UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND WATER-SURFACE WATER RELATIONSHIPS IN THE BONAPARTE CREEK BASIN, OKANOGAN COUNTY, WASHINGTON, 1979-80

By F. A. Packard, S. S. Sumioka, and K. J. Whiteman

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CONTENTS

	Page
Abstract	1
Introduction	2
Description of the study area	2
Geology and ground water	5
Crystalline rocks	5
Glaciofluvial deposits	5
Valley morphology	9
Ground-water hydrology	10
Ground-water pumpage	10
Ground water-surface water relationships	14
Aeneas Valley segment	14
Upper Bonaparte Creek segment	20
Lower Bonaparte Creek segment	28
Bannon Creek segment	32
Ground-water divide between Sanpoil and Aeneas-Bonaparte drainages	34
Summary and conclusions	36
References cited	38
Appendix A. Water-level elevations in wells, March 1979 through April 1980	39
B. Water-level elevations in lakes, April 1979 through April 1980	40
C. Water-level elevations of streams in the Bonaparte area, July 1979 through April 1980	41
D. Drillers' logs of selected wells, Bonaparte study area	43

ILLUSTRATIONS

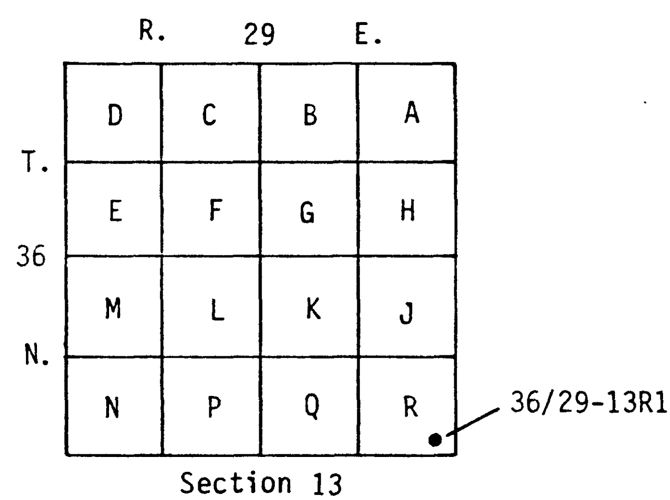
		Page
FIGURE 1.	Map showing location of study area, with ground-water-segment boundaries	3
2.	Graph showing normal meteorological and streamflow values	4
3.	Map showing generalized geology of the study area, with April 1980 water-level contours	6
4.	Hydrograph of water levels in two irrigation wells, 1979-80	11
5.	Hydrographs of water levels in selected lakes and wells in the Aeneas Valley, 1979-80	15
6.	Map showing discharge data, and locations of cross sections and detailed maps	16
7.	Hydrogeologic map of the Aeneas Valley segment, April 1980	17
8.	Hydrogeologic map of the upper Bonaparte segment, April 1980	21
9-12.	Hydrologic cross sections of ground water-surface water relationships:	
	9. Along upper Peony Creek	22
	10. Along lower Peony Creek	23
	11. In the western part of the upper Bonaparte segment	24
	12. In the eastern part of the upper Bonaparte segment	25
13.	Hydrograph of water levels in Lake UL 6, 1979-80	27
14-16.	Hydrologic cross sections of ground water-surface water relationships:	
	14. In the eastern part of the lower Bonaparte segment	29
	15. In the center of the lower Bonaparte segment	30
	16. In the western part of the lower Bonaparte segment	31
17.	Hydrogeologic map of the Bannon Creek and lower Bonaparte segments, April 1980	33
18.	Hydrogeologic map of the vicinity of the Aeneas/Sanpoil divide	35

TABLES

TABLE 1.	Records of selected wells in the Bonaparte Creek area	12
2.	Results of seepage measurement in Round and Long Lakes	18

WELL- AND SPRING-NUMBERING SYSTEM

Wells in Washington are assigned numbers that identify their location in a township, range, and section. Well number 36/29-13R1 indicates, successively, the township (T.36 N.) and range (R.29 E.) north and east of the Williamette base line and meridian; the letters indicating north and east are ommitted. The numbers following the hyphen indicate the section (13) in the township, and the letter following the section gives the 40-acre subdivision of the section, as shown below. The number following the letter is the serial number of the well in the 40-acre subdivision.



METRIC (SI) CONVERSION FACTORS

Multiply	By	To obtain
inches (in.)	25.4	millimeters (mm)
	2.540	centimeters (cm)
	0.0254	meters (m)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
	28.32	liters per second (L/s)
degrees Fahrenheit (°F)	0.5556, after subtracting 32	degrees Celsius (°C)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

Ground water-surface water relationships were studied in five morphologic segments in the Bonaparte Creek basin during 1979 and 1980. In one segment, kettle lakes were found to be closely associated with the ground-water system. In the other four segments, a close relationship was found between streamflow and ground water. On the basis of the 1979-80 information, it was concluded that additional ground-water development would adversely affect lake levels and streamflow, thereby reducing surface-water resources already closed to further appropriation. The ground-water divide between the Bonaparte and Sanpoil basins was 6 miles southeast of where it was previously thought to be.

INTRODUCTION

Bonaparte Creek, a tributary to the Okanogan River, is located in north-central Washington in Okanogan County (fig. 1). It is approximately 30 miles long, and has a drainage basin area of 148 square miles. Surface-water flow in Bonaparte Creek and in the Sanpoil River has been closed to further appropriation by the Washington State Department of Ecology, and water rights on Bonaparte Creek have been adjudicated by the courts. However, numerous requests for additional ground-water appropriations have been made for sites in the Bonaparte Valley and in the Aeneas Valley tributary to the southeast.

Because increased ground-water pumping could affect adjacent surface-water lakes and streams, a study was started by the Geological Survey, in cooperation with the Washington State Department of Ecology (WSDOE), to: (1) define the relationship between surface flow in Bonaparte Creek and the ground-water system in that valley; (2) define the relationship between kettle lakes and the ground-water system in the Aeneas Valley; (3) determine the location of the ground-water divide between the Aeneas Valley and the valley of the Sanpoil River to the southeast; and (4) determine whether ground-water pumping would affect streams, lakes, and ground-water divides in the area. This report contains the results of observations and analyses of data collected in 1979 and 1980.

DESCRIPTION OF THE STUDY AREA

The study area (fig. 1) includes a 10-mile reach of Bonaparte Creek and a 7-mile reach of Aeneas Valley. The valley floors range in altitude from 2,000 to 2,600 feet and the surrounding peaks rise to altitudes of more than 6,000 feet. The lowest temperatures and highest precipitation occur at the higher altitudes. Precipitation ranges from 13 to more than 40 inches, and temperature varies greatly, the extremes being above 110°F and below -30°F (average meteorological conditions are shown in figure 2). Snowmelt is responsible for much of the high runoff, so that discharge in Bonaparte Creek typically is greatest in March through May and lowest in August and September of the year.

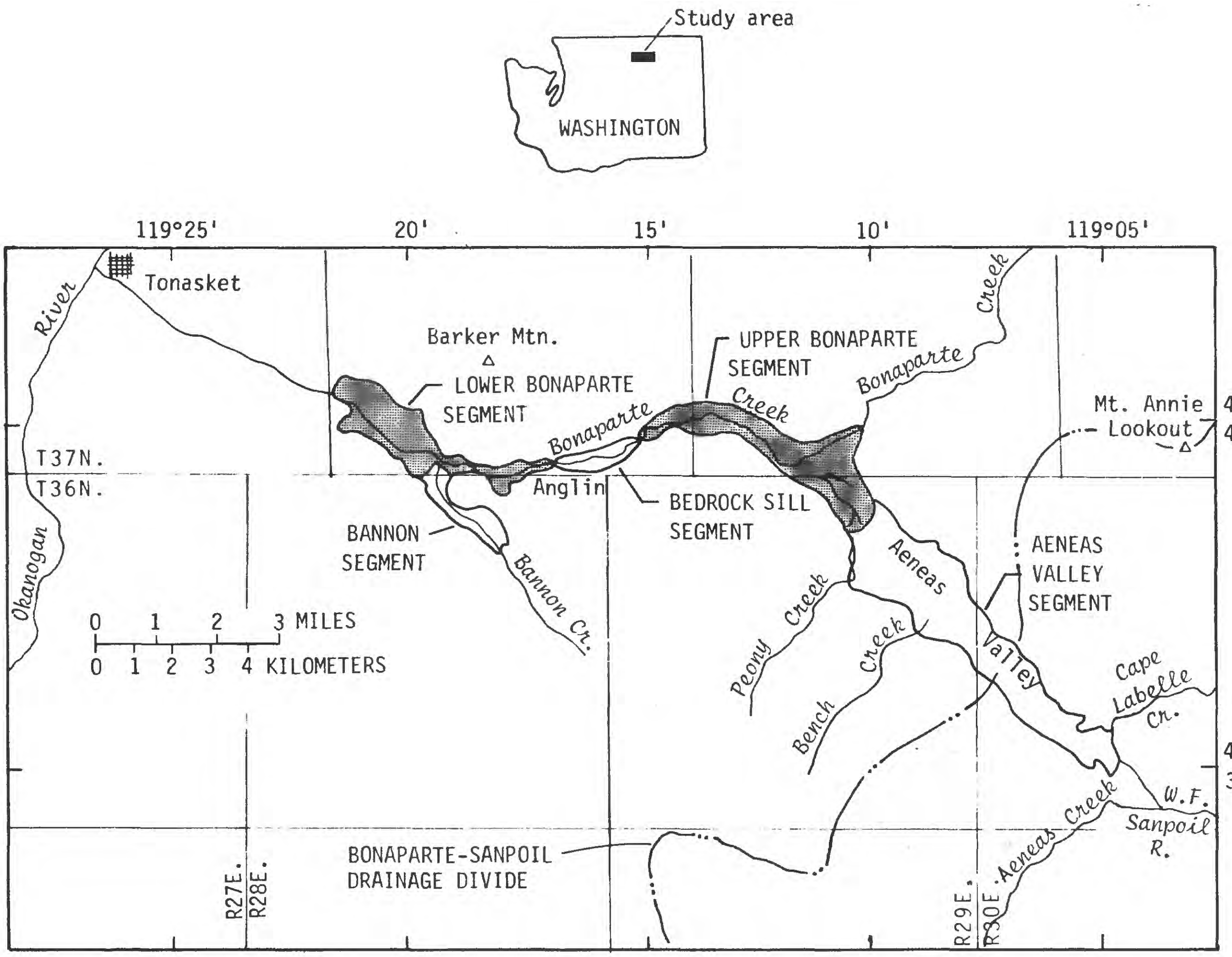

FIGURE 1.--Location of study area, with ground-water-segment boundaries.

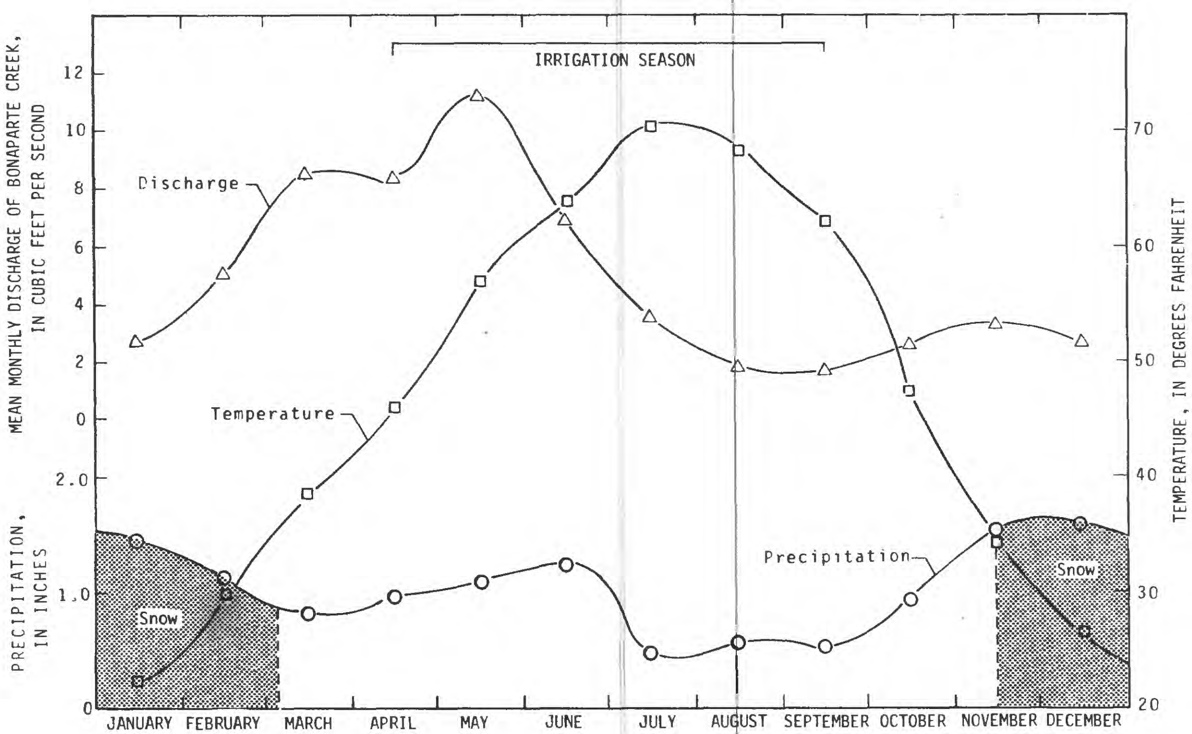

FIGURE 2.--Normal meteorological and streamflow values. (Meteorological data from Omak 2SW, 1941-70; discharge data from Bonaparte Creek near Wauconda, 1967-73.)

GEOLOGY AND GROUND WATER

The general geology of the area has been described by Fox and Rinehart (1972), and the ground-water and surface-water resources have been studied by Walters (1974). Neither study covered the Bonaparte Valley in enough detail to answer questions of concern in this study. Geologic mapping of pertinent rock units for this report (fig. 3) was accomplished largely through the use of aerial photographic stereographic coverage to identify the patterns of characteristic morphology for each unit. The work was then field checked in places and some stratigraphic work was done, but most of the field time was spent in establishing elevation control, making water-level measurements, or in collecting other hydrologic data.

There are two major rock types in the Bonaparte Valley, crystalline bedrock and an overlying thin mantle comprising several kinds of glaciofluvial sand and gravel. The thickest sections of the sands and gravels occur as narrow, elongate bodies of fill along bedrock valleys. These deposits are the most productive aquifers in the study area.

Crystalline Rocks

Hills on all sides of the Bonaparte and Aeneas valleys are composed of Mesozoic granite gneiss, the foliation of which dips conspicuously to the northeast. To the east, gneissic rocks grade into the massive Colville granite batholith. These crystalline rocks are fractured and yield water to wells and springs, but, typically, yields are small.

