HYDROGEOLOGIC FEATURES OF THE ALLUVIAL DEPOSITS IN THE OWL CREEK VALLEY, BIGHORN BASIN, WYOMING

By Maurice E. Cooley and William J. Head

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Conversion factors

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

Multiply	By	To obtain
inch	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
acre	0.4047	hectare
gallon per minute (gal/min)	3.78543	liter per minute
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
acre-foot (acre-ft)	1,233.	cubic meter
	0.001233	cubic hectometer
	0.000001233	cubic kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
foot per day (ft/d)	0.3048	meter per day
gallon per minute per foot [(gal/min)/ft]	12.4194	liter per minute per meter
micromho per centimeter at 25° Celsius (µmho)	1.0	microsiemen

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ABSTRACT

The principal surficial deposits in Owl Creek Valley are the Embar Ranch and Arapahoe Ranch terrace deposits, flood-plain alluvium, alluvial-fan deposits, and pediment deposits. All the deposits are thin. Conspicuous terraces in Owl Creek Valley include an unnamed terrace at 500 feet above Owl Creek, the Embar Ranch terrace 160 to 120 feet above the creek, and the Arapahoe Ranch terrace 50 to 20 feet above the creek. The flood-plain alluvium and part of the Arapahoe Ranch terrace deposits are the main water-yielding units comprising the alluvial aquifer. The flood-plain alluvium yields water to wells throughout the valley, but the Araphoe Ranch terrace deposits yield water principally in only two widely spaced areas. Locally, the alluvial-fan deposits yield some water to wells.

Thickness of the alluvial deposits generally ranges from 20 feet to a maximum thickness of about 50 feet, as determined from well logs, surface-resistivity measurements, or both. The deposits are consistently between 30 and 40 feet thick between the Owl Creek and Thermopolis anticlines, about 20 feet thick near the mouth of Owl Creek, and 20 to possibly 35 feet thick upstream from the Owl Creek anticline.

Chemical quality of water in the alluvial aquifer generally is not desirable or is marginal for most purposes except for stock watering. In the eastern one-half of the area, the concentration of dissolved solids generally exceeds 2,000 milligrams per liter. In the western one-half, the dissolved-solids concentration is between about 500 and 2,000 milligrams per liter; the water having the smallest concentration of dissolved solids occurs along the tributary Red Creek and along North Fork Owl Creek near the western edge of the area.

Measurements of specific conductance of the water in Owl Creek indicate a progressive increase in the downstream direction. During September 1976 (during low flow and maximum diversion for irrigation) specific conductance was about 300 micromhos per centimeter at 25°C in upstream reaches of the area investigated and more than 3,300 micromhos per centimeter at 25°C in the downstream reaches. The increases principally are due to return flow of irrigation water, but at places inflow from tributaries and from water from the alluvial deposits significantly increase the specific conductance of water in Owl Creek.

INTRODUCTION

The alluvial deposits form the principal aquifer in the Owl Creek Valley and the source of water to many stock and domestic wells and to a few irrigation wells. In 1975, the U.S. Geological Survey, in cooperation with the Wyoming State Engineer, began an investigation of the hydrology and geology, including the geomorphology, of Owl Creek Valley (fig. 1) to determine possible favorable areas for obtaining ground water of adequate chemical quality for irrigation and other uses. The part of Owl Creek basin investigated is downstream from Anchor Reservoir and includes North Fork, South Fork, and the mainstem of Owl Creek (pl. 1). However, the area downstream from Embar Ranch (pl. 1) was emphasized during the study.

Methods of Investigation

Mapping of the surficial deposits in the bottom land along Owl Creek determined their areal extent and identified the deposits that comprise that part of the alluvial aquifer (pl. 1) which has the best potential for ground-water development. The mapping was done on aerial photographs and on 7½-minute topographic maps (scale 1:24,000) with contour intervals of 20 or 40 feet. All data were plotted on the topographic maps, which subsequently were reduced photographically to a 1:62,500 scale.

Eight direct-current (surface) resistivity measurements were made south of Arapahoe Ranch and near the Thermopolis anticline to help determine the thickness of the alluvial deposits (pl. 2). The field technique used the Schlumberger[1] array. Interpretations were based on Hummel's curve-matching methods (Keller and Frischknecht, 1960) and on a computerized interpretation method using modified Dar Zarrouk functions (Zohdy, 1975). The resistivity data were not refined for lithology and porosity interpretations.

In addition, water from wells and streams was sampled for chemical analysis, and the specific conductance of the flow of Owl Creek was measured at selected places.

Previous Investigations and Acknowledgments

The principal hydrologic investigation of the Owl Creek area was by Berry and Littleton (1961). Other reports that include all of the Bighorn basin are by Lowry and others (1976), who briefly described the ground-water resources; Andrews and others (1947), who mapped the main alluvial deposits; and Zapp (1956), who constructed a structure-contour map of the Tensleep Sandstone.

[1] The use of trade names in this report is for identification only and does not constitute endorsement by the U.S. Geological Survey.

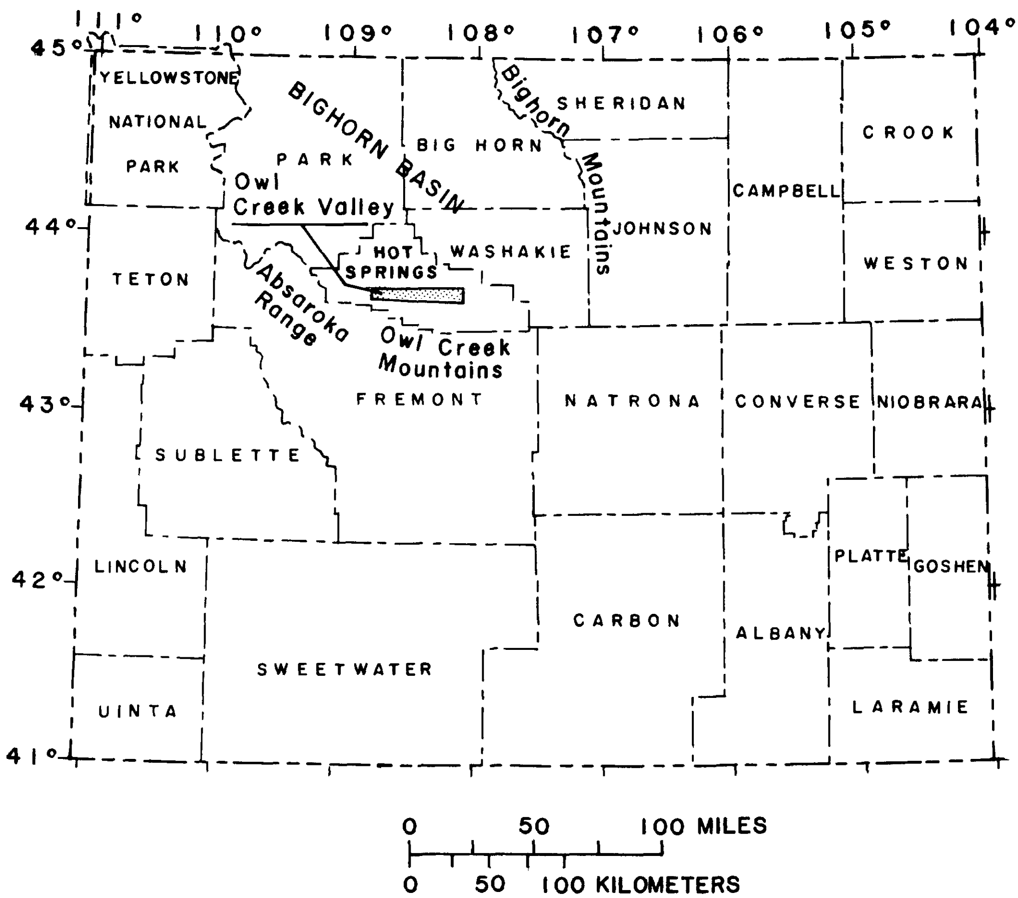

Figure 1.--Location of Owl Creek Valley.

Many thanks are given to the ranchers of the area who contributed information concerning their well-water supplies, diversion of surface water, and springs of the area. The authors gratefully acknowledge the help given by K. L. Pierce, U.S. Geological Survey, concerning correlations of terraces presented in this report. Water-well information was obtained from the files of the Wyoming State Engineer, Cheyenne, Wyo.

Location-Numbering System

The location of a well or spring is designated by a numbering system based on the Federal system of land subdivision. The first number denotes the township, the second denotes the range, and the third number denotes the section. The section is divided into quarters (160 acres) and lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Similarly, each quarter may be further divided into quarters (40 acres) and again into 10-acre tracts and lettered as before. The first letter following the section number denotes the quarter section; the second letter, if shown, denotes the quarter-quarter section; and the third letter denotes the quarter-quarter-quarter section, or 10-acre tract. For example, the location 44-97-25cdc is in the SW¼ of the SE¼ of the SW¼ of sec. 29, T. 44 N., R. 97 W. (fig. 2). In tracts containing two or more wells or springs, consecutive numbers (1, 2, 3) are placed at the end of the location number (for example, 43-96-17bb2).

In part of the area south of Owl Creek and South Fork Owl Creek, the land survey is based on a local baseline and the Wind River Meridian. There the township is denoted as north of the baseline and the range is denoted as east or west of the meridian (for example, 8N-2E-5bcc).

As a means of identification, the U.S. Geological Survey assigns an eight-digit station number (such as 06270000) to most sites where surface-water data are collected. Where assigned, station numbers are used in this report. The station numbers increase in downstream order. Stations on tributaries are assigned numbers between upstream and downstream stations on main stems. Gaps are left in the numbering system to allow for new stations that may be established. The first two digits of the station number denote the drainage basin. Station numbers beginning with "06" are in the Missouri River drainage.

STREAMFLOW, INCLUDING SOME CHEMICAL EFFECTS OF INFLOW

Owl Creek occupies an intermediate area between the low (altitudes less than 4,300 feet), dry, central Bighorn basin and the high (altitudes greater than 8,000 feet), humid, Absaroka Range and Owl Creek Mountains flanking the basin. The channels of South Fork Owl Creek and of Owl Creek (mainstem) decrease in altitude from 6,440 feet at Anchor Reservoir to 4,270 feet at the mouth of Owl Creek. The annual precipitation at Thermopolis (altitude 4,330 feet) averages about 13 inches, of which most occurs during the summer months. However, during some summers, runoff from precipitation and base flow is insufficient to maintain the volume of streamflow that is needed to be diverted from the creek for irrigation.

