WATER RESOURCES OF HANSON AND DAVISON COUNTIES, SOUTH DAKOTA

By Donald S. Hansen

U.S. GEOLOGICAL SURVEY

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The inch-pound units used in this report may be converted to metric units by the following conversion factors:

Multiply inch-pound unit	By	To obtain metric unit
inch	25.4	millimeter
foot (ft)	0.3048	meter
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.78543	cubic decameter
mile (mi)	1.609	kilometer
acre-foot (acre-ft)	1,233	cubic meter
acre	0.4047	hectare
gallons per minute (gal/min)	0.06309	liters per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
square foot per day (ft^2/d)	0.0929	square meter per day
micromho per centimeter at 25°C (µmho/cm at 25°C)	1	microsiemens per centimeter at 25°C (uS/cm at 25°C)

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ABSTRACT

Surface water covers about 0.6 percent of Hanson and Davison Counties, and occurs primarily as intermittent streams and ponds. The James River is the major waterway in the counties, and has an average annual discharge of about 300 cubic feet per second.

Five glacial and four bedrock aquifers were delineated in Hanson and Davison Counties. The glacial aquifers are the Floyd, Plum Creek, Ethan, Warren, and Alexandria. The glacial aquifers are outwash deposits confined by as much as 275 feet of glacial till. The bedrock aquifers are the Niobrara, Codell, Dakota, and Sioux Quartzite wash, and are as much as 80, 350, 700, and 500 feet below land surface, respectively.

The glacial aquifers averaged 13 to 40 feet in thickness and contain about 670,000 acre-feet of water in storage. Recharge to the Floyd and Plum Creek aquifers is from the Sioux Quartzite wash aquifer and from fractures in the Sioux Quartzite. Recharge to the Ethan and Warren aquifers is from the Niobrara aquifer. Reported yield to wells from the Floyd and Plum Creek aquifers was as much as 1,000 gallons per minute. Predominant chemical constituents in water from the glacial aquifers are sulfate, calcium, and sodium. Water from the glacial aquifers is used for municipal, domestic, and stock purposes. Water from the Floyd, Plum Creek, and Ethan aquifers is of suitable quality for irrigation use.

The bedrock aquifers averaged 40 to 110 feet in thickness and contain about 11.3 million acre-feet of water in storage. The direction of water movement in the aquifers is to the northeast. The average reported yield from wells in the bedrock aquifers ranged from 1 to 75 gallons per minute. Reported yield from wells in the Niobrara aquifer was as much as 1,000 gallons per minute. Predominant chemical constituents in water from the Niobrara and Codell aquifers were sulfate, sodium, and calcium. Predominant chemical constituents in water from the Dakota and Sioux Quartzite Wash were sulfate and calcium. Water from the bedrock aquifers is used for stock, domestic, and municipal purposes. Water from the Niobrara aquifer is used for irrigation.

The 1975 water use was about 1.4 billion gallons. Sixty-five percent of the water used is from bedrock aquifers and 35 percent is from glacial aquifers.

INTRODUCTION

Purpose and Scope

In July 1977, the South Dakota Geological Survey and the U.S. Geological Survey began a 4-year study to evaluate the water resources and geology of Hanson and Davison Counties. The purpose of this report is to provide hydrogeologic information for future water development and planning in the counties. This study is part of an evaluation of the water resources and geology of eastern South Dakota (fig. 1).

Hanson and Davison Counties encompass 864 mi^2 of the central part of eastern South Dakota and are located in the south-central part of the James Basin (fig. 1). Relief in the area is relatively low. Land surface altitudes in 90 percent of the area range from 1,300 to 1,400 ft above the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which will be referred to as sea level in this report. National Geodetic Vertical Datum of 1929: A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. Land surface altitudes increase gradually toward the Coteau du Missouri in southwestern Davison County where altitudes are as much as 1,650 ft.

Methods of Investigation

Methods of investigation included the collection and tabulation of drillers' logs, well inventories, test drilling, observation-well installation, measurement of static water levels, and chemical analysis of water samples. The test hole, observation well, and water-quality sampling sites in Hanson and Davison Counties are shown in figure 2. Wells and test holes are numbered according to the Federal land survey system (fig. 3).

Acknowledgments

The author would like to acknowledge the residents of Hanson and Davison Counties for their cooperation in providing information on their water wells, and local drilling companies that supplied supplemental test-hole information.

WATER RESOURCES

Water Budget and Drainage

The water resources of Hanson and Davison Counties occur as surface water and ground water. The average annual precipitation for the area is 21 inches. The total volume of water from precipitation that moves through the area in streams and aquifers is about 970,000 acre-ft. About 98 percent of the water is returned to the atmosphere by evaporation and transpiration. About 1 percent of the average annual precipitation becomes streamflow; however, this quantity may vary from year to year due to variations in precipitation. Less than 1 percent of the precipitation percolates downward to become ground water. In a given year the water budget shows a change in ground-water storage which can be detected by and calculated from water-level changes in observation wells in the aquifers. The long-term (greater than 10 years) changes in storage are zero except where or if the ground-water discharge to wells increases.

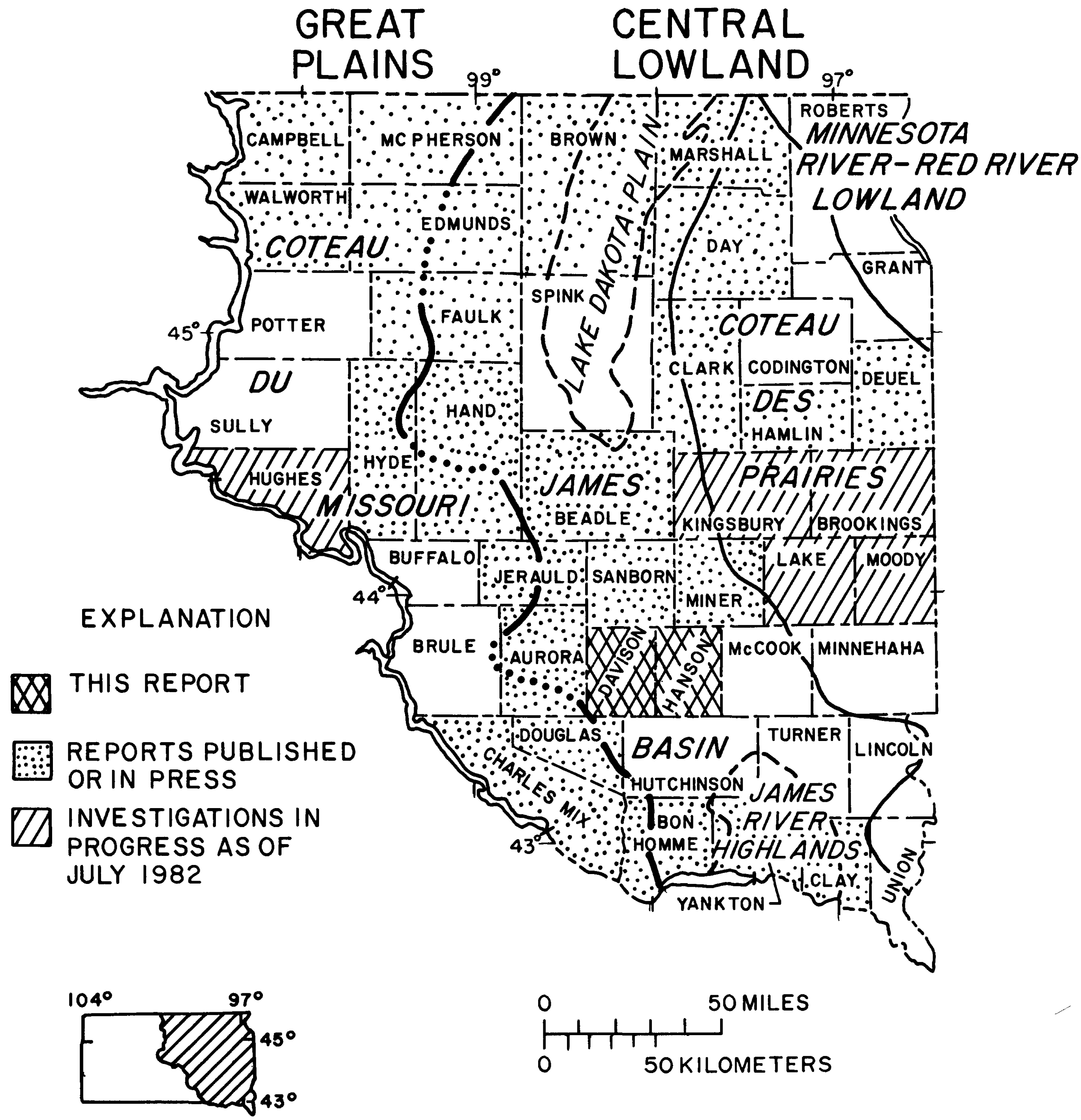


Figure 1.-Index map showing area of this report, status of county investigations, and major physiographic divisions in eastern South Dakota

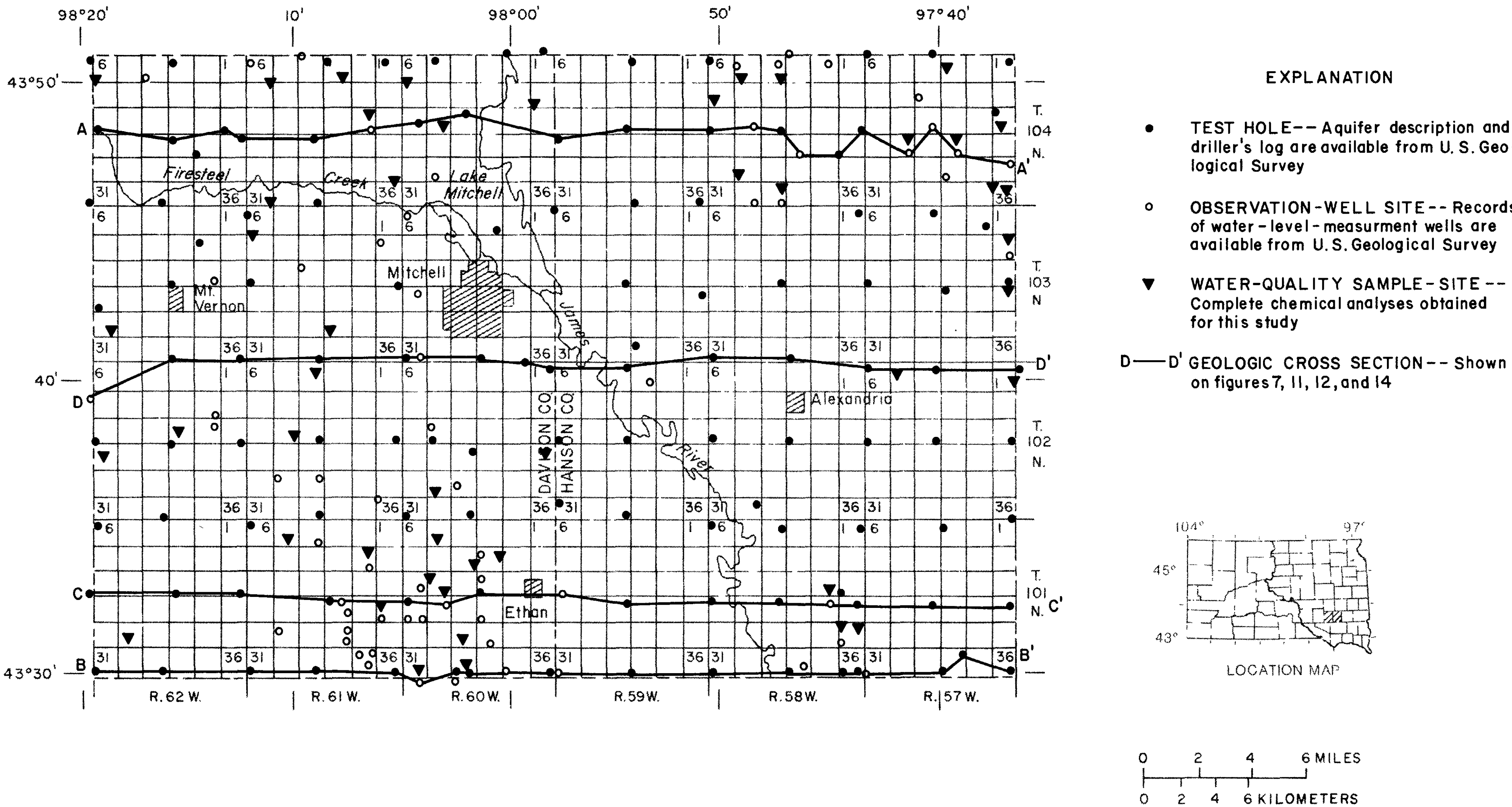


Figure 2.-Location of data sites in Hanson and Davison Counties

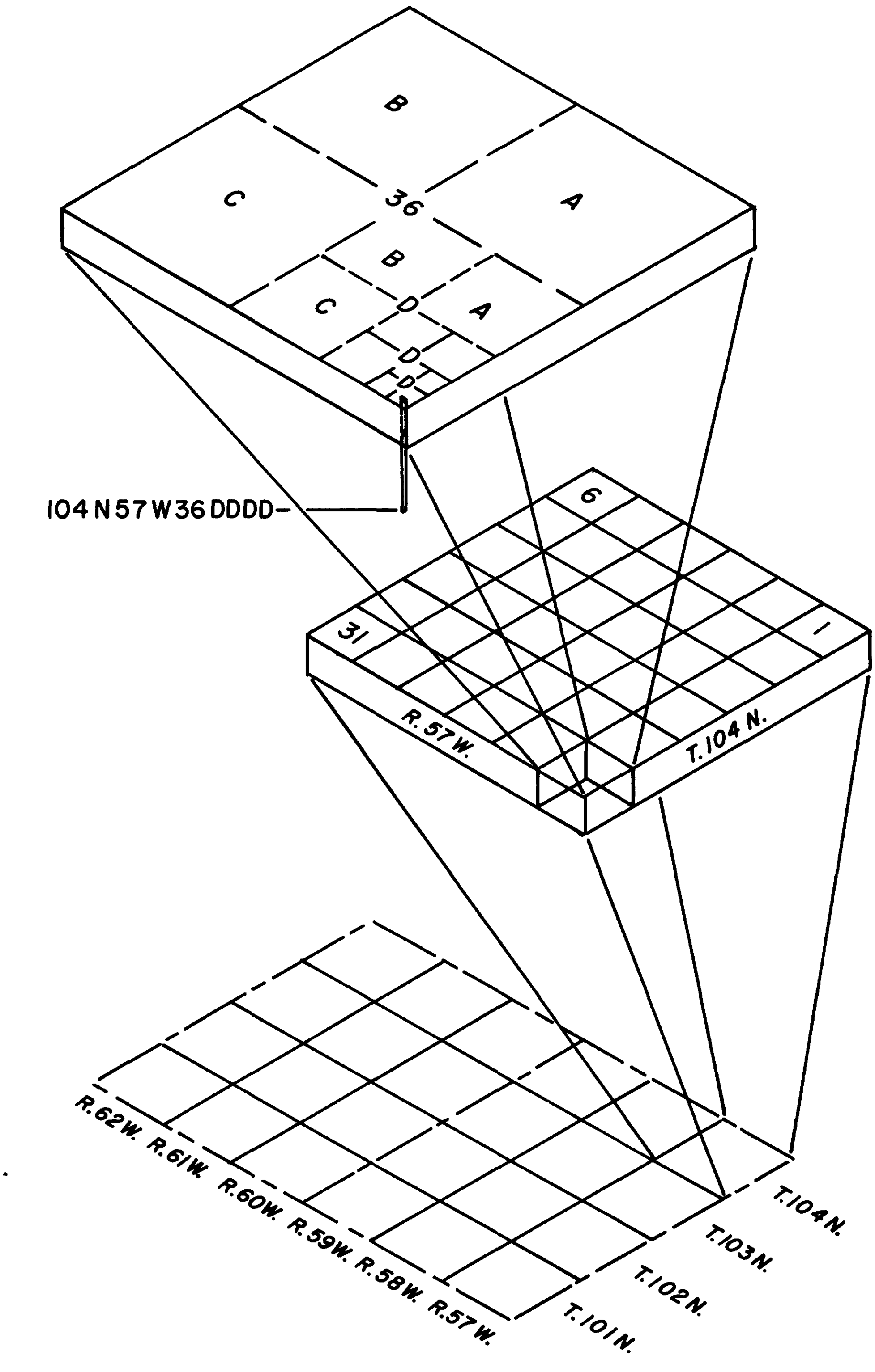


Figure 3.-Well numbering diagram showing location of well 104N57W36DDDD

Drainage of Hanson and Davison Counties is primarily through the James River and its intermittent tributaries (fig. 4). Present drainage patterns in the James Basin were formed by meltwaters following the margin of the glacier that moved southward. Wide channels were subsequently eroded and are presently occupied by intermittent streams.

Surface Water

Streamflow

The main source of streamflow in the counties is the James River and its intermittent tributaries. Average annual discharge at Mitchell is about 300 ft^2/s. Streamflow in the creeks is dependent upon the seasonal variation of precipitation. Creeks generally flow during the spring and early summer from snowmelt runoff and rainfall, but generally do not flow during the late summer, fall, and winter. Firesteel Creek receives discharge from ground-water storage; however, the creek may go dry in the late summer when evaporation exceeds ground-water discharge. A summary of gaging-station records for Firesteel and Enemy Creeks is given in table 1.

Table 1.—Summary of streamflow data for gaging stations in the area

Station number	Station name and location	Drainage area (square miles)	Period of record	Discharge for period of record (cubic feet per second)		
				Maximum	Minimum	Average
06477500	Firesteel Creek near Mount Vernon 104N62W26CC.	540	1955 to 1980	6,610	0	20.9
06478052	Enemy Creek near Mitchell 102N60W13BB.	181	1975 to 1980	1,390	0	3.50

Floods

Extreme flooding in this area is a rare event, although valley bottoms and areas of internal drainage are flooded occasionally during the spring from snowmelt runoff and precipitation. Maps of flood-prone areas along the James River have been prepared by the U.S. Geological Survey and are available from its Huron office. The flood-prone areas are shown on topographic maps at a scale of about 2½ inches to the mile. These maps show areas that have an average chance of 1 in 100 of being flooded in any year.

