Geology and Ground-Water Resources of the Ahtanum Valley, Yakima County, Washington

By BRUCE L. FOXWORTHY

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By Bruce L. Foxworthy

ABSTRACT

The Ahtanum Valley covers an area of about 100 square miles in an important agricultural district in central Yakima County, Wash. Because the area is semiarid, virtually all crops require irrigation. Surface-water supplies are inadequate in most of the area, and ground water is being used increasingly for irrigation. The purpose of this investigation was the collection and interpretation of data pertaining to ground water in the area as an aid in the proper development and management of the water resources.

The occurrence and movement of ground water in the Ahtanum Valley are directly related to the geology. The valley occupies part of a structural trough (Ahtanum-Moxee subbasin) that is underlain by strongly folded flow layers of a thick sequence of the Yakima basalt. The upper part of the basalt sequence interfingers with, and is conformably overlain by, sedimentary rocks of the Ellensburg formation which are as much as 1,000 feet thick. These rocks are in turn overlain unconformably by cemented basalt gravel as much as 400 feet thick. Unconsolidated alluvial sand and gravel, as much as 30 feet thick, form the valley floor.

Although ground water occurs in each of the rock units within the area, the Yakima basalt and the unconsolidated alluvium yield about three-fourths of the ground water currently used. Wells in the area range in depth from a few feet to more than 1,200 feet and yield from less than 1 to more than 1,000 gallons per minute.

Although water levels in water-table wells usually are shallow—often less than 5 feet below the land surface—levels in deeper wells tapping confined water range from somewhat above the land surface (in flowing wells) to about 200 feet below. Wells drilled into aquifers in the Yakima basalt, the Ellensburg formation, and the cemented gravel usually tap confined water, and at least 12 wells in the area flow or have flowed in the past. Ground-water levels fluctuate principally in response to changes in stream levels, variations in the flow of irrigation ditches and in rates of water application, variations in local precipitation, and seasonal differences in withdrawals from wells. Annual fluctuations of levels generally are less than 10 feet except in localities of heavy pumping. Periodic measurements of water levels in two observation wells in the area indicate, locally at least, a persistent decline in artesian pressures in confined basalt aquifers, although the record is too short to show whether withdrawal by pumping has reached, or is nearing, an optimum balance with recharge.

The aquifers are recharged by precipitation, by infiltration from streams, and by ground-water underflow into the area. Ground water is discharged by seepage to streams, by evapotranspiration, by springs and seeps at the land surface, and, artificially, by withdrawal from wells. It is estimated that the seepage discharge to the Yakima River from the area studied may range from about 20,000 to 25,000 acre-feet per year. The consumptive waste of ground water by phreatophytes probably exceeds 4,000 acre-feet per year and may represent a large reclaimable source of water in the area. The annual withdrawal of ground water from wells in the area for domestic, industrial, irrigation, public, and stock supplies is estimated to be 6,300 acre-feet.

The chemical quality of the ground water generally is satisfactory for most purposes, although the water from many wells is harder than is desirable for domestic use.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The surface-water supplies that usually are available for irrigation in the Ahtanum Valley during the growing season are inadequate for the full development of the agricultural potential of the area. About 60 percent of the irrigable land in the area is irrigated entirely with surface water, but only about 15 percent receives an amount considered adequate throughout the growing season. An additional 10 to 15 percent of the irrigable land is, or has been, irrigated partly or entirely with ground water. Hence, although ground water does not now constitute a major part of the total irrigation water used, the acreage that has been supplied by ground water is nearly as large as that for which adequate supplies of surface water are available. Because the surface-water resources of the area are completely apportioned, future agricultural development of the area will depend largely upon the availability and proper utilization of ground water, even though the efficiency of surface-water utilization might be improved. Ground water also provides virtually all the water now used for domestic, industrial, and municipal purposes; hence, its availability could be a limiting factor in future population growth and industrial development within the area.

The purpose of this investigation was the collection and interpretation of data pertaining to ground water in the Ahtanum Valley in order to aid in the proper development and management of the water resources. Special consideration has been given to the source and movement of the ground water, its availability throughout the valley, its hydraulic relation to the streams, and its suitability for domestic and irrigation use.

The occurrence of underground water in any area is controlled by the character, distribution, and structure of the rocks and is influenced by the climate and the drainage pattern of the area. Therefore, discussions of the geology, landforms, climate, and drainage in the Ahtanum Valley, and their relation to the occurrence of ground water in the area, are included in this report.

The report is based largely upon fieldwork done by the writer between April 1951 and July 1952. During that time, wells were canvassed and well logs and hydrologic data were gathered. A network of observation wells was established, in which water levels were measured periodically. Detailed geologic mapping was done on aerial photographs.

In 1953, during the course of this investigation, the writer prepared a brief report on ground water in the lower Ahtanum Valley (Foxworthy, 1953), at the request of, and under cooperative financing with, the State of Washington's Department of Conservation, Division of Water Resources. Many of the data presented in that report are included herein, although the area covered and the scope of the present report are much broader than those of the earlier report.

This study is part of a continuing program of the U.S. Geological Survey for the collection and interpretation of information bearing on the Nation's ground-water resources. It was conducted under the supervision of M. J. Mundorff, former District Geologist of the Ground Water Branch of the Geological Survey for the State of Washington.

LOCATION AND EXTENT OF THE AREA

The area of this investigation is the Ahtanum Creek valley, in central Yakima County (fig. 1). The area extends from the Yakima River westward for 21 miles and ranges in width from 6 miles at the west end to about 3 miles in the eastern part. It constitutes the southwestern part of the Ahtanum-Moxee subbasin. The total area mapped is about 100 square miles.

The center of the area is about 11 miles west-southwest of Yakima, which is the county seat of Yakima County and the largest commercial center in south-central Washington. The southern side of the valley, south of Ahtanum Creek, is part of the Yakima Indian Reservation.

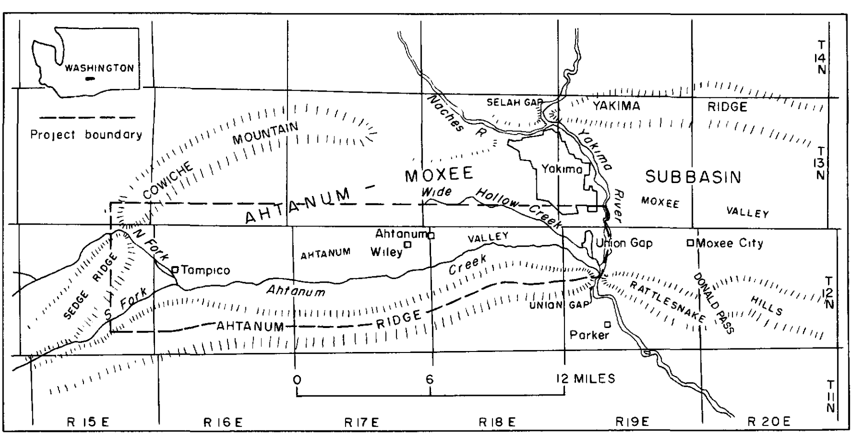

FIGURE 1.—Map of the Ahtanum-Moxee subbasin, Yakima County, Wash., showing location of study area.