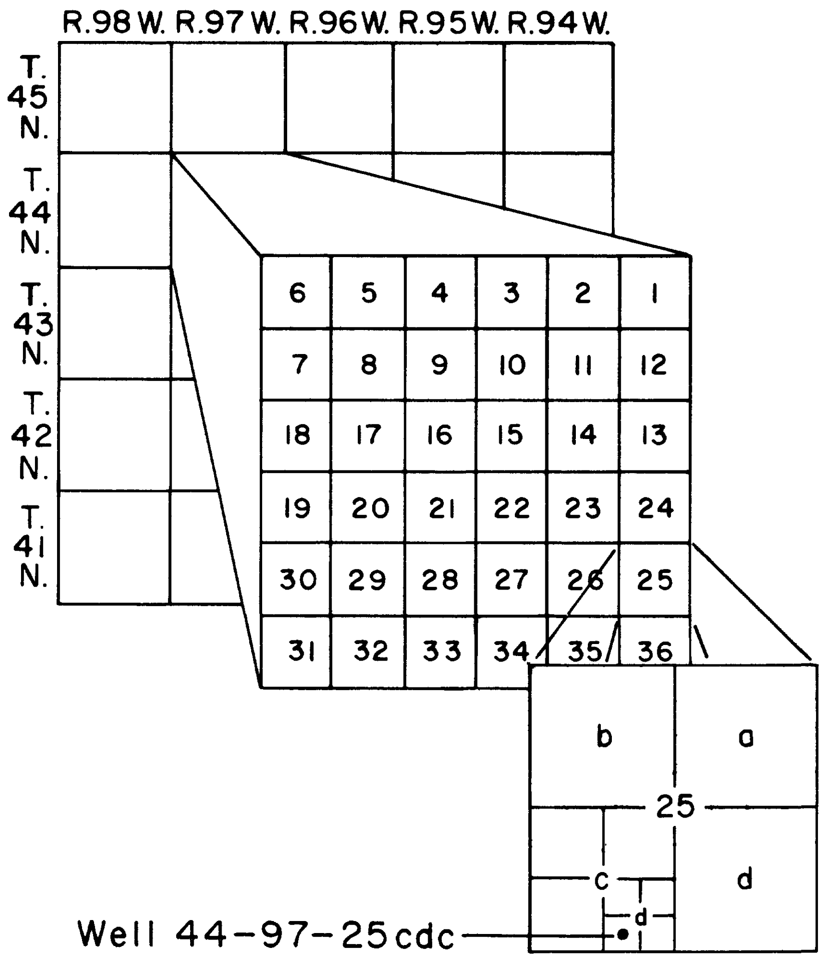

Figure 2.--Location-numbering system.

About 14,000 acres are being irrigated at the present time (1976), mainly in the area downstream from the confluence of North and South Forks.

Streamflow records of North and South Forks near Anchor Reservoir (pl. 2) indicate that August and September have the smallest flows (table 1). Generally, the flows during September are less than those for August. In some years there is no flow in the North Fork during September, and flows of the South Fork may be less than 500 acre-ft. Since 1961, the annual flow of South Fork upstream of Anchor Reservoir has been between 12,180 and 44,870 acre-ft. Streamflow records of North Fork show annual flows between 3,320 and 17,640 acre-ft.

Anchor Reservoir, the only large storage structure along Owl Creek or North and South Forks, affects the flow of South Fork and the mainstem of Owl Creek. However, the reservoir is situated on the steeply dipping, densely fractured strata along Anchor anticline (pl. 2) and stores water only temporarily; the water in the reservoir leaks downward (principally along the fractures) and apparently recharges aquifers in the Paleozoic rocks. The rate of downward leakage is rapid, allowing for little evaporation of the water that is stored temporarily. For example, the loss of flow by Anchor Reservoir during the 1975 water year was 20,180 acre-ft; 31,130 acre-ft of water flowed into the reservoir, but the outflow, measured 1.6 miles downstream from the reservoir, was only 10,950 acre-ft (table 1). The loss of flow caused by Anchor Reservoir is replaced by diversion from the Bighorn River at the Lucerne Pumping Station (pl. 2). The water enters Owl Creek at a point about 4 miles upstream from its mouth.

To determine some chemical aspects of the flow of Owl Creek, field measurements of specific conductance were made and the water from the stream at selected locations was analyzed chemically (pl. 2; tables 2-4). Specific conductance, which is a measure of the ability of water to conduct an electrical current, is related to the concentration of dissolved solids. The specific-conductance measurements show a progressive downstream increase in the concentration of dissolved solids. The specific conductance of North and South Forks near Anchor Reservoir was less than 150 μmho in May during early spring runoff and about 300 μmho in September during low flow and maximum diversion for irrigation. At the crossing of Owl Creek by State Highway 120, the specific conductance was 1,600 μmho in May and 3,380 μmho in September. The increases in the specific conductance are due mainly to return flows of irrigation water that had been diverted from the creek, but in some reaches inflow from tributaries and from water in the nearby alluvial deposits significantly affect the chemical quality of Owl Creek. Part of the inflow to the creek is percolation of some of the irrigation water into the alluvial deposits and then into the creek.

Anomalously slow or rapid rates of increase of the specific conductance with distance were found in some reaches along South Fork and the mainstem of Owl Creek downstream of Anchor Reservoir. Only slight increases in the specific conductance through the year were noted for South Fork through Anchor Reservoir (table 4). Slow rates of increase in the specific conductance were noted near the confluence of Red Creek and

Table 1.--Streamflow records of Owl Creek
[Selected monthly and annual discharge, in acre-feet]

Water year	May	June	July	Aug.	Sept.	Total, water year
06260000, South Fork Owl Creek near Anchor, Wyo.						
1961	3,550	8,030	1,580	790	1,550	17,630
1962	3,640	9,670	3,950	1,800	743	26,290
1963	6,090	15,050	4,730	1,280	1,370	31,770
1964	2,980	9,000	5,620	1,090	484	22,580
1965	2,720	18,170	11,730	3,560	1,330	40,840
1966	3,560	2,690	1,510	582	1,340	12,180
1967	5,250	21,890	11,330	2,050	1,250	44,870
1968	1,520	8,120	2,460	1,730	1,070	17,840
1969	4,850	4,630	2,680	676	421	16,390
1970	5,190	9,750	3,390	812	690	21,180
1971	4,770	11,290	4,560	1,700	1,040	25,310
1972	4,900	12,450	4,260	1,960	984	29,250
1973	8,730	7,510	2,690	1,810	2,130	24,700
1974	6,630	11,880	3,990	1,570	593	28,520
1975	3,000	10,150	12,450	2,090	966	31,130
1976	6,500	9,360	4,950	2,700	910	28,020
06262300, North Fork Owl Creek above Basin Ranch, near Anchor, Wyo.						
1962	1,630	4,220	1,220	427	184	------
1963	6,170	8,290	1,300	328	286	17,640
1964	3,010	5,350	1,130	53	0	11,430
1965	2,110	4,620	1,320	421	33	10,140
1966	2,080	207	25	18	319	3,320
1967	2,470	7,590	2,620	649	503	14,300
1968	1,070	6,850	917	1,180	505	12,370
1969	839	2,180	820	194	105	5,750
1970	3,480	2,020	565	206	252	7,340
1971	3,180	2,430	358	257	245	7,650
1972	2,630	2,450	204	128	2.6	8,180
1973	-----	-----	-----	---	---	-----
1974	2,640	1,700	361	199	121	-----
1975	2,200	6,220	3,480	119	17	-----

Table 1.--Streamflow records of Owl Creek--Continued

Water year	May	June	July	Aug.	Sept.	Total, water year
06260400, South Fork Owl Creek below Anchor Reservoir, Wyo.						
1961	3,220	5,120	1,200	615	1,150	12,000
1962	3,510	8,900	4,500	1,570	737	20,880
1963	4,720	5,010	3,790	1,380	1,410	17,280
1964	3,560	4,860	4,870	753	239	16,180
1965	2,800	7,730	4,890	3,210	1,240	21,770
1966	2,790	2,350	1,140	257	802	9,130
1967	5,030	2,930	1,410	2,320	1,030	13,430
1968	1,580	6,040	2,730	1,420	968	14,600
1969	3,750	3,850	2,450	627	316	12,530
1970	4,240	6,200	4,040	588	465	16,280
1971	2,700	7,460	5,490	1,210	573	17,990
1972	2,150	8,950	4.810	1,440	743	19,880
1973	1,150	7,160	2,050	1,170	1,040	13,180
1974	5,540	8,000	5,340	1,280	464	21,990
1975	1,100	3,350	1,700	3,710	626	10,950
1976	5,110	8,450	4,740	1,810	681	21,840

Table 2.--Chemical analyses of surface water

(Chemical analyses listed before 1960 are from Berry and Littleton, 1961, tables 3 and 4.)
[Analytical results in milligrams per liter except as indicated]