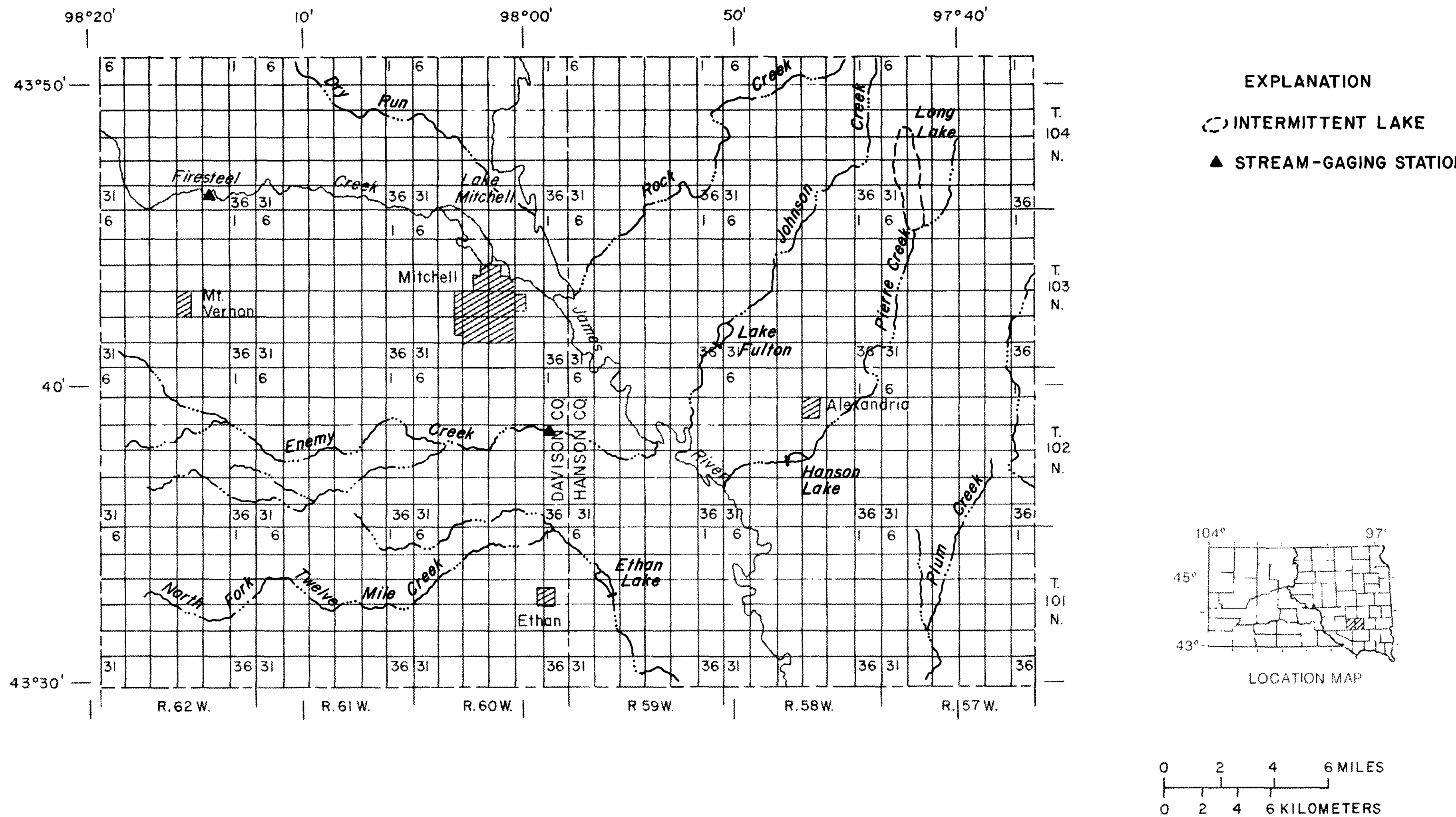


Figure 4.-Drainage map of Hanson and Davison Counties

Lakes, Ponds, Dugouts, and Stock Dams

Lakes and ponds cover about 0.6 percent of the land surface in Hanson and Davison Counties. Lake Mitchell is a reservoir on Firesteel Creek, Lake Ethan is a reservoir on Twelve Mile Creek, Lake Hanson is a reservoir on Pierre Creek, and Lake Fulton is a reservoir on Johnson Creek (fig. 4). The total surface area of these lakes is about 2 mi^2. Lake Mitchell, the largest of the lakes, covers about 1 mi^2 and is used as the public water supply for the city of Mitchell. Ponds and marshes are limited to the northeastern part of Hanson County. They are used primarily for stock watering and wildlife propagation. Dugouts and stock dams are a minor source of surface water and are generally restricted to low lying areas such as stream valley bottoms where the maximum amount of runoff can be collected. During periods of drought, such as in 1976, most of the dugouts are dry.

Chemical Quality

Dissolved-solids concentration varies inversely with the magnitude of streamflow. Specific conductance values can give an indication of dissolved-solids concentration. Table 2 shows that the specific conductance increases with a decrease in instantaneous discharge in the James River and in Firesteel and Enemy Creeks. Specific conductance varies with discharge in Firesteel and Enemy Creeks from 880 μmhos/cm at 25°C with a discharge of 30 ft^3/s to 3,400 μmhos/cm at 25°C with a discharge of 0.01 ft^3/s discharge.

Dissolved-solids concentration in lakes generally decreases in the spring because of dilution from snowmelt runoff and rainfall. The drought of 1976 caused a water-level decline in Lake Mitchell and caused an increased dissolved-solids concentration in the spring of 1977. Chemical analyses of selected lakes and streams in Davison County are in table 3.

Ground-water Occurrence and Quality

Ground water may be obtained from confined glacial outwash aquifers and bedrock aquifers. The glacial aquifers are lenticular in shape and composed of coarse shale pebbles and medium to coarse sand. Glacial aquifers contain about 670,000 acre-ft of water in storage. The bedrock aquifers include the Niobrara, Codell, Dakota, and Sioux Quartzite wash and contain about 11.3 million acre-ft in storage. The Sioux Quartzite wash is a weathered quartzite sand unit overlying the Sioux Quartzite. The storage was calculated by multiplying the areal extent of the aquifer by average thickness by an estimated specific yield of 0.2.

Table 2.—Instantaneous discharge, temperature, and specific conductance of stream waters

Enemy Creek near Mitchell Lat 43°38'33", long 097°59'09"				James River near Mitchell Lat 43°41'36", long 097°57'54"				Firesteel Creek near Mount Vernon Lat 43°46'03", long 098°14'33"			
Date of sample	Instantaneous discharge (cubic feet per second)	Temperature (°C)	Specific conductance (micromhos per centimeter at 25°C)	Date of sample	Instantaneous discharge (cubic feet per second)	Temperature (°C)	Specific conductance (micromhos per centimeter at 25°C)	Date of sample	Instantaneous discharge (cubic feet per second)	Temperature (°C)	Specific conductance (micromhos per centimeter at 25°C)
11-20-78	0.06	0.0	1,900	10- 1-68	16	--	1,670	10-18-78	0.02	--	--
12-11-78	.08	1.0	2,250	3-24-69	84	1.0	1,740	12-11-78	.03	1.0	3,100
3-22-79	30	1.5	880	4- 4-69	8,140	--	369	3-20-79	2.3	9.0	1,260
4-17-79	12	--	2,050	8- 1-69	495	--	927	4-24-79	.76	18.5	1,680
5-25-79	2.6	18.0	2,100	12- 4-69	95	0.0	1,370	6-18-79	.02	20.0	2,100
6-21-79	.59	20.0	2,150	4- 8-70	202	10.5	868	7-23-79	.01	29.0	2,450
7-27-79	.03	23.0	2,100	5- 1-70	435	--	1,010	8-27-79	.01	25.0	2,200
8-15-79	3.1	21.0	--	10- 1-70	4.1	--	1,810	10-23-79	.04	4.5	2,830
9-11-79	2.0	--	--	1- 1-71	3.4	--	2,970	11-27-79	.07	3.0	3,100
11-30-79	.06	3.0	1,920	3- 1-71	625	--	564	12-13-79	.06	4.0	3,350
12-13-79	.08	3.0	2,100	8- 1-71	55	--	1,420	1-22-80	.01	0.0	3,400
1-24-80	.24	1.0	2,180	5- 1-72	2,450	--	716	6-27-80	.50	24.0	2,500
2-13-80	.06	0.0	2,460	9- 1-72	268	--	1,140				
3-20-80	.16	4.0	940								
4-25-80	.08	19.0	1,660								
5-21-80	.09	21.0	1,730								

Table 3.—Chemical analyses of stream and lake waters

[Analyses by U.S. Geological Survey Laboratory unless otherwise noted. umhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

Date of sample	Alkalinity, total (mg/L)	pH	Total hardness (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Bicarbonate (mg/L)	Sulfate, dissolved (mg/L)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Nitrite plus nitrate, dissolved, as N (mg/L)	Dissolved solids, sum of constituents (mg/L)	Discharge (cubic feet per second)	Specific conductance (µmhos/cm at 25°C)	Phosphorous orthophosphate, dissolved, as PO_4 (mg/L)	Phosphorous, dissolved, as P (mg/L)	Phosphorous, total, as P (mg/L)	Noncarbonate hardness (mg/L)	Sodium adsorption ratio	Sodium percent	Silica, dissolved, as SiO_2 (mg/L)	Carbon dioxide, dissolved, as CO_2 (mg/L)
Lake Mitchell[1/]																									
10- -56	150	7.9	310	70	34	190	280	200	0	69	17	20	0.3	0.3	636	--	--	--	--	--	--	--	--	--	--
9- -70	130	--	260	84	12	160	230	100	400	55	13	18	.5	.0	575	--	--	--	--	--	--	--	--	--	--
3- -77	220	7.9	540	110	67	260	570	1,500	530	130	23	55	.3	.1	1,160	--	--	--	--	--	--	--	--	--	--
Firesteel Creek near Mount Vernon																									
4-14-77	160	8.2	360	90	30	200	330	--	--	100	14	72	.2	.04	757	--	1,170	--	--	0.33	190	2	37	19	2.0
3-20-80	200	8.6	220	52	23	240	350	60	130	180	10	61	.3	.03	801	--	1,180	0.03	0.04	--	25	5	62	2.2	--
James River near Mitchell																									
10- 1-68	250	8.0	440	85	55	300	450	--	--	200	10	130	--	.1	1,160	43	1,670	--	--	--	190	4	48	--	--
4- 4-69	89	8.1	100	25	9.5	110	63	--	--	24	9	11	--	.6	215	8,140	369	--	--	--	13	1	32	--	--
10- 1-70	200	8.0	500	96	63	240	600	--	--	210	31	130	--	--	1,300	4.1	1,810	--	--	.5	300	4	46	--	--
3- 1-71	120	7.6	180	44	16	150	110	--	--	46	12	23	--	--	402	625	564	--	--	.8	51	2	34	--	--
10- 1-71	300	8.0	380	80	45	370	280	--	--	130	17	58	.3	--	802	36	1,230	.34	--	.11	85	3	41	8.7	--
5- 1-72	160	7.5	230	53	24	190	170	--	--	54	14	25	--	--	453	2,450	716	--	--	.41	74	2	32	14	--
9- 1-72	240	8.2	370	81	40	290	310	--	--	94	17	35	--	--	747	68	1,080	--	--	.22	130	2	34	22	--

1/ Analyses by South Dakota State Department of Health.

Glacial Aquifers

Glacial aquifers in Hanson and Davison Counties are primarily unconsolidated sand and gravel outwash deposited by meltwater from receeding glaciers. The outwash deposits are usually confined by glacial till and contain alternating layers of till. Till has a hydraulic conductivity of about 0.002 ft/day (Norris, 1962) and is not a major source of water; however, locally it may contain thin, discontinuous sand and gravel lenses which may yield as much as 2 gal/min.

The Floyd, Plum Creek, Ethan, Warren, and Alexandria are the major glacial aquifers in Hanson and Davison Counties (fig. 5). The Floyd aquifer is the continuation of the same named aquifer in Miner and Beadle Counties and the Warren aquifer is the continuation of the same named aquifer in Sanborn County. The Warren and Alexandria aquifers are limited in extent and thickness and are discontinuous, but, may be an important source of water when other water sources are unavailable.

Floyd aquifer.—The Floyd aquifer (fig. 6) consists of a complex system of interconnected sand and gravel layers, intermixed and confined by a gray pebbly till. In T. 104 N., R. 57 W., the aquifer is composed of medium sand and fine gravel interlayered with till. The aquifer exceeds 20 ft in thickness in about 70 percent of the area. In T. 104 N., R. 58 W., the aquifer is composed of coarse gravel and sand and contains little or no till. The aquifer exceeds 25 ft in thickness in approximately 75 percent of the area. A geologic section of the aquifer is shown in figure 7, and the hydrologic characteristics are in table 4.

Recharge to the Floyd aquifer is from the underlying, fractured Sioux Quartzite which in turn is recharged by precipitation on outcrops in central Hanson County, and by leakage from the till. Recharge to the Floyd aquifer by infiltration of precipitation through the till is unlikely in Hanson County because of the 45 to 275 ft of till that confines the aquifer. Water-level fluctuations from observation wells indicate that seasonal changes do occur, however, the recharge area is probably in McCook County. Inflow from McCook County is about 10 acre-ft/day.

The direction of water movement in the Floyd aquifer is to the northwest (fig. 8). Discharge of about 500 acre-ft/yr from the quartzite quarry at Spencer, S. Dak., caused the direction of movement to change from east to south in the southern part of the aquifer. The gradient of the potentiometric surface decreases from 20 ft/mi in the east half of T. 104 N., R. 57 W. to 4 ft/mi in the west half. The gradient was as much as 40 ft/mi to the west in the northern part of T. 104 N., R. 58 W. Depth to water in wells ranged from 3 to 25 ft below land surface in T. 104 N., R. 58 W. and ranged from 45 to 65 ft below land surface in T. 104 N., R. 57 W.

Discharge from the Floyd aquifer is (1) from stock and domestic wells, (2) leakage to fractures in the Sioux Quartzite near the Spencer Quarry, and (3) possibly by leakage to the underlying Codell aquifer. Outflow to Miner County from the aquifer is about 11 acre-ft/day.

Water-level fluctuations in the Floyd aquifer (fig. 9) are caused by seasonal changes in recharge. Water levels in most observation wells rose from October 1979 to March 1980 because of recharge from precipitation and snowmelt. Water levels in most wells declined 2 to 4 ft from April to August 1980 because of below normal precipitation. Water levels in all observation wells were at a minimum level between July and October 1980. Above normal rainfall during August 1980 probably did not recharge the aquifer because of deficient soil moisture. Water levels in most wells rose 0.5 to 2.0 ft from September to December 1980.

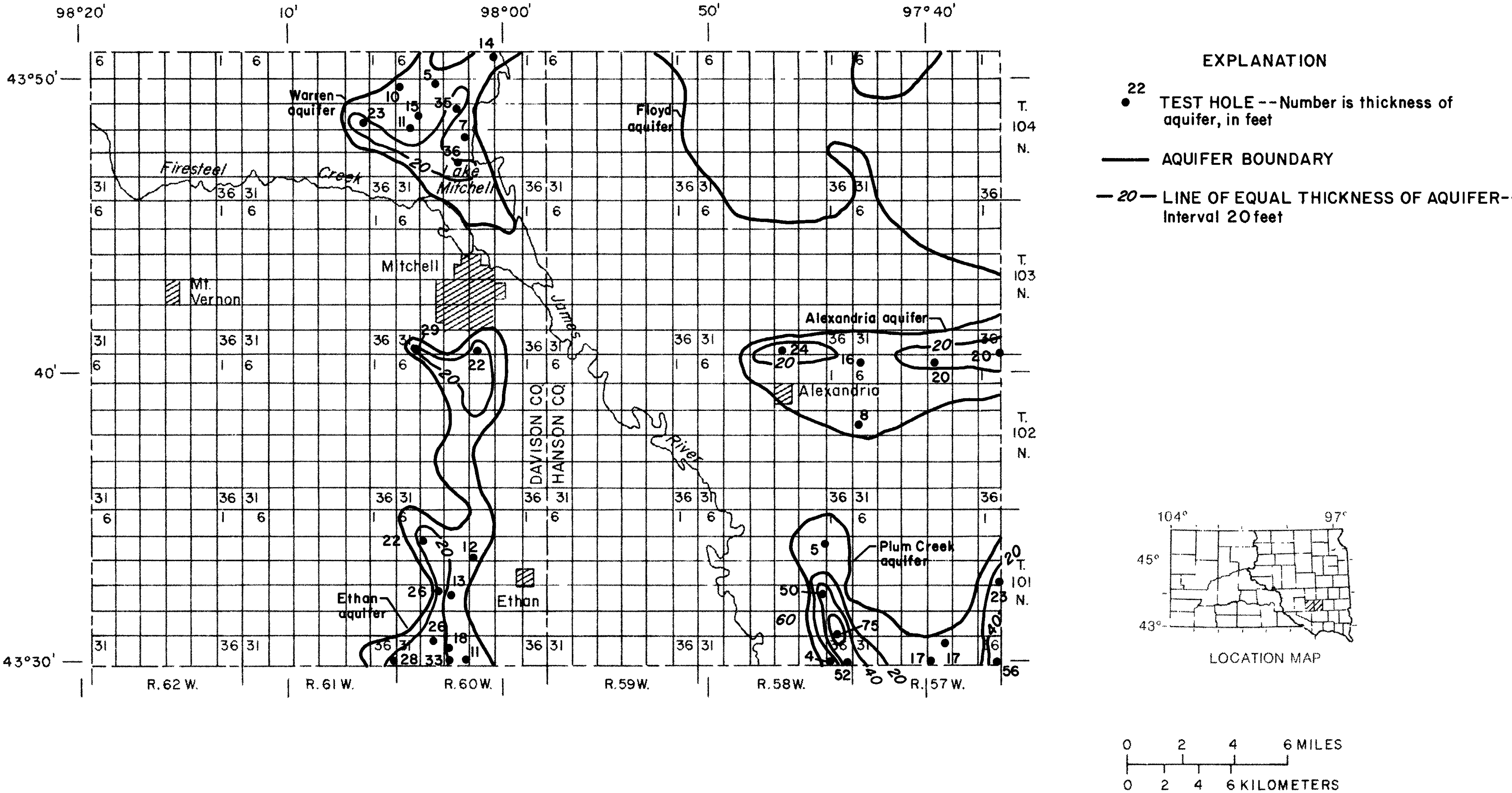


Figure 5.-Location and thickness of glacial aquifers in Hanson and Davison Counties. (Thickness of the Floyd aquifer is shown in figure 6.)