Because there is virtually no farming, and consequently little ground-water use in the mountain valleys drained by the upper reaches of the North and South Forks of Ahtanum Creek, these areas were not included in the investigation.

PREVIOUS INVESTIGATIONS

In 1893, I. C. Russell made a preliminary investigation of the geologic features of central Washington to ascertain whether the region was favorable for a supply of artesian water for irrigation. In his description of what is called in this report the Ahtanum-Moxee subbasin, Russell presented well logs and descriptions of some of the pioneer wells in Yakima County.

A more detailed study of part of Yakima County, including the Antanum-Moxee subbasin, was made by G. O. Smith (1901), who described the main geologic features, the general conditions affecting ground water, and the flowing artesian wells in the subbasin.

Smith (1903) also mapped the geology of the Ellensburg quadrangle, which covers an area of 820 square miles and includes the Ahtanum Valley. In his description of the quadrangle, Smith treated in detail the rock units and geologic structure of the Ahtanum Valley and included a general evaluation of ground-water resources in the Yakima area.

In 1943 a short report on the ground water of the Ahtanum Valley was completed by S. N. Twiss of the Soil Conservation Service, U.S. Department of Agriculture. Twiss differentiated a rock unit that had not been recognized as a separate unit by earlier workers, and he described the water-yielding potentialities of the various rock materials in the valley.

In 1954, J. E. Sceva completed a report evaluating the streamflow records from the Yakima basin, including the Ahtanum Valley, with regard to possible subsurface flow of water past stream-gaging stations. The report contains descriptions of the rock units and the larger structural features in the Yakima basin, and of their influence on the hydrology of the region; discussions of the various subbasins, including the Ahtanum-Moxee subbasin, and the utilization of water within them; descriptions of the geologic conditions at each gaging station; a generalized geologic map and a section along the Yakima River; and detailed geologic sections at the sites of gaging stations.

The geology of the Yakima East quadrangle, which includes the eastern 1½ miles of the lower Ahtanum Valley, and of the adjacent Moxee Valley was mapped and described in detail by A. C. Waters (1955). Although Waters' report is concerned primarily with the area east and northeast of the Ahtanum Valley, it provides an excellent description of the rock units and geomorphology of the region.

Because all these publications deal with the area herein considered, they have been consulted frequently during this investigation.

ACKNOWLEDGMENTS

The fieldwork and preparation of this report were greatly facilitated by the assistance of many persons. Well owners, operators, and drillers provided many of the well data included in this report. Special acknowledgment is given to the owners who allowed their wells to be used for water-level observations and for aquifer tests. The Rankin Equipment Co., of Yakima, contributed many records of pumping tests. Mr. J. L. Dobie furnished information and collaborated in the collection of fossils. Vertebrate fossils from the collection of the State College of Washington have proved extremely valuable in the assignment of ages for the rock units; appreciation is expressed to Mr. Harold E. Culver for the use of his lucid field notes, and to Mr. W. Frank Scott for his help in making the fossils available for examination. The cooperation of personnel of the State Division of Water Resources in supplying well records and comments on this report also is gratefully acknowledged. Assistance given by members of the Geological Survey includes the identification of invertebrate fossils by Mr. T. C. Yen and identification of vertebrate fossils by Miss Jean Hough.

WELL-NUMBERING SYSTEM

Well numbers used in this report are based on and show locations of wells according to the rectangular system for subdivision of public land, indicating township, range, section, and 40-acre tract within the section. For example, in the well number 12/17–9J1, the part preceding the hyphen indicates successively the township and range

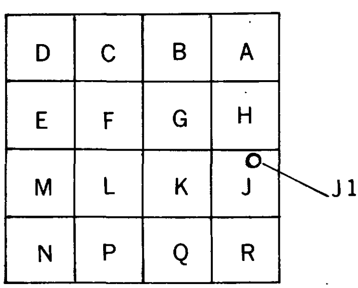

FIGURE 2.—Diagram showing well-numbering system.

(T. 12 N., R. 17 E.) north and east of the Willamette base line and meridian. The first number following the hyphen indicates the section (9), and the letter (J) gives the 40-acre subdivision of the section as shown in figure 2. The last number is the serial number of the well (1) in that particular 40-acre tract. Thus, the first well recorded in the NE¼SE¼ sec. 9, T. 12 N., R. 17 E., would have the number 12/17–9J1, and the second well would have the number 12/17–9J2.

GEOGRAPHY

LANDFORMS

The Ahtanum Valley descends eastward from the foothills of the Cascade Mountains to the Yakima River. It is one of several structurally controlled eastward-trending valleys in the central Yakima basin. In general, the valley has steep sides, a relatively flat floor, and considerable downvalley slope. Altitudes within the area range from about 940 feet at the Yakima River to about 4,100 feet at the crest of Cowiche Mountain.

The major landforms of the area are directly related to the geologic structure. The valley itself occupies the southwestern part of the Ahtanum-Moxee subbasin, which is a structural trough, or syncline (fig. 1). The ridges that border the area on the south, west, and northwest are formed by structural upfolds, or anticlines.

The valley is bordered on the south by Ahtanum Ridge, a narrow, even-crested anticlinal ridge that rises about 1,000 feet above the valley floor and locally exceeds 2 miles in width. It extends eastward from the irregular and deeply eroded Cascades some 40 miles to the Yakima River. Its eastward extension, beyond the Yakima River, is known as the Rattlesnake Hills. The Yakima River, flowing southward across the axis of the ridge, has eroded a narrow, steep-walled gorge called Union Gap, for which the nearby town is named.

Sedge Ridge and Cowiche Mountain are similar to Ahtanum Ridge, though somewhat higher. They are the topographic expression of the Sedge Ridge–Cowiche Mountain anticline and form the west and northwest boundaries of the Ahtanum-Moxee subbasin.

Discussions of ground water in the area may be related effectively to the valley's three main physiographic sections, herein termed the lower valley, the upper valley, and the upland benches.

The lower valley includes the broad valley floor along the lower, or eastern, reach of Ahtanum Creek and the adjacent lower slopes of Ahtanum Ridge. For a distance of approximately 6 miles west of the Yakima River, the lower valley floor has no marked natural boundary on the north. This part of the valley floor is a southern continuation of a broad alluvial plain that extends southwestward from Yakima. Farther west, however, the lower valley is bordered on the north by a moderately dissected terrace remnant that rises, at places, more than 100 feet above the valley floor. The lower valley floor is about 1 to 2½ miles wide and has a relatively flat cross-valley (north-south) profile. The downvalley (easterly) gradient of the lower valley floor ranges from about 36 to 75 feet per mile and averages 52 feet per mile.

Fourteen miles west of the Yakima River, the valley floor is sharply constricted by resistant lava rock which forms low bluffs and vertical cliffs along both sides of Ahtanum Creek for a distance of 3 or 4 miles. In this constriction, locally called the Narrows, the valley floor is less than half a mile wide. Upstream from the Narrows, the valley floor widens somewhat, although it is less than a mile wide at its widest point, in the vicinity of Tampico. The upper valley, as described in this report, comprises the Narrows and the valley floors to the west, including those of the North and South Forks of Ahtanum Creek for distances of about 4 and 3 miles, respectively, upstream from their confluence.