Location (pl. 2)	Date of collection	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption (ratio)	Specific conductance (μmho)	pH
NORTH FORK OWL CREEK																		
Near gaging station North Fork Owl Creek above Basin Ranch near Anchor, Wyoming.	9- 2-47	36	21	6.8	[1]28		128	--	33	0.4	0.4	0.5	190	80	0	--	283	7.5
At station 1, sec. 12 T. 43 N., R. 100 W.	9-14-76	23	18	4.7	43	1.4	120	15	31	1.4	.4	.2	195	66	--	2.3	309	9.0
At confluence with South Fork, sec. 2, T. 43 N., R. 98 W.	9- 2-47	33	158	70	[1]190		392	--	723	.13	.7	.6	1,380	682	361	--	1,790	7.6
SOUTH FORK OWL CREEK																		
Near gaging station South Fork Owl Creek near Anchor, Wyoming.	7- 1-47	17	11	6.1	[1]3.4		57	--	10	1.6	.1	.5	79	53	6	--	116	8.3
----------Do------------	9- 2-47	19	12	5.4	10	2.0	77	--	8.7	1.5	.7	.5	108	52	0	.6	148	7.0
At or near station 6, sec. 2, T. 43 N., R. 98 W.	9- 2-47	17	92	44	[1]51		254	--	293	5.0	.2	.4	642	410	--	--	904	7.8
----------Do------------	9-14-76	17	61	19	27	1.9	180	0	140	2.3	.3	.4	357	230	--	.8	547	8.3
OWL CREEK (MAIN STEM)																		
At station 12, sec. 21 T. 43 N., R. 95 W.	11- 4-76	20	170	91	250	4.2	320	0	1,050	14	.8	.4	1,770	810	--	3.8	2,240	7.8
At station 15, sec. 15, T. 43 N., R. 95 W.	11- 4-76	18	180	91	250	4.4	340	0	1,090	13	.8	.5	1,810	830	--	3.7	2,300	7.8
At station 17, sec. 14, T. 43 N., R. 95 W.	11- 4-76	17	160	92	320	4.6	340	0	1,120	14	.8	.3	1,890	780	--	5.0	2,340	7.8
At station 20, sec. 5, T. 43 N., R. 94 W.	7- 2-47	18	102	38	102	6.8	--	--	432	13	.3	2.0	811	411	241	2.2	1,170	8.5
----------Do------------	9- 2-47	26	370	186	[1]610		359	--	2,530	59	.8	.7	3,960	1,690	1,400	--	4,240	7.8
----------Do------------	9-14-76	20	170	75	270	6.0	360	0	960	22	1.0	2.5	1,700	730	--	4.3	2,190	8.2

[1] Sodium plus potassium, reported as sodium.

Table 3.--Specific conductance of streamflow

[Visual condition of flow: M, muddy; SM, slightly muddy; C, clear]

Station number (pl. 2)	Field specific conductance (µmho)			Drainage and remarks
	5-20-76	9-14-76	11-4-76	
1	[1] 150M	305C	348C	North Fork Owl Creek, sec. 7, T. 43 N., R. 99 W.; only relatively limited irrigation occurs upstream of this station.
2	120M	302SM	320SM	South Fork Owl Creek, sec. 10, T. 43 N., R. 99 W.; upstream of main area irrigated along South Fork; some diversion of water from North Fork enters South Fork about 4.6 mi upstream of this station.
3	210M	456SM	---	South Fork Owl Creek at Embar Ranch, sec. 7, T. 43 N., R. 99 W.
4	---	354C	---	Red Creek, sec. 4, T. 8 N., R. 2 E.
5	330M	519C	---	South Fork Owl Creek, sec. 3, T. 43 N., R. 98 W.; small increase in specific conductance between stations 3 and 5 (distance 3.8 mi) indicated particularly by September measurements due to inflow of water having greater specific conductance from Red Creek and alluvial-fan deposits.
6	---	547C	---	South Fork Owl Creek, sec. 2, T. 43 N., R. 98 W.
7	340M	592C	---	Owl Creek at Arapahoe Ranch, sec. 29, T. 43 N., R. 97 W.; small increase in specific conductance between stations 5 and 7 (distance 3.5 mi) and stations 6 and 7 (distance 3 mi) probably due to flow from North Fork,[1] even though considerable irrigation takes place between stations 5 and 7.
8	650SM	1,080C	---	Owl Creek at Middleton School, sec. 14, T. 43 N., R. 97 W.; large increase in specific conductance between stations 7 and 8 (distance 4 mi) due to irrigation return flow; considerable flow is diverted to Thompson Reservoirs.

Table 3.--Specific conductance of streamflow--Continued

Station number (pl. 2)	Field specific conductance (μmho)			Drainage and remarks
	5-20-76	9-14-76	11-4-76	
9	780SM	1,780C	1,325C	Owl Creek, sec. 16, T. 43 N., R. 96 W.; large increase in specific conductance between stations 8 and 9 (distance 4 mi) due to irrigation return flow and to discharge of mineralized water from adjacent alluvial deposits.
10	1,950SM	2,600C	2,200C	Mud Creek, sec. 23, T. 43 N., R. 96 W.
11	1,600SM	3,380C	2,192C	Owl Creek at State Highway 120, sec. 19, T. 43 N., R. 95 W.[2]
12	---	---	2,194C	Owl Creek, sec. 21, T. 43 N., R. 95 W.; minimal increase in specific conductance between stations 11 and 12 (distance 1.8 mi) probably due to absence of surface inflow and to minor irrigation return flow.
13	---	---	2,235C	Owl Creek, sec. 15, T. 43 N., R. 95 W.
14	---	---	2,246C	Owl Creek, sec. 15, T. 43 N., R. 95 W.; ranchers reported springs can be seen in channel during low-flow periods.
15	---	---	2,289C	Owl Creek, sec. 15, T. 43 N., R. 95 W.; slight increase in specific conductance between stations 14 and 15 (distance 0.3 mi) probably due to ground-water inflow from springs, including "hot" springs, reported by ranchers to be present in channel.
16	---	---	2,321C	Owl Creek, sec. 15, T. 43 N., R. 95 W.
17	---	---	2,329C	Owl Creek, sec. 14, T. 43 N., R. 95 W.; upstream from diversion ditch from Lucerne Pumping Station (Bighorn River).
18	---	---	---	Owl Creek, sec. 11, T. 43 N., R. 95 W.; downstream from diversion ditch from Lucerne Pumping Station.

Table 3.--Specific conductance of streamflow--Continued

Station number (pl. 2)	Field specific conductance (µmho) 5-20-76	9-14-76	11-4-76	Drainage and remarks
19	2,450SM	1,910C	2,300C	Owl Creek at U.S. Highway 20, sec. 8, T. 43 N., R. 94 W.; small flow on 5-20-76; most of flow is diverted for irrigation upstream from this station; much of flow on 9-14-76 was derived from diversion from Bighorn River.
20	---	2,190C	2,375C	Owl Creek near mouth, sec. 5, T. 43 N., R. 94 W.; increase in specific conductance between stations 19 and 20 (distance 1.1 mi) in September mainly due to inflow from irrigation return flow.
			11- 8-76	Precipitation did not occur from November 4 to 8.
18			2,299C	
19			2,341C	
20			2,426C	

[1] North Fork may also adversely affect Owl Creek. Chemical analyses of water collected September 2, 1947, from both forks near their confluence show that the dissolved-solids concentration of North Fork, presumably sampled at low-flow stage, was about double the dissolved-solids concentration of South Fork (table 2).

[2] Very large increase in specific conductance between stations 9 and 11 (distance 4.5 mi) is the largest for any reach of Owl Creek. This increase principally is from a combination of inflow of mineralized water from Alkali Draw and at times from Mud Creek, irrigation return flow, and discharge of water from nearby alluvial deposits. In Alkali Draw drainage area, Thompson Reservoirs store water diverted from Owl Creek between stations 7 and 8. Ranchers report that, since the filling of the reservoirs and their associated ditch distribution system, irrigation and ditch-water losses have caused an accelerated accumulation of salts (alkali encrustations) in fields and pastures. Most of the salts were incorporated originally with the surficial deposits of area, and present accumulations represent redistribution of the salts. Salt accumulation adversely affects chemical quality of ground water. Water analyzed chemically from wells 43-96-7dbc and 43-96-18abb contains more than 2,200 mg/L of dissolved solids.

Table 4.--Specific conductance of South Fork Owl Creek at gaging stations near Anchor reservoir, 1974-76.

Date	Field specific conductance (μmho)		Remarks
	06260000, South Fork Owl Creek near Anchor (upstream from Anchor Reservoir)	06260400, South Fork Owl Creek below Anchor Reservoir	
1974			
Sept. 17	150	155	Distance between gaging stations is 3.2 miles; effects of Anchor Reservoir, including operations for trying to seal the reservoir floor to prevent downward leakage of water, are not noticeable on the specific conductance.
Oct. 12	142	145	
Nov. 9	150	---	
Dec. 14	187	---	
1975			
Jan. 11	190	---	
Feb. 14	180	---	
Mar. 12	170	---	
May 14	110	140	
June 4	88	105	
July 7	80	82	
Aug. 4	80	80	
Sept. 13	125	155	
Nov. 15	160	200	
Dec. 23	160	260	
1976			
Feb. 11	170	170	
May 8	115	136	
June 3	67	80	
July 8	66	68	
Aug. 10	110	120	
Oct. 12	140	150	

South Fork, near the confluence of North and South Fork, and near the axis of the Thermopolis anticline (table 3). Rapid rates of increase occur between stations 9 and 11 west of the steep southwest limb of the Thermopolis anticline, between stations 14 and 15 along the gentle northeast limb, and near the mouth of Owl Creek. Downstream from station 17, differences in the specific conductance are related to the volume of flow diverted to the creek from the Bighorn River by the Lucerne Pumping Station.

SYNOPTIC HYDROGEOLOGIC DESCRIPTION OF THE SEDIMENTARY ROCKS

Owl Creek Valley is underlain by sedimentary rocks ranging from the Tensleep Sandstone (Permian and Pennsylvanian age) to the Willwood Formation (Eocene age). However, thick shale and thin sandstone strata of Cretaceous age are exposed in most of the valley, particularly between the Thermopolis and Embar anticlines (pl. 1). The Frontier Formation is the main water-yielding unit of Cretaceous age that crops out near Owl Creek. Water in the sedimentary rocks generally is under artesian conditions, but only a few wells flow at the land surface. These rocks yield small quantities of water to wells (Berry and Littleton, 1961, table 2); maximum yields are reported to be less than 60 gal/min (table 5).

In general, minimal well yields and chemical quality limit the development of water from the Triassic to Cretaceous sedimentary rocks; minor development is mainly for the watering of stock. Water analyzed chemically from these rocks contains between about 1,000 and 4,600 mg/L (milligrams per liter) of dissolved solids (table 6); the concentration of dissolved solids in the flow of the hot springs near Thermopolis is about 2,200 mg/L. Water in the sedimentary rocks is slightly less mineralized than water in the overlying alluvial deposits in much of the area downstream from the Middleton School. At places in that area, wells completed in the sedimentary rocks are used for domestic purposes.

