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WATER RESOURCES OF SHALLOW AQUIFERS IN THE UPPER POPLAR RIVER BASIN, NORTHEASTERN MONTANA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-51

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

The following factors can be used to convert inch-pound units in this report to the International System of Units (SI).

Multiply inch-pound units	By	To obtain metric units
acre	4047	square meter (m^2)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)

temperature, degrees Celsius (°C) = 0.556 (°F-32)

WATER RESOURCES OF SHALLOW AQUIFERS IN THE UPPER POPLAR RIVER BASIN, NORTHEASTERN MONTANA

By

R. D. Feltis

ABSTRACT

The aquifer system studied in the upper Poplar River basin in northeastern Montana is the sequence of formations above the Bearpaw Shale. The formations, which range in age from Late Cretaceous to Holocene, are the Fox Hills Sandstone, Hell Creek Formation, Fort Union Formation, Flaxville Formation, Wiota Gravel, glacial deposits, and alluvium. Most wells obtain water from the Fort Union Formation or younger rocks.

Recharge from precipitation occurs readily through sand and gravel deposits of the Flaxville Formation, which occur as large terrace remnants, and the Wiota Gravel. Recharge to bedrock aquifers occurs where they are exposed at land surface or by leakage from permeable terrace, glacial, or alluvial deposits.

The potentiometric surface of the Fort Union and overlying rocks indicates movement of ground water from the high interstream areas toward valleys of the Poplar River and East Fork Poplar River and principal tributary streams. Water then may move down the valleys through the alluvium several miles before discharging as streamflow. Some ground water discharges as springs or seeps on hillsides.

Water samples from wells tapping the aquifers show the diversity of water quality. Sodium bicarbonate type water occurs in the Fox Hills-Hell Creek aquifer, Fort Union Formation, and alluvium. Magnesium bicarbonate water is present in the Flaxville Formation and in the Fort Union Formation where it is recharged from the Flaxville. Calcium bicarbonate or magnesium bicarbonate typ water occurs in the glacial outwash deposits. The range in dissolved-solids concentration for the various aquifers is: Fox Hills-Hell Creek aquifer, 940 to 1,300 mg/L (milligrams per liter); Fort Union Formation, 520 to 1,470 mg/L; glacial outwash deposits, 570 to 770 mg/L; and alluvium, 880 to 1,490 mg/L. The dissolved-solids concentration of one water sample from the Flaxville Formation was 400 mg/L.

Seepage measurements of the Poplar River and East Fork Poplar River from the international boundary to the south edge of the study area in October 1977 showed a net gain of 2.84 cubic feet per second from a total flow of 11.7 cubic feet per second. This gain is discharge of water from the alluvium to the rivers.

INTRODUCTION

Purpose and scope

The purpose of this report is to describe the water resources of shallow aquifers in the upper Poplar River basin near Scobey, Mont. (fig. 1). This purpose includes (1) description of the occurrence and movement of ground water, (2) determination of the extent of interchange between ground water and surface water, and (3) determination of the chemical quality of the water. The report can be used in the future to compare conditions before and after construction and operation of an electric power-generating facility and strip mine near Coronach, Saskatchewan, Canada.

Wells were inventoried and water levels measured in and surrounding the area of detailed study to provide data for preparation of the potentiometric map. Only data points within and near the area of detailed study are shown on the maps included in this report.

Water-quality, surface-water, and geologic data are included in the report. Water samples were collected from selected wells for chemical analysis. Streamflow measurements were made to determine gaining and losing reaches of the Poplar River and East Fork Poplar River. The geologic map of the area was made under the direction of Roger B. Colton (Colton and others, 1978) as part of a series of 15-minute geologic maps of northeastern Montana. Field work for the investigation was begun in September 1976 and completed in October 1977. The report includes some data from the files of the U.S. Geological Survey and State and local governmental organizations.

Numbering system for wells, springs, and sites

The system of numbering wells, springs, or sites is based on the rectangular system for the subdivision of public lands (fig. 2). A well, spring, or site number consists of as many as 13 characters and is assigned according to its location within a given township, range, and section. The first three characters consist of the township number and the letter N designating position north of the Montana Base Line. The next three characters consist of the range number and the letter E designating position east of the Montana Principal Meridian. The next two characters indicate the section. The letters following the section number indicate the position of the well within the section. The first letter denotes the quarter section (160-acre tract); the second, the quarter-quarter section (40-acre tract); the third, the quarter-quarter-quarter section (10-acre tract); and the fourth, the quarter-quarter-quarter-quarter section (2.5-acre tract). The subdivisions of the sections are lettered A, B, C, and D in a counterclockwise direction beginning in the northeast quadrant. If two or more wells, springs, or sites are located within a 2.5-acre tract, consecutive numbers are added in the order of inventory in that tract. For example, well 37N48E08CDCC2 is the second well inventoried in the SW1/4 SW1/4 SE1/4 SW1/4 sec. 8, T.37 N., R.48 E.