The upper valley is sharply delimited by steep banks and bluffs that rise to well-defined upland benches on the north and south sides of the valley floor and on the west between the North and South Forks of Ahtanum Creek. In general, these upland benches are terrace remnants formed between bedrock valley walls and overlying irregularities in the upper surface of the underlying bedrock. The benches adjacent to the valley floor slope upward toward the margins of the basin, merging with the alluvial fans and pediment slopes along the flanks of the anticlinal ridges.

The upland bench on the north side of the valley locally is more than 200 feet above the valley floor. It extends eastward beyond the Narrows and merges with the terrace remnant that separates the lower Ahtanum Valley from Wide Hollow. This terrace gradually diminishes in height toward the east and dies away near the center of the lower valley.

The bluffs and slopes on both sides of the valley have been moderately gullied by small, intermittent streams. From the mouths of the gullies and ravines, fan-shaped deposits of gravel have been built out onto the edges of the valley floor. On the south side of the lower valley, these alluvial fans coalesce to form a continuous, undulating slope along the base of Ahtanum Ridge.

DRAINAGE

The most important stream in the area is Ahtanum Creek, a perennial stream which flows eastward through the entire length of the Ahtanum Valley and enters the Yakima River at Union Gap. Wide Hollow Creek, which flows southeastward across the east end of the lower valley and enters the Yakima River less than half a mile above the mouth of Ahtanum Creek, also is a perennial stream, although its flow is largely supported during the summer months by waste water from irrigation outside the area.

The Ahtanum Creek drainage area covers about 171 square miles, almost half of which lies to the west of the area studied, on the high, well-dissected east slope of the Cascades. This headwater region is drained by the North Fork and South Fork of Ahtanum Creek, which converge near Tampico to form the main stream. Gradients along Ahtanum Creek range from 36 feet per mile near Union Gap to more than 100 feet per mile along the North and South Forks above Tampico.

The drainage pattern in the area mapped is closely controlled by the structure of the underlying rocks. Ahtanum Creek and its South Fork follow the axis of the structural trough that forms the Ahtanum Valley, whereas the North Fork, after following a course paralleling the Sedge Ridge-Cowiche Mountain anticline, turns directly across that upfold. Also, because the geologic structure closely controls the topography, most of the intermittent streams in the area flow generally in the direction of dip of the underlying rocks.

In the lower valley Ahtanum Creek splits into three main courses which converge again into one main stem before leaving the area. At some places these natural distributaries have been incorporated into a complex system of canals used to irrigate that part of the valley. During the summer the water of Ahtanum Creek is diverted for irrigation and returned to the main channels of the creek several times in its course between Tampico and the Yakima River.

CLIMATE

The climate of the Ahtanum Valley is of the continental semiarid type characteristic of southeastern Washington. Summer days are clear, hot, and dry, and the nights usually are cool. Winters are comparatively wet and cloudy and have occasional periods of cold.

Precipitation and perhaps other weather conditions in the region vary substantially with elevation and with proximity to the Cascade Mountains. Because these factors differ considerably from place to place within the Ahtanum Valley, observations made at one place may not relate directly to weather conditions in other parts of the area. For this reason, and to provide supplemental information not available from the area itself, climatological data from four weather stations in the Yakima basin are included herein. Weather observations made at the U.S. Weather Bureau station at the Yakima Airport doubtless apply over much of the lower Ahtanum Valley. A weather station at Rimrock, about 15 miles northwest of Tampico, is about 1,700 feet higher and some 30 miles closer to the crest of the Cascades than the Yakima station. Data from the Rimrock station probably are indicative of weather conditions over much of the headwaters area of

Ahtanum Creek, and the climate in the upper Ahtanum Valley probably is intermediate between climatic conditions at the Rimrock and Yakima stations. At a weather station at White Swan, 16 miles southwest of the Yakima Airport and at about the same elevation, only temperature and precipitation data are recorded. These data compare very closely with similar data for Yakima. Evaporation data, which are not available for the Yakima station, have been obtained from a station near Prosser. The Prosser station is about 45 miles southeast of Yakima, in an area climatologically similar to the lower Ahtanum Valley.

Figure 3 shows the mean monthly precipitation at three stations, Rimrock, White Swan, and Yakima, all in or near the Ahtanum Valley. The records indicate that more than half the precipitation in the Yakima region occurs during the 4 months from November through February. December is the wettest month of the year and July is the driest. There is a tendency (at 2 of the 3 stations) for June to be wetter than either April or May, largely because of occasional thunderstorms.

Figure 3 also indicates a general relationship between precipitation and altitude. For example, at the Yakima station, 1,061 feet above sea level, the mean annual precipitation is 7.21 inches, whereas at Rimrock, 2,730 feet above sea level, the mean is 26.2 inches. Although no climatological data are available for the upper valley, this relation-

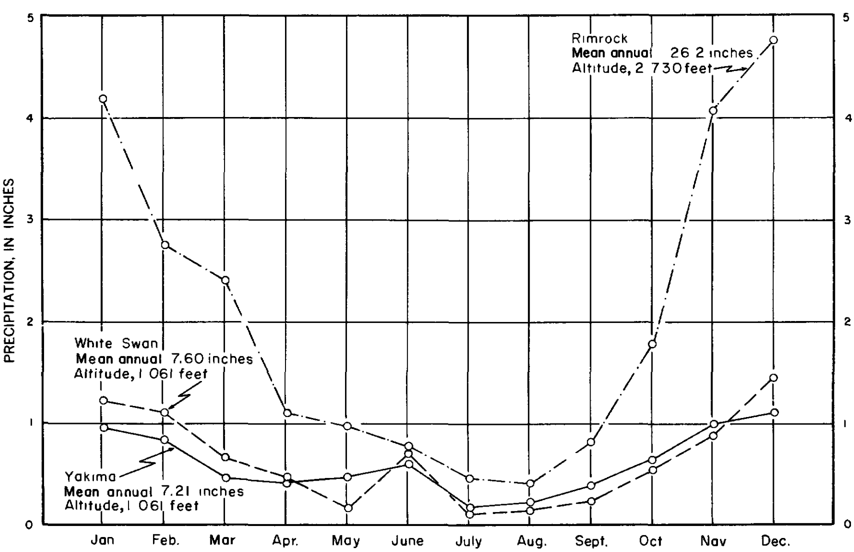

FIGURE 3.—Mean monthly precipitation at three stations in and near the Ahtanum Valley. (From U.S. Weather Bureau records.)

ship suggests that at Tampico, at about 2,120 feet, a mean of about 15–18 inches might be expected.