Localities where the Frontier Formation occurs at shallow depths beneath the alluvial deposits are along the concealed anticline near the mouth of Owl Creek, in a long, broad area that borders a dip slope eroded on the Frontier Formation along the south side of the valley from State Highway 120 to south of the Arapahoe Ranch, and in an area mainly along the South Fork near the Owl Creek anticline (pl. 2). Wells completed in both the alluvial deposits and the Frontier Formation may yield a greater quantity of water than wells completed solely in either unit.

The sedimentary rocks have been folded into a series of well-defined anticlines, broad synclinal areas, and a few monoclines. Most of the anticlines are asymmetric: dips are nearly vertical along the steep southwest limb of Thermopolis anticline and are as much as 60 degrees along the north limb of Embar anticline, 35 degrees along the southwest limb of Anchor anticline, and 25 degrees along the northeast limb of Owl Creek anticline. The steep southwestern limb of the Thermopolis anticline comprises a conspicuous monocline, which in places is accentuated by faults. Another monocline extends from Dry Cottonwood Creek on the northeast side of the Embar anticline northwestward and westward to near Basin Ranch (pl. 1). Dips along this monocline range from 30 to about 60 degrees.

Table 5.--Yields, depths, and other hydrologic information of selected wells

[Data from files of the Wyoming State Engineer, Cheyenne, and from Berry and Littleton, 1961, table 2]

Well number	Depth (feet)	Yield (gallons per minute)	Drawdown (feet)	Specific capacity [(gal/min)/ft] of drawdown)	Geologic unit and remarks
8N-2E-8dd	35	20R	-	-	Alluvial-fan deposits (flood-plain alluvium along Dry Cottonwood Creek); 1-hour test.
8N-4E-10dcc	58	300R	-	-	Flood-plain alluvium; 1-hour test.
8N-4E-11ccc	85	26R	3R	-	Frontier Formation; ½-hour test; drawdown almost equaled the distance between the static water level and well depth.
11ccd1	29	60R	-	-	Alluvial-fan deposits; ½-hour test.
11ccd2	86	60R	-	-	Frontier Formation; ½-hour test.
14bbb	29	60R	-	-	Alluvial-fan deposits; 1-hour test.
43-94-4cbb	25	25R	12R	2.1	Flood-plain alluvium; 24-hour test.
5bb	45	20R	22E	-	Pediment deposits; 1-hour test.
5daa	140	46R	6R	7.7	Frontier Formation; 24-hour test, well flows at land surface.
5dac	25	25R	[1] 6	4.2	Flood-plain alluvium; 24-hour test.
5dca	20	25R	[1] 3	8.3	Flood-plain alluvium; 24-hour test.

Table 5.--Yields, depths, and other hydrologic information of selected wells--Continued

Well number	Depth (feet)	Yield (gallons per minute)	Drawdown (feet)	Specific capacity [(gal/min)/ft] of draw-down)	Geologic unit and remarks
43-95-18dd	45	8	[1] 11	0.7	Chugwater Formation; 1-hour test.
25ab	1,200E	25R	10R	2.5	Tensleep (?) Sandstone; flows at land surface; 3-hour test.
43-96- 8cc	30	20R	0	-	Arapahoe Ranch terrace deposits; 1-hour test.
17bb1	42	332	2.8(?)	-	Arapahoe Ranch terrace deposits.
24abb	110	23R	[1] 77	.3	Frontier Formation; 1-hour test.
43-97-12db	34	400R	3R	133	Arapahoe Ranch terrace; deposits 6-hour test.
44-94-32bb1	32	20R	[1] 8	2.5	Pediment deposits; 1-hour test.
32bb2	28	30R	0	-	Pediment deposits; 1/6-hour test.
32bdb	43	20R	10R	2.0	Pediment deposits; 1-hour test.
44-95-32dac	300	15R	100R	0.2	Frontier (?) Formation; 1-hour test.

E Estimated.

R Reported.

[1] Some confusion exists as to the drawdown reported at the completion of a well. The depth to the static level plus the reported drawdown is greater than the depth of the well. The drawdown is assumed to indicate that the depth of the bailing or pumping level is below the land surface. Therefore, the difference between the depths to the static level and the assumed bailing or pumping level is the value reported in this column.

Table 6.--Chemical analyses of ground water in the sedimentary rocks in the Owl Creek Valley

[Analytical results in milligrams per liter except as indicated;
Kmv, Mesaverde Formation; Kc, Cody Shale; Kf, Frontier Formation; Jm, Morrison Formation; TRc, Chugwater Formation.
Analyses by Wyoming State Laboratories, Wyoming Department of Agriculture, and U.S. Geological Survey]

Location	Depth of well (feet)	Water yielding unit	Date of collection	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption (ratio)	Specific conductance (µmho)	pH	Remarks
GROUND WATER FROM WELLS																					
Sedimentary-Rocks																					
43-99-10db	400	TRc	7-22-46	--	38	15	[1]913		232	--	1,830	26	1.3	2.7	3,040	157	0	--	3,950	8.0	--
8N-4E-7caa	440	Kf	7-22-46	--	10	8.1	[1]1,510		516	33	2,700	52	2.8	10	4,600	58	0	--	5,660	8.4	--
8N-4E-16aba	50	Kf,Qa	7-23-46	--	114	41	[1]445		332	--	1,060	30	.8	1.6	1,930	453	181	--	2,440	8.0	--
8N-3E-1cda	80	Kc	9-17-76	5.7	59	23	240	3.0	222	0	550	15	.6	3.7	1,010	240	--	6.7	1,430	8.0	--
43-95-12bcc	53	Kc	7-22-46	--	23	10	[1]674		403	--	1,120	46	.6	1.6	2,120	98	0	--	2,960	7.8	--
43-94-7bcb	36?	Kc,Qf	9-14-76	9.8	140	92	560	4.0	410	0	1,500	110	1.2	7.4	2,590	740	--	9.0	3,260	8.0	--
43-97-5bcb	--	Kc,Qf	9-14-76	49	130	78	480	5.3	730	0	920	91	1.2	1.5	2,110	640	--	8.3	2,900	8.1	--
43-97-11ccc	68	Kc,Qf	9-14-76	6.2	4.7	2.0	540	1.9	930	6	310	53	1.4	3.4	1,380	20	--	53	2,110	8.4	--
44-97-25cdc	--	Kmv	6-23-70	9.8	245	193	67	9.6	807	0	840	11	.4	1.3	1,770	1,400	--	.8	2,330	7.9	--
GROUND WATER FROM SPRINGS																					
Hot Springs near Thermopolis																					
43-94-31bbb		---	6-12-33	71	382	75	266	49	740	0	777	334	3.8	.1	---	1,262	--	3.2	--	--	Black Sulfur Spring.
31bbb		---	7-28-55	43	355	81	270	50	742	0	760	338	2.8	0	2,270	1,220	--	3.3	3,210	7.0	--
43-94-31bcb		---	6-12-33	82	385	76	262	49	766	0	769	328	3.7	.1	---	1,273	--	3.2	--	--	Bighorn Spring.
31bcb		---	7-28-55	41	298	116	263	49	759	0	745	320	2.6	0	2,210	1,220	--	3.3	3,160	7.0	Do
31bcb		---	2-24-71	40	360	86	250	51	708	0	774	294	5.5	0	2,200	1,250	--	3.1	2,860	--	Do
43-95-14bca		Jm	11- 4-76	11	3.1	1.5	750	2.6	1,800	0	50	110	.9	.1	1,800	14	--	89	2,880	8.1	

[1] Sodium plus potassium, reported as sodium.

The tilted sedimentary rocks along the anticlines and monoclines are fractured extensively and therefore transmit water readily, as indicated by the position of the hot springs along the Thermopolis anticline (pl. 2). Relatively larger quantities of water should be obtained from wells drilled in the more extensively fractured tilted rocks than in strata that are inclined at only a few degrees and contain fewer fractures. A few wells are known to withdraw water from fractured shaly rocks (Berry and Littleton, 1961, table 6) including the Chugwater Formation (Triassic) and the Cody, Mowry, and Thermopolis Shales (all Cretaceous) along these folds. The steeply tilted strata along the Thermopolis anticline and the monocline that extends generally eastward from near the Basin Ranch are relatively favorable areas for transmitting ground water and for the development of wells (pl. 2). In these areas slightly larger yields of water may be obtained from wells completed in both the alluvial deposits and the sedimentary rocks than in wells completed only in one or the other.

SPRINGS NEAR THE THERMOPOLIS ANTICLINE

The Thermopolis anticline forms an important control on the discharge of ground water in the sedimentary rocks. This control is evidenced principally by the occurrence of the hot springs at Thermopolis near the anticline. Multiple levels --at 60, 100-160, 450-500, and 700-800 feet above river level--of travertine along the Bighorn River (pl. 1) attest to the present and past activity of these springs. Another spring (43-95-14bca) near the Thermopolis anticline and about 20 feet above Owl Creek discharges a small volume of water from the Morrison Formation. White alkali from previous activity of this spring is incorporated in the colluvial and alluvial-fan deposits as much as 60 feet above Owl Creek near the spring and is sufficiently extensive to be seen easily from the air. The water of this spring is soft, which is in contrast to the very hard water from other springs and most wells near Owl Creek (table 6). In addition, ranchers report (Lewis Freudenthal, oral commun., 1976) that springs, including some they refer to as "hot" springs, are visible at low-flow stage in the channel of Owl Creek, near station 14, about 2 miles downstream from the axis of the Thermopolis anticline (pl. 2).

A brief analysis of the fracture and fold pattern in the area near the Thermopolis anticline was made to determine the structure and its possible relation to the discharge of ground water from the sedimentary rocks (fig. 3). The fractures were plotted on aerial photographs at an approximate scale of 1:48,000. The analysis revealed that a concentration of the fractures coincided with the location of the hot springs at Thermopolis and 2 miles north of Thermopolis. The springs at Thermopolis are clustered near the crest of the Thermopolis anticline and near a bend along steeply tilted strata on the southwest limb of the anticline, whereas the springs 2 miles north of Thermopolis are on the gently dipping northeast limb of the anticline. A concentration of the fractures also occurs along Owl Creek near station 14 (pl. 2) where springs are reported by ranchers in the creek channel. Another area along Owl Creek having a concentration of fractures is near State Highway 120. This area is along the zone of steeply tilted and fractured strata on the southwest limb of the Thermopolis anticline. However, the widespread alluvial deposits in this area conceal indications of any discharge of water that may be from the sedimentary rocks.

