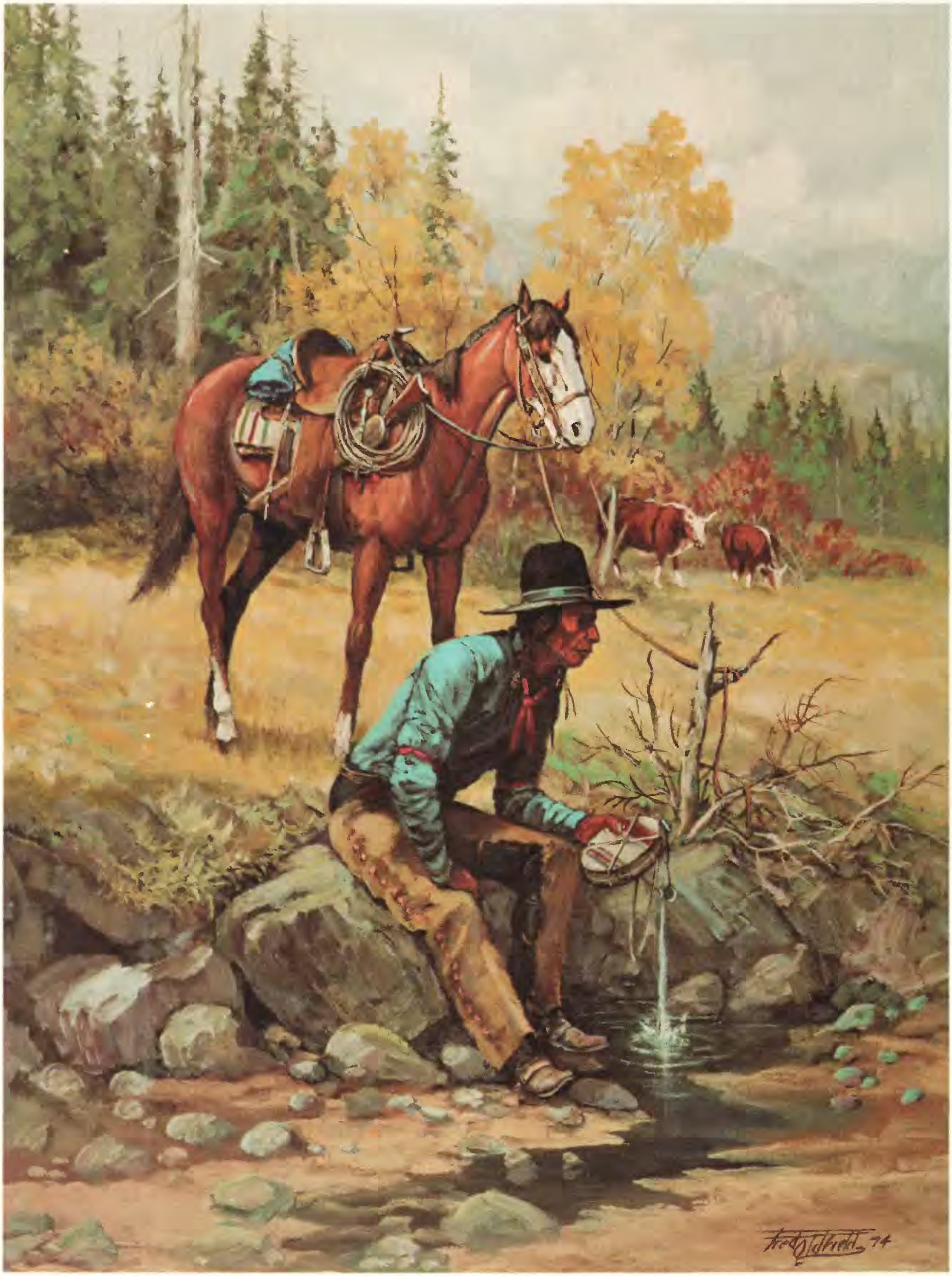

RECONNAISSANCE OF THE WATER RESOURCES OF THE UPPER KLICKITAT RIVER BASIN, YAKIMA INDIAN RESERVATION, WASHINGTON

U.S. GEOLOGICAL SURVEY

Open-File Report 75-518

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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By Denzel R. Cline

Open-File Report 75-518

Prepared in cooperation with the
Yakima Tribal Council

Tacoma, Washington
1976

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, 1305 Tacoma Avenue South, Tacoma, Wash. 98402

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The following factors are provided for conversion of English values used in this report to metric values:

Multiply	By	To obtain
Inches	25.4	millimetres (mm)
	2.54	centimetres (cm)
	0.0254	metres (m)
Feet (ft)	0.3048	metres (m)
Miles (mi)	1.609	kilometres (km)
Square miles (mi^2)	2.590	square kilometres (km^2)
Acres	4047.	square metres (m^2)
Acre-feet (acre-ft)	1233.	cubic metres (m^3)
Cubic feet per second (ft^3/s)	28.32	litres per second (l/s)
	0.02832	cubic metres per second (m^3/s)
Gallons per minute (gal/min)	0.06309	litres per second (l/s)
Gallons (gal)	3.785	litres (l)

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ABSTRACT

The upper Klickitat River basin, covering 749 square miles in the Yakima Indian Reservation, lies immediately east of the crest of the southern Cascade Range and is dominated on its western margin by 12,276-foot Mount Adams, a glacier-mantled volcano. The Klickitat River, which flows south to the Columbia River, discharges about 1,200 cubic feet per second (870,000 acre-feet per year) of water at the point where it leaves the reservation; probably about 60 percent of this quantity is ground-water discharge. Flow of the Klickitat River leaving the reservation is estimated to comprise about 75 percent of the average annual flow and over 90 percent of the average 7-day low flow of the river at a gage near its mouth (drainage area of 1,297 square miles). The annual 7-day low flows of the river at the reservation boundary, upstream from Summit Creek, at 2- and 10-year recurrence intervals, are about 600 and 500 cubic feet per second, respectively. Several streams provide irrigation water to about 5,600 acres in the Camas Prairie-Glenwood area. About 12,000 acre-feet of the water was delivered by Hellroaring Ditch in 1974. The area around Mount Adams yields considerably more water per square mile than the remainder of the basin because probably about 140 inches of precipitation falls on the upper slopes of this mountain, mostly as snow, whereas less than 30 inches falls in the southern part of the basin along the Klickitat River. Ground water in large quantities (more than 400 cubic feet per second in the fall of 1974 and mostly from the Mount Adams area) discharges into the Klickitat River canyon in a 13-mile reach in the southern part of the reservation; about one-half of the water is discharged from large springs. The largest spring discharges about 40 cubic feet per second.

Lava flows underlie the entire basin, and unconsolidated sedimentary deposits overlie the lavas in the Camas Prairie-Glenwood area and in small areas elsewhere. A spring supplies water to much of the Camas Prairie-Glenwood area through a public system, so not many wells are used now. About 36 million gallons (110 acre-feet) of ground water was used in 1974. The unconsolidated deposits yield from 1 to 500 gallons per minute of water to wells, and the basalt can yield more than 100 gallons per minute and possibly several thousand gallons per minute to deep wells. Ground-water recharge and discharge on the reservation is estimated to average 550,000 acre-feet per year.

INTRODUCTION

Location and Extent of the Study Area

The upper Klickitat River basin (fig.1), defined as that part of the Klickitat River basin within the Yakima Indian Reservation, is the westernmost of three major river basins in the reservation. The basin has a drainage area of 749 square miles in Yakima and Klickitat Counties of south-central Washington and comprises a mostly mountainous upland immediately east of the crest of the southern Cascade Range. The basin ranges in elevation from 12,276 feet on Mount Adams, a glacier-mantled volcano on the western margin of the study area, to about 1,000 feet, in the 700- to 1,000-foot-deep canyon of the Klickitat River where it leaves the southern boundary of the reservation. The northern headwaters of the Klickitat River are in the 8,000-foot-high Goat Rocks, a rugged mountain mass also supporting snowfields. About 37 miles downstream from the reservation, the Klickitat River discharges into the Columbia River. The study area covers about one-half of the entire Klickitat River basin.

The study area comprises mostly mountainous terrain and plateaus cut by valleys and, in the southern part, by deep canyons. The eastern part of the basin is slightly more than 5,000 feet in elevation in a few places; most of the basin lies below the 5,000-foot elevation. The Camas Prairie-Glenwood area, the only part of the study area with significant residential and agricultural development by homes and farms, is a broad, relatively level valley floor between 1,800 and 2,000 feet in elevation, lying above and southwest of the Klickitat River canyon (fig.2).

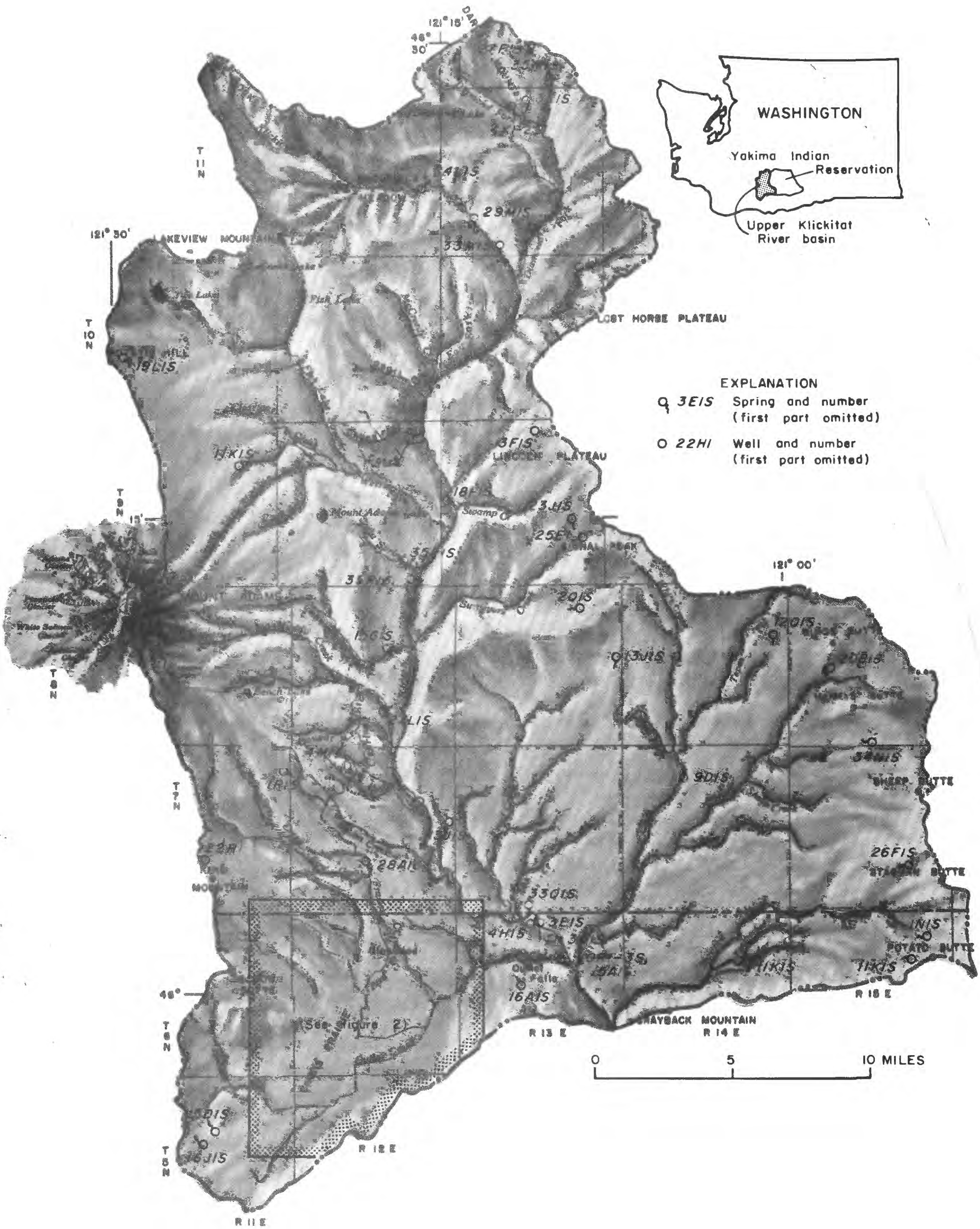


FIGURE 1.--Location of springs and wells in upper Klickitat River basin, Yakima Indian Reservation, Washington, and index map. See figure 2 for wells and springs in Camas Prairie-Glenwood area (outlined block).

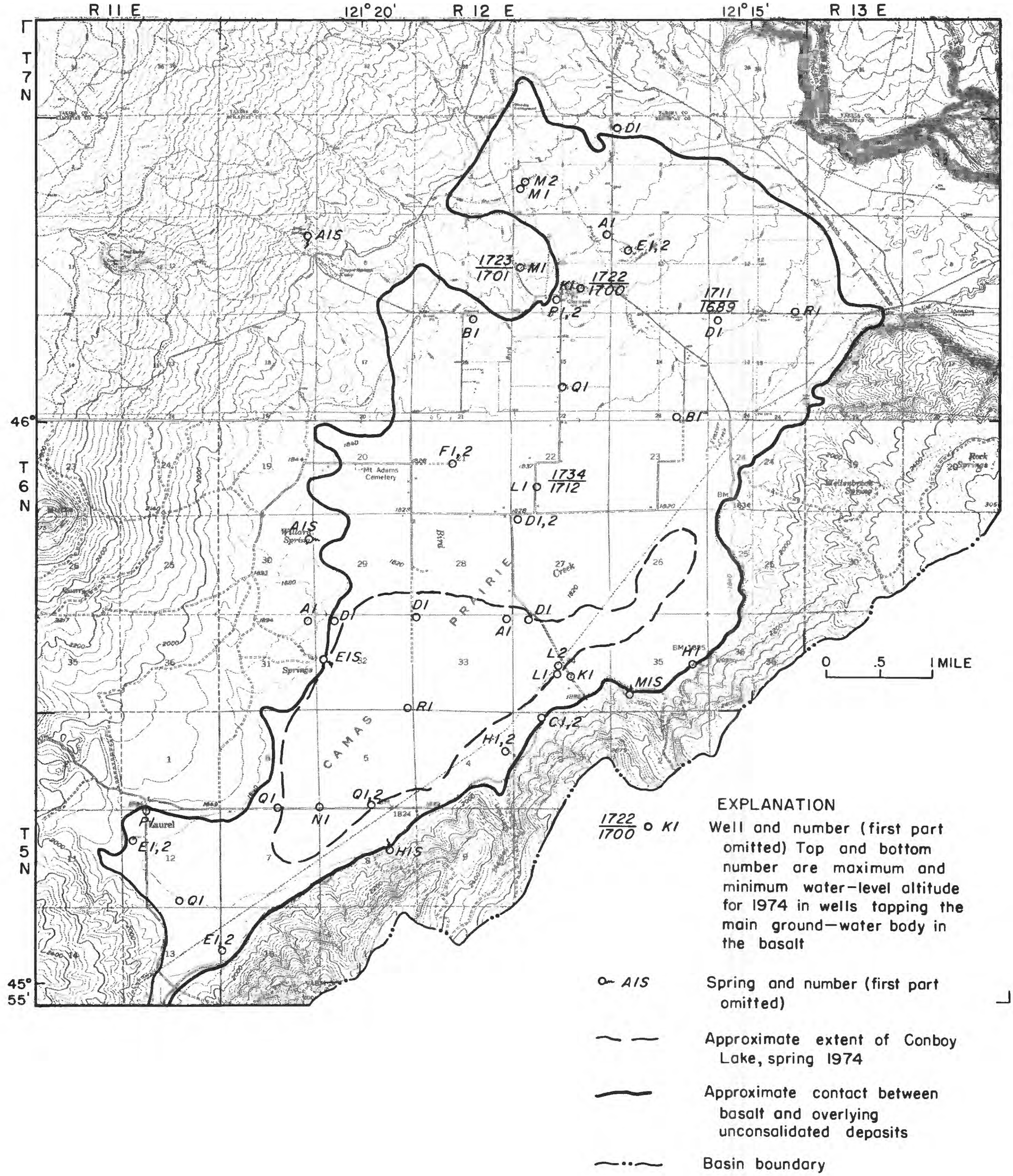


FIGURE 2.--Location of wells, springs, and related hydrologic data on unconsolidated deposits and basalt in the Camas Prairie-Glenwood area.