The annual precipitation at the Yakima station from 1910, the first year of record, to 1956 is shown in figure 4. As the figure shows,

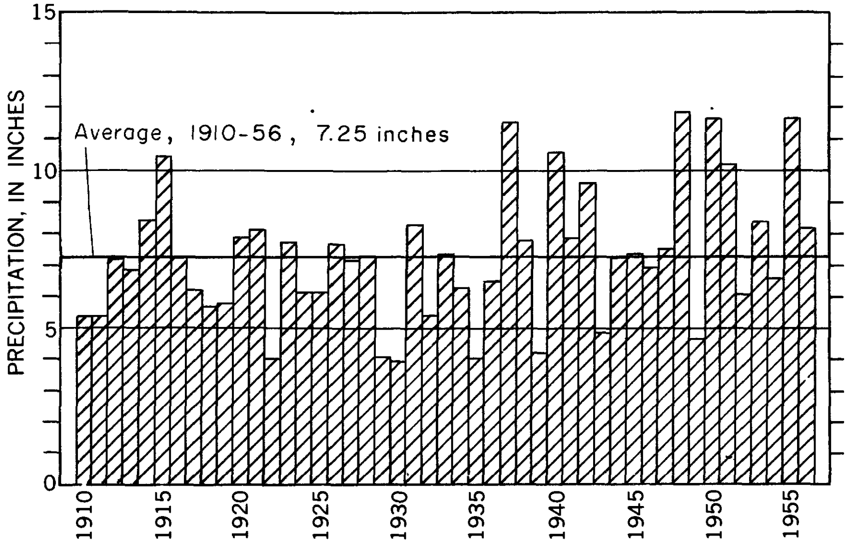

FIGURE 4.—Graph showing annual precipitation at Yakima during the period 1910–56. (Data from U.S. Weather Bureau records.)

there has been considerable variation in annual precipitation during the 47-year period. The least amount, 3.90 inches, fell in 1930; the greatest amount, 11.87 inches, in 1948. However, the annual precipitation was less than 6 inches in only 12 of the years of record (about 1 year in 4), and exceeded 9 inches in only 8 years (about 1 year in 6). The annual precipitation during 1917–36 averaged about 1 inch less than the long-term mean, a deficiency of about 14 percent per year. During 1937–56, the annual precipitation averaged about 1 inch more than the long-term mean.

Snowfall data from the Yakima station, not presented herein, indicate that about one-fifth of the annual precipitation at that station falls as snow.

Temperatures in the Ahtanum Valley are relatively mild, but the area occasionally has extremely high and low temperatures. Weather Bureau records show that, although the average temperature at Yakima during the period of record was 50.2° F, a high of 111° F (July 1928) and a low of −25° F (February 1950) have been observed. July is the warmest month and January is the coolest. The mean temperatures at the Yakima station for those months are 71.4° F and 26.9° F.

The regional movement of air generally is from the west and southwest; however, because of the effect of the topography of the Ahtanum Valley, the wind comes from the west or northwest during most of the year. Winds are mostly light; wind speed at the Yakima station averages 5.6 miles per hour.

The average relative humidity is comparatively high in winter, moderate to low during most of the year, and very low in summer afternoons and evenings. At the Yakima station the monthly relative humidity is highest, 81 percent, in December. It is lowest, 41 percent, in July.

Evaporation in the Ahtanum Valley is great during the months of low humidity. No evaporation data are available for the Yakima station, but those for a class A Weather Bureau land pan at a weather station near Prosser, in the lower Yakima Valley about 45 miles southeast of Yakima, probably are representative of the Ahtanum Valley. Average monthly pan evaporation at the station near Prosser during the period 1948–56, in inches, is as follows: March, 2.61; April, 4.35; May, 5.64; June, 6.58; July, 7.56; August, 6.29; September, 4.29; October, 2.09; and November, 0.75.

The average growing season at the Yakima station is 193 days. The average dates of the last killing frost in spring and the first in fall are April 13 and October 23, respectively. This growing season and its limits probably apply over most of the lower Ahtanum Valley. The growing season in the upper valley is shorter, but its length probably is closer to the Yakima average than to the 111-day average recorded at Rimrock.

VEGETATION

Vegetation in the area reflects the areal range of climatic conditions. In the eastern part, the slopes and ridges are generally treeless, and in their native condition they are covered with sagebrush and associated desert shrubs and grasses. Trees are more abundant closer to the high Cascades, and extensive thick groves of yellow pine, fir, cedar, and mountain hemlock grow in the headwaters area. However, except in the extreme western part of the area, conifers are rare. One of the most abundant trees in the upper valley is the scrub white oak, which grows in dense thickets along stream courses and in ravines west of the Narrows.

Cottonwood, willow, and associated water-loving plants (phreatophytes or "well-plants") grow in belts and clumps along streams and in marshy parts of the valley floor. These phreatophytes grow only

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in areas where their roots can be sent down to the water table or to some other secure, perennial supply of water. The consumptive use of ground water by the phreatophytes is an important factor in the study of water resources of the Ahtanum Valley and is discussed in a subsequent part of this report.

CULTURE AND INDUSTRY

Union Gap is the only incorporated city in the area; in 1950 it had a population of about 1,800. The remainder of the population is scattered throughout the valley or centered around the three small communities of Ahtanum, Tampico, and Wiley. Probably less than one-tenth of the valley's population lives south of Ahtanum Creek, on the Yakima Indian Reservation.

Although there is some manufacturing in and near Union Gap, the principal industries in the valley are agriculture, animal husbandry, and the processing of agricultural products. Fruit of the finest quality is grown and processed within the area. Hops are an important crop, and much hay is grown throughout the valley. Sheep and beef cattle graze in the uplands during the open seasons of the year and are wintered in the valley.

Some grain has been grown on the upland by dry-farming methods, but most of the crops in the Ahtanum Valley require irrigation during at least part of the growing season. In the valley, most of the water supply developed as of 1958 is used for these irrigation needs.

HISTORY OF WATER USE

The first known irrigation in the Ahtanum Valley began about 1864 (Kinnison, 1952, p. 3). At that time, and for many years thereafter, the magnitude of irrigation was small and the surface-water supplies were more than adequate to irrigate the developed lands of both the settlers north of Ahtanum Creek and the Yakima Indians south of the creek. However, continued development of irrigable land, with the accompanying need for more water, subsequently led to a series of legal acts aimed at apportioning the water resources of the area and regulating their use for irrigation.

The first of these acts was an agreement in 1908 between the Yakima Indian Nation and the non-Indian water users,[1] wherein one-quarter of the total surface inflow of Ahtanum Creek was allotted to the lands of the Yakima Indian Reservation, south of Ahtanum Creek, and three-quarters to the lands north of the Creek.

[1] Agreement of May 9, 1908, between U.S. Indian Bureau and W. W. Clidden et al., representing users of water from Ahtanum Creek. Approved June 30, 1908, by Franklin Pierce, First Assistant Secretary of the Interior.

By an adjudication decree in 1925,[2] the tracts of land north of Ahtanum Creek were assigned water rights according to preexisting irrigation usage. These water rights are ranked according to classes numbered from 1 to 32, the lower numbers representing the more generous allotments. According to Wallace Owen, stream patrolman for the Ahtanum Valley, the lands having water right numbers 1 to 4 are usually assured adequate surface water for irrigation, but lands having water rights numbered higher than about 8 receive little or no surface water for irrigation after the middle of July. No supervised apportionment of the surface water is made until the summer flow of Ahtanum Creek no longer supplies all the irrigation demands. As the flow of the creek diminishes in early summer, surface irrigation water for the higher numbered water rights is decreased gradually, class by class, until toward the end of the irrigation season only the lower numbered classes receive surface water. Those landowners who in the past have planted crops requiring more water than they could obtain from their surface-water rights have been obliged to obtain the extra water by buying or leasing water rights or by developing ground-water supplies. Mr. Owen reported (oral communication, August 1951) that the water shortage has been considerably relieved by the greater development of ground-water supplies in recent years, even though more land has been put under irrigation during that time.