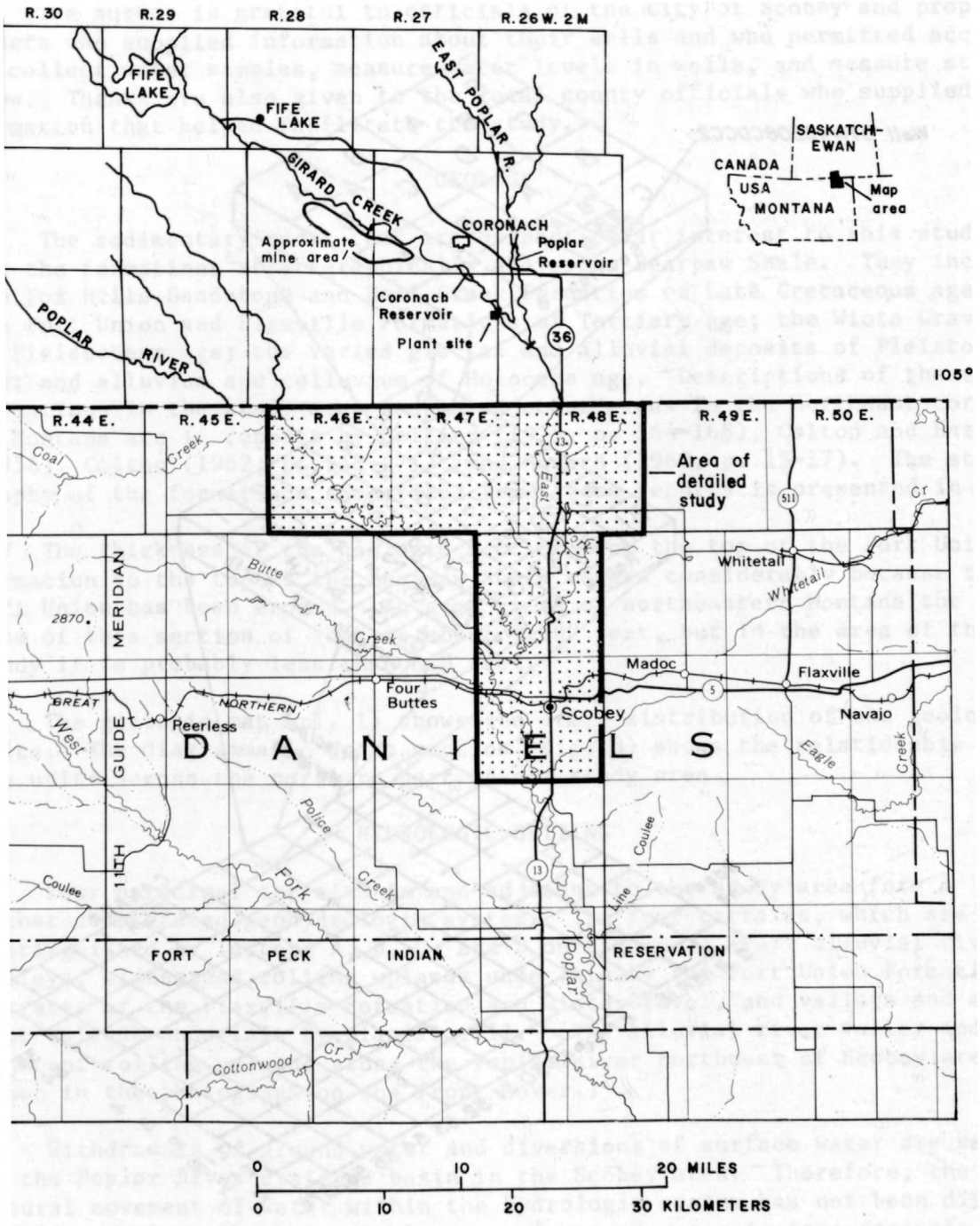

Figure 1.--Location of study area.

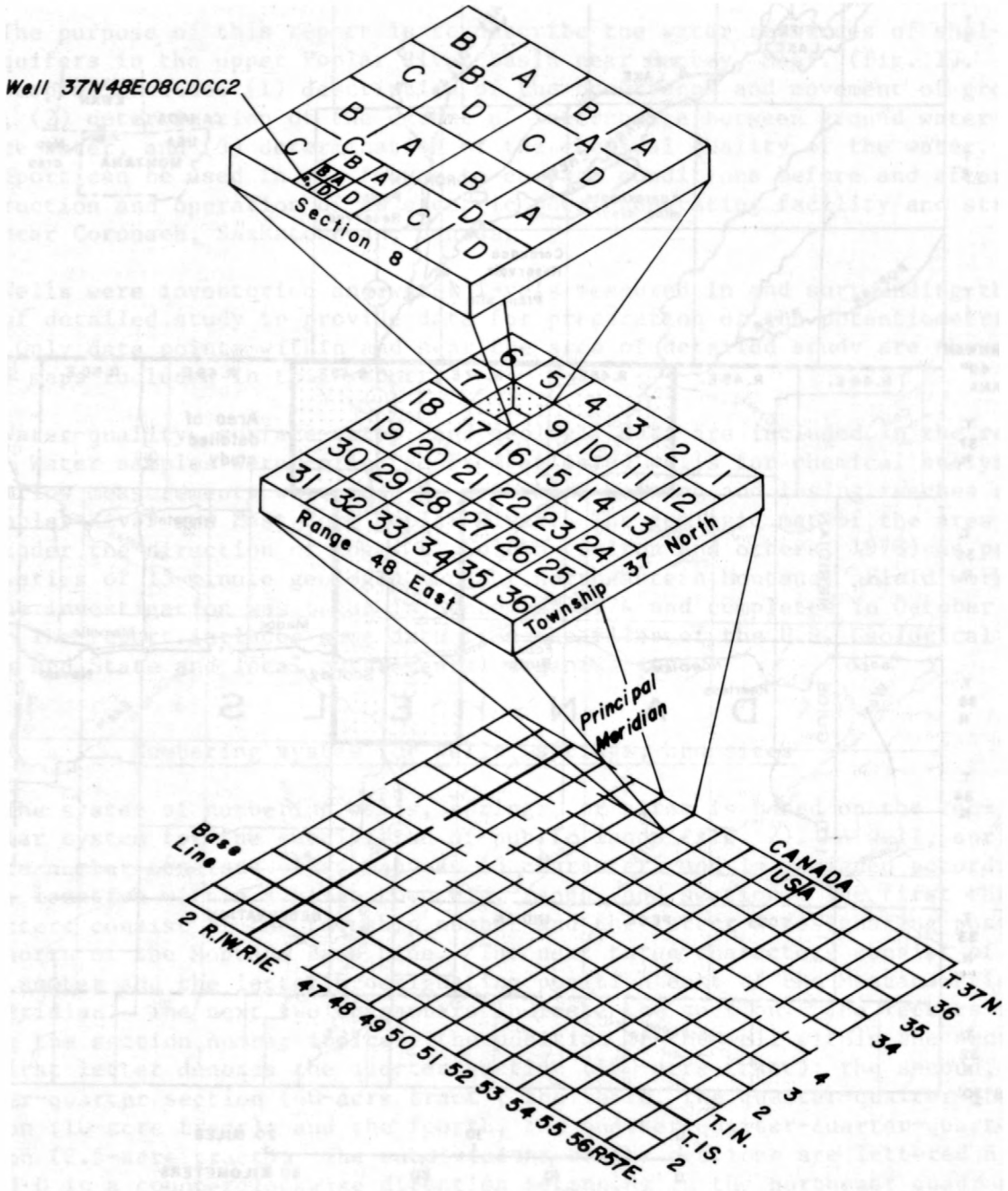

Figure 2.--Numbering system for wells, springs, and sites.

Acknowledgments

The author is grateful to officials of the City of Scobey and property owners who supplied information about their wells and who permitted access to collect water samples, measure water levels in wells, and measure streamflow. Thanks are also given to the local county officials who supplied information that helped facilitate the study.

GEOLOGY

The sedimentary rocks that are of particular interest to this study are the formations stratigraphically above the Bearpaw Shale. They include the Fox Hills Sandstone and Hell Creek Formation of Late Cretaceous age; the Fort Union and Flaxville Formations of Tertiary age; the Wiota Gravel of Pleistocene age; the varied glacial and alluvial deposits of Pleistocene age; and alluvium and colluvium of Holocene age. Descriptions of these formations in the study area and in adjacent areas in the northeast corner of Montana are in reports by Collier (1925, p. 164-168), Colton and Bateman (1956), Colton (1962, p. 242-271), and Howard (1960, p. 15-17). The stratigraphy of the formations summarized from these reports is presented in table 1.

The thickness of the geologic section from the top of the Fort Union Formation to the top of the Bearpaw Shale ranges considerably because the Fort Union has been eroded. In some areas of northeastern Montana the thickness of this section of rock is about 1,200 feet, but in the area of this study it is probably less than 800 feet.

The geologic map (pl. 1) shows the areal distribution of the geologic units. The diagrammatic cross section (fig. 3) shows the relationship of the units across the northern part of the study area.

