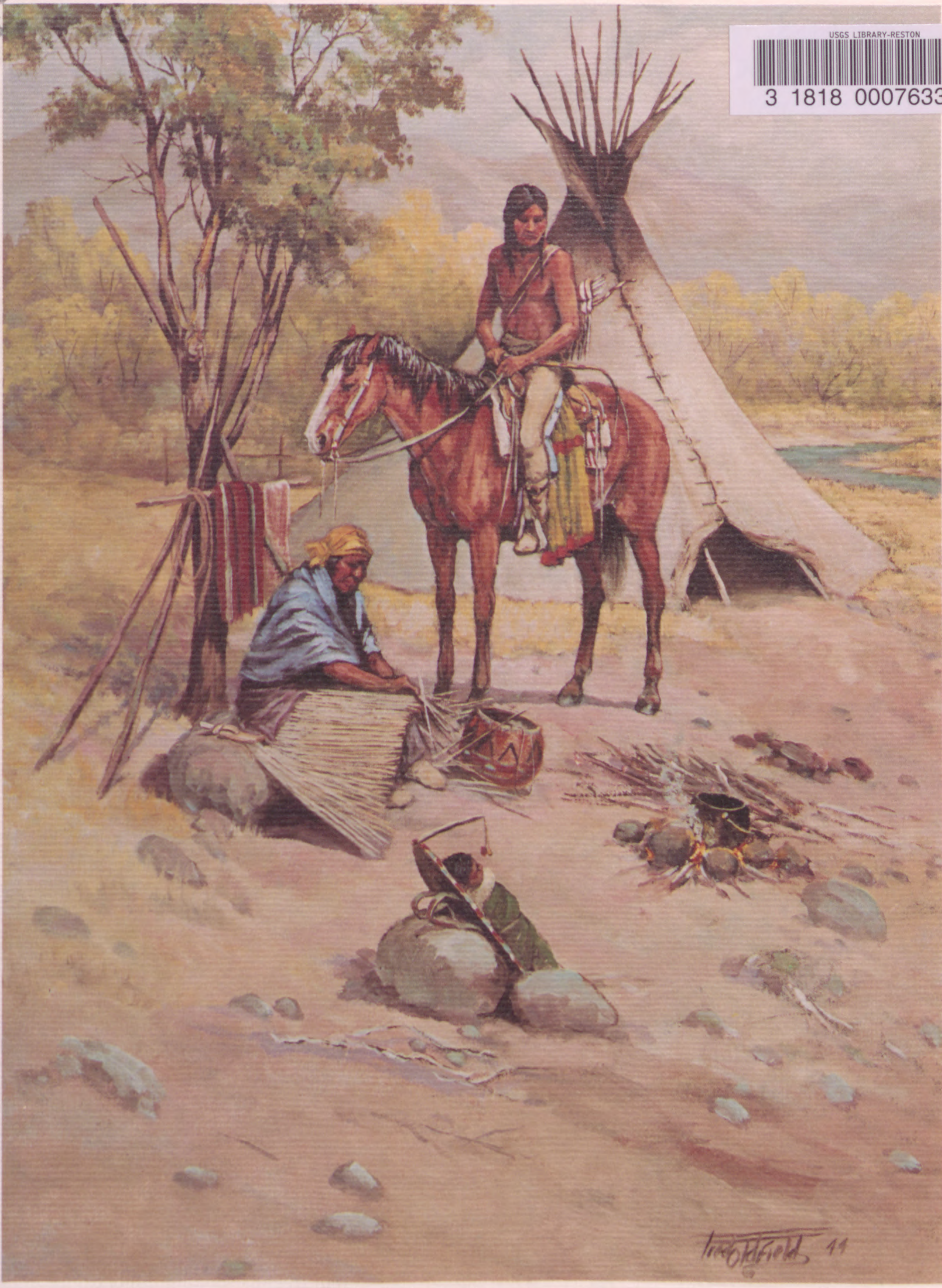

WATER RESOURCES OF THE SATUS CREEK BASIN YAKIMA INDIAN RESERVATION, WASHINGTON

U.S. GEOLOGICAL SURVEY

Open-File Report 76-685

Prepared in cooperation with the Yakima Tribal Council

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY,

WATER RESOURCES OF THE SATUS CREEK BASIN, YAKIMA INDIAN RESERVATION, WASHINGTON

By M. J. Mundorff, R. D. Mac Nish, and D. R. Cline

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Tacoma, Washington
1977

Cover provided by the
Yakima Tribal Council
from painting by Fred Oldfield,
who was born and raised on the
Yakima Indian Reservation

For further information on this investigation and on other water-resources studies in Washington carried out by the U.S. Geological Survey, contact the U.S. Geological Survey, Water Resources Division, 1201 Pacific Avenue, Suite 600, Tacoma, Washington 98402.

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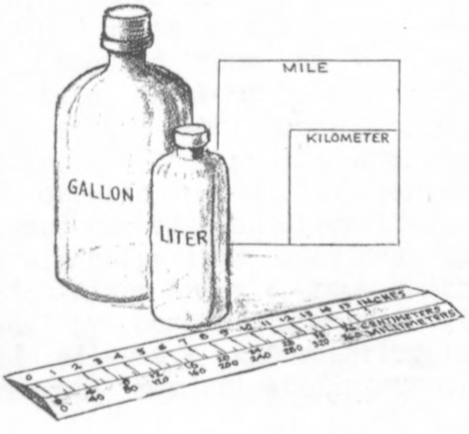
METRIC CONVERSION TABLE

Multiply	By	To obtain
Inches	25.4	millimeters (mm)
	2.54	centimeters (cm)
	.0254	meters (m)
Feet (ft)	.3048	meters (m)
Miles (mi)	1.609	kilometers (km)
Square miles (mi^2)	2.590	square kilometers (km^2)
Acres	4047.	square meters (m^2)
Acre-feet (acre-ft)	1233.	cubic meters (m^3)
Cubic feet per second (ft^3/s)	28.32	liters per second (L/s)
	.02832	cubic meters per second (m^3/s)
Gallons per minute (gal/min)	.06309	liters per second (L/S)
Gallons per minute per foot [(gal/min)/ft]	.2070	liters per second per meter [(L/s)/m]
Feet per second (ft/s)	.3048	meters per second (m/s)
Feet squared per day (ft^2/d)	.0929	meters squared per day (m^2/d)



WATER RESOURCES OF THE SATUS CREEK BASIN, YAKIMA INDIAN RESERVATION, WASHINGTON

By M. J. Mundorff, R. D. Mac Nish, and D. R. Cline

ABSTRACT

The Satus Creek basin lies on the east flank of the Cascade Range in south-central Washington. The basin is entirely within the Yakima Indian Reservation and is bordered and drained on the east by the Yakima River.

Average annual precipitation ranges from about 35 inches in the western upland to less than 10 inches in the eastern lowland. This amounts to a yearly total of about 562,000 acre-feet, most of which falls in the upland. Much of the precipitation falls as snow, and the streamflow from the upland reflects this fact, having a high sustained runoff during the snowmelt months of April, May, and June.

In 1973 about 176,000 acre-feet of water was carried by canals for irrigation of about 19,000 acres in the lowland; of this quantity, about 173,000 acre-feet was imported from the adjoining Toppenish Creek basin. This high application rate of about 9.25 acre-feet of water per acre is largely responsible for severe waterlogging problems in many parts of the lowland. Also contributing to the problem are the fine-grained sedimentary deposits that generally overlie the alluvial sand and gravel aquifers in the lowland and retard downward percolation of applied water into those units. In other areas the upward discharge from aquifers in the underlying Yakima Basalt of the Columbia River Basalt Group contributes to waterlogging. Relieving artesian heads by pumping, combined with reduced application and improved drainage, could alleviate the waterlogging, and free water for use in the irrigation of presently nonirrigated parts of the basin.

Young volcanic rocks (basalt) in the southwestern, upland part of the basin appear to contain significant ground-water reservoirs. These rocks receive nearly 70,000 acre-feet a year in recharge from precipitation and, although much of this water is what sustains the high base flows of the streams draining the rocks, the remaining water offers potential for development as a high-altitude source for irrigation water.

INTRODUCTION

Location and Extent of Area

The Satus Creek basin in the southeastern part of the Yakima Indian Reservation in south-central Washington (fig. 1) is oval shaped, about 40 miles long (east-west) and 20 miles wide. It drains generally northeastward to the Yakima River. The 710-mi^2 basin includes the drainage basin of Satus Creek and a smaller area (about 92 mi^2) to the east that is drained directly to the Yakima River. The basin is bounded on the north by the crest of Toppenish Ridge and on the south by the crest of Horse Heaven Hills which is generally the southern boundary of the reservation. The Yakima River forms the eastern boundary of the basin, and the Satus Creek-Klickitat River drainage divide forms the western boundary.

For this study and report, the Satus Creek basin was divided into two general areas of discussion--the lowland and the upland. The lowland, which covers about 66 mi^2 (42,000 acres), is the more heavily developed by homes and farms and includes the area east and downslope of the Satus Pump Canal (fig. 1). The upland includes the area west and upslope of the canal, and covers about 644 mi^2 (412,000 acres). The major drainage subbasins of the project area are shown in figure 1.

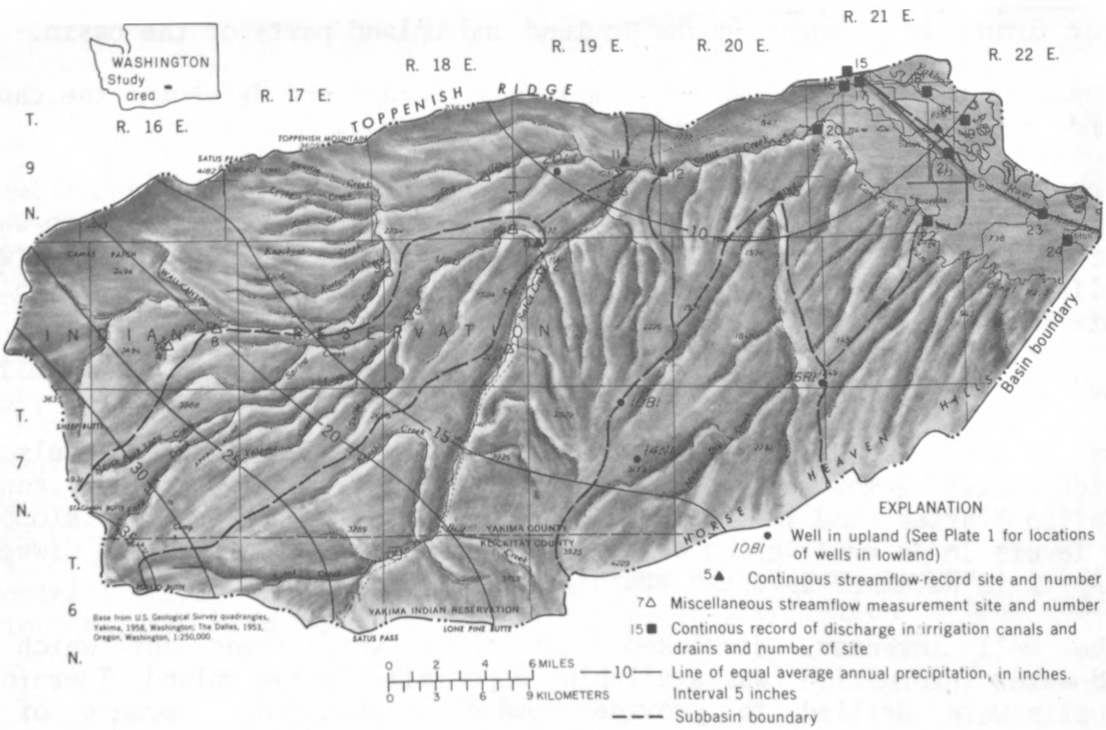


FIGURE 1.--Measuring-site subbasins, streamflow measuring sites, wells in the upland, and areal distribution of average annual precipitation in the Satus Creek basin. Precipitation from U.S. Weather Bureau (1965).

Purpose and Scope of Investigation

This report is part of a comprehensive water-resources study of the Yakima Indian Reservation conducted by the U.S. Geological Survey in cooperation with the Yakima Tribal Council.

The objectives of the investigation include the following:

1. Evaluate the surface-water resources of the basin.

2. Identify aquifers and evaluate the ground-water resources and potential for future development in the lowland and upland parts of the basin.

3. Evaluate the waterlogging problem in the lowland and determine the causes and possible means of its alleviation.

Long-term records of flows in streams, diversions to canals, and flows in drains provided basic data for analysis and evaluation of the surface-water resources. For additional data, continuous-recording gaging stations were established on Dry, Logy, and Mule Dry Creeks. Miscellaneous discharge measurements also were made at other sites on these streams, to determine the areas contributing to streamflow and to the gains and losses in various reaches of the streams.

An inventory was made of 129 wells in the basin, and water levels in selected wells were measured in the spring of 1971 and 1972 before annual irrigation started, and in September of 1971 before irrigation stopped. Water levels in a small group of representative wells were measured biweekly from April to November 1973 and monthly thereafter to April 1974.

The well inventory disclosed that there were areas for which no ground-water information was available, especially in the upland. Therefore, test wells were drilled to provide needed information. Because of the expense involved, however, only one well was drilled in the basalt upland. In the lowland, nine test wells were drilled to depths ranging from 20 to 334 feet, and one was augered to a depth of 87 feet. Logs of these wells provide information on the underlying strata, on water levels in different aquifers, and on vertical gradients at specific points. Pumping tests performed on eight of these wells allowed a determination of the water-yielding characteristics of the aquifers tapped, and water samples provided information on ground-water quality.

Geophysical logs obtained from a 334-foot-deep test well and several existing wells provided information at various locations and depths, such as (1) temperature differences, (2) the electrical conductivity of the water, (3) the borehole diameter, and (4) the natural gamma radiation. These data were used in correlating stratigraphic units, determining which parts of the aquifer are the major water yielders, delineating changes in water quality with depth, and generally interpreting the ground-water-flow system in the basin.

Most of the data on the chemical quality of water in the entire Yakima Indian Reservation were collected during a separate study concurrently under way by the U.S. Geological Survey (Fretwell, 1977), and those data relating to Satus Creek basin are discussed briefly in this report. Considerable data on nitrate concentrations in ground water were collected during this study, and are included in both reports.

Previous Investigations

Early reports on the geology of south-central Washington include those by Russell (1893), Smith (1901), and Waring (1913). Russell's report graphically describes the Horse Heaven "Ridge" (Hills), the "Satas" Creek basin, "Satas" (Toppenish) Ridge, and Snipes Mountain, and the report by Waring includes additional information on the geology of Toppenish Ridge and the Satus Creek basin. A report by Kinnison and Sceva (1963) relates the effects of geologic and hydraulic factors on streamflow in the area. Detailed bedrock stratigraphy and geologic data are given in reports by Laval (1956), Schmincke (1964, 1967), and Sheppard (1967).

Many studies have been made relative to the utilization and development of surface-water supplies in the Yakima River basin, but studies of either ground water or surface water in the Satus Creek basin have been limited in scope. Results of these limited studies were presented chiefly in the form of administrative or other unpublished reports and memorandums. Data from previous studies have been utilized liberally in preparation of this report.

Acknowledgments

The cooperation of the Yakima Tribal Council and BIA (Bureau of Indian Affairs) is gratefully acknowledged. Personnel of the BIA assisted in the well inventory, measurement of water levels in wells, maintenance of water-stage recorders on streams, and many other field operations. Bureau personnel also determined elevations in the observation-well network, and provided much information relating to streamflows, canal diversions, shallow water levels and other project data.

A special thanks is due the many well owners and operators for permitting and assisting in measurement and testing of their wells. Without their cooperation the investigation would have been incomplete.

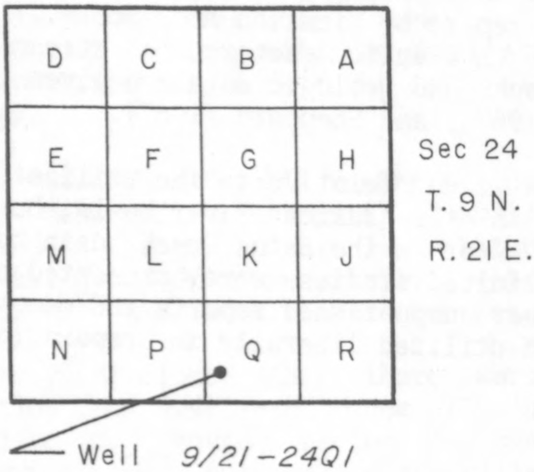
Fieldwork and preliminary analyses were accomplished under the supervision of D. O. Gregg, and included efforts by D. R. Cline, and E. G. Nassar. Gregg and Nassar left the project prior to its completion, and the authors, using the data collected by the earlier project personnel, compiled this report.

Well- and Location-Numbering System

Wells inventoried during this study (table 12, p. 89) have been assigned numbers which identify their location, within a section, township, and range.

For example, in the well number 9/21-24Q1, the part preceding the hyphen indicates successively the township and range (T.9 N., R.21 E.) north and east of the Willamette base line and meridian; the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec.24), and the letter "Q" gives the 40-acre subdivision of the section, as shown in the figure below. The numeral "1" indicates that this well is the first one inventoried within the 40-acre subdivision. In table 12, a computer printout, this same well number is given as 09N21E24Q01.

The same numbering system is used in this report to indicate the location of certain geologic and hydrologic features described in the text.



In table 12 the wells are also numbered according to their latitude and longitude locations.

The hydrologic environment is composed of the many physical factors that in different ways affect and control the quantity and quality of water in the basin, and its occurrence and movement through the basin. Physical factors of greatest importance include climate, geology, topography, and drainage.

Climate

The Satus Creek basin has a continental-type climate characteristic of south-central Washington. Generally during the summer, days are hot and dry and nights are cool, whereas winters are cool to cold. Storm systems move across the area from west to east, and, as they cross the Cascade Range, they lose much of their moisture. As the air moves eastward, it becomes progressively drier and the amount of precipitation decreases rapidly, as shown in figure 1. Precipitation ranges from about 35 inches in the southwestern part of the basin to less than 10 inches in the northeastern part (U.S. Weather Bureau, 1965).

The only weather station ever located in the basin was a precipitation gage at Satus Pass, which was established in June 1956. In November 1967, the station was moved 2 miles south-southwest of the pass. Although now outside the basin, this station provides a complete, though short-term, precipitation record representative of the western and higher part of the basin. A station at Bickleton, about 17 miles nearly due east of Satus Pass and about 3 miles south of the crest of Horse Heaven Hills, provides data that is probably representative of rainfall on the central part of the basin. A station at Sunnyside, about 6 miles east of the basin (about 9 miles north of Mabton), provides a long-term record for both precipitation and temperature. Data for these three stations are given in table 1.

The record of precipitation at Satus Pass is for slightly less than 12 years. To determine whether this short-term record could be considered representative of a longer period, the record was compared to that at Glenwood, a station about 20 miles due west of the Satus Creek basin. The correlation of 9 comparable years, 1957-63 and 1965-66 (fig.2), indicates that the annual precipitation at Satus Pass generally is about 75 percent of the annual precipitation at Glenwood. Based on the 21-year record during 1951-72 at Glenwood, which averaged 34.1 inches, the long-term average annual precipitation at Satus Pass probably is nearer 25.6 inches instead of the 21.50 inches shown in table 1.

Precipitation at the Satus Pass station is unequally distributed through the year. Average precipitation during the first 6 months of the water year, October-March, is 17.95 inches, whereas during the second 6-month period April-September it is only 3.55 inches (table 1), less than 17 percent of the annual total. Average precipitation during the 3-month period June-August is only 0.81 inch. The unequal time distribution of precipitation in the headwaters area of the basin has a marked effect on stream runoff.

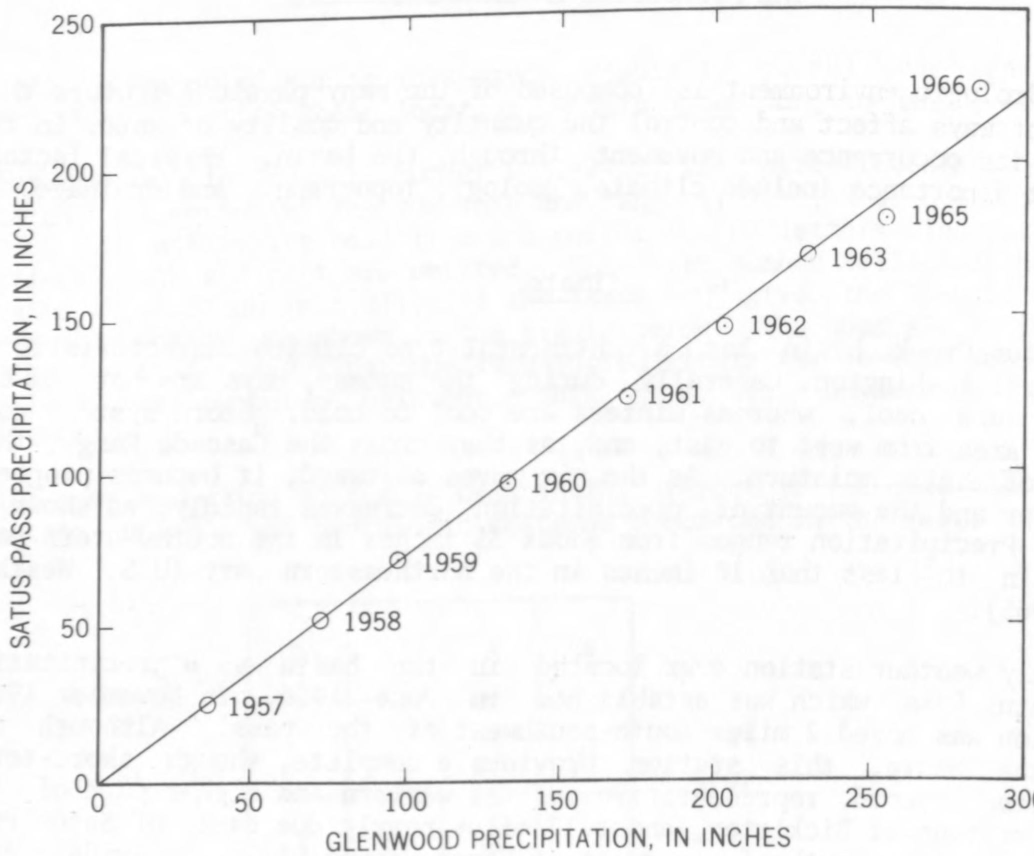


FIGURE 2.--Comparison of cumulative annual precipitation at Satus Pass and at Glenwood, during the period 1957-66.

Average annual precipitation at Bickleton is 12.63 inches (table 1), of which 9.57 inches occurs during the first 6 months of the water year. Precipitation during the last 6-month period of the water year averages 3.06 inches, less than 25 percent of the total. Annual precipitation at Sunnyside, representative of the lowlands adjacent to the Yakima River, averages only 6.90 inches. The month with greatest precipitation is January, during which the average is 0.89 inch.

Precipitation varies greatly from year to year. The greatest annual precipitation at Satus Pass was in 1960 when a total of 28.44 inches was measured, whereas in 1965 the least annual precipitation, 14.66 inches, was measured. Longer term records undoubtedly would show greater extremes.

Considerable snow falls at higher elevations in the basin. Mean monthly snowfall at Bickleton, based on records through 1960, is given in table 1. Snowfall in the mountains generally accumulates until spring, when the melting of the snowpack provides increased streamflow. Streamflow records indicate that snow remains at the higher altitudes in the Satus Creek basin until May or early June.

TABLE 1.--Average monthly and annual precipitation, snowfall, temperature, and evaporation at stations in and near the Satus Creek basin through 1973

[From records of the U.S. Weather Bureau]

Station[a]	Years of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average annual
							Precipitation (inches)							
1	79	0.89	0.66	0.48	0.42	0.51	0.84	0.18	0.21	0.35	0.72	0.76	0.88	6.90
2	12	3.82	2.80	2.63	1.32	.81	.32	.28	.21	.61	1.61	4.05	3.04	[b]21.50
3	40	1.83	1.57	1.15	.72	.75	.88	.18	.17	.36	1.03	1.81	2.1	12.63
							Snowfall (inches)							
3	(c)	9.8 (18)	5.1 (18)	3.7 (19)	.6 (20)	trace (21)	0 (21)	0 (20)	0 (18)	0 (19)	0.3 (18)	3.9 (20)	6.7 (16)	30.1
							Temperature (degrees Fahrenheit)							
1	77	30.2	36.0	44.2	52.6	60.5	66.2	72.1	69.7	63.2	52.6	39.7	33.8	51.7
							Evaporation (inches)							
4	(d)	-- (0)	-- (0)	2.6 (18)	4.2 (26)	5.7 (31)	6.8 (32)	7.9 (32)	6.6 (32)	4.2 (31)	2.3 (30)	0.9 (11)	-- (0)	41.2

[a]Stations: 1 - Sunnyside, altitude 747 ft, about 9 miles north of Mabton.
2 - Satus Pass, altitude 3,090 ft.
3 - Bickleton, altitude 3,000 ft, about 15 miles east of Satus Pass.
4 - Prosser, altitude 870 ft, about 11 miles east of Mabton.

[b]Correlation with Glenwood station about 30 miles to west indicates that the average annual precipitation is about 25.6 inches during a longer period of time (21 years).

[c]Number of years of record through 1960 are shown in parentheses below value for each month.

[d]Number of years of record during the period 1931-62 are shown in parentheses below value for each month.

Evaporation data, which indicate how much water can be lost back to the atmosphere, are given in table 1 for the lowland. Evaporation is highest in the summer and is nearly nonexistent in the winter. Evaporation at higher altitudes would be less, but would have the same monthly pattern. Because evaporation is measured from open-water surfaces, this measured water loss is greater than the actual evaporation and transpiration losses from the land. Thus, evapotranspiration rates are much less than the evaporation rates given in table 1, but also follow the same seasonal pattern. Methods used to estimate evapotranspiration are given on page 75.

Generalized Geology of the Basin

The geology of the Satus Creek basin has been mapped in detail in only a few places, but broad reconnaissance mapping in the basin was carried out by Russell (1893), Waring (1913), Warren (1941), and others. The Yakima Basalt and the Ellensburg Formation were mapped in detail in parts of the Toppenish Ridge and the Horse Heaven Hills by Laval (1956). Olivine basalts of Tertiary and Quaternary age, herein called the young basalt, were mapped in the upland areas of the basin by Sheppard (1967). Geologic features of the basin are shown in figure 3.

The oldest rocks found in the Satus Creek basin consist of the Yakima Basalt, the uppermost formation within the Columbia River Basalt Group, a thick sequence of lava flows that underlie south-central and eastern Washington, western Idaho, and north-central and eastern Oregon. The flows of the group were extruded during the Miocene and early Pliocene Epochs and have an aggregate thickness that probably exceeds 10,000 feet. In the Satus Creek basin only the Yakima Basalt, the uppermost part of the group, is exposed or is partly penetrated by the deepest well--1,141-foot well 8/22-1G1.

The lava flows accumulated in a subsiding basin, whose subsidence was accompanied by warping and folding, forming ridges around its margin. Between the Toppenish Ridge on the north and Horse Heaven Hills on the south the basalt flows rise at low angles toward the west end of the Satus Creek basin. Structural features of the Yakima Basalt shown in figure 3 were adapted chiefly from a map by Newcomb (1970), and partly from a map by Sheppard (1967). The configuration of the upper surface of the Yakima Basalt underlaying the lowland (fig. 4) probably shows the structure of the basalt, but this may also be, in part, an erosional surface.

During long periods in which no lavas were extruded, streams from hills and mountains around the margin of the basin spread sand and gravel deposits, and finer sediments (silt and clay) accumulated in lakes formed in low-lying areas. These alluvial and lacustrine deposits were covered by later lava flows, as volcanic activity was renewed from time to time. Sometime during the Pliocene Epoch the volcanic activity ceased, but the deposition of alluvium from the north and west continued, forming the Ellensburg Formation. The lower part of the Ellensburg Formation is interbedded with the upper part of the Yakima Basalt.

By the end of Pliocene time the Satus Creek basin had assumed virtually its present shape by folding and faulting, and by erosional and depositional forces. Toppenish Ridge to the north and Horse Heaven Hills to the south are chiefly anticlinal (upfolded) ridges, with perhaps some faulting accompanying the folding. In the valley between the two ridge crests, from altitudes of 3,000 to 3,500 feet on the west, the basalt slopes gradually northeastward to the Yakima River valley. Flow surfaces are nearly flat, generally dipping only 1 or 2 degrees, at least in the eastern one-half of the basin.

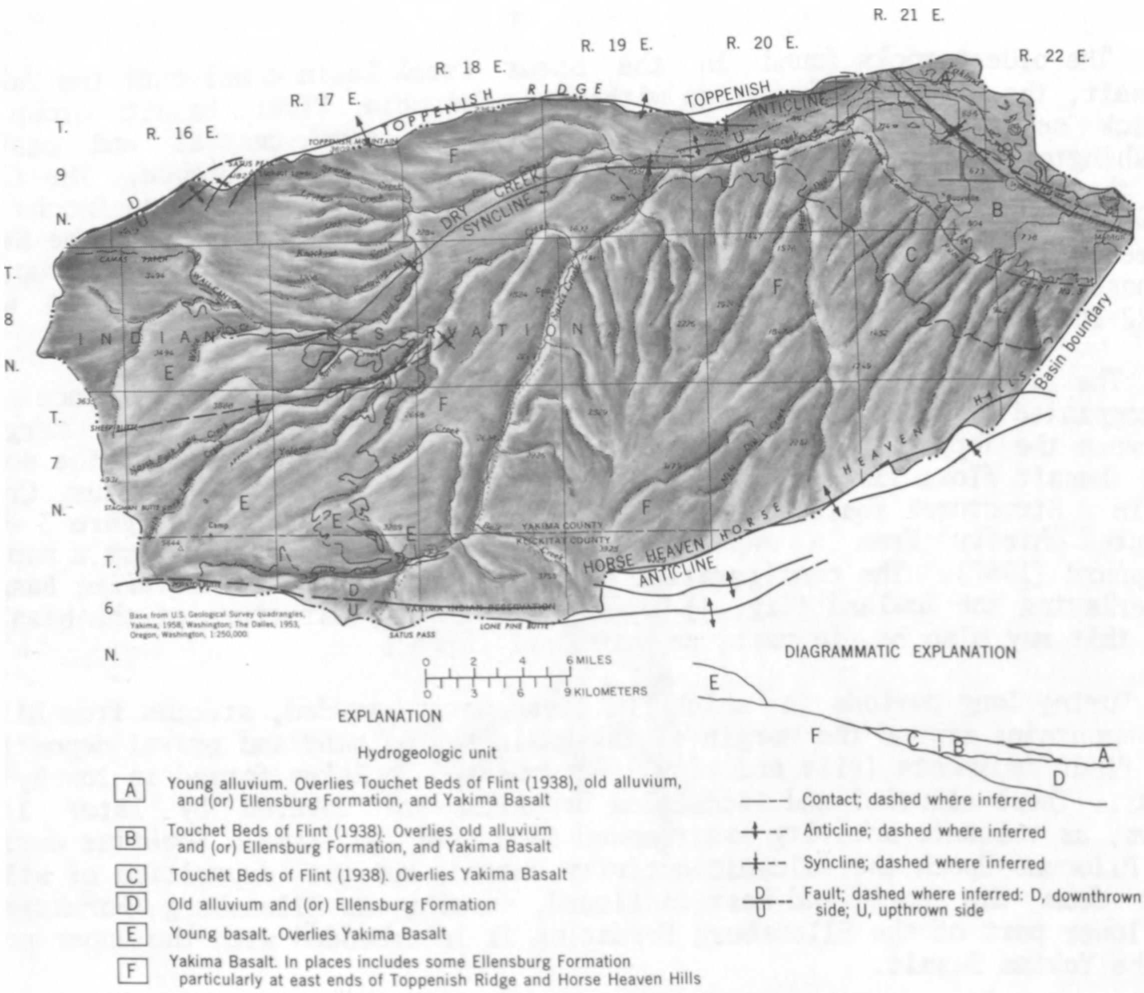
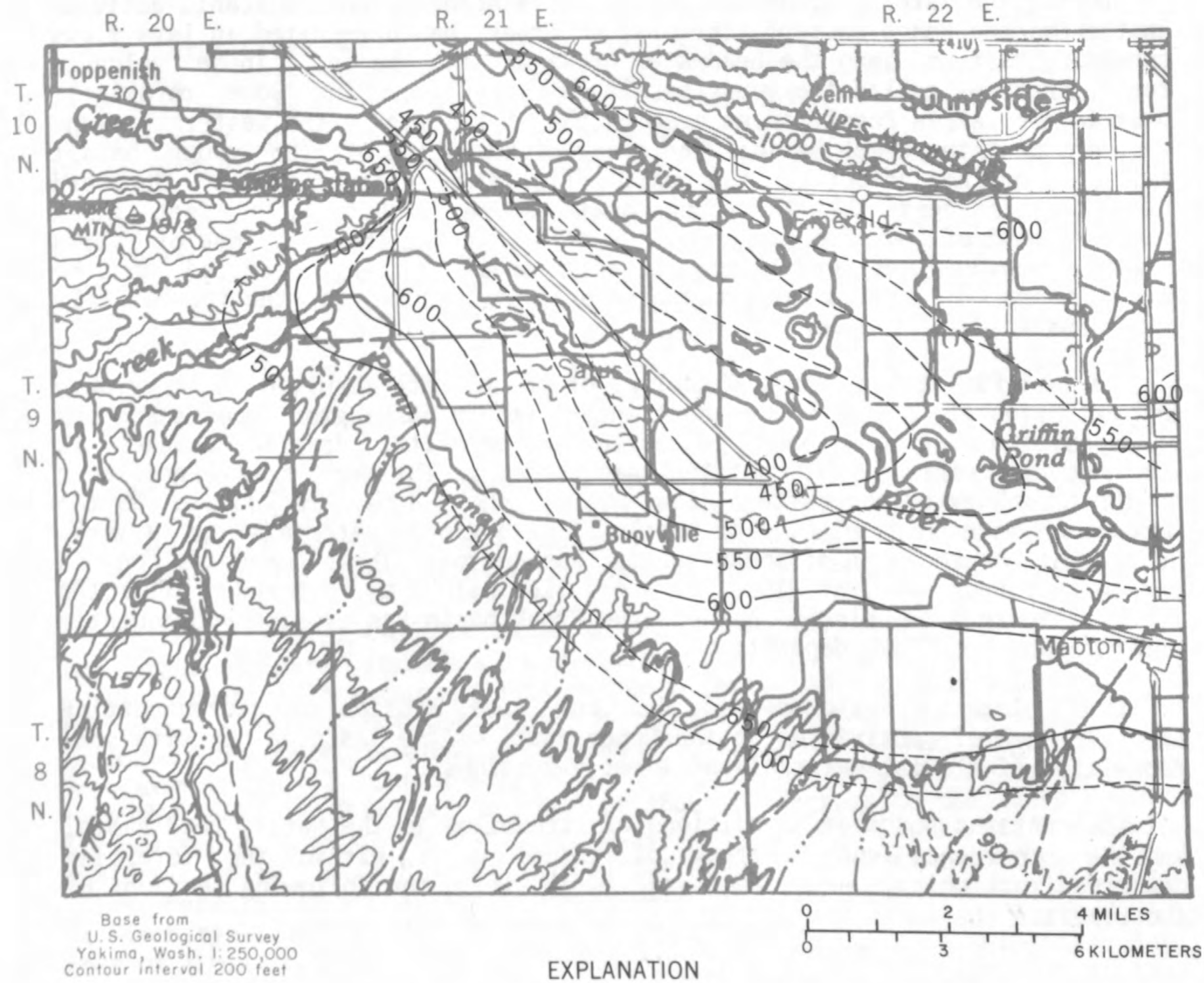


FIGURE 3.--Generalized hydrogeologic features in Satus Creek basin.



EXPLANATION

——600----

Line connecting points of equal altitude on surface of Yakima Basalt, in feet above mean sea level; dashed where approximate. Contour interval 50 feet.