In 1945 the State of Washington established a ground-water code (Washington State legislature, 1945) requiring permits for the withdrawal of ground water in excess of 5,000 gpd (gallons per day). The regulation of ground-water withdrawals is designed to prevent the indiscriminate and wasteful development of this valuable resource.

In 1957 the validity of the aforementioned 1908 agreement was challenged by the U.S. Bureau of Indian Affairs. In the resulting lawsuit[3] the Bureau of Indian Affairs petitioned for a higher proportion of the surface-water inflow than the 25 percent provided for in the original agreement. The decision on this lawsuit was pending when this report was written. A judgment for the Bureau of Indian Affairs would necessitate the development of additional irrigation supplies to replace surface water diverted from the non-Indian lands, and probably would result in accelerated development of additional ground-water supplies in the area.

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[2] *State of Washington* v. *Annie Achepohl et al.*, Cause No. 18279, Superior Court of the State of Washington, Yakima County.

[3] *United States* v. *Ahtanum Irrigation District et al.*, Civl. cause No. 31?, United States Dist. Court, Eastern Dist. of Washington, Southern Div.

GEOLOGY

DESCRIPTION OF THE ROCK UNITS

YAKIMA BASALT

The oldest and most prominent rock unit exposed in the Ahtanum Valley is the Yakima basalt. This formation is composed of a sequence of basaltic lava flows several thousand feet thick, interbedded with a few minor sedimentary strata. It is the basal rock unit, or bedrock, of the Yakima region, and in the lower Ahtanum Valley and many other places the top of the formation is hundreds of feet below the land surface. The basalt is quite resistant to erosion and weathering and is a notable cliff-forming rock. Arched strata of basalt form the highest ridges of the region, including Ahtanum Ridge, Sedge Ridge, and Cowiche Mountain.

The basalt is a dense rock, having a texture so fine that most of the individual crystals cannot be seen by the unaided eye. Fresh, unweathered surfaces are black or dark gray; weathered surfaces range in color from gray to reddish brown. According to Warren (1941, p. 802) the basalt consists principally of small crystals of calcic labradorite, pyroxene, and olivine in a dense matrix of sodic labradorite, augite, and volcanic glass. Magnetite and apatite are common accessory minerals. Calcite, siderite, zeolites, opal, and chalcedony are common in veins and vesicles in the basalt.

Individual flow layers in the Yakima basalt range from less than 20 to more than 200 feet in thickness, and individual flows may differ considerably in thickness from place to place. The thicker flows, especially in their basal parts, exhibit a characteristic jointing that forms well-developed prismatic columns at right angles to the upper and lower surfaces of the flow layers. Subsequent jointing has divided many of the columns into closely spaced plates or irregular blocks. In the upper parts of the thicker flows, and in the thinner flows, the jointing may be predominantly irregular or platy. The abundance and configuration of jointing vary greatly from flow to flow and may even change abruptly in short distances within the same flow. Usually the joints are most abundant at the top of a flow and decrease in number toward the base. However, in areas of strong folding, such as along the north side of Ahtanum Ridge, there are zones of extreme shattering that apparently extend from base to top across the flow layers.

The upper parts of many of the lava flows are characterized by zones of abundant gas cavities (vesicles) which give the rock a spongy appearance. These vesicles were formed by bubbles of gases that issued from the molten lava as it solidified. At places the vesicles have been partly or completely filled with secondary minerals deposited by water percolating through the rocks. Generally, however, except where the vesicular zones have been fractured or deeply weathered, the vesicles are separated from each other by the encasing solid rock.

Enough time elapsed between extrusion of some lava flows to allow considerable weathering, and thin soil zones developed at places on top of the basalt and were buried by subsequent flows. One buried soil zone more than a foot thick can be seen in a small basalt quarry on the north slope of Ahtanum Ridge, due south of Wiley (SE¼NE¼ sec. 23, T. 12 N., R. 17 E.). Generally, weathering did not affect the basalt deeper than a few feet below the upper surfaces of the flows. It is the upper parts of certain flows, rendered relatively permeable by weathering, jointing, and (in conjunction with these processes) vesicularity that constitute the principal water-bearing zones in the basalt sequence.

The base of many flows is a layer of dense black volcanic glass, usually less than half an inch thick, which is the result of a quick chilling of the first part of the basalt flow as it came in contact with the cooler surface below.

The total thickness on the basalt in the Yakima area has not been determined, for no wells have penetrated to the rocks beneath. However, it is at least 2,000 feet at Union Gap. An oil test well (12/19–17C1) was drilled in that gorge to an approximate depth of 3,800 feet, almost entirely in basalt (table 5). The well was drilled through steeply dipping flow layers; consequently, for most of its depth the well penetrates the flow layers diagonally, and it may even follow the dip of the flows for a considerable distance at depth. However, the total penetration of the well is almost certainly equivalent to more than 1,000 feet stratigraphically—that is, across the flow layers. As there is also about 1,000 feet of basalt exposed in and above the gorge, the basalt sequence must be at least 2,000 feet thick at Union Gap and probably is much thicker.

In the western part of the Ahtanum Valley, the upper 2 or 3 lava flows (total thickness about 250 feet) are separated from the main body of the basalt by a discontinuous member or tongue of the overlying Ellensburg formation. The upper, separated group of flows is similar in appearance, thickness, and stratigraphic position to the Wenas basalt member of the Yakima (previously the Wenas basalt of formation rank) which is exposed at Selah Gap. Although these 2 basalt units may be equivalent, no method of definite correlation has been found because at other places in the region, 1 layer, and possibly 2, of sedimentary rocks similar in appearance and lithology to the Ellensburg formation are interbedded with lava flows in the upper part of the basalt sequence (Mackin, 1947; Waters, 1955, p. 670–672).

The name Yakima basalt is applied locally to the thick sequence of basaltic lava flows underlying southeastern Washington and extending into Oregon and Idaho; elsewhere this sequence is known as the Columbia River basalt. The name was applied by Smith (1901) to that part of the Columbia River basalt that poured out in the Yakima region during the Miocene epoch. The age assignment was made on the basis of fossil plants in the Manastash formation (Eocene), which underlies the Yakima basalt in the vicinity of Cle Elum, Wash., and fossil plants in the overlying Ellensburg formation, which were first assigned an age of late Miocene (Russell, 1893, p. 103). Subsequent workers have assigned an age of Miocene or early Pliocene, and Pliocene, to the Ellensburg formation.

In 1952 an assemblage of fossil fresh-water mollusks was collected from large blocks of loose debris high on the northwest flank of Sedge Ridge, in a locality some 4½ miles west of Tampico (NE¼SW¼ sec. 16, T. 12 N., R. 15 E.). The enclosing material, once an alluvial sand, has been altered to a tan or rusty-brown highly resistant richly fossiliferous quartzite. It can be traced for about half a mile in a band roughly parallel to the strike of the basalt flows of Sedge Ridge. Although the contact of the fossiliferous material with the basalt was not seen, apparently being covered by slope wash, the material almost certainly is a minor interflow deposit near the top of the sequence of basalt flows. Mr. T. C. Yen of the U.S. Geological Survey has identified the fossils (*Sphaerium*, sp. undet.; *Viviparus* cf. *V. leiostracta* Brusinia; *Fluminicola* cf. *F. williamsi* (Hannibal); *Goniobasis* cf. *G. kettlemanensis*), and he listed their age as probably Pliocene. This new evidence indicates that at least the latest flows of the Yakima basalt may have poured out during the Pliocene epoch.