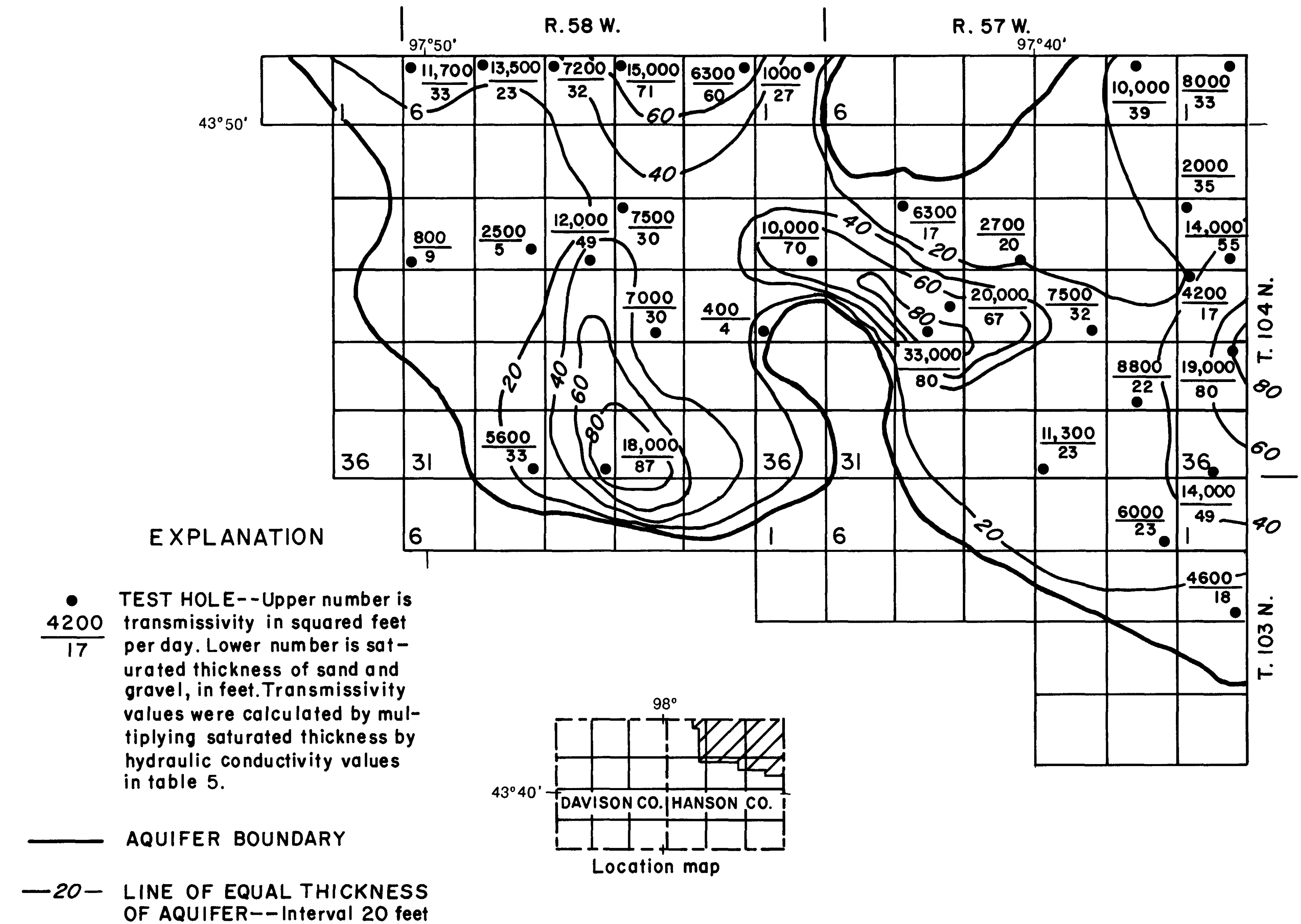


Figure 6.-Transmissivity and thickness of the Floyd aquifer

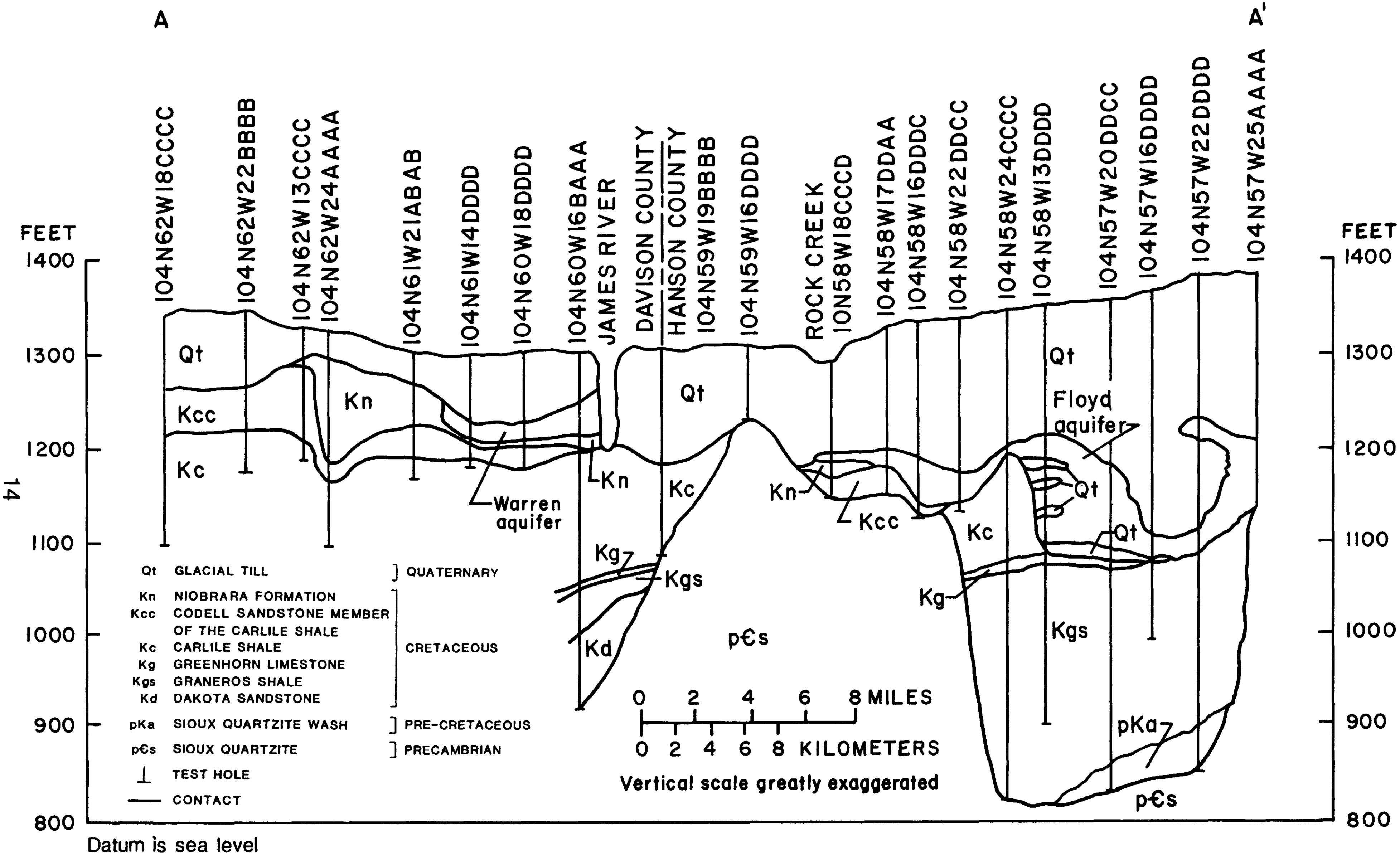


Figure 7.-Geologic section A-A' showing the Floyd, Warren, and Sioux Quartzite wash aquifers. Location of section is shown in figure 2

Table 4.--Summary of the hydrologic characteristics of major aquifers in Hanson and Davison Counties

Aquifer name	Areal extent (square miles)	Maximum thickness (feet)	Average thickness (feet)	Range in depth below land surface (feet)	Range of water level below land surface[1/] (feet)	Artesian (A) and (or) water table (WT) aquifer	Estimated amount of water in storage[2/] (acre-feet)	Reported well yield (gallons per minute)	Suitable for irrigation use
GLACIAL AQUIFERS									
Floyd	84	87	40	45-275	3-66	A	430,000	1,000	Yes.
Plum Creek	27	75	18	120-195	63-111	A	60,000	1,000	Do.
Ethan	33	33	20	3-75	12-51	A, WT	85,000	100-400	Yes, may be marginal.
Warren	21	30	13	40-80	12-15	A	35,000	10	No.
Alexandria	31	24	15	45-55	-	A	60,000	10	Do.
BEDROCK AQUIFERS									
Niobrara	425	140	65	0-80	9-70	A, WT	3.5 million	1,000	Yes.
Codell	547	94	40	0-350	9-87	A	2.8 million	5-50	No.
Dakota	340	400	110	250-700	F-12	A	4.8 million	1-50	Do.
Sioux Quarztie wash	28	105	60	400-500	F-21	A	215,000	15-75	Do.

1/ F, Flowing at land surface.

2/ Storage was estimated by multiplying areal extent by average thickness by specific yield (0.2).

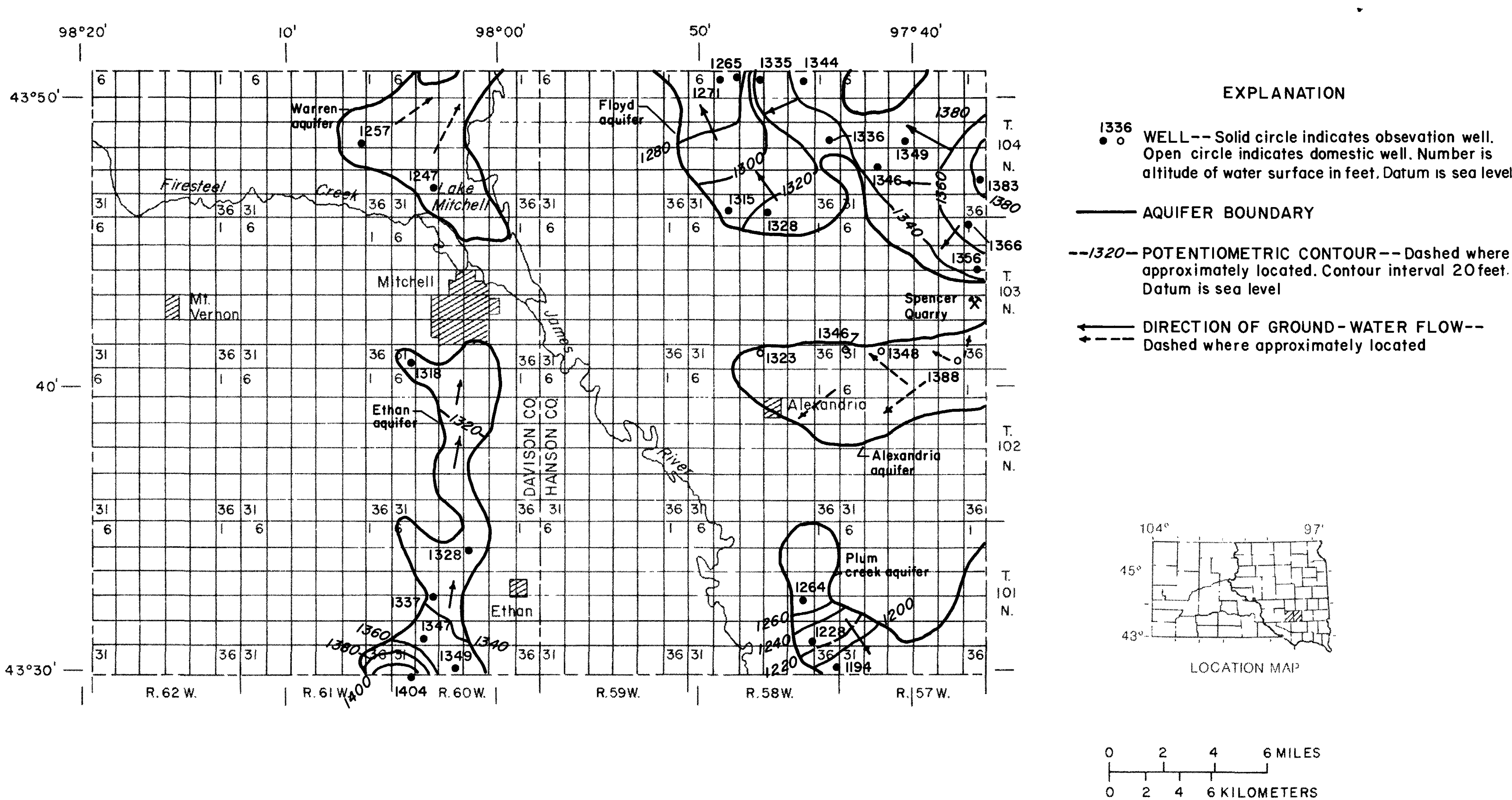


Figure 8.-Potentiometric surface of the glacial aquifers in Hanson and Davison Counties, November 1980

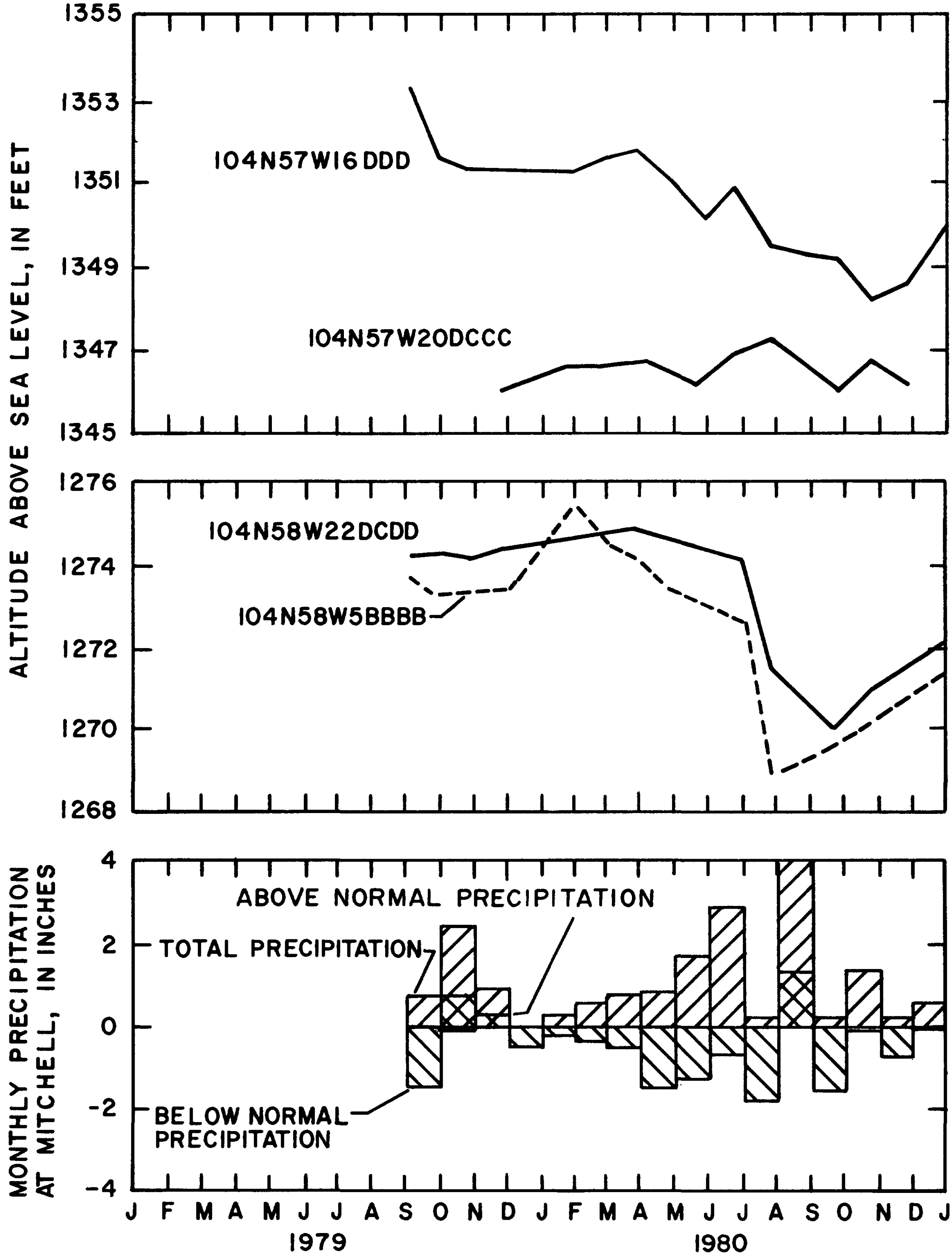


Figure 9.-Water-level fluctuations in the Floyd aquifer and monthly precipitation at Mitchell

The water-bearing properties of the Floyd aquifer are best determined by aquifer tests. Values of transmissivity, hydraulic conductivity, and storage coefficient indicate the aquifer's ability to transmit and store water. Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Hydraulic conductivity is the rate of flow of water transmitted through a porous medium of unit cross-sectional area under a unit hydraulic gradient at the prevailing kinematic viscosity. Storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in potentiometric head. Values of hydraulic conductivity were calculated from an aquifer test in the Floyd aquifer in Miner County for a medium-grained gravel and coarse-grained sand. These values were about 40-60 percent lower than the values obtained for the aquifer by Koch (1980). Table 5 was developed by decreasing Koch's hydraulic conductivity values 40 to 60 percent. Using the aquifer test results, values were estimated at other locations based on examination of samples collected during test drilling. The relation of particle-size classification to hydraulic conductivity was used to estimate the hydraulic conductivity at the test-hole sites in Hanson County. The lower conductivity values in each range were assigned to relatively unsorted material, and higher values were assigned to well-sorted material. An estimate of transmissivity was calculated by multiplying hydraulic conductivity of the sand and gravel layer by the layer thickness and calculating the sum of all the layers from the test hole. Figure 6 shows the calculated transmissivities in Hanson County.

Table 5.—Estimated values of hydraulic conductivity for various grain sizes found in wells in the Floyd aquifer

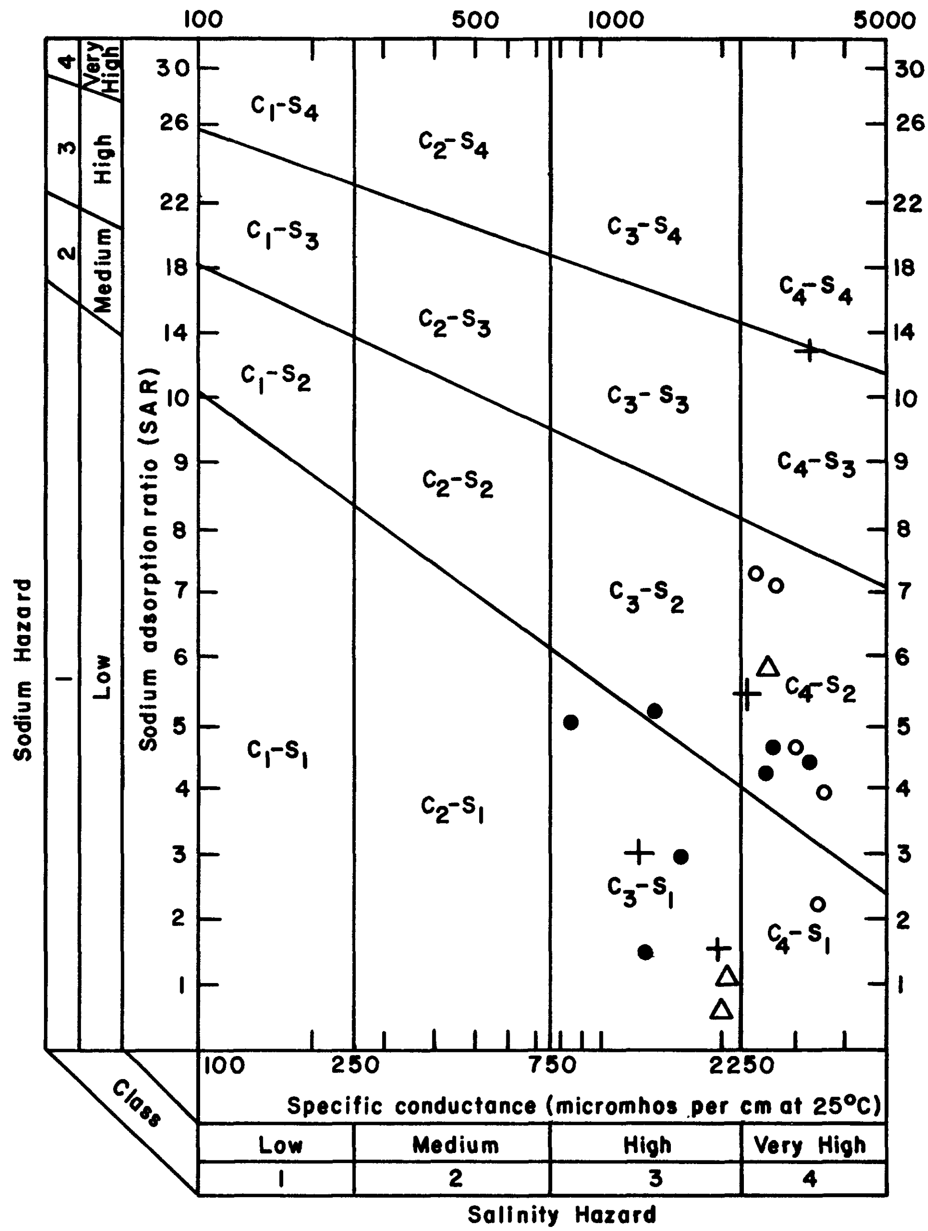
	Hydraulic conductivity (K) (feet per day)
Sand, fine	20
Sand, coarse, to medium	160
Sand, very coarse to coarse	200
Sand, coarse and gravel	250
Gravel, fine	400
Gravel, medium	500
Gravel, coarse	600

The predominant chemical constituents in water from the Floyd aquifer are sulfate, sodium, and calcium. A summary of the chemical analyses is given in table 6. Dissolved solids ranged from 740 to 2,830 mg/L and averaged 1,510 mg/L. Hardness values ranged from 210 to 1,300 mg/L and averaged 690 mg/L. The salinity and sodium hazard is shown in figure 10. The interpretation of these hazards for irrigation are given as supplemental information. The water is used for stock, domestic, irrigation, and municipal purposes.

Table 6.—Summary of chemical analyses of water from the Floyd aquifer

[All values based on 8 samples. °C, degrees Celsius; µmhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

	Mean	Minimum value	Maximum value
Temperature, water (°C)	9.8	7.0	13.5
Specific conductance (µmhos/cm at 25°C)	2,060	1,160	3,710
pH, field	7.8	7.3	8.4
Alkalinity (mg/L)	240	150	390
Nitrogen (mg/L)	2.0	.0	14
Orthophosphate as phosphorus, dissolved (mg/L)	.04	.0	.20
Phosphorus, dissolved (mg/L)	.03	.01	.08
Orthophosphate as phosphate dissolved (mg/L)	.01	.0	.07
Hardness (mg/L)	690	210	1,300
Noncarbonate hardness (mg/L)	460	.0	1,100
Calcium, dissolved (mg/L)	180	60	290
Magnesium, dissolved (mg/L)	56	17	130
Sodium, dissolved (mg/L)	219	77	400
Sodium adsorption ratio	4	1	5
Sodium percent	40	22	62
Potassium, dissolved (mg/L)	20	13	24
Chloride, dissolved (mg/L)	80	30	180
Sulfate, dissolved (mg/L)	770	220	1,600
Fluoride, dissolved (mg/L)	.6	.3	1.2
Silica, dissolved (mg/L)	24	11	31
Boron, dissolved (µg/L)	1,000	490	1,600
Iron, dissolved (µg/L)	690	30	2,700
Manganese, dissolved (µg/L)	1,000	30	2,500
Dissolved solids, sum of constituents (mg/L)	1,510	740	2,830



EXPLANATION

● FLOYD AQUIFER

△ PLUM CREEK AQUIFER

○ ETHAN AQUIFER

+ NIOBRARA AQUIFER

Figure 10.–Diagram of classification of ground water for irrigation

Plum Creek aquifer.—The Plum Creek aquifer (fig. 5) is composed of medium-to coarse-grained sand and gravel outwash. The aquifer is confined by a gray pebbly till and generally is less than 20 ft thick (figs. 11 and 12). In sections 25, 26, 35, and 36 of T. 101 N., R. 58 W., the aquifer is as much as 75 ft thick, and in section 36 of T. 101 N., R. 57 W., the aquifer is as much as 56 ft thick. The aquifer slopes southward about 25 ft/mi and is as much as 195 ft below land surface at the Hanson-Hutchinson County line. Hydrologic characteristics of the Plum Creek aquifer are in table 4 and the irrigation classification is shown in figure 10.