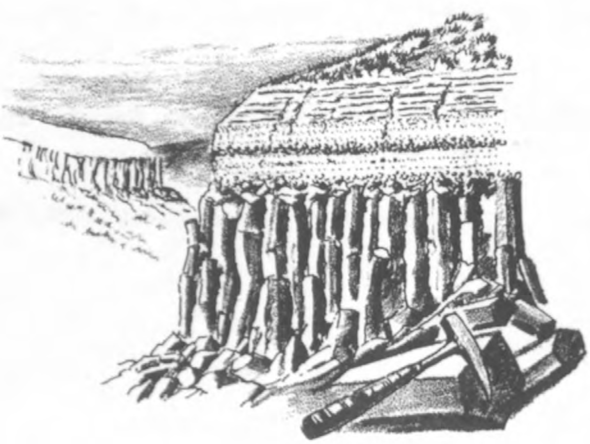
FIGURE 4.--Contours on top of the Yakima Basalt in the lowland of Satus Creek basin.

During the late Pliocene and early Pleistocene Epochs, volcanic activity in the Cascade Range west of the Satus Creek basin resulted in lava flows spreading eastward into the headwater areas of the basin. These volcanic rocks, herein called the young basalt (although including some rhyolite), overlie the Yakima Basalt in an area of about 120 mi^2 in the western, upland part of the Satus Creek basin. The areal distribution of the young basalt and a syncline affecting the unit (fig. 3) were determined by Sheppard (1967), who suggests that the young basalt may be 1,200 to 1,500 feet thick near the head of Logy Creek where it overlies several thousand feet of Yakima Basalt. Because considerable erosion and canyon cutting occurred in the basin before this period of volcanic activity, some of the young basalt occurs as intracanyon flows.

In late Pleistocene time, a cooling of the climate resulted in the growth and extension of a thick ice sheet into northern Washington from Canada and in deposition of glacial and glaciofluvial deposits, drastic changes in drainage, and other significant geologic effects. The event most significant to the hydrology of the eastern lowland of the Satus Creek basin was the deposition of a thick blanket of mostly fine-grained materials in a large lake that covered much of south-central Washington. These deposits, named the Touchet Beds by Flint (1938, p. 494), lie below an altitude of 1,150 feet. In only a few places in the Satus Creek basin has erosion subsequently cut through these lake deposits.

During latest Pleistocene and Holocene time, erosion and canyon cutting were the chief activities in the upper parts of the basin, along with some deposition of fluvial materials at lower elevations.

The patterns and areal conditions of streamflow in the Satus Creek basin, and the occurrence and movement of ground water within the foregoing described rock units, are discussed in detail in the following sections of the report.



Topography and Drainage

The Satus Creek basin is a structural and topographic basin open to the east along the Yakima River. The altitudes in the basin range from about 5,800 feet at Potato Butte in the southwestern upland of the basin to about 650 feet near Mabton in the eastern lowland (fig. 1). The surface at many places in the basin is formed on dip slopes of the underlying lava flows.

The structural basin is asymmetrical. The low point of the structure--and of the topographic basin--is approximately along the course of lower Satus Creek, from near the eastern end of Toppenish Ridge to the mouth of Dry Creek and thence approximately along Dry Creek. This structural low is only 2 to 3 miles south of the crest of Toppenish Ridge in the eastern part of the basin, but is 6 to 8 miles south in the western part. In contrast, it generally is 12 to 16 miles north of the crest of the Horse Heaven Hills.

Even though much of the surface apparently is on dip slopes of the underlying Yakima Basalt, considerable erosion has occurred and some surfaces may represent the tops of resistant flows from which less resistant flows or strata of the Ellensburg Formation have been eroded away.

In the upland part of the basin the major streams occupy deep gorges, and even minor ephemeral streams occupy canyons several hundred feet deep. Many of the streams follow courses established directly down the original slope of the basin (fig. 1), but the courses of others apparently are controlled by geologic structures, probably including folds, faults, and joint patterns. For examples, (1) the middle reach of Mule Dry Creek flows nearly north through T.8 N., R.20 E., at an angle of about 60 degrees to the very uniform northeastward slope of the land surface; (2) Kusshi Creek starts flowing northeast in T.7 N., R.17 E., then turns and flows directly southward for 4 miles, parallel to and in the opposite direction from Satus Creek, into which it discharges; and (3) six tributaries to Dry Creek all flow due east through most of their courses, then discharge into Dry Creek along a nearly straight north-south line about 4 miles long. These examples--and many others that can be seen on topographic maps--suggest control of the drainage by geologic structures that have not as yet been mapped. As described later (p. 31) geologic structures are important controls on the occurrence, movement, and recovery of ground water from the basalt.

Hydrologic Cycle in the Basin

Generally, in the Satus Creek basin the hydrologic cycle--the pattern of water movement through the natural system--is simple, but in detail and in parts of the basin it is quite complex. Only the generalized pattern of water movement and occurrence is described here; some of the complexities are described and explained later in the report.

Except for a considerable amount of water imported for irrigation in the lowland of the basin, all the water within the basin is derived from precipitation. Water leaves the basin by surface-water outflow, by ground-water discharge and underflow, as evaporation from soil, plants, and water surfaces, and as transpiration by vegetation.

The eastern two-thirds of the basin receives an average annual precipitation of less than 15 inches. Probably most of this water is returned to the atmosphere within a few months as evaporation and transpiration from the soil and vegetation; a small amount becomes runoff--especially when the ground is frozen--and leaves the basin as streamflow. A small part of the precipitation percolates downward through the soil to reach the water-table aquifer.

In the western one-third of the basin, where average annual precipitation ranges from 15 to 35 inches, a much larger proportion becomes surface-water runoff or percolates downward to aquifers. A considerable part of the precipitation during the winter occurs as snowfall, which results in a lag between precipitation and runoff, from a few days to several months. That portion of the precipitation not used by plants or leaving by direct runoff to streams becomes ground-water recharge to aquifers in the basalt. A large part of this ground water discharges to streams heading in the upland area, particularly Logy Creek. A smaller part leaks downward to recharge deeper aquifers and moves eastward down the hydraulic gradient toward the Yakima River valley.

The Yakima River receives the principal discharge from the basin. All surface water discharges into the Yakima River, and, because the Satus Basin is closed structurally on the north, west, and south, almost all ground water also discharges eastward toward the Yakima River.

The hydrologic cycle in the lowland of the Satus Creek basin is complicated artificially by the importation, for irrigation, of large amounts of water from the adjoining Toppenish Creek basin. These importations have provided a large part of the recharge to sand and gravel aquifers, and have also caused waterlogging in large areas.

SURFACE-WATER RESOURCES

The surface-water resources of the Satus Creek basin consist of the discharges of Satus Creek and its major tributaries, Dry, Logy, and Mule Dry Creeks. As mentioned earlier, however, most of the water used for irrigation within the basin lowland is obtained by canal diversion from the adjoining Toppenish Creek basin--namely from Toppenish Creek and Marion Drain. The streamflow gaging stations within the basin for which records are available, and the lengths of the periods of records, are listed in table 2, and the locations of the streams and data-collection sites are shown in figure 1. The measured discharges of the principal streams during the period of this study are given in table 3, and miscellaneous streamflow records are given in table 4.

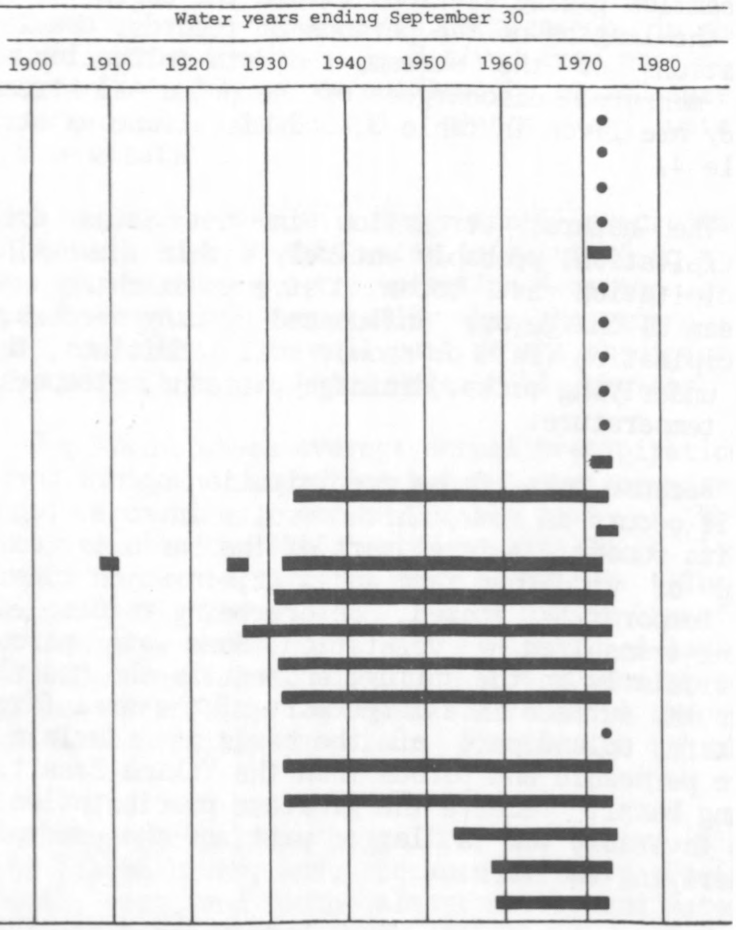
The natural streamflow in the Satus Creek basin is derived from precipitation, probably entirely within the basin. However, the portion of precipitation that becomes stream discharge and the time distribution of stream discharge are influenced by many factors, including the nature of the precipitation (rain or snow), soil conditions, the character and thickness of the underlying rocks, drainage patterns, steepness of topography, vegetation, and temperature.

Because most of the precipitation occurs during the winter months, some of it occurs as snow, which results in some lag (as much as several months) in its runoff. A large part of the basin is covered by a rather thin soil zone of windblown sand and silt, in which considerable quantities of water are temporarily stored, before being returned directly to the atmosphere or being transpired by vegetation. Some water percolates through the soil zone, particularly in the spring, and enters the underlying Yakima Basalt, which is near the surface in a large part of the area (fig. 3). About 120 mi^2 in the western, upland part of the basin is underlain by the young basalt which is more permeable and porous than the Yakima Basalt. The areas underlain by the young basalt receive the greatest precipitation in the basin, and conditions are favorable for a large part of the precipitation to percolate into the underlying aquifers.

Water entering the young basalt and the Yakima Basalt moves generally downward and northeastward in the mountainous areas, but some of it discharges to the streams that are in deep canyons that cut through water-bearing zones in the basalt. Ground water following this route to streams has a much greater lag time (perhaps years) than the water that is retarded by being stored in the annual snowpack.

TABLE 2.--Surface-water data sites and periods of record

Number in fig. 1	Station name
1	Satus Creek
2	Satus Creek
3	Logy Creek
4	Logy Creek
5	Logy Creek at gage
6	Satus Creek
7	South Fork of Dry Creek
8	South Fork of Dry Creek
9	Dry Creek
10	Dry Creek
11	Dry Creek at gage
12	Satus Creek at gage (upper)
13	Mule Dry Creek at gage
14	Satus Creek at gage (lower)
15	Satus East Lateral
16	Satus No. 2 Pump
17	Satus West Lateral
18	Coulee Drain
19	McBride Drain
20	Satus Feeder Canal
21	South Drain
22	Satus No. 3 pump
23	Drain 302
24	Drain 303



Explanation: ● Occasional streamflow measurement

▬ Continuous streamflow record

TABLE 3.--Monthly and annual discharges of streams in the Satus Creek basin

[All values in acre-feet]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
				Satus Creek, upper gage (site 12)[a]. Drainage area, 438 mi^2									
1971	1,345	2,575	8,980	42,260	15,945	19,805	22,235	17,385	10,925	4,740	1,770	1,655	149,620
1972	1,780	2,260	3,495	19,305	27,905	39,830	11,570	12,580	10,650	3,970	1,980	1,630	136,955
1973	1,820	2,300	5,810	7,870	5,440	8,290	4,475	4,370	2,345	1,045	645	685	45,095
				Dry Creek (site 11).									
1971	0	237	771	12,280	4,540	5,640	7,990	2,370	451	104	0	0	34,380
1972	0	458	1,920	6,600	10,700	14,500	2,920	1,460	439	77	20	0	39,094
1973	18	255	1,400	3,610	1,560	3,200	764	379	156	60	26	94	11,522
1974	9	4,910	10,260	--	--	--	--	--	--	--	--	--	
				Logy Creek (site 5). Drainage area, 109 mi^2									
1971	994	1,230	1,760	7,770	4,010	5,030	5,460	6,050	6,470	3,180	1,210	1,220	44,384
1972	1,330	1,460	1,370	3,640	5,800	10,400	4,400	5,860	5,820	2,910	1,640	1,350	45,980
1973	1,340	1,350	1,610	3,260	1,950	2,330	1,780	2,310	1,650	1,080	881	871	20,412
				Satus Creek (above Dry and Logy Creeks)[b]. Drainage area, 172 mi^2									
1971	351	1,108	6,449	22,210	7,395	9,135	8,785	8,965	4,004	1,456	560	435	70,853
1972	450	342	205	9,065	11,405	14,970	4,250	5,260	4,391	983	320	280	51,921
1973	462	695	2,800	1,000	2,930	2,760	1,931	1,681	539	[c](-95)	(-262)	(-290)	(14,151)
				Mule Dry Creek (site 13). Drainage area, 91 mi^2									
1971	0	0	0	5,300	1,010	1,340	1,530	381	77	0	0	0	9,638
1972	0	0	0	927	1,540	1,320	342	132	0	0	0	0	4,261

[a]Location of gaging sites shown in figure 1.

[b]Obtained by subtracting discharges of Dry and Logy Creeks from those of Satus Creek at site 12.

[c]Negative discharge values (in parentheses) could indicate loss between the gaging stations; but probably indicates some error in applying the rating curves, hence the annual value (in parenthesis) is questionable.

TABLE 4.--Streamflow measurements in Satus Creek basin during the fall of 1972

Site no. in fig. 1	Altitude (ft)	Date of measurement	Discharge (ft^3/s)
		Satus Creek	
1	1,350	11-2-72	5.42
2	1,120	11-2-72	4.73
6	975	11-1-72	26.6
		Logy Creek	
3	1,785	11-2-72	20.4
4	1,250	10-3-72	22.3
		11-2-72	21.2
[a]5	1,135	11-2-72	22
		South Fork Dry Creek	
7	3,370	11-2-72	5.54
8	3,150	11-2-72	4.39
		Dry Creek	
9	1,840	11-2-72	5.50
10	1,450	11-2-72	4.59
[a]11	965	11-2-72	.26

[a]Continuous-record station

Main Stem Satus Creek

Streamflow in the main stem of Satus Creek is measured at two long-term gaging stations operated by the BIA (sites 12 and 14 in fig. 1). The upstream site (12) measures discharge from 438 mi^2, or about 71 percent of the drainage basin, and includes practically all of the high-precipitation area. A nearly continuous record of discharge has been obtained at site 12 since May 1933. Because discharge past the lower site (14) includes a large amount of irrigation return flow from water brought into the basin from the adjoining Toppenish Creek basin, it does not represent the natural surface-water yield of the basin.

Annual discharge past site 12 has ranged from slightly more than 25,000 acre-feet in 1944 to about 238,000 acre-feet in 1956. Average annual discharge during the 39 years of complete record, through 1973, was about 100,000 acre-feet, and for the last 10 years was about 103,000 acre-feet (table 11). Figure 5 graphically shows the number of years that annual discharge was in a designated range. For example, in 3 of the 39 years, the annual discharge was less than 40,000 acre-feet and in 27 of the 39 years the annual discharge was more than 80,000 acre-feet. An annual discharge of 100,000 acre-feet is approximately equal to 4.3 inches of water spread over the drainage area of 438 mi^2.

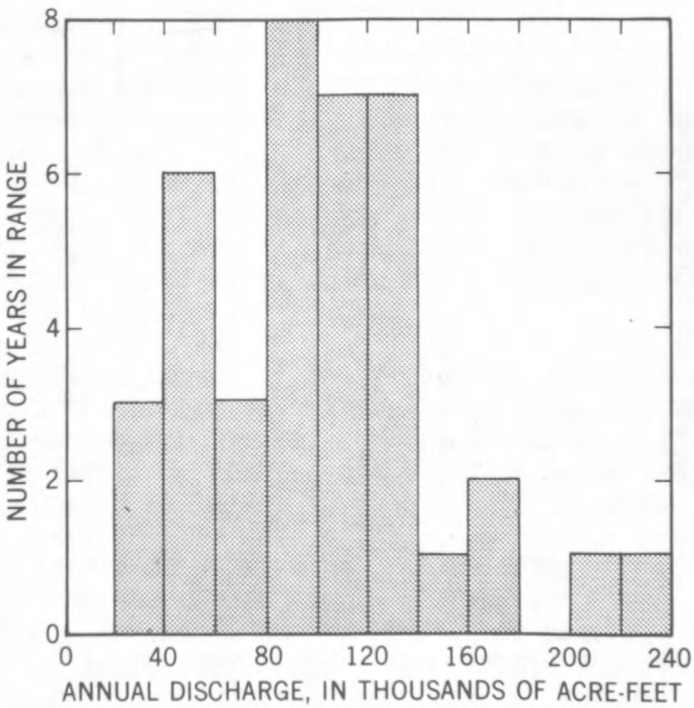


FIGURE 5.--Number of years that discharge of Satus Creek at site 12 was in designated range.

The relation of stream discharge to precipitation and temperature for the 1971 water year (fig. 6) shows that runoff resulting directly from rainfall generally occurs rapidly, within a day or two, depending on antecedent conditions. Snowmelt runoff generally occurs with a rise in temperature; for example, at the end of January 1971, discharge increased greatly without any rainfall. Then, late snowfall in March and April of 1971 resulted in a large runoff during May, June, and the first part of July, during which period there was very little rainfall. During July, the discharge of Satus Creek approached that postulated in the curve for ground-water flow (fig. 6); that is, most of the flow of Satus Creek was derived from ground water discharging to the creek.

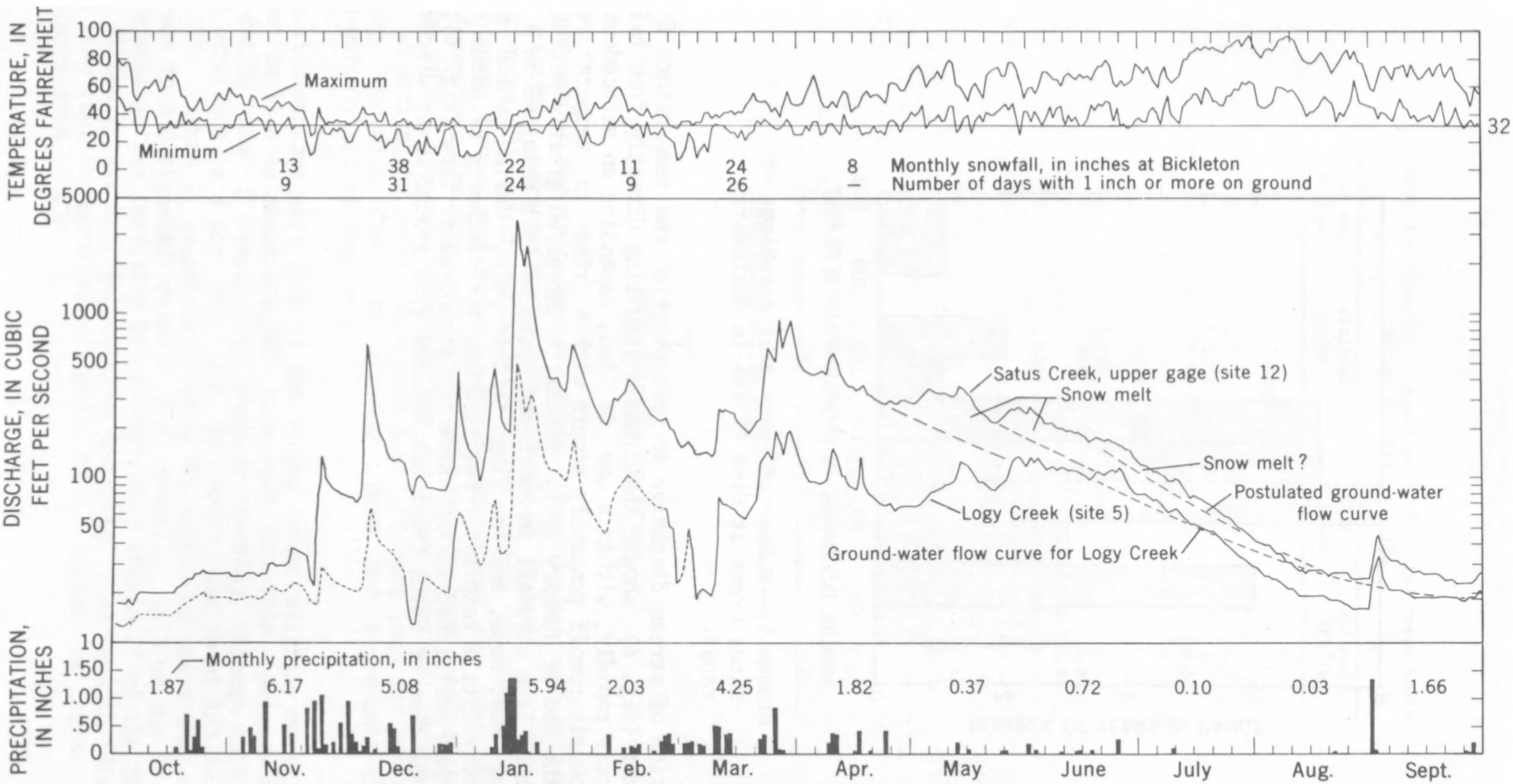


FIGURE 6.--Discharges of Satus and Logy Creeks, and precipitation and temperature near Satus Pass, 1971 water year.

Dry Creek

Dry Creek drains an area of about 157 mi^2 which is about 5 to 10 miles wide and extends about 25 miles along the south flank of Toppenish Ridge. A gaging station established in 1970 at site 11 (fig. 1) provided a continuous record during the 1971-73 water years and for the first 3 months (October, November, and December) of the 1974 water year. The station was destroyed by a flood on January 16, 1974, and the record for the period January 3-16 was lost. Monthly and annual discharges for the period of record are given in table 3.

The average annual runoff for the 3 complete years of record was 28,300 acre-feet. However, the runoff is extremely variable, as can be seen by comparing the various months and years. Note particularly that more water was produced during the first 3 months of the 1974 water year than during the entire 1973 water year.

The short-term record for Dry Creek can be adjusted to be representative of long-term conditions, by correlation with the long-term record at site 12 on upper Satus Creek. Average annual discharge at site 12 during the 1971-73 water years was about 10 percent higher than that for the entire period of record at that station. A 10-percent reduction in annual discharge at the Dry Creek station would leave about 25,500 acre-feet as the probable long-term average discharge past the Dry Creek gaging site; this annual discharge is equivalent to about 3.0 inches over the area, considerably less than the 4.3 inches over the Satus Creek basin above site 12. Study of the discharge records (tables 3 and 4) and the hydrographs (figs. 7 and 8) show that the base flow of Dry Creek declines very rapidly and the creek is dry or nearly dry in June or July, and remains dry until the rainy season in autumn.

About 40 mi^2 of the Dry Creek headwaters area is underlain by the permeable young basalt which permits a relatively large percentage of the average annual precipitation of about 20 inches to become recharge. Although the base flow at the gaging station (site 11) declines rapidly to nearly zero (figs. 7 and 8), part of the reason for the lack of base flow is that water is being lost from the stream and going into ground-water storage in the lower reaches of the valley. The Dry Creek canyon is not deeply incised and therefore the stream is above the water table along several parts of its reach except during the spring when ground-water levels are high. In the spring the stream is below the water table, and the water therefore is discharging to the stream along most of its reach. As the water table drops below the level of the stream channel, water is lost from the stream back into the ground. That the stream does lose water along its lower course is shown by discharge measurements made on November 2, 1972 (table 4), during which the discharge decreased from 5.50 ft^3/s at site 9 (fig. 1), to 4.59 ft^3/s at site 10, and to 0.26 ft^3/s at site 11, a loss of 5.24 ft^3/s in this reach of about 15 miles. Little water is lost at this time of the year by evapotranspiration, but in the summer evapotranspiration losses from the creek and vegetation along the streambanks are greater.

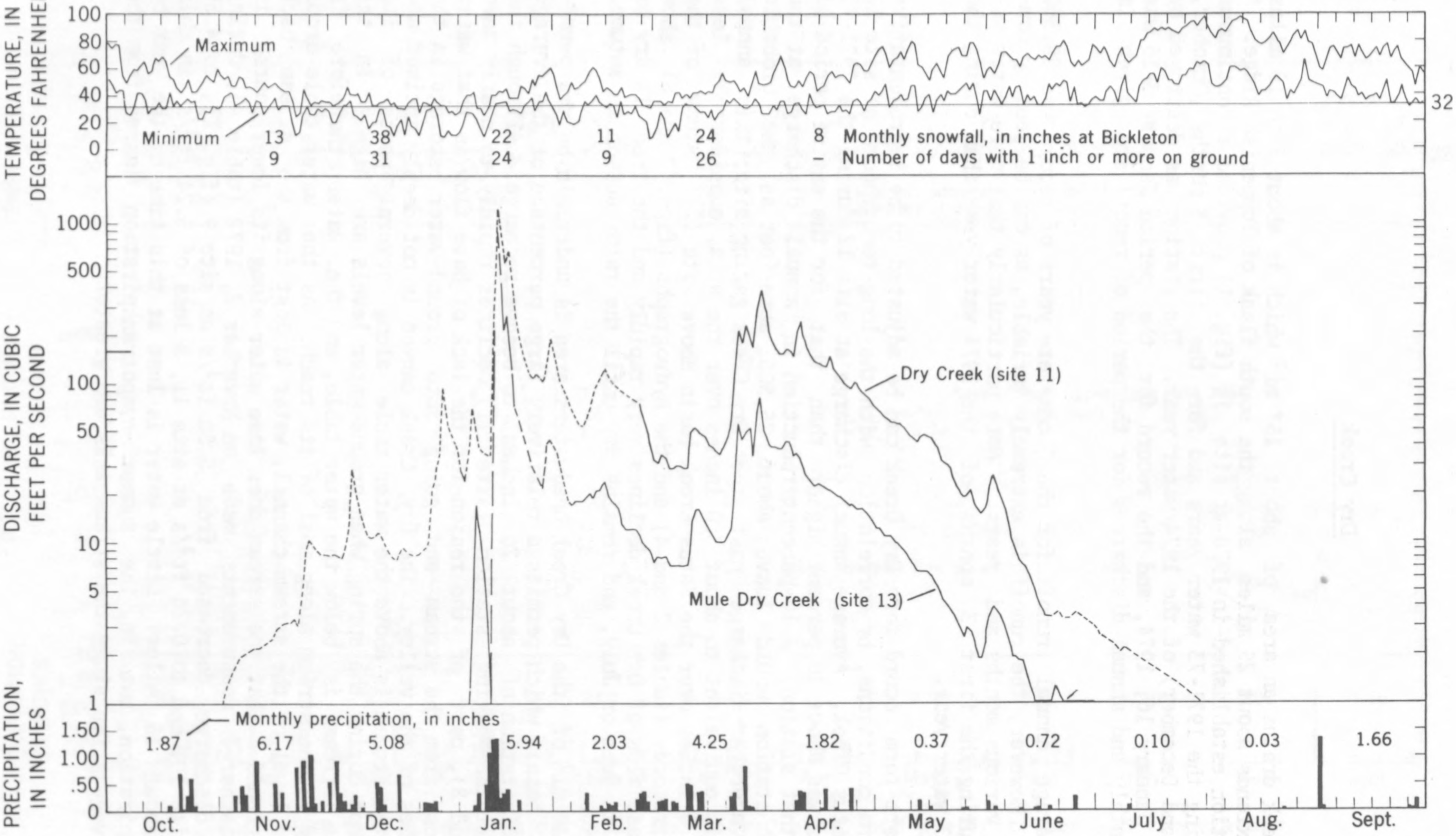


FIGURE 7.--Discharges of Dry Creek and Mule Dry Creek, and precipitation and temperature near Satus Pass, 1971 water year.

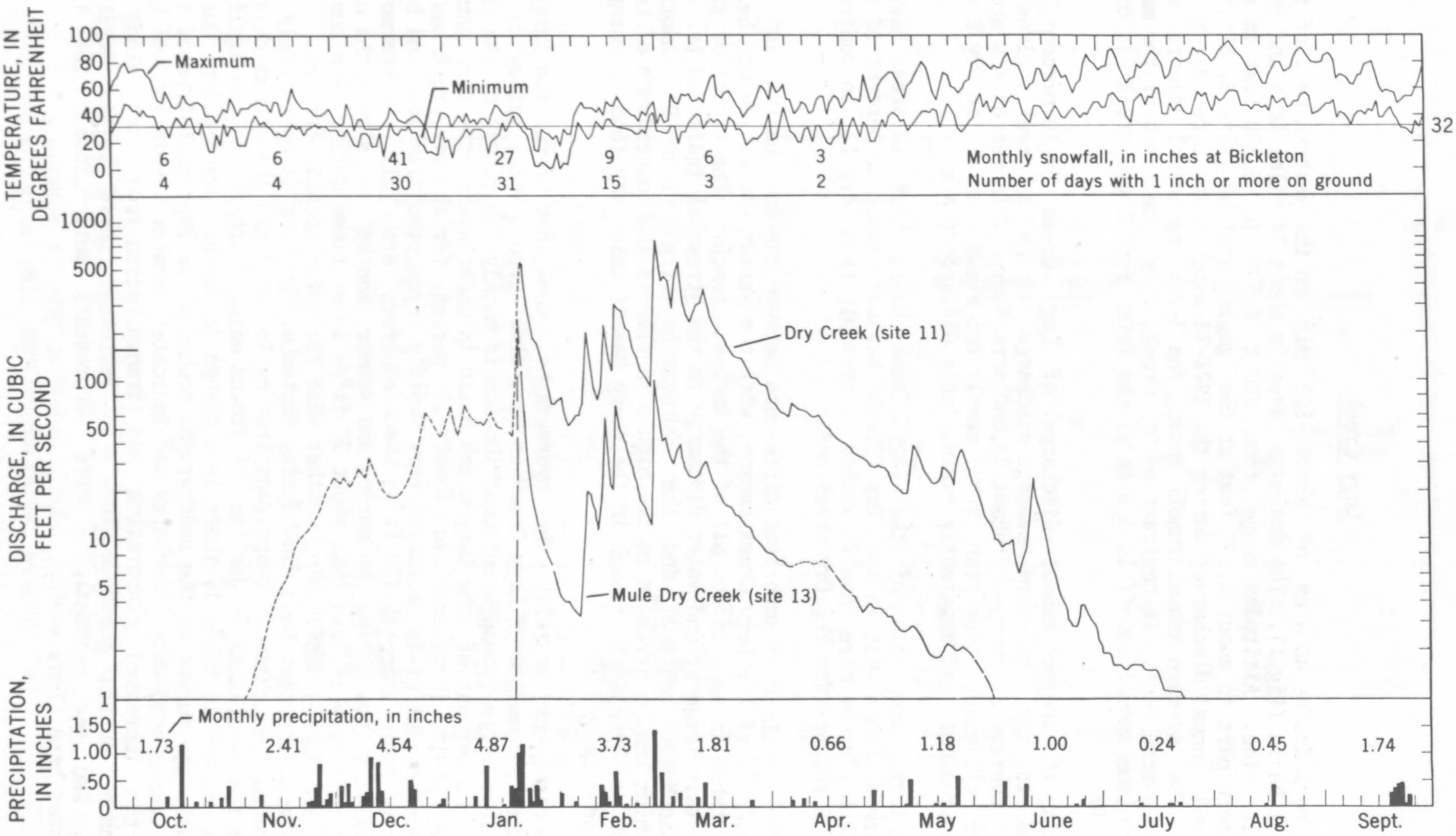


FIGURE 8.--Discharges of Dry Creek and Mule Dry Creek, and precipitation and temperature near Satus Pass, 1972 water year.

Logy Creek

Logy Creek drains an area of about 109 mi^2 in the western part of the Satus Creek basin (fig.1). The drainage area is about 24 miles long and only 4 to 7 miles wide. Altitudes range from about 4,500 to 5,800 feet in the upper western part to about 1,135 feet at the gaging station (site 5, fig.1). Monthly and annual discharges during the 1971-73 water years are given in table 3. The average annual runoff during the 3-year period of record was about 36,900 acre-feet. In contrast to Dry Creek, where the ratio of the maximum to minimum annual runoff is 3.0 to 1, the ratio for Logy Creek is only about 2.2 to 1.

Reducing the average annual discharge of Logy Creek by 10 percent, to correspond to the long-term average discharge of Satus Creek, gives a long-term average discharge of about 33,000 acre-feet. This represents about 5.7 inches of water over the area, nearly two times that of the Dry Creek basin. Two reasons that apparently explain this difference are:

(1) A larger proportion of the Logy Creek basin lies in areas having higher rainfall than that in the Dry Creek basin. About 52 percent of the Logy Creek basin has more than 20 inches of precipitation (fig.1), in contrast to about 25 percent for the Dry Creek basin.

(2) Perhaps the most important difference between the two basins is the deeper incision of the Logy Creek canyon, with the stream level being below the water table in most if not all of the incised reach. The effect of this is to sustain large ground-water discharge to the stream as indicated by the monthly discharge (table 3) and the hydrographs (figs. 6 and 9). Another factor which may contribute to the high base flow is the coincidence of Logy Creek with a synclinal trough in the young basalt which may tend to channel flow to the stream.

These data, particularly the hydrographs, show that by far the largest part of the streamflow of Logy Creek is base flow--ground-water inflow to the stream. This large ground-water contribution is mainly the result of the fact that about 63 percent of the Logy Creek basin is underlain by the more permeable young basalt, in contrast to about 25 percent for the Dry Creek basin. This permeable aquifer is recharged very rapidly from precipitation, and base flow at site 5 may approach 100 ft^3/s when aquifers are full. Furthermore, decline of base flow during the spring and summer months is slow; the only time that base flow is less than about 20 ft^3/s is at times during late summer and fall, and during subfreezing weather when the water locally freezes. The steady, almost-constant base flow during September-November is most likely due to the gradual decrease in evapotranspiration losses along the stream channel balancing the natural slow decline of ground-water discharge as the aquifers drain. As noted in table 1, there is a change in monthly evaporation. During June-August, the curves on the hydrographs probably are representative of less than the true ground-water discharge and indicate greater depletion of base flow by the increased evaporation and transpiration from plants along the stream channel during those months. In September these losses begin to decrease, and the hydrograph curve represents more closely the true ground-water base flow.