ELLENSBURG FORMATION

The Yakima basalt is overlain by the Ellensburg formation, which consists of several hundred feet of semiconsolidated clay, silt, sand, and gravel. In the Ahtanum Valley, rocks of the Ellensburg formation underlie the gravels of the upland benches in the vicinity of the Narrows and crop out in bands along the slopes of Ahtanum Ridge and Sedge Ridge. In general, the formation is easily eroded, and over much of the uplands it has been entirely stripped away from the underlying basalt.

A somewhat unusual topography has been developed on the south side of the lower valley by differential erosion of the sedimentary rocks. Headward erosion by northward-flowing intermittent streams has formed a number of steep, narrow canyons in the north flank of the anticlinal Ahtanum Ridge, creating well-defined spur ridges that extend northward from the main ridge. The bases of these spur ridges are formed in the resistant basalt of Ahtanum Ridge, the central parts in steeply dipping beds of the Ellensburg formation, and the noses in moderately resistant cemented gravel. As a result of differential erosion, most of the spur ridges terminate in knobs consisting of this resistant cemented gravel. Saddles occur where the less resistant Ellensburg formation appears at the land surface—for example, between the knobs and the basalt of Ahtanum Ridge.

In appearance and lithology, the Ellensburg formation in the Ahtanum Valley is identical to exposures of the formation in other parts of the Yakima region. It consists of 85 to 95 percent semi-consolidated clay, silt, and sand and only 5 to 15 percent gravel and conglomerate. The color is predominantly gray, tan, and buff, although there are a few relatively thin rusty-brown sand and gravel strata. The clay and silt parts are massive at most places, but excellent bedding and shaly parting also are found. Some sand and gravel strata are crossbedded. The thickness of the individual beds ranges from a few feet to more than 100 feet; strata of clay, silt, and fine sand usually are somewhat thicker than strata of the coarser materials.

The Ellensburg formation is mostly indurated and tough, but some sand and gravel strata are weakly cemented and appear moderately permeable. Cementing material is mostly argillaceous.

The silt and sand are composed chiefly of pumice, volcanic ash, quartz, and scattered feldspar and hornblende particles. Clay-size particles consist mostly of finely divided pumice and ash. The gravel of the Ellensburg formation contains large amounts of tuff and a distinctive purple or gray tuffaceous hornblende andesite. Minor amounts of diorite, quartzite, and various granitic and metamorphic rock types also are found locally in the gravel; basaltic fragments are rare.

In the area mapped, most of the gravel of the Ellensburg formation is found in the lower valley and is best exposed along the north side of Ahtanum Ridge 2 to 3 miles west of Union Gap. In that locality, the gravel includes a wide variety of rock types.

Beneath the upper valley and in the adjacent slopes, a discontinuous layer of the Ellensburg is interbedded with lava flows 250 to 300 feet below the present upper surface of the basalt. This sedimentary bed crops out in a discontinuous band on the lower slopes of Sedge Ridge and along the north flank of Ahtanum Ridge. The same stratum has been reported in the logs of four wells in the Narrows and the upper valley. It is 20 to 30 feet thick in surface exposures and is reported to be 77 feet thick at well 12/16–15F1, about 2½ miles east of Tampico. The bed could not be found on the north side of the valley, and apparently it has been hidden by an overlying body of cemented gravel (pl. 1).

The sedimentary bed apparently pinches out a short distance east of the Narrows, for it could not be traced farther east by surface mapping and has not been reported in the logs of wells east of the Narrows. However, probably only a few of the deeper wells in the lower valley have been drilled deep enough into the basalt to have reached the horizon of the bed.

To show the interbedded Ellensburg material on the geologic map (pl. 1), its thickness has been exaggerated somewhat. Its true thickness is shown in the geologic sections.

A section of about 900 feet of the Ellensburg formation is exposed in sec. 11, T. 12 N., R. 18 E., and well logs indicate that this unit is almost certainly more than 1,000 feet thick beneath the east end of the lower valley floor. At least the lower part of the main body of the Ellensburg formation apparently is conformable with the underlying Yakima basalt. The contact between the Ellensburg formation and the overlying cemented gravel generally is sharp where it is exposed along the north flank of Ahtanum Ridge, where at several places an angular unconformity exists between the two units. However, logs of wells in the lower valley indicate considerable gradation and interbedding of the upper part of the Ellensburg formation and the lower part of the overlying cemented gravel in the center of the subbasin.

Most of the material constituting the Ellensburg formation obviously was derived from a region of intense volcanic activity. Its composition shows that the volcanism that produced it was violently eruptive, as opposed to the slow, quieter extrusions of the Yakima basalt. The source area for the Ellensburg apparently was west of the Yakima region, in the area occupied by the present Cascade Mountains.

Most of the material making up the Ellensburg formation was deposited by streams or in lakes and ponds. However, scattered thin beds of volcanic ash or shards of volcanic glass indicate that at least small amounts fell directly from the sky.

The first determination of the age of the Ellensburg formation was made by F. H. Knowlton (Russell, 1893, p. 103) on the basis of fossil plants, which were classified as belonging to the upper part of the Miocene series. Smith (1903) cited an unpublished report by Knowlton confirming this age determination. Subsequently the Ellensburg formation has been assigned ages of Miocene or early Pliocene (Merriam and Buwalda, 1917, p. 255–256; Beck, 1940).

In 1936, during construction of a tunnel through Yakima Ridge about 6½ miles north of the city of Union Gap, fossil bones were found in sedimentary rocks mapped by Smith (1903) as the Ellensburg formation (NE¼NW¼ sec. 5, T. 13 N., R. 19 E.). Elephant remains were found 8 to 10 feet stratigraphically above the top of the Wenas basalt member, and camel bones were collected from a clay layer about 15 feet below the base of the Wenas member. These fossils subsequently were borrowed from the collection of the State College of Washington and were identified by Miss Jean Hough. In her report on the fossils, Miss Hough states her belief that the possible age of these vertebrate fossils (*Mammut* (*Miomastodon*) *merriami* Osborn, and a large camelid, *Pliauchenia merriami* Frick?) is not younger than late Pliocene and not older than middle Miocene; the balance of evidence being in favor of an early Pliocene age. This age assignment, along with the age determination for the fossils from Sedge Ridge, strongly indicates that the main body of the Ellensburg formation probably was deposited entirely during the Pliocene epoch, and that the Wenas basalt member, and perhaps the uppermost flows of the main body of the Yakima basalt, probably are of early Pliocene age.

CEMENTED BASALT GRAVEL

An extensive body of cemented basalt gravel overlies the older rocks along both sides and throughout the entire length of the Ahtanum Valley. The cemented gravel is moderately resistant to erosion, and it caps, or forms entirely, the upland-bench deposits in the west half of the Ahtanum-Moxee subbasin. It may be wholly or partly contemporaneous with similar gravel bodies in other parts of the Yakima basin. A typical exposure of the cemented gravel may be seen in a small gravel pit at the north base of Ahtanum Ridge, in the SW¼NW¼ sec. 11, T. 12 N., R. 18 E. Smith (1903) mapped the gravel in the Ellensburg formation and did not describe it in detail. On the basis of lithology, structure, and hydrologic properties, however, the cemented gravel should be treated as a separate rock unit.