HYDROLOGIC SETTING

Four principal terrains in and adjacent to the study area form a rather complicated geohydrologic system. The four terrains, which are distinguished by letters A, B, C, and D on figure 3, are: alluvial river valleys, widespread rolling uplands underlain by the Fort Union Formation, terraces of the Flaxville Formation and Wiota Gravel, and valleys and adjacent uplands underlain by glacial till. (The alluvial river valley and adjacent rolling uplands along the Poplar River northwest of Scobey are shown in the photograph on the front cover.)

Withdrawals of ground water and diversions of surface water are small in the Poplar River drainage basin in the Scobey area. Therefore, the natural movement of water within the hydrologic system has not been disturbed greatly. The only development of ground water is from domestic and stock wells and from municipal wells at Scobey. Most wells obtain water from the Fort Union Formation or younger rocks. Surface water is diverted for irrigation along the Poplar River; however, much of the irrigation water recharges the alluvium along the river valley or returns as surface flow to the river. Water spreading for irrigation is practiced along some tributary streams and is a source of recharge to the ground-water system.

Table 1.--Stratigraphy of formations in northeastern Montana[1]

System	Series	Formation	Thickness (feet)	General character
Quaternary	Holocene	Alluvium and colluvium	0-50	Fine- to coarse-grained flood-plain deposits of Poplar River valley and major tributaries; consist mostly of silt and sand with gravel lenses. Also include slope-wash deposits on hillsides and in valleys consisting chiefly of locally derived silt, sand, and gravel.
	Pleistocene	Glacial and alluvial deposits	0-100	Unconsolidated glacial till, glacial lake deposits, and poorly to well-sorted silt, sand, and gravel in various types of glacio-fluviatile deposits. Also include stream deposits of preglacial or interglacial periods which may be, in part, buried by till.
		Wiota Gravel	0-10	Brown gravel containing sparse glacial erratics overlain, in places, by till. Consist of 95 percent brown quartzite pebbles derived from the Flaxville Formation, and less than 5 percent erratics consisting of limestone, dolomite, igneous, and metamorphic rocks from Canada. The erratics are generally absent in unglaciated areas.
Tertiary	Pliocene or Miocene	Flaxville Formation	0-85	Brown moderately well-sorted and well-stratified sand and sandy gravel deposits. Lithology 90 percent brown and red quartzite; remainder chalcedony and fragments from the Fort Union Formation. Locally contains large lenses of volcanic ash as much as 20 feet thick.
	Paleocene	Fort Union Formation	800±	Well-sorted and well-stratified gray clay, bentonitic gray clay, brown carbonaceous clay, lignite, buff silt, gray silty limestone concretions olive-gray sand, and buff calcareous sandstone. Marked lateral variation in lithology. For distribution of lignite see Collier (1925).
Cretaceous	Upper Cretaceous	Hell Creek Formation	220-280[2]	Well-stratified sequence of shales, siltstones, sandstones, and carbonaceous shales. Overall appearance is somber greenish gray. Lower 50 to 100 feet is predominately medium-tan sand, locally cemented to sandstone. A few quartzite pebbles occur in basal 50 feet.
		Montana Group: Fox Hills Sandstone	85-115[2]	Consists of upper sandstone unit 50 to 80 feet thick underlain by transitional marine shale unit 35 feet thick. Lower unit consists of thin-bedded well-laminated shale grading to silt in upper part. Upper sandstone contains numerous concretions. Upper part of formation removed by erosion in many places before deposition of Hell Creek Formation.
		Montana Group: Bearpaw Shale	1,100-1,200	Dark-olive-gray slightly fissile semiconsolidated jointed clayey shale. Contains hard elliposoidal concretions of several kinds, many containing marine fossils. A few sandy beds present in the upper part. Thin bentonite seams present and bentonite is also disseminated through some shale zones.

[1]Based chiefly on data from Collier (1925), Colton and Bateman (1956), Colton (1962), and Howard (1960).
[2]Total thickness of Fox Hills Sandstone and Hell Creek Formation in the upper Poplar River basin ranges from about 135 to 210 feet.

The very low gradient and wide meandering nature of the Poplar River and East Fork Poplar River have produced a series of ponds, some nearly 1 mile long, that are hydraulically connected to the ground-water reservoir. During periods of high streamflow, surface water may seep from the stream channel into bank storage, but during the rest of the year seepage toward the valleys helps maintain streamflow.

GROUND WATER

Occurrence

An aquifer may be either unconfined or confined. An unconfined aquifer has a water table that is not constrained by overlying, less permeable beds. The water table is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. A confined aquifer is overlain by less permeable beds so that the ground water is confined and the water level in a well stands above the top of the aquifer it taps. If the water level in a well rises above the land surface, the well is a flowing well. Both flowing and nonflowing wells can tap the same aquifer, depending upon the altitude of the land surface at the well locations relative to the altitude of the water levels in the wells.

In the study area, water is unconfined in alluvium of the river and tributary valleys, in terrace gravels, and in bedrock aquifers in and near areas of outcrop. Confined conditions occur in deep bedrock aquifers. Relatively impermeable glacial till can act as a confining bed over preglacial alluvial deposits or over some glacial outwash deposits. Therefore, both unconfined and confined conditions can occur in glaciated areas. Flowing and nonflowing wells have been drilled in the study area.

Aquifers

Ground water in the upper Poplar River basin occurs (1) in alluvium of the Poplar River and East Fork Poplar River and tributaries, (2) in gravels of the Flaxville Formation, (3) in the Wiota Gravel, (4) in sand and gravel of the glacial deposits, (5) in sandstone and coal aquifers in the Fort Union Formation, and (6) in sandstone of the Fox Hills-Hell Creek aquifer.[1]

The six general categories are not necessarily separate aquifers, but may be interconnected so that water can move from one aquifer into another, depending upon local geologic and hydrologic conditions. Ground water may move from an unconfined aquifer to a confined aquifer or the reverse can also occur.