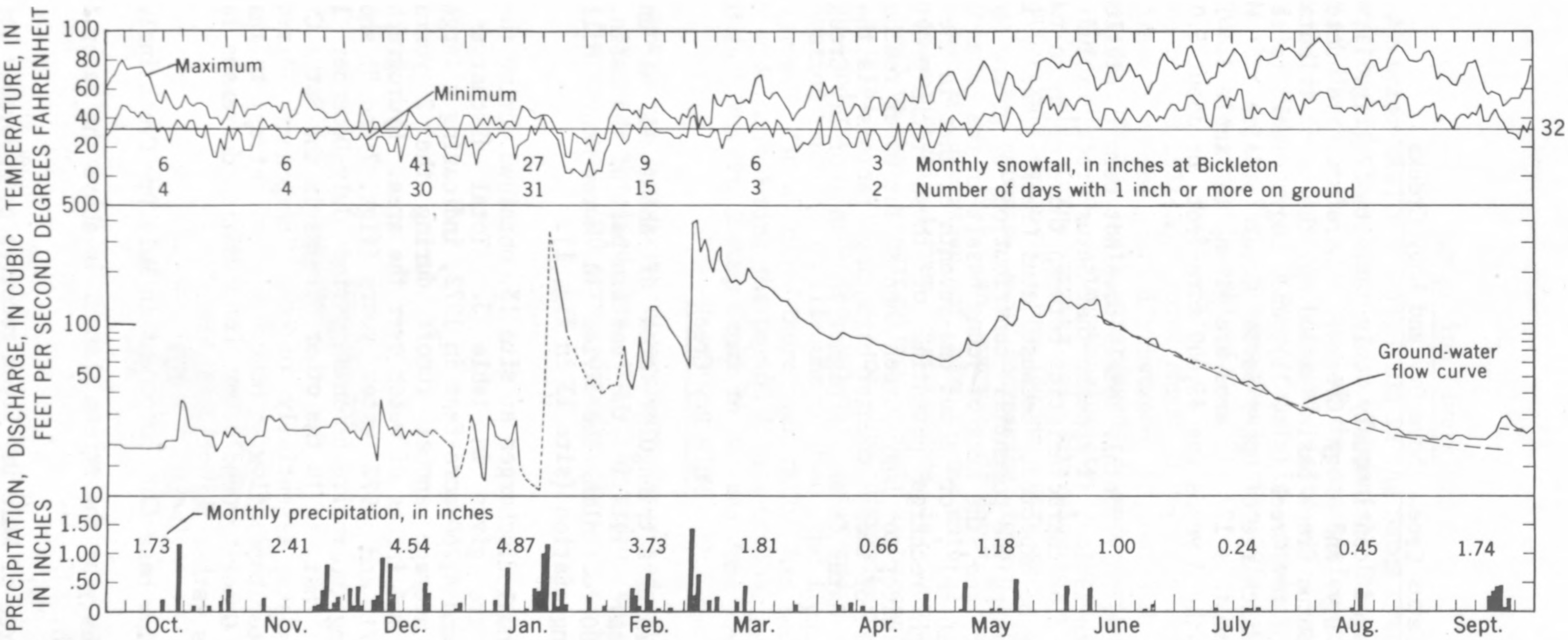


FIGURE 9.--Discharge of Logy Creek, and precipitation and temperature near Satus Pass, 1972 water year.

Satus Creek above Dry and Logy Creeks

Satus Creek is gaged continuously only at site 12 (fig. 1), downstream from the mouths of Dry and Logy Creeks. Therefore, to determine the discharge of the Satus Creek basin excluding the two tributaries, the combined discharges of Dry Creek (site 11) and Logy Creek (site 5) were subtracted from the discharge of upper Satus Creek at site 12. Monthly and annual discharges from this 172 mi^2 area are given in table 3. The average annual runoff during the 3 years was 45,600 acre-feet, or about 5.0 inches of water over the area.

Although the use of only monthly totals does not permit detailed analysis of the runoff characteristics, it appears that Satus Creek, excluding Dry and Logy Creeks, has low-flow characteristics between those of these two streams. This might reasonably be expected, because Satus Creek is deeply incised, as is Logy Creek, increasing the potential contribution of ground water to the stream. On the other hand, the area of young basalt in the Satus Creek headwaters totals only 10 mi^2, or about one-seventh of that in the Logy Creek basin. Thus, the high recharge potential of these rocks provides larger quantities of ground water to Logy Creek than to the upper reaches of Satus Creek. The net result of these counter-balancing factors is that the base flow per unit area of Satus Creek is higher than that of Dry Creek, but less than that of Logy Creek.

Mule Dry Creek

Mule Dry Creek drains a triangular area of about 91 mi^2 on the north flank of the Horse Heaven Hills in the eastern part of the basin. Altitudes range from about 4,200 feet along the divide in Horse Heaven Hills to about 860 feet at the gaging station (site 13 in fig. 1).

Monthly and annual discharges at site 13, obtained during the 1971 and 1972 water years, are given in table 3. Total discharges were 9,640 acre-feet in 1971 and 4,260 acre-feet in 1972, indicating a large variation between years. The average annual runoff during the 2 years was 6,950 acre-feet, or about 1.4 inches of water over the area. Hydrographs of daily discharges during 1971 and 1972 water years (figs. 7 and 8) show that the creek was dry during the entire 6-month period July-December 1971. The hydrographs indicate that, as in the other streams in the Satus Creek basin, stream discharge consists essentially of two components--direct surface runoff and ground-water base flow. However, in contrast to that shown by hydrographs for Logy Creek, ground-water contribution decreases rapidly, and stream discharge ends rather abruptly in June.

Reasons for the low base-flow component in Mule Dry Creek include:

(1) During most of the year the stream channel is above the water table along most of its reach.

(2) The headwaters area of Mule Dry Creek receives considerably less rainfall than do those of Logy, Satus, and Dry Creeks.

Irrigation Diversions

Most of the water used for irrigation in the Satus Creek basin is brought in from sources outside the basin--from Toppenish Creek and Marion Drain. The quantity of diversion is the sum of the quantities measured in the East Lateral (site 15 in fig. 1), West Lateral (site 17), and Satus No. 2 Pump Canal (site 16). Water in No. 2 Pump Canal is augmented by diversion from Satus Creek, through the Satus Feeder Canal (site 20). Diversions to the Satus Creek basin are given in table 5.

During the period 1931-50, total annual diversions--including those from Satus Creek itself--ranged generally between 60,000 and 80,000 acre-feet. During the period 1955-73, with increased demand for water for additional lands below the Satus No. 3 Pump Canal (site 22, which is supplied through the Satus No. 2 canal), the amount of diversion was increased and ranged between 150,000 acre-feet in 1955 and 180,000 acre-feet in 1972. Between 1950 and 1955 the amounts were increasing toward the larger average diversion. Since about 1955, an average of about 12 percent of the water has been obtained by diversion of part of the natural flow of Satus Creek; however, the amount obtained from that source is supplemental, and varies greatly from year to year, ranging from about 2 percent to more than 22 percent of the total diversion. Most of the diversions from Satus Creek start in March, and the bulk of the water is delivered during the early part of the irrigation season (April-June), when the flow of the creek is relatively large. Since 1954 there generally has been little diversion during July and none during the period August-October. In some years the water carried in Satus No. 2 Pump Canal in May and June is mostly from Satus Creek.

In addition to the irrigation diversions described above, about 3,000 acre-feet of water are obtained from the Sunnyside Irrigation District for use in a small area, about 900 acres, immediately west of Mabton.

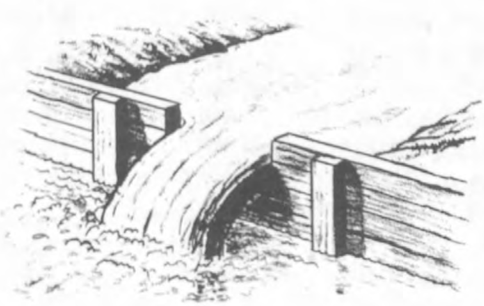


TABLE 5.--Water imported from Toppenish Creek and diverted from Satus Creek, for irrigation in Satus Creek basin lowland, during 1931-73

[All values in acre-feet; measuring sites shown in figure 1]

Year	Water imported from Toppenish Creek				Water diverted from Satus Creek		
	Satus Lateral		No. 2 Pump Canal (site 16)	Total imported	Satus Feeder Canal (site 20)	Percentage of total	Total diversion[a]
	East (site 15)	West (site 17)					
1931	39,050	--	6,890	--	--	--	--
32	37,620	4,600	6,620	48,840	14,250	22.6	63,090
33	34,040	1,350	7,020	42,410	30,400	41.8	72,810
34	40,630	6,870	16,940	64,440	9,550	12.9	73,990
35	42,850	5,270	(b)	(b)	17,600	(b)	(b)
1936	40,760	5,480	15,560	61,800	11,200	15.3	73,000
37	39,960	4,180	10,140	54,280	16,650	23.5	70,930
38	42,170	4,980	14,100	61,250	10,060	14.1	71,310
39	47,190	8,920	20,060	76,170	5,460	6.7	81,630
40	43,070	6,560	17,640	67,270	9,035	11.8	76,305
1941	42,700	8,890	18,100	69,690	6,480	8.5	76,170
42	46,890	8,370	21,800	77,060	6,790	8.1	83,850
43	40,930	6,630	18,100	65,660	13,320	16.9	78,980
44	45,640	9,470	14,400	69,510	3,500	4.8	73,010
45	43,030	7,040	18,300	68,370	6,990	9.3	75,360
1946	40,140	6,260	9,980	56,380	14,510	20.5	70,890
47	45,710	6,874	13,000	65,584	7,860	10.7	73,444
48	36,100	4,530	11,700	52,330	10,870	17.2	63,200
49	45,800	5,920	14,200	65,920	13,710	17.2	79,630
50	41,720	5,580	28,500	75,800	15,140	16.6	90,940
1951	41,280	6,020	51,300	98,600	15,780	13.8	114,380
52	47,360	5,370	56,850	109,580	17,420	13.7	127,000
53	42,350	5,930	76,350	124,630	6,300	4.8	130,930
54	39,760	9,380	62,400	111,540	23,610	17.5	135,150
55	37,760	4,970	92,600	135,330	14,460	9.7	149,790
1956	36,400	2,650	89,500	128,550	27,080	17.4	155,630
57	34,630	4,420	99,200	138,250	17,860	11.4	156,110
58	34,840	5,880	99,400	140,120	22,040	13.6	162,160
59	36,250	7,200	94,600	138,050	15,790	10.3	153,840
60	38,670	5,030	92,200	135,900	17,240	11.3	153,140
1961	39,110	4,610	94,600	138,320	21,140	13.3	159,460
62	45,210	5,620	92,200	143,030	24,410	14.6	167,440
63	39,330	6,360	91,100	136,790	18,900	12.1	155,690
64	45,920	7,980	105,000	158,900	20,460	11.4	179,360
65	43,410	5,880	102,000	151,290	17,270	10.2	168,560
1966	42,780	6,980	95,600	145,360	28,370	16.3	173,730
67	46,100	6,660	106,000	158,760	15,670	9.0	174,430
68	46,840	8,000	111,000	165,840	9,390	5.4	175,230
69	45,570	6,990	89,500	142,060	20,640	12.7	162,700
70	49,370	11,260	91,600	152,230	16,620	9.8	168,850
1971	47,840	12,430	71,500	131,770	38,080	22.4	169,850
72	49,750	11,330	94,700	155,780	24,320	13.5	180,100
73	52,770	11,140	109,000	172,910	3,090	1.8	176,000

[a] Does not include an average annual diversion of about 3,000 acre-feet from Sunnyside Irrigation District.

[b] No record for 1935, hence no total given.

GROUND WATER

Ground water occurs in several geologic units in the Satus Creek basin. A description of these units and their water-yielding characteristics is summarized in table 6. Plate 1 (in pocket) shows the locations of wells in the lowland and figure 1 shows the location of four wells in the upland that provided data for the ground-water study.

Basalt Aquifer

The basalt aquifer system as defined in this report comprises the Yakima Basalt of the Columbia River Basalt Group and the young basalt described earlier (table 6). The two basalt units display some significant differences in ability to accept recharge from precipitation, a point which will be covered in more detail in the following section.

The Yakima Basalt underlies the entire Satus Creek basin, and is overlain by the young basalt only in the southwestern, upland part of the basin (fig. 3).

The thickness of individual flows within the Yakima Basalt generally ranges from about 20 to 100 feet and averages perhaps 40 to 50 feet. Most of the basalt flows individually comprise a dense, fine-textured dark basalt in the basal and central parts and a coarser, vesicular, more jointed, and locally rubbly basalt at and near the top of the flow. The basalt is cut by several systems of joints. One system of fractures is normal to the flow surface and at places divides the flows into large, hexagonal columns. A second system of joints is parallel to the flow surfaces, nearly horizontal at most places before folding, and generally rather widely spaced in the central part of the flows. Another type of jointing commonly occurs in the upper part of the flows where the jointing has random orientation and is closely spaced which results in a "brickbat"-type structure. These joints serve as avenues for the movement of ground water. At some places the fractured flow surfaces are covered by sedimentary materials and at other places weathering and erosion have enlarged the openings and fractures. It is these vesicular, rubbly fractured "interflow zones" immediately below the base of the succeeding flows that serve as the principal water-bearing zones in the basalt ground-water reservoir. Although the configuration of the upper surface of the Yakima Basalt underlying the lowland of the Satus Creek basin (fig. 4) may show local effects of erosion, it shows mainly the structure of the basalt, which can greatly affect the movement of ground water. The lateral hydraulic conductivity of the water-bearing interflow zones generally is many times greater than the vertical hydraulic conductivity of the rock separating these zones. After percolating downward to the water table, almost all the water moves laterally in these zones. Where faults have cut the basalt layers and displaced aquifer zones, large differences in head (hydraulic pressure) may occur. For example, if a fault crosses a basin between the recharge area and the discharge area, water levels on the recharge side of the fault may be much higher than on the discharge side. Other structures, such as anticlines (upward folds) and synclines (downward folds), also affect the pattern of movement of the ground water in the basalt layers.

TABLE 6.--Summary of geologic units and their water-yielding characteristics, Satus Creek basin

Geologic unit and age	Maximum thickness (ft)	Description	Water-yielding characteristics
Young alluvium (Holocene)	[a]36	Chiefly sand and gravel, with some boulders and a few sand and silt layers. Limited extent along Yakima River, lower Satus and Toppenish Creeks.	Capable of yielding several hundred gallons per minute to properly constructed drilled or dug wells where saturated thickness is 20 to 25 feet.
Touchet Beds of Flint (1938) (Pleistocene)	[b]150	Thin-bedded strata of silt, very fine sand, and clay with a few coarser sand layers and scattered pebbles and cobbles. Forms a blanket over older deposits in the lowland of the basin up to an altitude of about 1,150 feet.	Will yield 5 to 10 gal/min of water to relatively shallow wells. In some places may yield as much as 50 gal/min. Its chief significance in the lowland is its poor permeability and retarding of vertical groundwater flow.
Old alluvium (Pleistocene?)	[a]62	Chiefly sand and gravel with some sand and silt. Deposited by Yakima River and Satus and Toppenish Creeks.	Most permeable unit in the lowland. Capable of yielding 500 to 2,000 gal/min to properly constructed wells at some places.
Young basalt (Pliocene and Pleistocene)	1,200-[c]1,500	Thin, black, porous, fresh-looking lava flows that occupy 120 mi^2 in the western upland of basin.	Supplies most of base flow to Satus Creek and tributaries. Potential yields to wells not known.
Upper part of Ellensburg Formation (Pliocene)	[a]183 [d]750	Mostly poorly sorted and roughly stratified, partly cemented sand and gravel, with some strata of sand, silt, pumice, and clay. At many places quartzite and light-colored volcanic rocks predominate in the gravel.	Supplies water to many wells in lowland. The cleaner, less cemented strata generally yield 250 to 500 gal/min to properly constructed wells, and much more in some places.
Saddle Mountains Member of Yakima Basalt	[a]150	Basalt generally similar to Yakima Basalt described below.	Generally yields some water where saturated, possibly as much as 100 gal/min in places.
Beverly Member of Ellensburg Formation	[a]250	Generally fine-grained sedimentary strata of clay, silt, volcanic ash, and pumaceous sand.	Generally not considered an aquifer in the Satus Creek basin, although in places sand strata may yield some water.
Yakima Basalt of Columbia River Basalt Group (Miocene and Pliocene)	[a]1,000 [e]>5,000	Thick sequence of dark gray to black lava flows, each generally 20 to 100 feet thick. Basal parts of flows are generally dense and fine grained; upper parts are in many places vesicular and locally rubbly. Flows have both horizontal and vertical joints.	Water-bearing zones occur at and near the tops of some flows, immediately below the base of overlying flows. Wells drilled 500 to 1,000 feet below the water table or potentiometric surface generally will yield 500 to 1,000 gal/min with moderate drawdown. Water level may be at great depths beneath parts of the upland.

[a]From well logs

[b]Composite thickness, from well logs and outcrops.

[c]From geologic section B-B' of Sheppard (1967).

[d]From Laval (1956).

[e]Based on data from outside Satus Creek basin; probable depth exceeds 5,000 ft.

Because the fine-grained sedimentary materials and weathering products fill the interstices between some flows, probably less than half the interflow zones are capable of yielding significant quantities of ground water. Thus, only one in five interflow zones may be permeable enough to transmit and yield large quantities of water.

Recharge, Movement, and Discharge of Ground Water

Most ground-water recharge occurs in the higher, western one-third of the basin where the heaviest precipitation occurs, and where the more porous young basalt overlies the Yakima Basalt. Ground water then moves to the main area of discharge, which is the Yakima River valley. As mentioned earlier, some ground water also discharges to the streams, such as Logy and Satus Creeks.

No direct evidence is available on ground-water occurrence and water levels in the young basalt, as no wells have been drilled in these rocks in the upland areas. However, the relatively high base flow of Logy Creek compared to those of Dry and Satus Creeks, indicates that these rocks do store and transmit large amounts of water in the Satus Creek basin. Miscellaneous measurements indicate that the base flow of Logy Creek is rarely less than 20 ft^3/s, whereas Dry Creek becomes dry and the base flow of Satus Creek above Logy Creek is only a few cubic feet per second.

Rain and snowmelt percolate downward to reach the ground-water body in the young basalt, which overlies the much less permeable Yakima Basalt. Some of the water from the young basalt leaks downward to recharge the Yakima Basalt, but a large part presumably moves laterally along the contact between the two units to discharge at low points of a syncline (fig. 3) along Logy Creek.

The area underlain by the young basalt receives an average of about 198,000 acre-feet of precipitation per year of which about 102,000 acre-feet is lost to evapotranspiration (table 7). Thus, about 96,000 acre-feet of water leaves the area as streamflow or enters the underlying ground-water reservoir. Of this amount an estimated 27,000 acre-feet per year runs off the area in streams--much as snowmelt--leaving about 69,000 acre-feet of water to enter the young basalt. About 42,000 acre-feet of this ground-water recharge is discharged to streams in the upland as base flow, and the remaining 27,000 acre-feet recharges the underlying Yakima Basalt and moves as underflow to the lowland.

The 42,000 acre-feet per year, or an average of 58 ft^3/s, estimated to comprise base flow is discharged mainly to Logy Creek. The base flow of Satus Creek downstream from Dry and Logy Creeks is rarely less than 25 ft^3/s, and, combined with seepage losses in the lower reaches of Dry and Satus Creeks, which are probably at least 5 to 10 ft^3/s at low-flow stages (table 4), the actual minimum ground-water contribution to base flow from the young basalt may be 30 to 35 ft^3/s. Estimating outflow to be 30 to 35 ft^3/s at minimum stages, and taking into account that some water is lost by evapotranspiration and that base flow is higher at other times of the year, an average outflow of about 55 to 60 ft^3/s seems a reasonable estimate.

TABLE 7.--Quantities of water involved annually in precipitation and evapotranspiration in upland and lowland, according to rock units and types of land cover and use

Area	Precipitation (inches)	Subarea	Acres (1000's)	Average precipitation (inches)	Average evapotranspiration (inches)	Total precipitation (acre-ft)	Total evapotranspiration (acre-ft)	Difference[a] (acre-ft)
UPLAND	>30	100 percent young basalt	16.9	32.0	14.0	45,100	19,700	25,400
	25-30	95 percent young basalt, 5 percent Yakima Basalt	32.1	27.5	13.5	73,600	36,100	37,500
	20-25	80 percent young basalt, 20 percent Yakima Basalt	52.8	22.5	12.8	99,000	56,300	42,700
	15-20	5 percent young basalt, 95 percent Yakima Basalt	58.0	17.5	12.0	84,600	58,000	26,600
	10-15	100 percent Yakima Basalt	207	12.0	11.5	207,000	198,000	9,000
	<10	100 percent Yakima Basalt	38.3	8	8	25,500	25,500	0
		Subtotals:						
		Young basalt				198,000	102,000	96,000
		Yakima Basalt				337,000	292,000	45,000
		Totals				535,000	394,000	141,000
LOWLAND	10-15	Irrigated	12.0	[b]110.0	34.0	[b]110,000	34,000	76,000
		Nonirrigated	2.4	11.0	11.0	2,200	2,200	0
		Nonirrigated, waterlogged[c]	5.5	11.0	24.0	5,000	11,000	-6,000
	<10	Irrigated	7.0	[b]106	34.0	[b]61,800	19,800	42,000
		Nonirrigated	.3	8.0	8.0	200	200	0
		Nonirrigated, waterlogged[c]	4.5	8.0	24.0	3,000	9,000	-6,000
	10	Lakes, ponds, and streams	.6	10.0	60	500	3,000	-2,500
		Subtotals:						
		Irrigated	19.0			[b]172,000	53,800	118,000
		Nonirrigated[d]	13.3			10,900	25,400	-14,500
		Totals	32.3			183,000	79,200	104,000
		Grand totals				[e]718,000	473,000	245,000

[a] The difference between precipitation and evapotranspiration, which becomes streamflow and ground-water recharge; where negative, indicates water is lost to the atmosphere from streams and shallow ground-water bodies.

[b] Water diverted into basin, nearly all from Toppenish Creek, averaged 156,000 acre-feet per year during 1964-73. Average of 98.5 inches per year of irrigation water applied to the area is included with precipitation, which is estimated to be about 27,000 acre-feet per year in the lowland.

[c] Waterlogged areas are those in which water table is within 5 feet of land surface.

[d] Includes lakes, ponds, and streams.

[e] Precipitation is estimated to be 562,000 acre-feet per year over the basin.

Ground-water underflow in the Yakima Basalt is estimated to average about 30,000 acre-feet of water per year (p. 39); most of this, an estimated 27,000 acre-feet comes from the young basalt, while the remaining 3,000 acre-feet comes from precipitation directly where the Yakima Basalt is exposed at the surface in the remainder of the upland area. This direct recharge by precipitation to the Yakima Basalt is significantly less because (1) the area underlain by Yakima Basalt receives less rainfall, with an average of about 12 to 12.5 inches and with less than 10 percent of the area receiving more than 15 inches; (2) most of this rainfall either runs off as surface water, or is lost to evapotranspiration; and (3) the less permeable Yakima Basalt is less able to accept water applied to its surface than is the young basalt.

The potentiometric surface[1] of water in the Yakima Basalt slopes from west to east. A sufficient number of measured water levels are available to define adequately the 700-foot contour in the lowland (fig. 10). However, only one water-level measurement provided information on the main potentiometric surface in the irrigated lowland. In three of the four wells in the upland (fig. 1) water levels in the uppermost water-bearing zones stood at higher levels than those in the deeper zones. The water levels in the four wells are shown in the following table:

Well no.	Altitude at well (ft)	Depth of well (ft)	Depth to water (ft)	Final altitude of water level (ft)
7/19-10B1	2,805	408	232	2,573
7/19-14N1	3,064	160	160	
		710	226	2,838
8/20-36R1	1,740	140	140	
		408	268	1,472
9/19-20L1	1,317	308	141	
		476	140	
		698	184	
		698	[a]201	1,116

[a]When the lower zones were isolated from the upper zones.

[1]Surface defined by the levels at which water would stand in tightly cased wells tapping an aquifer.

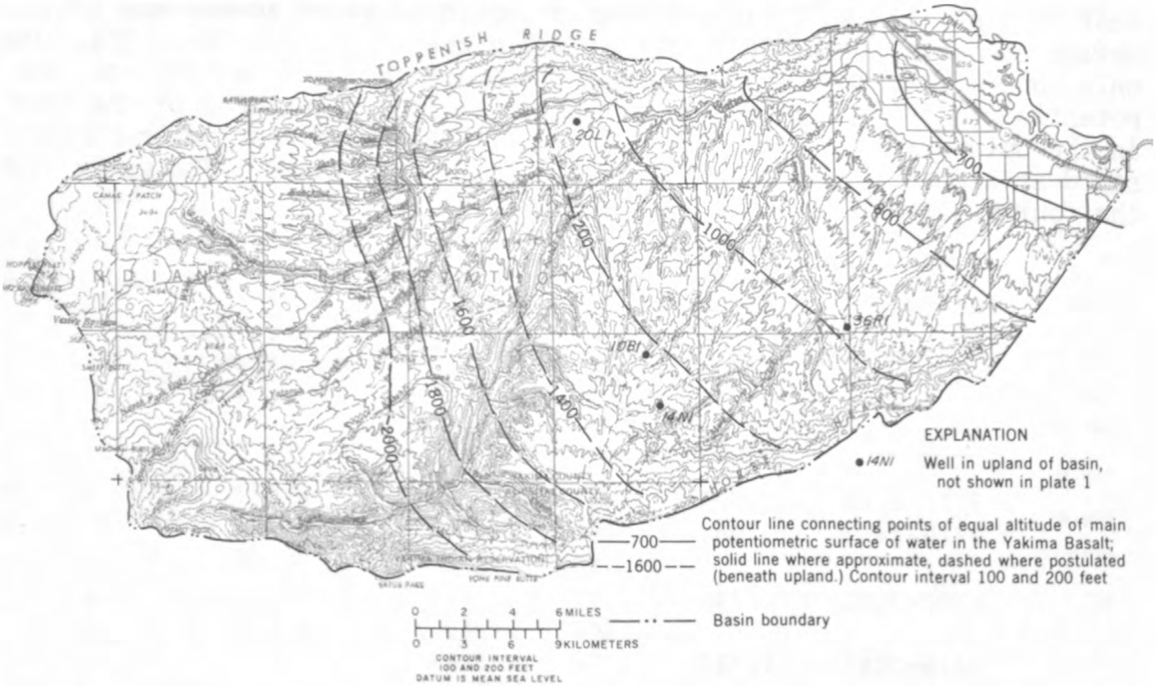


FIGURE 10.--Contours showing the main potentiometric surface of water in the Yakima Basalt.

Wells 10B1, 14N1, and 36R1 have water levels that are much higher than the main water table, which is probably near the elevation of the floor of the Satus Creek canyon. Water levels in these three wells reflect water-bearing zones that are high above the principal zones in the Yakima Basalt.

The fourth well, the Dry Creek test well (9/19-20L1), tapped three water-bearing zones, at depths of 235 to 308 feet, 358 to 444 feet, and 544 to 576 feet. The water levels in the upper two zones were virtually the same during the testing, ranging from about 140 to 145 feet below land surface, whereas the deeper zone had a water level of about 200 feet below land surface after the upper zones had been isolated by an inflatable packer installed in the well. The composite water level in the well, when it was open to all zones, was 184 feet below land surface. During a pumping test of the well, water flowed down the borehole from the two upper zones into the lower zone at a rate of about 65 gal/min. The altitude of the water level in the lower zone was about 1,115 feet, about 20 or 25 feet below the bottom of the Dry Creek Canyon 1 mile to the north and about the same level as the confluence of Logy and Satus Creeks about 3 miles due south of the well. Thus, it seems probable that the water level measured in the deeper zone of the well represents approximately the main potentiometric surface at that point, and that water levels in deeper aquifers would rise to at least the 1,115-foot altitude. Deeper water levels actually may be a little higher, because of possible upward movement of water from deeper aquifers. The bottom of well 9/19-20L1 is at an elevation of 619 feet, more than 50 feet below the level of the Yakima River in the presumed discharge area.

The main potentiometric surface is believed to be about the same as, or lower than the bottom of the main stream channels in much of the upland. If it were higher, springs would be prevalent along the stream channels and would supply a considerable amount of base flow throughout the year. However, topographic maps show few springs of this nature, although minor springs occur at higher altitudes along the canyon walls, and indicate perched ground-water bodies. Also, stream-discharge records do not indicate any significant gains along the middle reaches of Dry, Logy, and Satus Creeks. Based on this assumption, contours shown in figure 10 may represent the probable upper limit of the water table and potentiometric surface in the central and western parts of the basin. Possible geologic structural control, such as a fault, may disrupt the movement of ground water and create a more complicated water surface than the one shown in figure 10.

The discharge area for water in the Yakima Basalt, as well as in all other aquifers in the Satus Creek basin, is the Yakima River valley, at altitudes generally between 640 and 700 feet. The basalt is overlain by sedimentary deposits in varying thickness and is not exposed in the valley except several miles downstream from Mabton. Much of the discharge from the basalt is by upward leakage into the overlying Ellensburg Formation and Touchet Beds. Near places of discharge the potentiometric surface generally is higher in successively deeper aquifers.

Water-Yielding Characteristics

A pumping test was performed on the Dry Creek test well (9/19-20L1) in June 1973 (Gregg and Lum, 1973). When pumped for 31.5 hours at 200 gal/min, the well had a water-level drawdown of 67 feet, and when the rate was increased to 250 gal/min for 13.5 hours the total drawdown was 90 feet. Transmissivity of the Yakima Basalt tapped by this well was determined to be roughly 2,000 ft^2/d (feet squared per day); values ranged from 1,500 to 2,400 ft^2/d for the drawdown and recovery parts of the aquifer test. The values were determined by use of the straight-line solution of the Theis nonequilibrium formula (Jacob, 1950). Because a composite aquifer was involved in the test, the transmissivity value must be accepted with some reservation.

In a study of aquifers of the Yakima Basalt in east-central Washington, Luzier and Burt (1974) estimated transmissivities of aquifers penetrated by wells 500 to 1,000 feet deep. They found transmissivities to range from 1,600 to 4,000 ft^2/d and concluded in their report (Luzier and Burt, 1974, p. 25) that "***the average transmissivity of basalt aquifers in east-central Washington, within the depth range penetrated by the large-yield wells, is remarkably uniform over broad areas. On a more localized scale, however, transmissivity may vary over a wide range."

It would seem, therefore, that a transmissivity of 2,000 ft^2/d for the 500 feet of saturated thickness at the Dry Creek test site provides a reasonable value. A further check on transmissivities can be made by using specific-capacity data according to the method described by Theis, Brown, and Meyer (1963, p. 331-341). The transmissivity of basalt aquifers is roughly equivalent to the specific capacity (gallons per minute per foot of drawdown) multiplied by 270. The following table lists pumping-test data for wells that are more than 500 feet deep and yield water from the Yakima Basalt:

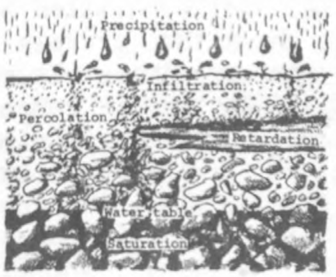
Well no. (locations shown in fig. 1 and pl. 1)	Depth (ft)	Depth to water (ft)	Yield (gal/min)	Drawdown (ft)	Specific capacity [(gal/min)/ft]	Transmissivity (ft^2/d)[a]
7/19-14N1	710	226	3	--	--	--
8/22-1G1	1,141	50	300	15	20	5,400
-1G2	1,080	53	950	23	41	11,100
-1G3	1,004	26	450	74	6.1	1,600
-11J1	556	92	1,302	276	4.7	1,300
-12H1	551	40	215	120	1.8	490
-12J1	500	104	180	237	.8	210
9/19-20L1	698	185	250	90	2.8	760
9/21-26M1	960	+3	325	104	3.1	840

[a] Determined by multiplying specific capacity value by 270.

According to this method of estimation, pumping of the Dry Creek test well (9/19-20L1) indicated an aquifer transmissivity of about 760 ft^2/d. This value may be less than that determined by the aquifer test because friction losses in a well create additional drawdown, thus giving a lower specific capacity. The three Mabton city wells (8/22-1G1, 1G2, 1G3; pl. 1) penetrate about twice the saturated thickness of most other wells, and their specific capacities indicate an average estimated aquifer transmissivity that is at least several times that of the aquifers tapped by the other wells. This suggests that some of the other wells have not been drilled deeply enough to reach the more productive aquifers underlying the Satus Creek basin. Also, the well yield is increased as more aquifers are tapped.

The above data suggest that wells penetrating 400 to 500 feet of saturated basalt could be expected to yield 200 to 300 gal/min on the average, with drawdowns of about 100 feet. Wells penetrating 1,000 feet of basalt, should encounter more and better water-bearing zones that should yield 500 to 1,000 gal/min with moderate drawdowns.

The above transmissivities can be used with the potentiometric-surface map (fig. 10) to make estimates of the total ground-water outflow through the Yakima Basalt from the upland to the lowland. If a transmissivity of 2,000 ft^2/d is assumed for a saturated basalt thickness of 1,000 feet, then, because the total saturated thickness probably exceeds 2,000 feet, a transmissivity of 4,000 ft^2/d appears reasonable. According to the potentiometric-surface map (fig. 10) the gradient to the west of the 800-foot contour line may be about 50 to 70 feet per mile, or an average of about 60 feet per mile. The width of the aquifer (width of the valley between Toppenish Ridge and Horse Heaven Hills) is about 15 miles, therefore, using the equation $Q = TIW$ (transmissivity x gradient x width), total underflow from the upland would be about 42 ft^3/s, or 30,000 acre-feet per year. These values should be considered very rough approximations, however, because of the tenuous nature of the data used in arriving at this estimate. Also, any faults or confining beds, if existing, could retard the flow of ground water through the basalt.



Valley-Fill Aquifers

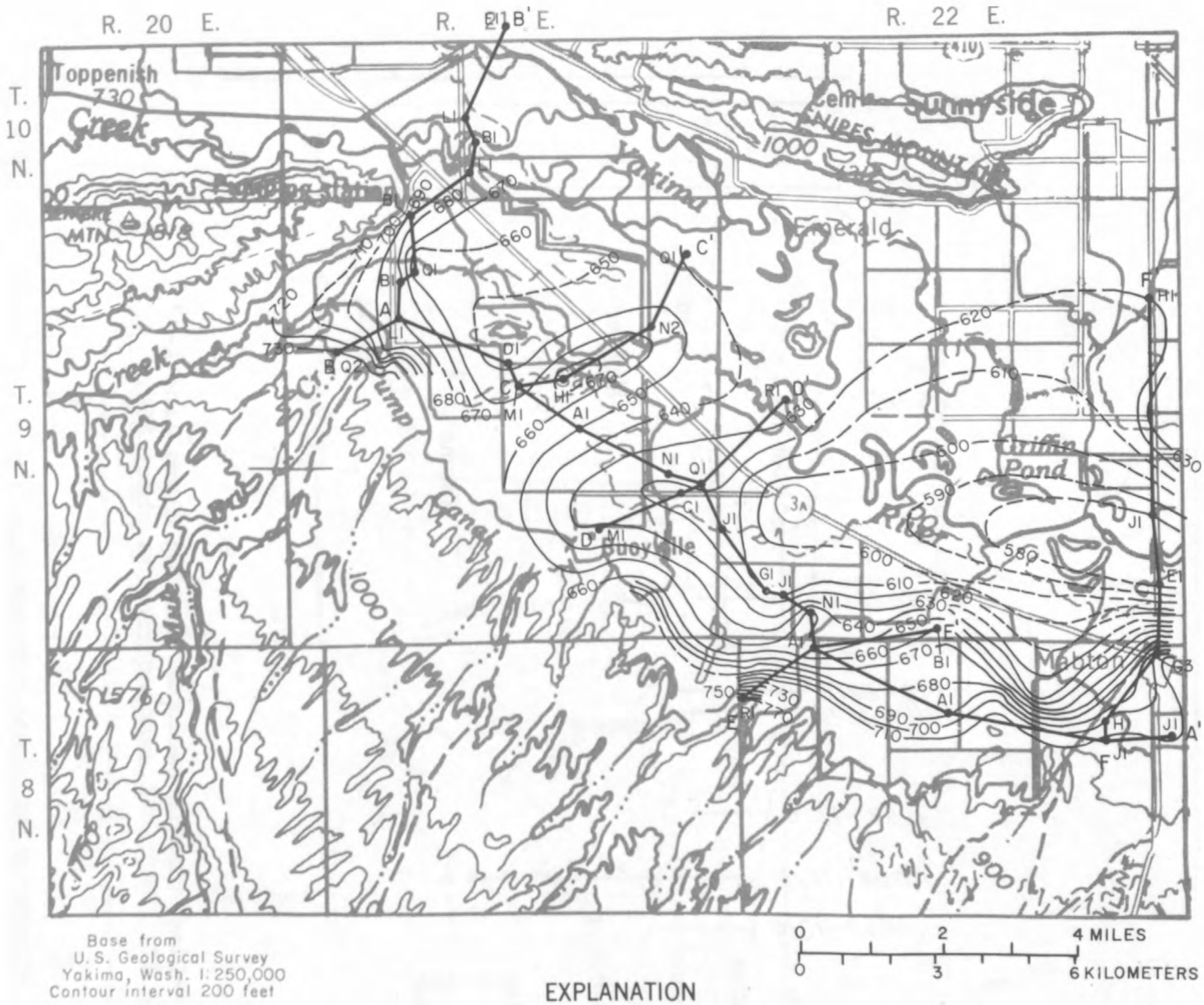
Overlying the basalt are partly cemented and unconsolidated valley-fill deposits of sand, gravel, silt, and clay. These deposits comprise the Ellensburg Formation, the old alluvium, the Touchet Beds of Flint (1938), and the young alluvium; except for the Touchet Beds these sedimentary units form the principal aquifers in the lowland of the Satus Creek basin (table 6); they are herein referred to as the valley-fill aquifers.