Recharge to the Plum Creek aquifer is by infiltration of snowmelt and rainfall on Sioux Quartzite outcrops to the north and subsequent movement southward through the quartzite fracture system into the aquifer. The direction of water movement is to the southeast at a gradient of 20 ft/mi (fig. 8).

Discharge from the Plum Creek aquifer is from irrigation, domestic, and stock wells. Outflow to Hutchinson County is about 8 acre-ft/day.

Water-level fluctuations in observation wells from the Plum Creek aquifer (fig. 13) are caused by seasonal changes in recharge. Water levels generally rose from December 1979 to May 1980 because of recharge from snowmelt and spring rains. Water levels declined from June 1980 to late September 1980 because of below normal precipitation.

The predominant chemical constituents in water from the Plum Creek aquifer are sulfate, bicarbonate, and calcium (table 7). Three water samples collected from wells where the aquifer was greater than 20 ft thick had dissolved-solids concentrations of about 1,700 mg/L. Specific conductance of water, collected from wells where the aquifer was less than 20 ft thick, ranged from 2,360 to 3,300 μmhos/cm at 25°C and averaged 2,730 μmhos/cm at 25°C. Higher dissolved-constituent concentrations in the thinner sections of the aquifer (less than 15 ft) probably are caused by leakage from the glacial till. Field hardness values ranged from 570 to 1,680 mg/L and averaged 1,480 mg/L.

Water in the Plum Creek aquifer is used for domestic, stock, and irrigation use.

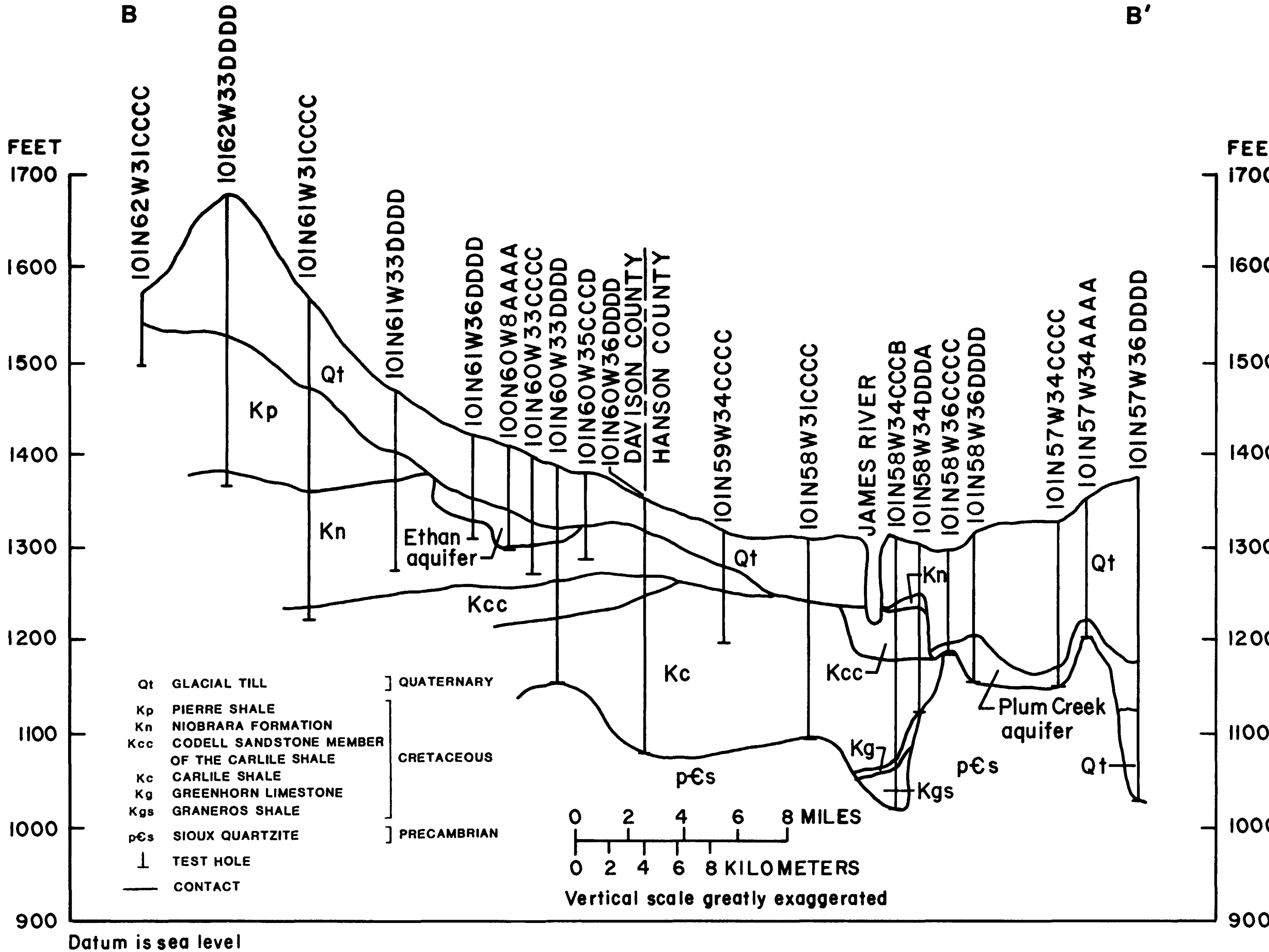


Figure 11.-Geologic section B-B′ showing the Ethan and Plum Creek aquifers. Location of section is shown in figure 2

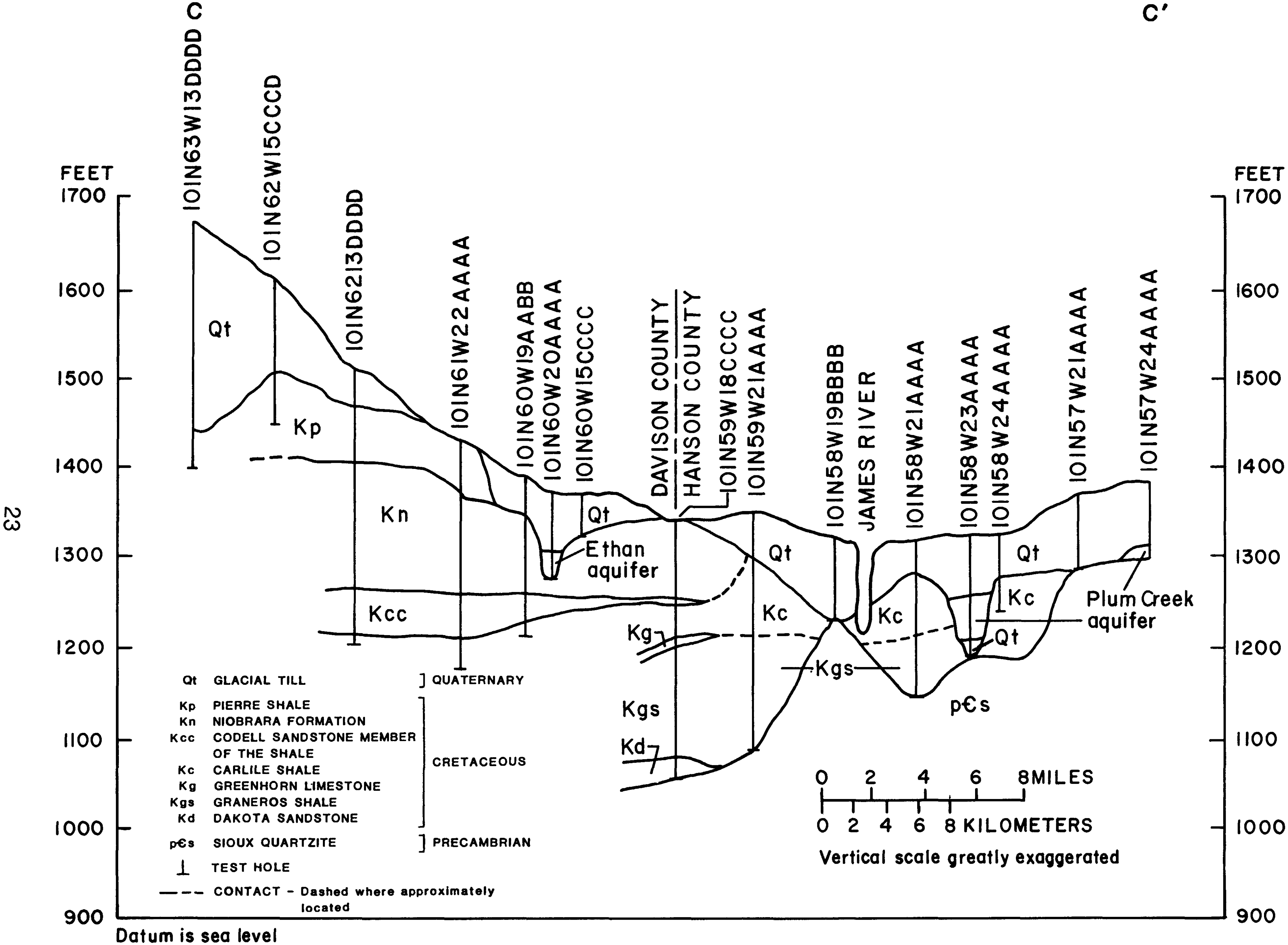


Figure 12.–Geologic section C–C′ showing the Ethan and Plum Creek aquifers. Location of section is shown in figure 2

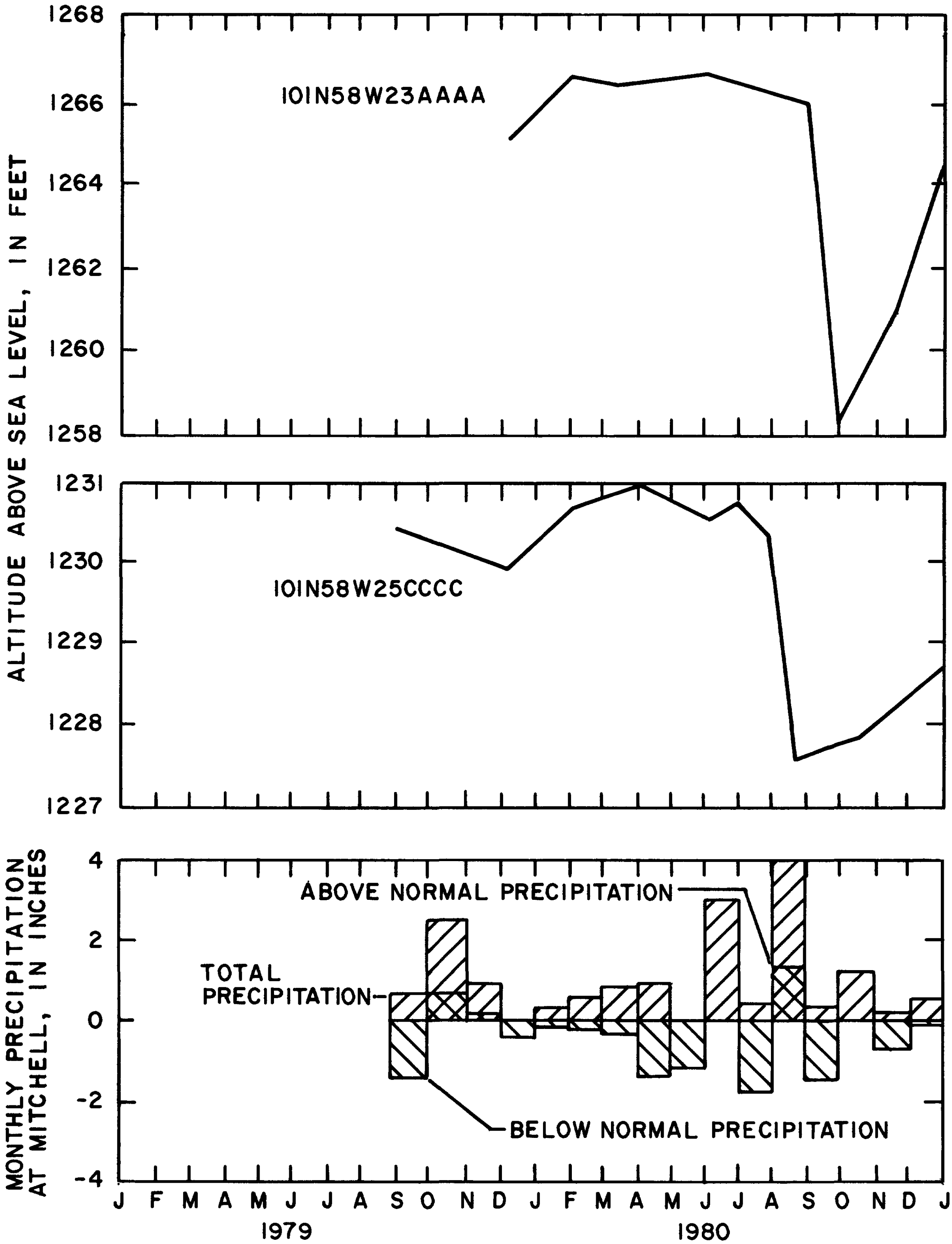


Figure 13.–Water-level fluctuations in observation wells in the Plum Creek aquifer and monthly precipitation at Mitchell

Table 7.—Chemical analyses of water from the Plum Creek aquifer

[μmhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter]

	Well 101N58W 23AAAA	Well 101N58W 25CCCC	Well 101N58W 25DADC
Date of sample	7-30-80	7-30-80	7-30-80
Calcium, dissolved (mg/L)	150	300	300
Magnesium, dissolved (mg/L)	48	91	82
Sodium, dissolved (mg/L)	340	53	98
Potassium, dissolved (mg/L)	19	24	18
Bicarbonate (mg/L)	500	460	490
Alkalinity, total (mg/L)	410	380	400
Sulfate, dissolved (mg/L)	900	910	900
Chloride, dissolved (mg/L)	23	5.7	13
Boron, dissolved (μg/L)	1,400	790	740
Dissolved solids, sum of constituents (mg/L)	1,750	1,640	1,680
Hardness (mg/L)	570	1,100	1,100
Percent sodium	55	9	16
Sodium adsorption ratio	6	0.7	1
Specific conductance (μmhos/cm at 25°C)	2,620	2,060	2,200
pH	7.2	7.5	7.2

Ethan aquifer.--The Ethan aquifer (fig. 5) is a glacial outwash deposit composed of medium- to coarse-grained sand intermixed with fine- to medium-grained gravel. The outwash lies directly on the Niobrara Formation and is confined by gray pebbly till in the southern part of Davison County (fig. 11). In the north half of T. 102 N., R. 60 W. the aquifer is at or near land surface and is under water-table conditions (fig. 14). The aquifer increases in depth below land surface southward to 65 to 75 ft near the Hutchinson-Davison County line where it is under artesian conditions. The Ethan aquifer probably would not supply enough water for irrigation, however, irrigation may be possible when a properly constructed well is completed, such that both the Ethan and Niobrara aquifers supply water to the well. Hydrologic characteristics are in table 4 and classification for irrigation use is shown in figure 10.

Recharge to the Ethan aquifer is by infiltration of snowmelt and rainfall during spring and early summer where it is at or near land surface and from the Niobrara aquifer. Inflow from Hutchinson County probably does not occur because of a ground-water divide at the county line. Observation well data 5 mi south of the Davison-Hutchinson County line indicates that the direction of ground-water movement in the Ethan aquifer is to the south.

The direction of water movement in the Ethan aquifer (fig. 8) is to the north at a gradient of about 5 ft/mi. The gradient between the Davison-Hutchinson County line and 1 mi north is about 60 ft/mi. Depth to water in wells tends to increase southward from 9 to 12 ft northwest of Ethan to 24 to 53 ft below land surface southwest of Ethan. An exception to this trend is indicated in observation well 100N60W8AAAA (at the county line) where water levels ranged from 1 to 12 ft below land surface.

Discharge from the Ethan aquifer is from irrigation and stock wells and by evapotranspiration in T. 102 N., R. 60 W. where the aquifer is at or near land surface.

Water-level fluctuations in observation wells from the aquifer (fig. 15) are caused by seasonal changes in recharge. Water levels in wells 101N60W33DCCC and 101N60W33CCCC rose 1 to 2 ft during the spring and early summer months of 1980 because of recharge from snowmelt and rainfall. Water levels declined 7 to 10 ft from late May to September 1980 because of below-normal precipitation and irrigation withdrawals. Water levels rose about 1.0 ft from October to December 1980.

Predominant chemical constituents in water from the Ethan aquifer are sulfate, sodium, and calcium. Dissolved-solids concentration was 660 to 1,360 mg/L higher in wells 100N60W8AAAA and 101N60W31DDDD than other wells sampled. The ground-water divide in this area may have caused water stagnation in the aquifer that resulted in the higher dissolved-solids concentration. Dissolved-solids concentration ranged from 1,760 to 3,120 mg/L and averaged 2,310 mg/L. Hardness concentrations ranged from 510 to 1,600 mg/L and averaged 1,100 mg/L. Chemical analyses of water from the aquifer is in table 8. Water from the aquifer is used for domestic, municipal, stock, and irrigation purposes.