Glaciofluvial Deposits

During the Pleistocene Epoch, the entire Okanogan drainage was overridden by the Cordilleran ice sheet, which rounded the higher peaks and modified parts of Bonaparte Creek valley (Waters and Krauskopf, 1941). The glacier melted and left large quantities of sand and gravel on the hillslopes and along the valley bottoms in the form of terrace and pitted outwash-plain deposits.

The thickest section of glaciofluvial clastics is found in the Aeneas Valley between sec. 33, T.36N., R.30E. and sec. 11, T.36N., R.29E. (fig. 3). Although no detailed study of the stratigraphy of these sediments was made, well-sorted, well-rounded sand and gravel of apparent fluvial origin were observed. Unsorted, angular boulder deposits, more typically glacial in origin, were also observed. The many kettle depressions found in the valley were formed when large ice blocks from a stagnant glacier were buried by outwash debris brought in by melt water. Subsequent melting of the blocks left depressions, many of which have filled with water to form lakes.

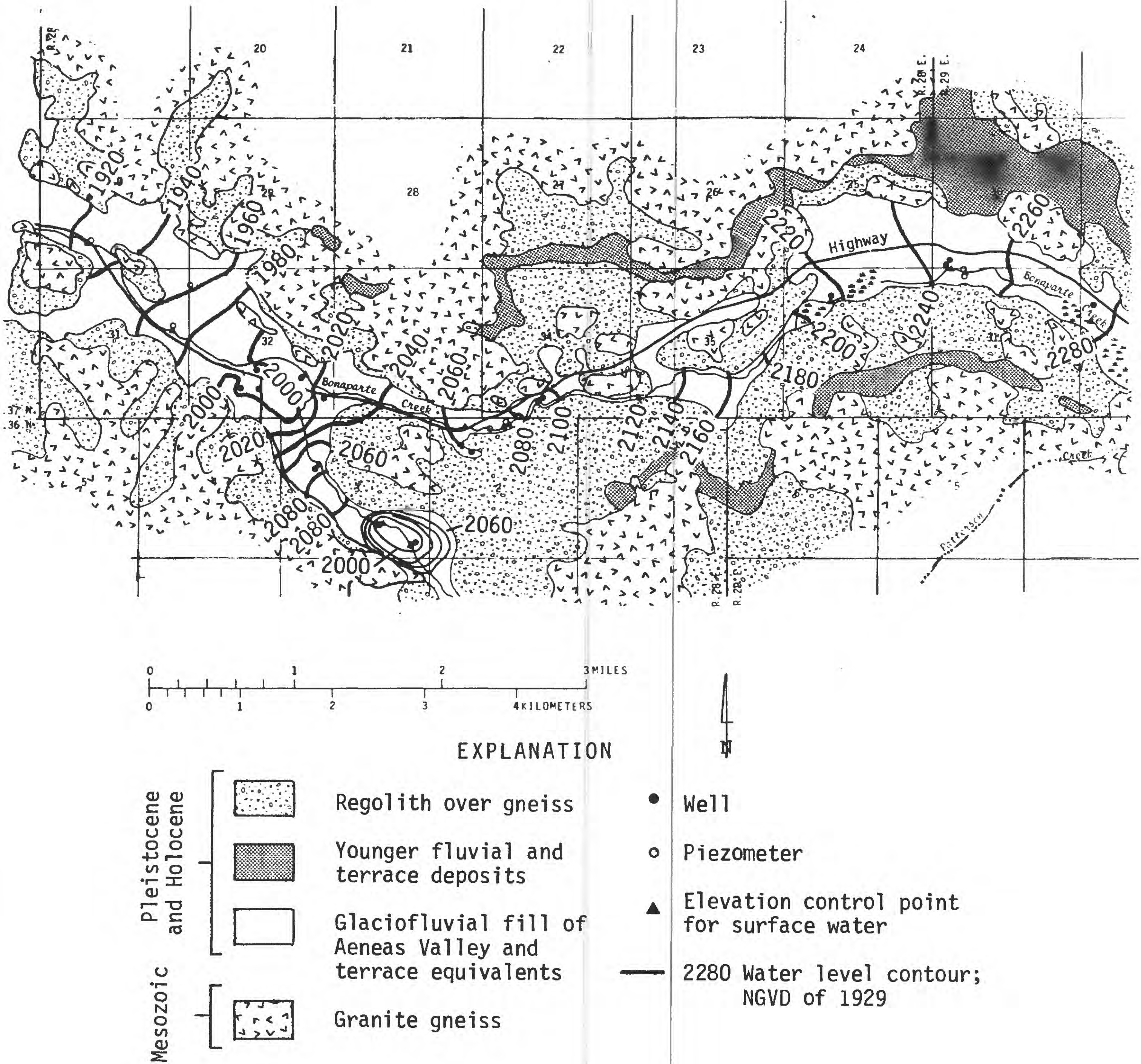

FIGURE 3.--Generalized geology of the study area, with April 1980 water-level contours.

FIGURE 3.--Continued

Deposits equivalent to the Aeneas Valley sands and gravels are found downvalley from sec. 11, T.36N, R.29E, in the form of paired, pitted terraces along each wall of the Bonaparte Creek valley. Both terraces are at an altitude of approximately 2,650 feet, and probably were deposited by streams on either side of a glacier that extended from the Okanogan Valley up the Bonaparte Creek valley to the vicinity of sec. 11.

Younger fine-grained fluvial fill found along the floor of the Bonaparte Creek valley downstream from the Aeneas Valley sediments occurs at levels from 200 to 700 feet below the pitted terraces noted above. Within these younger fill deposits, a second and lower sequence of terraces occurs in secs. 30, 31, and 32, T.37N., R.28E., in the northwesternmost part of the study area. The fine sand found in these terraces was probably deposited just above and at the margins of the Okanogan Valley glacier at a time when it reached a standstill at a lower elevation. These and other fluvial clastics in the Bonaparte Creek valley intertongue with alluvial-fan deposits brought in by tributary streams along the Bonaparte Creek drainage. A number of outcrops of glacial till are present in the northwesternmost part of the study area, specifically in sec. 25, T.37N., R.27E. and sec. 30, T.37N., R.28E. The relationship of these tills to the fluvial clastics is unknown.

The geologic map (fig. 3) shows the areal distribution of granite gneiss, of glaciofluvial fill of the Aeneas Valley and its terrace equivalents, and of younger fluvial and terrace deposits of the Bonaparte Valley. The map also shows distribution of regolith, or rubble, consisting of either shallow soil cover or alluvial fan deposits over granite gneiss bedrock. Each map unit has a different hydrologic character; the Aeneas Valley fill is the thickest aquifer with the largest tranmissivities, followed generally by the thinner but still permeable fluvial fill of the Bonaparte Valley, then by the terrace deposits, by the very thin rubble deposits, and finally by the poorest aquifer, the relatively impermeable granite gneiss.

Valley Morphology

Based on morphology, the study area was divided into five general valley reaches or segments (fig. 1) to aid in isolating areas of homogeneous ground water-surface water relationships. These are the Aeneas Valley segment, the upper Bonaparte, the bedrock sill, the lower Bonaparte, and the Bannon segments.

The uppermost segment, the Aeneas Valley segment, is about 5 miles long and 3/4 mile wide. The valley floor (approximately 2,650 feet in altitude) is nearly flat and contains many kettle depressions, some of which hold water year-round. There are no through-flowing perennial streams that drain the entire length of the segment, and most tributary streams either terminate on alluvial-fan sheetflow surfaces or flow into kettle depressions. Thus, much of the runoff entering the segment is trapped by lakes or filters into the porous glaciofluvial sediment of the valley. A drainage system that formerly carried runoff northwestward from Bench Creek to Peony Creek was cut approximately 100 feet deep into the northern half of the Aeneas Valley during the Holocene. At present this drainage consists of a broad-bottomed valley without a defined channel, and runoff entering the system either travels as sheetflow or infiltrates into the subsurface. The Aeneas Valley segment is bordered on the southeast (sec. 28, T.36 N., R.30 E.) by the headwaters of the Sanpoil River and on the northwest by a scarp 200 feet high, located in the SW¼ sec. 2, T.36 N., R.29 E.

The upper Bonaparte segment, downgradient from the Aeneas Valley, is approximately 4 1/2 miles long and 1/2 mile wide, and is floored by a flat alluvial surface sloping to the west and northwest. The drainage is characterized by through-flowing perennial stream channels (Peony Creek and Bonaparte Creek) alternating with broad, marshy reaches.

Downstream from the upper Bonaparte segment is a 2-mile-long reach characterized by a stream channel set in a flood plain 100-500 feet wide. Low gneiss hills rise abruptly on both sides. This segment, the bedrock sill segment, extends approximately to the small settlement of Anglin in sec. 34, T.37 N., R.28 E. No detailed work was done in this segment.

Below Anglin is the lower Bonaparte segment, a valley about 4 miles long, floored by an alluvial surface that gradually widens and reaches a maximum width of about 1/2 mile in the vicinity of the Bannon Creek confluence. The segment ends in the SW¼ sec. 30 where Bonaparte Creek valley narrows abruptly. Streamflow at that point crosses a bedrock sill, and the stream gradient increases downstream. Along the lower two-thirds of the segment the channel is entrenched into alluvium, with at least two terraces 20-100 feet above the streambed.

The fifth morphologic segment, the Bannon Creek segment, is tributary to Bonaparte Creek. This segment has an alluvial fan surface 1/4 to 1/2 mile wide and approximately 2 miles long. The master channel ends in a sheetflow alluvial surface just above the point where runoff flows into Bonaparte Creek.

Ground-Water Hydrology

In the Bonaparte and Aeneas Valleys, ground water occurs in both the glaciofluvial fill and the granite gneiss, but most of the water withdrawn is from the fill aquifer. Permeability of the granite gneiss is inferred to be small compared with that found in the glaciofluvial fill aquifer; consequently, only the glaciofluvial fill was studied in detail. Though the gneiss and glaciofluvial aquifers may be in hydraulic communication, data are insufficient to prove this, and water-level contours for the fill aquifer were conservatively terminated at the gneiss outcrops (fig. 3a and b).

Buried ridges or sills of gneissic rock crossing the Bonaparte Valley may act as impermeable barriers between permeable elements of the fill aquifer system. For example, although there is a narrow fill connection along the bedrock sill segment between the upper and lower Bonaparte segments, most of the ground water in the upper segment probably is discharged to Bonaparte Creek above this sill and passes to the lower segment as surface flow in Bonaparte Creek. At the downstream end of the lower Bonaparte segment another gneissic bedrock sill underlies the stream. In this place, however, a narrow band of fill to the north of the stream channel probably diverts some ground-water flow into the next basin downstream.

Ground-Water Pumpage

Historic and present pumping have created two areas of lowered ground-water levels, the first in the Bannon segment and the second to the north of the Bannon segment along its boundary with the lower Bonaparte segment. There, ground water that originally would have discharged as base flow to Bonaparte Creek is now being withdrawn by wells. Such base-flow discharge would have occurred along reaches in the lower Bonaparte segment or at the several bedrock sills downstream.

Most wells in the study area (table 1) are used for domestic purposes. During the 1979 water year, only three wells were heavily used for irrigation (36/29-13F1, 36/28-3D1, and 3Q1; see page v for explanation of well-numbering system). Generally, irrigation pumping begins in April and continues into early September. Hydrographs of water levels in two of these irrigation wells (fig. 4) show that full recovery took place after drawdowns of as much as 31 feet during the pumping season. Both wells lie in the northern area of lowered ground-water levels. Well 36/28-3Q1, in the southern cone of lowered water levels, showed a year-to-year water-level decline of about 2 feet. Another well in the southern depression cone, 36/28-3R1, whose bottom was at an altitude of 2,023 feet, was dry throughout the study period. The well was reportedly pumped dry a number of years ago (B. Jellison, oral commun., 1979).

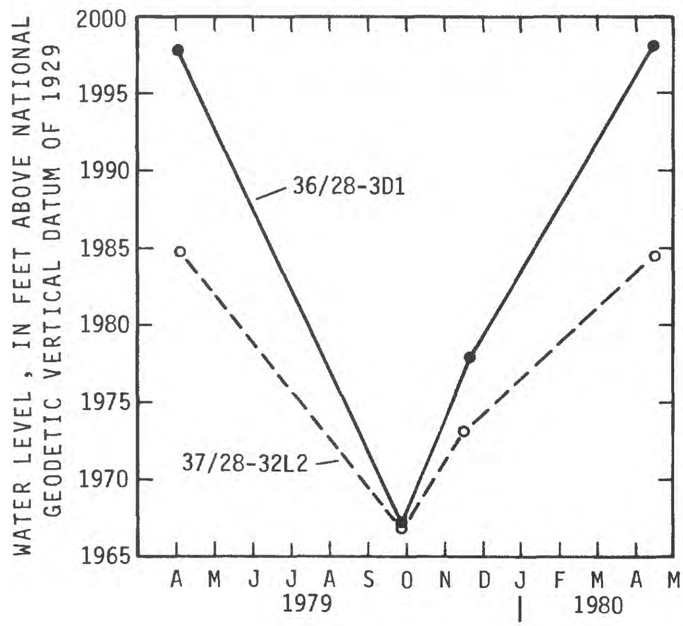

FIGURE 4.--Hydrograph of two irrigation wells, 1979-80.