The lower part of the Ellensburg Formation was deposited contemporaneously with the upper part of the Yakima Basalt. Some geologists have included the sedimentary interbeds as units of the Yakima Basalt; others have designated these upper lava flows, interbedded with sediments of the Ellensburg, as units in the Ellensburg Formation. In this report the terminology of Bingham and Grolier (1966) is followed in that the sedimentary beds are all considered to be part of the Ellensburg Formation and the lava flows are all considered to be part of the Yakima Basalt.

In the Satus Creek basin, those parts of the Ellensburg Formation interbedded with the upper parts of the Yakima Basalt are mostly fine-grained materials so are not productive aquifers. In most of the upland areas, the upper part of the Ellensburg Formation, and in places the lower part also, have been eroded from the basalt, but in the lowland east of the Satus Pump canals many wells pump water from the Ellensburg Formation overlying the uppermost Yakima Basalt strata. The logs of wells in the lowland show that the Ellensburg Formation above the uppermost basalt flow consists predominantly of sand and gravel and that many of the strata are moderately to well cemented (table 13, p. 96). The geologic sections (locations in fig. 11) in figures 12-17 show the units and their relationship to each other.

Where exposed in gravel pits at 8/21-18N and 9/21-6K, the Ellensburg Formation comprises predominantly moderately well-cemented gravel with lenses of sand. The deposits are rather poorly sorted; sizes range from sand to 6-inch cobbles. Basalt and andesite predominate, but the most striking characteristic of this unit is the yellowish- to reddish-colored quartzite pebbles which make up 20 to 25 percent of the exposure. Other strata include sand, clay, and gravelly clay. The maximum recorded thickness of the Ellensburg Formation in the basin is 178 feet, as shown by the log of well 9/21-24Q1. The estimate by Laval (1956) of the total thickness of 750 feet for the upper Ellensburg Formation indicates that in the Satus Creek basin lowland much of the upper part of the formation has been removed by erosion.

The old alluvium overlies the eroded surface of the Ellensburg Formation, but no surface exposure of the old alluvium was seen in the area. However, what is believed to be sand and gravel layers of this unit were observed in samples obtained from two test wells drilled by the U.S. Geological Survey. At well 9/21-8L1, only dark, basaltic gravels were found in the 38- to 100-foot interval between the overlying Touchet Beds and the underlying Yakima Basalt. At well 9/21-24Q1, gravels composed of basalt, some andesite, and a little quartzite were found below the base of the Touchet Beds at 64 feet and down to a depth of 117 feet. Between 117 and 209 feet, the log records sand and gravel, with some clay, and the interval between 117 and 136 feet was logged as semiconsolidated. This suggests that the interval between 117 and 209 feet is the upper part of the Ellensburg Formation; below 209 feet the strata are typical quartzitic conglomerate of the Ellensburg Formation.



EXPLANATION

•J1

Well location and abbreviated number
See geologic section for complete number.

——— 680 - - - -

Line connecting points of equal altitude at base of Touchet Beds, in feet above mean sea level; dashed where approximate.

D———————D'

Location of geologic sections of figures 12–17

FIGURE 11.--Contours on the contact between the base of the Touchet Beds of Flint (1938) and the underlying old alluvium and Ellensburg Formation in the lowland, and locations of geologic sections shown in 12-17.

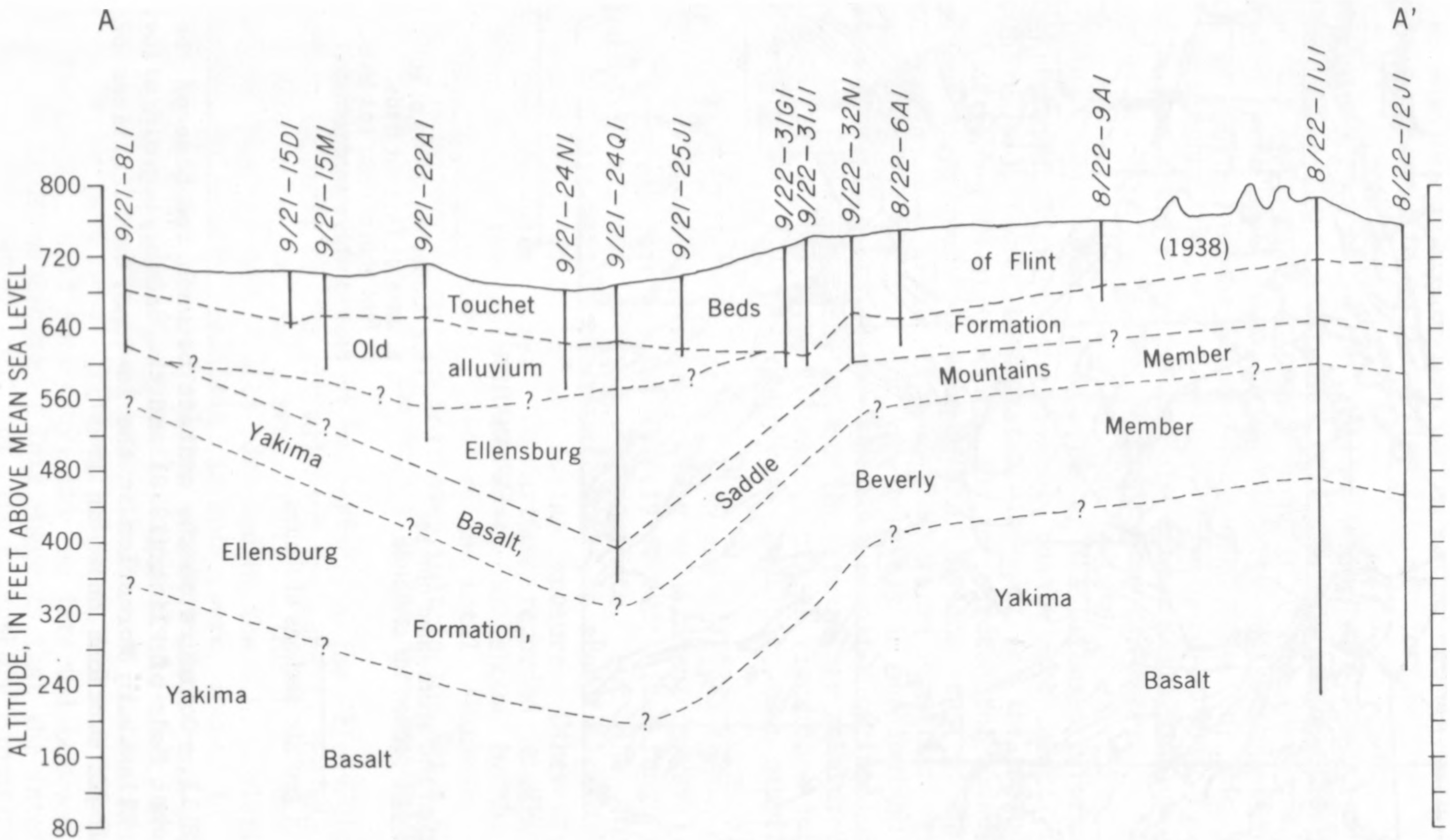


FIGURE 12.--Diagrammatic geologic section along line A-A' of figure 11. Vertical exaggeration is about X50.

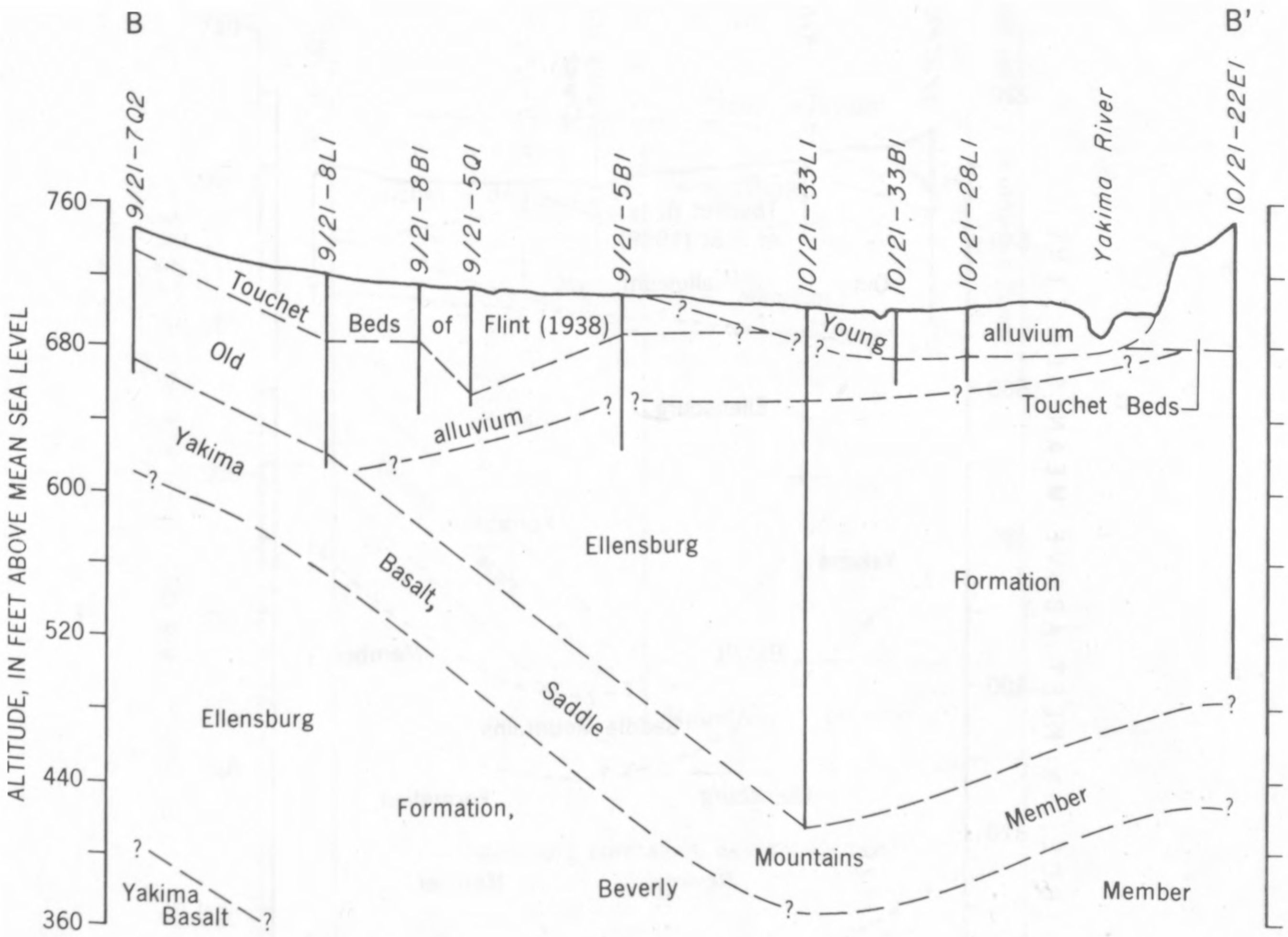


FIGURE 13.--Diagrammatic geologic section along line B-B' of figure 11. Vertical exaggeration is about X50.

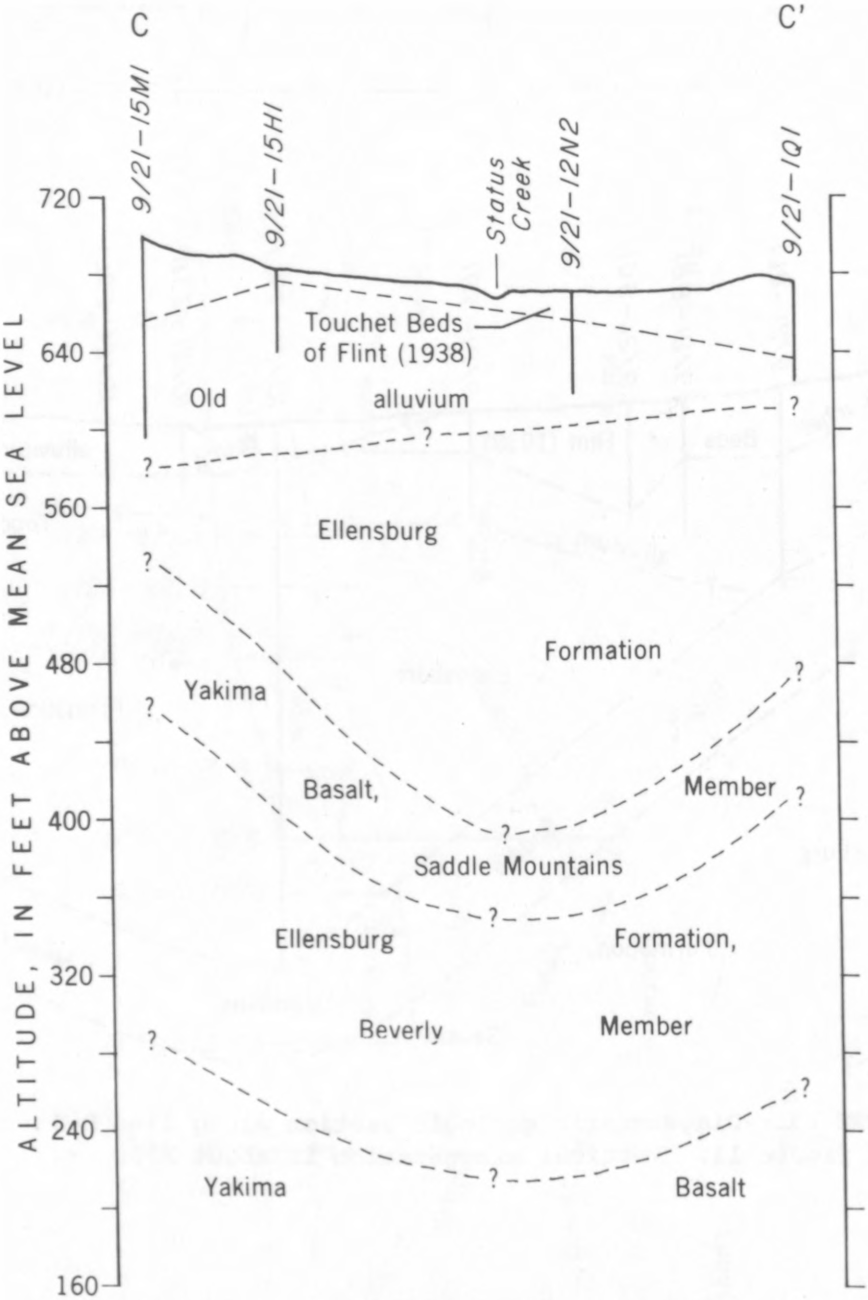


FIGURE 14.--Diagrammatic geologic section along line C-C' of figure 11. Vertical exaggeration is about X50.

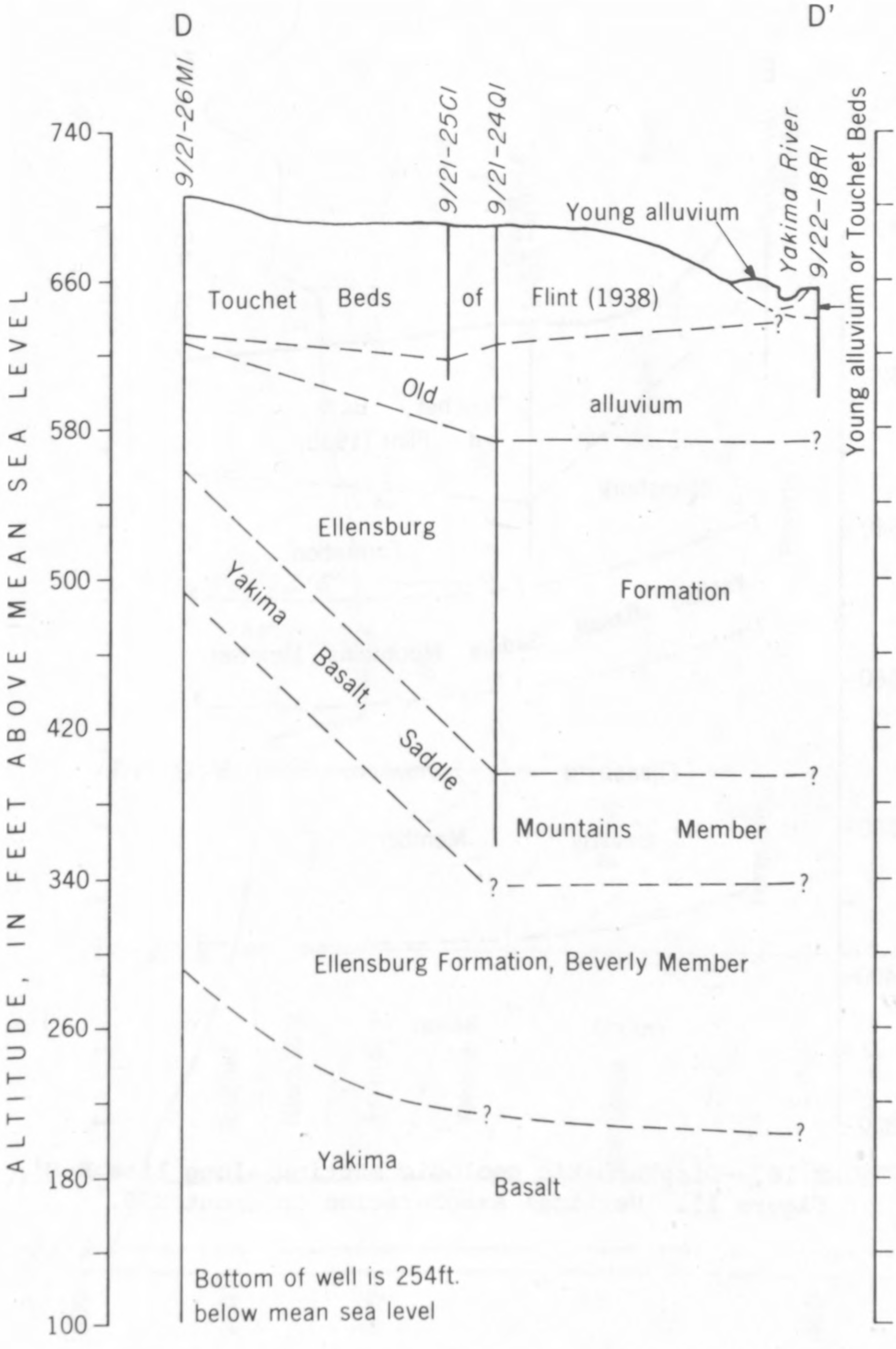


FIGURE 15.--Diagrammatic geologic section along line D-D' of figure 11. Vertical exaggeration is about X50.

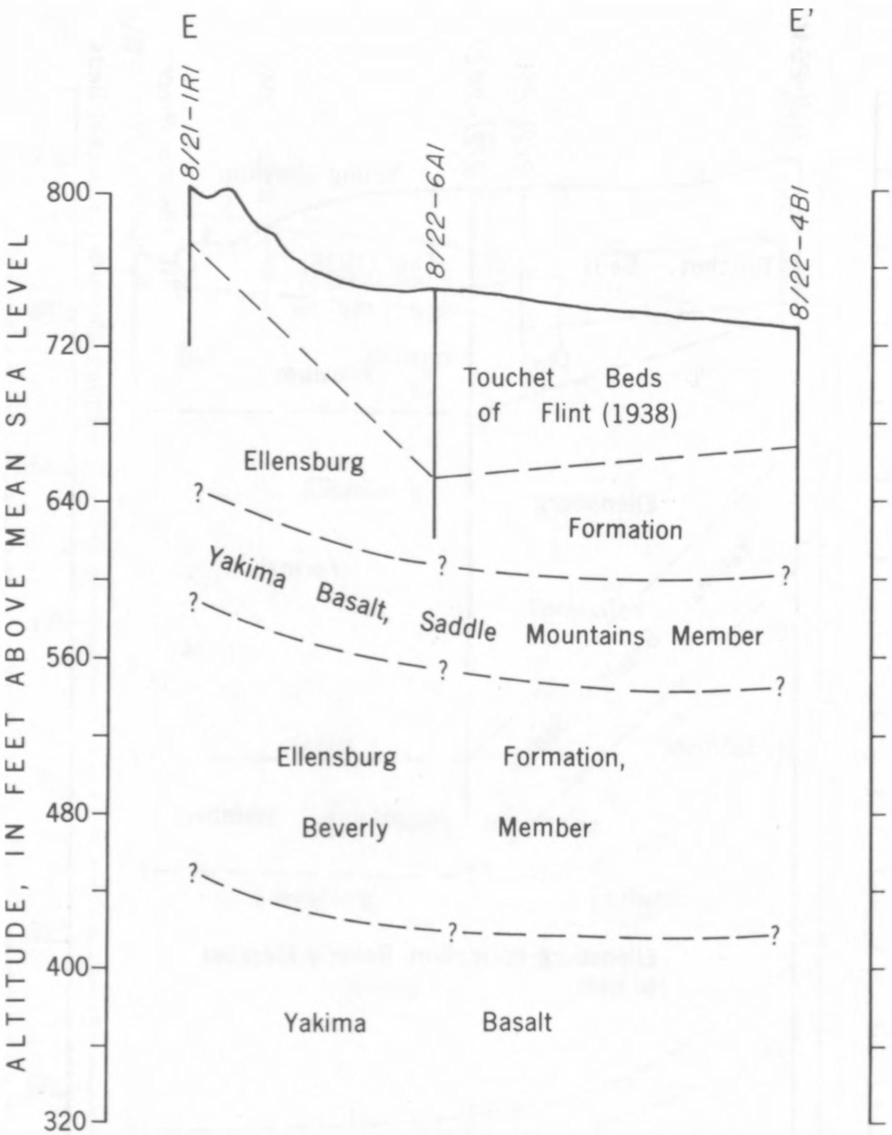


FIGURE 16.--Diagrammatic geologic section along line E-E' of figure 11. Vertical exaggeration is about X50.

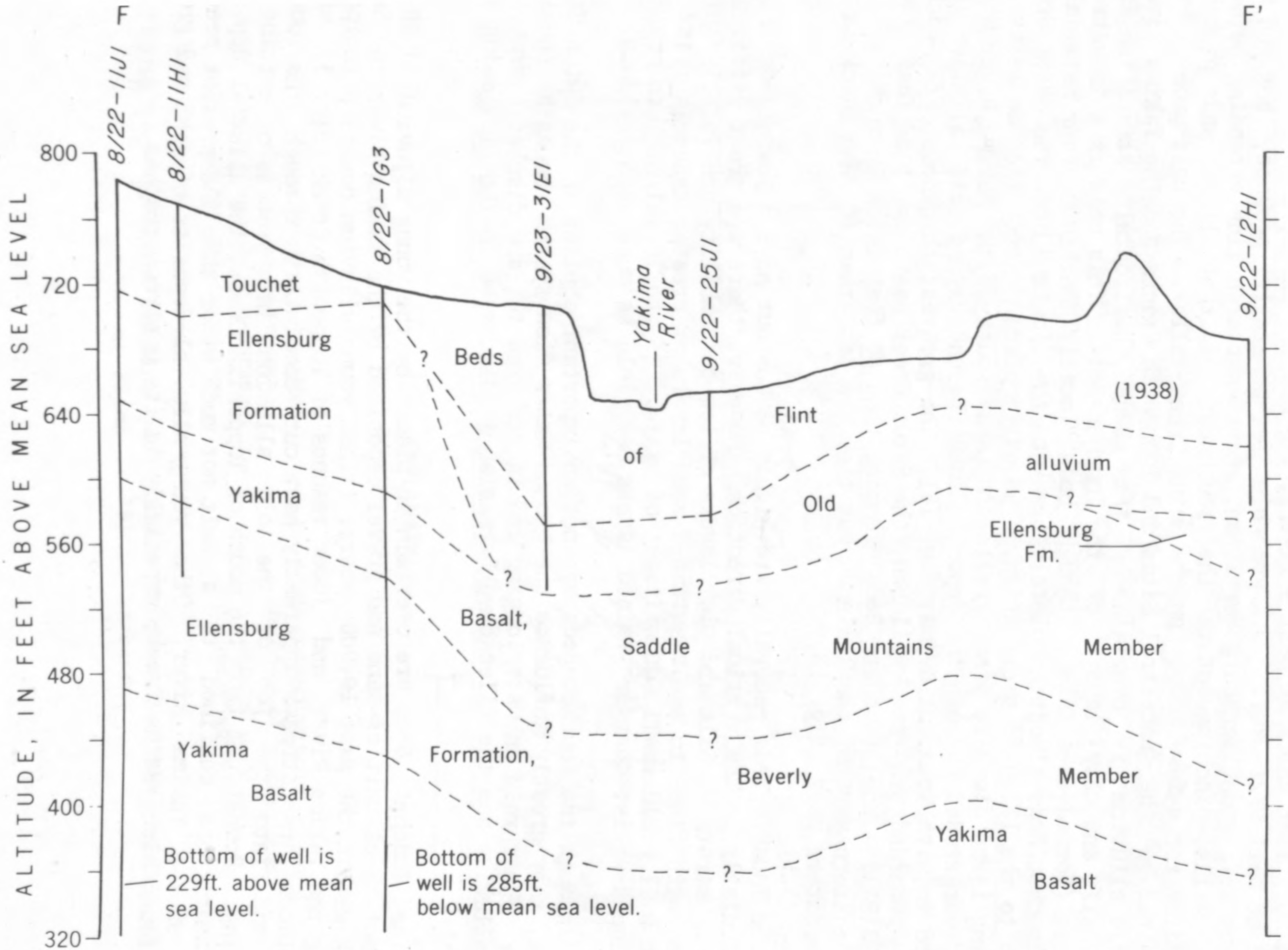


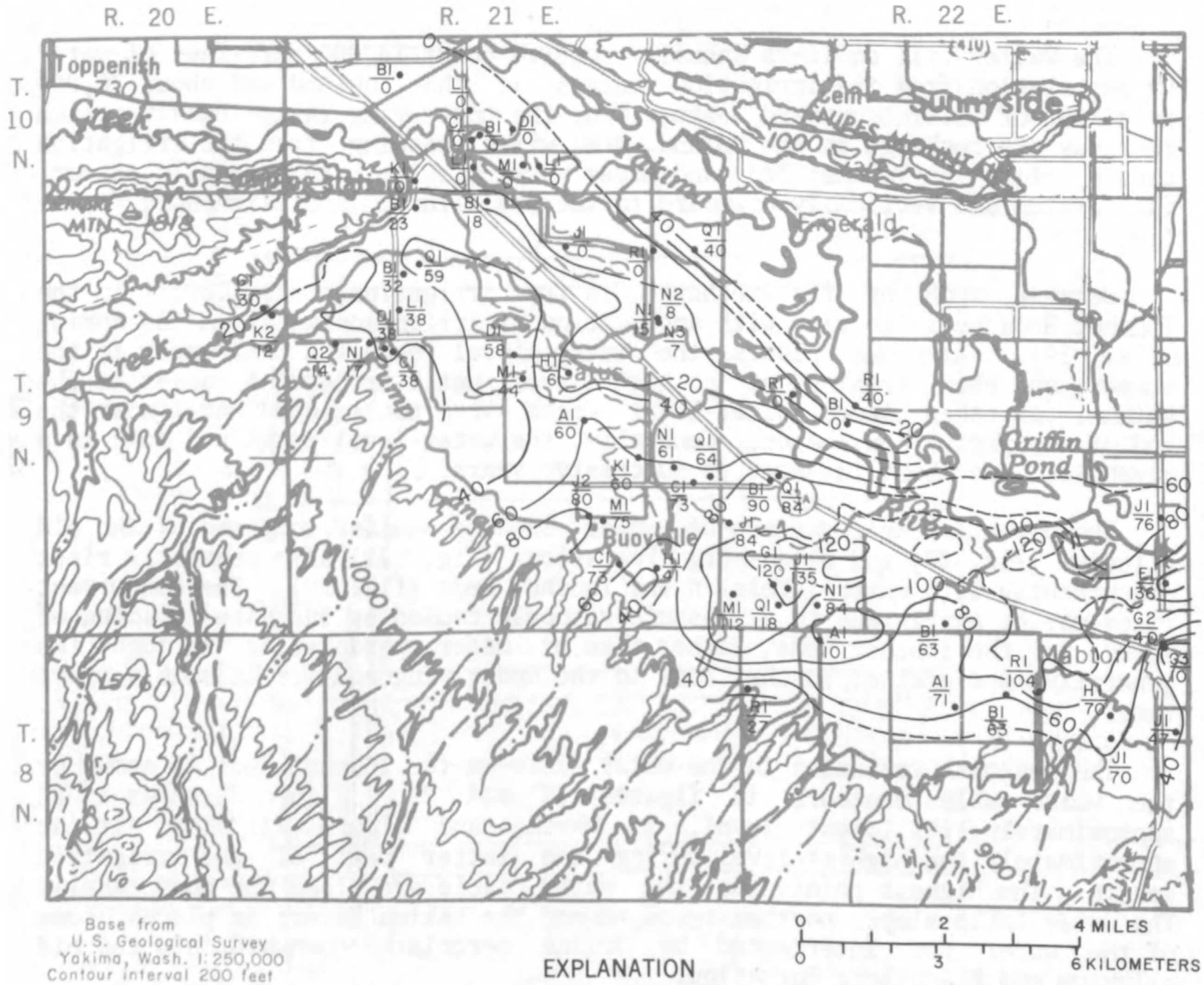
FIGURE 17.--Diagrammatic geologic section along line F-F' of figure 11. Vertical exaggeration is about X50.

As the old alluvium is not exposed at the surface, being overlain by Touchet Beds or young alluvium, and it has not been observed except in samples from only two wells, its areal extent is not known. The unit is about 62 feet thick at well 9/21-8L1, the maximum known, and about 53 feet thick at well 9/21-24Q1. It probably is generally present, between the Touchet Beds and Ellensburg Formation, northeast of a line extending between these wells, pinching out to the southwest of that line, and probably extending for a few miles up the Satus Creek valley. The unit probably was deposited by the ancestral Satus and Toppenish Creeks and the Yakima River. The old alluvium is overlain by thin-bedded, horizontally stratified fine sand, silt and clay layers of the Touchet Beds. This unit is a lacustrine deposit (formed in a lake), though beds locally contain coarser materials. The Touchet Beds almost completely blanket the lowland of the Satus Creek basin to the 1,150-foot elevation. The only place where the deposits are missing is an elongate area parallel to, and south of the Yakima River where the river eroded through the deposits into the underlying old alluvium (now filled in with young alluvium; fig. 18). The greatest thickness of Touchet Beds recorded in any well in the Satus Creek basin is 136 feet (well 9/23-31E1). The Touchet Beds are more than 80 feet thick in much of the southeastern part of the lowland, but they are less than 60 feet thick in the northwestern part (fig. 18).

The Touchet Beds generally are highly porous but have a low permeability, particularly in the vertical direction. However, there are great differences between strata. Silt and clay layers of low permeability are locally interbedded with fine- to medium-grained sand layers of greater transmissivity and which will yield small quantities of water (5 to 10 gal/min) to properly developed wells; coarser grained layers may yield as much as 50 gal/min.

Although the Touchet Beds are not an important aquifer in the Satus Creek basin, they greatly influence the ground-water flow system beneath the lowland. Their role in waterlogging and in recharge to, and discharge from, the old alluvium and the Ellensburg Formation is discussed in the following section.

The Touchet Beds are overlain in places by the young alluvium, a 20- to 30-foot-thick unit of sand and gravel deposited by the Yakima River and Satus Creek within the past 10,000 years. The young alluvium occurs principally along the Yakima River and lower reaches of Toppenish Creek (fig. 3), where in places these streams apparently have cut completely through the Touchet Beds and into the top of the old alluvium, in a process of cutting and filling. Downstream from the mouth of Toppenish Creek, the alluvial deposits apparently are confined to a belt not much wider than the present meander belt of the Yakima River. Other young alluvial deposits of sand and gravel are found along Satus Creek, especially in its upstream reaches.



EXPLANATION

• J1/135

Well
Top number is abbreviated well number within section
Bottom number is thickness of Touchet Beds, in feet

——100– – –

Line connecting points of equal thickness of Touchet Beds;
Interval is 20 feet;
dashed where approximate

FIGURE 18.--Contours showing generalized thickness of the Touchet Beds of Flint (1938) in lowland.

Recharge, Movement, and Discharge of Ground Water

The valley-fill aquifers annually receive about 13,000 acre-feet of water by percolation from the irrigation canals in the lowland and about 20,000 acre-feet of water by upward leakage from the underlying Yakima Basalt, which receives its recharge in the upland. The water leaking from the irrigation canals enters the Touchet Beds and moves very slowly, both laterally to surface drains and vertically downward to the old alluvium and Ellensburg Formation.

Because much of the recharge is from irrigation, water levels in the Touchet Beds begin to rise with application of irrigation water in the spring (fig. 19). At some places the water level reaches a peak early in the summer, and then remains at a high level until irrigation ceases in the autumn. At other places, water-level peaks are not reached until near the end of the irrigation season. Generally, the water-level peaks and lows in a given well are about the same in successive years.

The potentiometric surface of water in the aquifer composed of the old alluvium (fig. 20) and Ellensburg Formation (fig. 21) also generally rises concurrently with water levels in the Touchet Beds (fig. 19). The concurrent rises may be partly due to a pressure response caused by increased loading of water in the Touchet Beds, rather than by water percolating through the generally fine-grained Touchet Beds to the underlying aquifer in such a short time.

The seasonal variation in the water table in the Touchet Beds is shown by the water-table contours in figures 22 and 23. Figure 22 shows it at approximately its lowest level, in March, and figure 23 shows it at approximately the highest level during the latter part of the irrigation season. The highest points on the water table are along the pump canals. The water table slopes northeastward toward the Yakima River; in places, some of the water not intercepted by drains percolates downward into the old alluvium and Ellensburg Formation.

The seasonal variation in the potentiometric surface of the aquifer comprising the old alluvium and the Ellensburg Formation is shown by the contours in figures 24 and 25. Figure 24 shows the potentiometric surface in March, which is generally its period of lowest level, coinciding with low water levels in the Touchet Beds, and figure 25 shows the potentiometric surface during August-October when it is generally at its highest level, during the latter part of the irrigation season, which roughly coincides with the time of highest water levels in the Touchet Beds.