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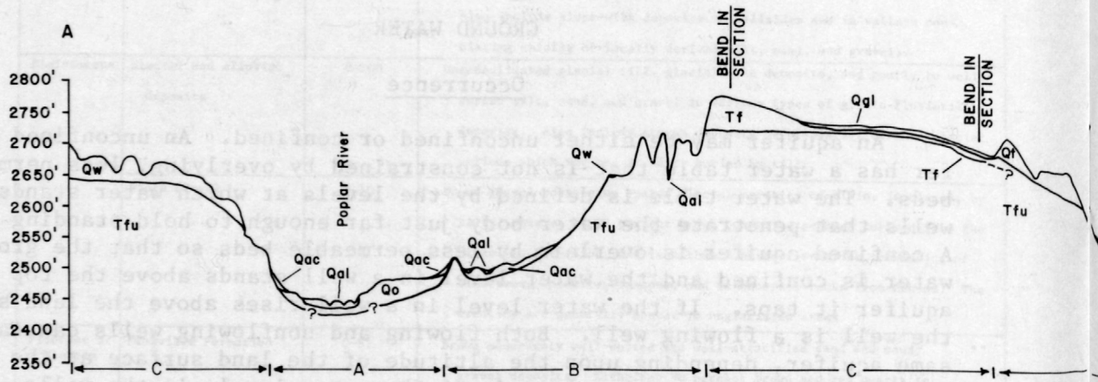
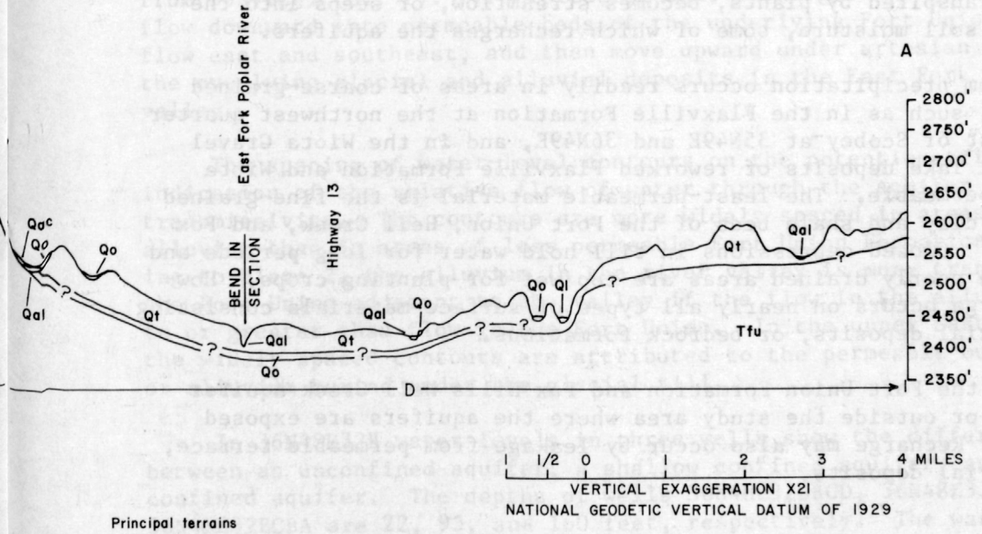
[1] Because the stratigraphic boundary separating the Fox Hills Sandstone and Hell Creek Formation is not well defined in the study area, the two formations are herein called the Fox Hills-Hell Creek aquifer.





EXPLANATION

HOLOCENE	Qal	Alluvium	
	Qac	Alluvium and colluvium	
	Ql	Lake and pond deposit	
PLEISTOCENE	Qgl	Glacial lake deposit	QUATERNARY
	Qo	Outwash deposit, undifferentiated	
	Qt	Till, undifferentiated	
PLIOCENE OR MIOCENE	Qw	Wiota Gravel	TERTIARY
	Tf	Flaxville Formation	
PALEOCENE	Tfu	Fort Union Formation	

——— Contact-- Dashed where approximately located

Figure 3.--Diagrammatic cross section of upper Poplar River basin. Line of section shown on plate 1.

Principal terrains

A	Alluvial river valleys
B	Uplands underlain by Fort Union Formation
C	Terraces of Flaxville Formation and Wiota Gravel
D	Valleys and uplands underlain by glacial till

Recharge

The source of ground water in the upper Poplar River basin is precipitation within the basin. Precipitation that reaches the land surface is evaporated, is transpired by plants, becomes streamflow, or seeps into the ground to become soil moisture, some of which recharges the aquifers.

Recharge from precipitation occurs readily in areas of coarse-grained terrace deposits, such as in the Flaxville Formation at the northwest quarter of 37N47E and east of Scobey at 35N49E and 36N49E, and in the Wiota Gravel (pl. 1). Glacial lake deposits of reworked Flaxville Formation and Wiota Gravel are also permeable. The least-permeable material is the fine-grained glacial till and clay and shale beds of the Fort Union, Hell Creek, and Fox Hills Formations. Closed depressions in till hold water for long periods and in some years the poorly drained areas are too wet for planting crops. However, some recharge occurs on nearly all types of surface materials consisting of alluvium, glacial deposits, or bedrock formations.

Recharge to the Fort Union Formation and Fox Hills-Hell Creek aquifer may occur within or outside the study area where the aquifers are exposed at land surface. Recharge may also occur by leakage from permeable terrace, glacial, or alluvial deposits.

Ground-water movement

A potentiometric map was prepared by contouring the altitude of water levels in wells tapping the alluvium, glacial deposits, Wiota Gravel, Flaxville Formation, and Fort Union Formation (pl. 2). Most water wells in the study area were drilled to the first principal aquifer; therefore, the water levels used to construct the map reflect the shallow-aquifer system. The shallow wells tap unconfined and confined aquifers. The direction of ground-water movement in and adjacent to the study area can be inferred from the water-level contours on the potentiometric map. Movement is perpendicular to and downgradient from the contours, as indicated by the arrows on the map.

In general, water moves through the aquifers from the high interstream areas toward alluvium of the Poplar River and East Fork Poplar River valleys or the principal tributary stream valleys. Some ground water discharges as springs or seeps on hillsides or as streamflow. The springs or seeps may be from coal or sandstone beds in the Fort Union Formation or from the gravel around the terraces of the Flaxville Formation. Ground water may move down the Poplar River and East Fork Poplar River valleys through the alluvium several miles before discharging as streamflow.

Water may move through several aquifers from recharge areas to the stream valleys. As an example, precipitation that recharges the Flaxville Formation in 37N47E06 might move southeast into the glacial deposits and continue as subsurface flow in the outwash deposits that extend northwest from 36N48E09 (pl. 1). Precipitation that recharges the gravels might also flow downward into permeable beds of the underlying Fort Union Formation, flow east and southeast, and then move upward under artesian pressure into the overlying glacial and alluvial deposits in the East Fork Poplar River valley.

The spacing of water-level contours on the potentiometric map gives an indication of the relative flow of water through the aquifer and the aquifer transmissivity. The contours are more widely spaced in areas of permeable alluvium than in areas of less permeable Fort Union Formation. Thus, according to plate 2, the alluvium in the river valley is more transmissive than the Fort Union adjacent to the valley if the flow in the alluvium is equal to or greater than flow in the Fort Union. In the upper East Fork valley the widely spaced contours are attributed to the permeable outwash gravel or alluvium buried under the glacial till.

In 36N48E32B water levels in three wells show the difference in head between an unconfined aquifer, a shallow confined aquifer, and a deeper confined aquifer. The depths of wells 36N48E32BBCD, 36N48E32BBCA, and 36N48E32BCBA are 22, 95, and 160 feet, respectively. The water levels in these wells, relative to land surface, are -16, -10, and +1 feet, respectively. The higher heads at depth indicate upward movement of water from deeper aquifers to shallow aquifers for this area. Only a few wells tap the deeper aquifers and well completion is not certain. Therefore, it is not possible to show the regional trend in water movement in the deep aquifers.

Quality of ground water

Water samples were collected from 20 wells and 1 spring for chemical analysis. The sites were selected to show the chemical characteristics of water from several different aquifers. Chemical analyses of water for common constituents are listed in table 2 and for nutrients and minor elements in table 3.

Chemical-constituent diagrams on pl. 2 show the differences in water types. The water in each formation is generally of the same type; however, some changes occur within geologic units in different geographic areas.