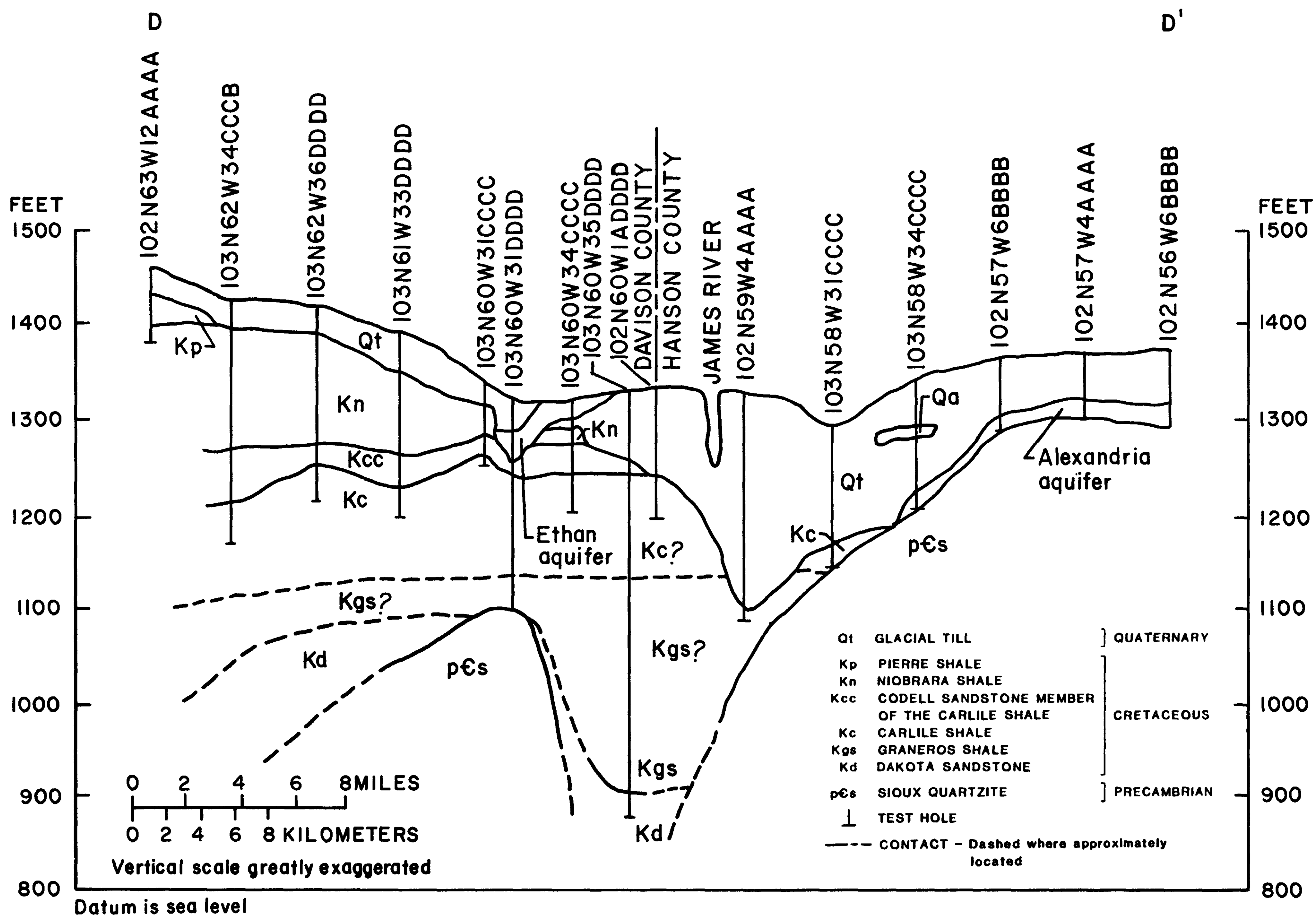


Figure 14.-Geologic section D-D' showing the Ethan and Alexandria aquifers. Location of section is shown in figure 2

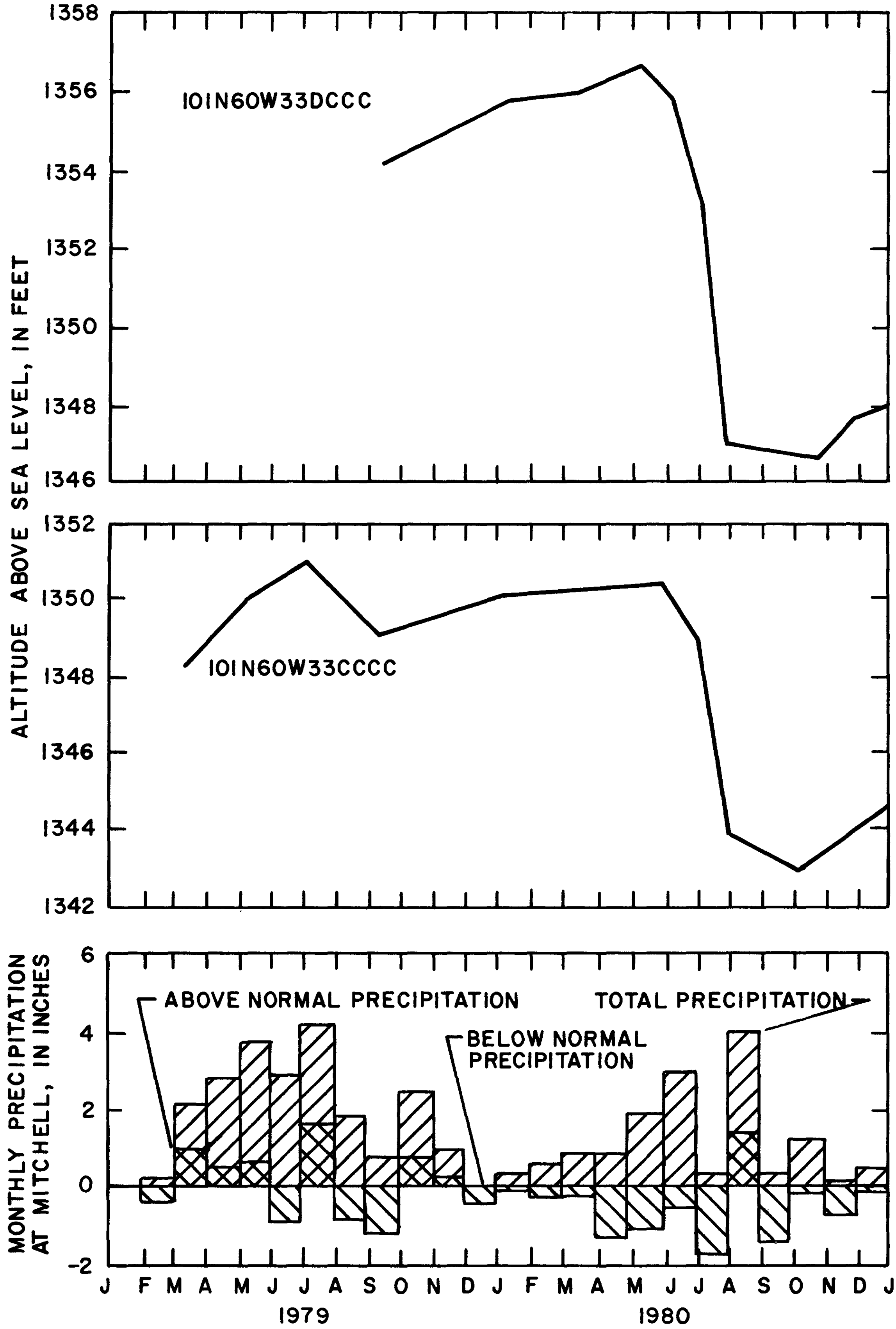


Figure 15.–Water-level fluctuations in observation wells in the Ethan aquifer and monthly precipitation at Mitchell

Table 8.--Chemical analyses of water from the Ethan aquifer

[°C, degrees Celsius; µmhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

	101N60W 20AAAA	101N60W 28CDDC	101N60W 33CCCC	101N60W 31DDDD	100N60W 8AAAA	
Date of sample	7-30-80	8-29-79	10-03-78	8-10-76	10-03-78	7-30-80
Temperature, water (°C)	15	20.5	--	--	16	--
Specific conductance (µmhos/cm at 25°C)	2,740	2,500	2,300	3,160	3,550	2,870
pH, field	7.3	7.6	7.8	7.0	7.5	7.7
Bicarbonate, dissolved (mg/L)	--	530	380	290	270	200
Alkalinity (mg/L)	400	430	310	240	220	160
Nitrogen (mg/L)	.1	.01	--	--	.38	--
Orthophosphate as phosphorus, dissolved (mg/L)	.01	.01	--	--	.01	--
Phosphorus, dissolved (mg/L)	.01	.0	--	--	.02	--
Orthophosphate as phosphate, dissolved (mg/L)	.03	.03	--	--	.03	--
Hardness (mg/L)	880	600	510	1,600	1,500	1,300
Noncarbonate hardness (mg/L)	480	160	--	--	1,300	--
Calcium, dissolved (mg/L)	260	170	140	410	410	390
Magnesium, dissolved (mg/L)	57	42	40	150	120	79
Sodium, dissolved (mg/L)	31	390	360	210	330	260
Sodium adsorption ratio	4	7	7	2	4	3
Sodium percent	43	58	59	21	31	29
Potassium, dissolved (mg/L)	22	21	20	30	47	45
Chloride, dissolved (mg/L)	26	56	60	45	47	80
Sulfate, dissolved (mg/L)	1,100	980	790	1,950	2,000	1,500
Fluoride, dissolved (mg/L)	.6	.4	--	--	.4	--
Silica, dissolved (mg/L)	22	16	--	--	22	--
Boron, dissolved (µg/L)	3,500	3,900	--	--	1,500	--
Iron, dissolved (µg/L)	940	130	--	--	190	--
Manganese, dissolved (µg/L)	780	330	--	--	4,100	--
Dissolved solids, sum of constituents (mg/L)	2,040	1,940	1,760	--	3,120	2,700

Warren and Alexandria aquifers.—The Warren and Alexandria aquifers (fig. 5) are composed of coarse sand, intermixed with layers of clay and stringers of medium-grained gravel. The Warren aquifer is discontinuous and is overlain by 70 to 80 ft of gray pebbly till (fig. 7). The Alexandria aquifer overlies the Sioux Quartzite and is covered by 40 to 50 ft of till (fig. 14). Water in both aquifers is under artesian conditions. Hydrologic characteristics of the aquifers are in table 4.

Recharge to the Warren aquifer is from the Niobrara aquifer and from Lake Mitchell where the aquifer and the lake are in hydraulic connection. Recharge to the Alexandria aquifer may be by leakage from the overlying glacial till. Reported water-level data from the Alexandria aquifer indicates that there is inflow from McCook County.

The direction of water movement in the Warren aquifer is to the northeast at a gradient of 10 ft/mi (fig. 8). The direction of water movement in the Alexandria aquifer, determined by reported water levels, is to the north and southwest indicating a probable ground-water divide in the area (fig. 8).

Discharge from the Warren aquifer is to Dry Run and the James River (fig. 4). Reported water-level data indicates that there may be discharge from the Alexandria aquifer to fractures in the Sioux Quartzite. Discharge from both aquifers is to domestic, municipal, and stock wells.

Water-level fluctuations in the Warren aquifer are caused by seasonal changes in recharge. Below-normal precipitation (3 inches) from June to September 1980 caused a 2-ft water-level decline in well 104N61W14DDDD. Below-normal precipitation (0.6 inches) from July to September 1979 caused a 1.2-ft water-level decline. During the spring and early summer of 1980, water levels rose 0.5 ft but did not rise to levels measured in July of 1979 because of below normal precipitation.

Predominant chemical constituents in water from the Warren aquifer are sulfate and calcium. Predominant chemical constituents in water from the Alexandria aquifer are calcium, magnesium, bicarbonate, and sulfate. Specific conductance of water from the Alexandria aquifer ranged from 2,100 to 5,380 µmhos/cm and averaged 3,540 µmhos/cm. Hardness concentration, determined from field analyses, ranged from 1,100 to 2,700 mg/L and averaged 1,900 mg/L. Chemical analyses of water from both aquifers are given in table 9. Water from the aquifers is used for stock, domestic, and municipal purposes.

Bedrock Aquifers

The bedrock aquifers in Hanson and Davison Counties, in order of increasing age, are Niobrara, Codell, and Dakota (fig. 16). Bedrock aquifers are found in the northeast, north-central, and southwest part of Hanson County. Davison County is underlain by all three aquifers. A water-bearing unit of weathered quartzite sand (Sioux Quartzite wash) overlies the Sioux Quartzite in northeastern Hanson County and probably is hydraulically connected to the Dakota aquifer.

Table 9.--Chemical analyses of water from the Warren and Alexandria aquifers

[μmhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter]

	Warren aquifer		Alexandria aquifer	
	Well 104N61W 14DDDD	Well 104N60W 29DDDC	Well 102N57W 1ADDC	Well 102N57W 5BBBB
Date of sample	4-09-80	3-03-76	7-30-80	7-30-80
Calcium, dissolved (mg/L)	330	200	450	500
Magnesium, dissolved (mg/L)	120	84	120	350
Sodium, dissolved (mg/L)	110	84	49	130
Potassium, dissolved (mg/L)	22	20	1.8	21
Bicarbonate, dissolved (mg/L)	460	560	280	610
Alkalinity, total (mg/L)	380	460	230	500
Chloride, dissolved (mg/L)	20	--	13	39
Sulfate, dissolved (mg/L)	1,100	550	1,400	2,300
Boron, dissolved (μg/L)	1,400	--	500	330
Dissolved solids, sum of constituents (mg/L)	1,950	1,400	2,210	3,770
Hardness, total (mg/L)	1,300	860	1,600	2,700
Iron, dissolved (μg/L)	30	1,800	22,000	6,700
Percent sodium	15	--	6	9
Sodium adsorption ratio	13	--	.5	1
Specific conductance, field (μmhos/cm at 25°C)	2,250	1,750	2,550	4,550
pH, field	7.7	6.9	7.6	8.4

System	Series	Geologic unit	Thickness (feet)	Section	Water-bearing unit	Description
Quaternary	Pleistocene and Holocene	Alluvium and glacial drift	15-535		Buried outwash deposits (sand and gravel)	Clay, yellowish-brown, silty; contains sand and gravel; sand and gravel may occur in large concentrations.
Cretaceous	Upper Cretaceous	Pierre Shale	0-265			Shale, dark-gray to black; may contain bentonite or marl.
		Niobrara Formation	0-120		Solution features in Niobrara Formation	Chalky marl, light-brown to gray; contains some pyrite, gypsum, and shell fragments.
		Codell Sandstone Member	0-100		Codell Sandstone	Sandstone, yellow, fine-grained; contains gray-brown silts, shale, and some pyrite.
		Carlile Shale	0-130		Sand lenses	Shale, gray-brown to black, greasy; contains some pyrite; locally sandy.
		Greenhorn Limestone	0-10		Greenhorn Limestone	Limestone and calcareous shale, light-gray, fossiliferous.
		Graneros Shale	0-135			Shale, gray, silty; some concretion zones.
		Dakota Sandstone	0-400		Dakota sands	Sandstone; light-brown to gray, fine to coarse-grained; interbedded with carbonate and gray shale.
Precretaceous		Sioux Quartzite wash	0-105		Quatzite wash	Quartzite sand, pink to light-brown, subrounded; highly weathered unit underlying the Sioux Quartzite.
			0-?		Joints in Sioux Quartzite	Quartzite, pink, well cemented, massive, well fractured and jointed.
Precambrian		Igneous and metamorphic rocks	0-?			Granites, andesites, rhyolites, shists.

Figure 16.--Generalized stratigraphic column for Hanson and Davison Counties.

Niobrara aquifer.--The Niobrara aquifer is composed of a fractured, gray calcareous marl that contains numerous solution cavities (fig. 17). The marl is indurated and brittle in southern Davison County and grades to a less indurated carbonate clay in northern Davison County. The shaded region in figure 17 indicates the area where fractures and openings in the Niobrara have developed enough for irrigation. Wells in the aquifer outside the shaded region may produce enough water for stock and domestic wells; however, fractures here are discontinuous and less extensive. Structure contours (fig. 18) show that the Niobrara surface slopes to the east and is incised by a narrow north-south trending valley west of Ethan. The bedrock valley contains the Ethan aquifer. The Niobrara Formation is present in Hanson County as thin marl layers but it is not an aquifer. Hydrologic characteristics of the Niobrara aquifer are given in table 4.

Recharge to the Niobrara aquifer is from precipitation and snowmelt on the outcrop area, located in the flood plain of the North Fork of Twelve Mile Creek. The South Fork of Twelve Mile Creek, located 3 mi south of the county line in T. 100 N., R. 60 W., probably is another recharge area to the aquifer.

The general direction of water movement in the aquifer is to the northeast at a gradient of 5 to 10 ft/mi (fig. 19). The direction of water movement in the irrigation area (fig. 20) is to the north and south away from the North Fork of Twelve Mile Creek. The gradient of the potentiometric surface north of the creek is 15 ft/mi and the gradient south of the creek is 20 ft/mi. Higher gradients south of the creek may be caused by irrigation development. The Niobrara and Ethan aquifers are hydraulically connected east of the shaded area (fig. 20). The gradient of the potentiometric surface decreased from 20 ft/mi to 10 ft/mi because of increased transmissivity caused by the greater thickness of the combined Ethan and Niobrara aquifers.

The Niobrara aquifer is under artesian conditions with the exception of the shaded area (fig. 20). Irrigation wells in this area lower water levels in the aquifer during the summer from artesian to water-table conditions.

Discharge from the Niobrara aquifer is (1) by evaporation east of Ethan, (2) to the Ethan aquifer, and (3) from irrigation wells.

Water-level fluctuations (fig. 21) are caused by seasonal changes in recharge and by irrigation wells. Water levels rose from late October to early June because of recharge from snowmelt and rainfall, and declined from July to September because of irrigation withdrawals. Records of long-term water-level fluctuations show close correlation with long-term trends in precipitation. The water-level decline from 1973 to 1977 in well 101N61W35AAAA was caused by below normal precipitation.

Predominant chemical constituents in water from the Niobrara aquifer are sulfate, sodium, and calcium (table 10). Dissolved-solids concentration ranged from 1,400 to 1,970 mg/L and hardness concentration ranged from 370 to 1,000 mg/L. Dissolved-solids concentration generally increased with increased distance from the North Fork of Twelve Mile Creek. Irrigation wells near the creek may have caused decreased dissolved-solids concentration by inducing recharge from the creek. Water in the Niobrara aquifer is used primarily for stock watering and irrigation (fig. 10).