Purpose and Scope of Study

A 1-year reconnaissance investigation of the water resources of the upper Klickitat River basin of the Yakima Indian Reservation (fig. 1) was started in January 1974 by the U.S. Geological Survey in cooperation with the Yakima Tribal Council. The investigation was directed toward determining the quantity, distribution, availability, quality, and use of ground and surface waters in this part of the reservation, particularly in the Camas Prairie-Glenwood area (fig. 2). The Camas Prairie-Glenwood area was added to the reservation in 1972, and is the only area of significant habitation and water use in the upper Klickitat River basin. Nearly all of the wells in the upper Klickitat River basin are in this area. However, many of the wells were not in use as of 1974 owing to the installation in 1970 of a public water-supply system that obtains its water from McCumber Spring about 3½ miles north of Glenwood (at number 7/12-28A1s in fig. 1), and because Conboy Lake National Wildlife Refuge has been extended to an area that includes a number of formerly occupied homes and farms. The Camas Prairie-Glenwood area is the only irrigated part of the basin, and most of the remaining area is forested. Water for irrigation is diverted from streams north of Glenwood and brought to the area in Hellroaring Ditch (fig. 1). Although the population in the Camas Prairie-Glenwood area is small, about 550 people in 1972, it is increasing. The Bureau of Indian Affairs and the Yakima Indian Tribe are expanding their logging operations in the upper Klickitat River basin and taking over the maintenance of recreational sites.

Data collection for the study consisted of inventorying wells and springs, measuring water levels and streamflows, sampling and analyzing both ground and surface water for chemical and sanitary quality, and collecting information on water use in the area. Much of this basic data is tabulated in tables 5-11 at the end of the report.

Previous Studies

No previous water-resources investigations have been made in the upper Klickitat River basin, although streamflow and water-temperature data have been gathered by the U.S. Geological Survey for many years. Stream and air temperatures in the State are summarized in a map by Collings and Higgins (1973). A concurrent study is being made by Fretwell (written commun., 1975) of the quality of water on the reservation--in greater detail than that given in this report. Several reports present some information on thermal and mineral springs in the study area (Landes, 1905; Valentine, 1960; and Livingston, 1974). The generalized geology of the area is included on the State map by Huntting and others (1961), and in reports by Newcomb (1970) and Hammond (1973). Detailed bedrock geology of the southern and eastern part of upper Klickitat River basin is described by Sheppard (1960, 1964, 1967).

Acknowledgments

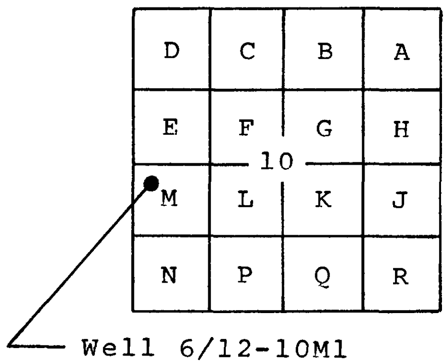
The collection of data and information for this report could not have been accomplished without the assistance of many individuals and agencies, in particular the Bureau of Indian Affairs, the Klickitat County Public Utility District 1, and Delmer Staack, a local resident who periodically read the staff gage on Hellroaring Ditch.

Data-Site Numbering Systems

Wells and springs inventoried during this study have been assigned numbers identifying them by location, within a section, township, and range.

For example, in the well symbol 6/12-10M1, the part preceding the hyphen indicates successively the township and range (T.6 N., R.12 E.) north and east of the Willamette base line and meridian. Because the study area lies entirely north and east of the base line and meridian, the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec.10), and the letter "M" 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 subdivision. For a spring the letter (s) is added at the end of the number.

T.6 N., R.12 E., sec. 10



Measuring and sampling stations on streams are numbered in downstream order, and in this report have an 8-digit number, such as 14106500. Owing to space limitations on some maps in this report, the area-designation prefix "14" has been omitted. In this study some stream-measuring sites were not given official station numbers, and are designated by letters, also in downstream order.

GEOHYDROLOGIC SETTING

The occurrence and movement of surface and ground water through the study area are controlled mainly by climate, slope and shape of the land surface, and type of rock materials that occur beneath the land.

Precipitation as rain and snow is the source of virtually all water in the basin. Generally, a part of the precipitation that reaches the land surface runs off overland to streams, a part is seasonally stored in the snowpack and glaciers, a part is evaporated back to the atmosphere, a part soaks into the soil and returns to the atmosphere through plant roots and stems and "transpiration" from leaves, and a part becomes ground-water recharge by percolating downward to the ground-water body. The ground water slowly moves through the rocks and drains through springs, seeps into lakes and streams, or is pumped from wells.

Climate and Precipitation

Hot, dry summers and cold, wet winters characterize the climate in the study area. The average annual precipitation ranges from about 140 inches on Mount Adams in the western part of the area to less than 30 inches at the lower elevations in the southern part of the basin (U.S. Weather Bureau, 1965). During 1951-71 the recorded precipitation at Glenwood averaged 34 inches per year (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1951-71). Most of the precipitation falls during the period November-April, with much occurring as snow, especially above the 2,500-foot elevation. July and August are the driest months, and often have little or no rain, particularly at the lower elevations. The snow at higher elevations seasonally accumulates in snowfields, and on the glaciers of Mount Adams; the late-spring and summer snowmelt then contributes to the flow of streams and to recharge of the ground-water reservoirs at lower elevations in the basin.

Geology of the Area

In the upper Klickitat River basin, geologic conditions are such that ground-water occurrence and movement play an important part in the streamflow regimen, particularly during the late summer periods of low streamflows. For this reason, the following discussion of geologic conditions provides the framework for an understanding of the surface water-ground water relationship.

The upper Klickitat River basin is a part of the southern Cascade Range that has a history of geologic events that included (1) widespread extrusion of many lava flows totaling several thousand feet in thickness, (2) north-south uplift of the range with resulting upwarping and erosion of the lava flows, (3) localized extrusion of lavas, pumice, and ash from Mount Adams and several smaller volcanic and cinder cones, and (4) glaciation, which mantled the higher peaks with ice, resulting in erosion of these peaks and adjacent valleys, and deposition of the materials in places downvalley. Erosion by glaciers and streams has continued to the present time. The principal area of deposition of unconsolidated materials is the Camas Prairie-Glenwood area (fig.2); other areas are in some reaches of the major stream valleys.

The study area, including the Goat Rocks to the north, is underlain by various volcanic rocks (compositely referred to as "basalt" in this report) along with associated minor sedimentary rocks included with the basalt.

Individual basalt flows vary in thickness and areal extent. Some flows, such as those underlying the Camas Prairie-Glenwood area, were deposited in valleys eroded into earlier, more extensive flows. Such older flows form the ridge along the southern and southwestern side of Camas Prairie. Individual older flows generally are much thicker than the younger flows; older flows in the southern part of the study area range in thickness from 60 to 150 feet, whereas younger flows are from 3 to 40 feet thick, with most flows in the Glenwood area being from 10 to 15 feet thick (Sheppard, 1964, 1967).

Locally, sediments were deposited on top of one basalt flow before another flow buried them. Wells 6/12-22L1 and 6/12-27D1, which are 0.4 mile apart (fig.2), reportedly penetrated basalt and bottomed in sand and gravel at depths of 240 feet and 245 feet, respectively, below land surface (table 7). Although sediments in the basalt are reported to occur at only one locality, they also may be present in other places in the study area.

The basalt surface beneath Camas Prairie forms a closed bedrock basin that is filled with unconsolidated deposits. These deposits are at least 160 feet thick, as indicated by the driller's record of well 5/12-18E1. There, the basalt surface is below the 1,700-foot elevation, whereas the lowest point in the basalt surface surrounding the unconsolidated deposits (at Outlet Creek in sec.18, T.6 N., R.13 E.) is at the 1,800-foot elevation, or at least 100 feet higher.

The basin could have been formed by (1) faulting--breaking and shifting of the rocks, (2) bending of the rock layers, (3) damming of a valley eroded in the older lava flows by the deposition of younger lava flows, or (4) combinations of the above. On their maps, Newcomb (1970) and Hammond (1973) show a fault that extends along the base of the ridge running along the southeast side of Camas Prairie. This fault, which has the downthrown side to the northwest (Camas Prairie), is only a short distance southeast of well 5/12-18E1. Sheppard (1964) shows a fold instead of a fault in the older basalt flows. All three authors show two faults at right angles to this fault or fold which extend to the southeast from Camas Prairie. One of these two faults ends not far east of well 5/12-18E1 and the other just east of well 6/12-34K1.

Unconsolidated deposits, which locally overlie the basalt in places, mainly in valleys, and, in particular, the Camas Prairie-Glenwood area, consist of clay, silt, sand, gravel, cobbles, and boulders; some of these materials are sorted, and some are mixed. Well-sorted materials, particularly the finer grained deposits, commonly occur in layers.

The thickest and most extensive unconsolidated deposits are in the Camas Prairie-Glenwood area (fig.2). The deposits beneath the southern part of Camas Prairie are fine grained for at least the upper 60 to 80 feet in most places, and consist of clay, silt, and some sand. (See logs of test holes in table 7.) However, in well 5/12-18E1, which is only 0.7 mile from a test hole penetrating 59 feet of mixed clay, silt, and sand (5/11-12Q1, fig.2), sand and gravel is present from the surface to at least 160 feet below the surface. This is the greatest known thickness of the unconsolidated deposits in the study area. In Glenwood and a few miles to the north the deposits consist of much sand, gravel, and boulders, but thicknesses are generally 50 feet or less (table 7). The distribution, character, and thickness of the unconsolidated deposits beneath Camas Prairie are only partly known. Information is needed particularly on the extent of the sand and gravel deposit penetrated by well 5/12-18E1.

Unconsolidated deposits in the study area outside of the Camas Prairie-Glenwood area are relatively minor in extent. Some deposits left by glaciers occur on the intervalley uplands in the vicinity of Mount Adams. Unconsolidated deposits also occur in some parts of the major valleys, such as McCormick Meadow along the upper end of the Klickitat River (T.11 N., R.12 E., fig.1), and downvalley from the glaciers on Mount Adams, such as along Big Muddy Creek.

GROUND WATER

Occurrence and Movement

Ground water probably occurs nearly everywhere in the upper Klickitat River basin and moves from points of recharge to points of discharge at springs, and into streams and lakes. However, depths to water, and the yield of water-bearing zones vary considerably over the area. Ground water that can be tapped by wells generally occurs in (1) fracture zones and openings in the basalt, (2) sand and gravel deposits interbedded between basalt flows, and (3) unconsolidated sand and gravel deposits in the valleys.

In the valleys, ground water in the unconsolidated deposits generally is near land surface, and water levels stand at or slightly higher than stream level. In the lowest valleys, wells that penetrate some distance below the stream channels may tap water-yielding zones in the basalt in which the static water level stands above river level. In some places, mainly in the higher valleys, streams lose water to underlying deposits, where the water table is below the streambed.

Water-yielding zones in the basalt commonly occur at the tops and bottoms of individual lava flows and in sedimentary deposits between flows, so there may be several water-yielding zones in a sequence of lava flows. The younger flows commonly being more highly fractured and having more water-yielding zones, generally yield more water where saturated than do the older flows. Within the basalt underlying the uplands one or more ground-water bodies may occur, with the main (or regional) ground-water body occurring at considerable depth below land surface, particularly beneath the high land within a few miles of the Klickitat River. Small water-yielding zones that occur in places perched above the main ground-water body may drain dry during the summer and fall. In general, if ground water is present in several zones in the upper several hundred feet of basalt in any area that is considerably higher than the Klickitat River, the water levels of the different zones will be progressively deeper.