The contours show that ground water moves generally eastward in the northwestern part of the lowland and northward in the southeastern part of the lowland, all toward the Yakima River and its sloughs. About midway between Granger and Mabton, the contours are widely spaced, indicating that ground water is discharging freely. In contrast, closely spaced contours in the southern half of the lowland (fig. 25) indicate that water is not discharging freely. Two reasons for the difference in contour intervals between the northwestern and southeastern parts of the lowland are as follows:

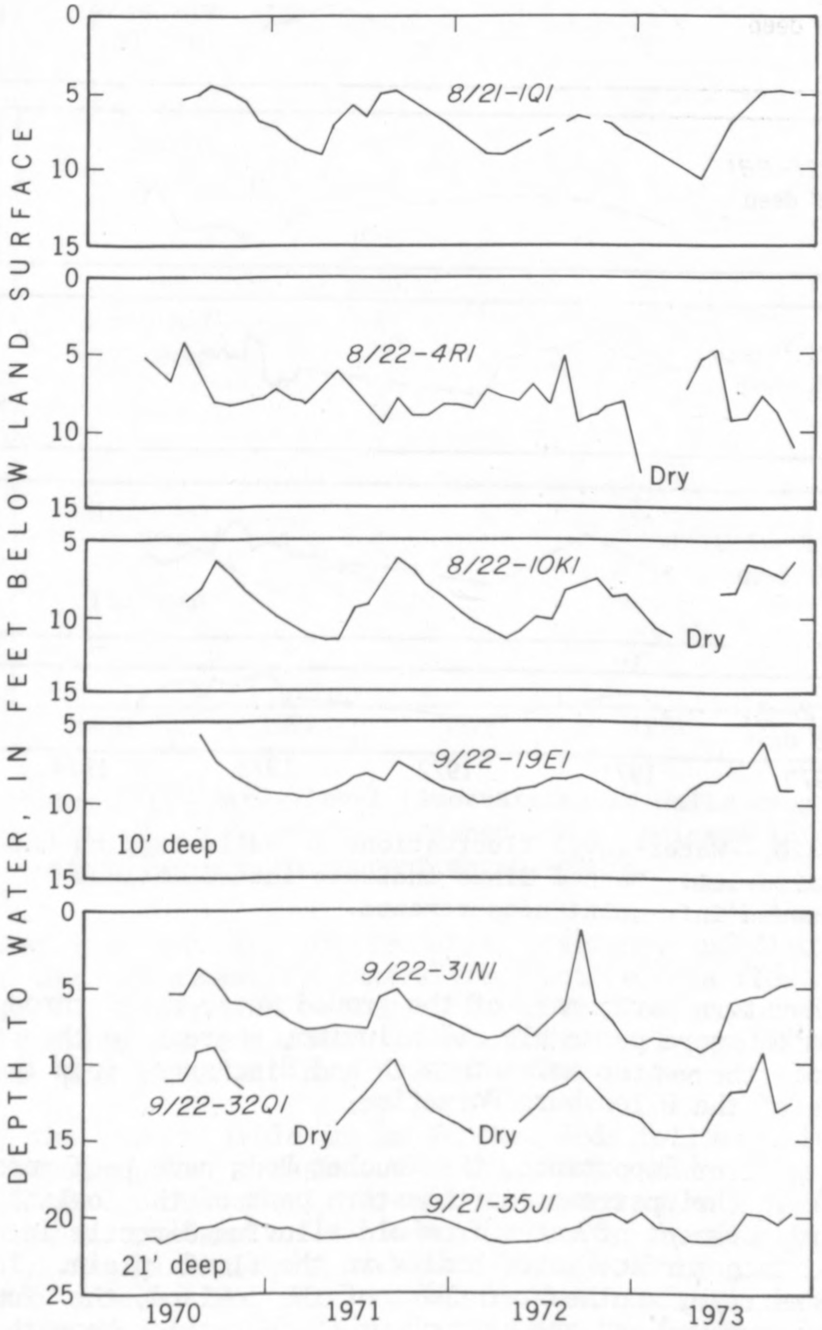


FIGURE 19.--Water-level fluctuations in piezometers ending in the Touchet Beds of Flint (1938).

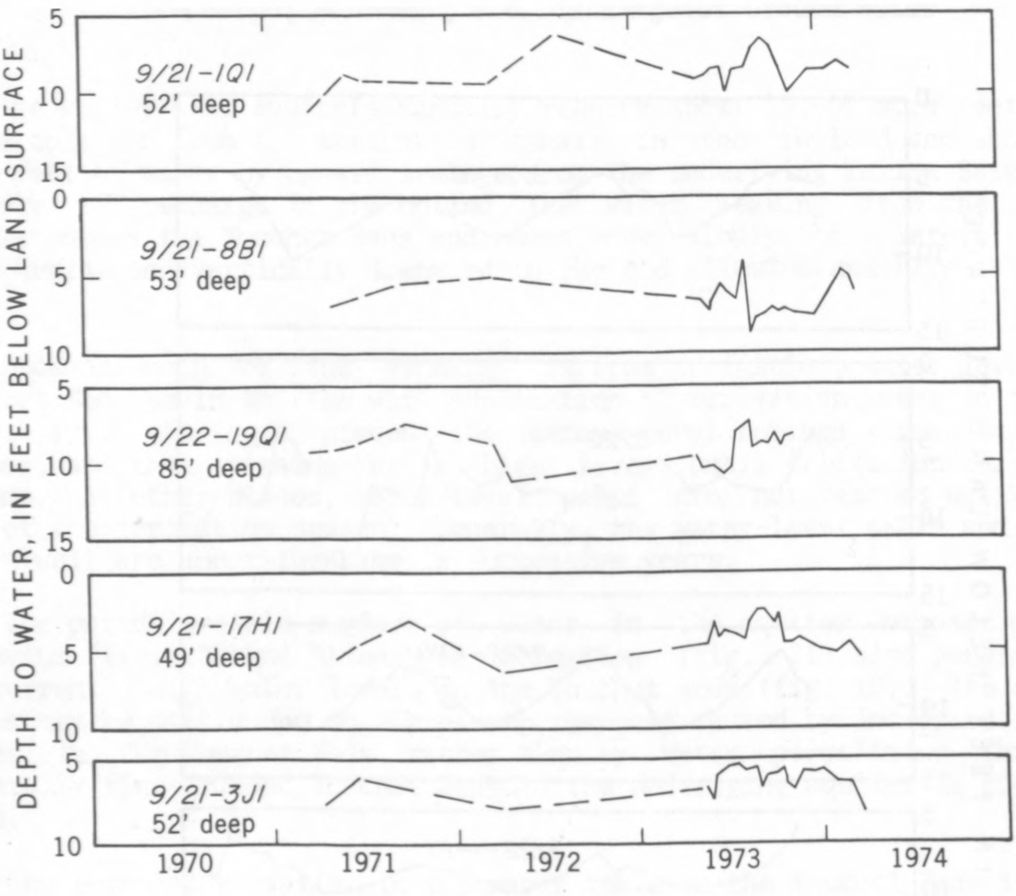


Figure 20.--Water-level fluctuations in wells tapping the old alluvium. Dashed lines indicate interpolations between infrequent measurements.

1. In the northwestern part, most of the ground water moves through and discharges from the more permeable old alluvium, whereas in the southeastern part most of the water moves through and discharges from the less permeable parts of the Ellensburg Formation.

2. Probably of greater importance, the Touchet Beds have been removed by the Yakima River in the upstream, northwestern part of the lowland, resulting in the upward movement of water from old alluvium directly into the young alluvium and into surface-water bodies in the flood plain. In contrast, in the downstream, southeastern part of the lowland, the Touchet Beds have not been removed and are as much as 50 feet thick beneath the Yakima River flood plain. In this reach ground water can discharge into surface-water bodies on the flood plain only by moving laterally or vertically through the much less permeable Touchet Beds, and large gradients are required to affect this discharge. (Compare cross-sections B-B' and D-D' with cross-section F-F' in figs. 13, 15, and 17.)

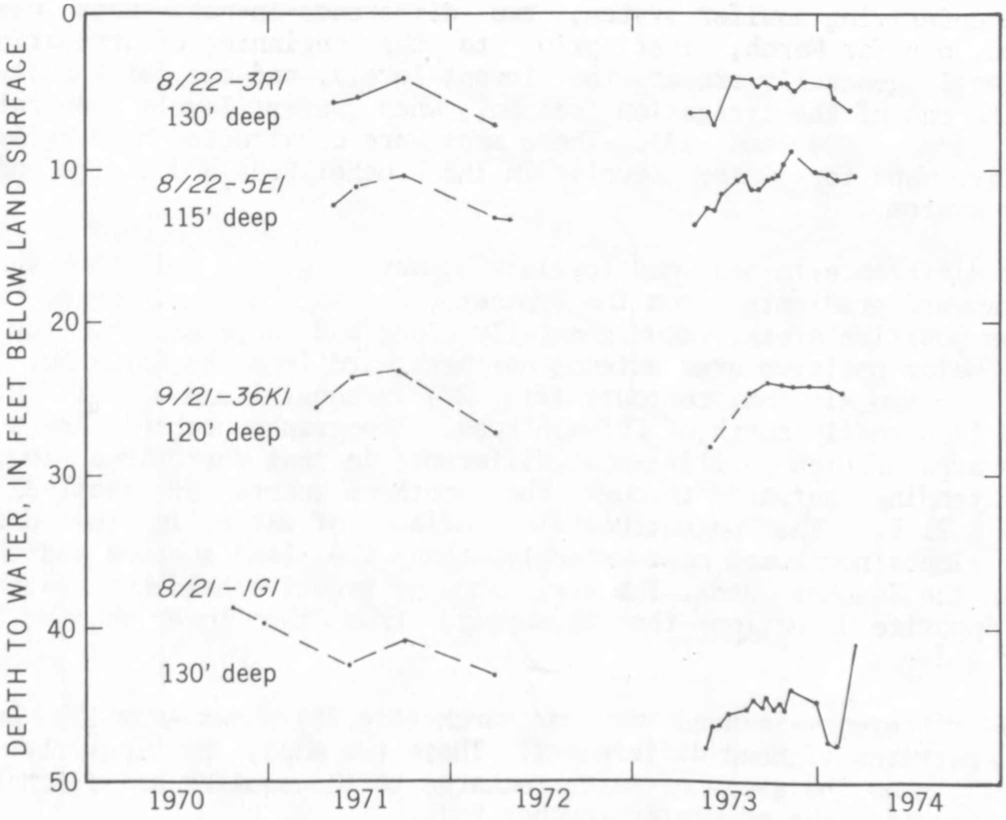


FIGURE 21.--Water-level fluctuations in wells tapping the Ellensburg Formation. Dashed lines indicate interpolations between infrequent measurements.

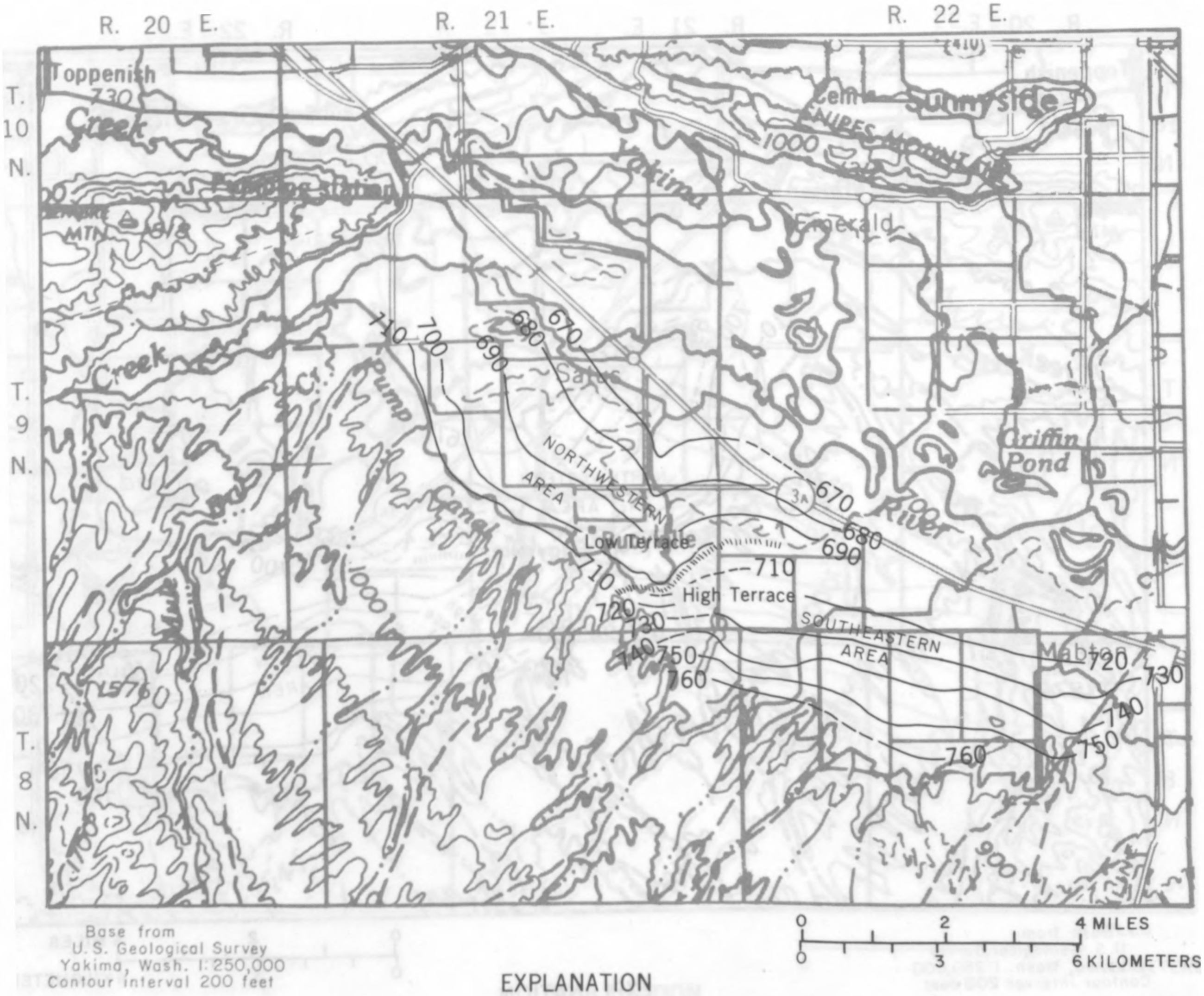
The foregoing discussion of recharge, movement, and discharge of ground water in the lowland presents a generalized picture of a flow system that may have great local differences because of the complex geometry of the aquifer units and the hydraulic variations within individual aquifers. Lack of data precludes more precise determination of the flow system.

Although the water table in the Touchet Beds follows fairly closely the generalized topographic expression of the land surface, the potentiometric surface of water in the underlying aquifer system is more uniform. For this reason, in places the head on the water is greater in the underlying aquifer system than in the Touchet Beds, and ground water moves upward from the lower aquifer system to enter the Touchet Beds. Also, recharge from irrigation to the Touchet Beds is seasonal, whereas recharge to the lower aquifer system, by downward leakage from the Touchet Beds and upward leakage from the Yakima Basalt, continues throughout the year, although at a reduced rate during the nonirrigation season. For these reasons, the vertical direction of ground-water movement between the two aquifers may change from season to season.

To show generally the seasonal differences in heads between the Touchet and the underlying aquifer system, two difference-in-head maps were constructed, one for March, just prior to the beginning of irrigation, when water levels generally are at the lowest levels, and one for August-October near the end of the irrigation season, when water levels generally are highest (figs. 26 and 27). These maps were constructed by overlaying the respective maps for water levels in the Touchet Beds and in the underlying aquifer system.

The difference-in-head map for late summer (fig.27), indicates that maximum downward gradients, from the Touchet Beds to the underlying aquifer, shown as positive areas, occur generally along and adjacent to the canals. Another major positive area extends northeastward from the Satus No. 3 Canal, between the two +10-foot contours (fig. 27) in secs. 1 and 2, T.8 N., R. 21 E., and lies mostly north of Colwash Road. Topography probably is a factor in this area of high positive-head difference in that there is a low, broad ridge extending eastward through the southern parts of secs. 31 and 32, T.9 N., R.21 E. The potentiometric surface of water in the underlying aquifer slopes northward more steeply than the land surface and the water table in the Touchet Beds. The areas showing negative head have water moving in the opposite direction--that is, upward from the lower aquifer into the Touchet Beds.

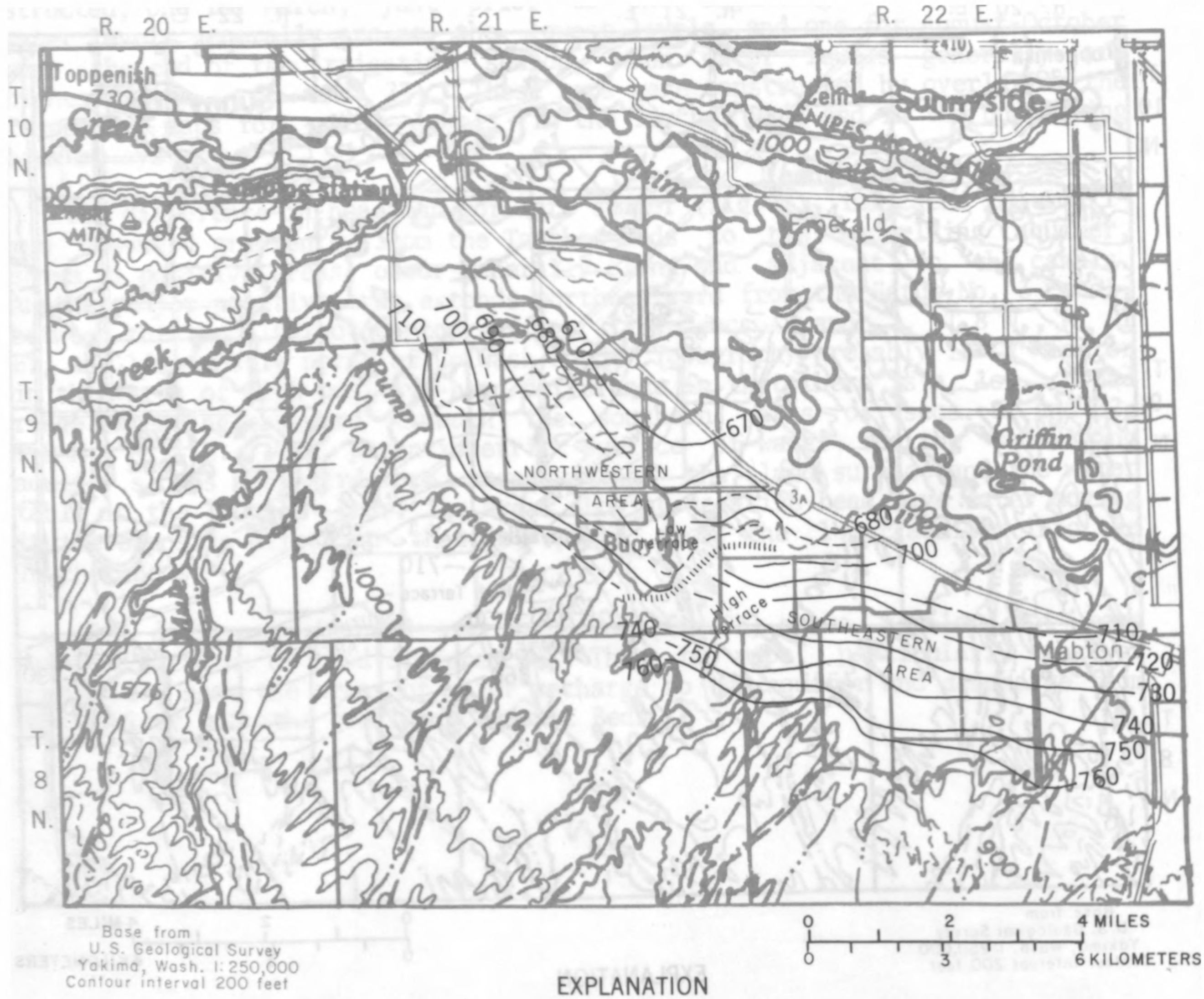
The difference-in-head map for March (fig.26) shows similar but more subdued patterns of head differences. These two maps, particularly that of figure 27, show the areas of major recharge to the aquifer and discharge from the aquifer into the overlying Touchet Beds.



EXPLANATION

——710--- WATER TABLE CONTOUR——shows altitude of water table, in feet above mean sea level; dashed where approximate. Water table in northwestern area is from mostly 1967 data; that in southeastern area is from mostly 1972–73 data. Interval is 10 feet

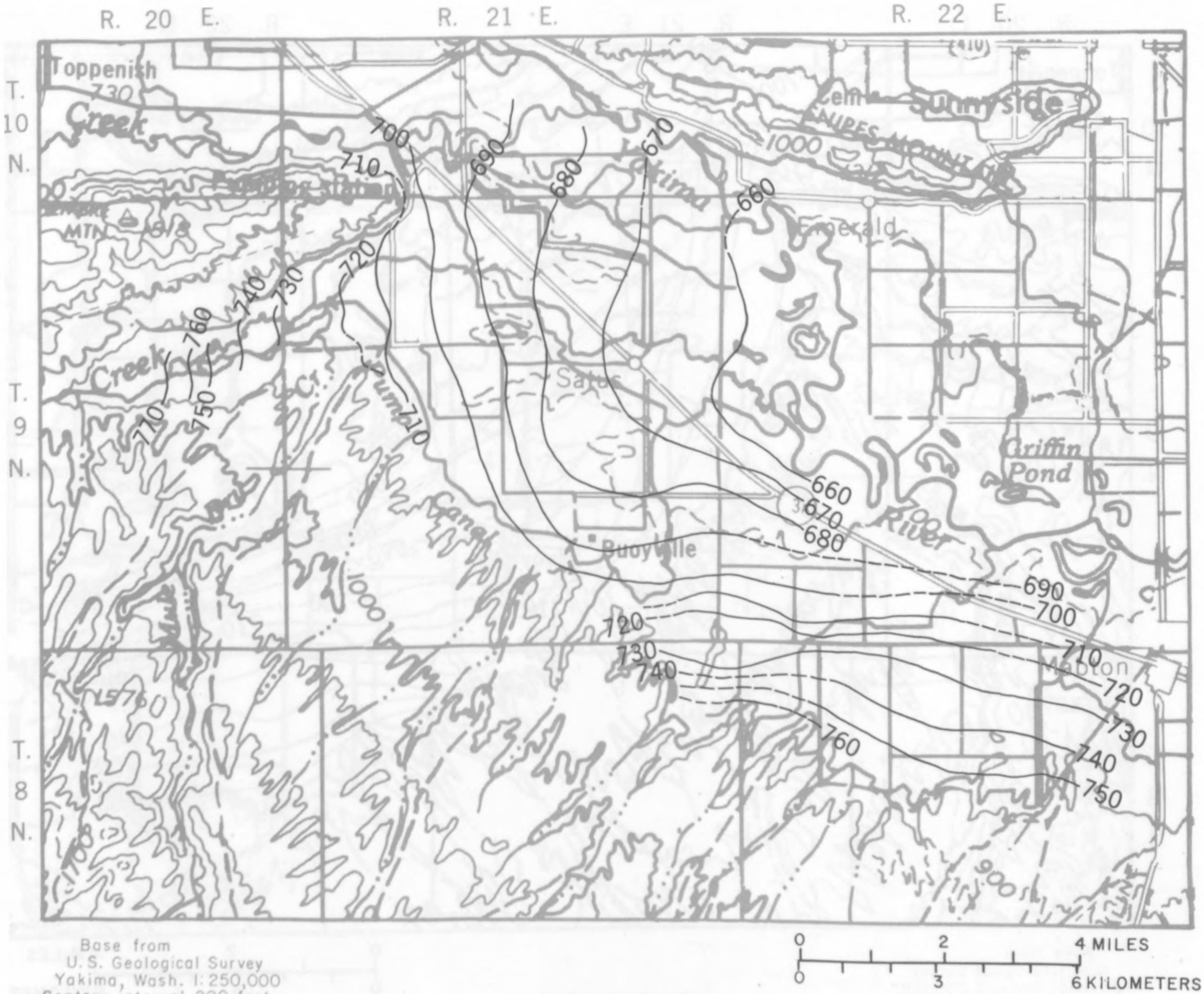
FIGURE 22.--Contours on water table in Touchet Beds of Flint (1938) underlying the Satus Creek lowland during low-water-level period, March 1972.



EXPLANATION

— 720 — --- WATER TABLE CONTOUR--shows altitude of water table, in feet above mean sea level; long dashes where approximate, short dashes where intermediate. Water table in northwestern area is mostly from 1969 data; that in southeastern area is mostly from 1972 data. Interval is 5 and 10 feet.

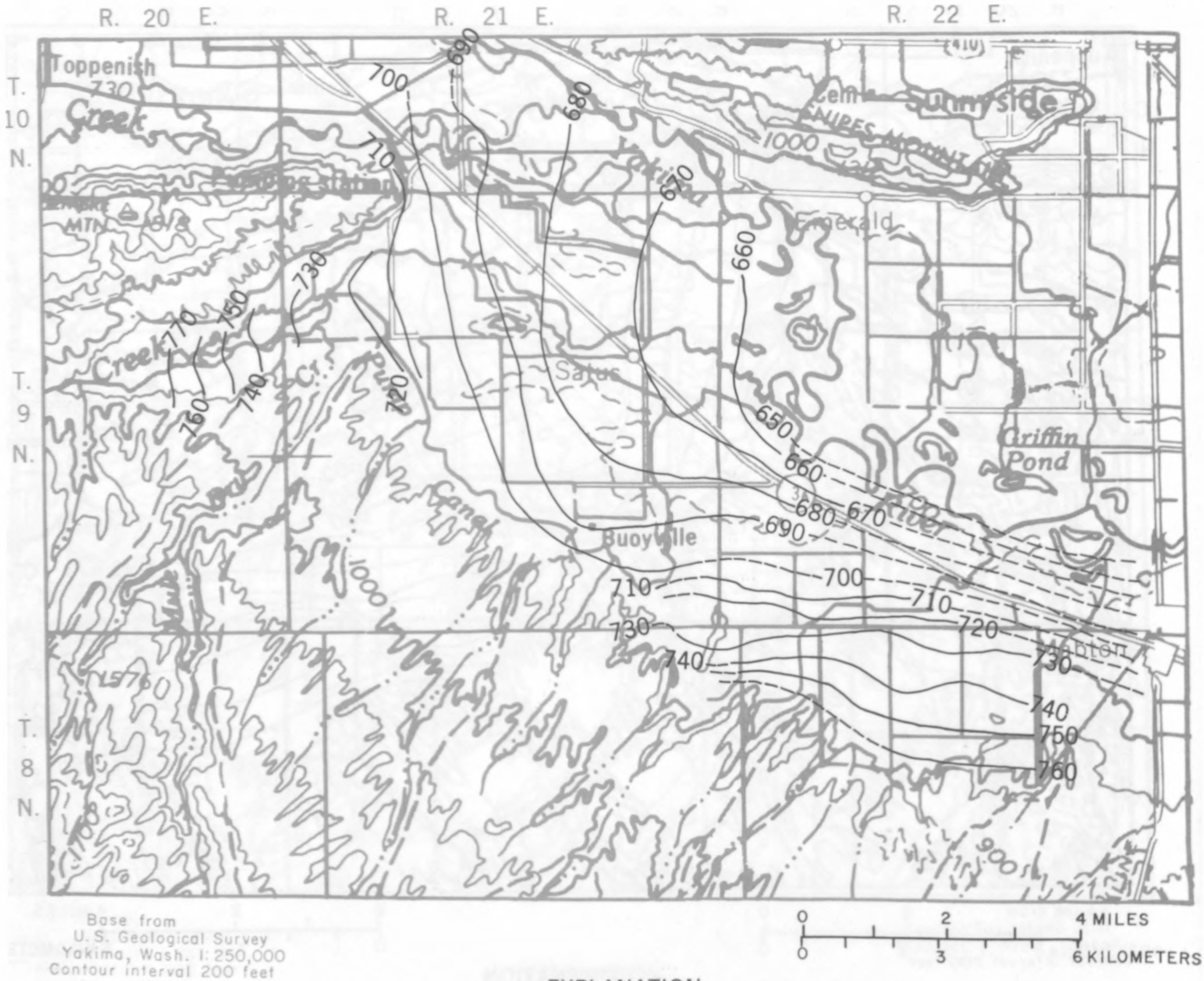
FIGURE 23.--Contours on water table in Touchet Beds of Flint (1938) underlying the Satus Creek lowland during high-water-level period, August-October 1972.



EXPLANATION

——710 - - - POTENTIOMETRIC CONTOUR——connecting points of equal altitude of potentiometric surface, in feet above mean sea level; dashed where approximate Interval is 10 feet.

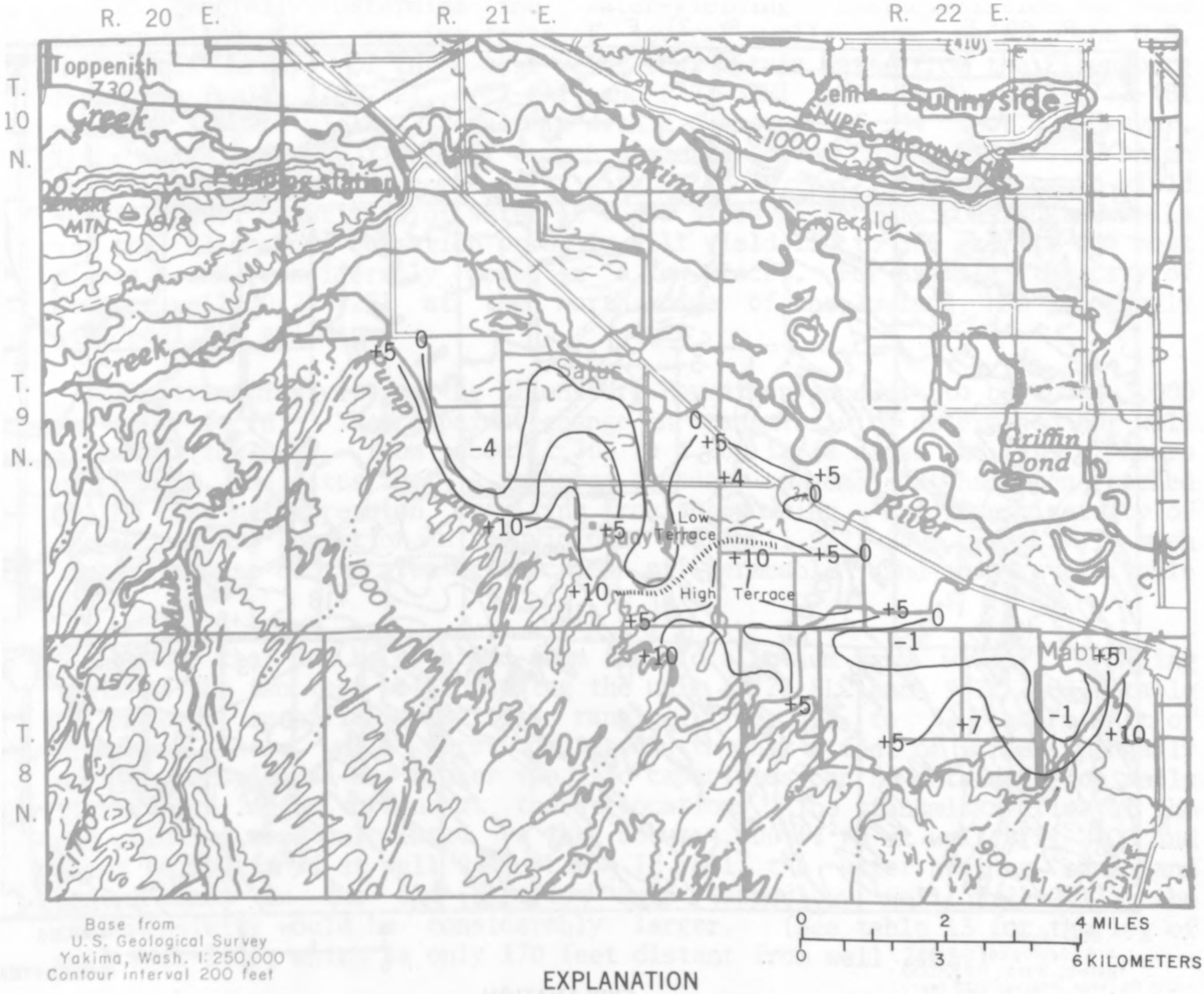
FIGURE 24.--Contours on potentiometric surface of water in the old alluvium and Ellensburg Formation underlying the Satus Creek lowland during low-water-level period, March 1972. A few water levels are higher in the spring than in the fall.



EXPLANATION

—650— — — POTENTIOMETRIC CONTOUR——connecting points of equal altitude of potentiometric surface, in feet above mean sea level; dashed where approximate Interval is 10 feet

FIGURE 25.--Contours on potentiometric surface of water in the old alluvium and Ellensburg Formation underlying the Satus Creek lowland during high-water-level period, August-October 1972. A few water levels are higher in the spring than in the fall.

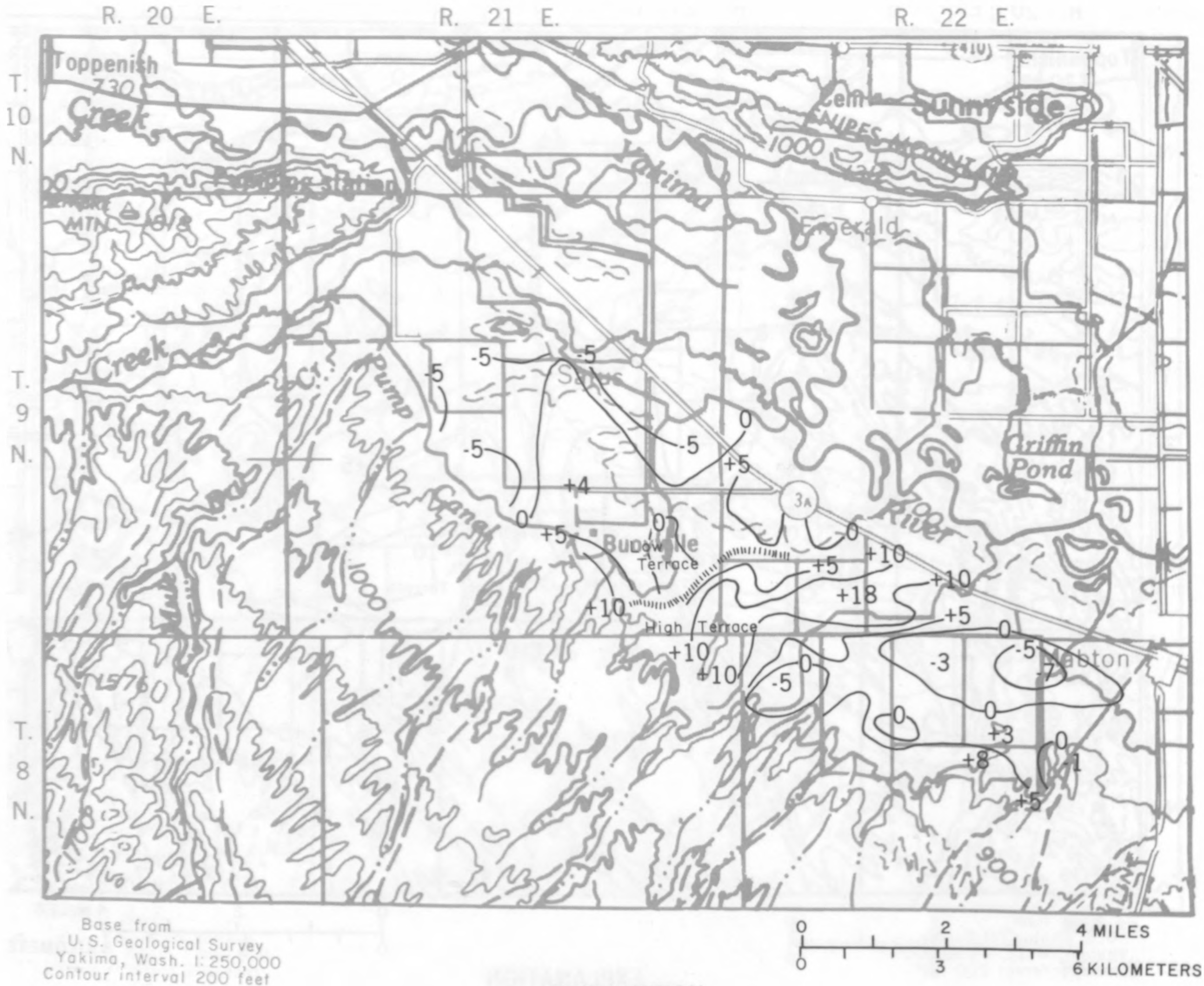


EXPLANATION

——+10——

Line connecting points of equal difference in height of water table in Touchet Beds, in feet above (+) or below (–) potentiometric surface in old alluvium and Ellensburg Formation. Interval is 5 feet.