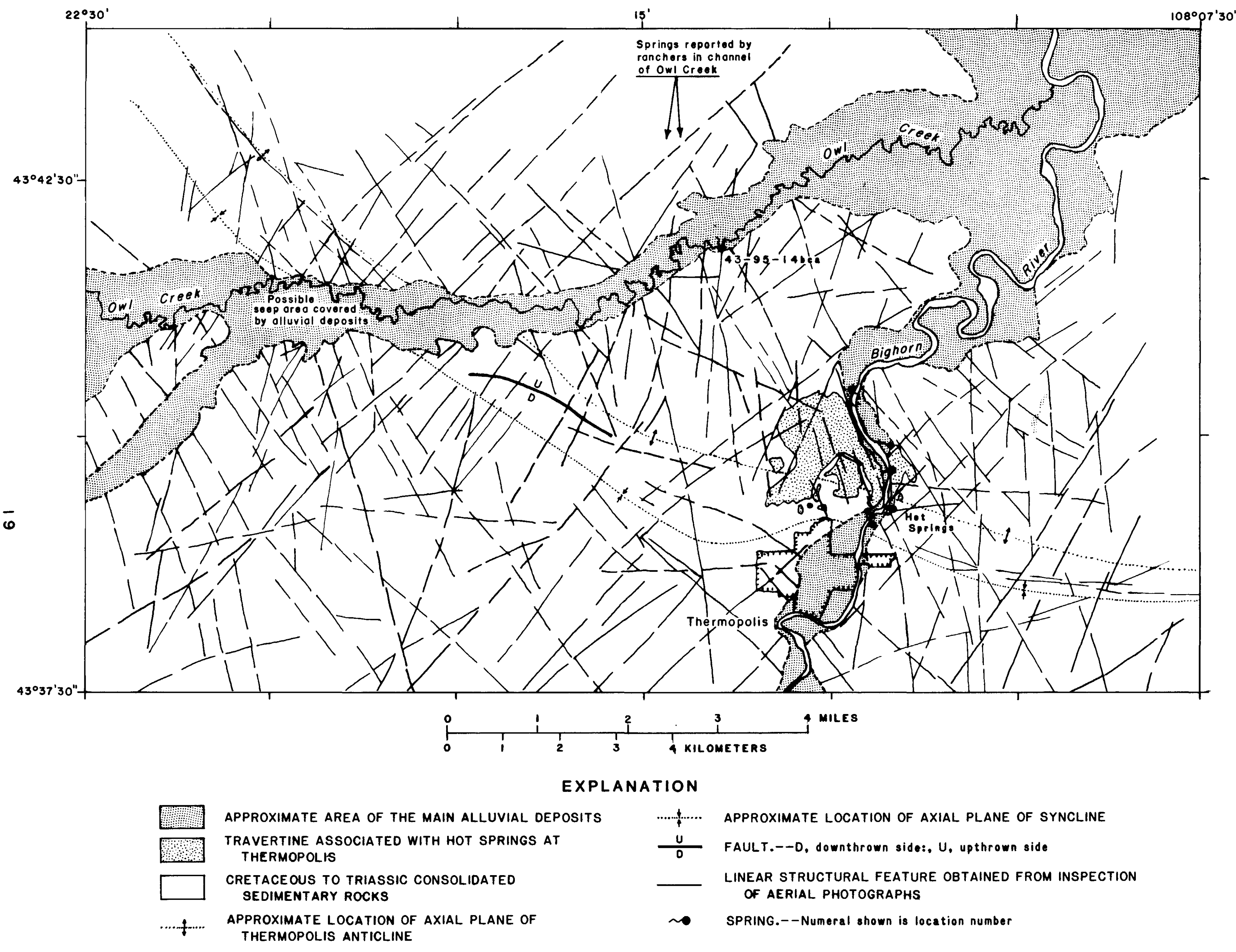

Figure 3.--Relationship of the hot springs near Thermopolis and other springs, or possible spring areas, to the Thermopolis anticline and linear structural features.

An attempt was made by the use of field specific-conductance measurements and selected chemical analyses of water to obtain information about the ground-water discharge from the sedimentary rocks to Owl Creek near the Thermopolis anticline (tables 2 and 3). The chemical analyses at stations 12, 15, and 17 (pl. 2) and specific conductances at stations 11-16 show only slight differences in the chemistry of Owl Creek. Apparently at the time of sampling, irrigation return flow and discharge of water from the alluvial deposits mask any effects that water discharge from the sedimentary rocks may have on the flow of Owl Creek.

DESCRIPTION OF THE SURFICIAL DEPOSITS

Only the principal surficial deposits were mapped and described during this investigation (pl. 1, table 7). For convenience of mapping, the deposits were grouped as terrace deposits (Qt1A to Qt4), the Arapahoe Ranch terrace deposits (Qta), and the Embar Ranch terrace deposits (Qte); the older (Qfo) and younger (Qfy) flood-plain alluvium; the younger (virtually undissected) alluvial-fan deposits (Qay); the older (dissected) alluvial-fan deposits (Qao); and the pediment deposits (Qp). The flood-plain alluvium, the alluvial-fan deposits, and part of the Arapahoe Ranch terrace deposits comprise the alluvial aquifer. (See Alluvial Aquifer.) Principal exposures of the alluvial and terrace deposits are in the broad part (as much as 5 miles wide) of Owl Creek Valley between the Thermopolis and Embar anticlines, and downstream from the Thermopolis anticline.

The distribution of the alluvial deposits along the Bighorn River and Kirby Creek is shown on plate 1, but it is not discussed in this report.

Terrace Deposits

Terrace deposits occur at heights ranging from about 20 to 500 feet above Owl Creek. Only the Embar Ranch and Arapahoe Ranch terrace deposits are widely distributed in Owl Creek Valley. Remnants of the other terrace deposits occur only at scattered localities (pl. 1) and are not discussed in this report.

Embar Ranch Terrace Deposits

The most conspicuous terrace along Owl Creek is the one herein named the Embar Ranch terrace for the well-preserved remnant between the North and South Forks, north of the Embar Ranch. The terrace was mapped as terrace no. 2 by Andrews and others (1947). At Embar Ranch the terrace is about 160 feet above the North and South Forks. Near Arapahoe Ranch its height is about 120 feet, but where the terrace is crossed by State Highway 120, 2.5 miles north of Owl Creek, it is 150 to 160 feet above the creek.

Table 7.--Geohydrologic description of surficial deposits

Geologic unit	Description and thickness	Hydrology
Younger flood-plain alluvium (Qfy)	Deposits similar to the older flood-plain alluvium. Thickness mainly about 20 to 40 feet.	In combination with older flood-plain alluvium, unit is most widespread unit of the alluvial aquifer.
Older flood-plain alluvium (Qfo)	Principally clay to sand with relatively small quantity of gravel downstream of junction of North and South Forks; consists mainly of pebbles to cobbles upstream along both forks from the junction. Thickness mainly about 20 to 40 feet.	In combination with younger flood-plain alluvium, unit is most widespread unit of the alluvial aquifer.
Deposits in abandoned valley of North Fork Owl Creek (Qn)	Principally silty to sandy sediments. Thickness unknown.	Hydrologic characteristics unknown.
Alluvial-fan deposits (Qay, Qao)	Principally clay to sand. Thickness as much as 40 feet.	Minor unit of the alluvial aquifer.
Pediment deposits (Qp)	Principally clay to sand; pebbles and cobbles locally present. Generally 10 to 15 feet thick.	Generally does not yield water except near Lucerne.
Arapahoe Ranch terrace deposits (Qta)	Consists mainly of deposits similar to the Embar Ranch terrace deposits. Thickness is less than 15 feet except where buried channels are present.	Part of alluvial aquifer. Remnant in secs. 7 to 9, and 15 to 18, T. 43 N., R. 96 W. has greatest well yields reported in the area. Yields some water to wells south of Owl Creek mainly in secs. 5 and 6, T. 43 N., R. 94 W.
Embar Ranch terrace deposits (Qte)	Consists of dense siliceous pebbles and small cobbles overlain by more than 2 feet of silty to sandy sediments. Thickness is about 15 feet.	Remnants of the terraces are too small to store sufficient ground water for development of wells. Long remnant of the terrace north of Embar Ranch would be recharged from irrigation if this remnant were farmed.
Terrace Qt3, Qt2A, Qt2, and Qt1A deposits	Principally rounded pebbles and cobbles. Terrace Qt3 deposits present only on divide between North and South Forks northwest of Anchor Reservoir. Remnants of terrace Qt2A deposits present along South Fork near Embar anticline. Remnants of terrace Qt2 and Qt1A are near the Bighorn River. Thickness generally less than 20 feet.	Do.
Terrace Qt4 deposits	Consists mainly of gravel to gravelly sand and silt. Remnants outline a broad northward- to northeastward-sloping pediment to the northwest of Anchor Reservoir. Thickness generally less than 20 feet.	Remnants of the terraces are too small to store sufficient ground water for development of wells.

At the level of the Embar Ranch terrace, the valley floor of Owl Creek between the Owl Creek and Thermopolis anticlines probably was a mile or more north of the present flood plain. Owl Creek apparently crossed the Thermopolis anticline about 3 miles north of its present valley. Partial confirmation of this old stream course of Owl Creek is from generally eastward dipping cross strata (indicating east-flowing currents) exposed in a small gravel pit excavated into a deposit of this terrace in sec. 3, T. 43 N., R. 96 W. on the divide between Coal Draw and Owl Creek.

The terrace deposits generally consist of rounded to subrounded, dense, siliceous pebbles and small cobbles composed chiefly of basalt and dark andesite with subordinate chert, limestone, and sandstone. Locally, the coarse-grained material is overlain by more than 2 feet of silty to sandy sediments, which in part represent an old soil. As best determined, the thickness of the deposits where exposed along the edges of the terrace remnants is not more than 15 feet.