Beneath the Camas Prairie-Glenwood area two major ground-water bodies are known, one in the shallow unconsolidated deposits and one in the underlying basalt. The water levels in wells tapping the unconsolidated deposits are generally less than

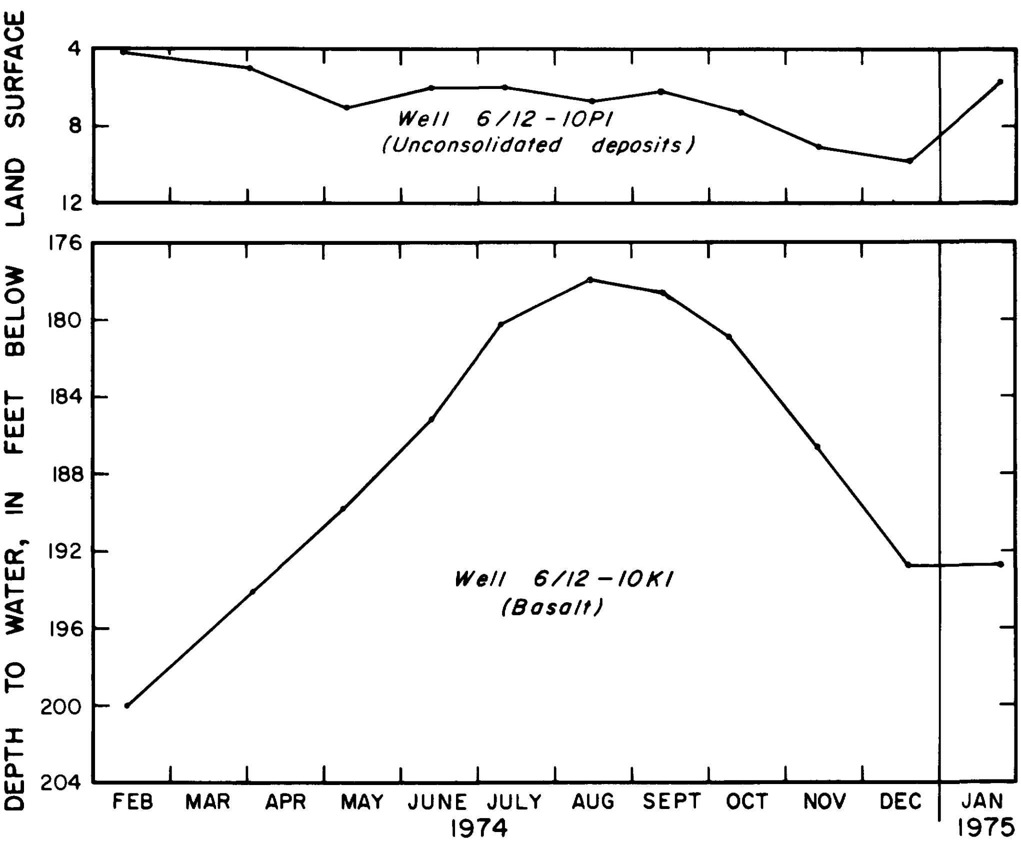


FIGURE 3.--Hydrographs of water levels in well 6/12-10K1 tapping basalt and well 6/12-10P1 tapping unconsolidated deposits, February 1974-January 1975, Glenwood, Wash.

20 feet below land surface (tables 5 and 6) and, according to 1974 data, water levels fluctuate several feet but probably no more than 10 feet (fig.3). The main ground-water body in the basalt occurs at depth, the water coming from confined zones that are generally 200 feet or more below land surface. Water levels range from about 100 feet below land surface at well 6/12-22L1 to over 200 feet at well 6/12-10M1 (tables 5 and 6). The altitude of the water table in the basalt aquifer, indicated at various wells (fig.2), shows the water table sloping generally from the southwest toward Glenwood and thence to the east. Water-level fluctuations in the basalt are much larger than in the unconsolidated deposits, probably nearly 25 feet in 1974 (figs.2 and 3). The highest water levels in the basalt usually occur in late summer. Wells 6/12-2D1 and 6/12-27D1 obtain water from saturated zones in the basalt that are perched above the main ground-water body, and water-level fluctuations in these zones are probably much less than in the main basalt ground-water body.

Ground water in the study area moves toward the rivers and streams, generally horizontally through the water-yielding zones, and downward where cracks and fractures occur in the rocks above the level of streams. In the vicinity of Camas Prairie, ground water moves obliquely toward Outlet Creek in a downstream direction. Some ground water moves downward to deeper zones in the basalt where the water moves toward the Klickitat River. A large amount of ground water is moving from the southern slopes of Mount Adams and King Mountain beneath the Glenwood area to the mouth of Outlet Creek and the Klickitat River. Some ground water in the basalt southwest and west of Camas Prairie may possibly move westward into the White Salmon River drainage basin, which is much lower than Camas Prairie. Little or no ground water is believed to move out of the project area along the southern boundary.

Recharge

Probably all of the recharge--or water added to the water-yielding zones--in the Klickitat River basin comes from precipitation, which as rainwater and snowmelt soaks into the ground and percolates downward to the water table to become ground water. Most of the recharge, therefore, occurs during the winter and spring. However, in the Camas Prairie recharge also occurs during the summer when a part of the irrigation water brought in by Hellroaring Ditch percolates to the water table.

Recharge in the basin is estimated to average about 550,000 acre-feet per year, based on estimates of ground-water discharge. Discharge equals recharge if the net change in ground-water storage is zero. Under natural conditions there generally is little change in net storage over long periods of time. Most of the recharge occurs on the slopes of Mount Adams and in the high country on the west side of the basin because of the heavy rain and snow in that area. At lower elevations, particularly on the eastern side of the basin, recharge is the smallest.

Discharge

Ground water is discharged naturally by seepage into streams and rivers, by outflow from springs, and in the summer a small amount by evapotranspiration from those areas where the water table is within a few feet of the land surface. A small quantity of ground water is also discharged artificially by pumping from wells. Streamflow in late summer and fall is generally composed almost entirely of ground-water discharge. The average streamflow in October (fig. 5 on p. 20) indicates the amount of ground-water discharge occurring when there is little loss by evapotranspiration or contribution by glacier melt water, and is considered to be equal to the average yearly discharge of ground water. Thus, the discharge of ground water in the basin above stations 14107000 and 14108000 (fig. 4) probably averages about 330 ft^3/s (220,000 acre-feet per year), and in the basin above station 14110000 discharge probably averages about 463 ft^3/s (340,000 acre-feet per year). The discharge of ground water in the whole upper Klickitat River basin is estimated to average approximately 760 ft^3/s (550,000 acre-feet per year), or about 60 percent of the average annual streamflow leaving the reservation. This quantity is based on an estimate of the average October streamflow leaving the reservation. The average October streamflows at stations 14107000 plus 14108000, and at station 14110000 (fig. 5) are 20 to 30 percent larger than the 2-year annual 7-day low flow (table 4). The 2-year annual 7-day low flow determined at the reservation boundary (discharge at site n plus that at sta. 14111100; fig. 4 on p. 18) was increased by about 25 percent to obtain the estimate for the October average flow, or average yearly ground-water discharge at the reservation boundary. Probably little or no ground water leaves the reservation by underflow, as indicated by several measurements of the flow of the Klickitat River.

Part of the streamflow originates at springs, of which there are many in the basin. Some of the springs--a small percentage of the total--are shown in figures 1 and 2 and listed in table 8. Some springs discharge large quantities of ground water; for example, Cascade Spring (6/13-10R1s) discharges about 18,000 gal/min (40 ft^3/s) of ground water. Measured or estimated discharges of springs in the project area ranged from 2 gal/min to 18,000 gal/min (table 8).

A large quantity of ground water discharges into the Klickitat River in a 13-mile reach in the southern part of the reservation. Large springs accounted for about one-half of the more than 400 ft^3/s increase in the flow of the river between station 14110000 and site n at the reservation boundary in the fall of 1974 (table 9). This increase in flow is larger than average because precipitation during the previous winter and spring was greater than normal. The discharge of ground water from a number of springs, such as springs 6/13-10R2s and 15A1s (table 8), increased the flow of Outlet Creek below Outlet Falls by more than 100 ft^3/s in 1974 (table 9). Also along this reach of the Klickitat River are Cascade Spring (6/13-10R1s), spring 6/13-3Q1s, Wonder Spring (6/13-3E1s), and nearby springs at the Washington State Fish Hatchery, including spring 7/13-33Q1s. Ground-water discharge to this reach of the river from the Camas Prairie-Glenwood area probably averages at least 150 ft^3/s, and may be much more. Faults in the vicinity of the southern boundary of the project area, and the presence of older basalts to the south of them, shown by Newcomb (1970), may be factors that control the discharge of large quantities of ground water in this area.

The quantity of ground water discharged artificially (as pumpage from wells) in the project area is small, estimated to be about 3 million gallons, or about 9 acre-feet in 1974. Except for well 7/11-22H1, the Camas Prairie-Glenwood area is the only place in the project area where wells are withdrawing water.

Well Yields

Basalt

The basalt underlying the Camas Prairie-Glenwood area can yield moderate to large quantities of water to wells. The largest yield known is 180 gal/min from well 6/12-27D1 (table 5); probably several hundred to possibly several thousand gallons per minute can be developed from wells drilled deeply into the basalt. Wells tapping only the uppermost part of the main ground-water body should produce 10 to 20 gal/min, which is sufficient for domestic use. Increased thickness of saturated material tapped by a well, and, in the case of basalt, an increase in the number of water-yielding zones penetrated, generally increases the quantity of water that can be obtained from a well. The large number of springs and the quantities of water they discharge from the basalt in the study area indicate that very large quantities of ground water are available in the basalt.

The deepest well known in the study area is 300 feet deep (well 6/12-10M1, table 5); however, many water-yielding zones probably exist below this depth, although water levels in these deeper zones may be lower than those in existing wells, possibly as much as several hundred feet deeper. The deep basalt wells in the Glenwood area are considered to be tapping the main ground-water body in the basalt. The altitude of water levels in wells tapping this body beneath the Glenwood area is about 1,700 feet above sea level (fig.2).

Some zones in the basalt above the main ground-water body yield small quantities of water. These zones may contain water the year around or only part of the year, or they may go dry during some years. Yields of wells tapping these zones are generally less than 5 gal/min, but may be as much as 10 gal/min.

The water-yielding characteristics of the basalt in the remainder of the study area probably are similar to those in the Camas Prairie-Glenwood area. However, wells drilled on the uplands may have to be deeper than wells in the Camas Prairie-Glenwood area to reach water.

Unconsolidated Deposits

The unconsolidated deposits in the Camas Prairie-Glenwood area vary widely in their capacity to yield water to wells--from no yield (well 6/12-3M2, table 5) to 500 gal/min (well 5/12-18E1, table 5). Although the reported drawdown of 10 feet in the latter well when pumping 500 gal/min indicates that possibly as much as several thousand gallons per minute can be withdrawn from the sand and gravel deposits beneath southern Camas Prairie, probably only several hundred gallons per minute can be obtained for longer periods of pumping, such as all summer. The unconsolidated deposits, particularly sand and gravel underlying Camas Prairie, are limited in extent, thus for long periods of pumping the yield could decrease greatly because the deposits become dewatered. The silt and clay deposits yield little or no water, so productive wells would have to be drilled through these deposits into sand and gravel, if present, or into basalt aquifers.

Unconsolidated deposits in the study area outside of the Camas Prairie-Glenwood area also undoubtedly vary widely in their capacity to yield water to wells. Glacier deposits on the intervalley uplands near Mount Adams are mostly unsaturated, but some may yield small amounts of ground water locally, probably less than 10 gal/min, if tapped by wells. Unconsolidated deposits, which occur in some parts of the major valleys, probably are subject in many places to flooding, especially those along Big Muddy Creek, so developing ground-water supplies from them may be difficult in many areas. Yields that can be obtained from unconsolidated deposits in the valleys of the study area are estimated to range from less than 1 gal/min to possibly 100 gal/min or more, if well-sorted sand and gravel beds are present. Test drilling in these valleys would provide information on the type and thickness of the subsurface materials and the yields that can be obtained from them.

Ground-Water Use

The total amount of ground water used in the upper Klickitat River basin in 1974 was about 36 million gallons. The major use of the ground water is for domestic and stock supplies, with most of the water coming from McCumber Spring (7/12-28A1s, fig.1), the source for a community system that serves much of the Camas Prairie-Glenwood area. Water from the system is also used for a school and several businesses in Glenwood. Quantities of water used were about 19 million gallons in 1971, about 26 million gallons in 1972, about 30 million gallons in 1973, and about 31 million gallons in 1974. In 1973, the maximum monthly use was nearly 4 million gallons and the minimum was a little more than 1 million gallons. Probably less than two dozen wells in this area were still being used in 1974, pumpage from these wells is estimated to have been about 3 million gallons during the year. One well outside the Camas Prairie-Glenwood area (7/11-22H1) obtains water by infiltration from Bird Creek, and supplies several stock tanks. A logging camp of about 70 people near Draper springs (6/12-7A1s) is supplied by the springs. The camp used an estimated 2 million gallons of water in 1974.

SURFACE WATER

General Streamflow Characteristics

The upper Klickitat River basin is drained by the Klickitat River and its many tributaries. Data-collection sites on these streams are shown in figure 4. The streamflow leaving the reservation comprises most of the water discharged to the Columbia River from the entire Klickitat River basin, particularly during the periods of low streamflows in late summer and early fall. The average yearly discharge of surface water from the 749-mi^2 study area is estimated to be about 75 percent of the discharge of the Klickitat River past the gage near Pitt (14113000, drainage area 1,297 mi^2), 7 miles upstream from the Columbia River and 30 miles downstream from the reservation, and the average 7-day low flow leaving the study area comprises more than 90 percent of the low flow of the Klickitat River near its mouth.

The average flow of the Klickitat River leaving the study area at the southern boundary of the reservation is estimated to be 1,200 ft^3/s, or 870,000 acre-feet per year. Flows upstream are less because less area is drained; however, there is a considerable difference in the yield from different parts of the basin (table 1). The West Fork of the Klickitat River yields much more water per square mile than does the Klickitat River above West Fork. Big Muddy Creek has a high yield per square mile also, indicating that the west-central part of the basin (Mount Adams area) yields more water than the rest of the project area because of the higher precipitation in that part.

TABLE 1.--Average streamflow at selected sites in upper Klickitat River basin

Station number in figure 4	Station name	Streamflow (ft^3/s)	Streamflow (acre-ft/year)	Years of record	Period of record	Drainage area (mi^2)	Basin runoff [(ft^3/s)/mi^2]
14107000.	Klickitat River above West Fork	336	243,400	30	1944-74	151	2.23
14108000.	West Fork Klickitat River	309	223,900	5	1944-48, 1953-54	87.0	3.55
14110000.	Klickitat River near Glenwood	841	609,300	62	1909-71	360	2.34
Site n plus station 14111100	Klickitat River at reservation boundary	[a]1,200	[a]870,000	--	--	749	1.60

[a]Estimated.

Note: All values are less than 3 percent different from those from records for 5 concurrent years.