FIGURE 26.--Difference in water levels between water table in Touchet Beds of Flint (1938) and potentiometric surface in the old alluvium and Ellensburg Formation underlying the Satus Creek lowland, during low-water-level period, March 1972.



EXPLANATION

——+10——

Line connecting points of equal difference in height of water table in Touchet Beds, in feet above (+) or below (—) potentiometric surface in old alluvium and Ellensburg Formation. Interval is 5 feet.

FIGURE 27.--Difference in water levels between water table in Touchet Beds of Flint (1938) and potentiometric surface in the old alluvium and Ellensburg Formation underlying the Satus Creek lowland, during high-water-level period, August-October 1972.

Water-Yielding Characteristics

To generally determine the water-yielding characteristics of the valley-fill aquifer, pumping tests of several wells were made by the U.S. Geological Survey. Of three test wells that obtain water from the Ellensburg Formation (wells 8/22-4B1, 8/22-9A1, and 9/21-35H1 in table 8), well 8/22-4B1 had the largest yield--262 gal/min with a drawdown of 34 feet. However, these wells had only 3 feet of 6-inch diameter screen during the tests, which suggests that larger diameter wells with 20 to 30 feet of screen could yield much larger quantities of water at these sites. Properly constructed wells in the Ellensburg Formation probably will yield 250 to 500 gal/min at most places, and considerably more in a few places. For example, the city of Granger well 10/21-22E1 at the north edge of the lowland, has reportedly yielded 1,850 gal/min.

The transmissivity of the Ellensburg Formation appears to be about 3,000 to 4,000 ft^2/d. The apparent change in transmissivity determined for well 8/22-4B1 (table 8), from about 1,300 to 4,200 ft^2/d after the first 2 hours of pumping, indicates that a recharge boundary of some sort had been reached by the cone of depression resulting from the pumping. The transmissivity of the Ellensburg Formation in the vicinity of well 9/21-24Q1 probably is much higher because of the greater thickness of permeable sand and gravel (table 13).

Yields that can be obtained from the old alluvium vary widely. Pumping tests of the two test wells tapping the unit (9/21-8L2 and 9/21-24Q3, table 8) indicate specific capacities ranging from 6.5 to 32.6 gal/min/ft of drawdown. These wells were completed with only 3 feet of screen; probably much larger yields and higher specific capacities can be obtained from wells fitted with longer screens at these locations. The transmissivities of the old alluvium were calculated to be about 4,000 ft^2/d at well 9/21-24Q3 and about 60,000 ft^2/d at well 9/21-8L2. If all the water-bearing sand and gravel zones in the old alluvium were tapped by well 9/21-24Q3, the transmissivity would be considerably larger. (See table 13 for the log of well 9/21-24Q1, which is only 170 feet distant from well 24Q3.)

Although some strata of the old alluvium have been logged as silty or clayey and others as cemented, where the clean, loose sand and gravel strata are encountered, yields of 1,500 to 2,000 gal/min probably could be obtained from properly constructed wells. Listed below are data from irrigation wells believed to obtain water mainly from the old alluvium:

Well no. (locations shown in pl. 1)	Depth (ft)[a]	Diam- eter (in.)	Yield (gal/ min)	Draw- down (ft)	Specific capacity [(gal/min) /ft]	Transmis- sivity (ft²/d)[b]
9/21-7Q1[c]	84	8	500	30	17	4,600
7Q2[c]	82	12	1,200	33	36	9,700
8N1	65	8	300	2	150	40,000
15M1	106	12	700	38	18	4,900
17D1[c]	65	6	200	29	7	1,900
24N1	113	12	1,200	85	14	3,800

[a] The casings of these wells were all perforated in their lower sections.

[b] Determined by multiplying specific capacity value by 270.

[c] Well also taps the Ellensburg Formation.

Specific capacities of some wells in the above table, and the corresponding aquifer transmissivities, may be much lower than they should be because of excessive "well loss" (head loss due to turbulence and restriction of flow into well). Even properly developed and screened wells do not achieve 100 percent efficiency at high pumping rates.

Although the generally fine-grained Touchet Beds will yield little water to wells, local layers of sand will yield 5 to 10 gal/min. Where the sand is coarser and thicker, larger quantities can be obtained, as shown by the yield of 33 gal/min at well 9/21-24Q2 (table 8).

TABLE 8.--Results of pumping tests by the U.S. Geological Survey of selected wells tapping valley-fill deposits in Satus Creek basin

Well no.	Depth interval tapped (ft)	Diameter (in.)	Static water level (feet below land surface)	Pumping rate (gal/min)	Duration of pumping (min.)	Duration of recovery (min.)	Drawdown (ft)	Specific capacity (gal/min)/ft	Transmissivity[a] (ft /d)	Aquifer
8/22-4B1	100-103	6	10.4	33	150	--	3.3	10	1,300	Ellensburg
						100			1,200	Formation
			10.4	262	140	--	32.9	8.0	1,400	
						120			1,300	
				262	140-360	--	34.0	7.7	4,800	
						120-300			3,700	
8/22-9A1	79-82	6	6.8	8	89	12	10.3	.8	(b)	Ellensburg
				38	236	--	47.6	.8		Formation
9/21-8K1[c]	--	--	--	--	1,368	--	.9	--	59,000	--
						420			62,000	
9/21-8L2	39-42	6	6.6	290	1,368	--	8.9	32.6	57,000	Old alluvium
						420			85,000	
9/21-24Q2	17-20	6	5.2	33	90	--	5.1	6.5	--	Touchet Beds
						100			4,400	
9/21-24Q3	86-89	6	3.3	110	245	--	40.1	2.7	2,800	Old alluvium
						170			6,400	
			4.2	32	120	--	12.8	2.5	3,000	
						80			4,700	
9/21-35H1	76-79	6	+8.4	22	120	--	46.9	.5	--	Ellensburg
						85			2,800	Formation

[a]Determined by Theis nonequilibrium formula, straight-line solution except for observation well 9/21-8K1.

[b]Could not be determined.

[c]Observation well; specific capacity and transmissivity determined from pumping test of nearby well 9/21-8L2.

Ground-Water Quality

General Characteristics

Results of chemical analyses of water samples from 10 wells in the Satus Creek basin (table 9) show that, based on specific conductance and hardness, the wells may be classified in the following two groups:

Group 1. Wells 8/21-1G1, 8/22-4B1, 8/22-9A1, 9/21-24Q3 and 9/22-32M1 yield water that is more mineralized than water in group 2, as shown by specific conductance ranging from 710 to 1,080 micromhos, and extreme hardness, ranging from 340 to 480 mg/L (milligrams per liter). All except well 9/21-24Q3 have a high nitrate concentration. All of these wells obtain water from the Ellensburg Formation or the old alluvium and are in irrigated areas, where the recharge to aquifers is chiefly by seepage through the Touchet Beds. Much of the mineralization probably is derived from leaching of the silts and clays in the Touchet Beds, with the nitrates coming from the soil horizons near the surface.

These waters generally are suitable for irrigation use. According to the U.S. Department of Agriculture (1954), all of the sampled waters show a very low sodium hazard, based on SAR (sodium adsorption ratio), and a medium to moderately high salinity hazard. Because of the extreme hardness, and the high nitrate in four of the five samples, the waters are not desirable for domestic use.

Group 2. Wells 9/19-20L1, 9/21-8L2, 9/21-27L1, 9/22-7N1 and 10/21-33B1 yield water that has a relatively low dissolved-minerals content, with specific conductances ranging from 326 to 495 micromhos, and a much lower hardness (98 to 200 mg/L) as compared to the water of group 1. Four of the five samples had low nitrate concentrations. The chemical character of this water can be related to the source of recharge and the aquifer through which the water moves. Well 9/19-20L1 is entirely in Yakima Basalt whose mineral constituents are less soluble than those in the silt of the Touchet Beds. Well 9/21-8L2 is in the old alluvium, which probably is recharged largely by seepage from Satus Creek. Well 9/21-27L1 is immediately adjacent to Satus Pump Canal No. 2, beneath which ground water probably is recharged largely by leakage from the canal through the Touchet Beds, and the high difference in head may result in fairly rapid movement of water through the Touchet Beds and into the aquifer. Well 9/22-7N1 is near the mouth of Satus Creek. The Touchet Beds are thin or absent there, and recharge probably is by seepage from Satus Creek. Well 10/21-33B1 is shallow and next to Toppenish Creek, in an area not underlain by the Touchet Beds.

This water also is suitable for irrigation use. Sodium hazard is very low and salinity hazard is medium. The water is much softer than that in group 1, and is more suitable for domestic use.

TABLE 9.--Chemical analyses of ground water from wells in the Satus Creek basin
[Analyses by U.S. Geological Survey]

				Milligrams per liter						
Well no.	Depth (ft)	Aquifer[1]	Date	Dissolved iron (Fe)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Dissolved sulfate (SO_4)
Group I										
8/21-1G1	130	E	5-22-74	0.02	110	35	30	4.4	215	130
8/22-4B1	103	E	10- 8-73	.07	100	36	32	6.2	165	240
8/22-9A1	82	E	10- 5-73	.26	120	44	30	1.5	122	120
9/21-24Q3	89	OA	10- 2-73	.06	80	33	18	5.4	185	150
9/22-32M1	142	E	5-22-74	.03	98	37	33	4.9	181	130
Group II										
9/19-20L1	696	Ya	6-20-73	--	21	11	28	9.0	179	12
9/21-8L2	42	OA	10- 4-73	.08	22	11	43	2.5	219	9.7
9/21-27L1	119	E	5-22-74	.02	33	12	19	4.1	111	29
9/22-7N1	--	A(?)	5-22-74	.04	41	23	25	3.1	247	28
10/21-33B1	41	OA	5-23-74	.29	31	13	25	3.8	206	17

[1] Aquifer: A, Young alluvium; E, Ellensburg Formation; OA, Old alluvium; Ya, Yakima Basalt.

Milligrams per liter								
Dissolved chloride (Cl)	Dissolved fluoride (F)	Total nitrate plus nitrite (N)	Hardness Ca, Mg	Noncarbonate hardness	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos)	Temperature (°C)
46	0.4	24	420	240	13	0.6	900	15.8
29	.6	14	400	260	15	.7	906	16.3
70	.8	56	480	380	12	.6	1,080	15.8
45	.2	.95	340	180	10	.4	727	14.4
45	.4	28	400	250	15	.7	900	17.6
8.3	.8	0	98	0	36	1.2	326	17.6
3.5	.3	1.6	100	0	48	1.9	362	13.4
13	.4	10	130	41	23	.7	370	15.8
16	.2	.00	200	0	21	.8	495	12.6
7.7	.2	.60	130	0	29	1.0	360	--

Nitrate Problem

For determination of nitrate concentrations, the U.S. Geological Survey collected samples from many wells distributed throughout the lowland. Sampled several times during May 1973-November 1974 were a number of wells that obtain water from the old alluvium or the Ellensburg Formation. The results of the analyses (table 10) show considerable variation in nitrate concentrations in water from the wells. The areal distribution shows that water with high nitrate concentrations occurs in the southeastern part of the lowland (fig. 28). The concentrations of nitrate (reported as N or nitrogen) in water from some wells is very large, exceeding 40 mg/L, and well 9/21-27J1 had a peak concentration of 170 mg/L.

No human or animal pollution has been identified as a source for such high nitrate concentrations over such a wide area as that in which wells tap the old alluvium and the Ellensburg Formation although several possible sources were explored. It might be explained by the fact that, as discussed previously, the source of much of the recharge to these units is leakage through the Touchet Beds from the canals and drains and seepage from irrigated fields. Although the surface and irrigation water is low in nitrate, as is the water in the Yakima Basalt (wells 9/21-26M1 and 9/21-27J2, table 10), the distribution of high nitrate concentrations strongly suggests that leaching of nitrate salts that had accumulated in the desert subsoil and Touchet Beds prior to irrigation is the source of the nitrate. Note that the area of high nitrate concentrations (fig. 28) corresponds in general to the area of the thickest section of Touchet Beds (fig. 18). The area of high-nitrate concentrations lies slightly southwest (toward the upland) of the area underlain by the thickest part of the Touchet Beds, indicating that these beds may be acting as a partial barrier to the movement of ground water toward the Yakima River. The hypothesis of a local accumulation of nitrate entrained by downward-moving water following irrigation is materially strengthened by calculations that indicate that early slugs of irrigation water applied in excess would, about now (1976), have moved to the area in which wells encountered water with high nitrate concentrations.

Nitrate data are lacking in the area northeast of the high-nitrate area in figure 28, except for well 8/22-4D1, which, being shallow, does not tap the old alluvium and therefore may not indicate nitrate concentrations in water beneath the Touchet Beds.

The changes in nitrate concentrations in water in a well are related to the complex ground-water-flow pattern in the vicinity of the well. The rate of water movement through the soil to the water table in the Touchet Beds, and through the Touchet Beds to the underlying aquifer, depends on both the vertical hydraulic conductivity of the materials in the section, and the vertical head differences. Both of these parameters change from place to place, and head difference also changes with time; thus, the time required for water that has leached some nitrate from surface sources to reach the aquifer varies from place to place. Under the conditions prevalent in the lowland, several months to many years may be required for a given particle of water to travel from the soil to the aquifer. Pumping is another factor that contributes to changes in nitrate concentration because it changes the flow pattern in the vicinity of the well. Assuming that the well has not been pumped for some time, it is possible that the first water withdrawn could have come from nearly vertical downward percolation in the vicinity of the well. However, soon after the pump is started, water is drawn in laterally from progressively greater distances. Considering the complexity of the flow system, and the limited data available, only a tentative conclusion can be offered for the changes in nitrate concentrations in particular wells. For those wells in which the nitrate concentrations fluctuated more than 10 mg/L (wells 8/22-6A1, 8/22-11E1, 9/21-27J1, and 9/21-36K1, table 10), there appears to be a pattern of higher nitrate concentrations in the spring than in the fall. These fluctuations may be due to seasonal variation in pumping stress, whose effects are described above, may cause the resultant nitrate-concentration variation to appear as a seasonal phenomenon.

TABLE 10.--Nitrate concentrations and specific conductance of ground water from wells and a spring in the lowland

Well number	Date sample collected	Total nitrite plus nitrate (N)	Specific conductance (micromhos)
8/21-1G1	5-22-74	24	900
-1R1	10-24-73	1.4	348
8/22-2N1s	11- 6-74	13	1,250
-3K1	10-24-73	11	655
-3R1	5-22-74	11	650
-4B1	10- 8-73	14	906
	10-24-73	[a]11	--
-4D1	10-24-73	2.7	810
-5E1	6-22-73	18	800
	5-22-74	15	875
-5Q1	6- 4-73	24	--
	5-22-74	33	640
-5R1	6- 4-73	22	--
	10-23-73	22	600
	5-22-74	25	625
-6A1	6-22-73	39	1,000
	10-24-73	15	>1,000
	5-22-74	28	>1,000
	9-18-74	23	910
-6B1	6- 5-73	42	--
	5-22-74	38	>1,000
-6R1	6- 1-73	1.4	--
	5-22-74	.74	310
-9A1	8-21-73	[b]52	1,000
	10- 5-73	56	1,080
-9F1	6- 4-73	32	--
	5-22-74	32	825
-10B1	5-22-74	6.3	500
-10R1	10-24-73	5.5	640
-11E1	5-22-74	45	>1,000
	9-18-74	30	1,200
9/20-12G1	11-27-73	.16	290
-12K2	9-18-74	.14	415
9/21-1Q1	7-26-73	1.6	330
	11-26-73	2.0	365
-2R1	11-27-73	1.8	315
-3B1	9-18-74	.68	385
-3N1	8-15-73	.77	380

Well number	Date sample collected	Total nitrite plus nitrate (N)	Specific conductance (micromhos)
9/21-4B1	8-15-73	3.6	412
	11-26-73	.78	460
-5Q1	11-26-73	.02	660
-8K1	11-26-73	.73	365
-8L1	8-15-73	.07	171
-8L2	8-16-73	1.0	355
	10- 4-73	1.6	362
-8N1	5-23-74	.56	190
-12N1	11-26-73	.04	282
-12N2	7-26-73	.01	260
-13A1	11-27-73	.02	330
-14A1	7-26-73	.01	286
	11-27-73	.01	240
-15D1	5-23-74	3.0	550
-15H1	8-15-73	.86	560
	11-27-73	.36	540
-15M1	9-18-74	1.9	550
-16B1	11-27-73	3.2	525
-17C1	11-27-73	.28	194
-17F1	5-23-74	.28	215
-21B1	10-24-73	2.3	450
-24N1	7-26-73	1.7	930
-24N2	7-26-73	4.8	>1,000
-24Q1	7-27-73	[c]6.0-0.08	[c]610-850
-24Q2	8- 7-73	.58	500
-24Q3	8- 8-73	.11	700
	10- 2-73	.97	710
-25H1	5-25-73	9.0	--
	10-23-73	9.2	710
-25J1	5-25-73	14	--
	5-22-74	15	800
-26M1	5-23-74	.00	290
-26R1	10-24-73	12	600
-27J1	10-24-73	[d]130-150	>1,000
	2- 7-74	170	>1,000
-27J2	3- 5-74	[e]3.0-0.07	270-320
-27L1	5-22-74	10	370
-27R1	5-22-74	.67	320
-35H1	8-14-73	[f]20-15	[e]530-600
	10-24-73	16	600
-35H2	9-28-73	8.5	410

Well number	Date sample collected	Total nitrite plus nitrate (N)	Specific conductance (micromhos)
9/21-36E1	7-26-73	13	500
	9-28-73	10	510
	10-24-73	12	500
	2- 7-74	14	470
-36K1	6- 1-73	30	--
	9-28-73	13	820
	5-22-74	35	>1,000
-36K2	5-25-73	67	--
	9-28-73	62	1,000
-36R1	10-23-73	18	800
	2- 7-74	21	775
9/22-7N1	5-22-74	.00	495
-19P1	5-22-74	.02	900
-19Q1	5-22-74	.00	725
-29D1	7-26-73	.30	860
-30B1	5-22-74	.03	760
-31G1	6- 5-73	48	--
	9-27-73	48	1,000
	5-22-74	40	>1,000
-31J1	6- 5-73	24	--
	9-27-73	27	940
	5-22-74	25	1,000
-31M1	10-24-73	[g]20-17	>1,000
-31Q1	5-22-74	13	>1,000
-32M1	6- 1-73	28	--
	5-22-74	28	900
-32M2	10-23-73	16	>1,000
-32N1	5-22-74	15	>1,000
	9-18-74	9.3	1,250
10/21-28L1	11-27-73	1.3	400
-29B1	11-27-73	.04	255
-32B1	5-23-74	.01	490
-32K1	11-27-73	.01	290
-33B1	5-23-74	.60	360
-33C1	9-18-74	.33	450
-34G1	11-27-73	.18	327
-34L1	8-15-73	.35	228

[a] 11 samples taken over a 2-hour period. Nitrite plus nitrate ranged from 10 to 14 mg/L, and averaged 11 mg/L.

[b] 4 samples taken over a 6½-hour period. Nitrite plus nitrate ranged from 48 to 56 mg/L, and averaged 52 mg/L.

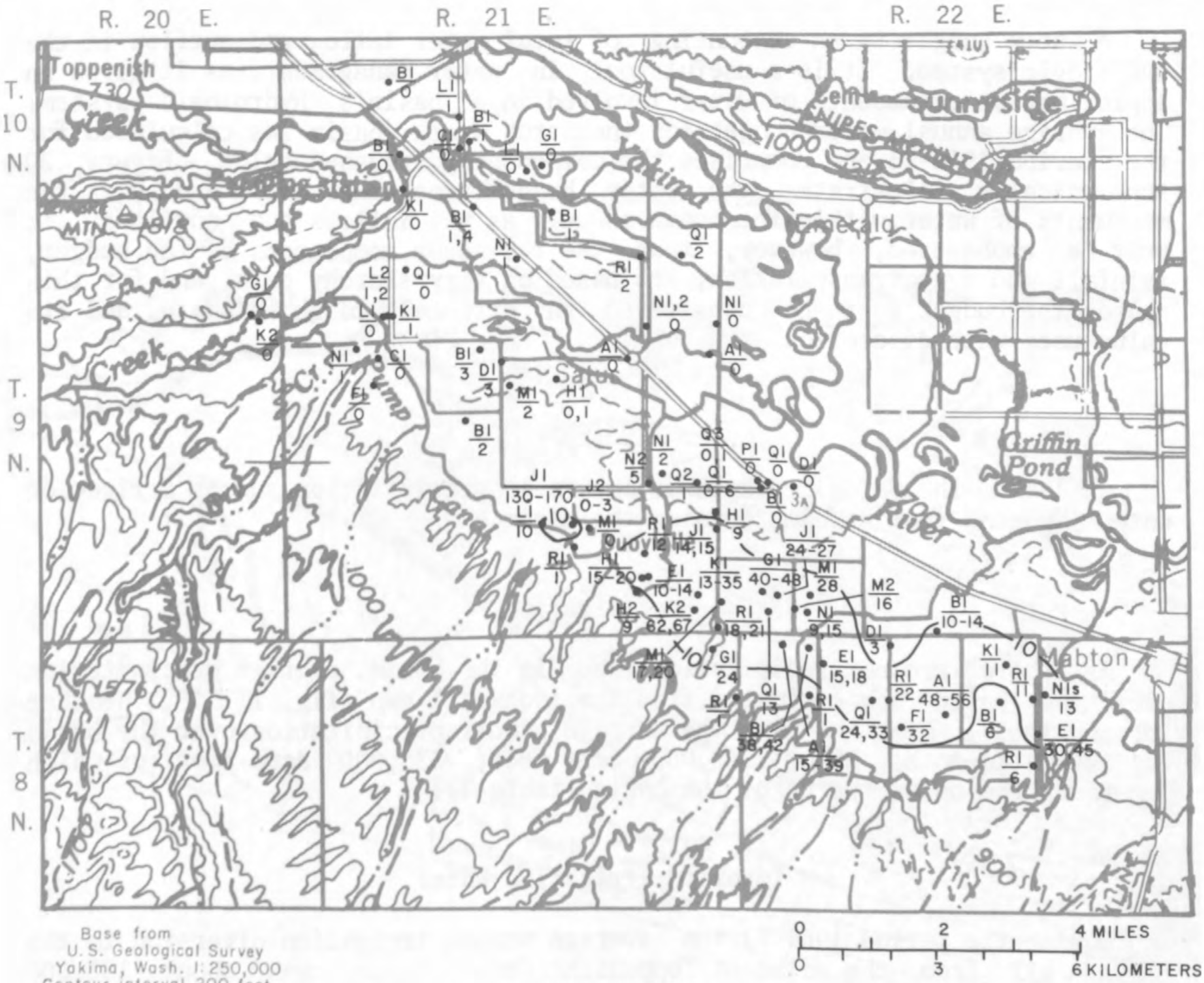
[c] 3 samples taken over a 7½-hour period. Nitrite plus nitrate concentrations initially at 6.0 mg/L, decreased to 0.08 mg/L, and increased to 0.14 mg/L by the completion of the sampling. Specific conductance varied between 610 and 850 micromhos.

[d] 2 samples taken over a ½-hour period. Nitrite plus nitrate concentration increased from 130 to 150 mg/L.

[e] 3 samples taken over a 4-hour period. Nitrite plus nitrate concentrations decreased from 3.0 to 0.07 mg/L.

[f] 3 samples taken over a 3-hour period. Nitrite plus nitrate concentrations decreased from 20 to 15 mg/L. Specific conductance varied between 530 and 600 micromhos.

[g] 2 samples taken over a 40-minute period. Nitrite plus nitrate concentrations decreased from 20 to 17 mg/L.



EXPLANATION

• B1 / 3

Well

Well and abbreviated number (above line) and concentrations of nitrite plus nitrate as nitrogen, in milligrams per liter (below line). Lowest and highest concentrations are given if three or more samples analyzed; only one value given if all values the same. Value given to nearest whole number. See table 10 for actual values.

——10——

Line bounding area in which concentrations of nitrite plus nitrate as nitrogen exceed 10 mg/l

FIGURE 28.--Nitrate concentrations in ground water underlying the lowland of Satus Creek basin.

THE WATER BUDGET

A water budget is an accounting of total water inflow and outflow in the hydrologic system. It is a useful tool in water management, as it gives an approximation of amounts of water involved in a basin's hydrologic system. The average annual water budget for the Satus Creek basin was calculated for the period 1964-73 and comprises the components discussed below. Figure 29 schematically illustrates the water budget for the basin and shows the movements of water within the basin as well as the inflows and outflows. It must be emphasized, however, that the two major components of the budget, rainfall and evapotranspiration, are based on very sketchy data, and for this reason the budget must be considered an extremely rough estimate, and its value used with discretion.

Inflow

Inflow to the Satus Creek basin occurs as precipitation and as irrigation water imported from streams outside the basin.

Precipitation

As there are no precipitation gages in the basin, average precipitation over the basin was estimated from the isohyetal map (fig. 1; U.S. Weather Bureau, 1965). From the map, the average annual precipitation over the basin was estimated to be about 562,000 acre-feet, 535,000 acre-feet of which occurs in the upland parts of the basin (table 7).

Imported Irrigation Water

During the period 1964-73 the average annual irrigation diversion to the basin, all from the adjacent Toppenish Creek basin, was about 153,000 acre-feet. All of this water was diverted through the Satus East and West laterals and the Satus No. 2 Pump Canal. During the same period a small diversion from the Sunnyside Irrigation District averaged about 3,000 acre feet per year. Thus, the average annual irrigation diversion into the Satus Creek basin from outside sources was about 156,000 acre-feet per year during the 10-year period ending in 1973. The annual distribution of this inflow is shown in table 11.

Outflow

Water leaves the Satus Creek basin by (1) evapotranspiration directly to the atmosphere from plants and from soil and water surfaces, (2) surface drainage in stream channels and manmade drains, and (3) subsurface or ground-water outflow.

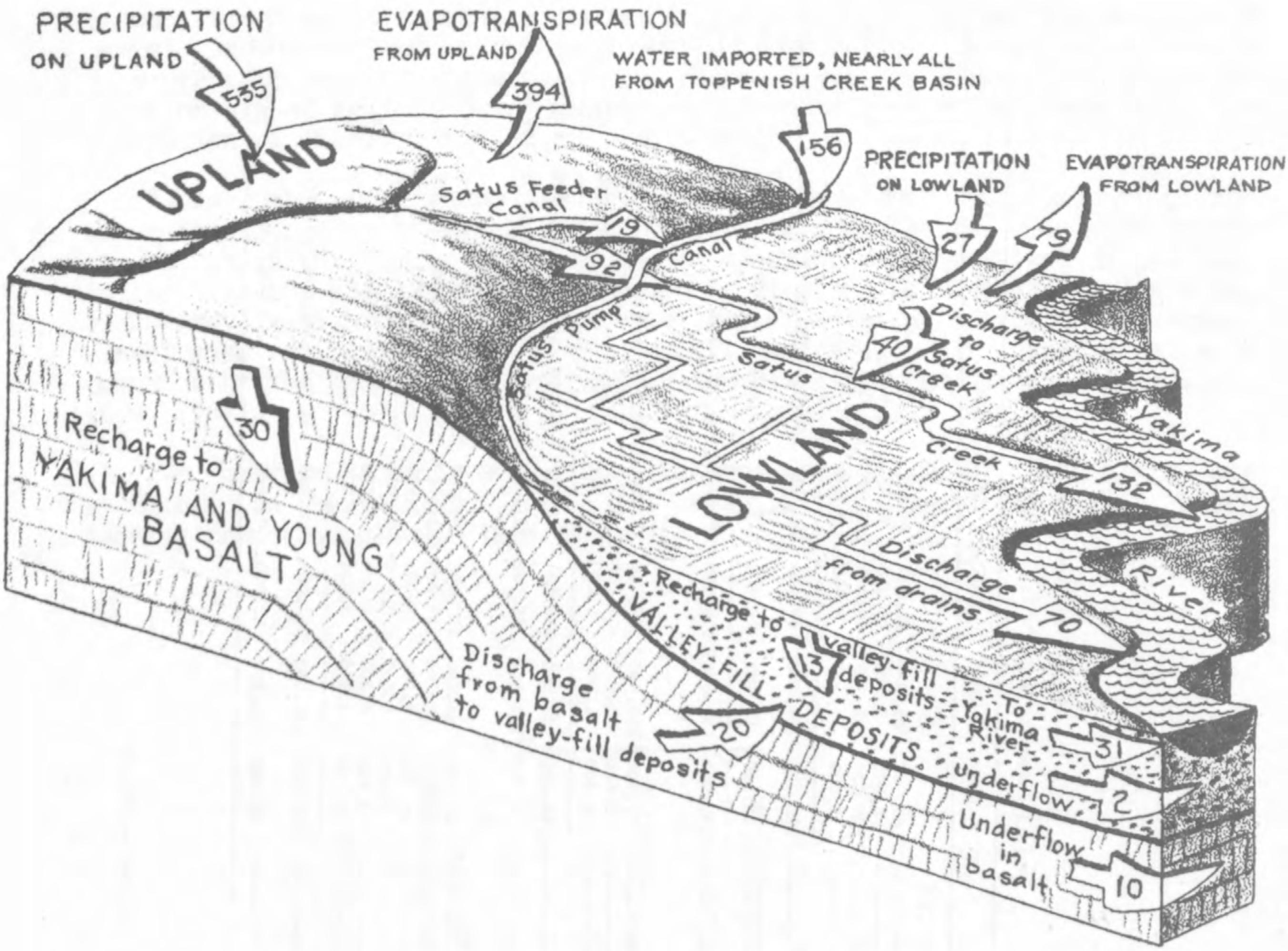


FIGURE 29.--Generalized water budget in Satus Creek basin. All values are in thousands of acre-feet per year, based on the average annual values for 1964-73.

TABLE 11.--Annual surface-water budget in the lowland

[All values in acre-feet; measuring sites shown in fig. 1]

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Average
Irrigation diversions into basin:											
Satus East Lateral (site 15)-------------	45,900	43,400	42,800	46,100	46,800	45,600	49,400	47,800	49,700	52,800	47,000
Satus West Lateral (site 17)-------------	8,000	5,900	7,000	6,700	8,000	7,000	11,300	12,400	11,300	11,100	8,900
Satus No. 2 Pump Canal (site 16)---------	105,000	102,000	95,600	106,000	111,000	89,500	91,600	71,500	94,700	109,000	97,600
Sunnyside Irrigation District[a]-----------	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total inflow from diversions[b]--------	162,000	154,000	148,000	162,000	169,000	145,000	155,000	135,000	159,000	176,000	156,000
Satus Feeder Canal[c] (site 20)---------	20,500	17,300	28,400	15,700	9,400	20,600	16,600	38,100	24,300	[a]3,100	19,400
Total irrigation diversions[b]-----	182,000	171,000	176,000	178,000	178,000	166,000	172,000	173,000	183,000	179,000	176,000
Streamflow into lowland from upland:											
Satus Creek (site 12)--------------------	51,900	130,000	100,000	73,800	89,600	136,000	121,000	150,000	137,000	45,100	103,000
Mule Dry Creek (site 13)-----------------	5,000	5,000	5,000	4,000	5,000	4,500	7,500	9,600	4,300	5,000	5,500
Ungaged[a]--------------------------------	1,800	1,800	1,800	1,500	1,800	1,600	2,700	3,500	1,600	1,800	2,000
Total inflow from upland[b]-----------	58,700	137,000	107,000	79,200	96,400	142,000	131,000	163,000	143,000	51,800	111,000
Total inflow to lowland[b]------------	221,000	291,000	255,000	241,000	265,000	287,000	286,000	298,000	302,000	228,000	267,000
Outflow from lowland:											
Satus Creek (site 14)--------------------	67,100	144,000	137,000	105,000	123,000	154,000	156,000	169,000	178,000	91,600	132,000
South Drain (site 21)--------------------	35,700	39,700	37,200	34,300	38,000	39,300	38,600	51,700	51,900	39,300	40,600
Coulee Drain (site 18)-------------------	10,300	9,000	8,600	9,900	9,500	9,600	9,300	8,500	8,800	8,900	9,200
Drain 302 (site 23)----------------------	9,800	9,600	9,900	10,800	10,800	10,500	9,300	10,000	9,400	7,600	9,800
Drain 303 (site 24)----------------------	8,900	6,000	6,400	4,900	6,500	8,400	7,900	8,200	9,300	7,000	7,400
Miscellaneous drains[a]-------------------	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total outflow[b]---------------------	135,000	211,000	202,000	168,000	191,000	225,000	224,000	250,000	260,000	157,000	202,000
Inflow minus outflow---------------	86,000	80,000	53,000	73,000	74,000	62,000	62,000	48,000	42,000	71,000	65,000

[a]Estimated.

[b]Rounded.

[c]Diversion from Satus Creek (not included as inflow).

Evapotranspiration

The greatest component of discharge from the basin is evapotranspiration, which consists of evaporation from soil and water surfaces and transpiration from plants and trees, most of which occurs during the summer. (Table 1 gives the seasonal pattern of evaporation rates; however, evapotranspiration rates from land, plant, and water surfaces are much smaller in the semiarid Satus Creek lowland, though similar in pattern.) In the upland areas the annual amount of water lost by evapotranspiration is estimated from an interpretation of data compiled by Hulet (1969). Figure 30 shows the relationship of land-surface elevation and evapotranspiration, upon which the estimation was based.

Table 7 shows the quantities of water as precipitation and irrigation diversion into the basin, and as evapotranspiration losses from the basin. The values in this table were computed by assuming average values of precipitation over the areas bounded by the isohyetal lines in figure 1, and average evapotranspiration values based on the curve relating elevation and actual evapotranspiration in figure 30 for nonirrigated areas. Irrigated areas were computed by the modified Blaney-Criddle formula (U.S. Department of Agriculture, 1967).

The average annual evapotranspiration from the Satus Creek basin was estimated to be 473,000 acre-feet, with 394,000 acre-feet of this total leaving from the upland. (See table 7.)

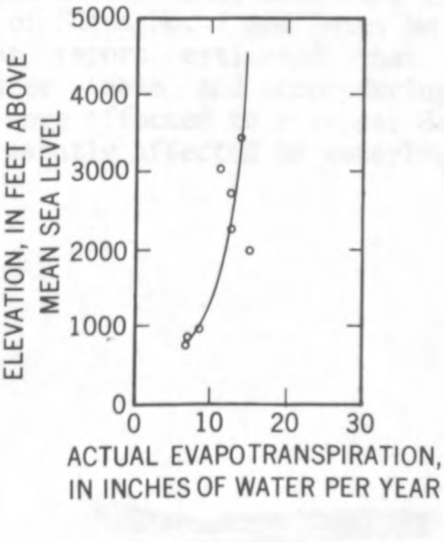


FIGURE 30.--Relationship of actual evapotranspiration to land-surface elevation, based on a 6-inch water-holding-capacity soil. Data from Hulet (1969).

Streamflow and Drains

The major portion of the precipitation that is not returned to the atmosphere by evapotranspiration, about 245,000 acre-feet (table 7), leaves as streamflow or in drains to the Yakima River. Direct stream runoff occurs mostly in winter and spring, and base flow (ground-water discharge) occurs for much longer periods; in perennial streams it occurs the year around.

Table 11 shows all surface-water inflows and outflows from the basin and includes values for intermediate points within the basin. The surface-water outflow from the Satus Creek basin averaged about 202,000 acre-feet per year during the period 1964-73 (table 11).

Ground-Water Outflow

About 43,000 acre-feet of water leaves the basin as ground-water outflow. About 31,000 acre-feet of this amount discharges directly to the Yakima River from the shallow ground-water body, and the remaining 12,000 acre-feet leaves the basin as underflow beneath the Yakima River. Of this amount of water, about 10,000 acre-feet discharges through the Yakima Basalt and about 2,000 acre-feet discharges through the deeper parts of the valley-fill aquifer (old alluvium and Ellensburg Formation).