Water from the Fox Hills-Hell Creek aquifer is of the sodium bicarbonate type. Chemical-constituent diagrams (pl. 2) for wells 36N48E01BBCD, 36N48E32BCBA, 37N48E04BBBA, and 37N48E05AAAA show the distinctiveness of the water type in the study area.

Table 2.--Chemical analyses (common constituents) of water from wells and one spring[1]

[Constituents are dissolved and in milligrams per liter, except as indicated.
Geologic source: Kfh, Fox Hills-Hell Creek aquifer; Tfu, Fort Union Formation; Tf, Flaxville Formation; Qo, glacial outwash; Qal, alluvium. Water source: W, water well; S, spring.
Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey]

Sampling site	Date (mo-day-yr)	Geologic source	Water source	Well depth	Specific conductance µmhos/cm at 25°C)	pH, field (units)	Water temperature (°C)	Hardness (Ca,Mg)	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
35N48E16CBCD	8-8-77	Qal	W	36	1,430	7.5	9.0	230	0	36	34	270	8	6	640	0
36N48E01BBCD	8-4-77	Tfu	W	60	2,160	7.2	9.0	230	0	51	24	450	13	4	760	0
09CDDC	8-3-77	Qal	W	42	1,320	7.5	7.0	380	0	66	52	180	4	6	560	0
11DCCA	8-4-77	Kfh	W	348	2,050	8.4	9.0	11	0	3.4	.6	510	67	1	98	23
18BDCA	8-4-77	Qal	W	16	1,900	7.4	11.0	310	0	54	42	340	8	8	690	0
27ABAB	8-9-77	Qal	W	20	1,430	7.6	10.0	330	0	50	50	240	6	12	680	0
32BCBA	8-6-77	Kfh	W	160	1,480	8.6	9.0	8	0	2.3	.4	380	61	1	780	21
33CCCA	8-9-77	Qal	W	16	2,230	7.7	8.0	450	0	52	90	360	7	10	790	0
37N46E01CDDC	8-2-77	Tfu	W	60	890	7.1	8.5	500	3	100	61	13	.3	5	610	0
08DDCA	8-2-77	Tfu	W	53	1,210	8.6	8.5	28	0	6.3	3.1	290	24	2	590	0
22ADCD	8-6-77	Qo	W	41	1,070	6.7	9.0	590	230	130	63	17	.3	5	430	0
27BCDC	8-2-77	Tfu	S	--	1,820	6.8	7.5	400	0	86	45	310	7	8	770	0
37N47E01CABA	9-16-75	Qo	W	55	1,190	7.5	8.5	520	210	100	65	37	.7	5	370	0
	10-8-76	Qo	W	55	1,260	--	8.0	630	310	140	67	40	.7	5	390	-
09CBBB2	8-5-77	Tf	W	80	710	7.0	10.0	340	0	62	45	21	.5	3	450	0
16ACCD	8-2-77	Tfu	W	400	1,270	6.9	7.0	570	0	110	74	95	2	8	710	0
22AAAA	8-4-77	Tfu	W	150	900	7.0	8.0	380	0	72	48	68	2	5	550	0
37N48E04BBBA	9-16-75	Kfh	W	227	1,670	8.7	--	11	0	2.9	1.0	430	56	2	610	120
	10-8-76	Kfh	W	227	1,710	--	10.0	8	0	2.3	.5	420	65	1	870	-
05AAAA	10-8-76	Kfh	W	218	1,720	8.4	8.5	23	0	6.1	2.0	410	37	2	860	0
19DDCC	8-4-77	Tfu	(2)	--	1,290	7.0	7.0	620	51	120	80	88	2	6	690	0
23CDBB	8-4-77	Qo	W	21	920	7.4	11.0	430	62	74	60	52	1	3	450	0
27BACA	8-5-77	Qo	W	24	880	7.3	7.0	400	67	69	54	48	1	3	400	0

Sampling site	Date (mo-day-yr)	Geologic source	Alkalinity, total as $CaCO_3$	Sulfide, total as S	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (Sum of constituents)	Nitrite plus nitrate (N)	Boron (B) (µg/L)	Iron, total (Fe) (µg/L)	Lithium (Li) (µg/L)	Manganese (Mn) (µg/L)	Analysis by
35N48E16CBCD	8-8-77	Qal	530	1.8	270	10	0.5	13	960	0.00	1,400	--	90	70	GS
36N48E01BBCD	8-4-77	Tfu	630	--	540	11	.5	15	1,470	.16	2,400	2,000	90	90	BM
09CDDC	8-3-77	Qal	460	--	280	6.5	.3	19	880	2.1	1,200	140	70	<10	BM
11DCCA	8-4-77	Kfh	850	--	220	38	1.7	14	1,300	.03	2,200	400	60	10	BM
18BDCA	8-4-77	Qal	570	--	430	25	.3	14	1,270	7.0	1,400	730	90	50	BM
27ABAB	8-9-77	Qal	560	--	270	8.6	.3	13	980	.02	1,900	970	100	150	BM
32BCBA	8-6-77	Kfh	670	--	35	93	3.3	9.9	940	.04	2,400	--	50	4	GS
33CCCA	8-9-77	Qal	660	--	500	57	.3	11	1,490	17	2,000	550	140	750	BM
37N46E01CDDC	8-2-77	Tfu	500	--	20	3.2	.5	20	520	.07	300	2,000	30	180	BM
08DDCA	8-2-77	Tfu	480	--	130	20	1.9	10	750	1.8	2,100	270	50	10	BM
22ADCD	8-6-77	Qo	350	1.4	240	20	.1	16	710	1.2	150	--	20	220	GS
27BCDC	8-2-77	Tfu	630	--	410	5.0	.2	16	1,260	.03	2,800	1,200	140	200	BM
37N47E01CABA	9-16-75	Qo	310	--	280	17	.3	14	700	17	110	--	--	--	GS
	10-8-76	Qo	320	.2	290	21	.4	13	770	21	120	--	--	--	GS
09CBBB2	8-5-77	Tf	370	.5	17	7.2	1.0	13	400	2.5	230	--	20	140	GS
16ACCD	8-2-77	Tfu	590	--	160	7.3	.2	17	820	.3	1,400	20	80	140	BM
22AAAA	8-4-77	Tfu	450	--	61	4.5	.2	15	550	.04	1,600	12,000	60	110	BM
37N48E04BBBA	9-16-75	Kfh	710	--	7.4	150	2.3	12	1,040	.03	2,000	--	--	--	GS
	10-8-76	Kfh	710	.2	5.8	160	2.5	12	1,030	0	2,100	--	--	--	GS
05AAAA	10-8-76	Kfh	700	.6	4.9	160	2.7	13	1,030	0	2,100	--	--	--	GS
19DDCC	8-4-77	Tfu	570	--	220	3.4	.2	15	870	.02	1,400	1,540	80	670	BM
23CDBB	8-4-77	Qo	370	--	140	3.2	.3	14	570	5.1	570	90	40	10	BM
27BACA	8-5-77	Qo	330	1.5	170	7.0	.4	15	570	.02	320	--	60	220	GS