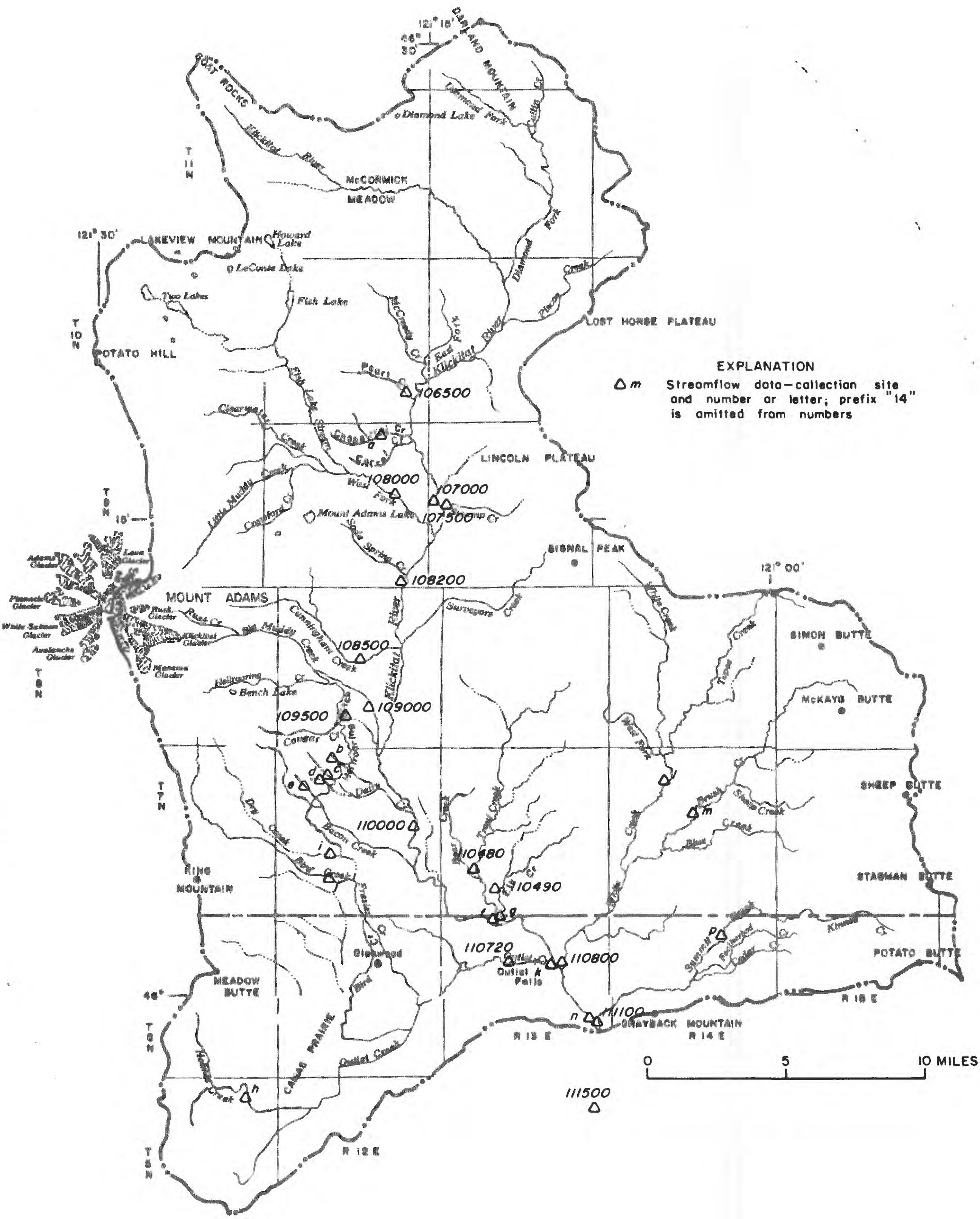


FIGURE 4.--Location of miscellaneous streamflow data-collection sites, upper Klickitat River basin. Adjacent table lists types of data available for each site.

Station number or letter	Stream discharge given in table 9	Chemical analysis given in table 11	7-day low flow recurrence intervals given in table 4
14106500			x
a	x		
14107000			x
14107500			x
14108000			x
14108200		x	
14108500			x
14109000		x	
14109500			x
b	x		
c	x		
d	x		
14110000	x		x
e	x		
14110480		x	
f	x		x
14110490	x	x	
g	x		
h	x		
i	x		
j	x		
14110720	x	x	
k	x		x
l	x		
m	x		
14110800	x	x	x
n	x		x
p	x		
14111100	x	x	x
14111500		x	

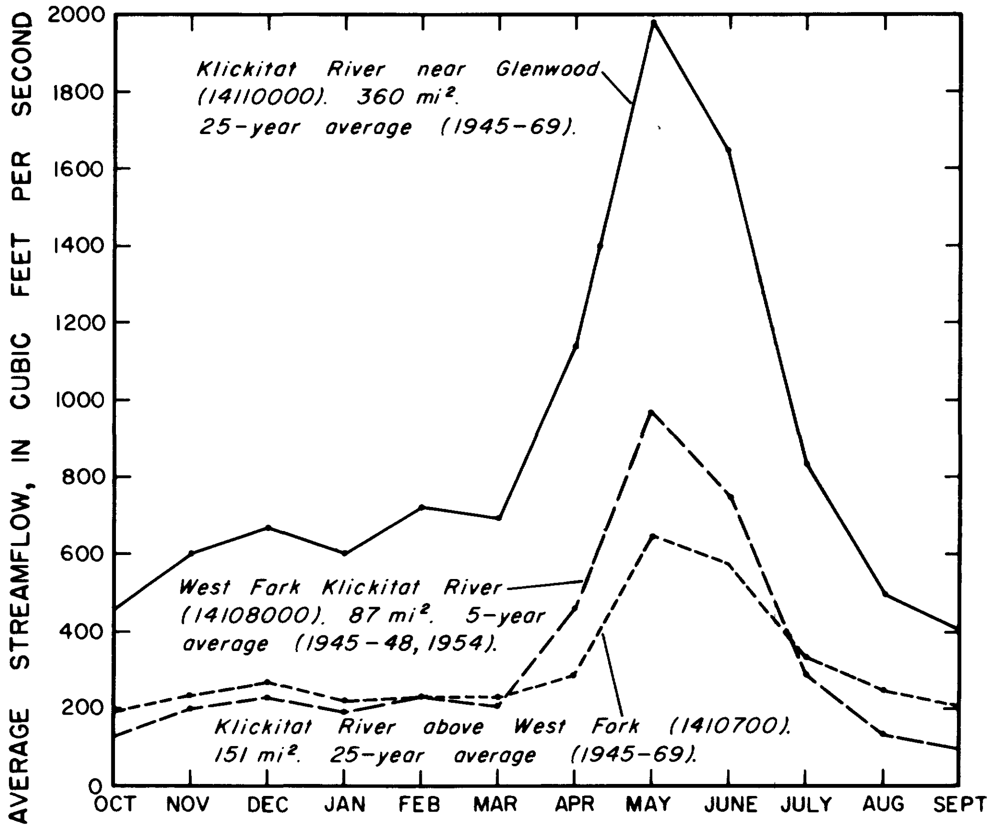


FIGURE 5.-Average monthly streamflow at three sites in the upper Klickitat River basin, Wash. All values are less than 18 percent different from those from records for 5 concurrent years.

Average monthly flows vary considerably during the year with the highest occurring in May and the lowest in September or October (fig.5). Figure 5 shows that more water runs off directly in the spring from the Klickitat River above West Fork than the West Fork Klickitat River, and, conversely, the base flows of late summer and fall of the West Fork Klickitat River are sustained much better than are those of the Klickitat River above West Fork. The relatively higher flows in late summer and fall of West Fork are due to more ground-water discharge and water released from storage in a glacier in the headwaters area of the Little Muddy Creek basin.

Floodflows

Annual peak flows (floodflows) of streams in the upper Klickitat River basin occur generally in late spring, usually in May, but they can occur anytime during the period of November through June. Annual peak flows of the Klickitat River near Pitt (sta. 14113000), 7 miles upstream from the Columbia River, and 30 miles downstream from the reservation), however, generally occur in winter, mostly in January or February. The spring thaw of the snowpack generally causes the annual flood peak at the higher altitudes, whereas heavy rains during a warm period, combined with melting snow, cause the major floods at lower altitudes, such as at Pitt.

Record peaks on the Klickitat River at three different locations (sta. 14107000, 14110000, and 14113000) have occurred in different years (table 2). A comparison of the peaks in table 2 show that a flood that is a record at one station often is not a record at another station. For example, a flood in January 1974 produced peaks well below the record peaks at stations 14107000 and 14110000, whereas at station 14113000 the flow of 47,400 ft^3/s greatly exceeded the previous known maximum--31,100 ft^3/s on December 23, 1964--and was very destructive in the lower Klickitat River valley. The flood of January 1974 also washed out a number of roads, culverts, and bridges in the reservation, particulary in the southern part along White and Trout Creeks, and at the mouth of Summit Creek.

An indication of how often, on the average, an annual peak flood can be expected to equal or exceed a given discharge is given in the table below. It should be noted, however, that no regularity of occurrence is implied; only the average over a long period of time is indicated.

Station and number	Annual peak discharge, in cubic feet per second, for indicated recurrence interval, in years					
	2	5	10	25	50	100
Klickitat River above West Fork (14107000)----	1,850	2,420	2,830	3,370	3,790	4,230
Klickitat River near Glenwood (14110000)-----	3,140	4,330	5,180	6,300	7,180	8,100
Klickitat River near Pitt (30 miles downstream from study area) (14113000)-------------	8,200	14,700	20,400	29,300	37,300	46,600

For example, at station 14107000 the peak flow for the year would be expected to equal or exceed 2,830 ft^3/s on the average of once in 10 years; a flood this size has one chance in 10 (10-percent chance) of occurring in any one year.

The average of the annual peak floods at a particular station is approximately the same as the peak flood given for a recurrence interval of 2 years--that is, a flood has a 50-percent chance of being larger or smaller than this each year.

The variations in recurrence interval of selected floods at different locations are listed below:

Station and number	Recurrence intervals (years)		
	Dec. 22, 1933	Dec. 23, 1964	Jan. 15, 1974
Klickitat River above West Fork (14110000)-------	--	5	10
Klickitat River near Glenwood (14110000)--------	400	1.5	70
Klickitat River near Pitt (30 miles downstream from study area) (14113000)----	18	30	100

TABLE 2.--Selected peak flows at stations in Klickitat River basin

[Highest flow given for each station is the maximum known]

Station number in figure 4	Station name	Drainage area (mi^2)	Years of record	Period of record	Peak flow: Date	Peak flow: ft^3/s
14107000.	Klickitat River above West Fork	151	30	1945-74	May 27, 1948	3,280
					Dec. 23, 1964	2,340
					Jan. 15, 1974	2,860
14108000.	West Fork Klickitat River	87	4	1945-48	May 26, 1948	1,560
14109000.	Big Muddy Creek	23	5	1917, 1945, 1947-49	June 8, 1948	1,180
14110000.	Klickitat River near Glenwood	360	64	1910-56, 1958-74	Dec. 22, 1933	9,870
					May 26, 1948	4,710
					Dec. 23, 1964	2,690
					Jan. 15, 1974	7,600
14113000.	Klickitat River near Pitt (not in project area)	1,297	49	1910-12, 1929-74	Dec. 22, 1933	25,500
					Jan. 7, 1948	15,700
					Dec. 23, 1964	31,100
					Jan. 15, 1974	47,400

Base Flows

Base flow is that part of the streamflow that comes from ground water discharged into the stream; thus, where ground-water discharges continuously, streams continue to flow all year long. The streamflow in late summer and fall, and sometimes in late fall and early winter, is all or nearly all base flow. Thus, annual base flows indicate not only the minimum streamflow that is available, but the minimum quantity of ground water that is discharged from the ground-water system. (Excluded from these considerations in the study area are low flows due to diversions to Hellroaring Ditch and to rare, temporary freezeups.) The distribution of streamflow in the basin during base-flow periods is shown in figure 6, which gives the lowest flows observed at various points in the basin. Streamflow was measured during the summer and fall of 1974 (table 9 at end of report, and fig. 4) in areas where measurements were lacking so as to define low flows.

The annual 7-day low flow is a good indicator of the minimum base flows to be expected during the year at a particular site (table 3). As can be seen by the lowest and highest values given in table 3, the annual 7-day low flow varies considerably at each station from year to year. The recurrence interval of low flows gives the best indication of how often, on the average, flows can be expected to decrease to some particular quantity. The annual 7-day low flow, on the average, can be expected to decrease to as low as the flow listed in table 4 in 1 year out of the number of years given. The flow at the 2-year recurrence interval is essentially the same as the average 7-day low flow. Analysis of recurrence intervals made for the two stations with long-term records (14107000 and 14110000) were used along with that for the Klickitat River near Pitt (14113000, south of the project area) to make correlations at a number of other sites (table 4). The annual 7-day low flows given for the various recurrence intervals in table 4 were computed from data obtained during 9 years from the West Fork Klickitat River, during 2 years from Pearl, Cunningham, and Outlet Creeks, and during 1 year from the others. Low flows based on measurements made during only 1 year are not as reliable as those computed for the other streams. The average 7-day low flow given for the West Fork Klickitat River (14108000) in table 3 is higher than the flow at the 2-year recurrence interval given in table 4 because the flows that were measured (table 3) occurred during years when the flows were, on the average, higher than normal.

Very unusual conditions in 1957--extreme and prolonged cold weather causing the river to nearly freeze up--resulted in an exceptionally low flow, which was excluded from the low-flow data for the Klickitat River above West Fork (14107000), tables 3 and 4. The 7-day flow during this period dropped to less than 6 ft^3/s. The 7-day low flow of Big Muddy Creek, 21 ft^3/s in September 1948, was also excluded from table 3 because it probably was the result of the diversion of water into Hellroaring Ditch for irrigation. Neither of these exceptionally low annual 7-day low flows that were excluded in table 3 can be reasonably predicted or expected.

