficient of 0.1.*

Natural recharge to the aquifer is largely from precipitation that falls within the vicinity of the aquifer. Recharge is sufficient to sustain an underflow estimated to be about half million gallons a day at the well field.

Natural discharge occurs largely along the South Branch Buffalo and Buffalo Rivers.



PUMPAGE FROM THE SURFICIAL AQUIFER FOR CITY SUPPLY FROM 1948 THROUGH 1966 WAS ABOUT 7 BILLION GALLONS WITH A MAXIMUM DECLINE OF 18 FEET IN WATER LEVEL

The rate of pumpage averaged about 460 million gallons a year or about 1.3 million gallons per day. The supply was furnished almost entirely from three of the four wells in the well field. Yields of the wells have not declined significantly although water levels are lower.

In 1948 and 1949 the water levels in the well field were lowered rapidly, about 9 feet, in response to initial pumpage. A rapid lowering can be expected when a well field is initially put into production because water is removed from storage until hydraulic gradients are developed that will transmit water to the wells. From 1950 to 1961 the water levels declined at an average rate of about 0.7 foot per year. During this period water was continuously being taken from storage within the aquifer and an undetermined but increasing amount was being diverted from the river.

From 1962 through 1966 water levels rose about 4 feet owing to a decrease in pumping rate.

Because of increased demands for water, the city faced the decision in 1960; whether to obtain additional supplies from increased development of ground-water sources, or to develop a surface-water supply. The city water managers were concerned by the declining water level in the aquifers, the reliability of estimates of potential maximum sustained yield of the aquifer, and the increase in mineralization, particularly in the sulfate content. Private consultants concluded that 1.5 to 2 million gallons per day are probably available from the well field near Dilworth for a very long time, and perhaps perennially. It was also suggested that additional large supplies could be obtained by a second well field located in the aquifer and that artificial recharge to the aquifer using water from the Buffalo River could effectively insure a high sustained yield.

Owing to the uncertainity of the yield and water quality changes of the aquifer, and to a higher sustained flow of the Red River of the North resulting from controlled releases of water from Orwell Reservoir, it was decided to obtain water from the river. Since 1962 Moorhead has used the river as its main source and has used ground water to supplement water needs during periods of high demand and to stabilize variations in quality of raw water at its treatment plant.

Optimum management of the ground-water resources requires adequate hydrologic and geologic data. These data are expensive to obtain; however this cost should be compared with the total costs involved in construction and maintenance of surface-water facilities that are used alternately. More information is needed on the development and management of the aquifers in the Red River Valley, and in particular, on the use of the ground-water reservoir as storage facilities for surface water.

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WATER RESOURCES OF THE BUFFALO RIVER WATERSHED, WEST-CENTRAL MINNESOTA

By
R. W. Maclay, L. E. Bidwell, and T. C. Winter

1969