Table 3.--Chemical analyses (nutrients and minor elements) of water from selected wells

[Analyses by U.S. Geological Survey. Geologic Source: Kfh, Fox Hills-Hell Creek aquifer; Tf, Flaxville Formation; Qo, glacial outwash; Qal, alluvium]

Variable	Units	Data							
Sampling site	--	35N48E16CBCD	36N48E32BCBA	37N46E22ADCD	37N47E01CABA	37N47E09CBBB2	37N48E04BBBA	37N48E05AAAA	37N48E27BACA
Date of collection	(mo-day-yr)	8-8-77	8-6-77	8-6-77	10-8-76	8-5-77	10-8-76	10-8-76	8-5-77
Geologic source	--	Qal	Kfh	Qo	Qo	Tf	Kfh	Kfh	Qo
Well depth	feet	36	160	41	55	80	227	218	24
Color (platinum cobalt scale)	--	8	180	6	--	27	--	--	6
Bromide (Br)	mg/L	.1	.9	0.1	.0	.0	.0	.0	.1
Iodide (I)	mg/L	.02	.15	.00	.02	.01	.02	.02	.00
Nitrite plus nitrate, total as N	mg/L	.01	.03	1.0	21	3.0	.00	.00	.01
Nitrite plus nitrate, dissolved as N	mg/L	.00	.04	1.2	--	2.5	--	--	.02
Nitrogen, ammonia, total as N	mg/L	.19	.42	.04	.00	.05	.41	.61	.06
Nitrogen, ammonia, dissolved as N	mg/L	.21	.43	.07	--	.08	--	--	.09
Nitrogen, ammonia, dissolved as NH_4	mg/L	.27	.55	.09	--	.10	--	--	.12
Nitrogen, total organic, as N	mg/L	1.0	.48	.91	.40	.39	.22	.13	2.2
Nitrogen, total kjeldahl, as N	mg/L	1.2	.90	.95	.40	.44	.63	.74	2.3
Nitrogen, total as N	mg/L	1.2	.93	2.0	21	3.4	.63	.74	2.3
Nitrogen, total as NO_3	mg/L	5.4	4.1	8.6	95	15	2.8	3.3	10
Phosphorus, total as P	mg/L	.03	.46	.02	.07	.00	.29	.32	.00
Phosphorus, total (PO_4)	mg/L	.09	1.4	.06	--	.00	--	--	.00
Aluminum, dissolved as Al	µg/L	0	20	0	20	10	30	20	0
Arsenic, dissolved as As	µg/L	8	1	0	0	0	2	1	0
Barium, dissolved as Ba	µg/L	100	300	400	10	200	20	60	200
Beryllium, dissolved as Be	µg/L	--	--	--	<7	--	<9	<9	--
Bismuth, dissolved as Bi	µg/L	--	--	--	<7	--	<9	<9	--
Cadmium, dissolved as Cd	µg/L	2	1	3	0	2	0	0	1
Chromium, dissolved as Cr	µg/L	8	8	8	<7	8	<9	<9	8

Table 3.--Chemical analyses (nutrients and minor elements) of water from selected wells--Continued

Variable	Units	Data							
Cobalt, dissolved as Co	µg/L	0	4	0	7	1	9	9	0
Copper, dissolved as Cu	µg/L	0	0	1	10	5	0	0	0
Gallium, dissolved as Ga	µg/L	--	--	--	7	--	9	9	--
Germanium, dissolved as Ge	µg/L	--	--	--	20	--	20	20	--
Iron, dissolved as Fe	µg/L	1,600	590	250	20	170	340	660	390
Lead, dissolved as Pb	µg/L	22	10	49	14	23	14	14	11
Mercury, dissolved as Hg	µg/L	.0	.0	.0	.0	.0	.0	.0	.0
Molybdenum, dissolved as Mi	µg/L	4	4	0	7	1	12	9	0
Nickel, dissolved as Ni	µg/L	5	10	6	7	5	9	9	5
Selenium, dissolved as Se	µg/L	0	0	2	27	5	0	0	0
Silver, dissolved as Ag	µg/L	--	--	--	3	--	5	5	--
Strontium, dissolved as Sr	µg/L	540	100	1,000	480	390	50	170	610
Tin, dissolved as Sn	µg/L	--	--	--	10	--	14	14	--
Titanium, dissolved as Ti	µg/L	--	--	--	3	--	210	270	--
Vanadium, dissolved as V	µg/L	.0	9	0.0	14	.0	18	18	.0
Zinc, dissolved as Zn	µg/L	20	10	50	--	2	--	--	30
Zirconium, dissolved as Zr	µg/L	--	--	--	10	--	20	20	--
Alpha, gross total as U natural	µg/L	15	40	15	19	23	41	25	14
Beta, gross total as CS-137	pCi/L	4.0	4.1	5.6	19	5.2	9.7	11	5.0
Beta, gross total as strontium/ yttrium-90	pCi/L	5.0	5.1	6.8	18	6.5	8.2	9.2	6.2

Water from the Fort Union Formation is either a sodium bicarbonate type or a magnesium bicarbonate type. The diagrams for wells 36N48E01BBCD and 37N46E08DDCA and for spring 37N46E27BCDC show a sodium bicarbonate type having more calcium and magnesium than in water of the underlying Fox Hills-Hell Creek aquifer. The diagrams for the Fort Union water in the vicinity of the terrace covered by gravels of the Flaxville Formation in 37N47E show a predominance of magnesium and calcium compared to sodium. Apparently, precipitation readily filters into the terrace gravels, and dissolves and transports calcium and magnesium to the underlying Fort Union Formation. Water in and near this recharge area (well 37N46E01CDDC in the Fort Union and well 37N47E09CBBB2 in the Flaxville) is low in sodium and dissolved-solids concentrations. Wells 37N47E16ACCD and 37N47E22AAAA are deeper, 400 and 150 feet respectively, but the water still contains less sodium than either calcium or magnesium. The analysis of water from well 37N48E19DDCC, several miles southeast, also shows a magnesium bicarbonate water. The potentiometric map (pl. 2) shows the changing water quality with movement of water downgradient to the southeast.

Water from shallow wells tapping glacial deposits (wells 37N46E22ADCD, 37N47E01CABA, 37N48E23CDBB, and 37N48E27BACA) is a calcium or magnesium bicarbonate type and is low in dissolved-solids concentration. These wells are in glacial outwash deposits along the margin of the unglaciated Poplar River valley and in outwash deposits that underlie the glacial till in the East Fork valley.

Water from shallow wells in alluvium of the river valley (wells 35N48E16CBCD, 36N48E09CDDC, 36N48E18BDCA, 36N48E27ABAB, and 36N48E33CCCA) is a sodium bicarbonate type, having more dissolved solids than water from wells in outwash deposits. Water from the valley alluvium is the same type and has nearly the same concentration of dissolved solids as the surface water (pl. 2).