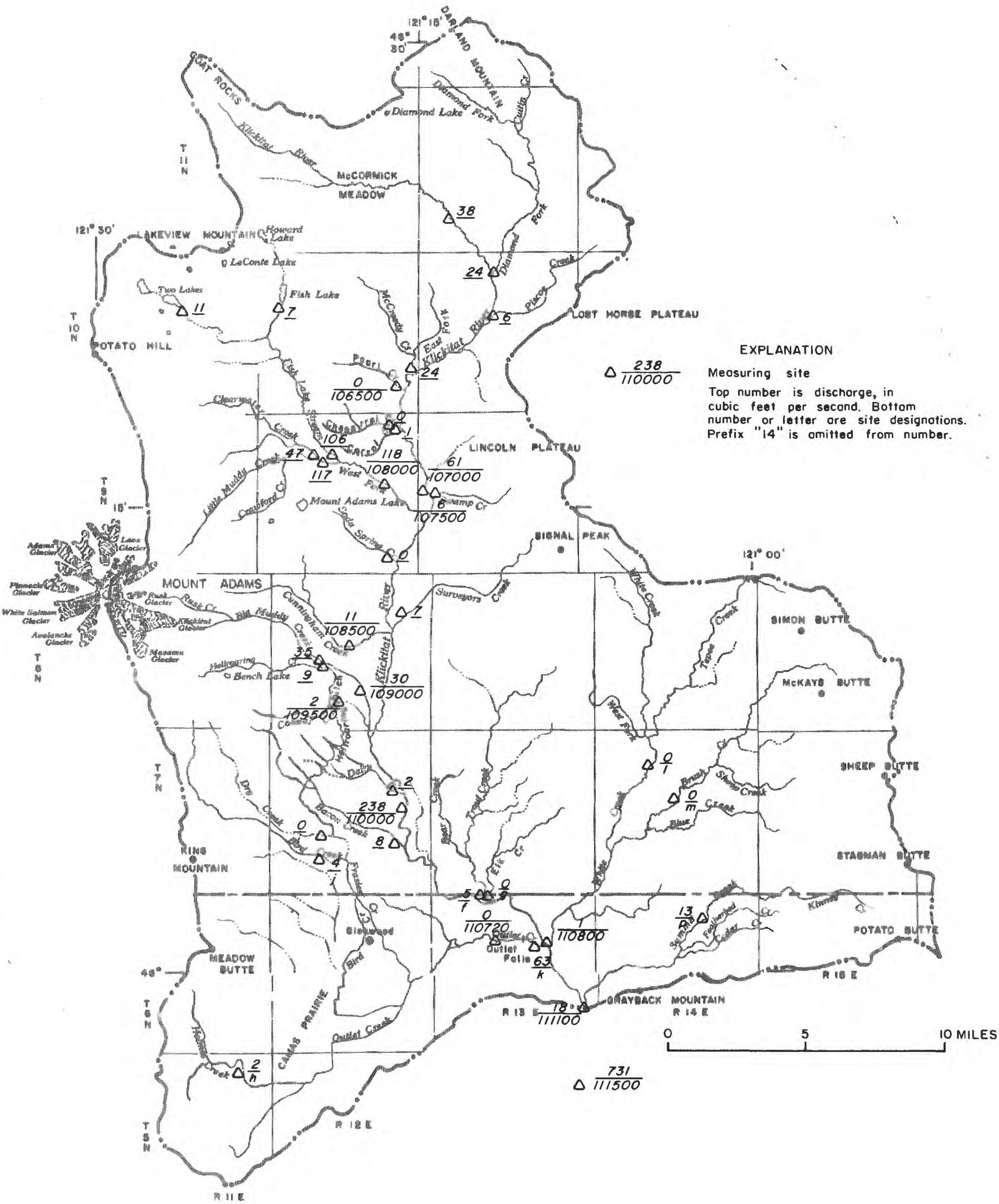


FIGURE 6.--Lowest streamflows observed at selected sites in the upper Klickitat River basin, Washington, during 1900-74. Discharge rounded to nearest whole number. Low flows caused by ice effects or diversion for irrigation were excluded at a few sites. Flow was measured or estimated only once at a number of sites, all during periods of relatively low flow.

TABLE 3.--Annual 7-day low flows at selected sites in upper Klickitat River basin

[Based on climatic year, April 1-March 31]

Station number in figure 4	Station name	Annual 7-day low flow (ft^3/s)		Years of record	Drainage area (mi^2)	Basin runoff [(ft^3/s)/mi^2]
14107000.	Klickitat River above West Fork[a]	Highest	115	30	151	0.76
		Lowest	63			.42
		Average	87			.58
14108000.	West Fork Klickitat River[a]	Highest	257	9	87	2.95
		Lowest	120			1.38
		Average	190			2.18
14109000.	Big Muddy Creek[b]	Highest	47	6	23	2.04
		Lowest	32			1.39
		Average	38			1.65
14110000.	Klickitat River near Glenwood[c]	Highest	488	59	360	1.36
		Lowest	245			.68
		Average	359			1.00

[a]Excludes low flows caused by severe freeze-up at station 14107000 in December 1944 (57 ft^3/s) and January-February 1957 (5.6 ft^3/s), and at station 14108000 in December 1944 (116 ft^3/s).

[b]Excludes flow of September 1948 (21 ft^3/s) because some water probably was diverted to Hellroaring Ditch.

[c]Includes the effect in some years of diversions to Hellroaring Ditch from Big Muddy, Hellroaring, Cougar, and Dairy Creeks.

Note: All average values are less than 17 percent different from those from records for four concurrent years.

TABLE 4.--Selected recurrence intervals of annual 7-day low flows at stream sites in upper Klickitat River basin
[Based on climatic year, April 1-March 31]

Station number or letter in figure 4	Stream name and location	Drainage area (mi^2)	7-day average low flows, in cubic feet per second, for indicated recurrence interval, in years					
			2	5	10	20	50	100
14106500.	Pearl Creek NW¼ sec. 36, T.10 N., R.12 E.	4.31	0.1	0	0	0	0	0
14107000.	Klickitat River above West Fork[a] SW¼ sec.18, T.9 N., R.13 E.	151	86	73	68	64	61	59
14107500.	Swamp Creek NE¼ sec.19, T.9 N., R.13 E.	10.4	4	3.5	3			
14108000.	West Fork Klickitat River[a] SE¼ sec.14, T.9 N., R.12 E.	87.0	185	163	152			
14108500.	Cunningham Creek SE¼ sec.15, T.8 N., R.12 E.	15.4	12	10	9			
14109500.	Cougar Creek[b] NE¼ sec.33, T.8 N., R.12 E.	3.34	.6	.5	.4			
14110000.	Klickitat River near Glenwood[c] SW¼ sec 13, T.7 N., R.12 E.	360	358	314	292	274	256	243
f.	Trout Creek NE¼ sec.5, T.6 N., R.13 E.	34	3.8	3.3	3.0			
k.	Outlet Creek[d] NW¼ sec.14, T.6 N., R.13 E.	130	76	68	63			
14110800.	White Creek SW¼ sec.11, T.6 N., R.13 E.	130	.7	.5	.4			
n.	Klickitat River above Summit Creek SW¼ sec.24, T.6 N., R.13 E.	704	600	530	500			
14111100.	Summit Creek SW¼ sec.24, T.6 N., R.13 E.	44.8	12	10	9			

[a] Excludes low flows caused by severe freeze-up at station 14107000 in December 1944 (57 ft^3/s) and January-February 1957 (5.6 ft^3/s), and at station 14108000 in December 1944 (116 ft^3/s).

[b] Prior to diversions to Hellroaring Ditch.

[c] Includes the effect in some years of diversions to Hellroaring Ditch from Big Muddy, Hellroaring, Cougar, and Dairy Creeks.

[d] May include some effect of diversions from Big Muddy, Hellroaring, Cougar, Dairy, and Bacon Creeks.

Base flows in different parts of the basin vary considerably, as indicated by the differences in the per-square-mile discharge of the annual 7-day low flow (table 3). The West Fork Klickitat River yields more than three times as much water per square mile as the Klickitat River above West Fork. The Mount Adams area yields considerably more base-flow water than the remainder of the basin, due to greater precipitation, greater storage in the snowpack, and greater recharge to the ground-water body, which subsequently discharges to streams. Probably only a small part of the low flow in the fall from this area is due directly to glacier melt water. Along the Klickitat River in the southern part of the study area there is a large increase in flow--about 400 ft^3/s in the fall of 1974--between station 14110000 and site n (fig. 4) at the southern boundary of the reservation (table 9). Much of this increase, which is about an 80-percent increase over the flow at station 14110000, comes from large springs, some of which are listed in table 8 and shown in figure 1. Inflow along this reach in mid-August 1974 was less than in the fall of 1974, and was a little more than 300 ft^3/s. Peak ground-water levels in the basalt in the Glenwood area occurred in August (fig. 3); water providing this peak presumably reached the Klickitat River in the fall. The increase in flow along this reach at other times of the year and in other years is unknown, but probably is usually less than in the fall of 1974.

Surface-Water Use

Surface water in the upper Klickitat River basin is used mostly for irrigation of about 5,600 acres in the Camas Prairie-Glenwood area by diversion in Hellroaring Ditch (fig. 4). Of the water diverted through Hellroaring Ditch, most is taken from Big Muddy Creek but small amounts are taken from other streams (Hellroaring, Cougar, Dairy, and North Fork Bacon Creeks) along the route to Camas Prairie. Normal operation of the ditch is from late May or June to the end of October, and flow is estimated to be 10,000 to 20,000 acre-feet each year. Some water is spilled from the ditch into Bacon Creek and diverted again downstream; the remainder of the water in the ditch is added to Dry Creek and thence into Bird Creek. Downstream the streamflow is diverted in several directions to be distributed to various parcels of land. Several streams flow into Camas Prairie, and during the winter and spring runoff period it becomes flooded, thus forming Conboy Lake. The lake is quite large in the winter and spring (fig. 2), but is mostly drained away in summer by ditches leading to Outlet Creek; the land is then used for farming. Conboy Lake National Wildlife Refuge also receives some water brought by Hellroaring Ditch for use by the waterfowl. Hellroaring Ditch normally contributes little water to Conboy Lake because the ditch is closed in winter. In the spring of 1974 the lake covered about 5 mi^2, but by midsummer most of the water was gone.

In 1974 the flow of Hellroaring Ditch was measured downstream from all of its water sources except North Fork Bacon Creek, which is very small, and upstream from the first discharge point, which is at Bacon Creek (ditch flow measured between sites d and e, fig.4). Approximate quantities of water, in acre-feet, carried in Hellroaring Ditch in 1974 are as follows:

April	370	August	4,400
May	1,100	September	3,700
June	600	October	920
July	850	November	60
Total			12,000

Because not all of the spillgates had been removed to drain the ditch during the winter of 1973-74, water was carried in the ditch in the spring and early summer. However, the water was not needed because greater-than-average precipitation had occurred during the winter.

The quantity of surface water used in the remainder of the basin is small; streams supply a youth camp (Camp Chaparral) the Signal Peak Ranger Station, a cattle camp, a check station, several small campgrounds, and watering trucks for settling the dust on the main logging roads. Camp Chaparral (sec.2, T.9 N., R.12 E.) obtains its water from Chaparral Creek. About 160 grade-school students and counselors stay at the camp for 3 months in the summer. The Signal Peak Ranger Station obtains water from Surveyors Creek about one-half mile below its source at spring 9/13-23J1s. The creek supplies water for about 30 people from June to mid-October, and a few people for a few weeks before and after this period.

Surface water is susceptible to contamination and vandalism. Chlorination of the water, prevention of cattle access to the water supply, protection of the facilities against vandalism, and periodic checks of the water quality will help reduce such problems.

QUALITY OF THE WATER

The chemical quality of both ground and surface waters in upper Klickitat River basin is generally similar and of excellent quality for most purposes; the only exceptions are four springs that will be discussed separately later (springs 6/13-4H1s, 9/13-18P1s, 11/12-24L1s, and 11/13-4K1s) and a few wells and springs that contain excessive amounts of iron. Most of the water has low concentrations of dissolved solids and is classified as soft (tables 10 and 11 at end of report). The chemical character of the water is similar for the most part, whether the water comes from streams, basalt, or unconsolidated deposits, although water obtained from basalt at the southern end of Camas Prairie tends to have somewhat higher concentrations of dissolved solids than water in the remainder of the study area. The quality of water in the entire reservation including the upper Klickitat River basin, is discussed in greater detail in a report being prepared by Fretwell (written commun., 1975).

The hardness of water generally is classified by Brown, Skougstad, and Fishman (1970, p. 95) as follows: soft, 0-60 mg/l; moderately hard, 61-120 mg/l; hard, 121-180 mg/l; and very hard, more than 180 mg/l. In the upper Klickitat River basin nearly all of the water sampled for hardness is classified as soft, and, excluding the four springs mentioned above, only three of the sampled waters were moderately hard.

Specific conductance is a general measure of the amount of dissolved constituents that are in the water. All of the water samples measured, except that from the four springs, had specific conductances of less than 200 micromhos (at 25°C), with most being less than 100 micromhos. Such specific conductances indicate that the water does not contain much dissolved solids.

Iron in excess of 300 μg/l (micrograms per litre) is generally considered undesirable (U.S. Public Health Service, 1962) because of staining, taste, and the formation of deposits. Most of the ground water sampled in the project area contains less than 300 μg/l of iron (table 10). However, four wells and springs (5/11-16J1s, 5/12-4H2, 5/12-8H1s, and 6/12-35H1), all in the southern part of Camas Prairie, yielded water containing between 300 and 500 μg/l of iron. Water from another well (6/12-2D1) contained considerably more iron, 2,100 μg/l.

Four springs yielded water that was markedly different from most water found in the study area. The waters from three of the springs--6/13-4H1s, 9/13-18P1s, and 11/12-24L1s (Soda Spring)--contain much higher concentrations of dissolved solids. However, the waters from these springs are fairly similar in chemical composition (have similar ratios between major constituents) to the water normally obtained from the basalt. Specific conductances range from 1,500 to 1,800 micromhos at 25°C, and hardnesses range from 600 to 670 mg/l. The waters are high in calcium, magnesium, sodium, bicarbonate, and chloride (table 10). The three springs also contain excessive iron, especially 9/13-18P1s and 11/12-24L1s which had 23,000 μg/l and 19,000 μg/l, respectively. Soda Spring (11/12-24L1s) has considerable carbon-dioxide gas bubbling out, and spring 6/13-4H1s also has gas that probably is carbon dioxide. Although only a little gas was noted at spring 9/13-18P1s, probably the water contains gas which escapes before the water discharges at the land surface as this spring flows out of sand and gravel on the riverbank. The water from these springs probably comes up from deep in the basalt. Volcanic rocks and volcanoes are known to yield carbon dioxide gas, and in the general region of Mount Adams a number of springs and wells yield this gas. The temperature of the water from the three springs is somewhat higher than that of nearby springs, and, in the case of spring 6/13-4H1s, the temperature of 23.8°C is 15°C higher than that of the other nearby springs (table 8), and the highest measured in the project area.

The water from the fourth spring, 11/13-4K1s, contains gas and is warmer than other springs in the vicinity, but it has a chemical composition different from that of any other water sampled. The spring, which produces a sodium bicarbonate type of water that contains little hardness or iron, has a specific conductance (440 micromhos at 25°C) that is intermediate in value to other waters in the study area (tables 10 and 11).