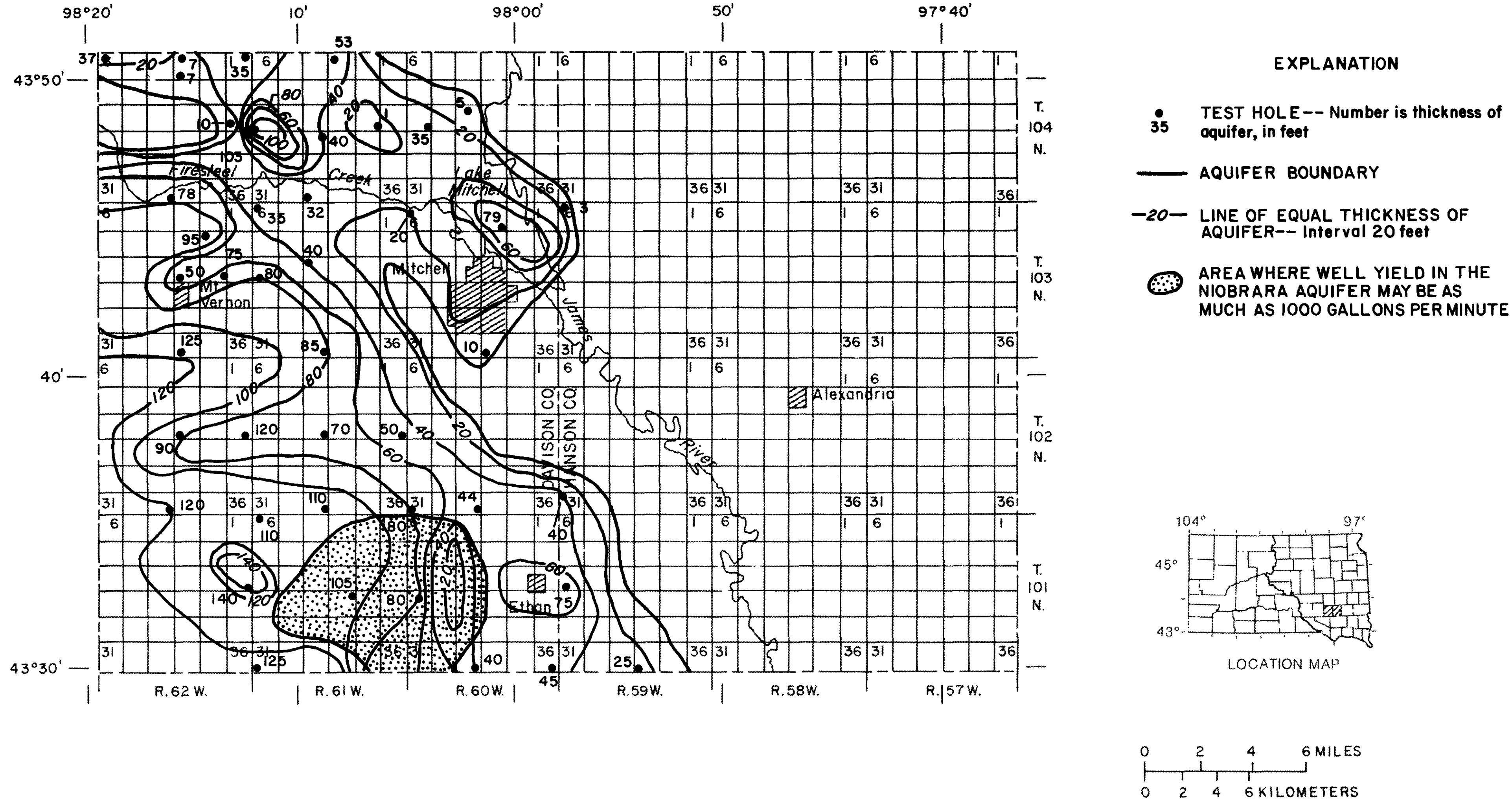


Figure 17.-Extent and thickness of the Niobrara aquifer

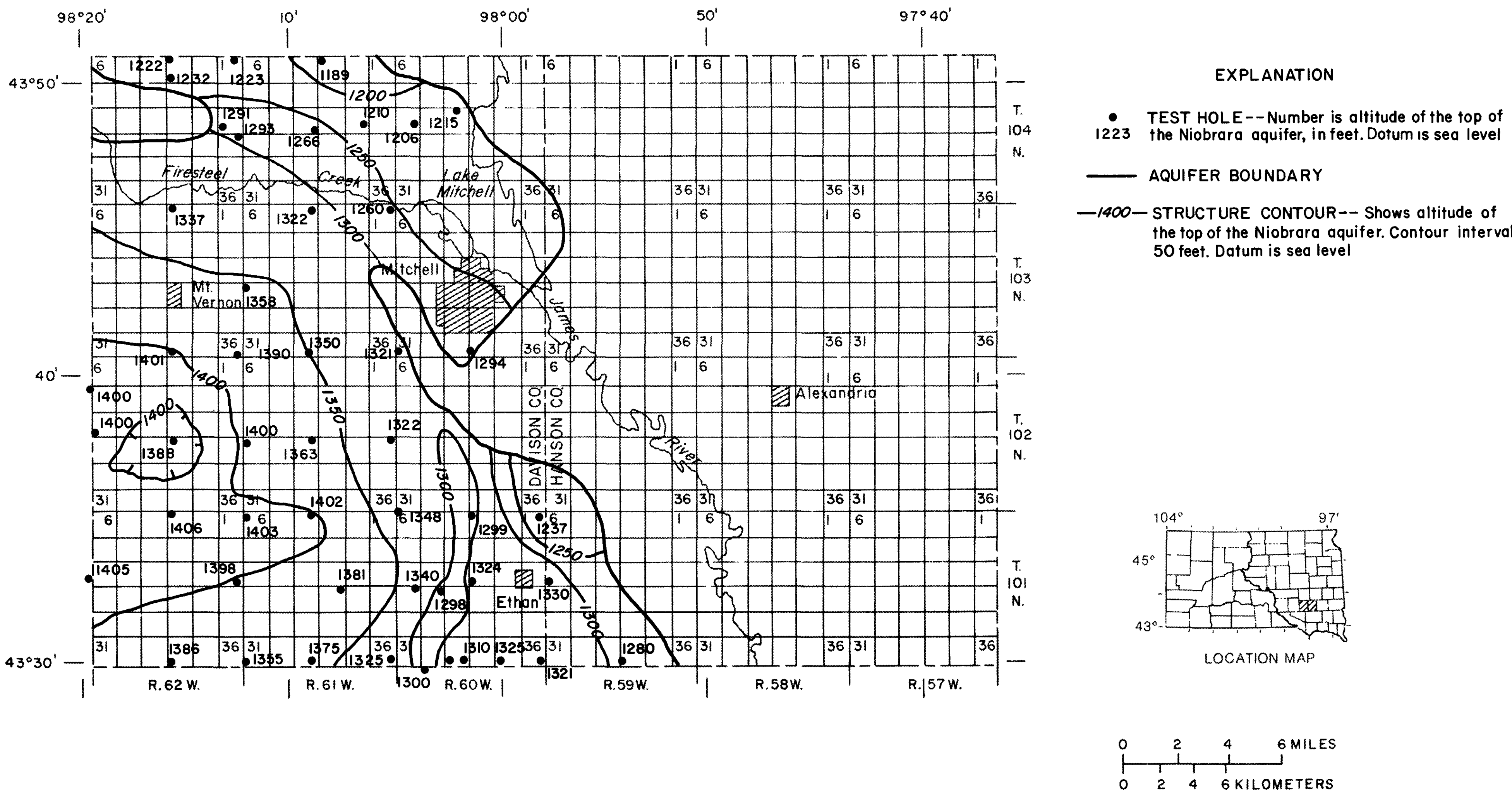


Figure 18.- Structure contours on the top of the Niobrara aquifer

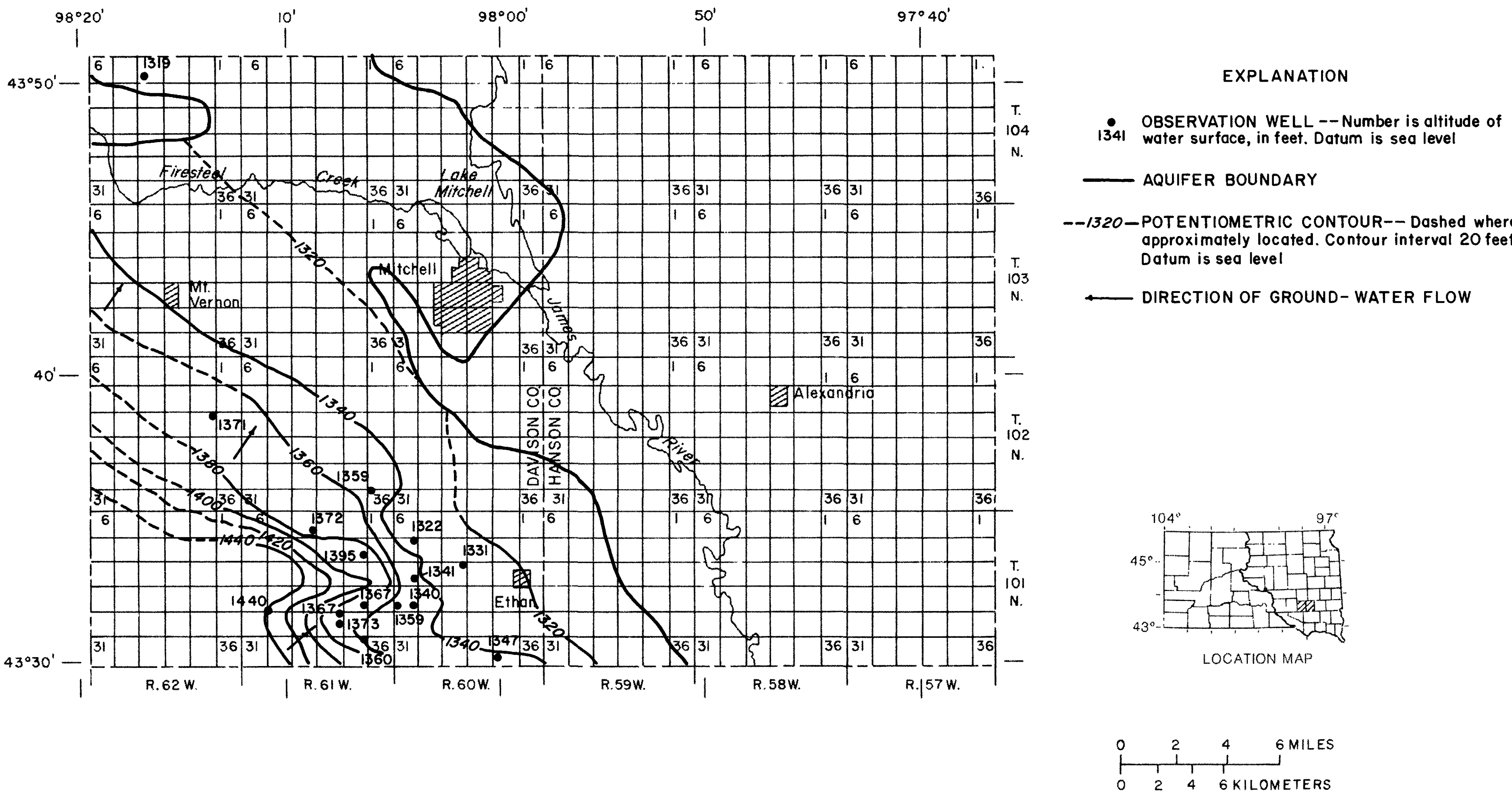


Figure 19.-Potentiometric surface of the Niobrara aquifer, November 1980

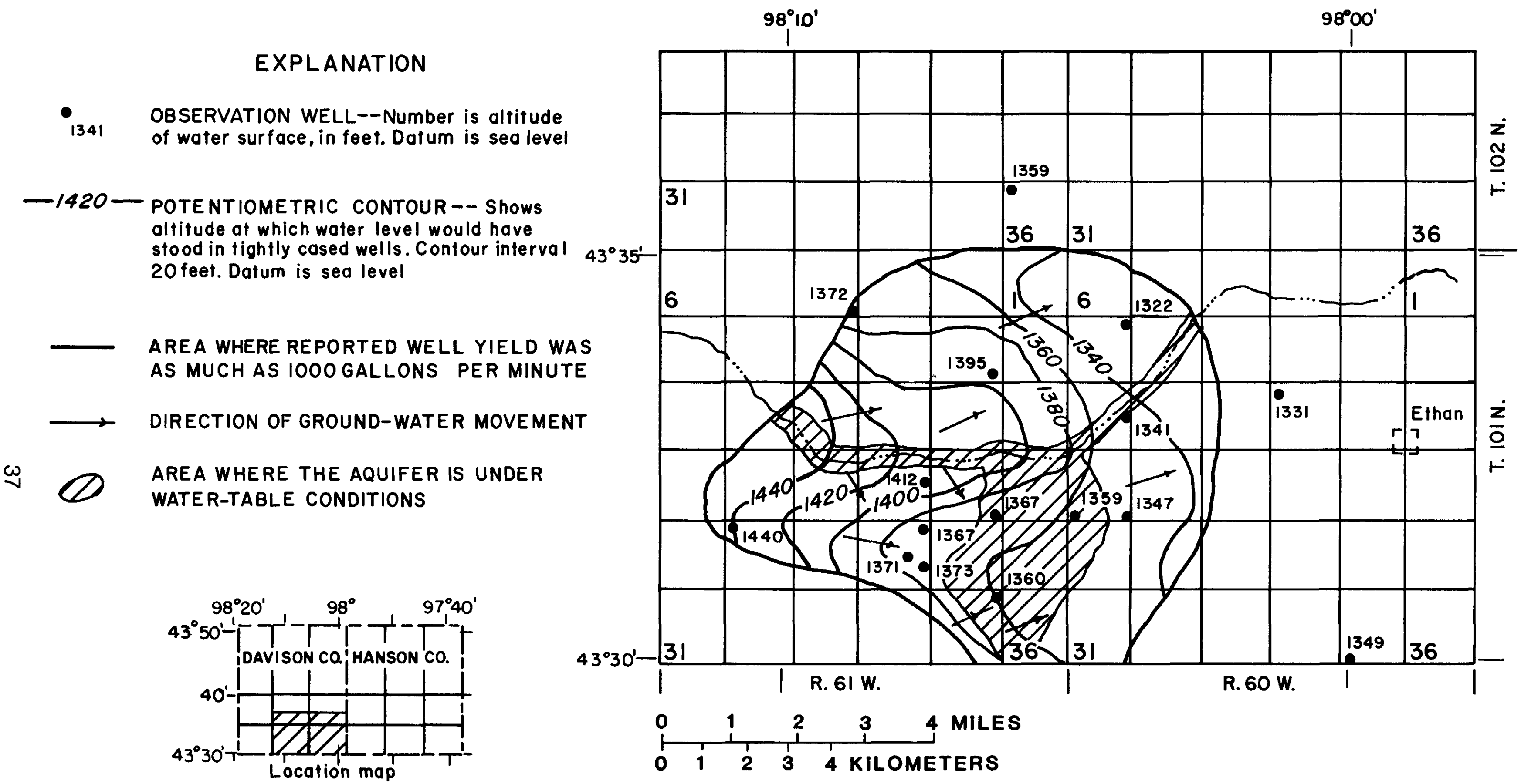


Figure 20.-Potentiometric surface of the Niobrara aquifer in the irrigation area, November 1980

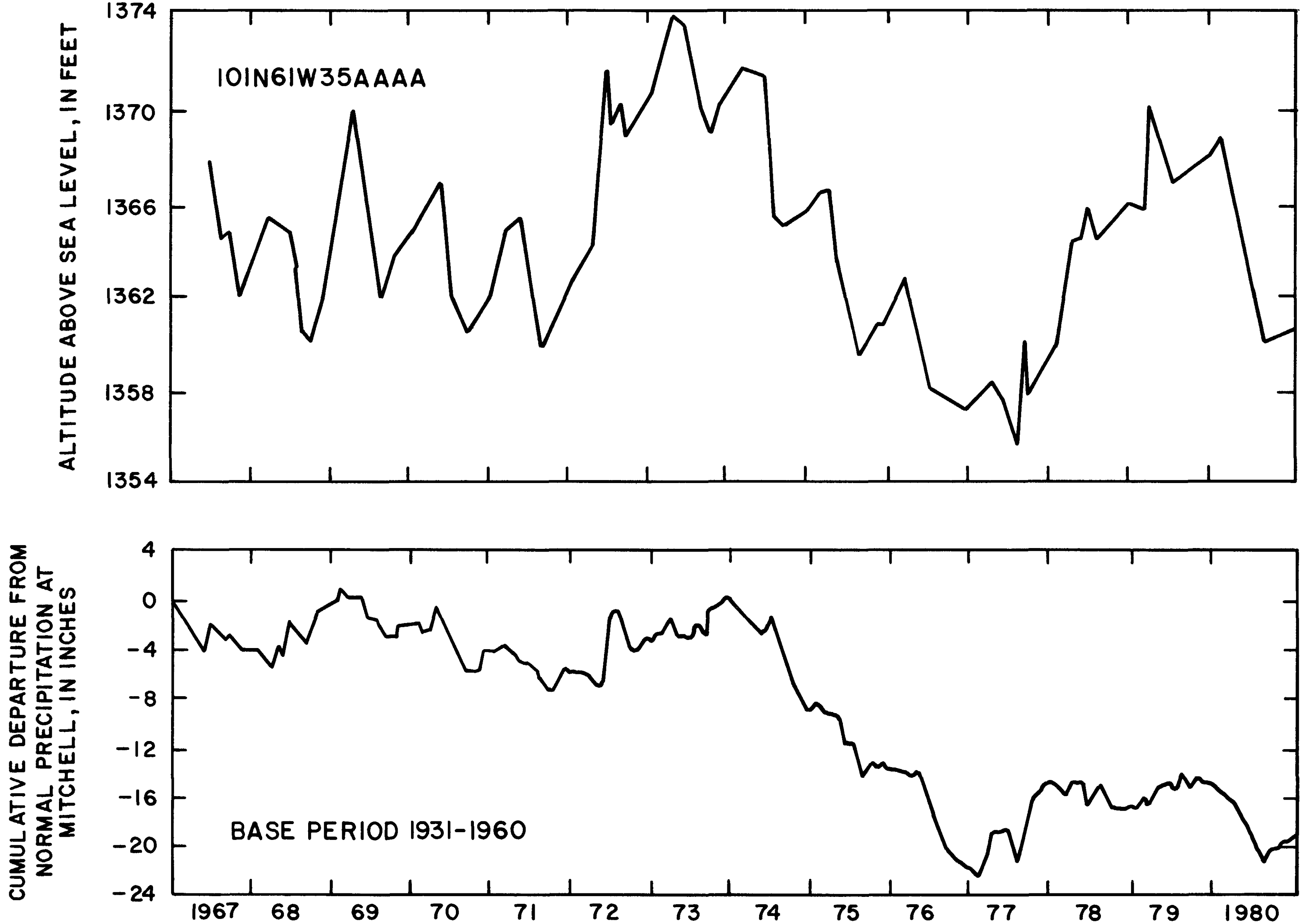


Figure 21.–Water-level fluctuations in observation wells in the Niobrara aquifer and departure from normal precipitation

Table 10.—Summary of chemical analyses of water from the bedrock aquifers

[°C, degrees Celsius; µmhos/cm at 25°C, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

	Number of samples	Mean	Minimum value	Maximum value	Number of samples	Mean	Minimum value	Maximum value
	Niobrara aquifer				Codell aquifer			
Temperature, water (°C)	5	15.2	14.0	18.0	14	11.9	7.0	18.0
Specific conductance (µmhos/cm at 25°C)	5	2,210	1,580	2,820	14	2,290	1,860	2,750
pH, field	5	7.6	7.2	8.4	14	7.8	7.6	8.1
Alkalinity (mg/L)	4	510	400	570	13	360	180	450
Nitrogen (mg/L)	4	.39	.01	1.3	13	.17	.0	.92
Orthophosphate as phosphorus, dissolved (mg/L)	4	.0	.0	.03	13	.01	.0	.09
Phosphorus, dissolved (mg/L)	4	.10	.0	.37	13	.01	.0	.04
Orthophosphate as phosphate, dissolved (mg/L)	4	.0	.0	.01	13	.0	.0	.03
Hardness, total (mg/L)	4	730	370	1,000	13	200	53	460
Noncarbonate hardness (mg/L)	4	300	.0	570	13	8	.0	96
Calcium, dissolved (mg/L)	4	200	100	310	13	54	14	120
Magnesium, dissolved (mg/L)	4	57	29	97	13	16	4.4	39
Sodium, dissolved (mg/L)	4	290	140	510	13	440	300	560
Sodium adsorption ratio	4	6	2	12	13	16	8	32
Sodium percent	4	45	23	74	13	80	63	95
Potassium, dissolved (mg/L)	5	19	17	22	14	19	10	27
Chloride, dissolved (mg/L)	4	42	19	61	13	120	44	190
Sulfate, dissolved (mg/L)	4	860	780	950	13	660	440	760
Fluoride, dissolved (mg/L)	4	.5	.4	.6	13	.9	.6	1.8
Silica, dissolved (mg/L)	4	16	9.1	22	13	9.5	6.0	25
Boron, dissolved (µg/L)	4	3,600	1,200	7,700	13	4,000	530	6,200
Iron, dissolved (µg/L)	4	4,700	90	18,000	13	570	50	2,500
Manganese, dissolved (µg/L)	4	180	60	400	13	45	10	280
Dissolved solids, sum of constituents (mg/L)	4	1,710	1,400	1,970	13	1,530	1,200	1,760

Table 10.--Summary of chemical analyses of water from the bedrock aquifers--Continued

	Number of samples	Mean	Minimum value	Maximum value	Number of samples	Mean	Minimum value	Maximum value
	Dakota aquifer				Sioux Quartzite wash aquifer			
Temperature, water (°C)	11	12.7	10.5	17.0	4	11.0	8.0	12.0
Specific conductance (µmhos/cm at 25°C)	11	2,560	2,230	3,050	4	1,980	1,920	2,040
pH, field	11	7.5	6.8	8.5	4	7.4	7.2	7.8
Alkalinity (mg/L)	11	140	130	200	4	260	250	270
Nitrogen (mg/L)	9	.13	.01	.84	4	.04	.03	.06
Orthophosphate as phosphorus, dissolved (mg/L)	9	.03	.0	.12	4	.03	.0	.09
Phosphorus, dissolved (mg/L)	10	.01	.0	.07	4	.01	.01	.02
Orthophosphate as phosphate, dissolved (mg/L)	9	.01	.0	.04	4	.01	.0	.03
Hardness, total (mg/L)	10	1,000	.0	1,300	4	740	710	760
Noncarbonate hardness (mg/L)	10	890	.0	1,200	4	480	450	510
Calcium, dissolved (mg/L)	10	320	31	380	4	200	200	200
Magnesium, dissolved (mg/L)	10	78	10	92	4	58	52	64
Sodium, dissolved (mg/L)	10	190	130	610	4	160	130	180
Sodium adsorption ratio	10	4	2	25	4	3	2	3
Sodium percent	10	27	17	91	4	31	28	33
Potassium, dissolved (mg/L)	10	22	5	32	1	17	17	18
Chloride, dissolved (mg/L)	10	98	64	130	4	34	25	41
Sulfate, dissolved (mg/L)	10	1,300	1,100	1,300	4	820	780	860
Fluoride, dissolved (mg/L)	10	2.0	1.3	2.7	4	.8	.5	1.4
Silica, dissolved (mg/L)	10	7.6	3.5	11	4	12	9.3	13
Boron, dissolved (µg/L)	10	950	410	4,000	4	450	230	740
Iron, dissolved (µg/L)	10	2,000	390	5,000	4	1,400	1,200	2,000
Manganese, dissolved (µg/L)	10	140	30	440	4	140	100	250
Dissolved solids, sum of constituents (mg/L)	10	2,100	1,980	2,170	4	1,460	1,390	1,520

Codell aquifer.--The Codell aquifer in the Codell Sandstone Member of the Carlile Shale (fig. 22) is a brown, fine to medium grained, moderately cemented sandstone with a hard, well cemented upper layer. Shale layers 1 to 2 ft thick are common throughout the aquifer, except in the Mount Vernon area where the aquifer is 50 to 70 percent shale. Structure contours on the top of the aquifer are shown in figure 23.

Recharge to the Codell aquifer in Davison County is by leakage from the overlying Niobrara aquifer. The Niobrara and Codell are in equilibrium in the Mount Vernon area. Recharge to the aquifer in northern Hanson County may be by leakage from the overlying Floyd aquifer and by leakage from fractures in the underlying Sioux Quartzite.