Except for the long remnant of the Embar Ranch terrace deposits north of Embar Ranch, the areal extent of the remnants are too small for ground-water development. In places, however, the remnant of the deposits north of Embar Ranch is more than 0.5 mile wide. If this remnant were farmed, some of the irrigation water would recharge the terrace deposits; but the water thus recharged would move laterally and discharge along the edges of the terrace remnant.

Arapahoe Ranch Terrace Deposits

Remnants of a terrace, referred to in this report as the Arapahoe Ranch terrace (terrace no. 1 of Andrews and others, 1947), are distributed in the Owl Creek drainage principally downstream from the Embar anticline. The largest remnant of the terrace is downstream from Arapahoe Ranch, the locality for which the terrace is named. In that area it forms a continuous exposure for about 8 miles along the north side of the valley. The height of the terrace decreases progressively eastward from 50 feet near Arapahoe Ranch to about 20 feet above the creekbed in secs. 16 and 17, T. 43 N., R. 96 W. and on downstream to the mouth of Owl Creek. Downstream from Arapahoe Ranch the deposits are farmed extensively. Other remnants of the Arapahoe Ranch terrace deposits are 30 to 50 feet above Owl Creek west of Arapahoe Ranch and 30 to 35 feet above the creek near the Embar anticline.

The Arapahoe Ranch terrace deposits consist principally of rounded pebbles and cobbles composed mainly of dark volcanic rocks derived from the Absaroka Mountains. In sec. 36, T. 9 N., R. 1 E., boulders composed of volcanic rocks are as much as 3 feet long. The large terrace remnant east of Arapahoe Ranch is capped by a 2- to 3-foot layer of sandy to silty sediments, including remnants of an old soil. The terrace deposits are less than 15 feet thick except in two buried channels. One channel extends east to southeastward from sec. 11, T. 43 N., R. 97 W., where logs of water wells indicate a maximum thickness of 42 feet. The thickness of the deposits are at least 36 feet in the other buried channel in secs. 7 and 8, T. 43 N., R. 94 W. near the mouth of Owl Creek.

Alluvium in Abandoned Valley of North Fork Owl Creek

West of Embar Ranch, mainly in secs. 1, 2, 10, and 11, T. 43 N., R. 99 W., alluvial deposits occupy a 0.5 mile-wide valley that extends between the North and South Fork Owl Creek (pl. 1). These deposits have been eroded to form a low terrace that is about 20 feet above both creekbeds. This terrace is lower than the older Arapahoe Ranch terrace and higher than the terraces formed from the older and the younger flood-plain alluvium. At this level, North Fork apparently joined the South Fork in this locality rather than at the present confluence 6½ miles farther downstream. Supporting evidence that this valley was occupied by North Fork is the gradient of the terrace surface itself, which slopes about 80 feet per mile. This gradient is about the same as that of North Fork and about 20 feet per mile greater than the gradient of South Fork. In a single exposure along South Fork, the deposits consist of lenticular beds of buff to reddish-brown sand to silt. The thickness and hydrologic characteristics of the deposits are not known because of the lack of information about wells that penetrate the deposits.

Flood-Plain Alluvium

Along Owl Creek the flood-plain alluvium, the principal deposits comprising the alluvial aquifer, consists of two main units--the older and the younger flood-plain alluvium. The older flood-plain alluvium forms a terrace 13 to 18 feet above the creek from its mouth to the canyon of South Fork near the Embar anticline. Generally, the younger flood-plain alluvium forms a terrace about 5 feet above the creekbed, but in a few places, this alluvium comprises two or more terraces. For example, at the crossing of Owl Creek by State Highway 120, terraces of the younger flood-plain alluvium are 3-4 and 8-9 feet above the creekbed. The older and the younger flood-plain alluvium were not mapped separately near the Thermopolis anticline, along South Fork near Anchor Reservoir, or along North Fork.

Exposures of the older flood-plain alluvium generally show a progressive decrease in the number of coarse-grained beds and a corresponding increase in the number of fine-grained beds in the downstream direction along Owl Creek. In the canyon of South Fork near Anchor Reservoir and near Basin Ranch along North Fork, exposures of the alluvium consist chiefly of pebbles and cobbles. As a result of the coarseness of the alluvium, little farming is done in these areas. Beds of gravel are exposed as far downstream as the confluence of North and South Forks, but silt to sand beds predominate. Downstream of the confluence of the two forks, the alluvial exposures consist of fine-grained beds, composed mainly of buff to light-gray sand, silty sand, and sandy silt, and locally of silt or clay. The fine-grained lithology allows the alluvium to be farmed extensively, particularly east of Embar Ranch. The lithologies are distributed in lenticular beds that range in thickness from less than 0.5 to about 2 feet. Some of the beds extend for a distance of more than 600 feet. Generally, only a small quantity of organic material is present.

Exposures of the younger alluvium also show a decrease in coarseness in the downstream direction. Pebbles and cobbles form most of the alluvium in the western part of the area. Exposures of the alluvium near Embar and Arapahoe Ranches and at the Middleton School show pebbly to cobbly material overlain by 1 to 3 feet of silt and sand. Downstream of the Middleton School the younger alluvium, ranging in composition from sand to silt, is similar to the older flood-plain alluvium in that area.

Drillers' logs of water wells indicate considerable sand and gravel in the subsurface part of the older and the younger flood-plain alluvium. At places in the area downstream of the Middleton School, sand and gravel underlie the generally fine-grained sediments present in exposures of the alluvial deposits. Some of the logs list sand and gravel as composing the bulk of the deposits. However, the logs are too few in number to determine the overall distribution and thickness of the sand and gravel in the flood-plain deposits.

Alluvial-Fan Deposits

Extensive areas of alluvial fans occur along the south side of Owl Creek Valley in the area near the junctions of Red Creek and Dry Cottonwood Creek with the South Fork and between the Thermopolis and Owl Creek anticlines (pl. 1). Most of the alluvial-fan deposits indicated as Qay are slightly dissected and are the lateral equivalents of the older flood-plain alluvium. The fan deposits indicated as Qao are dissected by gully erosion and were deposited before the older flood-plain alluvium.

All the fan deposits are fine-grained mixtures of sand and silt with some clay and few pebbles or cobbles. Material coarser than sand was not observed in broad areas underlain by the fan deposits in the area south of Owl Creek near the Middleton School or near Dry Cottonwood and Red Creeks. The deposits derived from the shaly Cretaceous formations contain more silt and clay than sand and are light gray to buff. The deposits derived from the Chugwater Formation and associated redbeds, such as the dissected fan deposits near Red and Dry Cottonwood Creeks, consist mainly of light-reddish-brown sand, silty sand, and sandy silt. The generally fine-grained character of the fan deposits limits the volume of water that can be withdrawn by wells, even though these deposits supply water to numerous stock and domestic wells.

Pediment Deposits

Scattered pediment deposits occur throughout the Owl Creek Valley. The deposits shown on plate 1 mantle slopes formed after the Embar Ranch terrace, and many of the slopes merge with the Arapahoe Ranch terrace. The pediment deposits include mainly slope-wash deposits, colluvium, and small areas of alluvial-fan deposits and flood-plain alluvium; locally, small exposures of the sedimentary rocks are included. For the most part, the deposits are composed of silt and sand, but some coarse detritus is present near cliffs or along some of the sandstone outcrops.

In places, particularly on slopes south of Padlock Rim, large areas of white alkali encrustations are present. The alkali has resulted from evaporation of seepage from irrigation and leakage from irrigation ditches and the Thompson Reservoirs. A few wells obtain water from the deposits near Lucerne (table 7). In this area the pediment deposits and permeable beds in the underlying Cretaceous rocks are recharged, in part, by seepage from a few stock ponds.

ALLUVIAL AQUIFER

The alluvial aquifer consists principally of the flood-plain alluvium and part of the Arapahoe Ranch terrace deposits and subordinately of the alluvial-fan deposits. A few large-capacity irrigation wells and more than 60 domestic and stock wells withdraw water from the alluvial aquifer. Results of aquifer performance tests made by Berry and Littleton (1961, p. 21) of three large-capacity wells completed in the Arapahoe Ranch terrace deposits are shown in the following table:

Well No.	Duration of test (min)	Discharge (gal/min)	Drawdown (ft)	Specific capacity [(gal/min)/ft)]	Transmissivity (ft^2/d)	Saturated thickness of water-bearing material (ft)	Hydrualic conductivity (ft/d)
43-96- 7bd	30	156	2.22	70	4,611	11	420
43-96-17bb2	440	16	16.65	.9	7,076	24	294
43-96-17bb3	440	170	14.21	12	7,487	24	308

These tests indicate that properly constructed wells may obtain a few hundred gallons per minute, perhaps as much as 500 gal/min (Berry and Littleton, 1961, p. 31), from the alluvial aquifer. However, records of wells in the files of the Wyoming State Engineer, Cheyenne, indicate a maximum reported yield of only 400 gal/min from wells completed in the alluvial aquifer (table 5). The depth to water in the alluvial deposits is shallow, less than 25 feet below the land surface. Movement of the ground water is toward Owl Creek, which is therefore a gaining stream (Berry and Littleton, 1961, pl. 2).

Thickness

The thickness of the deposits forming the alluvial aquifer generally ranges from 20 to 40 feet along Owl Creek, but a maximum thickness of 50 feet is indicated in the log of a well near the Bighorn River in sec. 18, T. 43 N., R. 94 W. (pl. 2). Well logs and surface-resistivity measurements indicate the deposits are mainly 30 to 40 feet thick in the broad part of Owl Creek Valley between the Owl Creek and Thermopolis anticlines. Well-log information shows the thickness of the alluvial deposits is about 20 feet near the mouth of Owl Creek. Upstream from

Embar Ranch along the North and South Forks the thickness may be as much as 35 feet, but in most of these reaches the thickness probably is less than 20 feet.

Eight direct-current, surface-resistivity measurements were made across the bottom land of Owl Creek at the Arapahoe Ranch and near the Thermopolis anticline (pl. 2; table 8). The depths of the alluvial deposits, as interpreted from the resistivity measurements, corresponds generally with the depths indicated from the well-log data. The greatest depths to the base of the alluvial deposits determined from the surface resistivity is below Owl Creek near Arapahoe Ranch and to the south of Owl Creek at the Thermopolis anticline (fig. 4). Both the resistivity measurements and well logs indicate that the greatest thicknesses of the alluvial deposits are in the wide valley of Owl Creek south of Padlock Rim and that thicknesses are slightly less in the narrow valley of Owl Creek across the Thermopolis anticline and downstream of this structure.