The temperature of ground water is generally nearly constant unless the ground water is close to land surface or is in the ground only a short time. Generally, water temperature increases with depth. Also, the average annual air temperature affects the water temperature so that mountain springs are colder than lowland springs, other factors being equal. The temperatures of ground water in the southwestern part of the basin range from 6°C to 12°C, excluding that of the warm spring (6/13-4H1s; tables 5 and 8). To the north in the higher country, measured temperatures were as low as 2.4°C for spring 12/13-27F1s, which is at an altitude of 6,470 feet above sea level near the top of Darland Mountain.

Most water sampled in the upper Klickitat River basin had little contamination; ground water and some surface water had virtually none. All of the wells and all but two of the springs sampled for fecal-coliform bacteria showed essentially no bacteria (table 10). The two springs that did show some fecal-coliform bacteria had low counts, three colonies per 100 millilitres; the bacteria was caused by cattle walking through the spring waters. It is surprising that more springs were not contaminated as cattle walk through a number of springs; samples were collected, however, as near the point where the water emerged from the ground as possible so as to minimize the problem of contamination at land surface. The presence of fecal-coliform bacteria indicates that the water may not be safe for human consumption. In places in the Camas Prairie-Glenwood area ground water may be contaminated where it is near the land surface, and therefore susceptible to pollution from sources such as septic tanks and barnyards. Because the shallow ground water was sampled at only one well, no definite conclusions about the presence of contamination can be made. Although samples collected from Big Muddy, Trout, Elk, and White Creeks (table 11) showed little contamination, samples from Summit Creek and at two sites on the Klickitat River had higher fecal-coliform bacteria counts; the maximum for all of the samples collected at these three places was 25 colonies per 100 millilitres from the Klickitat River near Dead Canyon (14111500, fig.4). Outlet Creek above Outlet Falls had the most variation of any of the streams sampled, ranging from 2 to 110 colonies per 100 millilitres and with an average of 34 colonies. The higher counts at this station (14110720) are due to the natural and irrigation drainage into the stream from the Camas Prairie-Glenwood area.

SUMMARY AND CONCLUSIONS

Ground-water recharge to, and subsequent discharge from, the upper Klickitat River basin is estimated to average about 550,000 acre-feet per year. Most of the recharge occurs in the Mount Adams area where an estimated 140 inches of precipitation per year falls on the upper slopes of the mountain.

A large quantity of ground water moves through the basalt beneath the Glenwood area toward the Klickitat River, as shown by the large change in water levels in wells and the large amount of ground water discharged into the river. Water levels fluctuated at least 22 feet in 1974 (fig. 3) and probably an average of at least 150 ft^3/s of ground water, and possibly much more, was discharged into the Klickitat River from the Camas Prairie-Glenwood area. One spring, 6/13-10R1s, was estimated to discharge about 40 ft^3/s. A continuation of the water-level measurements in well 6/12-10K1 would allow a better determination of the fluctuations of the water table in the basalt. Most of the basalt flows underlying this area are 10 to 15 feet thick, and partly fill a valley eroded into older basalt flows, which individually are between 60 and 150 feet thick (Sheppard, 1964, 1967) and in general probably yield less water for a given thickness than do the younger basalt flows. The largest yield known from wells tapping the basalt is 180 gal/min (table 5 at end of report), but possibly several thousand gallons per minute could be obtained if a well were drilled deeper. Exploration would help to determine the presence of water-yielding zones deeper than 300 feet below land surface in the Camas Prairie-Glenwood area.

Overlying the basalt in the Camas Prairie-Glenwood area are unconsolidated deposits consisting of clay, silt, sand, gravel, and boulders. At least 60 to 80 feet of fine-grained sediments underlie much of southern Camas Prairie; however, along the southern margin of the prairie deposits of sand and gravel are at least 160 feet thick, as indicated at well 5/12-18E1 (table 7 at end of report). The basalt surface in the vicinity of this well forms a basin that is at least 100 feet deep.

Unconsolidated sediments in the study area yield from less than 1 gal/min to 500 gal/min to wells. Sand and gravel deposits commonly yield 10 to 100 gal/min, and have yielded as much as 500 gal/min (well 5/12-18E1, table 5). Sustained yields of 500 gal/min may not be possible, however, such yields would depend on the extent and thickness of the sand and gravel deposit and its hydraulic interconnection with the basalt. Exploratory drilling would help determine these characteristics. Silt and clay deposits generally yield little or no water to wells.

The availability of ground water in basalt in the remainder of the study area is probably similar to that of the Camas Prairie-Glenwood area. Although the remainder of the area, which contains no permanent inhabitants, has many springs, only test drilling will help determine the availability of, and depth to, water in the basalt. The 100-foot dry hole drilled at the Signal Peak Ranger Station (9/13-25E1, fig. 1) probably would have yielded sufficient water if it had been drilled deeper.

The discharge of the Klickitat River is estimated to average about 870,000 acre-feet per year where the river leaves the reservation (table 1); this is about 75 percent of the average yearly discharge of the river near Pitt (sta. 14113000). During the late summer and early fall low-flow period, at which time the flow is mostly from ground-water contribution, the discharge of the river as it leaves the reservation comprises more than 90 percent of the discharge of the river near Pitt. Ground-water contribution to the Klickitat River within the reservation probably averages about 60 percent of the average yearly flow of the river leaving the reservation.

Streamflow is generally highest in May and lowest in September-October (fig. 5). Both average flow and low flow are greater from the Mount Adams area than from the remainder of the study area; the West Fork Klickitat River produces more water per square mile than other streams in the basin (tables 1 and 3). Recurrence intervals for annual 7-day low flows indicate not only the approximate average 7-day low flow (2-year-recurrence-interval flow), but how often, on the average, the flow can be expected to decrease to some particular quantity in one year out of the number given (table 4). The low flows of the West Fork Klickitat River and Klickitat River that occur at the 10-year recurrence interval are only about 20 percent less than those occurring at the 2-year recurrence interval, indicating that the low flows of the main rivers in the upper basin are quite sustained. Even low flows occurring at the 100-year recurrence interval on the Klickitat River at stations 14107000 and 14110000 are only about 30 percent less than those occurring at the 2-year recurrence interval. Better determinations of the low-flow characteristics at desired stream sites could be obtained from miscellaneous measurements made during several years, similar to those made in 1974. The locations with the highest priority for such measurements probably are the Klickitat River just above Summit Creek (site n, fig. 4), Outlet Creek (site k), Summit Creek (sta. 14111100), and Cunningham Creek (sta. 14108500).

Annual floodflows in the upper Klickitat River basin usually occur in May, but they may occur any time during the period November-June. Snowmelt is the main cause of the annual floods, with the largest floods occurring when rain and melting snow are combined. The largest floodflow recorded in the study area in 64 years was the 9,870 ft^3/s recorded on the Klickitat River near Glenwood (sta. 14110000) on December 22, 1933. Notable floods at several locations are listed in table 2. The probable size and frequency of floods that can be expected to occur in the basin can be determined by regional analysis if desired. Thus, for sites other than stations 14107000 and 14110000 on the Klickitat River, for which data are already available, calculations can be made to determine roughly the magnitude of, for example, the 50-year flood of White Creek at the mouth. The procedures are outlined in a report by Cummans, Collings, and Nassar (1975).

The use of ground water in the study area in 1974, mostly for domestic and stock supplies, came from both wells and springs and totaled about 36 million gallons, or about 110 acre-feet; virtually all of this is used in the Camas Prairie-Glenwood area. Only about 3 million gallons, or about 9 acre-feet, came from wells, with the greater part coming from springs. About 31 million gallons came from McCumber Spring (7/12-28A1s,fig.1), which is the source of a public water-supply system in the Camas Prairie-Glenwood area.

During the 1974 irrigation season, about 12,000 acre-feet of surface water was diverted via Hellroaring Ditch, from Big Muddy, Hellroaring, Cougar, Dairy, and North Fork Bacon Creeks to the Camas Prairie-Glenwood area for irrigation (fig.4). Water from Bacon, Bird, and Dry Creeks also is used, to irrigate a total of about 5,600 acres. Big Muddy Creek is the main source of water by late summer as the flow of other streams becomes very low, or the streams go dry.

Chemically, water in the project area is excellent, except for that from a few springs and wells (tables 10 and 11). Most of the water has low concentrations of dissolved solids, with specific conductances of less than 100 micromhos at 25°C and hardnesses of less than 60 mg/l. Iron concentrations are mostly less than 200 µg/l, but some waters have considerably higher concentrations. Three springs have excessive concentrations of iron, as much as 23,000 µg/l, and have much higher concentrations of dissolved constituents than do other waters (table 10). Specific conductance of the water from the springs ranged from 1,500 to 1,800 micromhos at 25°C, and hardness ranged from 600 to 670 mg/l. These springs are somewhat warmer than other springs in their vicinity (table 8 at end of report). One spring had a temperature of 23.8°C, 15°C higher than others nearby. At least one, and probably all three, of these springs give off carbon dioxide gas.

Ground water sampled from wells in the project area has little or no contamination as indicated by virtually no evidence of fecal-coliform bacteria (table 10). Even so, shallow ground water is susceptible to the danger of contamination, and shallow wells are not recommended for drinking-water supplies. Wells probably should be at least 30 feet deep to yield water safe for human consumption.

Some streams show little evidence of contamination (table 11), others had as much as 25 colonies of fecal-coliform bacteria per 100 millilitres of water, and Outlet Creek above Outlet Falls averaged 34 colonies and had as much as 110 colonies per 100 millilitres. If surface water is used for human consumption, it should be chlorinated.

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A P P E N D I X

Tables of basic data

TABLE 5.--Record of selected wells in upper Klickitat River basin

EXPLANATION

<u>Casing depth</u>: Number is to bottom of casing, or to first perforation if well is perforated.
<u>Well finish</u>: Ø, open end; P, perforated; W, cribbed with rocks; X, open hole.
<u>Material tapped</u>: B, basalt, including interbeds; U, unconsolidated deposits overlying the basalt.
<u>Yield, method determined</u>: B, bailer test from driller's report; I, indirectly determined using geohydrologic information; M, measured by U.S. Geological Survey; P, pumping test from driller's report; R, reported.

<u>Use</u>: D, domestic; I, small scale irrigation; S, stock; T, test hole (data from Harza Engineering Co., written commun., 1974); U, unused; Z, destroyed.
<u>Remarks</u>: A, complete chemical analysis; L, well log; P, partial chemical analysis.

Well number	Owner	Well depth (ft)	Diam-eter (in.)	Casing depth (ft)	Well finish	Material tapped	Alti-tude (ft)	Depth to water below land surface (ft)	Date measured	Yield (gal/min)	Yield Method deter-mined	Draw-down (ft)	Use	Remarks
5/11-1P1	Phillip Ohnemus	51	6	51	Ø	U	1,865	18.27	4- 1- 74	--	--	--	D,S	
12E1	Conboy Lake National Wildlife Refuge	66	10	--	--	--	1,845	1.39	4- 1-74	--	--	--	U	
12E2	---do---------------	17	36	17	Ø	U	1,845	1.40	4- 1-74	--	--	--	U	
12Q1	(test hole)	59	--	--	--	U	1,850	5	10- -73	--	--	--	T	L.
5/12-3C1	Conboy Lake National Wildlife Refuge	57	36	7	X	B	1,860	11.18	7-19-74	--	--	--	U	L.
3C2	---do---------------	51	6	--	--	B	1,860	14.08	7-19-74	--	--	--	U	
4H1	Agnes Miller	225	6	100	X	B	1,830	215	1972	6	R	--	S	A, L, 12.1°C.
4H2	---do-------	19	72	19	Ø	U	1,830	10.16	7-17-74	--	--	--	D	A.
5N1	(test hole)	60	--	--	--	U	1,820	7	10- -73	--	--	--	T	L.
5Q1	Conboy Lake National Wildlife Refuge	118	6	--	--	--	1,830	22.79	4-30-74	--	--	--	U	
5Q2	---do---------------	8	36	8	Ø	U	1,830	3.15	4-30-74	--	--	--	U	
6Q1	Chip Kreps	84	6	--	--	--	1,825	7.79 7.20	4-30-74 10-10-74	--	--	--	S	
18E1	Darrell Lee	160	8	160	Ø	U	1,860	3.42	5- 1-74	500	P	10	U	L.
18E2	---do------	7	36	7	Ø	U	1,855	1.81	5- 2-74	--	--	--	D	
6/12-2D1	F. T. Bean	131	6	--	X	B	1,970	99.20	6-14-74	--	--	--	U	A, 6.8°C.
3M1	L. C. Rolph	50	6	34	X	U	1,981	3.49	4- 4-74	9	B	5	D	A, L, 11.0°C.
3M2	Frank Ward	98	6	54	X	B	1,981	--	1974	0	I	--	U	L, no water.
10A1	John Finn	38	6	--	--	--	1,919	4.01	6-14-74	15	R	--	I	Run 1 sprinkler
10K1	Glenwood School	255	6	--	X	B	1,900	200.4	2-13-74	130	R	--	U	L.

6/12-10M1	U.S. Bureau of Indian Affairs Ranger Station	300	6	--	X	B	1,935	227.96	4- 5-74	67	M	--	U	A, 6.1°C.
10P1	Ada Conboy	13	36	13	Ø	U	1,895	4.13	2-11-74	--	--	--	U	
10P2	Audrey Eaton	265	10	--	X	B	1,895	187.34	4- 2-74	--	--	--	U	
11E1	L. D. Lloyd	13	36	13	Ø	U	1,905	6.60	7-16-74	--	--	--	D	
11E2	---do------	13	36	13	Ø	U	1,905	7	7-16-74	--	--	--	D	A, 10.0°C.
12R1	Ken Allbritton	30	60	30	Ø	U	1,830	1.29	4- 2-74	--	--	--	S	Used in winter.
13D1	T. B. Burns	200	6	40	X	B	1,850	155.26	4- 2-74	--	--	--	U	
15Q1	Roy Feller	11	24	6	W	U	1,852	1.85	2-12-74	--	--	--	U	
16B1	George Hathaway	46	6	--	--	--	1,875	15.10 14.25	7-19-74 9-11-74	7	M	3	U	P, 9.7°C.
21F1	Osmer Kuhnhausen	10	36	10	Ø	U	1,830	2.41	7-17-74	--	--	--	U	L.
21F2	---do-----------	150	5	50	X	B	1,830	--	--	0	R	--	U	No water, well has filled in to 60 ft.
22L1	Paul Ladiges	260	8	84	X	B	1,833	114.9	4- 5-74	14	M	--	D	L, P, 10.8°C.
23B1	Ken Sheridan	210	6	82	X	B	1,830	--	--	--	--	--	D,S	
27D1	E. W. Ziegler	247	8	47	P,X	B	1,828	90.20	5- 8-74	180	P	20	U	L.
27D2	---do--------	10	24	10	Ø	U	1,828	2.68	2-13-74	--	--	--	U	
31A1	(test hole)	29	--	--	--	B	1,852	--	--	--	--	--	T	L.
32D1	---do------	59	--	--	--	U	1,816	5	10- -73	--	--	--	T	L.
32R1	---do------	80	--	--	--	U	1,815	8	10- -73	--	--	--	T	L.
33A1	---do------	64	--	--	--	U	1,815	10	10- -73	--	--	--	T	L.
33D1	---do------	74	--	--	--	U	1,816	8	10- -73	--	--	--	T	L.
34D1	Conboy Lake National Wildlife Refuge	8	8	--	--	U	1,822	1.20	4- 5-74	--	--	--	U	
34K1	---do---------------	116	6	20	X	B	1,830	7.19	5- 1-74	--	--	--	U	L.
34L1	---do---------------	55	8	40	P	U	1,820	9.00	7-12-74	--	--	--	U	
34L2	(test hole)	41	--	--	--	U	1,817	--	--	--	--	--	T	L.
35H1	Paul Ladiges	104	6	--	X	B	1,875	29.04	7-18-74	--	--	--	D,S	A, 9.2°C.
7/11-22H1	Washington State Dept. of Natural Resources	6	16	0	P	U	3,800	2	6-11-74	8	M	1	S	Infiltration from stream.
9/13-25E1	Yakima Tribe	100	--	--	--	--	4,015	--	9- -73	0	R	--	Z	No water.