TABLE 1.--Records of selected wells in the Bonaparte Creek area

Well number	Owner or tenant	Altitude (ft)	Type	Depth (ft)	Driller	Date con-structed	Diameter (in.)	Finish
36/28-2C1	USGS observation well	2,083.48	Auger	15	USGS	12/79	1.25	Screened 12.4-15 ft
-2C2	---do----------------	2,082.08	Auger	12	USGS	12/79	1.25	Screened
-2D1	Burt Jellison #6	2,089.84	Dr	93	--	1973	10	--
-3D1	Burt Jellison #2	2,051.70	Dr	165	Thomas Well Drg.	1964	8	Perforated 146-163 ft
-3E2	Burt Jellison #4	2,081.74	Dr	38	--	--	4	--
-3Q1	Burt Jellison #3	2,166.92	Dr	230	--	--	14	--
-3R1	Burt Jellison #8	2,202.84	Dr	~180	--	--	8	--
36/29-3B1	USGS observation well	2,364.14	Auger	7.5	USGS	12/79	1.25	Open-end
-3B2	---do----------------	2,358.80	Auger	3	USGS	12/79	1.25	Open-end
-3D1	Coleen Picard	2,335.83	Dr	~16	--	1946	4	--
-11E1	Alvin Munce	--	Dug	~15	--	--	36	--
-11F1	---do------	2,529.99	--	--	--	--	--	--
-12P1	Clifford	2,554.90	--	--	--	1980	--	--
-13F1	Charles Jones	2,594.38	Dr	77	Thomas Well Drg.	--	12	--
-13K1	Ron Stoddard	2,579.45	Dug	15	--	5/78	60	--
-13L1	Jim Pratt	2,671.55	Dr	267	Aqua Drg.	5/78	6	Open-hole below 84 ft
-13R1	Wesley Rogers	2,620.10	Dr	250	Aqua Drg.	6/78	6	Open-hole below 42 ft
-13R2	John Frank	2,582.71	Dr	295	Aqua Drg.	6/78	6	Open-hole below 60 ft
-13R3	USGS observation well	2,582.71	Auger	9	USGS	12/79	1.25	Open-end
36/30-19C1	---do----------------	2,582.85	Auger	7.5	USGS	12/79	1.25	Open-end
-19Q1	Ralph Hart #2	2,606.82	Dr	140	Aqua Drg.	11/77	6	Perforated 136-138 ft
-19R1	Guy Fisher	2,601.19	Dug	~30	--	--	48	--
-29J1	Pilot Wheel Ranch	2,596.63	Dr	111	Thomas Well Drg.	1973	11	Open-end
-29J2	USGS observation well	2,602.53	Auger	22	USGS	12/79	1.25	Screened
-29K1	---do----------------	2,603.41	Auger	16	USGS	12/79	1.25	Screened 13.4-16 ft
-33B1	---do----------------	2,604.91	Auger	25	USGS	12/79	1.25	Screened 22.5-25 ft
-33G1	Ralph Hart #1	2,605.20	Dr	128	Thomas Well Drg.	6/70	12	Perforated 34-38 ft, 124-126 ft
-33L1	Ralph Hart#2	2,638.06	--	--	--	--	--	--
-33L2	Ralph Hart #3	2,641.71	--	--	--	--	--	--
37/28-30P1	USGS Observation well	1,938.14	Auger	18.5	USGS	12/79	1.25	Screened
-30P2	---do----------------	1,931.52	Dp	3.0	USGS	4/80	1.25	Screened
-31H1	---do----------------	1,979.63	Auger	15	USGS	12/79	1.25	Screened
-31H2	---do----------------	1,975.04	Dp	3.0	USGS	4/80	1.25	Screened
-32O1	---do----------------	2,013.74	Auger	77	USGS	12/79	1.25	Screened 74.4-77 ft
-32L1	Ed Buchert #2	2,011.93	Dr	128	Thomas Well Drg.	12/65	8	Perforated 115-126 ft
-32L2	Ed Buchert #3	2,011.98	Dr	~165	Joe Hubbard	1973	12	--
-32P1	Burt Jellison #1	2,031.51	Dr	202	Thomas Well Drg.	1967	10	Screened 192-202 ft
-32P2	Burt Jellison #5	2,024.72	Dr	120	--	--	8	--
-32R1	Ed Buchert #4	2,023.16	Dr	50	Joe Hubbard	1977	8	--
-32R2	Burt Jellison #7	2,027.49	Dug	30	--	--	48	--
-34P1	Arnold Haaland	2,106.17	Dug	17	--	1956	48	--
-36D1	Roger Gardinier	2,221.49	Dug	15	Robert Hirst	1977	48	--
37/29-30N1	Sundown #1	2,257.96	Dr	~70	--	--	6	--
-31D1	USGS observation well	2,251.82	Auger	8	USGS	12/79	1.25	Screened
-31D2	---do----------------	2,251.88	Auger	7.5	USGS	12/79	1.25	Screened
-31D3	Sundown #2	2,246.04	Dug	~5	--	--	48	--
-32E1	George Rickel #1	2,288.85	Dug	~25	--	1975	48	Open-end
-32F1	Jack Sherwood	--	Dr	70	Thomas Well Drg.	1974	8	Open-end
-32F2	George Rickel #2	--	--	--	--	--	--	--
-32K1	Roy Stoddard #5	2,345.13	Dr	~30	--	1940's	6	--
-32Q1	USGS observation well	2,335.23	Auger	8.5	USGS	12/79	1.25	Screened
-32R1	---do----------------	2,332.80	Auger	9	USGS	12/79	1.25	Open-end
-33M1	Roy Stoddard #1	2,370.52	Dug	~30	--	1956	48	--
-33M2	Roy Stoddard #2	2,373.91	Dug	~25	Thomas Well Drg.	1940's	48	--
-33N1	Roy Stoddard #3	2,354.62	Dug	20	--	~1965	48	--
-33N2	Roy Stoddard #4	2,367.71	Dr	75	--	--	10	--

Type: Dr = drilled, DP - drivepoint.
Use: Obs. = observation; Irr. = irrigation; Dom. = domestic; S - stock; PS = public supply.
Pump: T = turbine; C = centrifugal; S = submersible; J = jet.

Water-bearing zone		Use	Pump		Remarks
Material	Depth interval		Type	H.P.	
Coarse sand and granules	11-15	Obs.	None	--	Log.
Silt and sand	8-12	Obs.	None	--	Log.
--	--	--	None	--	Reported yield of 120 gal/min.
Sand, gravel	143-165	Irr.	T	50	Log. Reported yield 600 gal/min.
--	--	None	--	--	--
--	--	Irr.	T	20	--
--	--	None	--	--	--
Silty sand	1-7.5	Obs.	None	--	Log.
Black silt	--	Obs.	None	--	Log.
--	--	Dom.	C	1/2	Well caved in from former depth of 27 ft.
--	--	Dom.	C	1/2	--
--	--	Irr.	None	--	--
--	--	--	--	--	--
--	--	Dom., Irr.	S	--	--
--	--	Dom.	S	1/3	--
Granite	250-260	Dom.	S	1	Log.
Granite	--	Dom.	S	1	Log. Reported dry in summer.
Granite	--	Dom.	S	1	Log.
Coarse sand and silt	--	Obs.	None	--	Log.
White muck	--	Obs.	None	--	Log.
Coarse gravel	--	PS	None	--	Log. Reported yield of 25-30 gal/min.
--	--	Irr.	None	--	--
--	--	Dom., S	S	1	--
Coarse sand and granules	--	Obs.	None	--	Log.
Pebbles and granules, with some sand	--	Obs.	None	--	Log.
Coarse gravel	--	Obs.	None	--	Log.
--	--	Irr.	T	100	Log.
--	--	Dom.	--	--	--
--	--	Dom.	--	--	--
Sand, gravel	14-18.5	Obs.	None	--	Log.
Sand, silt	0-3	Obs.	None	--	--
Brown clay and silt	11-15	Obs.	None	--	Log.
Silt, sand	0-3	Obs.	None	--	--
Fine tan sand	61-77	Obs.	None	--	Log.
Gravel	110-128	Dom.	S	3/4	Log.
--	--	None	None	--	--
Sand	176-202	Irr.	T	100	Log.
--	--	Dom., S	S	1	--
--	--	None	None	--	--
--	--	S	--	--	--
--	--	Dom.	--	--	--
--	--	Dom.	S	--	--
--	--	Dom.	None	--	--
Silt and sand	--	Obs.	None	--	Log.
Sand and silt	6-7.5	Obs.	None	--	Log.
--	--	None	None	--	--
--	--	None	C	1	--
--	--	Dom.	S	1 1/2	Reported yield 15 gal/min.
--	--	Dom.	--	--	--
--	--	Dom.	J	1/2	--
Clay and silty sand	--	Obs.	None	--	Log.
Silt and sand	4-9	Obs.	None	--	Log.
--	--	Dom.	C	1	--
--	--	Dom.	C	--	--
--	--	None	None	--	--
--	--	--	None	--	Reported to pump sand.

GROUND WATER-SURFACE WATER RELATIONSHIPS

The Aeneas and Bonaparte Valleys are characterized by alternating reaches of gaining streams (perennial channelflow and marshes) and losing streams (ephemeral and intermittent channelflow and sheetflow surfaces). Similarly, kettle depressions in some areas hold water year round, whereas in other areas the lakes are ephemeral. These characteristics, along with morphology and water-table configuration help define relationships between ground water and surface water.

Aeneas Valley Segment

Kettle lakes in the Aeneas Valley are ground-water phenomena, and, as such, lake levels are a surface expression of the water table. Lake levels in the Aeneas Valley, therefore, rise and fall with the water table. Ground-water in the valley generally enters the lakes from their southeastern sides and exits along their northwestern sides.

Most of the small tributary streams and even some major streams that flow into Aeneas Valley and the adjacent reaches of Sanpoil River or Bonaparte Creek are ephemeral. For example, Cape Labelle Creek at the head of Aeneas Valley was flowing during the spring and summer months of 1979 along the reach in sec. 28, T.36N, R.30E. (fig. 3), but was dry during the fall and early winter.

During large runoff events in the Aeneas Valley, surface water flows toward and into Bonaparte Creek from points northwest of the center of sec. 13, T.36N., R.29E (fig. 3). In a like manner, surface water flows to the Sanpoil River southeast of the center of the NW¼ of sec. 29, T.36N., R.30E. Drainage in the valley between these two points is internal into the large lakes. For small-to-medium runoff events, the surface-water divide between the Sanpoil and Bonaparte Creek drainages lies on either side of this reach of interior drainage. No data are available on the divide location for very large flows, and the divide has been arbitrarily placed by J.R. Williams (1964, fig. 1) in the reach of interior drainage.

Staff gages were placed in a number of kettle lakes in the Aeneas Valley, where only the deepest kettle depressions contain water year round. Water-surface elevations of these lakes (fig. 5) are highest in spring and early summer months and lowest in the early winter months.

Two lakes were chosen for detailed study, Long Lake and Round Lake (figs. 6 and 7). Two auger holes were drilled and piezometers installed between these lakes - 36/30-19C1, on the north, downgradient side of Round Lake, and 36/29-13R1, on the southeastern, upgradient side of Long Lake. Water levels measured in these piezometers in December 1979 and again in April 1980 showed a consistent relationship with lake-water levels. Specifically, water levels in piezometer 19C1, just north of Round Lake, were lower than the water level in Round Lake, and water levels in piezometer 13R3, southeast of Long Lake, were higher than water levels in Long Lake. These data show a gradient and, therefore, a flow from the northwestern side of Round Lake into the ground-water system and, thence, into the southeastern side of Long Lake.

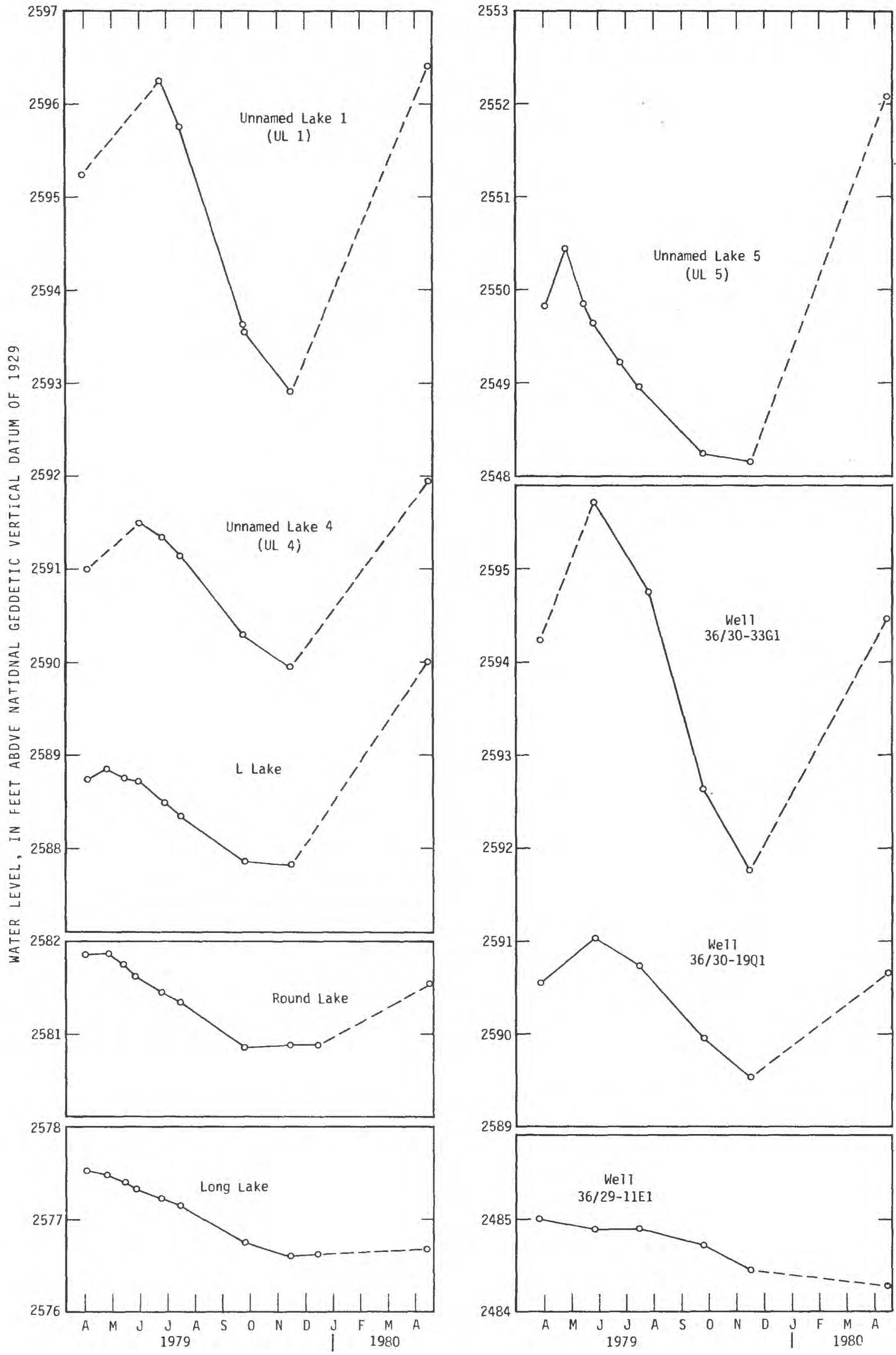

FIGURE 5.--Hydrographs of selected lakes and wells in the Aeneas Valley, 1979-80.