The gravel unit consists of 75 percent or more cemented basaltic gravel and 25 percent or less sand, silt, and clay in lenses and discontinuous layers. The color ranges from buff and gray to reddish brown and black. The gravel strata usually are massive but may exhibit fair to indistinct bedding. Crossbedding is rare in the gravel but is not uncommon in layers of sand. Pebbles and larger particles generally constitute about 75 percent of the gravel strata, boulders make up only a few percent and the matrix of sand and finer material generally is less than 25 percent. Most of the cobbles and pebbles are moderately well or well rounded; the finer material commonly is more angular.

The cemented gravel differs greatly in lithology from gravel typical of the Ellensburg formation, which Smith (1903, p. 3) correctly described as containing very little basalt. Most of the pebbles and larger particles in the cemented gravel consist of basalt which is identical in texture and composition to the Yakima basalt. Tuff and hornblende andesite are predominant accessory rock types in some parts of the report area; diorite, quartzite, and many granitic and metamorphic varieties are less common. The relative amount of each rock type varies considerably. For example, at the gravel pit described above, basalt constitutes only about half the pebbles and larger particles, whereas in the west half of the valley, and particularly on the pediment slopes, all or nearly all the large particles are basalt.

The matrix in the gravel is a heterogeneous mixture of sand, silt, and clay similar in composition to the gravel-free interbedded layers. Finely pulverized pumice, quartz, volcanic glass, augite, and clay minerals predominate. Cementing material commonly is argillaceous or ferruginous, or a combination of both. The gravel generally is well cemented and, at places, constitutes a true conglomerate. At most places the interbedded clay lenses are well indurated and tough, but the sandy layers are weakly cemented and friable. Some of these sandy layers appear to be moderately permeable and may typify the water-bearing zones in the cemented-gravel unit.

In some localities the basaltic cobbles and boulders have undergone considerable weathering in place. Weathering of a fragment of basalt rock typically forms concentric shells of decayed rock that separate from the core, giving an onionlike appearance. Evidently the weathered material has been incorporated to some extent in the matrix, so that it is difficult to determine what the size and degree of angularity of the gravel fragments were at the time of their deposition.

Exposures of the cemented gravel, and records of wells that have penetrated it, indicate that this unit is almost certainly more than 400 feet thick at some places. Few sand and clay layers within the gravel are thicker than about 10 feet. Cemented gravel rests on each of the older rock units in various parts of the area, and many exposures show some evidence of unconformity (either angular or erosional). Where bedding is evident, that in the upper part of the gravel unit appears to be horizontal, or nearly so. However, in the vicinity of the type locality described above, the basal part of the unit was somewhat tilted, apparently at the time of the deformation of the underlying Ellensburg formation. Also in the type area, minor thrust faults can be found in the cemented-gravel unit. Thus, at some places part of the basalt gravel apparently was deposited before or during the last deformation. Conversely, the obvious unconformity with Tertiary rocks in other parts of the valley, and the nearly horizontal attitude of the upper, younger layers of the gravel unit, indicate that the upper part of this rock body was deposited since the last period of deformation.

The cemented basalt gravel has the physical characteristics of fanglomerate, flood gravel, or glacial outwash, indicating that the agent of deposition was abundant fast-moving water. Much of this material obviously was deposited in the form of alluvial fans along the flanks of upfolds and was derived from the upfolds themselves. The terrace remnants along the upper valley and the north side of the lower valley indicate that the gravel unit formerly was much more extensive than it is at present. Because the gravel probably was deposited during the Pleistocene or glacial epoch, outwash from alpine glaciation may have contributed to it. The foreign rock types, such as quartzite and metamorphic and granitic rocks, that are present in the gravel may indicate deposition from melt water; however, they may have been derived by reworking of the Ellensburg formation in which these same rock types occur locally.

Smith (1903, p. 4) mapped a large deposit of cemented gravel in the small valley of Cowiche Creek, approximately 8 miles north of the Ahtanum Valley, and gave it the name Cowiche gravel. Smith did not describe the gravel in detail, but he attributed its deposition to the damming of Cowiche Creek by flows of the Tieton andesite in the Pleistocene epoch. Recent geologic reconnaissance and study of logs of wells in that area indicate that gravel apparently identical with some of that mapped as the Cowiche gravel is beneath, and interbedded with, the andesite flows. Therefore, the deposition of the Cowiche gravel was, at least in part, independent of any damming by the andesite flows.

In appearance, lithology, and stratigraphic relations with the older rocks, the Cowiche gravel of Smith is almost identical with some of the cemented gravel in the Ahtanum Valley. Also, the cemented-gravel unit in the Ahtanum Valley has been traced northward to within 3½ miles of the Cowiche gravel in an area where the 2 units are separated by the Cowiche Mountain anticline. For these reasons, it is concluded that the cemented basalt gravel in the area mapped was deposited during virtually the same time, and under the same general conditions, as was the Cowiche gravel of Smith and the other gravel bodies associated with the Tieton andesite. The interbedded relationship of the gravel and the Tieton andesite (of Pleistocene age) indicates that at least a large part of the deposition took place during the Pleistocene epoch.

ROCK MATERIALS OF RECENT AGE

The Ahtanum Valley is floored by a relatively thin mantle of unconsolidated and semiconsolidated stream deposits of Recent age. In the upper valley and through the Narrows, this alluvial material consists of unsorted to sorted gravel, sand, and silt. Downstream, the alluvium generally is slightly finer and better sorted, and in many places it includes discontinuous, semiconsolidated strata of silt and clay, which locally are called hardpan. However, even in the lower end of the valley near Union Gap, the alluvium contains a considerable proportion of cobbles. The thickness of the alluvium, as determined from well logs, ranges from a few feet to about 30 feet.

The material in the alluvial fans on both sides of the valley is generally coarser and less well sorted than that of the flood-plain alluvium. Most unconsolidated gravel throughout the Ahtanum Valley is composed of basalt particles; however, the gravel in the alluvial fans was derived from the Ellensburg formation or from the less basaltic parts of the cemented-gravel unit.

Over much of the upland benches, patches and mounds of windblown silt, or loess, a few feet thick overlie the resistant cemented gravel or the basalt. The patchy cover evidently is a remnant of a mantle of loess which covered the Yakima area at one time and which is similar to, and may be correlative with, the Palouse formation of eastern Washington. Some of the patches are large enough to be cultivated; the mounds generally are 10 to 30 feet long and a few feet high and are protected from erosion by grass and shrubs.

The unconsolidated alluvium in the valley floor and in alluvial fans is shown without pattern on plate 1. The loess is neither widespread nor thick enough to map separately from the underlying units.

STRUCTURE

The Tertiary rocks of the Yakima region have been deformed into a series of prominent east- and southeast-trending folds, which closely control the main topographic features. The upfolds, or anticlines, form the ridges; the downfolds, or synclines, make troughlike basins. The Ahtanum Valley occupies part of one such synclinal trough (the Ahtanum-Moxee subbasin) and is bordered on the south and west, respectively, by the Ahtanum Ridge and Sedge Ridge-Cowiche Mountain anticlines.