TABLE 6.--Depth to water below land surface, in observation wells in the Camas Prairie-Glenwood area

5/11-12E1. Conboy Lake National Wildlife Refuge

Date	Depth to water (ft)
1974	
Apr. 1	1.39
May 6	2.18
June 12	2.78
July 11	3.36
Aug. 16	4.68
Sept. 13	5.35
Oct. 9	5.88
Nov. 13	5.58
Dec. 18	2.38

5/11-12E2. Conboy Lake National Wildlife Refuge

Date	Depth to water (ft)
1974	
Apr. 1	1.40
May 6	2.50
June 12	3.03
July 11	3.36
Aug. 16	4.75
Sept. 13	5.52
Oct. 9	6.13
Nov. 13	5.84
Dec. 18	2.51

5/12-5Q1. Conboy Lake National Wildlife Refuge

Date	Depth to water (ft)
1974	
Apr. 30	22.79
June 12	21.42
July 11	20.92
Aug. 16	20.49
Sept. 13	20.25
Oct. 9	20.09
Nov. 13	19.98
Dec. 18	19.50

5/12-5Q2. Conboy Lake National Wildlife Refuge

Date	Depth to water (ft)
1974	
Apr. 30	3.15
June 12	4.75
July 11	5.95
Aug. 16	7.34
Sept. 13	8.2+ (dry)
Oct. 9	8.2+ (dry)
Nov. 13	8.2+ (dry)
Dec. 18	6.99

6/12-3M1. L. C. Rolph

Date	Depth to water (ft)
1974	
Apr. 4	3.49
May 8	5.06
June 12	5.10
July 11	4.31
Aug. 14	4.05
Sept. 13	4.43
Oct. 10	4.82
Nov. 13	6.60
Dec. 18	4.09

6/12-10K1. Glenwood School

Date	Depth to water (ft)
1955	
Sept. --	215
1974	
Feb. 13	199.9
Apr. 2	194.05
May 8	189.75
June 12	185.14
July 10	180.20
Aug. 14	177.90
Sept. 13	178.61
Oct. 9	181.10
Nov. 13	186.70
Dec. 18	192.78
1975	
Jan. 24	192.7

6/12-10M1. U.S. Bureau of Indian Affairs Ranger Station

Date	Depth to water (ft)
1974	
Apr. 5	227.96
May 8	223.93
June 12	219.15
July 11	214.34
Aug. 13	212.10
Sept. 13	213.11
Oct. 10	215.78
Nov. 13	221.36
Dec. 18	227.47

6/12-10P1. Ada Conboy

Date	Depth to water (ft)
1974	
Feb. 11	4.13
Apr. 2	4.91
May 8	6.98
June 12	6.02
July 11	6.00
Aug. 15	6.70
Sept. 12	6.12
Oct. 10	7.34
Nov. 13	9.15
Dec. 18	9.86
1975	
Jan. 24	5.7

6/12-13D1. T. B. Burns

Date	Depth to water (ft)
1974	
Apr. 2	155.26
May 8	151.59
June 12	146.91
July 12	141.81
Aug. 16	139.16
Sept. 13	139.38
Oct. 9	141.30
Nov. 13	147.29
Dec. 18	153.24

6/12-15Q1. Roy Feller

Date	Depth to water (ft)
1974	
Feb. 12	1.85
Apr. 5	1.29
May 8	3.25
June 12	5.22
July 11	2.15
Aug. 15	2.35
Sept. 13	4.28
Oct. 10	5.48
Nov. 13	4.92
Dec. 18	1.14

6/12-22L1. Paul Ladiges

Date	Depth to water (ft)
1974	
Apr. 5	114.9
May 8	110.6
June 12	106.3
July 11	101.6
Aug. 16	98.6
Sept. 13	99.10
Oct. 10	101.05
Nov. 13	105.6
Dec. 18	111.0

6/12-34K1. Conboy Lake National Wildlife Refuge

Date	Depth to water (ft)
1974	
May 1	7.19
June 12	8.19
July 11	9.38
Aug. 16	10.61
Sept. 13	11.40
Oct. 9	11.85
Nov. 13	12.46
Dec. 18	12.28

TABLE 7.--Materials penetrated by wells in the Camas Prairie-Glenwood area

Material	Thickness (feet)	Depth (feet)
5/11-12Q1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Silt, sandy, clayey	25	25
Clay, silty, with sand	25	50
Silt, clayey	9	59
5/12-3C1. Conboy Lake National Wildlife Refuge. Data from author's personal observation. Casing: 36-inch to 7 ft.		
Clay, sand, and gravel	7	7
Basalt	50	57
5/12-4H1. Agnes Miller. Drilled by George Zent. Casing: 6-inch to 100 ft.		
Unknown	20	20
Quicksand	?	?
Clay, hard	?	90
Quicksand, water	10	100
Basalt	125	225
5/12-5N1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Silt, sandy, clayey	12	12
Silt, clayey	22	34
Sand	9	43
Silt, clayey	17	60
5/12-18E1. Darrel Lee. Drilled by Four Star Drilling Co. Casing: 8-inch to 160 ft.		
Sand, gravel, and boulders	160	160

TABLE 7.--Materials penetrated by wells in the Camas Prairie-Glenwood area--Continued

Material	Thick-ness (feet)	Depth (feet)
6/12-3M1. L. C. Rolph. Drilled by George Zent and Sons. Casing: 6-inch to 34 ft. Backfilled 50-53 ft.		
Soil	1	1
Clay, sandy	2	3
Gravel and small boulders	9	12
Sand and clay with seams of sand yielding water	32	44
Gravel, cemented	6	50
Basalt	3	53
6/12-3M2. Frank Ward. Drilled by Swift Water Well Drilling. Casing: 6-inch to 54 ft.		
Sand, clayey soil, and cobbles	3	3
Sand and cobbles	9	12
Sand, cobbles, and boulders	30	42
Sand, cobbles, and gravel	9	51
Basalt, hard, black	11	62
Basalt, hard, light gray	14	76
Basalt, fractured, gray, large fracture at 82 ft	22	98
6/12-10K1. Glenwood School. Drilled by Albert Kastl. Casing: 6-inch.		
Clay, sand, gravel, and boulders	35	35
Basalt, cavity 125-130 ft	97	132
Pumice, soft, red	18	150
Pumice, soft, red(?)	75	225
Basalt, soft, gray	10	235
Basalt, soft, black	10	245
Basalt (?)	10	255
6/12-21F1. Osmer Kuhnhausen. Dug by owner. Casing: 36-inch to 10 ft.		
Dirt	5	5
Gravel, water-bearing	5	10

TABLE 7.--Materials penetrated by wells in the Camas Prairie-Glenwood area--Continued

Material	Thick-ness (feet)	Depth (feet)
6/12-22L1. Paul Ladiges. Drilled by Charles Jeter. Casing: 8-inch to 84 ft.		
Clay and sand	84	84
Basalt	156	240
Gravel and sand, water-bearing	20	260
6/12-27D1. E. W. Ziegler. Drilled by J. L. Harrison. Casing: 8-inch to 47 ft; perforated.		
Soft shale [clay], a little water at 15 ft	47	47
Hard shale [basalt], a little water at 49 and 122 ft	153	200
Lava rock [basalt]	45	245
Sand and pea gravel, water-bearing	2	247
6/12-31A1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Basalt, dense, weathered	29	29
6/12-32D1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Clay and silt (?)	2	2
Silt, sandy	6	8
Silt, clayey, with sandy layers	22	30
Sand, silty	5	35
Silt, clayey	17	52
Sand and clay (?)	7	59
6/12-32R1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Silt, clayey, soft	9	9
Silt, sandy, clayey	17	26
Sand, silty	3	29
Silt, clayey	51	80

TABLE 7.--Materials penetrated by wells in the Camas Prairie-Glenwood area--Continued

Material	Thickness (feet)	Depth (feet)
6/12-33A1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Silt and clay, sandy	4	4
Silt, clayey	3	7
Sand, silty	2	9
Silt, clayey	37	46
Sand	10	56
Silt, clayey	8	64
6/12-33D1. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Clay, silty	4	4
Silt, clayey	3	7
Sand and silt	23	30
Silt, clayey	25	55
Silt, sandy	5	60
Silt, clayey	6	66
Silt, sand, and clay (?)	8	74
6/12-34K1. Conboy Lake National Wildlife Refuge. Reported by former owner, George Hathaway. Casing: 6-inch to 20 ft.		
Sand and clay (?)	20	20
Basalt	96	116
6/12-34L2. Test hole. Data from Harza Engineering Co. (written commun., 1974).		
Silt, sandy	5	5
Silt, clayey	6	11
Sand, silty	9	20
Silt, clayey	21	41

TABLE 8.--Record of selected springs in upper Klickitat River basin

[Discharge: a, measured; b, part of flow measured and remainder estimated; c, estimated]

Spring name	Spring number	Altitude (ft above msl)	Discharge (gal/min)	Temperature (°C)	Date
--	5/11-15D1s	2,200	[b]5	9.0	5- 6-74
--	5/11-16J1s	2,360	[a]43	7.6	5- 3-74
			[c]5	--	7-18-74
--	5/12-8H1s	1,870	[a]5	9.5	4-25-74
			[a]5	--	4-30-74
			[a]3	--	7-17-74
Draper	6/12-7A1s	2,080	[c]60	7.4	7-16-74
Willard	6/12-30A1s	1,830	[c]400	6.8	4- 4-74
--	6/12-32E1s	1,825	[c]150	7.0	4- 4-74
			[c]50	7.1	7-16-74
--	6/12-35M1s	1,900	[a]2	--	7-18-74
Wonder	6/13-3E1s	1,325	[a]6,370	--	6-19-52
			[a]6,730	--	7-14-52
			[a]5,750	--	8- 2-52
			[a]5,700	--	8-20-52
			[a]5,880	--	9-23-52
			[a]7,050	--	6-17-53
			[a]8,170	--	7-13-53
			[a]8,480	--	7-27-53
			[a]8,170	--	8-19-53
			--	9.1	2-12-74
			[a]10,050	--	6- 5-74
			--	9.1	7-10-74
			[a]8,850	--	11-14-74
--	6/13-3Q1s	1,200	[c]4,500	7.4	9- 4-74
--	6/13-4H1s	1,215	[c]4	23.8	10-10-74
Cascade	6/13-10R1s	1,330	[c]18,000	--	10- 7-45
			[c]18,000	7.7	5- 7-74
--	6/13-10R2s	1,290	[c]4,500	7.9	5- 7-74
	6/13-10R3s	1,440	[a]80	8.0	5- 7-74
--	6/13-15A1s	1,220	[b]1,000	7.9	5- 7-74
--	6/13-16L1s	2,060	[a]38	8.4	9-11-74
--	6/14-11K1s	2,770	[c]5	7.5	8-13-74
--	6/15-1N1s	4,570	[a]14	3.3	8-14-74
--	6/15-11K1s	4,460	[a]7	5.1	8-13-74
--	7/11-1R1s	4,140	[b]60	3.2	9-12-74
--	7/12-4M1s	3,140	[a]30	8.0	6-10-74
			[a]24	6.1	7- 9-74
--	7/12-13J1s	2,190	[a]800	7.5	9-11-74

TABLE 8.--Record of selected springs in upper Klickitat River basin--Continued

Spring name	Spring number	Altitude (ft above msl)	Discharge (gal/min)	Tempera-ature (°C)	Date
McCumber	7/12-28A1s	2,355	[b]1,800	5.6	4- 3-74
--	7/13-33Q1s	1,585	[a]1,800	8.6 8.6	4-24-74 7-10-74
--	7/14-9D1s	2,535	[c]2	10.0	9-10-74
--	7/15-26F1s	4,230	[c]5	4.7	8-14-74
Bup	8/12-15G1s	2,715	[a]50 [a]30	4.8 5.0	6-13-74 7- 9-74
--	8/12-27L1s	2,540	[a]130	6.3	7-15-74
Jungle	8/13-2Q1s	3,910	[c]10	4.5	9-10-74
Lyon	8/13-13J1s	3,260	[a]9	5.2	9-10-74
--	8/14-12Q1s	3,220	[c]15	5.3	8-14-74
Coyote	8/15-20B1s	3,290	[a]4	6.6	8-14-74
Vessey	8/15-34N1s	3,455	[a]4	6.9	8-13-74
--	9/11-11K1s	4,620	[c]3,000	3.3	8-12-74
--	9/12-35B1s	2,730	[c]5	6.3 5.6	6-13-74 7- 9-74
--	9/12-35R1s	2,530	[b]3	10.2	9- 9-74
--	9/13-3F1s	4,470	[b]11	4.8	9-10-74
--	9/13-18P1s	2,700	[c]2	12.2	9-12-74
--	9/13-23J1s	4,220	[b]25	5.0	9- 9-74
--	10/11-19L1s	4,790	[c]5	2.9	7-15-74
Soda	11/12-24L1s	3,540	[c]2	9.5	8-15-74
--	11/13-3E1s	4,880	[a]10	4.5	9- 5-74
--	11/13-4K1s	4,660	[c]6	13.8	9- 5-74
--	11/13-4K2s	4,730	[a]3	10.3	9- 5-74
--	11/13-29M1s	3,505	[b]20	5.3	8-15-74
--	11/13-33M1s	3,490	[b]70	7.3	8-15-74
--	12/13-27F1s	6,470	[a]12	2.4	9- 5-74
--	12/13-35M1s	5,450	[a]23	3.7	9- 5-74