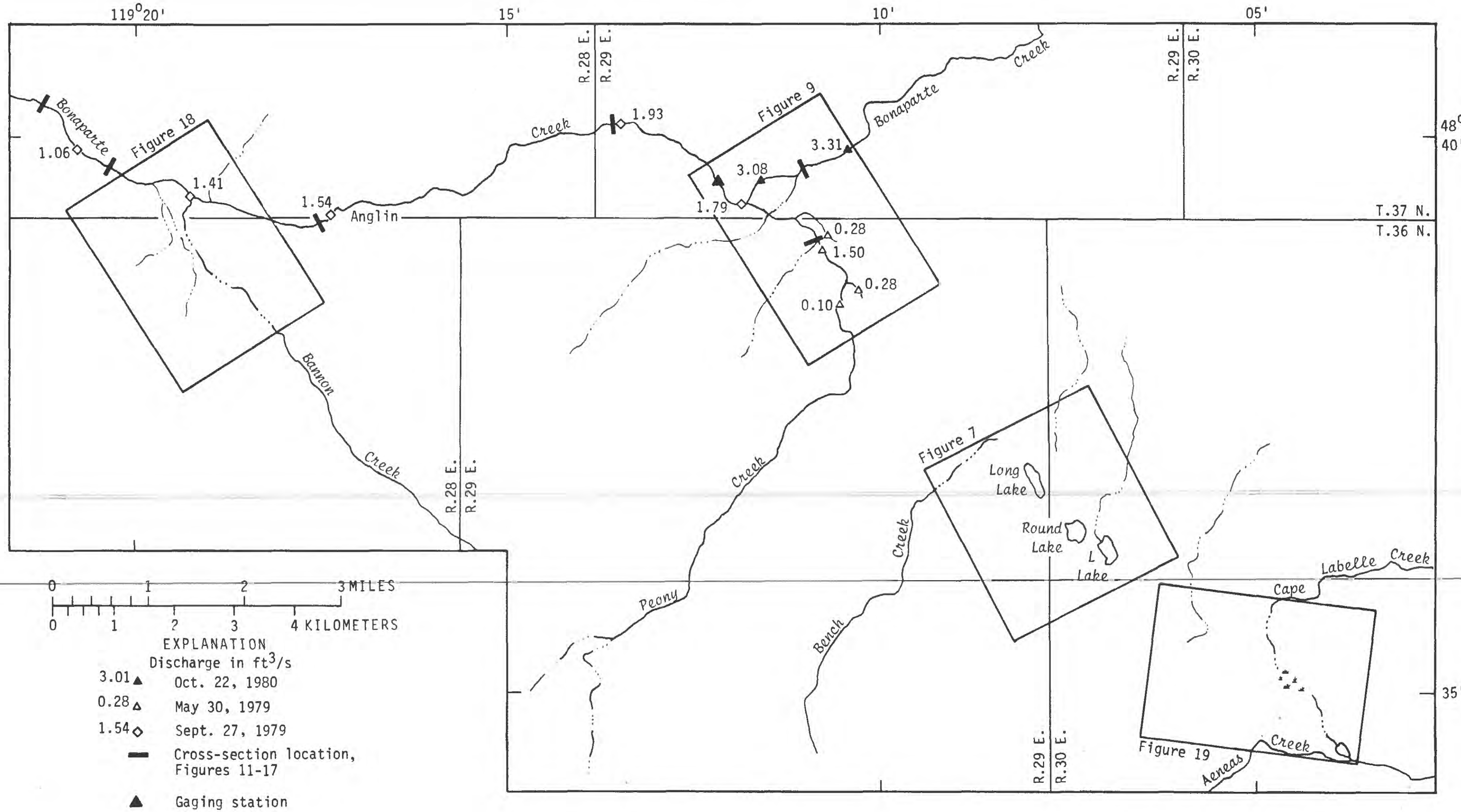

FIGURE 6.--Discharge data, in cubic feet per second, and locations of cross sections and detailed maps.

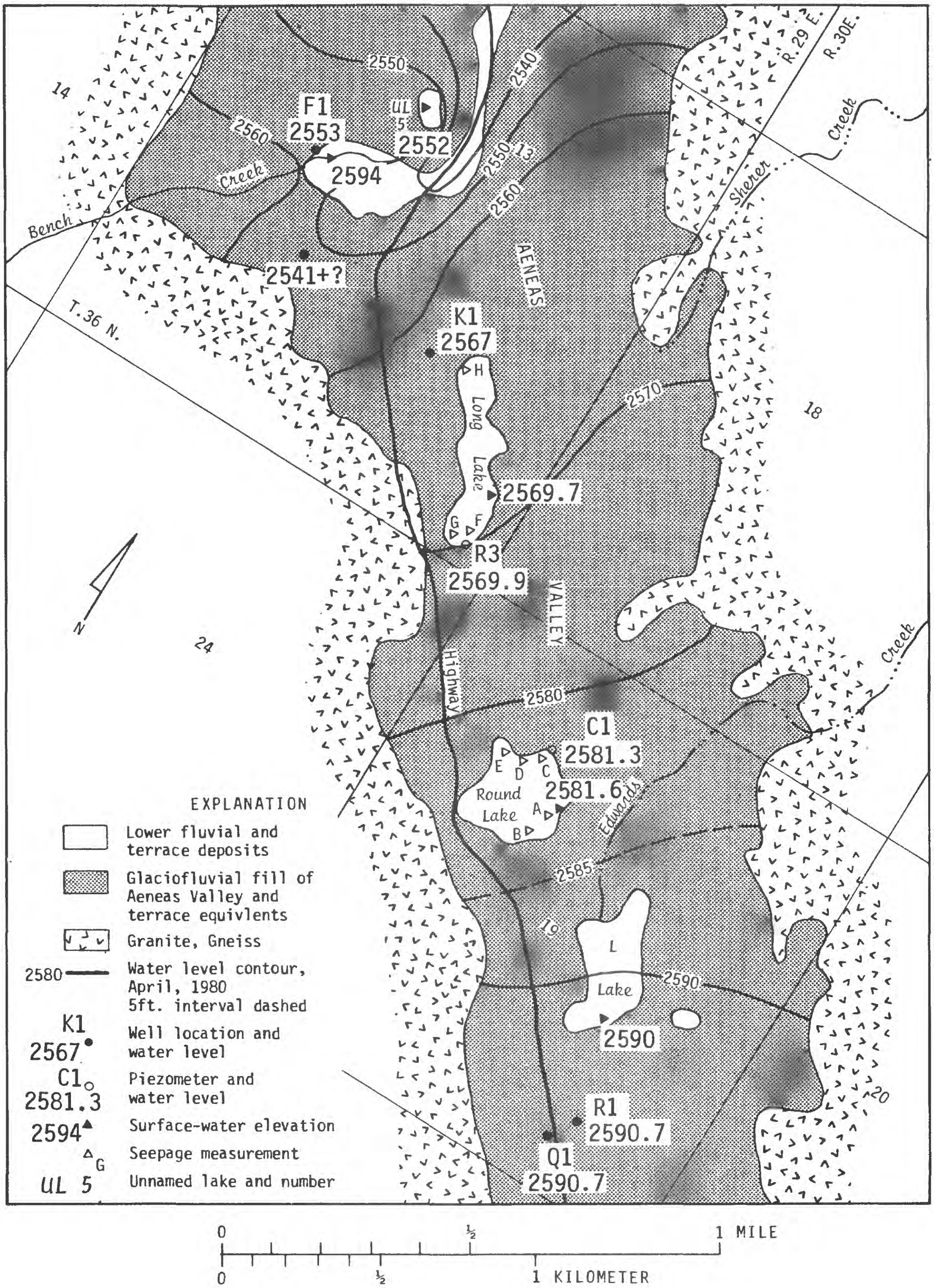

FIGURE 7.--Hydrogeologic map of the Aeneas Valley segment, April 1980.

Additional data show flow from the ground-water system into L Lake along its southeastern side. Water levels in well 19R1 are higher than those in L Lake to the northwest, and L Lake water levels, in turn, are higher than those in Round Lake. Water levels in well 13K1 are lower than those in Long Lake to the east. These data show a ground-water-flow system closely connected to the lakes, with the regional ground-water flow along the Aeneas Valley fill from southeast to northwest.

Seepage measurements (table 2) were made in Round and Long Lakes using a meter modified from a 55-gallon drum (Lee, 1977). The measurements show that the glaciofluvial fill is highly permeable and that the direction of flow is in general agreement with that inferred from ground-water gradients. Two seepage measurements along the eastern shore of Round Lake (fig. 7) showed inflow from the ground-water system into the lake, as ground-water gradients imply. Of three seepage measurements made along the western and northwestern shore of Round Lake, only one showed outflow from the lake to the ground-water system. Seepage measurements made along the southeastern shore of Long Lake showed inflow from the ground-water system to the lake, as gradients imply. One measurement made along the northwestern shore of Long Lake indicated outflow from the lake to the ground-water system, as implied by higher water levels in Long Lake than in well 13K1, west of the lake.

TABLE 2.--Results of seepage measurements in Round and Long Lakes

Station		Initial volume (mL)	Final volume (mL)	Duration test (hrs)	Date of test
Round Lake	A	0	1195	24	4/14/80
	B	0	1970	40	9/25/79
	C	980	1090	24	4/14/80
	D	1000	1245	28	4/16/80
	E	1000	840	28	4/16/80
Long Lake	F	0	1205	27	4/14/80
	G	0	7300	34	9/25/79
	H	1000	505	26	4/16/80

Note: See figure 7 for location of stations.

Lake stages and water levels in nearby wells fluctuate similarly, indicating connection between the two (fig. 5). High water levels in the wells measured occur somewhat later than high water levels in lakes, probably because recharge to the ground-water system is slower than the rise in lake levels, which are partly functions of ephemeral surface-water replenishment.

Thus, water-level data from wells, piezometers, and lakes and from seepage measurements strongly confirm a close relationship between ground water and surface water (lakes) along the Aeneas Valley. Deep kettle depressions intercept the water table and lake water is interchanged with ground water. Those kettles that bottom at altitudes above the ground-water table are usually dry because they do not intercept ground-water or surface flow. Kettle depressions that contain water during the spring of the year but are dry for the rest of the year are inferred to: (1) intercept the water table in spring, but lose their water because of a declining water table during the rest of the year; or (2) never intercept the water table, but fill because of spring surface inflow and then gradually lose this water by evaporation and by infiltration to the water table below.

In summary, because most lakes in the Aeneas Valley segment are part of the ground-water system, well pumping can lower lake water levels. The closer the well is to a lake and the greater the pumping time and rate, the greater would be the lowering of the lake level.

Upper Bonaparte Creek Segment

Flow in Bonaparte Creek (fig. 2) peaks in May, as a result of snowmelt, and reaches a low point in September (USGS record of gaging station, Bonaparte Creek near Wauconda, located in SE¼SW¼ sec. 32, T.37 N., R.29 E.; fig. 6). Flow increases in the late fall due to higher precipitation and reduced evapotranspiration, and decreases to a second low point in January, when precipitation occurs as and is stored as snowfall. The minimum flow recorded was 0.02 ft^3/s. Parts of the stream have been reported to be intermittent during the late summer and fall of some years (Arnold Haaland, Tonasket, oral commun., 1979).

Peony Creek and most of Bonaparte Creek in the upper Bonaparte segment gain water from the ground-water system (fig. 8). In April 1980, ground-water levels in piezometers were higher than adjacent stream levels in both Peony Creek and in Bonaparte Creek below the Peony Creek junction. Figures 8, 9, 10, 11, and 12 show ground-water contours, locations, and cross-section relationships among piezometers, wells and streams. In December 1979, these relationships were the same, except for ground-water levels in 36/29-3B2 and in 37/29-32R1, which were lower than those found in the adjacent streams.

Stream discharge measurements made in May 1979 along Peony Creek from a point in the NE¼ sec. 10 to the NE¼ sec. 3 indicate a significant gain in streamflow in the downstream direction. Discharge measurements (fig. 6) in Bonaparte Creek between the Peony Creek junction and a point in the NW¼ sec. 32 also indicate a gain in discharge. However, the difference in flow between these two points is less than the combined error (±5 percent) of the measurements, so that this reach cannot definitely be classified as a gaining one. In summary, data confirm that Peony Creek and Bonaparte Creek below Peony Creek gain water from the ground-water system over most of their length. A portion of this gain must come from ground water recharged in the Aeneas Valley, that slowly drains northeastward into the upper Bonaparte segment at a rate controlled by the gradients shown in figure 3 and by permeabilities of the fill.

Data indicate that Bonaparte Creek in the reach upstream from Peony Creek is a losing stream. April 1980 water-level measurements of 37/29-33M1 and 33M2 show that ground-water levels were much lower than water levels in the adjacent reaches of Bonaparte Creek (fig. 12). A seepage run in October 1980 (fig. 6) showed a downstream decrease in flow, but the decrease was less than the combined error (±5 percent) of the two measurements.

A device to measure hydraulic head in streambed sediment (potential probe, Carr and Winter, 1980) was used to determine whether sediment was saturated beneath the streambed along the above-mentioned losing reach of Bonaparte Creek. At every site, water rose in the probe above the streambed (positive water pressure in sediment), indicating that the ground-water flow in the sediment immediately beneath (6-12 inches) the streambed was saturated flow.

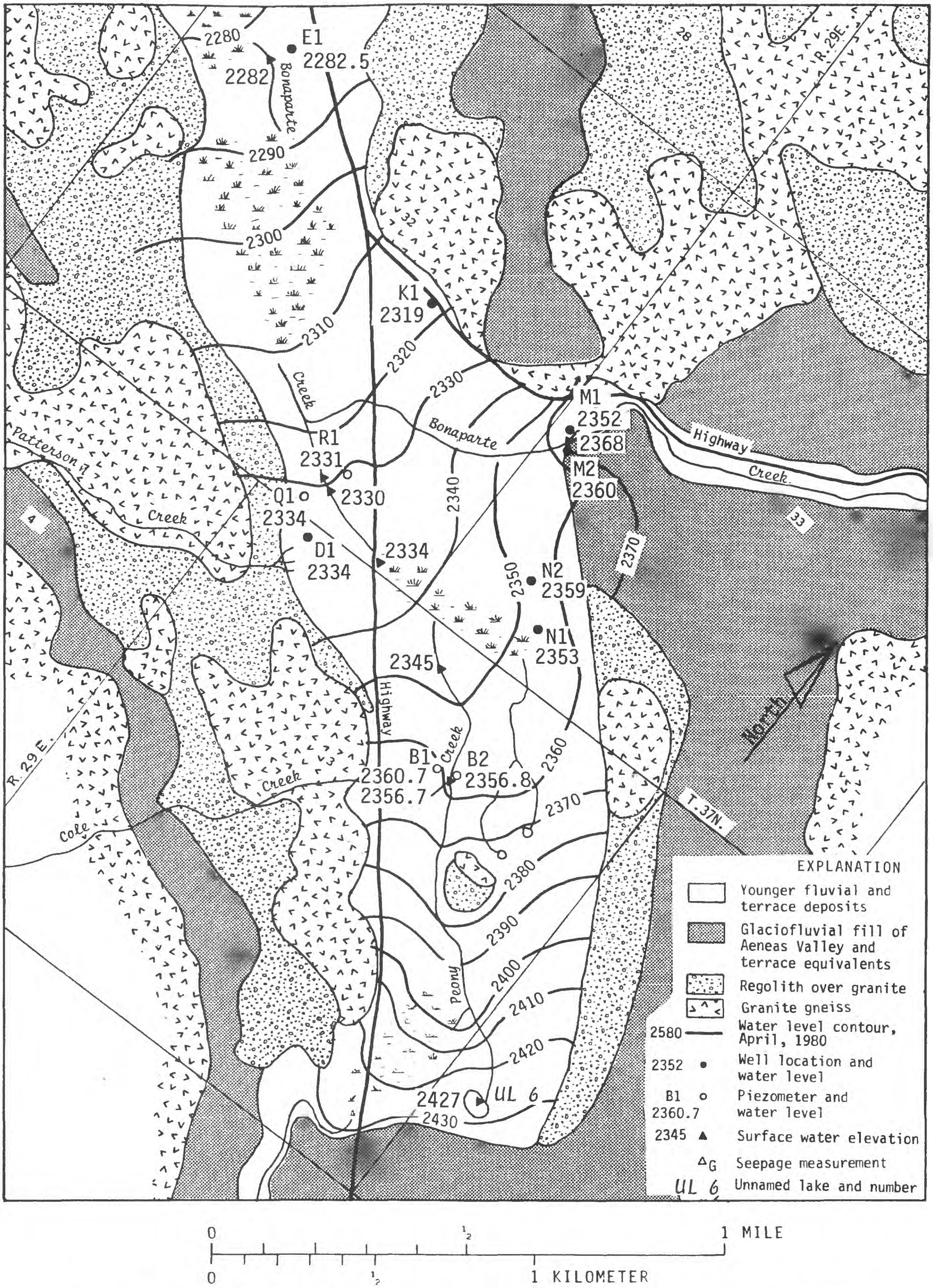

FIGURE 8.--Hydrogeologic map of the upper Bonaparte segment, April 1980.