SURFACE WATER

Drainage

The principal streams in the study area are the Poplar River[2] and the East Fork Poplar River (fig. 1). The drainage systems for these streams extend about 33 and 42 miles, respectively, into Canada. Other perennial streams are Coal Creek, which flows into the Poplar River at 37N46E08CBD, and Butte Creek, which flows into the Poplar River at 35N48E17CBB. Some creeks that drain into the Poplar and East Fork Poplar Rivers are perennial along parts of their courses but streamflow is lost to the ground and generally does not reach the rivers. However, the flow presumably reaches the main river valleys as underflow in the valley-fill alluvium.

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[2]Prior to December 1976 the Poplar River in Montana upstream from the confluence with the East Fork was called Middle Fork Poplar River and Lost Child Creek.

Glacial activity has affected the character of the Poplar River drainage. The wide flat valleys were developed by much larger quantities of water than presently flow down the valleys. The glacial-fed streams eroded wide valleys and deposited as much as 40 feet of well-sorted silt, sand, and gravel. In the valley of East Fork Poplar River, glacial deposits have altered stream channels and partly covered the preglacial valley. A terminal moraine that extends northwest across the valley from 36N48E13 (pl. 1) caused a shift in the position of the East Fork. The old stream channel occurs as a "C" shaped topographic low that begins in 36N48E21 and ends abruptly in 36N48E11. The terminal moraine covered the old channel and caused melt water from the glacier to erode the present channel through bedrock along the east side of the valley from 36N48E12 to 36N48E27. The location and direction of the buried river channel under and north of the moraine are unknown except as implied on the geologic map. The East Fork Poplar River has entrenched itself into glacial till in a steep-sided valley having a narrow flood plain from the "Narrows" in 36N48E12 to the international boundary. The gradients of the Poplar and East Fork Poplar Rivers are 2.5 and 2.2 ft/mi, respectively.

Seepage measurements

Streamflow measurements were made October 19-20, 1977, along the Poplar and East Fork Poplar Rivers to determine gains or losses in the surface-water system. Gains indicate flow from an adjacent aquifer to the stream channel; losses indicate flow from the stream channel to an adjacent aquifer.

The streamflow measurements were made during a period of base flow in the fall when the vegetation was dormant, no large rainfall occurred to produce runoff, the stage of the rivers was not fluctuating, and no water was being diverted for irrigation. During this period, flow is maintained by movement of ground water from the upland areas to alluvium of the principal river valleys and then to the stream channel. Twelve measurements were made, including two on Coal Creek and Butte Creek (pl. 2), the only streams that were flowing into the rivers.

Calculations made for eight reaches indicate that six reaches are gaining (table 4). However, the measured net gain of 2.84 ft^3/s (table 4) is not the total contribution of ground water to the valleys of the Poplar and East Fork Poplar Rivers. The potentiometric map (pl. 2) shows that ground-water movement is toward the stream valleys. The alluvium of the river valleys is as much as 40 feet thick in some areas and is capable of transmitting large quantities of water in the subsurface. Some water from the bedrock along the valleys discharges into the alluvium in the valley and probably moves through the alluvium and downvalley without reaching the stream channel.

Identification letter (pl. 2)	Stream	Location	Date	Discharge, in cubic feet per second: Instantaneous discharge	Increase or (-) decrease	Net gain or (-) loss
			East Fork Poplar River basin			
A	East Fork Poplar River	37N48E05AAA[1]	10-19-77	1.94	--	--
B	-----do.-----	36N48E12CCB	10-19-77	1.68	-0.26	--
C	-----do.-----	36N48E27BAA	10-19-77	.94	-.74	--
D	-----do.-----	36N48E33ACA	10-20-77	1.34	.40	-0.60
			Main stem Poplar River basin			
E	Poplar River	37N45E03ABA	10-19-77	3.84	--	--
F	Coal Creek	37N45E16AAA	10-19-77	1.41	--	--
G	Poplar River	37N46E36BCC	10-19-77	5.52	.27	--
H	-----do.-----	36N47E13DAD	10-19-77	6.47	.95	--
I	-----do.-----	35N48E05ABA	10-19-77	8.11	.30[2]	--
J	Butte Creek	35N48E07CBD	10-20-77	1.67	--	--
K	Poplar Creek	35N48E16CBC	10-19-77	10.8	1.02	--
L	-----do.-----	34N48E03CDD	10-20-77	11.7	.90	3.44
					Total	2.84

A loss in streamflow of the East Fork Poplar River was observed in two reaches of the stream. Upstream from site B (36N48E12CCB) the loss may occur in gravel of the "old" East Fork channel that is covered by the terminal moraine that extends northwest from 36N48E13B. Upstream from site C (36N48E27BAA) the loss occurs where the new channel was eroded through the bedrock from 36N48E12B to 36N48E27B. Water may move through permeable beds of the Fort Union Formation (possibly coal) in 36N48E12 and 36N48E14, west toward the old channel in 36N48E10 and 36N48E16. Some streamflow may recharge gravel beneath the present river channel, which was eroded deep into the bedrock and subsequently partly filled by alluvial gravel. This permeable gravel would transmit the water in the subsurface into the broad valley west of State Highway 13 north of Scobey. Water that seeps from the stream to the aquifer is not lost from the system but reappears as streamflow or moves downvalley as underflow.

Quality of surface water

Surface-water samples have been collected nearly monthly at four sites for chemical analysis. The four sites and period of record are: Poplar River at international boundary (July 1976 to current year) and near Scobey (August 1975 to current year), and East Fork at international boundary (December 1974 to current year) and near Scobey (August 1975 to current year). The analyses are published in annual water-data reports by the U.S. Geological Survey (1975-77). Chemical analyses of water from the four sites for August 1977 are given in table 5.

The chemical-constituent diagrams on plate 2 show the similarity of water types in water from the streams and water from wells in the valley alluvium. Examples of similar sodium bicarbonate type water are shown for well 36N48E18BDCA and surface-water site 36N47E13DAD, and for well 36N48E27ABAB and surface-water site 36N48E27BAA.

Table 5.--Chemical analyses of surface water

[Abbreviations: ac-ft, acre-foot; ft^3/s, cubic foot per second; °C, degree Celsius; JTU, Jackson turbidity unit; mg/L, milligram per liter; ml, milliliter; µmho/cm, micromho per centimeter; µg/L, microgram per liter]

Station number	Station location	Station name	Date of sample	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µmho/cm)
06178000	37N46E06DAA	Poplar River at International Boundary	77-08-16	0900	0.30	1630
06178150	36N47E13DAD	Poplar River near Scobey	77-08-15	1530	1.5	1740
06178500	37N48E05AAA[1]	East Fork Poplar River at International Boundary	77-08-17	1030	1.8	1330
06179000	36N48E27BAA	East Fork Poplar River near Scobey	77-08-17	1530	.52	1690

Date of sample	pH (units)	Air temperature (°C)	Temperature (°C)	Color (platinum-cobalt units)	Turbidity (JTU)	Dissolved oxygen (mg/L)	Percent saturation	Immediate coliform (col./100 mL)	Fecal coliform .7 µm-MF (col./100 mL)	Hardness (Ca,Mg) (mg/L)
77-08-16	8.2	16.0	12.0	--	30	7.4	76	400	370	300
77-08-15	8.7	19.0	18.5	--	55	7.8	90	1	5	240
77-08-17	8.2	17.5	15.5	12	15	7.6	84	68	16	330
77-08-17	8.6	25.0	19.5	--	35	8.8	104	380	330	290