The direction of water movement in the Codell aquifer in Davison County is from southwest to northeast (fig. 24), and the direction of water movement in northern Hanson County is northwest toward Sanborn County. The gradient of the potentiometric surface increased from 5 ft/mi in southern Davison County to about 18 ft/mi near Firesteel Creek. Higher gradients near the creek may be the result of decreased aquifer thickness.

Discharge from the Codell aquifer in Davison County is (1) by evaporation from outcrops along Firesteel Creek, (2) to Lake Mitchell, and (3) to the James River. Outflow in northern Hanson County to Sanborn County is about 0.5 acre-ft/d.

Water-level fluctuations in the Codell aquifer are caused by seasonal changes in recharge from the Niobrara and Floyd aquifers. Water levels rise from late October to early June because of recharge from snowmelt and spring rain and decline from late June to September (fig. 25). Records of long-term fluctuations show close correlation with long-term trends in precipitation. The water-level decline from 1973 to 1977 in well 101N61W35BAAA was caused by below normal precipitation. Water levels rose from 1977 to 1980 because of above normal precipitation. The hydrograph of an observation well in the Niobrara aquifer (fig. 21) shows a greater magnitude of water-level fluctuations in response to above or below normal precipitation than that of the Codell aquifer (fig. 25) because of irrigation withdrawals from the Niobrara aquifer.

Predominant chemical constituents in water from the Codell aquifer are sulfate and sodium. Specific conductance ranged from 1,715 to 3,000 μmhos/cm at 25°C and averaged 2,340 μmhos/cm at 25°C. Hardness concentration, determined by field analyses, ranged from 53 to 250 mg/L in the southwest part of Davison County and ranged from 250 to 460 mg/L in the northeastern part of the county. The average hardness of water from the aquifer was about 200 mg/L. A summary of the chemical analyses of water is in table 10. Water from the aquifer is used for domestic and stock purposes.

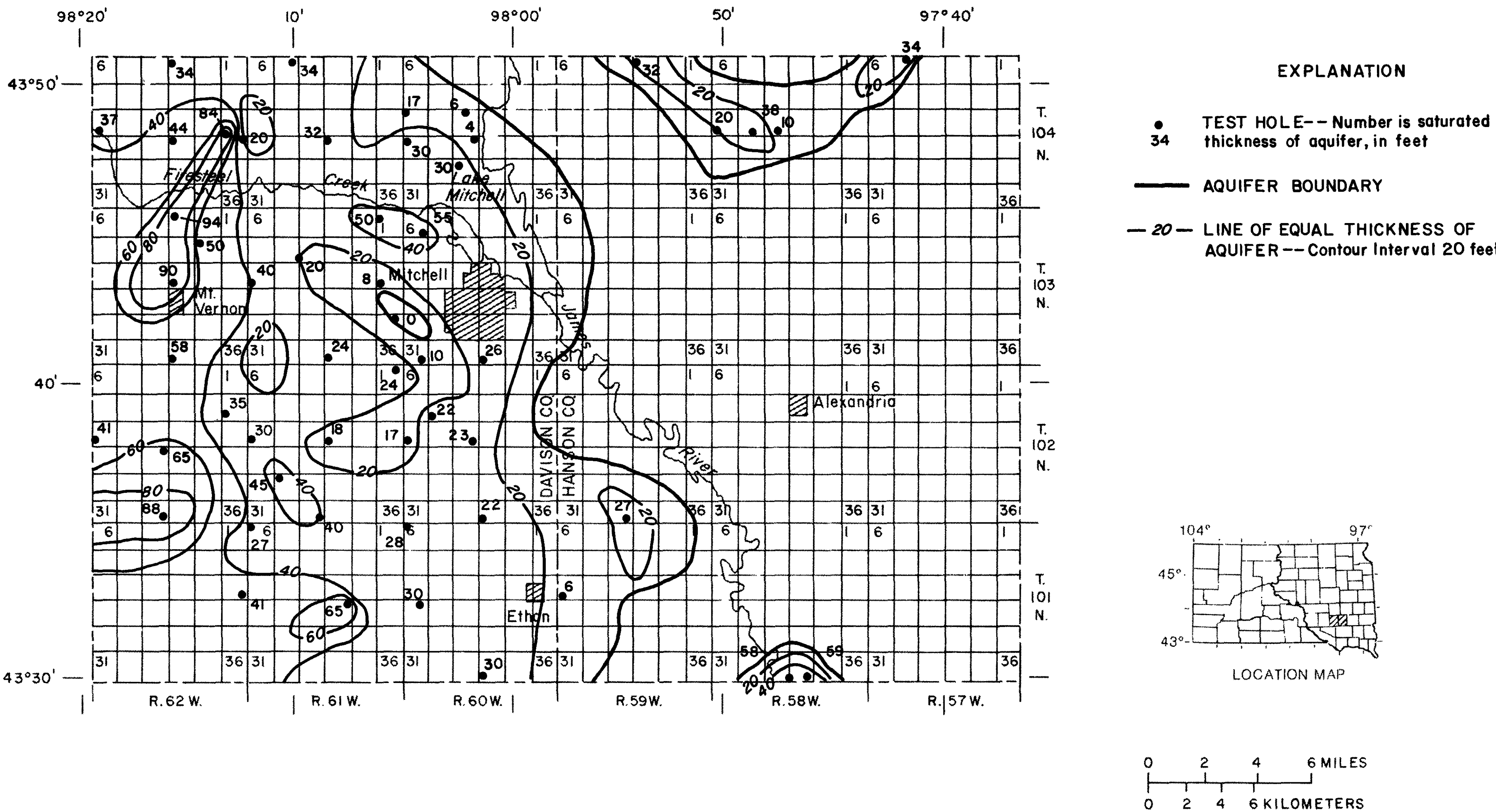


Figure 22.- Extent and thickness of the Codell aquifer in Hanson and Davison Counties

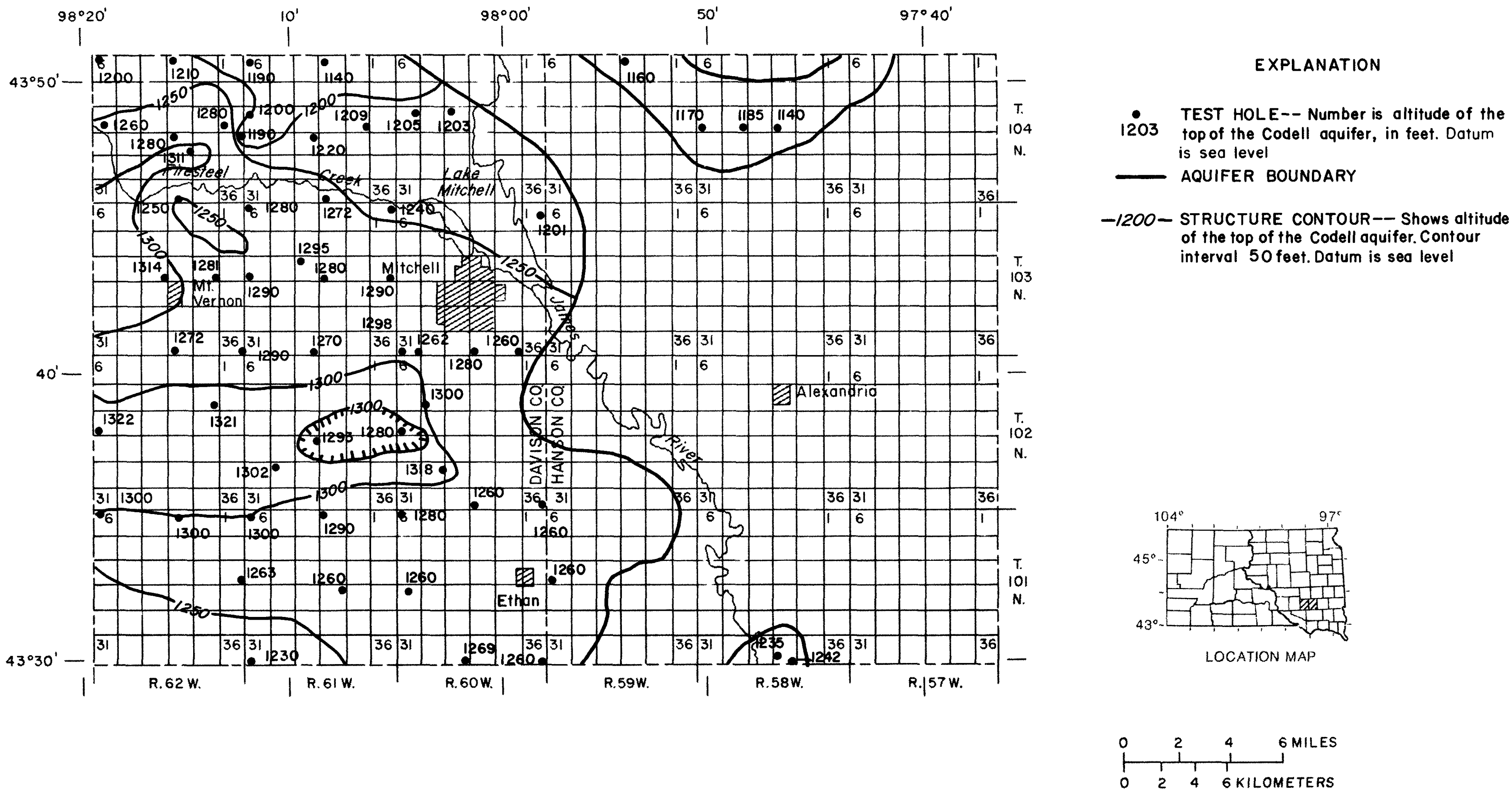


Figure 23.-Structure contours on the top of the Codell aquifer

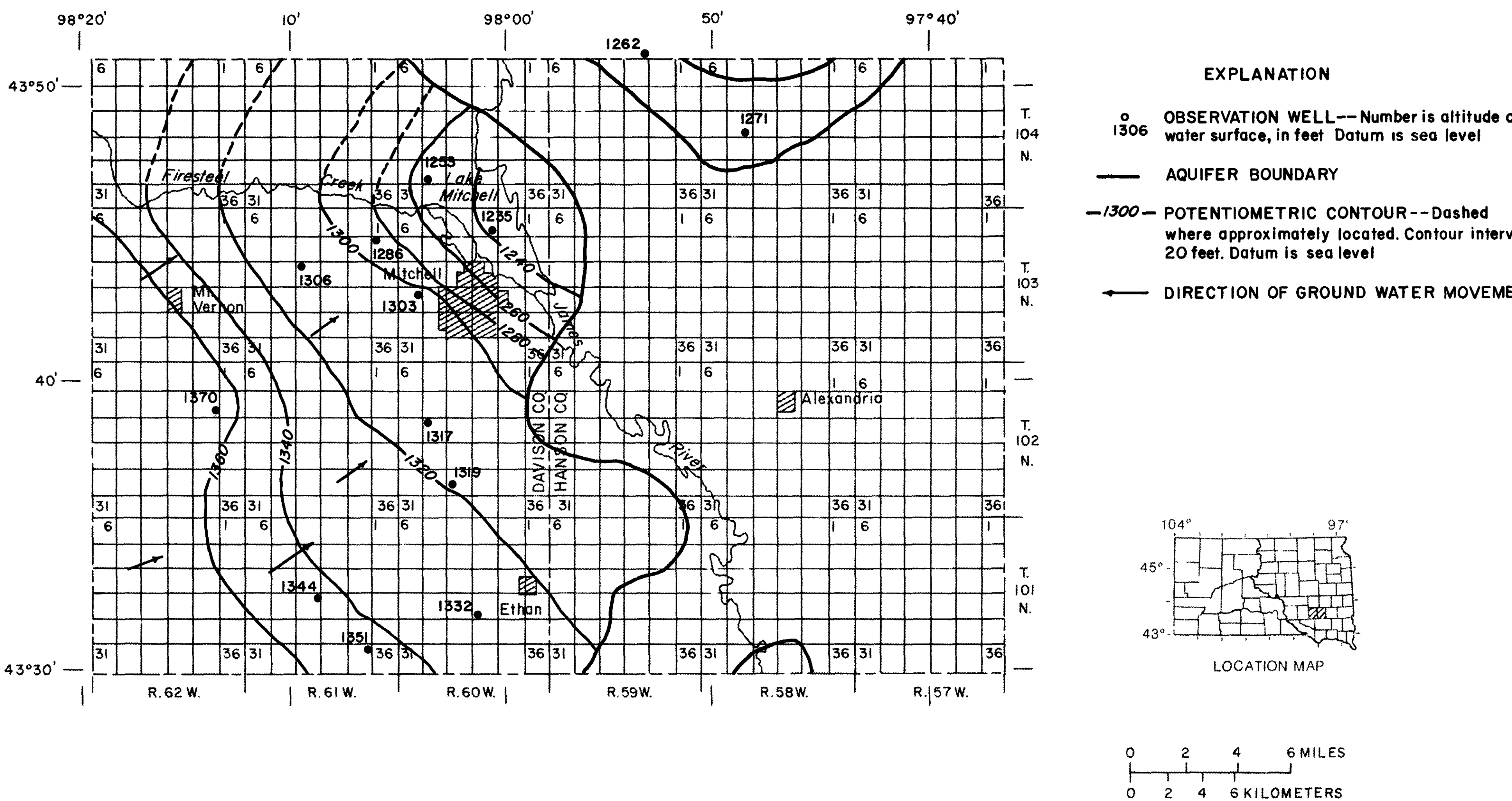


Figure 24.-Potentiometric surface of the Codell aquifer, November 1980

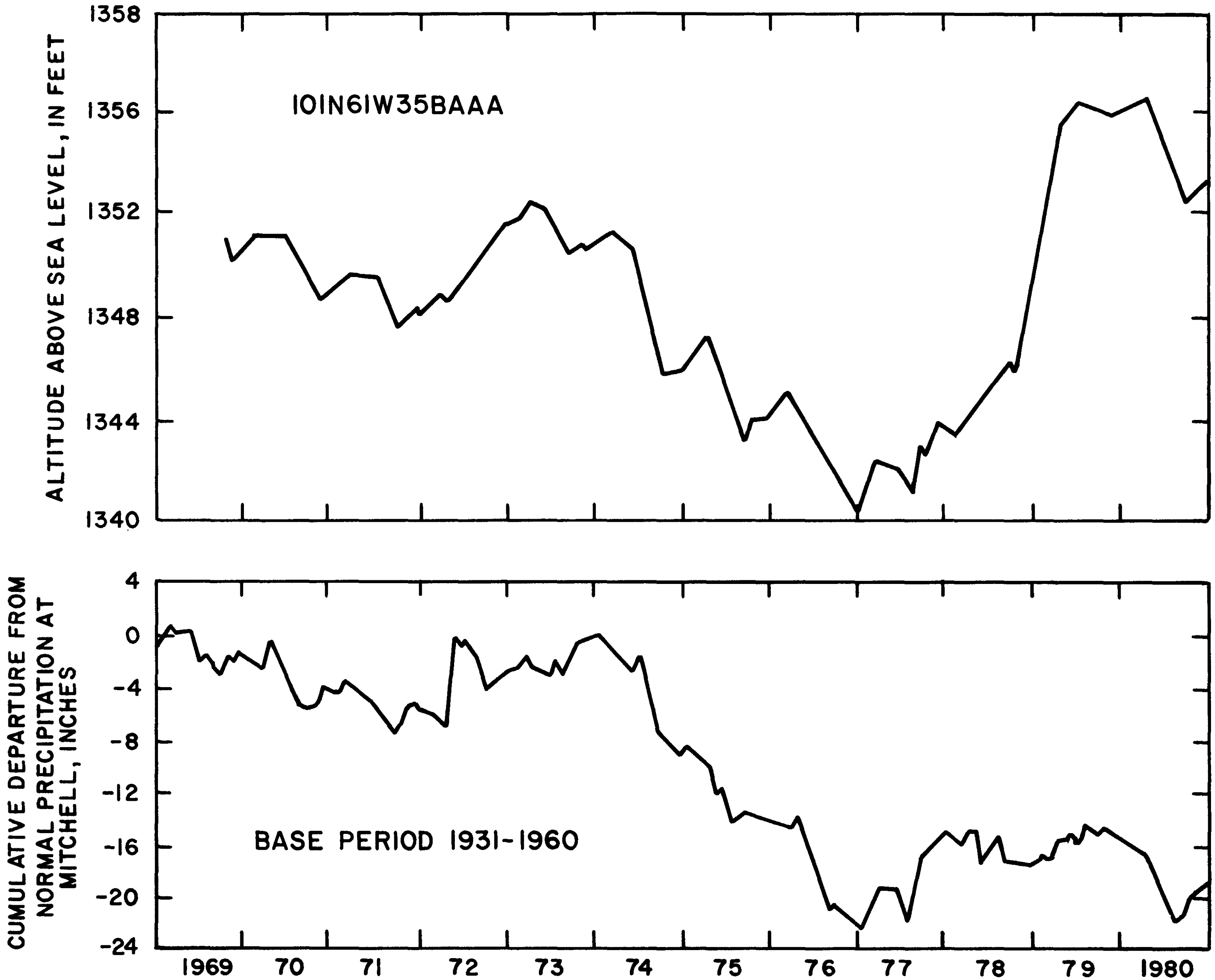


Figure 25.--Water-level fluctuations in observation wells in the Codell aquifer and cumulative departure from normal precipitation at Mitchell

Dakota aquifer.--The Dakota aquifer (fig. 26) is composed of a brown, medium-grained sandstone, interbedded with shale layers 5 to 25 ft thick. The thickness of the aquifer is 400 ft in western Davison County. The aquifer thins to the east and pinches out against the Sioux Quartzite ridge. Structure contours (fig. 27) show that the aquifer slopes to the west from 15 to 35 ft/mi. Depth to the top of the aquifer in the Mitchell area is as much as 500 to 600 ft below land surface, and is as much as 700 ft below land surface in western Davison County. Hydrologic characteristics of the aquifer are given in table 4.

Recharge to the aquifer is from the underlying Madison and Inyan Kara aquifers (Schoon, 1971). Discharge from the aquifer is from flowing wells in northern Davison County, Miner, Beadle, and Sanborn Counties.

The direction of water movement in the Dakota aquifer is indicated by arrows perpendicular to the potentiometric contours in figure 26. Uncontrolled flowing wells that penetrate the aquifer in T. 103 N. and 104 N. have caused the potentiometric surface to slope to the northeast at 8 to 14 ft/mi. Ten miles northwest of Ethan, the Sioux Quartzite ridge has caused a ground-water divide in the Dakota aquifer that caused the gradient of the potentiometric surface to slope to the southeast. Flowing wells in the Dakota aquifer are limited to the northern one-third of Davison County. Reported yields from wells ranged from 1 to 50 gal/min and averaged 2 gal/min.

Water levels in the Dakota aquifer declined 11 ft in observation well 104N61W30DAAA and 13 ft in well 104N61W24CACB from 1960 to 1979 (fig. 28). The water level in observation well 104N60W16BAAA declined 0.5 ft from September 1979 to December 1980. At Mitchell in the early 1900's, the water level was 1,313 ft above sea level and, declined to 1,300 ft several years later (Darton, 1909). In 1973, the water level was 1,232 ft for a total decline of about 81 ft in about 70 years.

Predominant chemical constituents in water from the Dakota aquifer are sulfate and calcium. Predominant chemical constituents in water from the aquifer in the northern one-third of T. 104 N., R. 61 W. is sodium and sulfate. Dissolved-solids concentration ranged from 1,980 to 2,170 mg/L and hardness concentration ranged from 1,100 to 1,300 mg/L. The average dissolved-solids concentration was 2,100 mg/L and the average hardness concentration was 1,200 mg/L. A summary of chemical analyses is given in table 10. Water from the aquifer is used primarily for stock watering.

Sioux Quartzite wash aquifer.--The Sioux Quartzite wash aquifer (fig. 26) is composed of weathered pink, medium to coarse quartzose sand. The aquifer overlies the Sioux Quartzite in a buried quartzite valley (fig. 7). Thickness of the aquifer ranges from 30 to 105 ft. Hydrologic characteristics are given in table 4.