Well logs indicate that the Arapahoe Ranch terrace deposits east of Arapahoe ranch and near the mouth of Owl Creek are mainly between 10 and 40 feet thick (pl. 2). The thicker parts of these deposits represent the fills of buried channels that are to the east of sec. 11, T. 43 N., R. 97 W., and in secs. 7 and 8, T. 43 N., R. 94 W.

Chemical Quality

The chemical quality of water in the deposits of the alluvial aquifer is better in the area west of Embar Ranch than it is east of the ranch. East of the ranch all the well water analyzed contains excessive concentrations of dissolved solids (table 9). Well water having a dissolved-solids concentration of less than 1,000 mg/L occurs mainly to the west of Embar Ranch. The smallest concentrations of dissolved solids were in water from well 8N-2E-5bcc along Red Creek (503 mg/L) and well 43-100-14dab near the North Fork (587 mg/L).

All the water analyzed is very hard; the hardness calculated as calcium carbonate ranged from 310 to 1,700 mg/L. Large concentrations of calcium, and sometimes magnesium, bicarbonate, and sulfate, are present in the water (table 6). In most analyses, fluoride was less than 1.0 mg/L, but the analyses of water from three wells completed in the Arapahoe Ranch terrace deposits indicated 1.0 to 2.4 mg/L of fluoride. Fluoride concentrations in excess of 1.5 mg/L cause mottling of children's teeth (U.S. Environmental Protection Agency, 1977). In a few wells nitrate concentration is large (one analysis indicated 240 mg/L of nitrate) and may impose a health hazard, particularly if consumed by children.

The classification of irrigation water in the main alluvial deposits composing the alluvial aquifer is shown in figure 5 (U.S. Salinity Laboratory Staff, 1954, p. 7981). Water in these deposits has a high to very high salinity hazard and a low to medium sodium hazard (fig. 5). The high to very high salinity hazard makes the water generally unsuitable for irrigation of most crops.

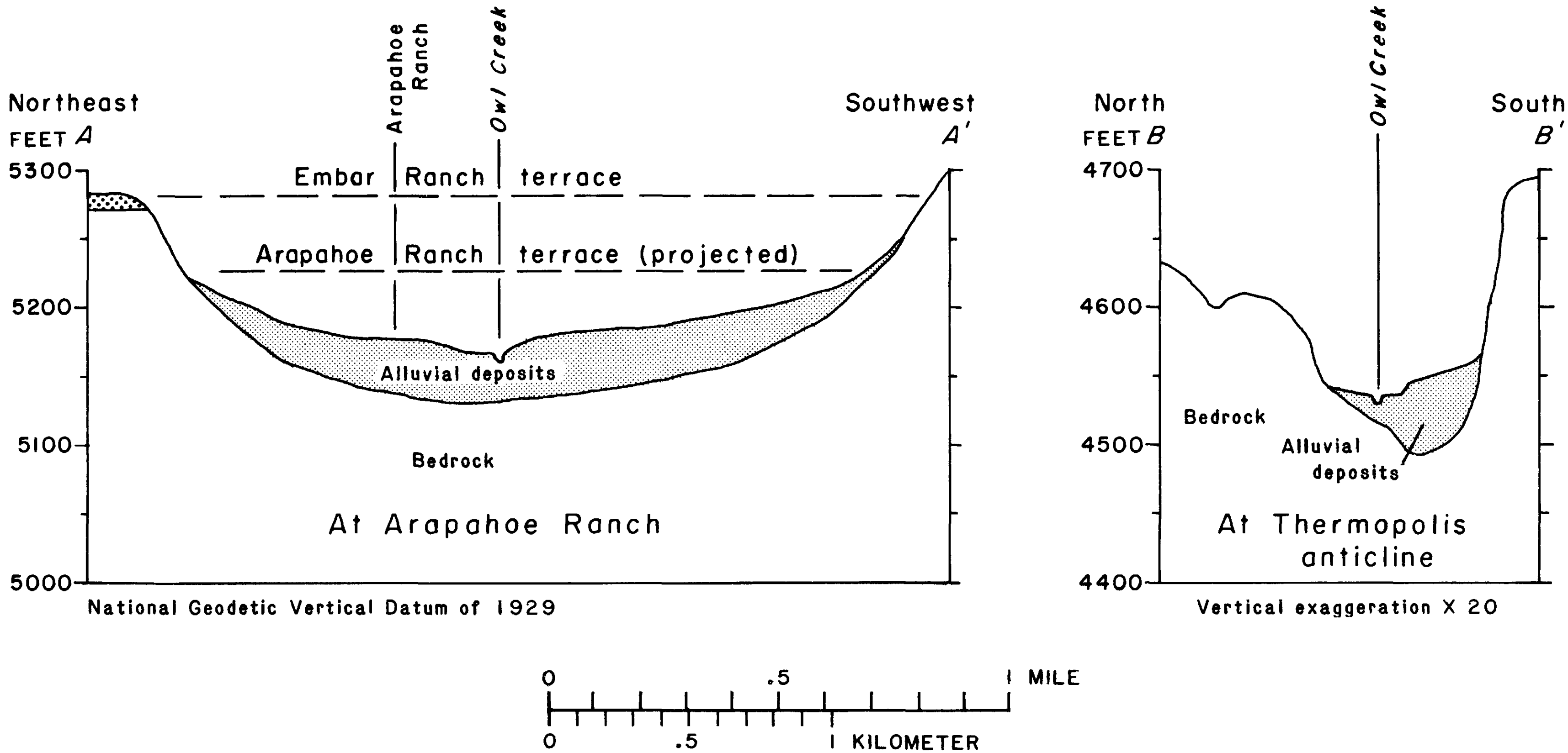

Figure 4.--Profiles of alluvial deposits in Owl Creek Valley obtained from surface resistivity measurements.

Table 8.--Geologic interpretation of geoelectric horizons indicated from surface-resistivity measurements

[Resistivity measurement or data-processing personnel included D. M. Hudson, T. O. McGowan, D. S. Barker, and K. T. Kilty.]

Location (section, township, and range) and measurement number	Depth to geoelectric horizon (feet)	Interpretation of geoelectric horizon and remarks
Near Arapahoe Ranch in secs. 5 and 6, T. 43 N., R. 97 W., and secs. 29 and 32, T. 9 N., R. 3 E., measurement numbers arranged from north to south.		
5	26	Probable base of alluvial deposits.
6	40	Base of flood-plain alluvium.
8	44	Do.
7	35	Do.
9	19	Probable base of alluvial deposits.
Near Thermopolis anticline, secs. 17 and 20, T. 43 N., R. 95 W., measurements arranged from north to south.		
3	18	Base of flood-plain alluvium; measurement made on a low terrace 4 feet above Owl Creek.
4	57	Probable base of alluvial deposits; measurement made on a dissected alluvial fan about 20 feet above Owl Creek.
2	50	Probable base of alluvial deposits; measurement made on a dissected alluvial fan about 30 feet above Owl Creek.

Table 9.--Chemical analyses of water in the surficial deposits

[Analytical results in milligrams per liter except as indicated. Analyses by Wyoming State Laboratories, Wyoming Department of Agriculture, and U.S. Geological Survey. Water-yielding unit: Qf, flood-plain alluvium along Owl Creek, undifferentiated; Qa, Older and younger alluvial-fan deposits, undifferentiated; Qta, Arapahoe Ranch terrace deposits]

Location	Depth of well (feet)	Water yielding unit	Date of collection	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (µmho)	pH
8N-3E-1cda	40(?)	Qf	9-17-76	4.0	100	58	230	3.7	180	0	810	15	0.6	0	1,310	490	--	4.4	1,860	7.4
9N-2E-32cbb	75	Qf,Kc	9-14-76	24	150	29	60	2.8	370	0	300	5.3	.5	.4	750	490	--	1.2	1,050	8.1
9N-3E-33acc	28	Qf	9-14-76	32	150	55	120	1.4	470	0	470	12	1.0	1.2	1,070	610	--	2.1	1,460	8.1
9N-2E-35aaa	44	Qf	7-22-46	--	285	121	[1]65		300	--	1,040	16	.2	0	1,960	1,210	964	--	2,010	7.3
43-95-16dd	42	Qf	7-23-46	--	248	88	[1]287		282	--	1,270	28	.4	8.0	2,280	981	750	--	2,540	7.5
43-97-14bab	30	Qf	9-14-76	23	110	50	310	5.1	540	0	680	12	.8	0	1,460	480	--	6.2	2,010	8.1
43-98-7bbb	--	Qf	9-14-76	17	140	34	110	2.6	340	0	440	6.2	.5	.7	914	490	--	2.1	1,260	8.0
44-94-33ccc	--	Qf	6- 7-67	20	199	6.5	158	9.4	160	0	578	140	.6	240	1,490	764	--	3.0	2,080	7.8
8N-2E-5bcc	23	Qa	9-14-76	11	93	36	20	1.9	260	0	200	2.7	.4	4.2	503	380	--	.4	756	8.2
9N-2E-33cdc	--	Qa	9-14-76	25	270	120	180	3.9	400	0	1,200	6.6	.8	.7	2,030	1,200	--	2.3	2,220	7.7
43-95-19abc	--	Qa	9-14-76	15	320	210	440	4.9	380	0	2,200	35	1.1	0	3,410	1,700	--	4.7	3,800	7.6
43-100-14dab	15	Qa	9-14-76	29	89	22	73	2.1	300	0	210	12	.5	2.8	587	310	--	1.8	883	7.6
43-96-7dbc	--	Qta	10-28-49	32	350	134	460	5.6	442	--	1,880	37	1.2	7.9	3,310	1,420	1,060	5.3	3,620	7.4
43-96-7dbc	--	Qta	9- 3-68	41	302	167	424	5.6	607	0	1,760	15	2.4	12	3,030	1,440	--	4.8	3,720	7.7
43-96-18abb	64	Qta	7-22-46	--	235	108	269		444	--	1,120	42	1.3	25	2,270	1,030	666	--	2,460	8.0
43-97-3ccd	--	Qta	7-22-46	--	183	81	282		573	--	802	44	1.1	40	1,830	790	320	--	2,200	7.9
43-94-8ccc	36	Qta	7-22-46	--	275	155	408		472	--	1,690	26	1.0	25	3,120	1,320	933	--	3,230	8.0

[1] Sodium plus potassium, reported as sodium.