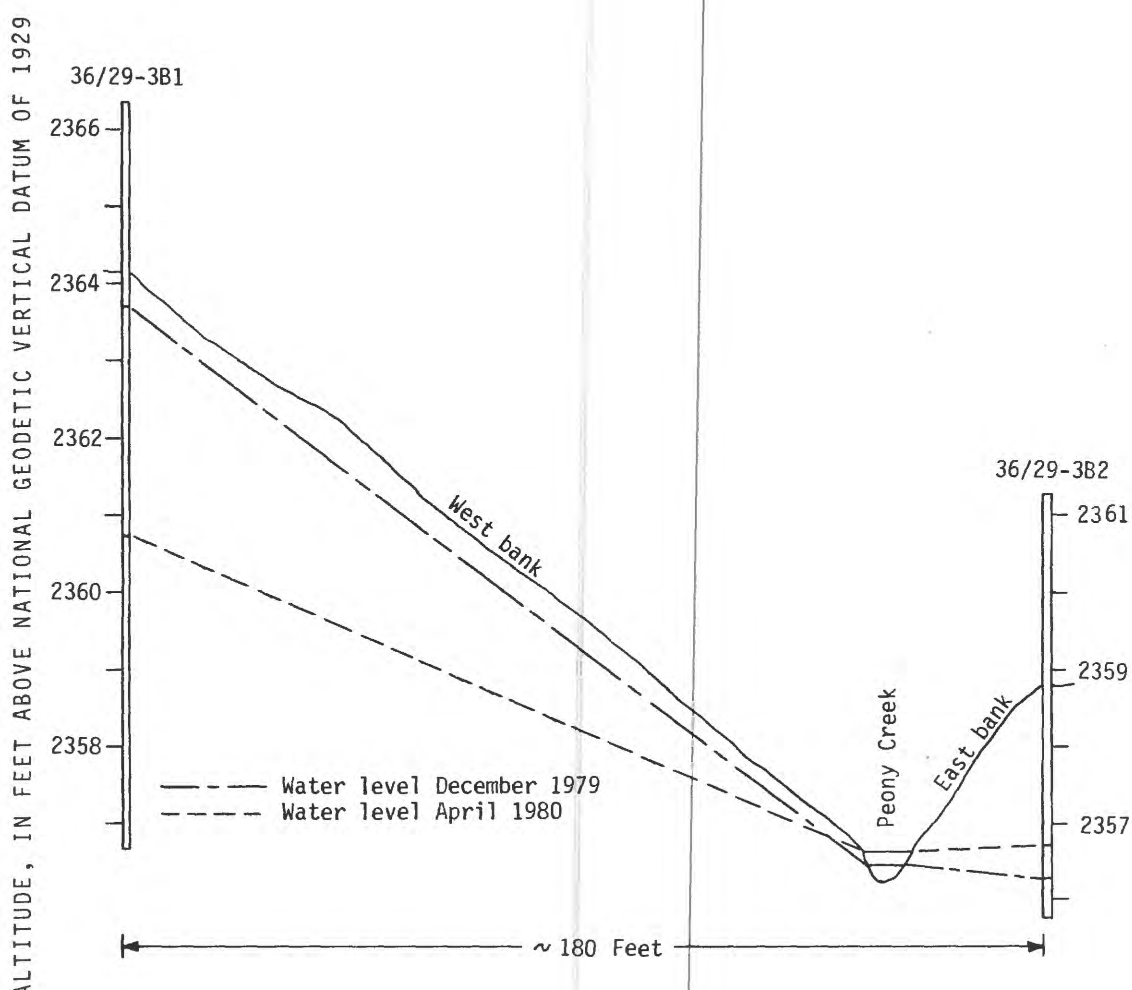

FIGURE 9.--Hydrologic cross section of ground water-surface water relationships along upper Peony Creek.

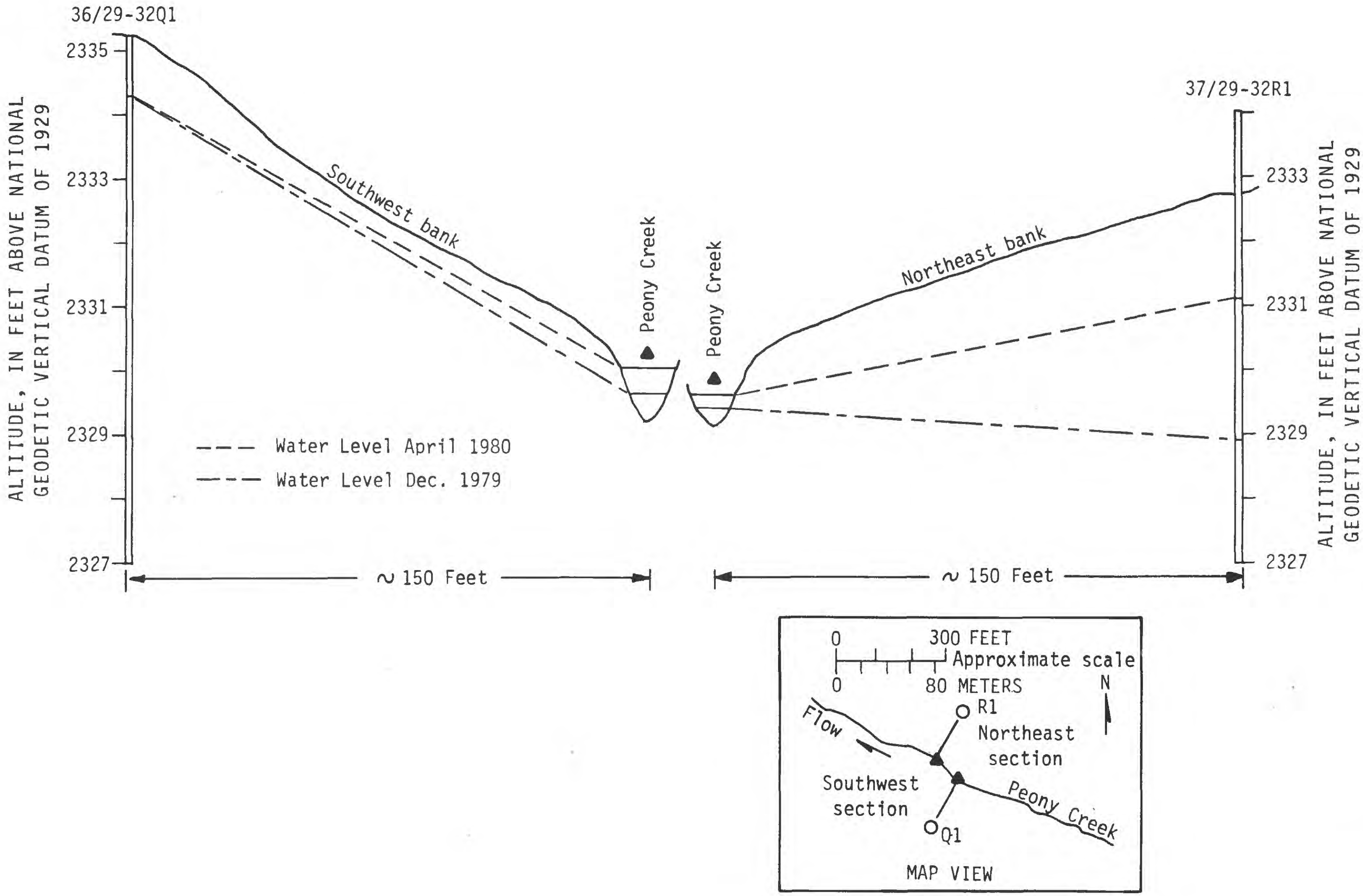

FIGURE 10.--Hydrologic cross section of ground water-surface water relationships along lower Peony Creek.

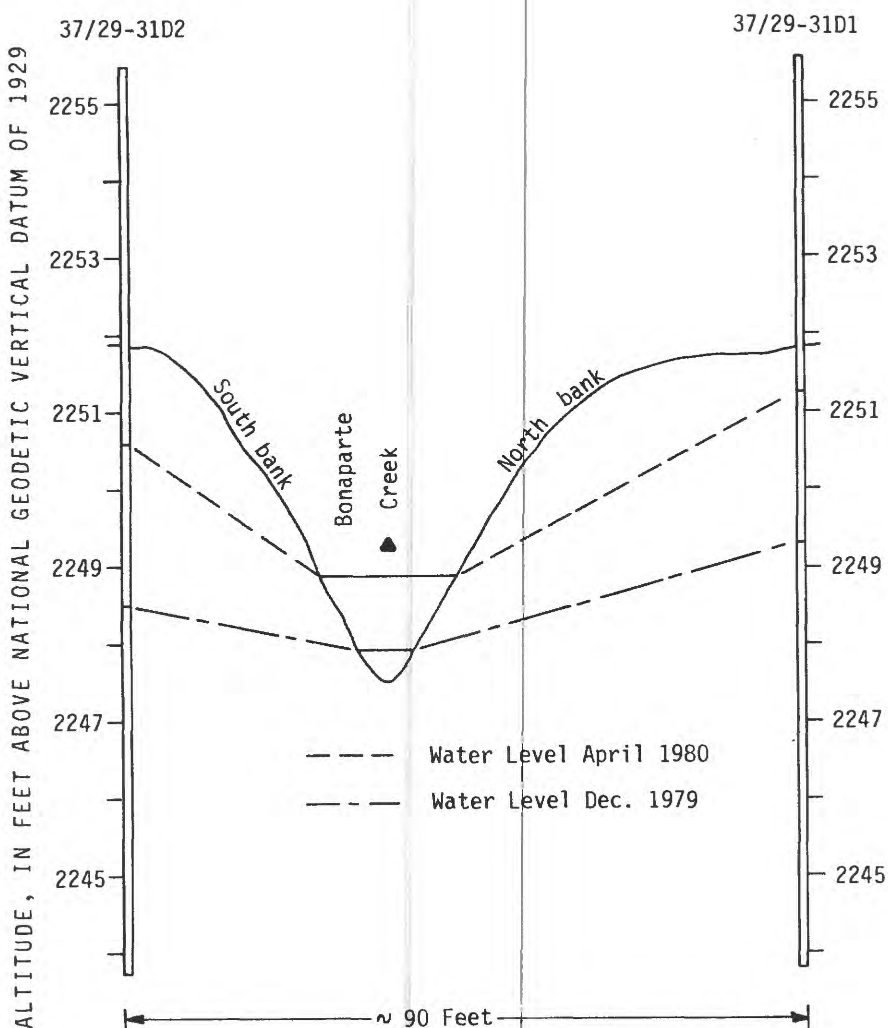

FIGURE 11.--Hydrologic cross section of ground water-surface water relationships in the western part of the upper Bonaparte segment.

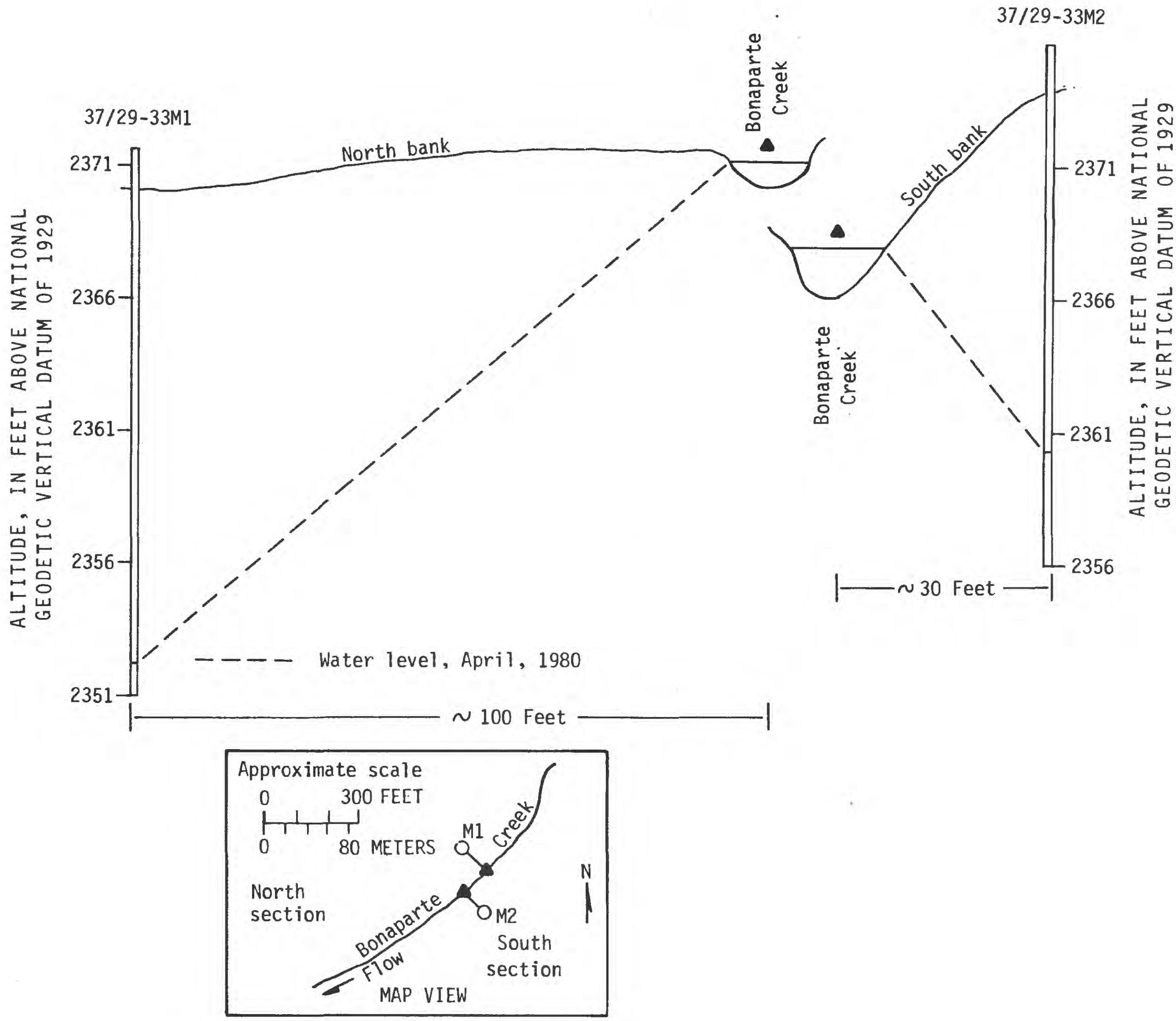

FIGURE 12.--Hydrologic cross section of ground water-surface water relationships in the eastern part of the upper Bonaparte segment.