Recharge to the Sioux Quartzite wash aquifer is from the Dakota aquifer through fractures in the Sioux Quartzite in Miner County (McGarvie, 1980). Evidence of recharge from the Dakota aquifer is shown by the similarity of water quality between the two aquifers (table 10). Discharge from the Sioux Quartzite wash aquifer is to the Floyd aquifer and to the quarry at Spencer, S. Dak., through fractures in the Sioux Quartzite.

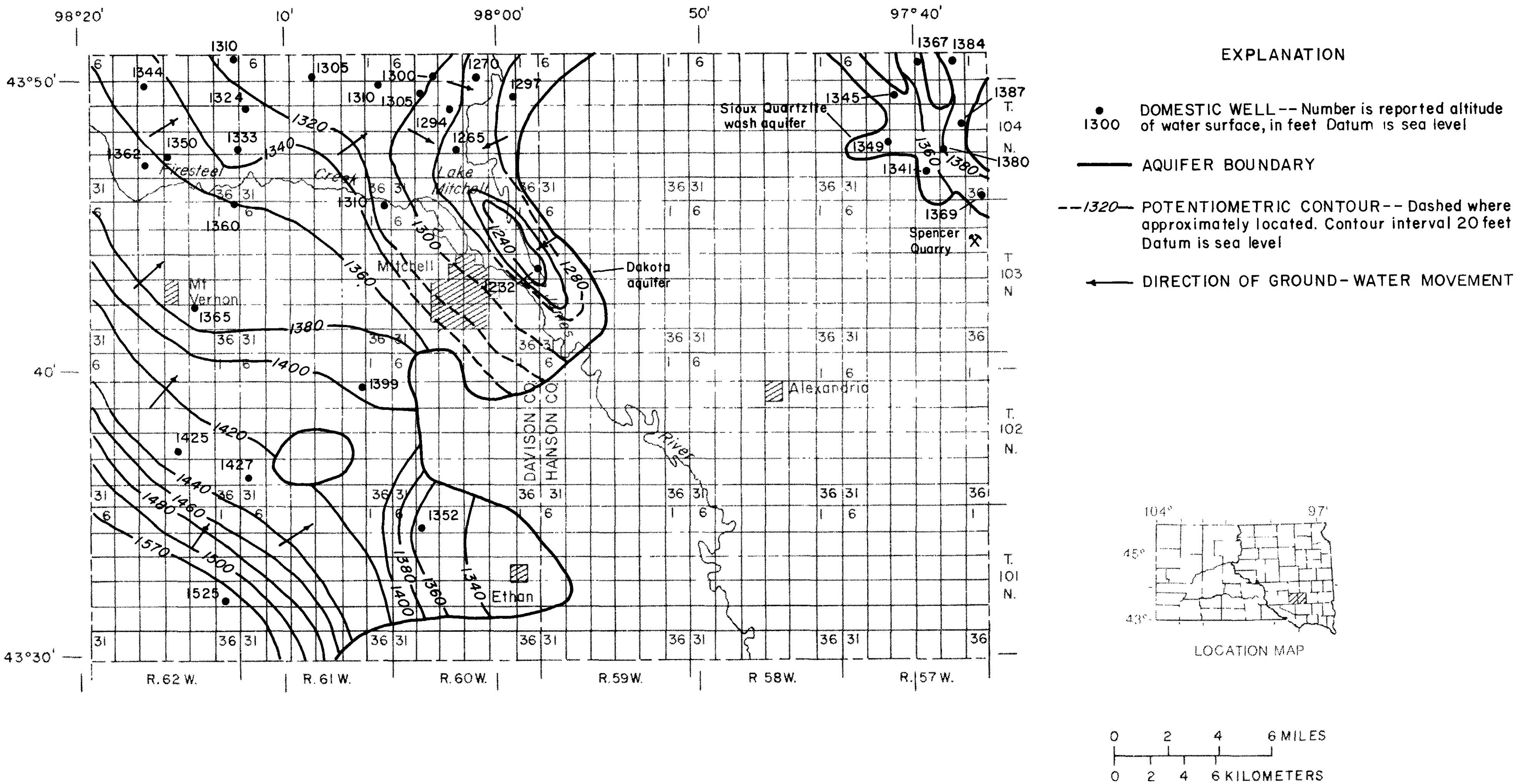


Figure 26.-Extent and potentiometric surface of the Dakota and Sioux Quartzite wash aquifers, November 1980

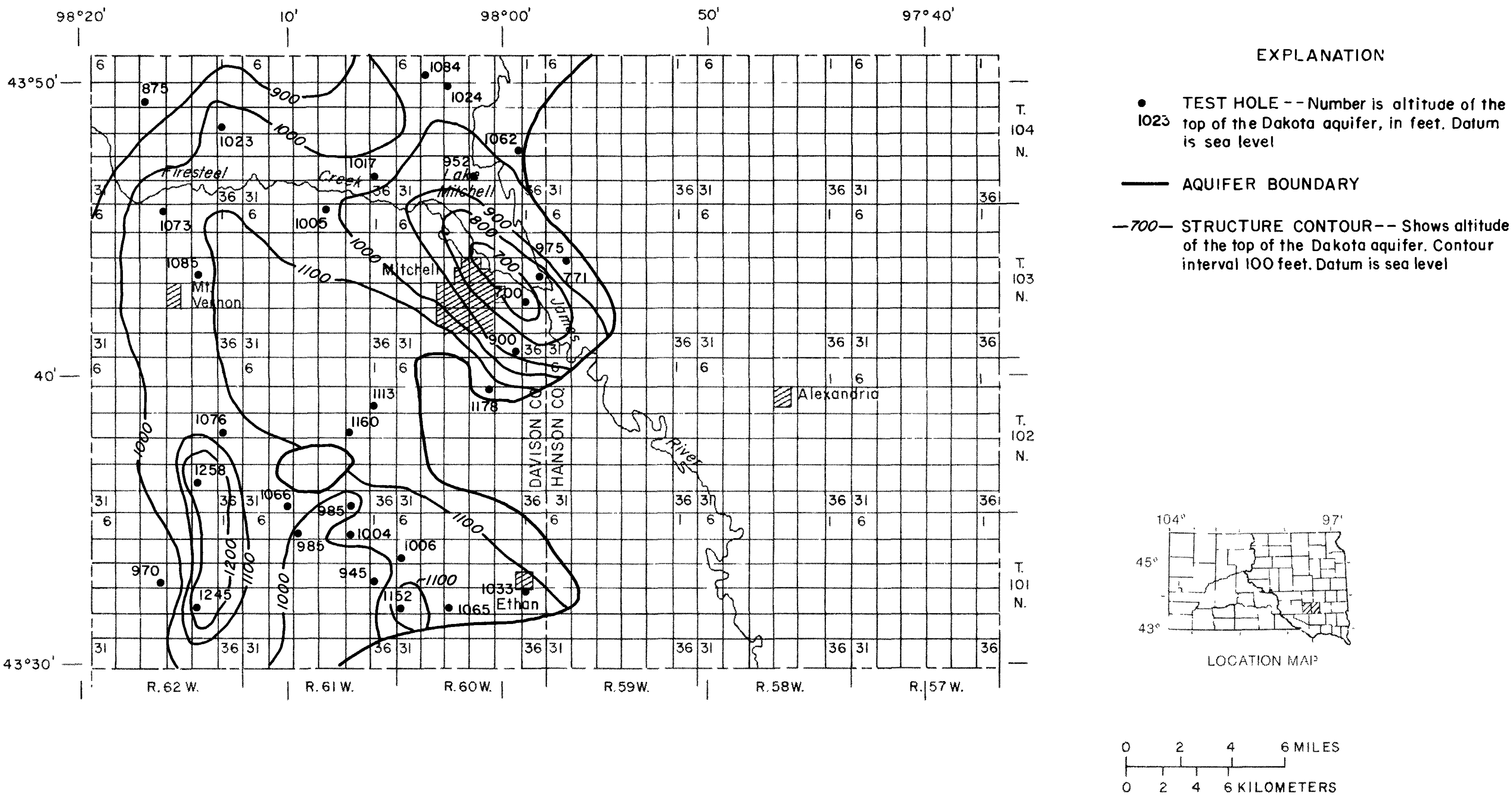


Figure 27.-Structure contours on the top of the Dakota aquifer

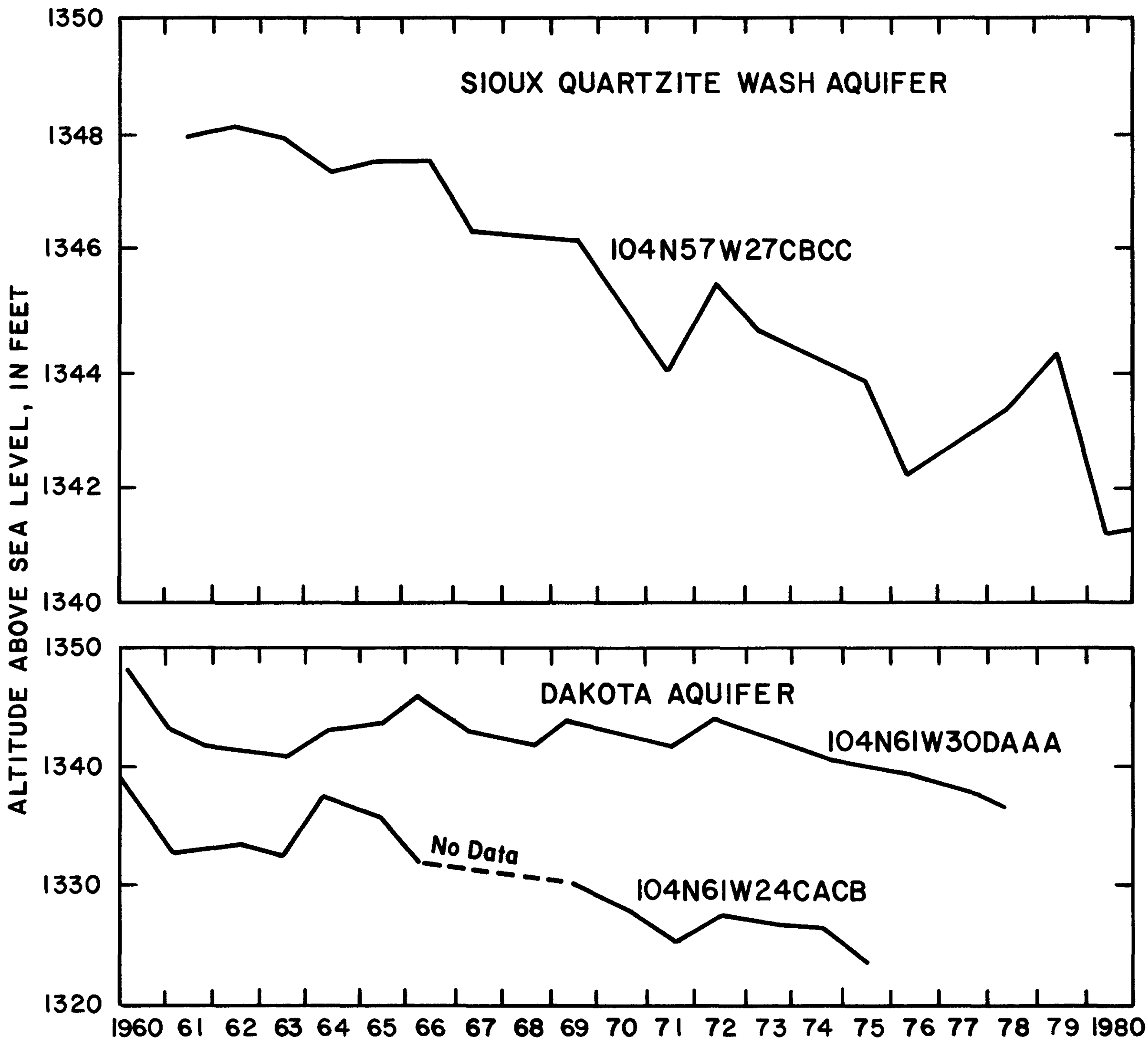


Figure 28.-Water-level fluctuations in observation wells in the Dakota and Sioux Quartzite wash aquifers

The direction of water movement in the aquifer is to the west and to the south toward the Spencer Quarry. The gradient of the potentiometric surface is 20 ft/mi (fig. 26). South of the Sioux Quartzite wash aquifer boundary, movement of water to the quarry is through fractures in the quartzite. The gradient of the potentiometric surface is steepest (about 40 ft/mi) within a 2-mi radius of the quarry.

Water-level fluctuations in well 104N57W27CBCC in the Sioux Quartzite wash aquifer is shown in figure 28. Water levels declined 7 ft in 19 years or about 0.4 ft/yr. Long-term water-level fluctuations correspond to departures from normal precipitation, however, because the aquifer is 500 ft below land surface, the magnitude of the fluctuations were small.

Predominant chemical constituents in water from the aquifer are calcium, sodium, and sulfate. Dissolved-solids concentration ranged from 1,390 to 1,520 mg/L and hardness concentration ranged from 710 to 760 mg/L. A summary of the chemical analyses of water from the aquifer are given in table 10.

WATER USE

Water use from glacial and bedrock aquifers in Hanson and Davison Counties was estimated to be 1.4 billion gallons in 1975 (table 11). Sixty-five percent of the water used is from bedrock aquifers and 35 percent is from glacial aquifers. Uncontrolled flowing wells in the Dakota aquifer discharge about 40 million gallons of water per year.

Table 11.—Estimates of withdrawal of ground water in million gallons per year from Hanson and Davison Counties for 1975

Aquifers	Total	Municipal	Rural domestic	Livestock	Irrigation
GLACIAL					
Floyd	37	—	9	28	—
Plum Creek	113	16	9	24	64
Ethan	53	—	2	3	48
Warren	3	—	1	2	—
Alexandria	55	22	9	24	—
BEDROCK					
Niobrara	258	—	—	—	258
Codell (Davison Co.)	478	—	139	339	—
Codell (Hanson Co.)	19	—	9	10	—
Dakota (Davison Co.)	92	—	7	85	—
Sioux Quartzite wash	68	10	48	10	—
Sioux Quartzite	215	—	25	190	—

SUMMARY

Surface water in Hanson and Davison Counties covers about 0.6 percent of the land surface. The primary sources of surface water are the James River, Lake Mitchell, and Firesteel Creek. Average annual discharge for the James River near Mitchell is about 300 cubic feet per second. With the exception of Firesteel Creek, all tributaries to the James River are usually dry during the late summer and fall.

Five glacial and four bedrock aquifers were delineated in Hanson and Davison Counties. The glacial aquifers are the Floyd, Plum Creek, Ethan, Warren, and Alexandria. The bedrock aquifers are the Niobrara, Codell, Dakota, and Sioux Quartzite wash aquifers.

The Floyd aquifer underlies about 84 square miles of northern Hanson County and has an average thickness of 40 feet. Depth to the aquifer ranged from 45 to 275 feet below land surface. Reported yield from wells was as much as 1,000 gallons per minute. Water in the aquifer is under artesian conditions and moves to the northwest.

Predominant chemical constituents in water from the Floyd aquifer are sulfate, sodium, and calcium. Dissolved solids ranged from 740 to 2,830 milligrams per liter and hardness ranged from 210 to 1,300 milligrams per liter. Water in the aquifer is used for stock, domestic, and irrigation purposes.

The Plum Creek aquifer underlies about 27 square miles of southeastern Hanson County. Reported yield from wells was as much as 1,000 gallons per minute in areas where the aquifer was greater than 20 feet thick. The average thickness of the aquifer is 18 feet. Water in the aquifer is under artesian conditions and moves to the southeast.

Predominant chemical constituents in water from the Plum Creek aquifer are sulfate, bicarbonate, and calcium. Specific conductance ranged from 2,360 to 3,300 micromhos per centimeter and hardness ranged from 570 to 1,680 milligrams per liter. Water in the aquifer is used for stock, domestic, and irrigation purposes.

The Ethan aquifer underlies 33 square miles of southern Davison County and ranges from 3 to 75 feet below land surface. Irrigation from the southern part of the aquifer, where the average thickness is 20 feet, may be possible when properly constructed wells penetrate the underlying Niobrara aquifer as well as the Ethan aquifer. Water in the aquifer is under artesian conditions in the south and becomes a water-table aquifer in the north. Direction of water movement is to the north.

Predominant chemical constituents in water from the Ethan aquifer are sulfate, sodium, and calcium. Dissolved-solids concentration ranged from 1,760 to 3,120 milligrams per liter and hardness ranged from 510 to 1,600 milligrams per liter. Water from the aquifer is used for stock, domestic, and irrigation purposes.

The Warren and Alexandria aquifers underlie 52 square miles of Davison and Hanson Counties. Reported yield from wells was as much as 10 gallons per minute at depths of 40 to 80 feet below land surface. The average thickness of the Warren aquifer is 13 feet and the average thickness of the Alexandria aquifer is 15 feet. Water in both aquifers is under artesian conditions. The direction of water movement in the Warren aquifer is to the east toward the James River. Water movement in the Alexandria aquifer is to the north and south.

Predominant chemical constituents in water from the Warren aquifer are sulfate and calcium and predominant chemical constituents in water from the Alexandria aquifer are sulfate, calcium, bicarbonate, and magnesium. Water in both aquifers is used for stock, domestic, and municipal purposes.

The Niobrara aquifer underlies 425 square miles of Davison and Hanson Counties and may yield as much as 1,000 gallons per minute in a 39-square mile area in southern Davison County. Depth to the top of the Niobrara aquifer ranges from land surface to 80 feet. The average thickness of the aquifer is 65 feet. Water in the Niobrara aquifer generally occurs under artesian conditions except in southern Davison County where drawdown from irrigation wells has caused a localized water-table condition.

The Codell aquifer underlies 547 square miles of Davison and Hanson Counties and is the most widely used bedrock aquifer in the two counties. Reported yield from wells was as much as 50 gallons per minute at depths ranging from 45 to 350 feet below land surface. The average thickness of the aquifer is 40 feet. Water in the aquifer is under artesian conditions and moves to the northeast.

The Dakota aquifer underlies 340 miles of Davison and western Hanson Counties. Depth to the top of the aquifer ranges from 700 feet below land surface in western Davison to 250 feet below land surface in eastern Davison County. Water in the aquifer is under artesian conditions. The average yield from flowing wells is about 2 gallons per minute in the northern one-third of Davison County. The average thickness of the aquifer is 110 feet.

The Sioux Quartzite wash aquifer overlies the Sioux Quartzite in northeastern Hanson County and probably is in hydraulic connection with the Dakota aquifer in Miner County. The average thickness of the aquifer is 60 feet. Reported yield from wells in the Sioux Quartzite wash aquifer was as much as 75 gallons per minute at depths ranging from 400 to 500 feet below land surface.

The 1975 water use was about 1.4 billion gallons. Sixty-five percent of the water used is from bedrock aquifers and 35 percent is from glacial aquifers.

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SUPPLEMENTAL INFORMATION

Water used for irrigation should not have a detrimental affect on the productivity of the soil. The main water properties that effect soil productivity are the total dissolved solids and the relative proportion of sodium to calcium and magnesium. Relatively small amounts of boron or other constituents can be toxic to certain plants.

The amount of dissolved solids in irrigation water and the soil properties determine the accumulation of salts in the soil. Salinity hazard is the tendency of water to cause an increase of salts in the soil. The specific conductance of the water is used to calculate the salinity hazard.

The relative proportion of sodium to calcium and magnesium in irrigation water can affect soil structure. Calcium and magnesium flocculate the soil, giving it looseness, providing for penetration of air and water, and good tillage properties. Sodium tends to deflocculate soil which produces packing, thus preventing or reducing the movement of air and water. The effect on soil of high concentrations of sodium in irrigation is called the sodium hazard which is determined by the SAR (sodium-adsorption ratio). If ample recharge is provided in the area of irrigation to cause a flushing action of the soil, then irrigators may be able to use worse quality water than indicated.

The salinity hazard and sodium hazard (U.S. Salinity Laboratory Staff, 1954) of water are shown in figure 10 which is interpreted as follows:

Sodium Hazard

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants, however, may suffer injury as a result of sodium accumulation in plant tissues even when exchangeable sodium values are lower than those causing deterioration of the physical condition of the soil.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions. Soils containing gypsum might not develop harmful levels of exchangeable sodium from such water. Chemical improvements may be required for replacement of exchangeable sodium from such water. Chemical improvements may be required for replacement of exchangeable sodium, except that improvements may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other additives may make the use of such water feasible.

Salinity Hazard

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown, usually without special practices for salinity control.

High-salinity water (C3) cannot be used for irrigation on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

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