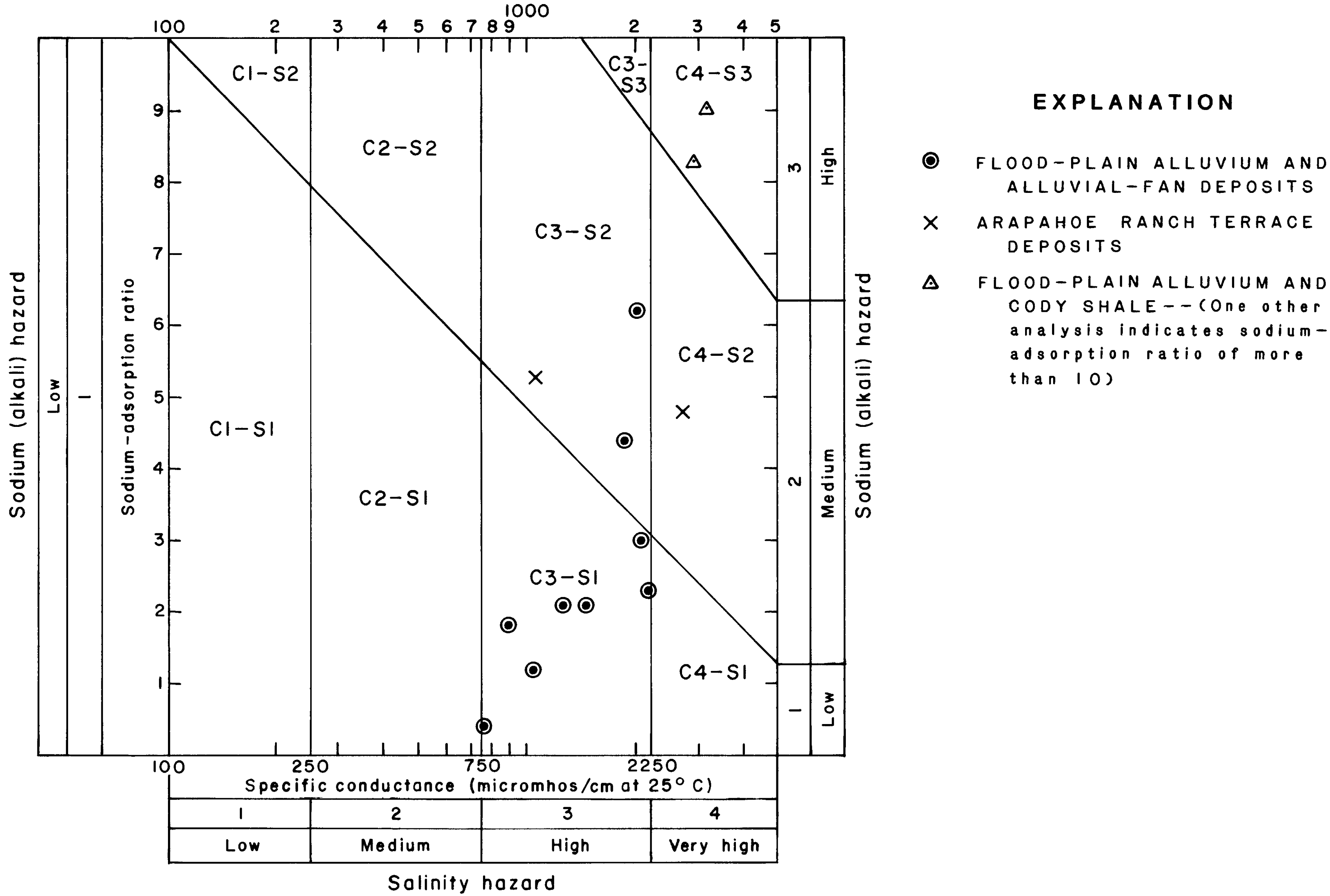

Figure 5.--Classification of irrigation waters in the main alluvial deposits.

Ground-Water Development

The flood-plain alluvial deposits and part of the Arapahoe Ranch terrace deposits appear to be the most hydrologically favorable deposits for development of ground water. According to Berry and Littleton (1961, p. 31) and the records in the files of the Wyoming State Engineer, the yields of eight irrigation wells completed in these deposits were between 50 and 400 gal/min, possibly as much as 500 gal/min. As best determined, during 1975-76, none of the irrigation wells were in operation and all irrigation water was diverted from Owl Creek. However, the excessive dissolved-solids concentrations of the water (table 6) is a major deterrent to development of water from these deposits, particularly in the part of Owl Creek Valley east of the Middleton School. The other units of the alluvial aquifer--the older and younger alluvial-fan deposits--yield small-quantities of water to wells, generally less than 50 gal/min.

The eastern part of the large remnant of the Arapahoe Ranch terrace deposits between sec. 12, T. 43 N., R. 97 W. and sec. 15, T. 43 N., R. 96 W. is a principal area for development of moderately large quantities--as much as 300 gal/min--of ground water. However, the water contains 2,270 to 3,310 mg/L of dissolved solids and has a very high salinity hazard. These conditions limit the use of water for many irrigation and industrial purposes. Wells completed in the deposits of a buried channel that is present in much of this area had test yields between 156 and 170 gal/min (Berry and Littleton, 1961, p. 21). Much of the western part of this terrace remnant probably yields only small quantities of water, less than 50 gal/min, to wells.

Unknown quantities of water are obtained from wells in the remnants of the Arapahoe Ranch terrace deposits near the mouth of Owl Creek. The chemical analysis of water from well 43-94-8ccc indicates that water from the deposits may contain more than 3,000 mg/L of dissolved solids. Distribution of the well data shows that the largest yields would be along the buried channel, which is present in the central part of the terrace remnant. The other remnants of the Arapahoe Ranch terrace are too small to store appreciable quantities of water.

Near Dry Cottonwood and Red Creeks the alluvial-fan deposits may yield a sufficient quantity of water for development of irrigation wells. Berry and Littleton (1961, table 6) reported that an irrigation well (completed in the older alluvial-fan deposits) was drilled in sec. 33, T. 91 N., R. 2 E. Unfortunately, information concerning the yields of this well and of two other irrigation wells drilled in sec. 15, T. 8 N., R. 4 E. and in sec. 33, T. 43 N., R. 97 W. are lacking. Elsewhere, the part of the fan deposits that adjoins the flood-plain alluvium yields small quantities, probably less than 50 gal/min, of water to wells. However, along the margins of the valley, the fan deposits are thin and may contain an insufficient saturated thickness even for the development of small-yield wells.

SUMMARY

The principal surficial deposits in Owl Creek Valley are the Embar Ranch and Arapahoe Ranch terrace deposits, flood-plain alluvium, alluvial-fan deposits, and pediment deposits. The flood-plain alluvium and the Arapahoe Ranch terrace deposits are the principal units of the alluvial aquifer along Owl Creek, whereas alluvial-fan deposits form a minor part of the alluvial aquifer. Small quantities of water are withdrawn from the artesian Cretaceous aquifers, particularly from the Frontier Formation.

Deposits of the alluvial aquifer are mainly 20 to 40 feet thick, with a maximum thickness of about 50 feet. These deposits occur throughout Owl Creek Valley. Aquifer-performance tests of three wells completed in the alluvial aquifer (Arapahoe Ranch terrace deposits) indicate yields of as much as 170 gal/min and transmissivities ranging from about 4,600 to 7,500 ft^2/d. Maximum reported well yields from the files of the Wyoming State Engineer, Cheyenne, Wyo., are as much as 400 gal/min.

The excessive dissolved-solids concentrations of water from the deposits of the alluvial aquifer is a main deterrent to development for irrigation and other uses. Water from the alluvial aquifer is cased out of many domestic wells. East of Embar Ranch where much of the land is cultivated, well water analyzed contains more than 1,300 mg/L of dissolved solids and much of the water has more than 2,000 mg/L of dissolved solids. West of the ranch where little of the land is cultivated, well water contains generally less than 1,000 mg/L of dissolved solids. Most of the water in the alluvial aquifer, classified for irrigation, has a high to very high salinity hazard and a low to medium sodium hazard.

Measurements of specific conductance were made of Owl Creek (including North and South Forks). Near Anchor Reservoir the specific conductance of North and South Forks during early spring runoff was less than 150 μmho. The specific conductance increases progressively in the downstream direction. Where Owl Creek is crossed by State Highway 120, the creek had a specific conductance of 1,600 μmho. In early autumn during low flow and maximum diversion for irrigation, the values for specific conductance were nearly double those obtained during the spring.

REFERENCES CITED

Andrews, D. A., Pierce, W. G., and Eargle, D. H., 1947, Geologic map of the Bighorn Basin, Wyoming and Montana, showing terrace deposits and physiographic features: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 71.

Berry, D. W., and Littleton, R. T., 1961, Geology and ground-water resources of the Owl Creek area, Hot Springs County, Wyoming: U.S. Geological Survey Water-Supply Paper 1519, 58 p.

Keller, E. V., and Frischknecht, F. C., 1960, Electrical methods in geophysical prospecting: Pergram Press, Oxford, New York, 517 p.

Lowry, M. E., Lowham, H. W., and Lines, G. C., 1976, Water resources of the Bighorn Basin, northwestern Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-512.

U.S. Environmental Protection Agency, 1975, National interim primary drinking water regulations: Federal Register, v. 40 no. 248, p. 59566-59587.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture, Agriculture Handbook 60, 160 p.

Zapp, A. D., 1956, Structure contour map of the Tensleep Sandstone in the Bighorn Basin, Wyoming and Montana: U.S. Geological Survey Oil and Gas Investigations Map OM-182.

Zohdy, A. A. R., 1975, Automatic interpretation of Schlumberger sounding curves, using modified Dar Zarrouk functions: U.S. Geological Survey Bulletin 1313, 39 p.

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