In the upper Bonaparte basin segment, there are three lakes with almost continuous surface-water outflow and only ephemeral surface inflow. Stage and outflow were measured in UL6 (unnamed lake 6; figs. 8 and 13) in SW¼ sec. 2, T.36 N., R.29 E. Outflow was also measured from the two small ponds in the NE¼ sec. 3, T.36 N., R.29 E., but no stage measurements were made. UL6 receives only ephemeral inflow, and yet there is surface outflow year round (Roy Stoddard, oral commun., 1979) across a shallow bedrock sill on its northwestern side; 0.28 ft^3/s was measured in May 1979 . The lake is underlain by glaciofluvial fill and is surrounded by a number of small kettle depressions that bottom at higher altitudes than does UL6. Water in UL6 is derived largely from ground-water flow from the southeast. Stage variation in this lake is minimal because of the natural outflow regulation (fig. 13).

The two ponds north-northwest of UL6 in sec. 3 have surface outflow most of the year (Roy Stoddard, oral commun., 1979), but they have little or no surface-water inflow. Both ponds are underlain by alluvial fill and are supplied largely from the ground-water system.

Ground-water pumping near the losing reach of Bonaparte Creek would steepen water-table gradients away from the stream. Where there is a saturated connection between the surface- and ground-water flow systems, these steepened gradients would cause increased seepage from the stream to the ground-water system and reduced streamflow. This would not occur if flow beneath the stream was unsaturated or if ground-water levels reached just to the streambed. All ground-water pumping in the Aeneas Valley or upper Bonaparte segments would intercept ground water that otherwise eventually would flow to Bonaparte or Peony Creeks or to the lakes noted in the upper Bonaparte segment.

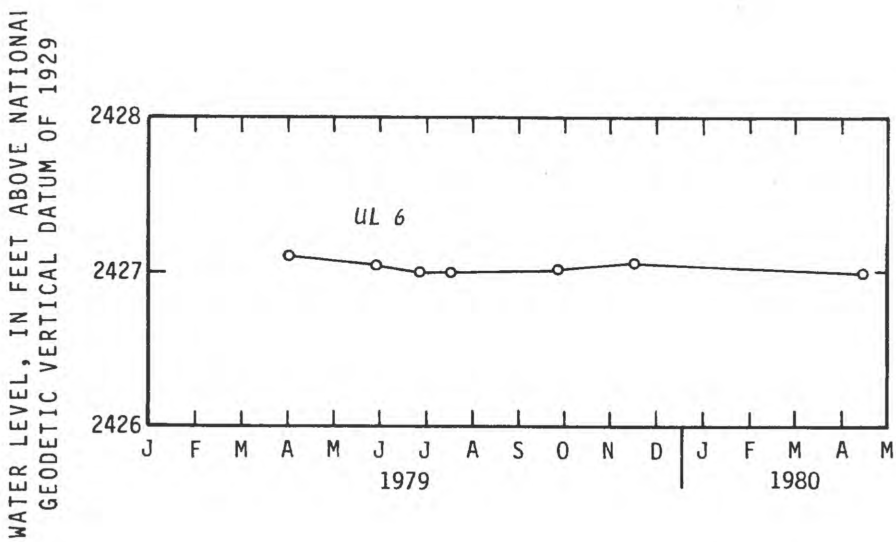

FIGURE 13.--Hydrograph of lake UL 6, 1979-80.

Lower Bonaparte Creek Segment

Two reaches with different ground-water and surface-water flow relationships can be inferred in the lower Bonaparte Creek segment. Near Anglin, April 1980 data for well 37/28-34P1 and two piezometers (fig. 14) showed ground-water levels higher than stream levels in adjacent reaches of Bonaparte Creek. This implies flow from the ground-water system into Bonaparte Creek. However, in December 1979, the water level in piezometer 2C1 was lower than the water level in the stream. Discharge measurements taken during low flow in September 1979 indicated a general decrease in flow between Anglin and the reach 1 1/2 miles downstream. However, the decrease is less than the combined error of the measurements (fig. 6).

Downstream from the data sites discussed above, several other water-level measurements were taken in April 1980, in wells 37/28-32L2 and 32L1 and in two sets of piezometers (figs. 15 and 16). These data show ground-water levels that are lower than surface-water levels in adjacent streams. In December 1979, the same relationship was measured, except for well 37/28-32L2, where measurements were not available. These data show that water from the stream is infiltrating into the ground-water system along this reach of Bonaparte Creek. Discharge measurements in the reach show a significant decrease in flow in a downstream direction (fig. 6). Additionally, in the SE$\frac{1}{4}$ sec. 32, T.37 N., R.28 E., surface flow disappears during the summer months and reappears again 1/4 to 1/2 mile downstream (B. Jellison, Tonasket, oral commun., 1979).

Based on the above data, the lower Bonaparte segment can be divided into two reaches. The upper reach probably gains water from the ground-water system during the spring high-flow parts of the year. However, during the low-flow fall and winter months, this reach may lose water to the ground-water system. The lower reach loses water during all seasons. Part of this loss flows into the cone of depression in sec. 32 (fig. 17).

At both piezometer sites (figs. 15 and 16) in the lower Bonaparte segment, piezometers adjacent to the stream indicated that infiltration was occurring under saturated conditions. Water levels in piezometers adjacent to the stream were at or above the streambed altitude. Potential-probe measurements showed a consistent rise of water above the streambed when the probe was pushed 6 to 10 inches into the bed sediment. These data show that saturated conditions existed beneath the bed of the losing reach of Bonaparte Creek during the spring high flow. A pumping well drilled near the stream would cause a steepening of the ground-water gradient away from the stream, and, where ground-water levels in the bed material are above the bed, stream discharge could be decreased.

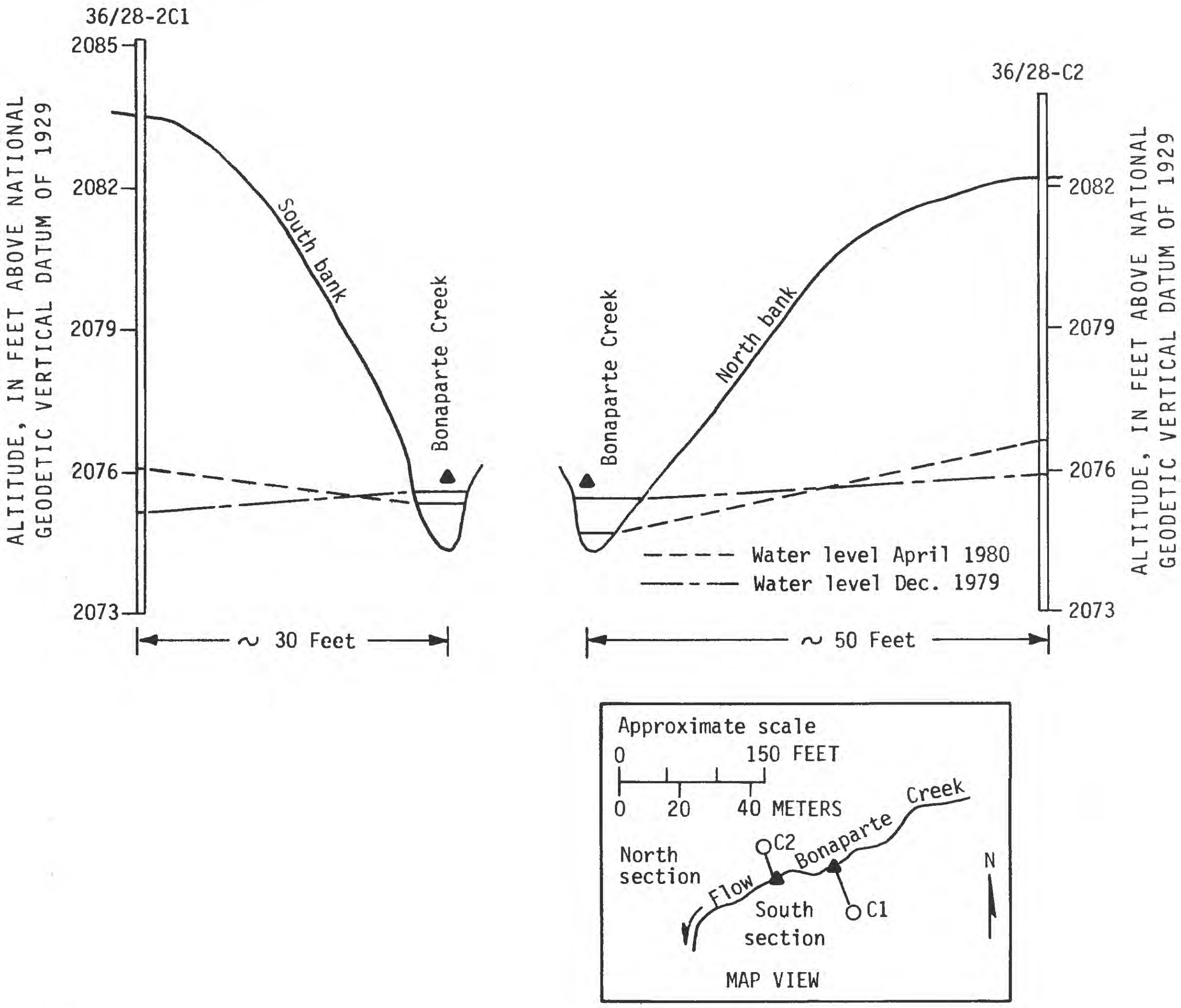

FIGURE 14.--Hydrologic cross section of ground water-surface water relationships in the eastern part of the lower Bonaparte segment.

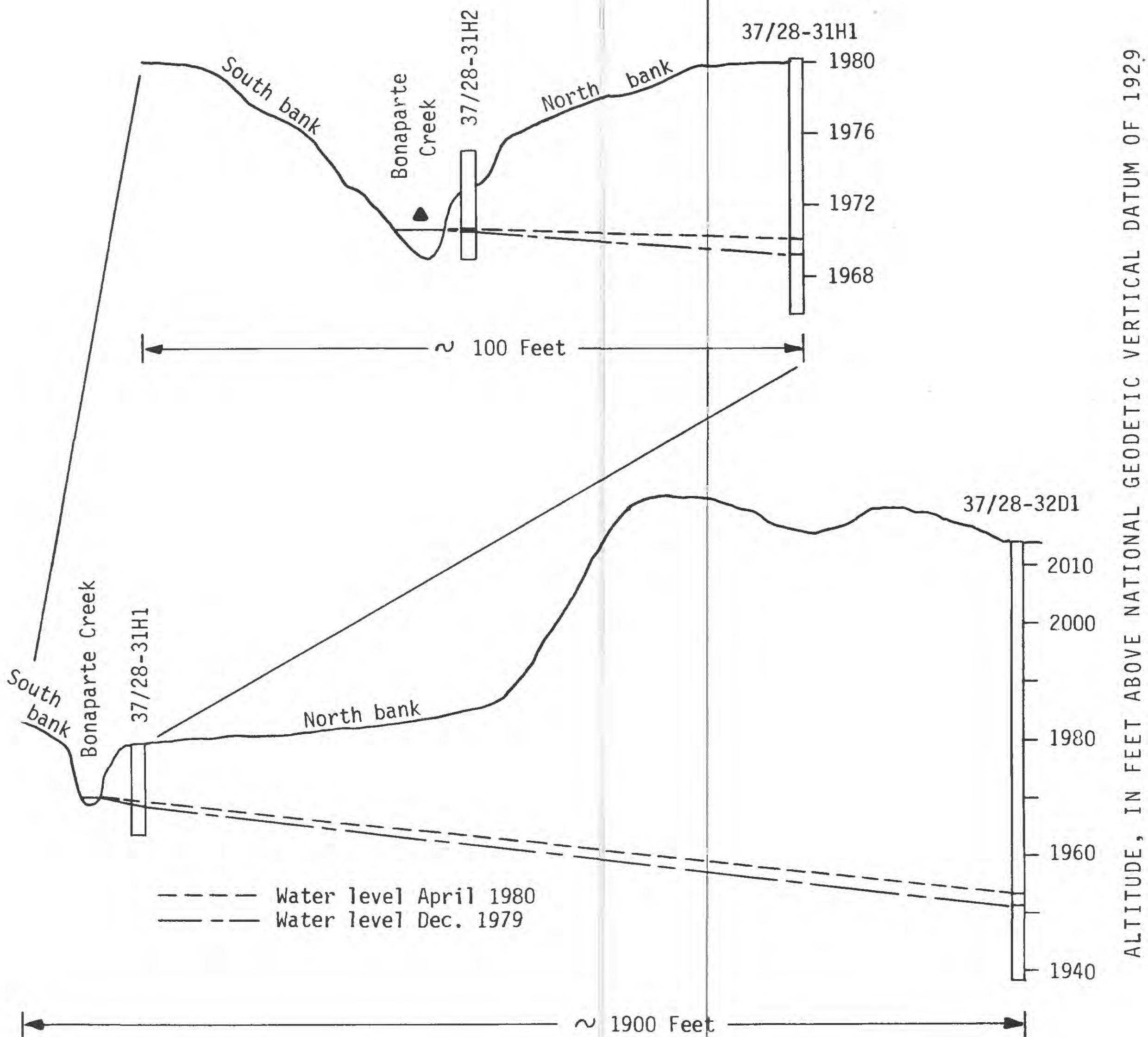

FIGURE 15.--Hydrologic cross section of ground water-surface water relationships in the center of the lower Bonaparte segment.