TABLE 9.--Miscellaneous streamflow measurements made in 1974 and on Outlet Creek in 1945

[Discharge: a, part of flow measured and remainder estimated; b, estimated]

Station number or letter in figure 4	Site name and location	Date	Discharge (ft^3/s)
a.	Chaparral Creek at Camp Chaparral SW¼NE¼ sec.2, T.9 N., R.12 E.	8-15-74	[a]0.6
b.	Dairy Creek, north branch, above Hellroaring Ditch NW¼SW¼ sec.4, T.7 N., R.12 E.	6-10-74	[b]2
		7- 9-74	[b]1.5
		10- 8-74	[b].2
c.	Diary Creek, middle branch, above Hellroaring Ditch NW¼NW¼ sec.9, T.7 N., R.12 E.	6-10-74	[b]5
		7- 9-74	[b]3
		10- 8-74	[b].3
d.	Diary Creek, south branch, above Hellroaring Ditch NE¼SE¼ sec.8, T.7 N., R.12 E.	6-10-74	[b]2
		7- 9-74	[b].5
		10- 8-74	[b].1
14110000.	Klickitat River near Glenwood (discontinued gage) SW¼SW¼ sec.13, T.7 N., R.12 E.	8-13-74	839
		9-18-74	540
		10-10-74	514
		11-15-74	463
e.	Bacon Creek, north branch, above Hellroaring Ditch SE¼NE¼ sec. 7, T.7 N., R.12 E.	6-11-74	[a]1.5
		7- 9-74	[a].45
		7-16-74	[a].51
		8-14-74	.33
		9- 9-74	.20
		10- 8-74	.10
		11-13-74	.10
f.	Trout Creek at mouth SE¼NE¼ sec.5, T.6 N., R.13 E.	6- 5-74	36.6
		7-16-74	17.8
		8-14-74	11.8
		9-17-74	9.26
		10-10-74	5.41
		11-14-74	4.86
14110490.	Elk Creek, 1 mile above mouth SE¼NE¼ sec.32, T.7 N., R.13 E.	11-14-74	0
g.	Elk Creek at mouth SW¼NW¼ sec.4, T.6 N., R.13 E.	10- 9-74	[b].07
		11-14-74	[b].04
h.	Holmes Creek near Laurel SE¼SE¼ sec.2, T.5 N., R.11 E.	10-11-74	2.4
i.	Dry Creek above Hellroaring Ditch NW¼NW¼ sec.28, T.7 N., R.12 E.	9-12-74	0
		10- 8-74	.0
j.	Bird Creek, 1 mile above Dry Creek SW¼SW¼ sec.28, T.7 N., R.12 E.	10- 8-74	4.0
		11-13-74	3.8

TABLE 9.--Miscellaneous streamflow measurements made in 1974 and on Outlet Creek in 1945--Continued

Station number or letter in figure 4	Site name and location	Date	Discharge (ft^3/s)
14110720.	Outlet Creek, 1 mile above Outlet Falls SE¼SW¼ sec.9, T.6 N., R.13 E. (chemical samples were taken 1 mile upstream)	10- 7-45	0
		8-15-74	12.3
		9-18-74	4.25
		10-10-74	5.31
		11-15-74	6.82
k.	Outlet Creek at mouth NW¼NW¼ sec.14, T.6 N., R.13 E.	10- 7-45	63.4
		8-15-74	124
		9-17-74	125
		10- 9-74	111
		11-14-74	109
ℓ.	White Creek, 4 miles above Brush Creek NW¼NW¼ sec.9, T.7 N.,R.14 E.	10- 9-74	b.02
m.	Brush Creek, 4 miles above mouth NW¼NW¼ sec.15, T.7 N., R.14 E.	10- 9-74	b.07
14110800.	White Creek at mouth SE¼SW¼ sec.11, T.6 N., R.13 E.	6- 5-74	60.2
		7-16-74	7.63
		8-14-74	2.81
		9-17-74	1.50
		10-10-74	1.41
		11-14-74	2.16
n.	Klickitat River at reservation boundary just above Summit Creek SE¼SW¼ sec.24, T.6 N., R.13 E.	8-14-74	1,150
		9-18-74	943
		10-10-74	945
		11-14-74	848
p.	Summit Creek, 6 miles above mouth SW¼SW¼ sec.2, T.6 N., R.14 E.	10- 9-74	13.4
		11-14-74	14.3
14111100.	Summit Creek at mouth SE¼SW¼ sec.24, T.6 N., R.13 E.	6- 5-74	91.8
		7-16-74	32.8
		8-14-74	23.2
		9-18-74	17.8
		10-10-74	17.5
		11-14-74	18.1

TABLE 10.--Chemical analyses of ground water from wells and springs, upper Klickitat River basin

Name or owner	Well or spring number	Date of collection	Micrograms per litre: Iron (Fe)	Micrograms per litre: Mangan-ese (Mn)	Milligrams per litre: Calcium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite plus ni-trate as N	Hardness (Ca,Mg)	Specific conduc-tance (micromhos at 25°C)	Fecal-coliform bacteria (colon-ies per 100 ml)
	5/11-15D1s	5- 6-74	120	0	27	9.2	5.4	1.3	123	1.3	1.1	0.0	--	110	192	--
	5/11-16J1s	5- 3-74	410	0	5.6	1.6	3.1	.6	30	1.3	1.1	.0	--	21	51	--
Agnes Miller	5/12-4H1	7-17-74	80	170	21	10	8.5	4.7	124	2.0	1.0	.2	0.19	94	195	<1
Do.	5/12-4H2	7-17-74	330	0	5.1	2.6	3.2	2.0	36	1.5	1.5	.1	.07	23	68	--
	5/12-8H1s	4-25-74	380	0	15	7.4	6.1	2.1	95	1.4	1.5	.0	--	68	152	--
F. T. Bean	6/12-2D1	7-11-74	2,100	10	5.2	2.2	2.7	.8	32	1.0	.7	.0	.01	22	50	<1
L. C. Rolph	6/12-3M1	7-11-74	70	0	7.6	2.7	3.2	1.6	50	2.0	1.0	.0	.09	30	82	<1
Draper Springs	6/12-7A1s	7-16-74	20	0	4.2	2.2	2.6	1.9	33	.1	.5	.1	.08	20	55	<1
U.S. Bureau of Indian Affairs Ranger Station	6/12-10M1	7-11-74	220	0	5.2	2.5	3.6	2.0	39	.3	.5	.1	.05	23	62	<1
L. D. Lloyd	6/12-11E2	7-16-74	110	0	7.9	2.1	2.8	2.2	44	1.5	.8	.1	.04	28	75	<1
George Hathaway	6/12-16B1	9-11-74	--	--	--	--	--	--	--	--	--	--	1.3	--	62	<1
Paul Ladiges	6/12-22L1	10-10-74	--	--	--	--	--	--	--	--	--	--	.31	--	160	<1
Willard Spring	6/12-30A1s	4- 4-74	120	0	3.6	2.5	2.8	1.9	30	.1	.5	.0	2.0	19	55	--
Conboy Lake National Wildlife Refuge	6/12-32E1s	4- 4-74	10	0	4.5	3.0	3.4	2.5	38	1.1	.3	.0	.17	24	67	--
		7-16-74											.02		64	<1
Paul Ladiges	6/12-35H1	7-18-74	500	0	11	4.8	4.2	2.0	64	1.5	1.4	.1	.45	47	110	<1
Wonder Spring	6/13-3E1s	2-12-74	50	0	8.9	4.5	4.2	1.1	59	1.1	.2	.1	.05	41	97	--
	6/13-3Q1s	9- 4-74	50	0	5.8	2.7	3.9	1.8	45	.6	1.0	.1	.13	26	78	<1
	6/13-4H1s	10-10-74	2,200	60	110	95	160	16	1,130	2.6	49	.4	.49	670	1,660	<1
Cascade Spring	6/13-10R1s	12- 4-73	--	--	5.9	2.9	4.0	2.1	45	1.1	.7	--	.11	27	72	<1
		2- 6-74	--	--	5.4	3.2	4.0	2.1	45	1.6	1.1	--	.11	27	76	--
		5- 7-74	--	--	6.1	3.2	3.8	2.1	46	1.3	.9	--	--	28	79	--
		9- 4-74	250	0	6.1	2.8	4.9	2.5	47	.6	1.0	.1	.16	27	80	--
	6/13-10R2s	5- 7-74	20	0	7.9	3.5	3.9	1.4	48	1.1	1.1	.0	--	34	77	--
	6/13-10R3s	5- 7-74	20	0	12	3.6	4.2	1.3	48	1.1	1.1	.0	--	45	83	--

	6/13-15A1s	5- 7-74	20	0	6.3	3.4	3.8	1.3	47	1.1	1.0	.0	--	30	85	--
	6/13-16L1s	9-11-74	--	--	--	--	--	--	--	--	--	--	.08	--	144	<1
	6/14-11K1s	8-13-74	--	--	--	--	--	--	--	--	--	--	.05	--	118	<1
	6/15-1N1s	8-14-74	--	--	--	--	--	--	--	--	--	--	.32	--	32	<1
	6/15-11K1s	8-13-74	--	--	--	--	--	--	--	--	--	--	.78	--	47	<1
	7/11-1R1s	9-12-74	--	--	--	--	--	--	--	--	--	--	.03	--	39	<1
	7/12-4M1s	6-10-74	30	0	6.7	2.0	2.9	.6	38	.9	.7	.0	--	25	60	--
		7- 9-74	--	--	--	--	--	--	--	--	--	--	.00	--	62	<1
	7/12-13J1s	9-11-74	--	--	--	--	--	--	--	--	--	--	.05	--	128	<1
McCumber Spring	7/12-28A1s	4- 3-74	30	0	4.3	1.6	2.9	1.5	26	.9	.2	.0	.22	17	46	--
	7/13-33Q1s	4-24-74	70	0	10	4.0	4.0	.6	54	.8	1.0	.0	--	41	86	--
		7-10-74	--	--	--	--	--	--	--	--	--	--	.08	--	90	<1
	7/14-9D1s	9-10-74	--	--	--	--	--	--	--	--	--	--	.03	--	80	<1
Bup Spring	8/12-15G1s	6-13-74	20	0	5.3	2.2	3.0	.7	36	.9	.8	.0	--	22	60	--
		7- 9-74	--	--	--	--	--	--	--	--	--	--	.01	--	61	<1
	8/12-27L1s	7-15-74	120	0	5.7	1.1	2.8	2.4	38	.3	.5	.1	.06	19	60	<1
Lyon Spring	8/13-13J1s	9-10-74	--	--	--	--	--	--	--	--	--	--	.01	--	68	<1
	8/14-12Q1s	8-14-74	--	--	--	--	--	--	--	--	--	--	.07	--	51	<1
Coyote Spring	8/15-20B1s	8-14-74	--	--	--	--	--	--	--	--	--	--	.04	--	63	<1
Vessey Springs	8/15-34N1s	8-13-74	--	--	--	--	--	--	--	--	--	--	.01	--	46	<1
	9/11-11K1s	8-12-74	--	--	--	--	--	--	--	--	--	--	.03	--	45	<1
	9/12-35B1s	6-13-74	120	0	5.5	2.4	3.6	.9	39	1.8	.9	.0	--	24	64	--
		7- 9-74	--	--	--	--	--	--	--	--	--	--	.00	--	76	<1
	9/12-35R1s	9- 9-74	--	--	--	--	--	--	--	--	--	--	.03	--	102	<1
	9/13-3F1s	9-10-74	--	--	--	--	--	--	--	--	--	--	.02	--	74	<1
	9/13-18P1s	9-12-74	23,000	760	97	86	150	16	951	2.2	92	.3	.01	600	1,800	<1
	9/13-23J1s	9- 9-74	--	--	--	--	--	--	--	--	--	--	.14	--	55	<1
	10/11-19L1s	7-15-74	40	0	2.1	.6	.8	.6	10	1.5	.7	.1	.05	8	20	<1
Soda Spring	11/12-24L1s	8-15-74	19,000	370	120	78	130	2.2	806	2.6	150	.2	.00	620	1,500	<1
	11/13-3E1s	9- 5-74	110	0	5.3	1.7	3.1	2.6	38	.6	1.0	.1	.17	20	68	3
	11/13-4K1s	9- 5-74	70	0	2.7	.4	100	3.5	279	.8	1.0	.5	.02	8	440	<1
	11/13-4K2s	9- 5-74	--	--	--	--	--	--	--	--	--	--	.02	--	95	3
	11/13-29M1s	8-15-74	--	--	--	--	--	--	--	--	--	--	.01	--	84	<1
	11/13-33M1s	8-15-74	--	--	--	--	--	--	--	--	--	--	.04	--	100	<1
	12/13-27F1s	9- 5-74	--	--	--	--	--	--	--	--	--	--	.25	--	31	<1
	12/13-35M1s	9- 5-74	--	--	--	--	--	--	--	--	--	--	.08	--	50	<1

TABLE 11.--Chemical analyses of surface water, Klickitat River basin

[Values are averages for each constituent]

Station number in figure 4	Station name	Milligrams per litre									Specific conductance (micromhos at 25 °C)	Fecal-coliform bacteria (colonies per 100 ml)	Number of samples
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrite plus nitrate as N	Hardness (Ca,Mg)			
14108200.	Klickitat River below Soda Springs Creek	5.1	2.0	3.1	1.2	32	2.4	1.1	0.04	21	56	5	4
14109000.	Big Muddy Creek	4.1	1.8	3.0	1.5	22	7.2	.8	.04	18	54	<1	4
14110480.	Trout Creek	5.4	2.2	3.0	.8	38	1.2	.6	.02	23	62	2	2
14110490.	Elk Creek	4.8	2.5	3.6	.9	39	1.4	1.1	.01	22	72	1	2
14110720.	Outlet Creek above Outlet Falls	3.9	2.2	2.7	.9	30	2.1	.8	.02	19	50	34	4-6
14110800.	White Creek	7.7	4.4	5.2	1.0	58	1.0	1.0	.02	38	97	2	2
14111100.	Summit Creek	5.6	3.2	3.1	.8	41	1.3	.9	.12	27	68	7	2
14111500.	Klickitat River near Dead Canyon	4.8	2.4	5.0	1.3	38	1.8	1.0	.05	22	63	14	2