The area of wetted channel in the Yakima River is about 6 million ft^2 over the length of its course along the east margin of the basin. This would imply an average discharge rate of 0.7×10^{-5} $(ft^3/s)/ft^2$, which is within the range of typical seepage rates quoted in a report by the U.S. Geological Survey (1975, p. 44).

Waterlogging has become a serious problem in the lowland of the Satus Creek basin, especially in the Satus No. 2 unit where several thousand acres have been affected in varying degrees. Increased salinity and sodium concentrations have occurred concurrently with the rise in the water table. These factors have adversely affected tillage, seed germination, and plant growth.

History of Irrigation Development and Waterlogging

There is little evidence to indicate the areal extent of waterlogging prior to irrigation. The U.S. Geological Survey Zillah quadrangle (1:125,000 scale), mapped in 1906, shows no ponds or marshy areas in the lowland except some backwater sloughs in abandoned meander channels along the Yakima River.

Beginning in about 1908, water was diverted from Satus Creek through Shearer Ditch, which extended through sec. 17, to the southern margins of secs. 16 and 15, T.9 N., R.21 E., for irrigation of about 2,000 acres. In 1925 the Wapato Project began delivery of water to the Satus No. 1 unit, and took over operation of the Shearer Ditch. Waterlogging began to be a problem in 1929 or 1930.

In 1933 the Satus No. 2 Pump Canal was put into operation and in 1953 the Satus No. 3 Pump Canal was put into operation. Subsequently, waterlogging became progressively more severe, and, according to an unpublished report by the BIA, a large part of Satus No. 2 and Satus No. 3 units developed serious drainage problems. That report estimated that 4,500 acres were severely affected by the high-water table and accompanying salt buildup, and that an additional 6,000 acres were affected to a lesser degree. Figure 31 shows the areas of the lowland presently affected by waterlogging.

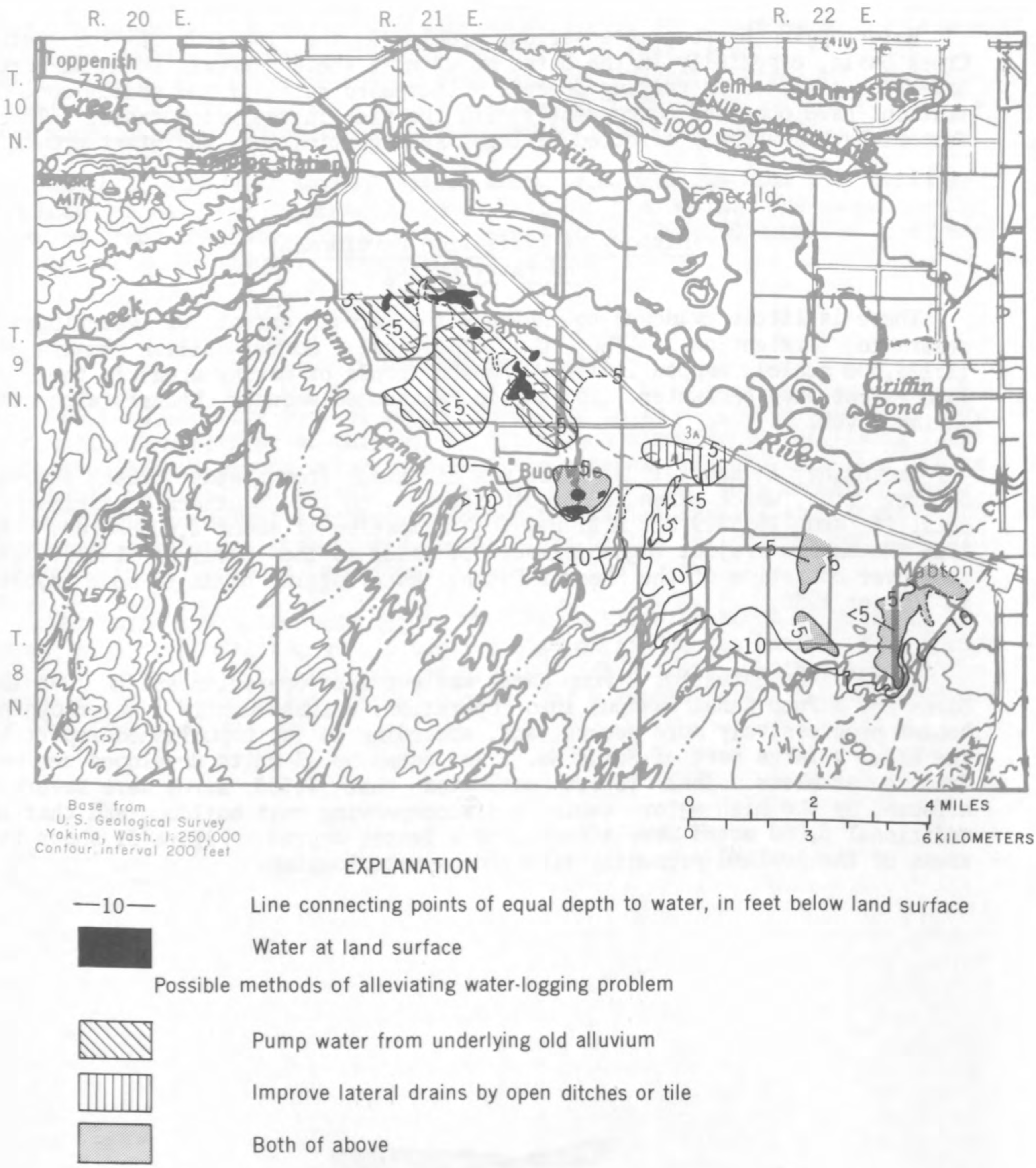


FIGURE 31.--Depth to the shallow water table during August-October, the period of highest water levels, and areas discussed in text relative to methods of alleviating waterlogging problems. Most of measurements in the northwestern part of lowland were made during August-October 1966 and 1967; most of measure--ments in southeastern part of lowland were made during August-October 1971, 1972, and 1973 (mostly 1973).

Causes of Waterlogging

Waterlogging in the lowland is caused in most places by the presence of the Touchet Beds at and near the surface, and often is compounded by the natural discharge from the deeper aquifers and the excessive application of irrigation waters on the land surface. The Touchet Beds underlie the entire lowland except for a narrow strip about a mile or less in width which parallels and is about a mile southwest of the Yakima River meander belt (fig. 18). The beds overlie deeper aquifers in their discharge area along the Yakima River valley, and the discharge from these aquifers raises the water table in the Touchet Beds to high levels. In places the potentiometric surface in these deeper aquifers is near or above land surface.

The rate of movement of ground water is dependent upon the hydraulic conductivity of the material and the hydraulic gradient. As the Touchet Beds almost everywhere have a low vertical permeability, the vertical movement of water is generally very slow, with the rate of vertical movement controlled by the hydraulic gradient, which in the lowland is measured by the difference between the water level in the Touchet Beds and the potentiometric surface in the underlying aquifer.

The irrigated area in the lowland is about 19,000 acres. During the 10-year period 1964-73, annual irrigation diversions to the area ranged from about 166,000 to 183,000 acre-feet, and averaged about 176,000 acre-feet (table 11), or about 9.3 acre-feet per acre. For irrigation in most semiarid parts of Washington, a diversion of about 5 acre-feet per acre is considered adequate.

Obviously, the application of excessive quantities of irrigation water on areas where the water table in the Touchet Beds is near land surface will result in waterlogging. Once the demand of the plants for water has been satisfied, remaining water has no place to go. The low transmissivity of the Touchet Beds prevents excess water from moving rapidly laterally to surface drains, and the upward gradients due to water discharging upward from the deeper aquifers prevents the excess water from draining vertically downward.

In order to determine the areas where vertical drainage of the soils is restricted, several water-table maps were drawn (figs. 22-25), and two difference-in-head maps (figs. 26 and 27) were constructed, as described previously. Because of many inadequacies in the data, however, these maps indicate only the general rather than the exact situation at any particular place. Inadequacies in the maps result from (1) the measurements being made in wells reaching different depths in the aquifer; (2) the measurements being made at different times, and even in different years; and (3) the existence of large areas with no representative measurements, making interpolation necessary. Nevertheless, the difference-in-head maps are believed useful for planning remedial measures.

Alleviation of Waterlogging

The only two ways to alleviate the waterlogging problem are to reduce the input of water to the area, and (or) increase the rate of removal of water from the area.

With an average annual application of about 9 acre-feet per acre, and assuming about 3 acre-feet per acre as the consumptive use, a surplus of about 6 acre-feet per acre goes to drainage. Reducing the average irrigation diversion to 5 acre-feet per acre would result in a drainage of about 2 acre-feet per acre.

When considering ways to improve the removal of water from the lowland to alleviate waterlogging, the poor transmissivity of the near-surface Touchet Beds and the head relationships between the shallow water-table aquifer and the deeper artesian aquifer are important factors. An initial consideration in drainage is that open ditches are difficult to maintain in the Touchet Beds as the sides slough in readily and block the ditches. Tile drains eliminate the sloughing problem, but are expensive to construct. Pumping water from wells in the Touchet Beds to remove water also is impractical because the low permeability retards the lateral spread of the radius of influence of the wells. This same phenomenon requires that drains (tile or open ditches) be closely spaced to effectively drain the near-surface zones.

Another alternative which may provide relief from waterlogging in areas covered by the Touchet Beds is to increase the rate of downward drainage from these beds by modifying the natural hydraulic gradients.

For example, where the present head of the upper aquifer is higher than the head of the lower aquifer, water is moving downward, with the rate of flow being directly proportional to the head difference (figs. 26 and 27). Pumping water from the lower aquifer and further lowering the head in this aquifer would increase the rate of flow downward. In other areas, where the head relationships are reversed and water is moving upward from the lower to the upper aquifer, lowering the head in the lower aquifer, by pumping to the point where its head is below that of the upper aquifer, would reverse the direction of flow.

The valley-fill aquifers (the old alluvium and the Ellensburg Formation) underlying the Touchet Beds have much higher transmissivities, thus the radius of influence of a pumping well in these units would cover a much larger area than would a single well in the Touchet Beds. The higher transmissivities also permit withdrawal of large amounts of water, which would provide an alternative source of irrigation water and allow a still greater reduction of imported water for irrigation. In areas underlain by the old alluvium, properly constructed wells may yield 1,500-2,000 gal/min, whereas the Ellensburg Formation is generally less permeable and yields considerably less, normally about 250 to 500 gal/min to individual wells.

Although pumping these lower aquifers in the waterlogged areas would promote vertical drainage and eventually could alleviate the waterlogging problem, the variation in thickness of the Touchet Beds--from a few feet to more than 100 feet (fig. 18)--will have some important effects on the degree and speed of drainage improvement. In general, the thinner the Touchet Beds, the more rapid and effective will be the increase in vertical drainage for a given increase in head difference (with the lower aquifers' head being pumped down to below the water table). Thus, in those waterlogged areas in T.9 N., R.21 E. (fig. 31)--where the Touchet Beds are thin (averaging about 40 ft, fig. 18) and where they are underlain mainly by old alluvium--this method of improving vertical drainage would be more successful. In the southeastern corner of this township, however, the Touchet Beds are almost 80 feet thick and this technique would not be as effective. Farther east, in T.9 N., R.22 E., the waterlogged areas are underlain by an even greater thickness of Touchet Beds (as much as 120 ft), and it is therefore doubtful that vertical drainage could be significantly improved by pumping the underlying aquifers. In T.8 N., R.22 E., the Touchet Beds are thinner, particularly to the south, but they are underlain by the Ellensburg Formation whose relatively low transmissivity makes this technique less effective than in T.9 N., R.21 E. The methods of drainage improvement most likely to succeed in each of the waterlogged areas in the lowland (fig. 31) indicate that pumping from the deeper aquifers is the best method in the northwestern part, and that using both drains and pumping is the best method in the southeastern part. Of course, it is suggested that in all waterlogged areas the application of imported water also be greatly reduced.

POTENTIAL FOR ADDITIONAL DEVELOPMENT OF WATER SUPPLIES

Surface-Water Supplies

A considerable potential exists for greater utilization of surface-water supplies and for development of additional ground water in the Satus Creek basin. If the surface-water diversion for irrigation in the lowland was reduced to 5 acre-feet per acre, an average of about 80,000 acre-feet of water would be available annually for irrigation of additional lands. Pumping to alleviate waterlogging in the lowland, and utilization of the pumped water for irrigation, would make even more surface water available for use elsewhere. There is considerable potential for more and better utilization of the water of Satus Creek itself. Although some of the creek water is used for irrigation of the lowland, in addition to the canal diversions from Toppenish Creek, much of this water is not really essential to the lowland, as indicated by the waterlogging. However, the main problem is that of transporting this water to irrigable lands.

Although water could be lifted 100 or 200 feet to land upslope from the present pump canals, much of that land is cut by innumerable gullies; this would require an expensive canal system to distribute water by gravity to those lands. To irrigate areas in the lower parts of the upland adjacent to Satus Creek by gravity distribution, diversion would be required several miles upstream; this would also require an expensive distribution system because of the many gullies. The only larger, less-gullied areas suitable for irrigation are generally at elevations ranging from 1,500 to more than 2,500 feet. However, where the upland surface is at 2,000 feet, Satus Creek is in a canyon more than 800 feet deep; at places, the creek is 1,200 to 1,500 feet below irrigable upland areas.

Another possibility might be high-altitude diversion. As discussed earlier, much of the surface-water runoff, and most of the base flow (ground water) originates in the headwater areas, and it might be feasible to divert water from some of the higher elevation streams to irrigate lands in the lower parts of the upland. It probably would not be feasible to divert water from these streams across and east of Satus Creek, but considerable irrigable land west of Satus Creek (fig. 32) could be reached by high-elevation (2,800 feet, or higher) diversions. Diversions from the tributary streams at those high elevations might capture nearly all of the base flow--50 ft^3/s during much of the irrigation season. It probably would rarely decrease to less than 30 ft^3/s. However, additional information is needed on the discharges of South Fork Dry Creek, Spring Creek, the North and South Forks Logy Creek, Yatama Creek, Kusshi Creek, and others. It also might be possible to use ground-water supplies to supplement any diversions from these streams during the low-flow periods.

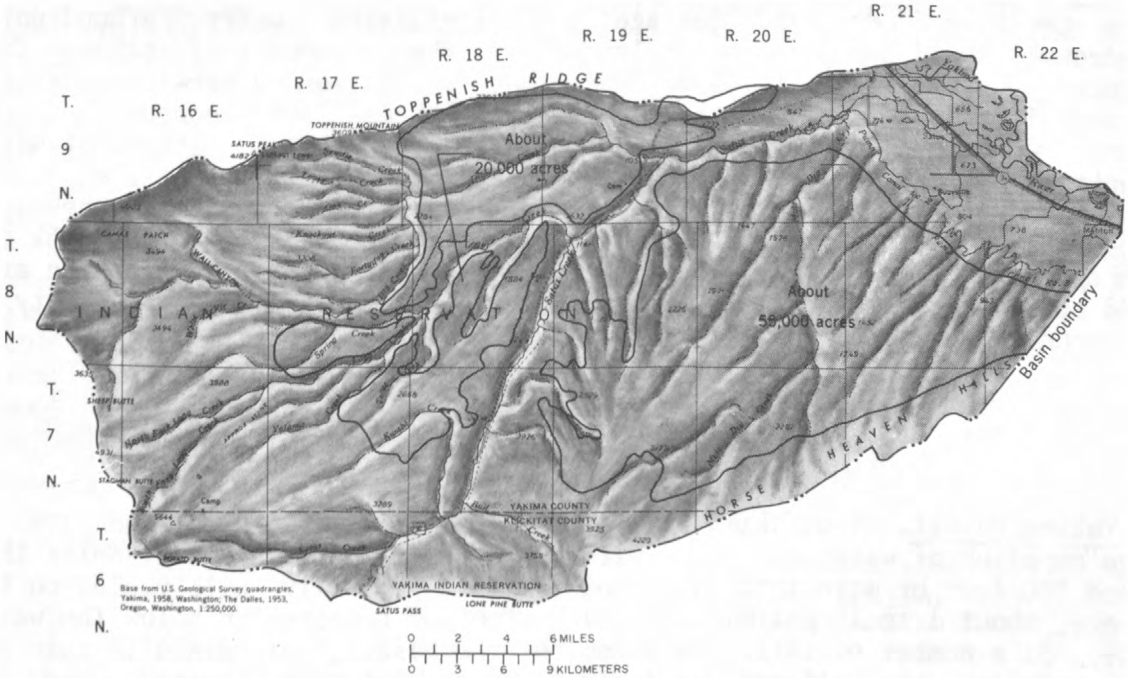


FIGURE 32.--Potentially irrigable land in the Satus Creek basin. (From data provided by the Bureau of Indian Affairs.)

Ground-Water Supplies

The Lowland

The use of ground water as a replacement for surface water, to alleviate waterlogging in the lowland, has already been discussed. However, quantities of ground water in addition to that required for relief of waterlogging could be developed in the lowland.

As most of the recharge to the alluvial aquifer is from seepage from Satus Creek and downward leakage of irrigation water, ground-water withdrawals would need to be balanced by these amounts of recharge from surface sources. If it is assumed that irrigation diversions average 5.0 acre-feet per acre, and the 2 acre-feet excess over consumptive use becomes recharge, then the limitation on total ground-water withdrawal might be approximately 40 percent of the quantity of surface water diverted to the area. Some of the water pumped would also return to the aquifer by seepage, and, along with other recharge--including some seepage from Satus Creek and from ephemeral channels immediately west of the canals--outflow from the area would continue and would tend to prevent too great a buildup of salinity in the ground water.

The Upland

Yakima Basalt.--The Yakima Basalt is capable of yielding moderate to large supplies of water at many places in eastern Washington. Wells that extend 500 feet or more into saturated basalt generally will yield, on the average, about 1 to 1½ gal/min for each foot of penetration below the water table. Of a number of interflow zones in the basalt, determined in this and other studies, one-half may yield significant quantities of water, and one out of five may be a highly productive aquifer. Generally, at least 500 feet and often 800 to 1,000 feet of the basalt must be penetrated below the water table or potentiometric surface to obtain 500 to 1,000 gal/min. Wells penetrating more than 800 feet of basalt below the Beverly Member of the Ellensburg Formation (table 6) may be more likely to tap a highly productive aquifer. Of course, a high-yielding zone might be penetrated in the first few hundred feet or, on the other hand, a 1,000-foot well might yield no water.

An area immediately southwest of the Satus pump canals could be explored for water in the Yakima Basalt. Up to an elevation of 1,000 feet, the water table probably ranges between 100 and 250 feet below the land surface. Wells 550 to 1,150 feet deep probably would be successful at some places, as indicated by the wells tabulated on page 38. However, as the land surface slopes upward to the west at a greater rate than does the water table, the water level might be at excessive depths upslope from the 1,200-foot elevation.

Wells drilled in the Satus Creek and Dry Creeks valleys at some places probably would have water levels near or above land surface. However, the main problem would be to find arable land at elevations where the water could be used.

There probably are places where the water table in the Yakima Basalt is held at relatively high levels by structural features such as folds or faults. However, more geologic mapping would be required to locate such features.

Young basalt.--The water-bearing characteristics of the young basalt are known only indirectly. Basalt of this age in parts of Idaho and eastern Oregon is a prolific aquifer and in the Satus Creek basin it apparently is the source of most of the base flow of Logy and Satus Creeks, as discussed earlier.

Much of the discharge of ground water from the young basalt apparently occurs from its basal part because the underlying Yakima Basalt is much less permeable and does not allow much downward percolation. Most of the ground water discharges into Logy Creek and its tributary valleys and to a lesser extent into the valleys of Dry and Satus Creeks. The altitudes of the contact between the young basalt and the Yakima Basalt were determined by transferring the contacts from the map by Sheppard (1967) to recent topographic quadrangle maps. Altitudes of the contacts in the stream channels are given below (from north to south):

	Altitude of contact (ft)
Dry Creek Drainage:	
Middle Fork Dry Creek----------------------	3,400
South Fork Dry Creek-----------------------	3,300
(White Fir Creek on Sheppard's map)	
Logy Creek Drainage:	
Spring Creek-------------------------------	2,850
Logy Creek---------------------------------	2,800
Section Corner Creek-----------------------	2,800
Yatama Creek-------------------------------	2,850
Tenie Creek--------------------------------	2,950
Satus Creek drainage:	
North Fork Kusshi Creek--------------------	3,100
South Fork Kusshi Creek--------------------	3,400
Telephone Canyon---------------------------	3,900

Sheppard's map (1967) shows a syncline with its axis along Logy Creek, and these altitudes confirm that a sag in the base of the young basalt centers along the creek. Most ground-water discharge from the rocks probably is channeled toward this sag.

On November 2, 1972, the South Fork of Dry Creek at site 7 (fig. 1) had a measured discharge of 5.54 ft^3/s (table 4). The altitude of the creek at that point is about 3,375 feet, which represents a low point on the water table that presumably slopes downward to the east. About 3 miles northwest of this measurement site is Camas Patch, a large flat area covering more than 4 mi^2 and with surface elevations ranging from 3,460 to 3,500 feet. In much of this area the water table probably is less than 100 feet below land surface.

No discharge measurements were made on other tributaries near the contact of the young basalt and the Yakima Basalt. However, a discharge of 20.4 ft^3/s was measured on November 2, 1972, at site 3 on Logy Creek (fig. 1), just below the mouth of Spring Creek (table 4). Presumably this water is entering one or more of the Logy Creek tributaries at or above the contact of the young basalt and the Yakima Basalt. Probably at least some of this discharge is entering Spring Creek at an elevation above 2,850 feet. The water table feeding this outlet may be considerably higher; an ephemeral pond at 8/17-30Q, at an elevation of 3,170 feet, may represent a water-table surface. At any rate, the water table probably reaches an elevation of at least 2,900 feet over a large area north of Spring Creek. In other broad, nearly flat or gently sloping areas between Spring and Yatama Creeks, the water table probably is not more than 300 feet below land surface, and could be much less.

If there are large quantities of water stored at least locally in the young basalt, large-capacity wells might be developed to augment the base flow of the tributaries or to sprinkler irrigate arable upland tracts. The base flow of these creeks probably is much greater during the early part of the irrigation season, and pumping might be required during only 2 or 3 months each year. The tributary valleys in these upstream reaches are relatively shallow, and diversions at points above 2,800 feet could easily reach irrigable lands (fig. 32) by gravity ditch or pipeline, or by a pumping distribution system.

It must be emphasized that nothing is known of the size or the bottom configuration of the presumed ground-water body in the young basalt. If the Yakima Basalt upon which the young basalt accumulated has a maturely dissected surface, ground water might occur in discontinuous pockets and (or) as thin sheets on top of the Yakima Basalt. However, the very slow rate of depletion of base flow in Logy Creek (figs. 6 and 9) suggests the presence of a considerable body of stored ground water in these rocks.

To test this hypothesis, two test observation wells were drilled in the upper Logy and Dry Creek basins. Unfortunately, neither well encountered significant amounts of water in the young basalt at the drilling sites, although the well drilled in the upper Logy Creek basin obtained water from the underlying old basalt. The details of the drilling and pumping tests on the two wells will be presented in a report being prepared by Pearson (written commun., 1976).

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TABLE 12.--Records of wells in Satus Creek basin
[Well locations shown in plate 1 and figure 1]

EXPLANATION

Local well number: Numbered by township, range, section, and 40-acre subdivision, as described on page 6.

Lat-long: Latitude and longitude well number.

Owner: Name of owner or tenant.

Use of water: The purpose for which water from the well is used; F, fire protection; H, domestic; I, irrigation; P, public supply; S, stock supply; U, unused.

Altitude of LSD (ft): The altitude of the land-surface datum, in feet, with reference to mean sea level.

Well depth (ft): The depth of the well, in feet below LSD, at the time of well inventory.

Major aquifer: The geologic unit that contributes the greatest quantity of water to the well; YA, Yakima Basalt; EL, Ellensburg Formation; OA, old and young alluvium and Touchet Beds.

Water level (ft): The measured water level of the well, in feet above or below LSD; +12, flows with head of 12 ft.

Date water level measured: Month and (or) year of measurement, usually during well inventory.

Yield (gpm): The pumping discharge of the well, in gallons per minute, usually reported by driller.

Drawdown (ft): The distance, in feet, that the water level was lowered by pumping at the stated yield rate.

Log available: D, driller's log; G, geologist's log; L, log available, but not listed in table 13.

TABLE 12.--Records of wells in Satus Creek basin--Continued

LOCAL WELL NUMBER	LAT-LONG	OWNER	USE OF WATER	ALTI-TUDE- OF LSD (FT)
07N19E10B01	460650N1202453.1	YAKIMA TRIBE	U	2805
07N19E14N01	460504N1202416.1	YAKIMA TRIBE	U	3064
08N20E36R01	460744N1201436.1	YAKIMA TRIBE	S	1740
08N21E01G01	461240N1200738.1	DEL MONTE CORP	H	770
08N21E01Q01	461200N1200740.1	BIA TUBE U-18	U	777
08N21E01R01	461206N1200713.1	DEL MONTE CORP	H	803
08N22E01G01	461235N1195956.1	MABTON CITY	U	719
08N22E01G02	461236N1195956.1	MABTON CITY	P	719
08N22E01G03	461234N1195957.1	MABTON CITY	P	719
08N22E03K01	461228N1200234.1	BRYCE GROW	H	768
08N22E03P01	461204N1200206.1	BRYCE GROW	H	739
08N22E04P01	461254N1200344.1	US GEOL SURVEY	U	730
08N22E04D01	461244N1200432.1	HUDNALL & DELAY	H	736
08N22E04R01	461200N1200330.1	BIA TUBE U-31	U	751
08N22E05E01	461231N1200543.1	DEL MONTE CORP	H	752
08N22E05Q01	461205N1200453.1	DEL MONTE CORP	H	755
08N22E05R01	461204N1200335.1	DEL MONTE CORP	H	752
08N22E06A01	461243N1200558.1	DEL MONTE CORP	H	750
08N22E06B01	461244N1200624.1	DEL MONTE CORP	H	749
08N22E06R01	461208N1200556.1	DEL MONTE CORP	H	788
08N22E09A01	461152N1200338.1	US GEOL SURVEY	U	759
08N22E09F01	461144N1200424.1	DEL MONTE CORP	H	759
08N22E10P01	461200N1200242.1	BRYCE GROW	H	765
08N22E10K01	461120N1200240.1	BIA TUBE K-35	U	764
08N22E10R01	461115N1200206.1	DEL MONTE CORP	H	771
08N22E11E01	461137N1200201.1	KEITH HART	H	760
08N22E11H01	461145N1200050.1	CF FLOWER	H	770
08N22E11J01	461128N1200053.1	CF FLOWER	I	785
08N22E12H01	461136N1195939.1	YAKIMA CHIEF R	I	755
08N22E12J01	461133N1195946.1	YAKIMA CHIEF R	I	755
08N22E12K01	461133N1200000.1	YAKIMA CHIEF R	I	755
09N19E20L01	461503N1202813.1	US GEOL SURVEY	U	1317
09N20E12G01	461650N1201524.1	TED FOILES	H	752
09N20E12K02	461648N1201528.1	YAKIMA TRIBE	H	750
09N20E14D01	461612N1201714.1	JACK SHATTUCK	H	783
09N21E01Q01	461732N1200802.1	WATSON TOTUS	H	678
09N21E02R01	461730N1200846.1	GEORGE UMTUCH	H	676
09N21E03R01	461804N1201020.1	TROY CURFMAN	H	695
09N21E03J01	461736N1201020.1	BUSTER GEORGE	H	684
09N21E03N01	461731N1201058.1	JOE ELWELL	H	695
09N21E04H01	461810N1201141.1	LUCY BILLY	H	695
09N21E05B01	461808N1201252.1	WAPATO IRRIG	H	709
09N21E05Q01	461724N1201252.1	ANITA WALSEY	H	712
09N21E07Q01	461637N1201418.1	JACK SHATTUCK	I	737
09N21E07Q02	461626N1201423.1	JACK SHATTUCK	I	746

WELL DEPTH (FT)	MAJOR AQUIFER	WATER LEVEL (FT)	DATE WATER LEVEL MEASURED	YIELD (GPM)	DRAW DOWN (FT)	LOG AVAIL-ABLE
408	YA	232	4-72	3	--	D
710	YA	226	4-72	3	--	D
408	YA	268	3-69	40	7	D
130	FL	45	9-73	--	--	L
--	OA	5	7-70	--	--	--
83	EL	35	9-67	20	2	D
1141	YA	50	-39	300	15	L
1080	YA	53	9-71	950	23	L
1004	YA	26	9-71	450	74	D
189	YA	36	9-71	17	5	--
130	EL	4	9-71	--	--	L
103	FL	8	8-73	262	34	G
30	OA	5	9-71	--	--	--
--	OA	5	5-70	--	--	--
115	FL	11	9-71	--	--	L
120	EL	9	9-71	--	--	--
139	EL	10	5-71	--	--	L
130	EL	17	6-71	25	5	D
109	FL	17	9-71	--	--	L
139	FL	33	9-71	--	--	L
82	FL	7	8-73	38	46	G
130	FL	9	9-71	--	--	L
67	FL	16	--	10	--	L
--	OA	9	7-70	--	--	--
100	FL	12	9-73	--	--	--
130	--	--	--	--	--	--
230	EL	20	7-71	24	--	D
556	YA	92	1-73	1302	276	D
551	YA	40	-63	215	120	D
500	YA	104	11-69	180	237	D
122	EL	40	--	30	15	--
698	YA	185	6-73	250	90	G
100	EL	--	--	70	20	D
60	OA	15	9-71	60	--	D
11	OA	9	6-71	--	--	--
52	OA	9	9-71	--	--	D
50	OA	6	9-71	200	--	L
25	OA	15	5-71	10	--	--
52	OA	6	9-71	40	--	D
--	--	--	--	--	--	--
53	OA	5	9-71	60	--	L
88	EL	40	4-53	20	--	D
63	OA	20	9-63	40	20	D
84	OA	14	9-71	500	30	--
82	OA	14	4-71	1200	33	D

TABLE 12.--Records of wells in Satus Creek basin--Continued

LOCAL WELL NUMBER	LAT-LONG	OWNER	USE OF WATER	ALTI-TUDE-OF LSD (FT)
09N21E08B01	461717N1201310.1	ALLEN DAVID	H	714
09N21E08K01	461650N1201310.1	BESSIE PIERCE	H	717
09N21E08L01	461651N1201314.1	US GEOL SURVEY	U	720
09N21E08L02	461651N1201316.1	US GEOL SURVEY	U	720
09N21E08N01	461626N1201348.1	ROY PLANK	I	738
09N21E12N01	461638N1200841.1	HOWARD SELAM	H	674
09N21E12N02	461637N1200841.1	SARAH QUEAMPTS	H	672
09N21E12N03	461636N1200841.1	EDITH KALAMA	H	675
09N21E13A01	461616N1200746.1	GORDON MCBRIDE	H	670
09N21E13A02	461617N1200751.1	MCBRIDE GUN CLB	H	665
09N21E14A01	461615N1200903.1	ROGER JIM	H	673
09N21E15D01	461615N1201117.1	RICH THOMPSON	H	704
09N21E15H01	461602N1201020.1	MARY JOHN	H	682
09N21E15M01	461557N1201106.1	BOB RASSMUSSEN	I	700
09N21E16B01	461624N1201136.1	ROLAND SPENCER	H	715
09N21E17C01	461619N1201324.1	LOTTIE L WALKER	H	763
09N21E17C02	461616N1201314.1	RAY WALKER	H	761
09N21E17D01	461621N1201330.1	CLARENCE JAMES	I	732
09N21E17D02	461620N1201332.1	CLARENCE JAMES	I	742
09N21E17F01	461600N1201328.1	JOHNNY WALKER	H	781
09N21E17H01	461610N1201235.1	O ELKSTRAND	U	710
09N21E17M01	461553N1201331.1	MARION EMRICK	I	759
09N21E21P01	461532N1201155.1	UNKNOWN	U	708
09N21E22A01	461525N1201005.1	UNKNOWN	U	712
09N21E23J01	461457N1200847.1	JEFFERY FOWLER	U	685
09N21E23K01	461458N1200920.1	YAKIMA AGENCY	U	685
09N21E24N01	461450N1200827.1	EM BLANSHAN	I	683
09N21E24N02	461443N1200843.1	EM BLANSHAN	H	685
09N21E24Q01	461442N1200750.1	US GEOL SURVEY	U	689
09N21E24Q02	461443N1200751.1	US GEOL SURVEY	U	689
09N21E24Q03	461442N1200752.1	US GEOL SURVEY	U	689
09N21E25C01	461437N1200808.1	ISAAC ALBERT	H	690
09N21E25H01	461420N1200731.1	DEL MONTE CORP	H	695
09N21E25J01	461409N1200731.1	DEL MONTE CORP	H	700
09N21E26M01	461411N1200943.1	HARLAN SHINN	F	706
09N21E26P01	461352N1200849.1	RON NELSON	H	698
09N21E27J01	461413N1201002.1	DEL MONTE CORP	H	710
09N21E27J02	461412N1201002.1	DEL MONTE CORP	H	710
09N21E27L01	461414N1201043.1	DEL MONTE CORP	H	720
09N21E27P01	461358N1201002.1	DEL MONTE CORP	H	716
09N21E35C01	461339N1200929.1	US GEOL SURVEY	U	729
09N21E35H01	461334N1200851.1	US GEOL SURVEY	U	699
09N21E35H02	461323N1200856.1	WAPATO IRRIG	H	740
09N21E35J01	461310N1201000.1	BIA TUBE 03-144	U	738
09N21E36E01	461340N1200844.1	YAKIMA TRIBE	S	694

WELL DEPTH (FT)	MAJOR AQUIFER	WATER LEVEL (FT)	DATE WATER LEVEL MEASURED	YIELD (GPM)	DRAW DOWN (FT)	LOG AVAIL- ABLE
53	QA	5	9-71	40	12	D
55	QA	3	9-71	--	--	--
107	QA	16	8-73	2	--	G
42	QA	7	8-73	290	8	L
65	QA	13	9-71	300	2	D
52	QA	5	--	40	--	L
52	QA	6	9-71	40	--	D
53	QA	5	9-71	60	10	L
20	QA	6	9-71	--	--	--
--	QA	2	9-71	--	--	--
--	QA	--	--	--	--	--
63	QA	12	9-71	40	19	D
42	QA	3	9-71	40	--	D
106	QA	7	6-66	700	38	D
--	QA	20	9-71	--	--	--
83	QA	45	5-71	40	--	L
80	QA	47	5-71	--	--	--
65	QA	19	7-63	200	29	D
130	--	--	--	200	--	--
100	--	69	5-71	40	10	--
49	QA	3	9-71	60	--	--
140	--	43	9-71	--	--	--
8	QA	3	9-71	--	--	--
199	EL	--	--	--	--	D
14	QA	8	5-59	--	--	--
74	QA	6	-68	60	--	L
113	QA	5	8-73	1200	85	D
90	QA	--	--	--	--	--
334	YA	1	8-73	15	15	G
21	QA	4	8-73	33	5	L
89	QA	4	8-73	108	40	L
85	QA	10	--	40	--	D
130	QA	6	9-71	--	--	L
90	QA	7	6-71	25	3	D
960	YA	+3	9-71	325	104	D
80	EL	--	--	--	--	--
--	QA	--	--	--	--	--
180	YA	25	3-74	30	140	D
119	EL	--	--	--	--	--
115	EL	15	10-73	--	--	--
87	EL	85	4-72	--	--	G
79	EL	+8	8-73	22	24	G
142	EL	--	--	7	--	L
21	QA	21	5-70	--	--	--
50	EL	+5	7-73	10	--	--