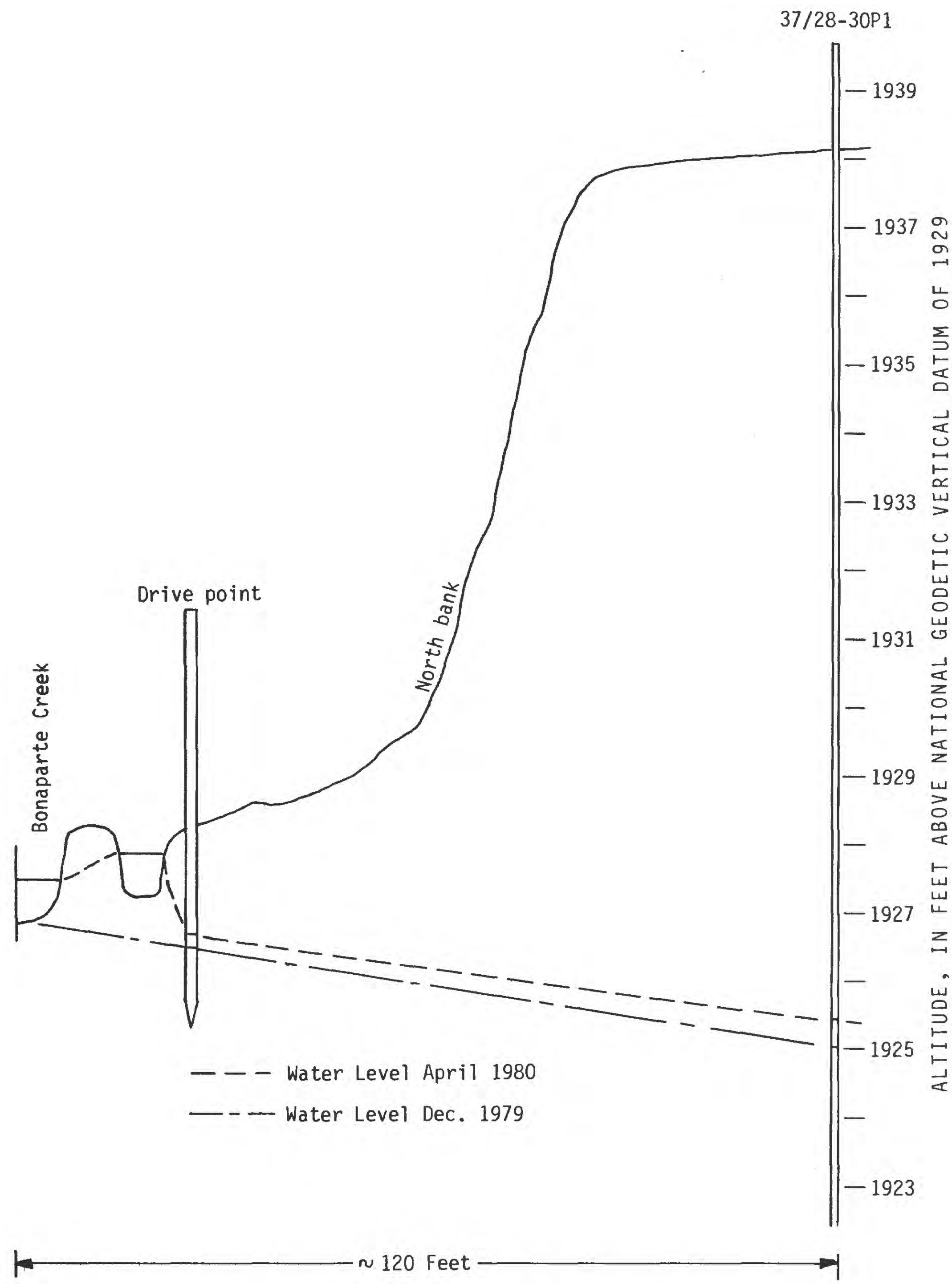

FIGURE 16.--Hydrologic cross section of ground water-surface water relationships in the western part of the lower Bonaparte segment.

A ground-water divide (fig. 17) is present in the S½ of sec 32, T.37N., R.28E. between the cone of depression and the regional flow to the immediate northwest. Pumping northwest of this divide would intercept ground water that eventually would enter the stream at one of the several bedrock sills downstream from the study area. Withdrawal of such water would, therefore, decrease flow in Bonaparte Creek.

Bannon Creek Segment

Altitudes of the streambed in Bannon Creek are above the April 1980 water table, showing that Bannon Creek is a losing stream. This is caused largely by the presence of two cones of depression, in sec. 3 and sec. 32 (fig. 17). The observed infiltration of Bannon Creek flow into the sandy material of its bed in the SE¼ sec. 3 (April 1980) supports this conclusion.

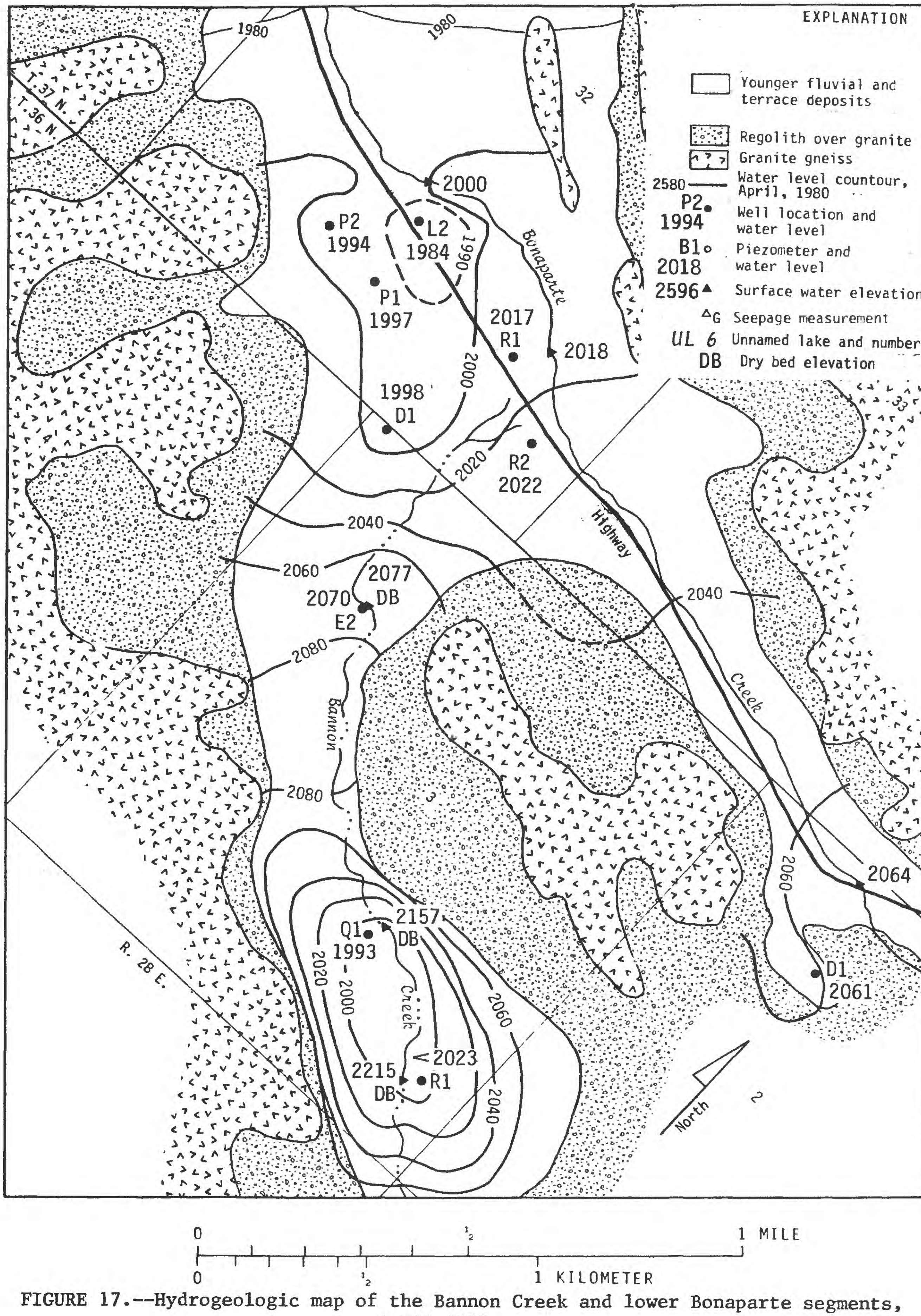

FIGURE 17.--Hydrogeologic map of the Bannon Creek and lower Bonaparte segments, April 1980.

GROUND-WATER DIVIDE BETWEEN SANPOIL AND AENEAS-BONAPARTE DRAINAGES

Based on 1980 water-level contours, the ground-water divide between the Aeneas Valley segment and the Sanpoil drainage has been drawn roughly along the axis of the ground-water mound beneath Cape Labelle Creek (fig. 18). From the marshy lake in the S½ sec. 28, the divide is interpreted to trend southwestward toward a granite ridge in sec. 32. East of this divide, ground water flows into the Sanpoil drainage basin.

South of the ground-water divide in sec. 33, Aeneas Creek loses flow to the fill deposits. The interpretation in figure 18 shows all ground-water flow contributed by Aeneas Creek to be moving eastward and southeastward to the West Fork of the Sanpoil River.

Ground-water pumping in the southeastern parts of the Aeneas valley segment could shift the divide eastward and divert ground water that presently flows to the Sanpoil basin. Gneissic bedrock sills in the Sanpoil Valley cause ground water in the fill aquifer to discharge to the surface. Therefore, interception by pumping in the Aeneas Valley could decrease flow in the Sanpoil River.

The position of this ground-water divide does not coincide with the surface-water divide that separates Sanpoil from Bonaparte surface flow (fig. 1). Additionally, it should be noted that this ground-water divide, based on 1980 water levels, lies 6 miles southeast of the previously inferred position in sec. 13 (Maddox, 1976).

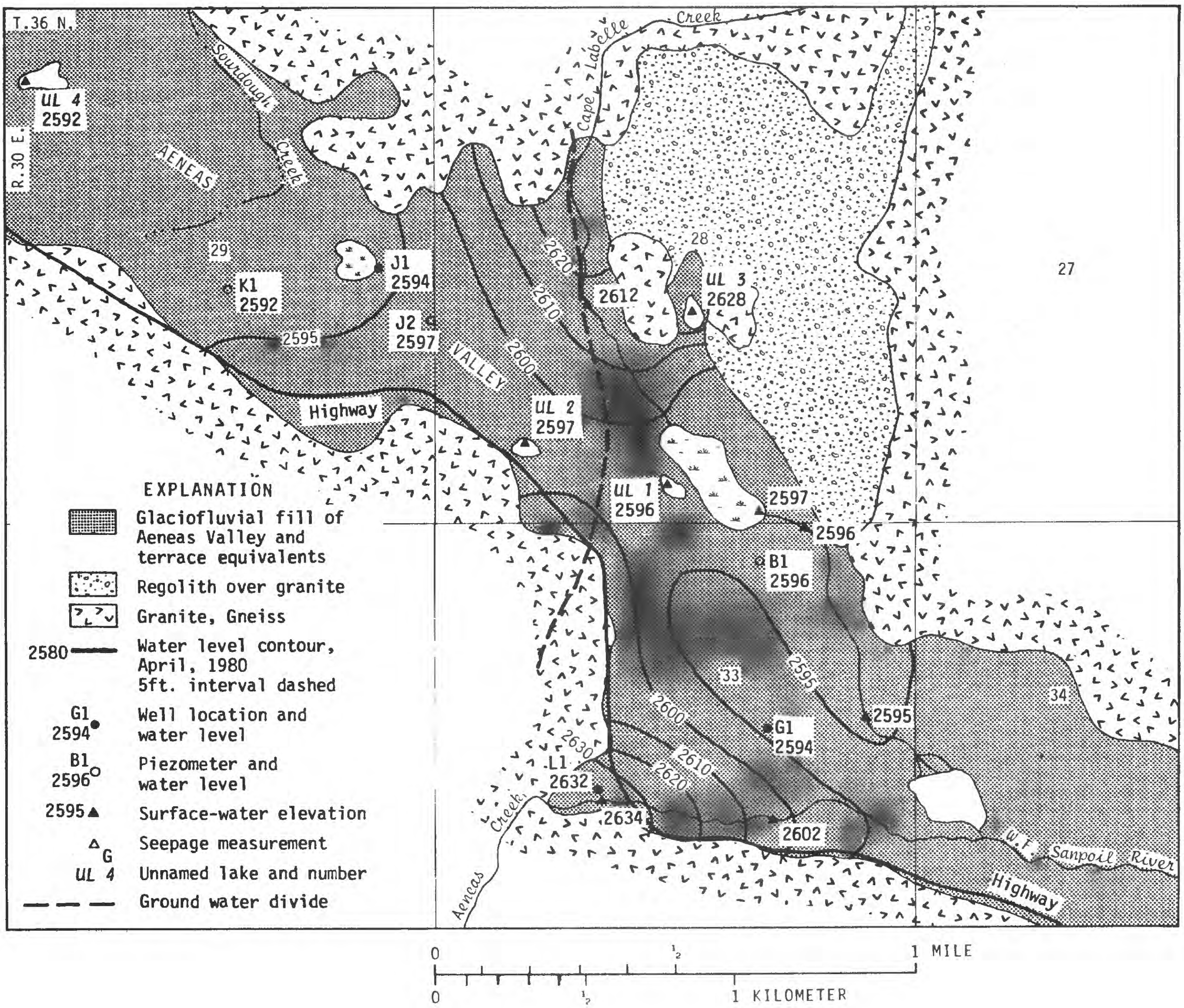

FIGURE 18.--Hydrogeologic map of the vicinity of the Aeneas/Sanpoil divide.

SUMMARY AND CONCLUSIONS

The study area, part of a 148-square-mile basin, has been divided into five valley segments based on morphology and on ground water-surface water relationships in the glaciofluvial fill.

Ground water occurs in glaciofluvial fill and in the underlying gneissic bedrock aquifers, but bedrock is so much less permeable than the fill aquifer that the two units are effectively separate. Only the fill aquifer was studied in detail.

During the study period, lakes in the Aeneas Valley and upper Bonaparte basin segments were closely connected with and dependent upon the ground-water system. Data to support this interpretation include: (1) ground-water gradients adjacent to lakes, shown by comparison of water levels in piezometers and wells with concurrent water levels in nearby lakes; (2) measurements of ground-water inflow to and outflow from lakes, using seepage instrumentation; (3) perennial discharge from lakes without significant surface-water inflow; (4) similar patterns of yearly water-level change for lakes and observation wells.

Bonaparte and Peony Creeks are hydraulically interconnected with the ground-water-flow system. Along some reaches, flow is from the ground into the streams; in other reaches the reverse is true. Data gathered during the study period to support this include: (1) water-level differences between piezometers and adjacent streams; (2) seepage measurements along Bonaparte and Peony Creeks that support the gain or loss inferred from water-level measurements; and (3) observations showing intermittent streamflow in reaches inferred to be losing.

Gaining reaches of streamflow in the upper Bonaparte segment include Peony Creek and Bonaparte Creek below the Peony Creek juncture. The easternmost one mile of Bonaparte Creek in the lower Bonaparte segment was gaining water during the spring high flows, but probably lost water during the rest of the year. All other major streams studied in the Aeneas, upper Bonaparte, lower Bonaparte, and Bannon segments were losing streams.

Two losing reaches along Bonaparte Creek were tested with a hydraulic potential probe to determine whether they had a saturated connection with the ground-water mound beneath their streambeds. In both places, the 1979-80 seepage measurements showed that the connection was saturated at least during the spring high-flow parts of the year.