Date of sample	Noncarbonate hardness (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Percent sodium	Sodium adsorption ratio	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Carbonate (CO_3) (mg/L)	Alkalinity as $CaCO_3$ (mg/L)
77-08-16	0	54	39	300	68	7.6	8.4	750	0	62
77-08-15	0	28	42	350	75	9.8	9.4	730	18	63
77-08-17	0	56	46	190	55	4.6	7.8	630	0	52
77-08-17	0	34	51	300	68	7.6	15	710	7	59

Date of sample	Carbon dioxide (CO_2) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved solids (sum of constituents) (mg/L)	Dissolved solids (tons per ac-ft)	Dissolved solids (tons per day)	Total nitrite plus nitrate (N) (mg/L)	Total ammonia nitrogen (N) (mg/L)
77-08-16	7.6	330	10	0.6	1.0	1110	1.51	0.90	0.01	0.02
77-08-15	2.4	350	11	.7	7.9	1180	1.60	4.78	.01	.02
77-08-17	6.4	260	5.2	.4	9.9	890	1.21	4.32	.01	.01
77-08-17	2.9	360	10	.4	6.6	1140	1.55	1.60	.03	.03

Table 5.--Chemical analyses of surface water--Continued

Date of sample	Total organic nitrogen (N) (mg/L)	Total kjeldahl nitrogen (N) (mg/L)	Total nitrogen (N) (mg/L)	Total nitrogen (NO_3) (mg/L)	Total phosphorus (P) (mg/L)	Dissolved ortho. phosphorus (P) (mg/L)	Dissolved orthophosphate (PO_4) (mg/L)	Total aluminum (Al) (µg/L)	Dissolved aluminum (Al) (µg/L)	Total arsenic (As) (µg/L)
77-08-16	0.78	0.80	0.81	3.6	0.10	0.01	0.03	610	10	4
77-08-15	1.3	1.3	1.3	5.8	.13	.08	.25	710	20	7
77-08-17	.34	.35	.36	1.6	.05	.01	.03	--	--	-
77-08-17	1.3	1.3	1.3	5.9	.14	.01	.03	490	10	6

Date of sample	Dissolved arsenic (As) (µg/L)	Total beryllium (Be) (µg/L)	Dissolved beryllium (Be) (µg/L)	Dissolved boron (B) (µg/L)	Total cadmium (Cd) (µg/L)	Dissolved cadmium (Cd) (µg/L)	Total chromium (Cr) (µg/L)	Dissolved chromium (Cr) (µg/L)	Total copper (Cu) (µg/L)	Dissolved copper (Cu) (µg/L)
77-08-16	3	0	0	1700	10	0	12	8	10	0
77-08-15	7	0	0	2100	10	0	12	0	10	2
77-08-17	-	-	-	2000	--	-	--	-	--	-
77-08-17	3	0	0	2200	10	0	16	4	10	1

Date of sample	Total iron (Fe) (µg/L)	Dissolved iron (Fe) (µg/L)	Total lead (Pb) (µg/L)	Dissolved lead (Pb) (µg/L)	Total lithium (Li) (µg/L)	Dissolved lithium (Li) (µg/L)	Total manganese (Mn) (µg/L)	Dissolved manganese (Mn) (µg/L)	Total mercury (Hg) (µg/L)	Dissolved mercury (Hg) (µg/L)
77-08-16	940	80	100	0	90	100	150	90	0.0	0.0
77-08-15	1100	40	100	0	110	120	100	8	.1	.0
77-08-17	--	20	--	-	--	--	--	--	--	--
77-08-17	1000	30	100	0	120	120	50	4	.1	.0

Date of sample	Total molybdenum (Mo) (µg/L)	Dissolved molybdenum (Mo) (µg/L)	Total nickel (Ni) (µg/L)	Dissolved nickel (Ni) (µg/L)	Total selenium (Se) (µg/L)	Dissolved selenium (Se) (µg/L)	Dissolved vanadium (V) (µg/L)	Total zinc (Zn) (µg/L)	Dissolved zinc (Zn) (µg/L)
77-08-16	1	2	50	3	0	0	.0	20	10
77-08-15	2	2	50	3	0	0	.0	20	10
77-08-17	-	-	--	-	-	-	--	--	--
77-08-17	4	2	50	5	0	0	.0	20	10

[1]Station is 10 feet north of international boundary.

CONCLUSIONS

The ground-water system in the upper Poplar River basin consists of a series of aquifers under differing hydrologic conditions. Water in the alluvium, Wiota Gravel, and Flaxville Formation is unconfined. Water in the Fort Union Formation is unconfined in and near shallow recharge areas but confined where deeper. Water is also confined in the Fox Hills-Hell Creek aquifer. Both unconfined and confined conditions can occur in glacial deposits.

Recharge from precipitation occurs readily in areas underlain by coarse-grained deposits. Sand and gravel deposits of the Flaxville Formation and the Wiota Gravel are important to recharge of the ground-water system. Water filters through these permeable deposits locally to recharge the underlying formation. Glacial lake deposits of reworked Flaxville Formation and Wiota Gravel are also permeable. Recharge to bedrock aquifers may occur within or outside the study area where they are exposed at land surface or by leakage from permeable terrace, glacial, or alluvial deposits.

The available hydrologic data indicate that water moves through the shallow aquifers from the high interstream areas to alluvium of the principal valleys. Water then may move down the valleys through the alluvium several miles before discharging as streamflow. Some ground water discharges as springs or seeps on hillsides. Regional water movement in the deeper confined aquifers is not known because data are not available to document gradients.

Water in the Fox Hills-Hell Creek aquifer is a sodium bicarbonate type and ranges in dissolved-solids concentration from 940 to 1,300 mg/L. Water in the Fort Union Formation is either a sodium bicarbonate or a magnesium bicarbonate type having a range in dissolved-solids concentration of 520 to 1,470 mg/L. The magnesium bicarbonate water occurs in or near the area where the Fort Union is recharged from the Flaxville Formation. One sample of water from the Flaxville Formation indicates a magnesium bicarbonate type having 400 mg/L dissolved solids. Water in glacial outwash deposits is a calcium or magnesium bicarbonate type having a range in dissolved-solids concentration of 570 to 770 mg/L. Water in the alluvium is a sodium bicarbonate type that ranges from 880 to 1,490 mg/L.

Base flow is maintained by movement of ground water from the upland areas to alluvium of the principal river valleys and then to the stream channel. Seepage measurements made in October 1977 showed a net gain in streamflow of 2.84 ft^3/s along the Poplar and East Fork Poplar Rivers. The gain is not the total contribution of ground water to the valleys because alluvium as much as 40 feet thick can transmit large quantities of water through the subsurface as underflow.

Water sampled from the Poplar and East Fork Poplar Rivers in 1977 was similar in quality to that of valley alluvium. The water was a sodium bicarbonate type having a range in dissolved-solids concentration of 890 to 1,180 mg/L.

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