TABLE 12.--Records of wells in Satus Creek basin--Continued

LOCAL WELL NUMBER	LAT-LONG	OWNER	USE OF WATER	ALTITUDE OF LSD (FT)
09N21E36K01	461321N1200752.1	DEL MONTE CORP	H	743
09N21E36K02	461309N1200755.1	DEL MONTE CORP	H	740
09N21E36R01	461256N1200730.1	DEL MONTE CORP	H	768
09N22E07N01	461640N1200729.1	MCBRIDE	--	665
09N22E12H01	461653N1195954.1	AC PRYDE	H	690
09N22E17R01	461535N1200515.1	FRED RUPLEY #1	I	655
09N22E18R01	461544N1200621.1	FRED RUPLEY #3	I	655
09N22E19F01	461510N1200730.1	BIA TUBE F-19	U	682
09N22E19P01	461443N1200620.1	LOREN SKIDMORE	H	690
09N22E19Q01	461443N1200637.1	RAY JACK	H	684
09N22E20R01	461523N1200524.1	FRED RUPLEY #2	I	655
09N22E25J01	461408N1200730.1	WH JOHNSON	I	655
09N22E29D01	461442N1200612.1	G E MOSEBAR	H	683
09N22E30R01	461439N1200647.1	NILES JIM	H	690
09N22E31G01	461323N1200643.1	DEL MONTE CORP	H	732
09N22E31J01	461321N1200630.1	DEL MONTE CORP	H	742
09N22E31M01	461314N1200728.1	LOTTIE WHITE	H	748
09N22E31N01	461300N1200710.1	BIA TUBE N-20	U	738
09N22E31Q01	461308N1200640.1	DEL MONTE CORP	H	742
09N22E32M01	461321N1200556.1	DEL MONTE CORP	H	740
09N22E32M02	461309N1200612.1	B BARNETT	H	743
09N22E32N01	461308N1200600.1	DEL MONTE CORP	H	743
09N22E32Q01	461300N1200520.1	BIA TUBE Q-26	U	738
09N22E36K01	461312N1200018.1	YAKIMA CHIEF H	I	710
09N23E31E01	461321N1195953.1	JA HAAS INC	I	708
10N21E22E01	462023N1201110.1	CITY OF GRANGER	P	750
10N21E28L01	461917N1201156.1	SILAS PETERS	H	702
10N21E29P01	461944N1201310.1	SIMON JOHN	H	712
10N21E29F01	461942N1201326.1	UNKNOWN	U	710
10N21E32B01	461851N1201253.1	C BEAVERT	H	707
10N21E32K01	461827N1201255.1	TOM LAROCK	H	700
10N21E33B01	461859N1201149.1	LENA PHILLIPS	H	701
10N21E33C01	461855N1201155.1	LENA SOHAPPY	H	702
10N21E33L01	461833N1201154.1	SHAKER CHURCH	H	702
10N21E34D01	461903N1201114.1	MOSE DICK	U	698
10N21E34G01	461840N1201030.1	JAMES STRONG	H	696
10N21E34L01	461837N1201039.1	LUCILLE TAIWASH	H	691
10N21E34M01	461842N1201110.1	MRS C TELEKISH	U	695
10N21E35C01	461855N1200936.1	R L WORNELL	U	693

WELL DEPTH (FT)	MAJOR AQUIFER	WATER LEVEL (FT)	DATE WATER LEVEL MEASURED	YIELD (GPM)	DRAW DOWN (FT)	LOG AVAIL-ABLE
120	EL	25	4-71	--	--	--
110	EL	12	9-71	--	--	--
--	EL	--	--	--	--	--
--	--	--	--	--	--	--
100	OA	7	10-46	45	18	D
78	OA	12	4-72	--	--	D
60	OA	12	11-70	--	--	D
10	OA	6	8-70	--	--	--
--	--	--	--	--	--	--
85	OA	7	9-71	40	--	D
60	OA	12	10-70	--	--	D
82	OA	7	-62	400	40	D
138	OA	15	3-71	40	--	--
95	OA	11	--	40	--	D
134	EL	27	6-71	20	2	D
140	EL	32	9-71	15	2	D
115	EL	29	10-73	40	--	L
--	OA	5	6-70	--	--	--
142	EL	19	6-71	20	10	D
142	EL	34	6-71	--	--	--
--	--	--	--	15	--	--
140	EL	31	9-71	20	7	D
--	OA	11	5-70	--	--	--
--	YA	58	-58	810	32	--
175	OA	50	3-64	50	0	D
252	EL	+5	3-68	1850	21	D
42	OA	12	9-71	40	--	D
60	OA	5	9-71	10	10	L
21	OA	7	9-71	--	--	--
24	OA	5	9-71	--	--	--
83	OA	15	--	40	--	D
41	OA	7	9-71	60	--	D
42	OA	7	9-71	--	--	L
292	EL	+1	7-72	120	--	D
42	OA	7	9-71	10	--	L
--	OA	11	9-71	--	--	--
44	OA	9	9-63	40	15	D
43	OA	7	9-63	40	18	L
16	OA	7	9-71	--	--	--

TABLE 13.--Logs of selected wells in the Satus Creek basin

Material	Thickness (ft)	Depth (ft)
7/19-10B1. Yakima Tribe. Altitude about 2,805 ft. Drilled by Courtney Bach, 1969. Casing: 8-inch to 125 ft.		
Soil	5	5
Yakima Basalt, Saddle Mountains Member:		
Basalt, medium hard, black	25	30
Ellensburg Formation, Beverly Member:		
Clay, sandy, soft, yellow	110	[a]140
Yakima Formation, undifferentiated:		
Basalt, medium hard, black	75	215
Basalt, hard, red	20	235
Basalt, medium hard, black	15	250
Basalt, broken, reddish	25	275
Basalt, hard, gray	95	370
Basalt, medium hard, black	20	390
Shale, soft, blue	10	400
Basalt, hard, black	8	408

[a]Depth may not be correct.

Material	Thickness (ft)	Depth (ft)
7/19-14N1. Yakima Tribe. Altitude 3,064 ft. Drilled by Courtney Bach, 1969. Casing: 6-inch to 120 ft.		
Soil	5	5
Yakima Basalt, Saddle Mountains Member:		
Basalt, broken	20	25
Ellensburg Formation, Beverly Member:		
Clay, sandy	115	[a]140
Yakima Basalt, undifferentiated:		
Basalt, hard, black; water, 2 gal/min at 160 ft	120	260
Basalt, soft, red	10	270
Basalt, hard, gray	136	406
Basalt, broken, medium hard, gray	32	438
Basalt, hard, black	177	615
Basalt, medium hard, broken	15	630
Basalt, hard, gray	80	710

[a]Depth may not be correct.

Material	Thickness (ft)	Depth (ft)
8/20-36R1. Yakima Tribe. Altitude about 1,740 ft. Drilled by Courtney Bach, 1969. Casing: 6-inch to 208 ft.		
Soil	4	4
Yakima Basalt, Saddle Mountains Member:		
Basalt, black	34	38
Basalt, soft, brown	12	50
Ellensburg Formation, Beverly Member:		
Sandstone, with clay, 2 gal/min at 140 ft	158	208
Yakima Basalt, undifferentiated:		
Basalt, hard	12	220
Basalt, broken	10	230
Basalt, medium hard	145	375
Sandstone, brown	10	385
Sandstone, blue	15	400
Clay, sandy, blue	8	408
8/21-1R1. Del Monte Corp. Altitude about 803 ft. Drilled by V. L. Pritchard, 1967. Casing: 6-inch to 83 ft.		
Touchet Beds of Flint (1938):		
Soil	27	27
Ellensburg Formation:		
Gravel, cemented	18	45
Sand, and gravel, hard-packed	35	80
Sand, and gravel, loose	3	83
8/22-1G3. City of Mabton. Altitude 719 ft. Drilled by Dilley Drilling Co., 1957. Casing: 16-inch to 130 ft, 12-inch 120 to 307 ft; perforated 96-115 ft, 295-305 ft.		
Touchet Beds of Flint (1938):		
Soil	10	10
Ellensburg Formation:		
Sand and gravel	5	15
Gravel, cemented	13	28
Sand, gravel, and water	45	73
Clay, blue	3	76
Gravel, sand, and water	51	127
Yakima Basalt, Saddle Mountains Member:		
Basalt, black, porous, water	5	132
Basalt, black	48	180
Ellensburg Formation, Beverly Member:		
Clay, gray	10	190
Gravel, blue clay, caving	39	229
Sand ("Rock Sand"), blue, heaving, and water	11	240
Shale and clay, blue	49	289
Yakima Basalt, undifferentiated:		
Basalt, black, with shale	8	297
Basalt, black, porous	3	300
Basalt, black, with shale	8	308
Basalt, black	4	312
Basalt, red, porous	16	328
Basalt, black to gray, and brown (sand at base of interval)	90	418
Basalt, black	32	450
Basalt, gray, with sand	3	453
Basalt, gray, black	34	487
Basalt, black, porous	26	513
Basalt, black	153	666
Basalt, red	24	690
Basalt, black	67	757
Basalt, gray to black, with sand	128	885
Basalt, black and gray (sand at 1,004 ft)	119	1,004
8/22-4B1. U.S. Geological Survey. Altitude about 730 ft. Drilled by Western Water Supply, 1973. Completed depth 103 ft. Casing: 6-inch to 100 ft. Screened 100 to 103 ft.		
Touchet Beds of Flint (1938):		
Sand, very fine, brown	8	8
Clay, and some fine sand	55	63
Ellensburg Formation:		
Clay, gravel, and some very fine to medium sand; pebbles mostly quartzite and basalt, with minor amounts of andesite, chert, and granitic types	12	75
Sand, much fine, and gravel, similar to foregoing, water	30	105
Sand and gravel, semiconsolidated	3	108
Sand and gravel, much from basalt and quartzite, some from andesite, chert, and granitic rocks, water	4	112
8/22-6A1. Del Monte Corp. Altitude 750 ft. Drilled by V. L. Pritchard, 1969. Casing: 6-inch to 130 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	16	16
Clay, sandy	54	70
"Hardpan"	14	84
Silt and clay, sandy	17	101
Ellensburg Formation:		
Gravel, hard-packed, and sand in clay	26	127
Gravel, packed sand, very hard drilling	3	130

TABLE 13.--Logs of selected wells in the Satus Creek basin--continued

8/22-9A1. U.S. Geological Survey. Altitude about 759 ft. Drilled by Western Water Supply, 1973. Completed depth 82 ft. Casing: 6-inch to 79 ft. Screened 79 to 82 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938):		
Clay, brown, some fine to very fine sand	71	71
Ellensburg Formation:		
Sand and gravel, to 2-inch diameter, mostly light colored, much quartzite, some chert and granitic rocks, less than one-third dark rocks, some silt, water	11	82
Sand, gravel, and clay	7	89

8/22-11H1. C. F. Flower. Altitude about 770 ft. Drilled by Columbia Drilling Co., 1971. Casing: 6-inch to 229 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938):		
Soil, and brown sandy clay	70	70
Ellensburg Formation:		
Gravel, cemented, medium	25	95
Clay, tan, sandy	11	106
Sand, and pea gravel	36	142
Yakima Basalt, Saddle Mountains Member:		
Basalt, black and brown	43	185
Ellensburg Formation, Beverly Member:		
Clay, tan, sticky	27	212
Clay, blue, and shale	3	215
Clay, tan, and shale	15	230

8/22-11J1. C. F. Flower. Altitude about 785 ft. Drilled by Columbia Drilling Co., 1973. Casing: 14-inch to 317 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938):		
Clay, tan	70	70
Ellensburg Formation:		
Gravel, large to small, and tan clay	66	136
Yakima Basalt, Saddle Mountains Member:		
Basalt, black and brown, broken	14	150
Basalt, black, and gray	35	185
Ellensburg Formation, Beverly Member:		
Clay, yellow, and brown rock	10	195
Clay, tan, and sand	39	234
Clay, blue to green	31	265
Clay, tan, and sand	50	315
Yakima Basalt:		
Basalt, brown and red	10	325
Basalt, brown, and black	35	360
Basalt, gray, soft	40	400
Basalt, gray, hard	97	497
Basalt, gray, soft	5	502
Basalt, brown and black, with green shaley clay seams	23	525
Basalt, brown, black, and gray	31	556

8/22-12H1. Yakima Chief Ranch. Altitude about 755 ft. Drilled by W. F. Ludwig, 1963. Casing: 10-inch to 100 ft, 8-inch 100-135 ft, 6-inch 200-300 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938) and Ellensburg Formation:		
Soil, sand, and gravel	135	135
Yakima Basalt, Saddle Mountains Member:		
Basalt	30	165
Ellensburg Formation, Beverly Member:		
Clay	135	300
Yakima Basalt:		
Basalt	251	551

8/22-12J1. Yakima Chief Ranch. Altitude about 755 ft. Drilled by Eastwood Drilling Co., 1969. Casing: 7-inch to 302 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938):		
Soil	47	47
Ellensburg Formation:		
Sand, gravel, and boulders; some water	76	123
Yakima Basalt, Saddle Mountains Member:		
Basalt, black, solid	43	166
Ellensburg Formation, Beverly Member:		
Shale, green, and sandstone layers, water (100 gal/min)	136	302
Yakima Basalt:		
Basalt, porous	8	310
Basalt, black	159	469
Basalt, broken, honeycombed, water	29	498
Basalt, black, solid	2	500

9/19-20L1. U.S. Geological Survey. Altitude about 1,317 ft. Drilled by R. J. Strasser Drilling Co., 1973. Casing: 8-inch to 39 ft.

Material	Thickness (ft)	Depth (ft)
Soil, sandy	2	2
Yakima Basalt:		
Basalt, broken, brown, and clay	8	10
Basalt, broken, gray	12	22
Basalt, hard, gray	10	32
Basalt, broken, gray	3	35
Basalt, hard, gray	71	106
Basalt, medium hard, brown to black	16	122
Basalt, hard, gray	113	235
Basalt, broken, gray	3	238
Clay, green	2	240
Basalt, medium hard, black	31	271
Basalt, porous, black	13	284
Basalt, broken, black	22	306
Basalt, hard, gray	19	325
Basalt, broken, black	12	337
Basalt, hard, gray	21	358
Clay, green	3	361
Basalt, broken, black	4	365
Basalt, gray, hard	9	374
Basalt, broken, black and brown	20	394
Basalt, hard, gray	6	400
Basalt, broken, brown and gray	12	412
Basalt, hard, gray	20	432
Basalt, soft, brown and black	12	444
Basalt, hard, gray	100	544
Basalt, black, and green clay	8	552
Basalt, porous, black	6	558
Basalt, hard, gray	6	564
Basalt, porous, black	10	574
Basalt, hard, gray	124	698

9/20-12G1. Ted Foiles. Altitude 752 ft. Drilled by Oltman, 1966. Completed depth 100 ft. Casing: 10-inch to 50 ft, 8-inch 50 to 100 ft.

Material	Thickness (ft)	Depth (ft)
Touchet Beds of Flint (1938):		
Soil	30	30
Yakima Basalt, Saddle Mountains Member:		
Basalt	50	80
Ellensburg Formation, Beverly Member:		
Ash, volcanic	10	90
Clay, blue	110	200

TABLE 13.--Logs of selected wells in the Satus Creek basin--Continued

Material	Thick-ness (ft)	Depth (ft)
9/20-12K2. Yakima Tribe. Altitude about 750 ft. Drilled by Henry Bach. Cased to 59 ft.		
Young alluvium:		
Sand	8	8
Sand, gravel, and silt, water	12	20
Touchet Beds of Flint (1938):		
Hardpan	12	32
Old alluvium:		
Silt, sand, and gravel; water	2	34
Rock, decomposed, and boulders	25	59
Ellensburg(?) Formation:		
Rock shale	1	60
9/21-1Q1. Watson Totus. Altitude 678 ft. Drilled by Henry Bach. Cased to 52 ft.		
Touchet Beds of Flint (1938):		
Sand	12	12
Sand, fine, and silt	28	40
Old alluvium:		
Gravel, cemented	8	48
Sand, fine	4	52
9/21-3J1. Buster George. Altitude 684 ft. Drilled by Henry Bach. Cased to 52 ft.		
Young alluvium:		
Sand	15	15
Old alluvium:		
Gravel, water	9	24
Gravel, cemented	8	32
Hardpan	8	40
Silt, "Swamp"	5	45
Hardpan	5	50
Gravel	2	52
9/21-5B1. Wapato Irrigation Project. Altitude about 709 ft. Drilled by Dilley Drilling Co., 1958. Casing: 6-inch to 88 ft.		
Touchet Beds of Flint (1938):		
Soil	18	18
Clay	5	23
Old alluvium and Ellensburg Formation:		
Sand ("rock sand")	6	29
Gravel, cemented	11	40
Sand ("rock sand")	10	50
Gravel	10	60
Unknown	28	88
9/21-5Q1. Anita Walsey. Altitude about 712 ft. Drilled by J. C. Riebe, 1963. Casing: 6-inch to 63 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	11	11
Sand, fine, heaving; water	48	59
Old alluvium:		
Gravel, cemented	3	62
Sand and gravel; good water	1	63
9/21-7Q2. Jack Shattuck. Altitude 746 ft. Drilled by Ring Drilling Co., 1968. Casing: 10-inch to 82 ft., perforated 19-82 ft.		
Touchet Beds of Flint (1938):		
Soil and sand	14	14
Old alluvium and Ellensburg Formation:		
Gravel and boulders	10	24
Silt, sandy	11	35

(continued)

Material	Thick-ness (ft)	Depth (ft)
9/21-7Q2.--continued		
Old alluvium and Ellensburg Formation--continued		
Gravel, cemented, and pea gravel	4	39
Gravel cemented, boulders, in layers	16	55
Silt, and large gravel	13	68
Gravel, cemented, and pea gravel	6	74
Yakima Basalt, Saddle Mountains Member:		
Basalt	8	82
9/21-8B1. Allen David. Altitude 714 ft. Drilled by Henry Bach, 1963. Casing 6-inch to 53 ft.		
Touchet Beds of Flint (1938):		
Sand	8	8
Silt and sand; water	24	32
Old alluvium:		
Gravel, cemented	15	47
Sand, gravel, and boulders	6	53
Clay, red, burned, at 53 ft	--	--
9/21-8L1. U.S. Geological Survey. Altitude about 720 ft. Drilled by Western Water Supply, 1973. Casing: 6-inch to 99 ft.		
Touchet Beds of Flint (1938):		
Clay, brown	8	8
Clay and silt, brown, and some gravel	13	21
Clay, sticky	10	31
Clay and silt, brown, and basaltic gravel	7	38
Old alluvium:		
Sand, and dark basaltic gravel; water	11	49
Sand, basaltic gravel, and clay, some water	4	53
Clay, brown, and sand and dark basaltic gravel, some stained buff to yellow, and below 93 ft., reddish brown; no water	45	98
Clay, sand, and basaltic gravel, a little water	2	100
Yakima Basalt, Saddle Mountains(?) Member:		
Basalt, black, solid	7	107
9/21-8N1. Roy Plank. Altitude about 738 ft. Drilled by V. L. Pritchard, 1961. Casing: 8-inch to 57 ft; perforated from 19 to 52 ft.		
Touchet Beds of Flint (1938):		
Soil and clay	17	17
Old alluvium:		
Gravel, sandy, basalt(?), and sand	25	42
Sand, black, loose, and gravel	15	57
Yakima Basalt, Saddle Mountains(?) Member:		
Basalt, burnt	8	65
9/21-12N2. Sarah Queampts. Altitude 672 ft. Drilled by Henry Bach, 1963. Cased to 52 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	15	15
Old alluvium:		
Gravel, cemented	9	24
Sand, gravel, silt; water	16	40
Hardpan	11	51
Sand and gravel; water	1	52

Material	Thick-ness (ft)	Depth (ft)
9/21-15D1. Richard Thompson. Altitude 704 ft. Drilled by J. C. Riebe, 1963. Casing: 6-inch to 63 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	12	12
Sand, fine, some silt, blue shale; water	46	58
Old alluvium:		
Gravel, cemented	3	61
Sand, gravel; good water	2	63
9/21-15H1. Mary John. Altitude 682 ft. Drilled by Henry Bach. Casing: 6-inch? to 42 ft.		
Touchet Beds of Flint (1938):		
Sand	6	6
Old alluvium:		
Sand and gravel, coarse	22	28
Gravel, cemented	12	40
Sand	2	42
9/21-15M1. Bob Rassmussen. Altitude about 700 ft. Drilled by King Drilling Co., 1966. Casing: 12-inch to 106 ft; perforated from 55 to 65 ft, 70 to 83 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	15	15
Sand, with water	23	38
Clay	6	44
Old alluvium, and Ellensburg Formation(?):		
Sand, gravel, and water	62	106
9/21-17D1. Clarence James. Altitude about 732 ft. Drilled by Henry Bach, 1963. Casing: 6-inch to 65 ft; perforated 33-62 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	38	38
Old alluvium, and Ellensburg Formation:		
Gravel, cemented, and boulders	7	45
Rock, decomposed, and boulders	20	65
9/21-22A1. Owner unknown. Altitude about 712 ft. Drilled by Western Water Supply, 1972.		
Touchet Beds of Flint (1938):		
Silt, light gray to brown, and very fine sand	21	21
Sand, very fine	1	22
Sand, dark brown, medium to coarse	30	52
Sand, very fine to medium grained, some medium-gray silt	5	57
Silt, medium-gray, some slightly sticky clay	3	60
Old alluvium and Ellensburg Formation:		
Gravel, mostly clean, well sorted, with occasional streaks of silty gravel	139	199

Material	Thick-ness (ft)	Depth (ft)
9/21-24N1. E. M. Blanshan. Altitude 683 ft. Drilled by Castle Drilling Co., 1959. Casing: 12-inch to 112 ft.		
Touchet Beds of Flint (1938):		
Soil	30	30
Clay, hard	5	35
Sand, green	15	50
Clay, hard	7	57
Sand, running	4	61
Old alluvium:		
Gravel, cemented	34	95
Gravel, loose	18	113
9/21-24Q1. U.S. Geological Survey. Altitude about 689 ft. Drilled by Western Water Supply, 1973. Casing: 6-inch to 300 ft.		
Touchet Beds of Flint (1938):		
Sand, and some dark brown clay	10	10
Sand, medium to very coarse, water	9	19
Sand, very fine to medium	11	30
Silt and dark gray clay	14	44
Silt,and very fine to fine sand	7	51
Sand, very fine to medium, some gray silt and clay, a little wood, water	5	56
Silt, gray, and very fine sand	8	64
Old alluvium:		
Sand, gravel and some cobbles, mostly basalt, with some andesite, a little quartzite, and a few thin layers of dark brown clay, water	24	88
Sand, gravel, mostly basalt, with some andesite, a little quartzite, and yellow clay, little water	10	98
Sand and gravel, mostly basalt, with some andesite and a little quartzite, water	12	110
Sand and gravel, mostly basalt, with some andesite, a little quartzite, and some dark brown clay	2	112
Sand and gravel, mostly basalt, with some andesite, and a little quartzite, water	5	117
Ellensburg Formation:		
Sand, gravel, and some clay, semiconsolidated, pebbles mostly basalt, much andesite, and some quartzite	19	136
Sand and gravel, mostly basalt, some andesite, a little quartzite and a few thin clay layers, water	24	160
Sand and gravel, similar to foregoing but coarser, water	15	175
Sand and gravel, very coarse, mostly basalt and andesite, a little quartzite, and a thin dark brown clay layer at 185 ft, water	20	195
Sand and gravel, very coarse, mostly basalt, a little andesite and quartzite, water	13	208
Sand, much very fine to fine, some medium, light gray, much pumice shards, and light brown silt	1	209
Sand and gravel, very coarse, mostly basalt, with some andesite and quartzite, water	14	223
Sand and gravel, very coarse, mostly quartzite, andesite, and basalt, a little granite and other rocks, water	72	295
Yakima Basalt, Saddle Mountains(?) Member:		
Basalt, broken, black	5	300
Basalt, solid, black	22	322
Basalt, broken, black, water	10	332
Basalt, solid, black	2	334

TABLE 13.--Logs of selected wells in the Satus Creek basin--Continued

Material	Thickness (ft)	Depth (ft)
9/21-25C1. Isaac Albert. Altitude about 690 ft. Drilled by Henry Bach. Casing: 6-inch to 85 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	25	25
Sand, fine, and silt	39	64
Clay, blue	9	73
Old alluvium:		
Gravel, pea-sized, and sand; water	12	85
9/21-25J1. Del Monte Corp. Altitude 700 ft. Drilled by V. L. Pritchard, 1967. Casing: 6-inch to 90 ft.		
Touchet Beds of Flint (1938):		
Soil, loose	16	16
Clay, sandy	39	55
Clay, sandy, gray-blue	29	84
Old alluvium:		
Gravel and sand, blue	5	89
Sand, brown; water	2	91
9/21-26M1. Harlan Shinn. Altitude 706 ft. Drilled by Ralph Cassel, 1963. Casing: 10-inch to 415 ft, 8-inch from 393 to 663 ft.		
Touchet Beds of Flint (1938):		
Soil, and silt	50	50
Sand	10	60
Clay, blue, sticky	15	75
Old alluvium(?):		
Sand and gravel, small	5	80
Ellensburg Formation:		
Gravel, partly cemented	25	105
Clay, sandy	15	120
Gravel, cemented	5	125
Sand, and small gravel	18	143
Clay	4	147
Yakima Basalt, Saddle Mountains Member:		
Basalt, broken	17	164
Basalt, broken, with shale	5	169
Basalt, broken	17	186
Basalt	28	214
Ellensburg Formation, Beverly Member:		
Clay	28	242
Shale, green	50	292
Clay, yellow	68	360
Clay, and shale, sandy	26	386
Clay and shale	29	415
Yakima Basalt:		
Basalt, gray	178	593
Basalt, black	12	605
Basalt, broken, mud filled	18	623
Basalt	22	645
Basalt, broken	18	663
Basalt, gray to black	162	825
Shale, green (sedimentary interbed)	25	850
Basalt	100	950
Basalt, rotten; water	10	960
9/21-27J2. Del Monte Corp. Altitude about 710 ft. Drilled by B and B Drilling Co., 1974. Casing: 6-inch to 162 ft.		
Touchet Beds of Flint (1938):		
Soil, brown	1	1
Sand, brown	34	35
Clay, gray	45	80
Old alluvium(?):		
Gravel, medium, water-bearing	15	95
Ellensburg Formation:		
Gravel, cemented	57	152
Clay, light brown	5	157

(continued)

Material	Thickness (ft)	Depth (ft)
9/21-27J2--Continued		
Yakima Basalt, Saddle Mountains Member:		
Basalt, fractured, water-bearing	2	159
Basalt, black	6	165
Basalt, vesicular, water-bearing	5	170
Basalt, black	10	180
9/21-35C1. U.S. Geological Survey. Altitude 729 ft. Drilled by U.S. Geological Survey, 1972. Casing: 1-inch to 85 ft. Screened from 85 to 87 ft.		
Touchet Beds of Flint (1938):		
Silt	32	32
Silt, clayey, light gray to brown	41	73
Ellensburg Formation:		
Cobbles in clay	6	79
Sand, and gravel, conglomeratic, clayey, blue-green	5	84
Sand and gravel	3	87
9/21-35H1. U.S. Geological Survey. Altitude about 699 ft. Drilled by Western Water Supply, 1973. Casing: 6-inch to 76 ft. Screened from 76 to 79 ft. Completed depth 79 ft.		
Touchet Beds of Flint (1938):		
Clay, brown	18	18
Clay, and sand	2	20
Sand, fine to medium, water	4	24
Clay, gray to brown, and some sand	5	29
Clay, gray to brown	7	36
Clay, gray	5	41
Ellensburg Formation:		
Sand and quartzitic gravel, and some clay	6	47
Clay, gray, sand and gravel	4	51
Clay, red-brown, sand and quartzitic gravel	8	59
Sand, mostly basaltic and some quartzitic gravel, and some clay, some water	15	74
Sand, gravel, and clay, semiconsolidated	2	76
Sand and mostly basaltic, quartzitic, and andesitic gravel, water	6	82
9/22-12H1. A. C. Pryde. Altitude about 690 ft. Drilled by D. P. Hammond, 1946. Casing: 6-inch to 98 ft.		
Touchet Beds of Flint (1938):		
Soil	6	6
Sand, gray	61	67
Old alluvium:		
Sand, coarse, brown	3	70
Gravel, cemented	26	96
Gravel, coarse, loose	4	100
9/22-17R1. Fred Rupley. Altitude about 655 ft. Drilled by Columbia Drilling Co., 1972. Casing: 12-inch to 78 ft.		
Touchet Beds of Flint (1938):		
Soil	6	6
Clay and sand	22	28
Clay, tan	12	40
Old alluvium:		
Sand, and clay, gray; water	18	58
Gravel, and sand; water	8	66
Gravel, large; water	12	78

Material	Thickness (ft)	Depth (ft)
9/22-18R1. Fred Rupley. Altitude about 655 ft. Drilled by Columbia Drilling Co., 1970. Casing: 16-inch to 60 ft; perforated 54-59 ft.		
Young alluvium or Touchet Beds of Flint (1938):		
Soil, clay, and sand	17	17
Old alluvium:		
Gravel, small, sand and brown clay, water	18	35
Clay, blue, sand, and small gravel	17	52
Gravel, large, and sand; water	8	60
9/22-19Q1. Ray Jack. Altitude 684 ft. Drilled by Henry Bach, 1965. Casing: 6-inch to 85 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	25	25
Sand, fine, silt, and blue muck	35	60
Hardpan	24	84
Old alluvium:		
Sand, gravel, and a little clay, water	1	85
9/22-20B1. Fred Rupley. Altitude about 655 ft. Drilled by Columbia Drilling Co., 1970. Casing: 16-inch to 60 ft; perforated 54-59 ft.		
Young alluvium:		
Soil, clay, and sand	15	15
Young alluvium(?):		
Gravel, small, and sand; water	23	38
Clay, blue, and sand	2	40
Old alluvium:		
Gravel, small, and sand; water-bearing	8	48
Gravel, large, and sand; water-bearing	12	60
9/22-25J1. W. H. Johnson. Altitude about 655 ft. Drilled by Storey Drilling Co., 1962. Casing: 12-inch to 82 ft.		
Touchet Beds of Flint (1938):		
Soil	3	3
Hardpan	6	9
Clay, sandy	67	76
Old alluvium:		
Sand, and gravel; water	6	82
9/22-30B1. Niles Jim. Altitude about 690 ft. Drilled by Henry Bach. Cased to 95 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	30	30
Sand, fine, and silt	42	72
Clay, blue, and shale	13	85
Hardpan	5	90
Old alluvium:		
Sand, and gravel, water	5	95
9/22-31G1. Del Monte Corp. Altitude 732 ft. Drilled by V. L. Pritchard, 1969. Casing: 6-inch to 119 ft. Well filled in to 134 ft.		
Touchet Beds of Flint (1938):		
Soil, sandy	20	20
Clay, sandy, hard	15	35
Soil, sandy	20	55
Clay	5	60
Clay, sandy	15	75

(continued)

Material	Thickness (ft)	Depth (ft)
9/22-31G1--Continued		
Touchet Beds of Flint (1938)--continued		
Hardpan	8	83
Clay, sandy, blue	12	95
Clay, blue	10	105
Hardpan	4	109
Clay, sandy, blue	11	120
Ellensburg Formation:		
Sand, and gravel, in clay with caliche	10	130
Sand, and gravel; water	6	136
9/22-31J1. Del Monte Corp. Altitude 742 ft. Drilled by V. L. Pritchard, 1968. Casing: 6-inch to 140 ft. Well filled in to 140 ft.		
Touchet Beds of Flint (1938):		
Topsoil	5	5
Soil, fine, gray	25	30
Clay, sandy, yellow	30	60
Clay	10	70
Clay, sandy	30	100
Clay, brown	35	135
Ellensburg Formation:		
Gravel	8	143
9/22-31Q1. Del Monte Corp. Altitude about 742 ft. Drilled by V. L. Pritchard, 1967. Casing: 6-inch to 139 ft. Well filled in to 142 ft.		
Touchet Beds of Flint (1938):		
Soil	10	10
Silt, sandy	45	55
Clay	7	62
Clay, sandy	18	80
Sand, blue, and mud	38	118
Ellensburg Formation:		
Sand, and gravel	24	142
Yakima Basalt, Saddle Mountains Member:		
Rock, solid	1	143
9/22-32N1. Del Monte Corp. Altitude about 743 ft. Drilled by V. L. Pritchard, 1968. Completed depth 140 ft. Casing: 6-inch to 140 ft.		
Touchet Beds of Flint (1938):		
Soil	4	4
Silt, sandy	26	30
Clay, sandy	20	50
"Hardpan"	20	70
Clay, sandy	14	84
Ellensburg Formation:		
Gravel, hard-packed (cemented?)	16	100
Clay, sandy, blue	20	120
"Hardpan"	5	125
Sand, blue, gray	5	130
Clay, yellow	8	138
Gravel, and sand	4	142
Yakima Basalt, Saddle Mountains Member:		
Basalt below 142 ft	--	--

Material	Thick-ness (ft)	Depth (ft)
9/23-31E1. J. A. Haas, Inc. Altitude about 708 ft. Drilled by Storey Drilling Co., 1964. Casing: 12-inch to 142 ft, 10-inch 142 to 175 ft; perforated 140-174 ft.		
Touchet Beds of Flint (1938):		
Soil	55	55
Sand	50	105
Sand, fine, water, "heaving"	15	120
Clay, blue	3	123
Sand; water, "heaving"	10	133
Clay, blue	3	136
Old alluvium:		
Sand, coarse, gravel; water	8	144
Sand, coarse	31	175
10/21-22E1. City of Granger. Altitude about 750 ft. Drilled by Gib King, 1968. Casing: 12-inch to 249 ft. Flowed 1,000 gal/min.		
Touchet Beds of Flint (1938):		
Soil and silt	30	30
Silt	30	60
Sand, water	10	70
Ellensburg Formation:		
Sand, and gravel; water	65	135
Clay	30	165
Sand, and gravel; water	17	182
Clay, blue	13	195
Sandstone; water	3	198
Clay, blue	41	239
Sandstone; water	10	249
Clay, blue	1	250
Sandstone, soft; water	2	252
10/21-28L1. Silas Peters. Altitude 702 ft. Drilled by Henry Bach. Cased to 42 ft.		
Young alluvium:		
Soil	2	2
Sand, and gravel, water	26	28
Old alluvium(?):		
"Hardpan"	8	36
Gravel, cemented	5	41
Sand, and gravel	1	42
10/21-32K1. Tom Larock. Altitude about 700 ft. Drilled by Henry Bach. Cased to 83 ft.		
Young alluvium:		
Sand	4	4
Gravel, boulders; sand; silt; water	16	20
Old alluvium or Ellensburg Formation:		
Gravel, cemented	28	48
Shale, clayey, blue	25	73
Sand, blue; water	2	75
Shale, clayey, blue	5	80
"Water strata"	3	83
10/21-33B1. Lena Phillips. Altitude 701 ft. Drilled by Henry Bach, 1963. Casing: 6-inch to 41 ft.		
Young alluvium:		
Gravel	6	6
Sand, gravel, boulders; water	22	28
Old alluvium:		
"Hardpan" and boulders	8	36
Sand, fine to medium, then gravel	5	41
10/21-33L1. Indian Shaker Church. Altitude about 702 ft. Drilled by Soil Sampling Service, Inc., 1972. Casing: 6-inch to 287 ft.		
Young and old alluvium:		
Sand, brown, and gravel	23	23
Sand, and gravel	30	53
Ellensburg(?) Formation:		
Clay, blue: dry	45	98
Clay, blue; damp	22	120
Clay, blue, with some thin layers of very fine sand	78	198
Clay, blue, with weathered sand and silt	2	200
Ellensburg Formation:		
Clay, hard, with some gravel	90	290
Yakima Basalt, Saddle Mountains Member:		
Basalt, vesicular, blue-green	2	292
10/21-34L1. Lucille Taiwash. Altitude about 691 ft. Drilled by J. C. Riebe, 1963. Casing: 6-inch to 44 ft.		
Young alluvium:		
Soil, sandy	10	10
Sand, and gravel, boulders, silt; water	26	36
Old alluvium:		
Gravel, cemented, boulders	6	42
Sand, and gravel; water	2	44

47°10'

PLATE 1