The gneiss bedrock sill separating the upper and lower Bonaparte segments probably causes most of the ground-water flow in the fill aquifer to discharge into the surface-water system. No data are available to support this inference.

The ground-water divide between the Aeneas Valley segment and the Sanpoil drainage in the fill aquifer system is located beneath and near Cape Labelle Creek, in sec. 28, T.36N., R.30E. This is 6 miles southeast of its previously inferred position and 2 1/2 miles southeast of the generally accepted surface-water divide.

Extensive ground-water development is planned for the Aeneas Valley and for parts of the Bonaparte Valley. It can be inferred from conditions analyzed during this study that: (1) water levels of lakes in the Aeneas Valley and upper Bonaparte basin would decline with significant increases in local ground-water pumping from the glaciofluvial fill aquifer; (2) base flow would decline in Peony Creek and in Bonaparte Creek in the upper Bonaparte segment with significant increases in ground-water pumping from the Aeneas Valley segment or from the upper Bonaparte segment itself; (3) low-flow declines in the lower Bonaparte segment would approximately equal base-flow declines in the upper segment; (4) additional ground-water development in the lower segment would increase ground-water gradients away from Bonaparte Creek and would cause increased losses from those reaches that are in saturated connection with the ground-water system; (5) wells located west of the ground-water divide of the depression cone in sec. 32 would intercept ground-water flow that would eventually be discharged to the surface by bedrock sills; thus, such ground-water development would reduce surface flow either in or just downstream from the study area; and (6) ground-water development in the Aeneas Valley segment could move the Aeneas-Sanpoil ground-water divide eastward and intercept water that presently flows into the Sanpoil River basin.

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APPENDIX A.--Water-level elevations in wells, March 1979 through April 1980

Well number	MP elevation	3/29/79	4/3/79	5/29/79	7/16/79	9/25/79	11/13/79	12/12/79	4/14/80
36/28-2C1	2,085.13							2,075.13	2,076.08
-2C2	2,083.88							2,075.88	2,076.57
-2D1	2,091.58		2,059.45	2,059.71	2,059.76	2,059.56	2,059.53		2,060.57
-3D1	2,052.00		1,997.77			1,967.14	1,978.03		1,997.98
-3E2	2,083.38		2,068.14	2,067.56	2,067.33	2,067.45	2,066.76		2,069.63
-3Q1	2,167.95		1,991.68			1,986.83	1,987.53		1,993.43
-3R1	2,202.84						2,023.		2,023.
36/29-3B1	2,366.37							2,363.70	2,360.73
-3B2	2.361.30							2,356.33	2,356.78
-3D1	2,338.04		2,330.62			2,335.13			2,334.37
-11F1	2,531.67	2,485.00		2,484.90	2,484.90	2,484.71	2,484.43		2,484.28
-12P1	2,554.90								2,535.36
-13F1	2,595.28	2,552.13					2,550.34		2,552.85
-13K1	2,579.45					2,564.44	2,565.62		2,567.03
-13L1	2,673.41		2,541.31						2,541.18
-13R1	2,623.24						2,567.86		2,559.12
-13R3	2,583.26							2,568.75	2,569.93
36/30-19C1	2,585.25							2,579.40	2,581.28
-19Q1	2,608.62	2,590.54		2,591.06	2,590.78	2,589.95	2,589.52		2,590.68
-19R1	2,599.09		2,589.89						2,590.72
-29J1	2,600.63	2,593.12				2,593.48	2,591.05		2,594.40
-29J2	2,605.12							2,591.50	2,596.69
-29K1	2,605.01							2,590.04	2,593.13
-33B1	2,607.19							2,591.84	2,595.76
-33G1	2,606.85	2,594.29		2,595.71	2,594.79	2,592.67	2,591.80		2,594.47
-33L1	2,638.06								2,632.47
-33L2	2,641.71								2,636.98
37/28-30P1	1,939.64							1,925.01	1,925.41
-30P2	1,931.51								1,926.70
-31H1	1,980.23							1,969.23	1,970.14
-31H2	1,975.04								1,970.69
-32D1	2,014.24							1,951.28	1,953.22
-32L1	2,011.93		1,984.51			1,967.13	1,972.22		
-32L2	2,013.27		1,984.53			1,966.76	1,973.32		1,984.48
-32P1	2,032.40		1,995.66				1,982.63		1,997.06
-32P2	2,025.07		1,994.32				1,983.37		1,994.41
-32R1	2,024.71		2,016.71	2,014.68	2,013.40	2,013.65	2,014.14		2,016.68
-32R2	2,027.49		2,024.95				2,016.17		2,022.08
-34P1	2,108.00		2,097.82				2,097.60		2,098.14
-36D1	2,222.49						2,219.55		2,218.93
37/29-30N1	2,259.31		2,248.04		2,247.25	2,246.88	2,247.21		2,247.98
-31D1	2,255.62							2,249.29	2,251.29
-31D2	2,255.48							2,248.49	2,250.60
-31D3	2,246.90		2,245.77	2,245.28	2,244.59	2,244.44	2,245.07		2,245.05
-32E1	2,290.31		2,284.54		2,284.31	2,284.43	2,284.44		2,282.47
-32K1	2,345.13	2,317.66					2,317.49		2,318.76
-32Q1	2,335.23							2,334.30	2,334.30
-32R1	2,534.08							2,328.93	2,331.12
-33M1	2,371.77	2,353.08					2,353.32		2,352.36
-33M2	2,375.81	2,359.39					2,357.71		2,360.37
-33N1	2,354.62		2,353.10		2,353.94	2,352.94	2,353.15		2,353.17
-33N2	2,368.97		2,358.62	2,360.27	2,360.82	2,359.79	2,359.41		2,359.27

[a]Dry above 2,023 ft.

[b]Oil cut.

APPENDIX B.--Water-level elevations in lakes, April 1979 through April 1980

Lake name	4/3/79	4/26/79	5/17/79	5/29/79	6/26/79
Unnamed lake #1 (UL1	2,595.28				2,596.24
Marsh northeast of UL1					
Unnamed lake #2 (UL2)					
Unnamed lake #3 (UL3)					
Unnamed lake #4 (UL4)	2,590.98			2,591.50	2,591.36
Marsh northwest of UL4				2,590.87	
L Lake	2,588.77	2,588.82	2,588.78	2,588.71	2,588.48
Round Lake	2,581.84	2,581.86	2,581.74	2,581.63	2,581.45
Long Lake	2,569.57	2,569.55	2,569.44	2,569.36	2,569.26
UL5	2,549.82	2,550.36	2,549.84	2,549.62	2,549.21
UL6	2,427.11			2,427.07	2,427.00

	7/16/79	9/25/79	11/13/79	12/12/79	4/14/80
Unnamed lake #1 (UL1)	2,595.77	2,593.56	2,592.92		2,596.41
Marsh northeast of UL1	2,593.47			2,596.52	
Unnamed lake #2 (UL2)				2,596.93	
Unnamed lake #3 (UL3)				2,627.61	
Unnamed lake #4 (UL4)	2,591.18	2,590.31	2,589.96		2,591.92
Marsh northwest of UL4					
L Lake	2,588.36	2,587.88	2,587.83		2,590.03
Round Lake	2,581.32	2,580.83	2,580.86	2,580.85	2,581.55
Long Lake	2,569.17	2,568.79	2,568.63	2,568.65	2,569.73
UL5	2,548.94	2,548.26	2,548.17		2,552.09
UL6	2,427.00	2,427.01	2,427.06		2,427.00

Note: Unnamed lakes (UL) are located on figure 18.

APPENDIX C.--Water-level elevations on streams in the Bonaparte area, July 1979 through April 1980

Location of measurement	7/16/79	9/25/79	12/12/79	4/14/80
Aeneas Cr south of well 36N/30E-33L2				2634.34
Aeneas Cr south of well 36N/30E-33L1				2634.25
Aeneas Cr south of well 36N/30E-33G1				2602.37
Cape Labelle Cr east of well 36N/30E-33G1				2595.11
Cape Labelle Cr northeast of well 36N/30E-33B1				2596.46
Marsh along Cape Labelle Cr northeast of unnamed lake #1		2593.47		2596.52
Cape Labelle Cr due west of unnamed lake #3				2612.12
Bench Cr east of well 36N/29E-13F1				2594.
Peony Cr near well 36N/29E-3B2			2356.54	2356.72
Peony Cr 200 yds northwest of well 36N/29E-3B2				2344.82
Peony Cr at east end of culvert on Aeneas Hwy, northeast of well 36N/29E-3D1				2333.70
Peony Cr at bridge northeast of well 37N/29E-32Q1			2329.69	2330.07
Peony Cr 100 ft downstream from above			2329.46	2329.60
Bonaparte Cr southeast of well 37N/29E-33M1				2371.28
Bonaparte Cr northwest of well 37N/29E-33M2	2367.27			2368.03

APPENDIX C.--Water-level elevations on streams in the Bonaparte area, July 1979 through April 1980--Continued

Location of measurement	7/16/79	9/25/79	12/12/79	4/14/80
Bonaparte Cr south of well 37N/29E-32E1				2282.06
Bonaparte Cr at bridge south of well 37N/29E-31D1			2247.94	2248.89
Bonaparte Cr south of well 37N/29E-30N1				2245.94
Bonaparte Cr south of well 37N/29E-31D3	* 2241.86			
Bonaparte Cr south of well 37N/28E-36D1				2215.80
Bonaparte Cr north of well 36N/28E-2C1			2075.45	2075.36
Bonaparte Cr south of well 36N/28E-2C2			2074.73	2074.66
Bonaparte Cr north of well 36N/28E-2D1				2064.14
Bonaparte Cr northeast of well 37N/28E-32R1				2018.28
Bannon Cr dry bed southwest of well 36N/28E-3R1				2215.
Bannon Cr dry bed north of well 36N/28E-3Q1				2157.
Bannon Cr dry bed north of well 36N/28E-3E2				2077.
Bonaparte Cr northwest of well 37N/28E-32L2				2000.48
Bonaparte Cr south of well 37N/28E-31H1			1970.55	1970.70
Bonaparte Cr south of well 37N/28E-30P1			1926.82	1927.89

*Measurement taken 8/8/79.

APPENDIX D--Drillers' logs of selected wells, Bonaparte study area

Material	From (ft)	To (ft)
36/28-2C1		
Silt and clay, dark, organic	0	2
Sand, silty, tan	2	5
Sand, fine, brown	5	6
Sand and gravel	6	7
Sand, coarse, and granules	7	15
36/28-2C2		
Soil, dark, organic	0	3½
Clay and silt	3½	7½
Silt and sand	7½	12
36/28-3D1		
Topsoil	0	2
Sand and gravel	2	20
"Hardpan"	20	35
Clay	35	110
Silt	110	143
Sand and gravel, water-bearing	143	165
36/29-3B1		
Silt	0	2
Sand, fine, silty	2	7.5
36/29-3B2		
Hole dug with post hole digger		
Silt, black, fine	0	3
36/29-13L1		
Sand, fine, and boulders	0	20
Sand, coarse	20	80
Granite, gray, and decomposed	80	83
Granite, gray, water-bearing at 250 ft	83	260
36/29-13R1		
Sand, gravel, boulders	0	40
Granite, decomposed	40	42
Granite, gray, with some fractures	42	250

APPENDIX D.--Drillers' logs of selected wells, Bonaparte study area--Con.

Material	From (ft)	To (ft)
36/29-13R2		
Sand and boulders	0	20
Sand and gravel	20	55
Granite, decomposed	55	60
Granite, gray, with some fractures	60	295
36/29-13R3		
Silt and cobbles	0	2
Sand, coarse, and silt	2	9
36/30-19C1		
Muck, black	0	3
Muck, white	3	7.5
36/30-19Q1		
Sand and gravel	0	50
Sand, fine	50	120
Gravel, coarse	120	140
36/30-29J2		
Soil, dark, organic, silty	0	1
Gravel, pebbles, cobbles	1	5
Sand, coarse, and fine gravel	5	13
Gravel, granules, pebbles	13	15
Sand, coarse, and fine gravel	15	22
36/30-29K1		
Soil, silty, with organic material	0	1
Sand, fine	1	6
Sand, coarse, and gravel	6	8
Gravel, pebbles	8	9
Gravel, fine to coarse	9	12
Gravel, with some sand	12	16

APPENDIX D.--Drillers' logs of selected wells, Bonaparte study area--Con.

Material	From (ft)	To (ft)
36/30-33B1		
Sand, fine, silt, and organic material-------------------	0	6
Sand, fine, and gravel----------------------------------	6	10
Silt, and fine grained sand-----------------------------	10	16
No return, probably sand and gravel---------------------	16	21
Gravel, coarse--	23	25
36/30-33G1		
Topsoil---	0	10
Sand, fine--	10	26
Sand and gravel---	26	35
Gravel, compacted---------------------------------------	35	38
Sand--	38	59
Silt--	59	122
Sand and gravel---	122	125
Bedrock---	125	126
37/28-39P1		
Sand, fine, and soil------------------------------------	0	1.5
Sand, fine, light brown---------------------------------	1.5	2.5
Gravel--	2.5	3
Sand, fine--	3	4.5
Gravel--	4.5	8
Sand, fine--	8	10.5
Gravel, cobbles---	10.5	11.5
Sand, with some gravel----------------------------------	11.5	14
Gravel--	14	14.5
Sand--	14.5	15
Gravel--	15	18.5
37/28-31H1		
Silt, dark brown organic--------------------------------	0	2
Sand and silt, tan, fine--------------------------------	2	5
Sand and silt, light brown, fine------------------------	5	8
Clay and silt, brown------------------------------------	8	15
37/28-32D1		
Silt, black---	0	2
Silt, fine, brown---------------------------------------	2	5
Clay and silt, tan--------------------------------------	5	44
Sand, fine, tan---	44	77

APPENDIX D.--Drillers' logs of selected wells, Bonaparte study area--Con.

Material	From (ft)	To (ft)
37/28-32L1		
Topsoil	0	2
Clay and silt	2	40
Sand, some gravel	40	44
Clay	44	56
"Hardpan"	56	63
Gravel, compact	63	76
"Hardpan"	76	110
Gravel, water-bearing	110	128
37/28-32P1		
Topsoil	0	5
Clay and silt	5	56
"Hardpan"	56	62
Clay, blue	62	68
"Hardpan," blue	68	112
Clay, hard, yellow	112	164
Gravel and sand, compact	164	176
Sand, fine	176	185
Sand, coarse	186	202
37/29-31D1		
Silt with organic material, dark brown	0	2
Silt, tan, and fine sand	2	5
Silt and clay, brown	5	8
37/29-31D2		
Silt and clay, dark, with organic material	0	6
Sand and silt, dark, wet	6	7.5
37/29-32Q1		
Clay, dark, organic	0	6
Sand, silty, medium to coarse	6	8.5
37/29-32R1		
Clay, black	0	2
Silt, black, water at 4 ft	2	5
Sand, fine, and black silt	5	9