In the area of this investigation, the Ahtanum-Moxee syncline slopes, or plunges, east (pl. 1, section *A–A'*). The axis of the syncline is located definitely only where the depth and configuration of the upper basalt flows can be determined from geologic mapping and reliable well logs. Information available at present indicates that smaller flexures are superimposed along and across the main folds, but the deep burial of the basalt and the scarcity of reliable deep-well logs precludes the early delineation of this structural detail.

Ahtanum Ridge, the anticlinal ridge south of the valley, is a tight asymmetrical fold—the inclination, or dip, being steeper on the north side of the ridge. This asymmetry is readily seen at Union Gap, where the arched basalt strata that form the ridge are well exposed. The flow layers at the north end of the gorge are vertical, but within half a mile to the south across the fold, the attitude changes to a moderate southerly dip.

From the east end of the Narrows to within 2 miles of Union Gap, the north side of Ahtanum Ridge is flanked by the upturned edges of Ellensburg strata. As a rule, the Yakima basalt and the Ellensburg formation on this flank of the ridge dip moderately or steeply north, toward the center of the valley. However, in the southern parts of secs. 9–12, T. 12 N., R. 18 E., sandstone and conglomerate strata of the Ellensburg formation have been overturned slightly past the vertical by strong thrusting from the south, and dip steeply south.

The intensity and complexity of the deformation in this part of the valley may be judged from the abrupt changes in the attitudes of the rocks. For example, in the SE¼SW¼ sec. 11, T. 12 N., R. 18 E., Ellensburg strata dip southward at a high angle; about 500 yards to the west, rocks of the same formation dip about 46° N.; half a mile farther west-northwest and north, in the SE¼NE¼ sec. 10, the strata dip about 20° S.

The complexity of the structure at this locality probably is due to either a slumping or a wrinkling of a large block of the sedimentary rocks during the major diastrophism that produced the Ahtanum Ridge anticline, although minor faulting also may have occurred here.

No evidence of major displacement by faulting was found in the area, although some minor displacement, which may have been caused by several small thrust faults, is present in the cemented-gravel unit in the structurally complex locality just described. The tight folding exposed at Union Gap shows that the basalt was strongly deformed by folding alone.

The Narrows, in secs. 13–15, T. 12 N., R. 16 E., is the result of a gentle cross flexure in the Ahtanum-Moxee subbasin. The lava flows in the bottom of that syncline were warped upward and were later cut through by stream erosion to produce this narrow, steep-walled part of the Ahtanum Valley. The Narrows has an important influence on the movement of ground water in the area, as the cross flexure partially separates the upper Ahtanum Valley from the rest of the Ahtanum-Moxee subbasin to the east (pl. 1, section *A–A′*), and retards ground-water flow from the upper valley. At the upstream end of the Narrows the nearly horizontal basalt strata emerge from beneath the alluvial materials and gradually pass into steep bluffs and vertical cliffs, as the valley floor slopes more steeply to the east than does the basalt. The flow layers are quite distinct at numerous places, and examples of typical columnar jointing may be seen along the highway. The attitude of the basalt throughout most of the Narrows is so nearly horizontal that no dip is discernible, but in sec. 13 a slight eastward plunge becomes apparent. Farther east the plunge gradually increases to about 2.5°, or 225 feet per mile, between the downstream end of the Narrows and Wiley. The steepness of the plunge probably diminishes somewhat between Wiley and Union Gap, as shown in section *A–A′* (pl. 1), but the top of the basalt probably is at least 1,500 feet below the land surface, or some 500 feet below sea level, at the Yakima River. Well 13/18–29Q1, just north of the lower valley (pl. 1), was reported to have penetrated basalt at about 60 feet below sea level (table 4).

GEOLOGIC HISTORY

At the end of the Miocene epoch, the area that is now the Ahtanum Valley was part of a vast, monotonous plain of basaltic lava that covered most of eastern Washington and extended eastward into Idaho and southward into Oregon. The basaltic lava flows were extruded from fissures which probably were centered somewhere southeast of the Yakima region. At the west side of the lava plain, approximately where the present Cascade Mountains now stand, there was a region of more intense volcanic activity at an elevation somewhat higher than the lava plain but probably lower than the present Cascades. Those ancestral Cascade Mountains were the source for the sedimentary materials, constituting the Ellensburg formation, that were transported by eastward-flowing streams and deposited along the west side of the lava plain.

The outpourings of basaltic lava probably continued intermittently into the Pliocene epoch, covering the discontinuous sedimentary deposits, changing stream courses, and forming new basins of deposition. Before the period of lava extrusion ended, there was increased uplift and volcanic activity in the ancestral Cascades, furnishing more volcanic debris and resulting in thicker deposits of sedimentary material which became interbedded with the upper basalt flows. After the flows ceased, and as the Cascades continued to rise, the main body of the Ellensburg formation was deposited. Most of the Ellensburg was deposited from streams or in lakes, but some ash and pumice fell directly from the sky.

The deformation that produced the sharp folds in the older rocks of the Yakima region probably began during Pliocene time, while the Ellensburg sedimentary material was still accumulating. This deformation undoubtedly was related to the Cascade uplift, but in part it may have been due also to subsidence of the center of the lava body, somewhere to the southeast. The folding proceeded slowly so that the Yakima River was able to maintain its course at Union Gap by eroding its channel as the Ahtanum Ridge anticline rose. The Yakima

River was never dammed to a very great depth by the uplift of Ahtanum Ridge; if it had been deeply ponded, the water would have spilled over and established a new course through Donald Pass (fig.1), a structural gap about 5 miles east of Union Gap and some 400 feet lower than the present crest of Ahtanum Ridge near Union Gap.

As the folding continued, the sedimentary material previously deposited on the parts of the plain that became the anticlinal ridges was eroded off and carried down into the centers of the synclinal basins. This process accounts in part for the great thickness of the Ellensburg formation (1,000–1,500 feet) in the center of the Ahtanum-Moxee subbasin. It is very unlikely that such a tremendous thickness of sedimentary material was continuous throughout the Yakima basin.

After the easily eroded Ellensburg material had been removed from the ridges, the underlying lava rock was exposed to erosion, and basaltic debris was carried down the flanks of the ridges and out to the centers of the valleys, forming a part of the cemented-gravel unit. The lower part of the cemented gravel along the ridges has been considerably tilted, indicating that deposition of the gravel began before the folding ended. However, probably most of the cemented gravel was deposited after the folding and uplift of the anticlinal ridges had ceased.

Deformation of the rocks in the Yakima area had ceased by the last of the Pliocene or the beginning of the Pleistocene, or glacial, epoch. Since then, the major topographic features in the Ahtanum Valley probably have not changed. Gravel continued to accumulate during Pleistocene time, and, as evidenced by the terrace remnants on either side, the valley probably was once filled with a nearly continuous sheet of gravel to a level as much as 200 feet above the present valley floor. Much of the gravel undoubtedly was deposited as fans, but melt water and outwash sediments from alpine glaciers in the Cascade Mountains may have contributed to the forming of the gravel sheet.

A change in physical conditions, probably related to the recession of Pleistocene glaciers, resulted in active erosion of the extensive gravel deposit into the form of the present valley floor. Sometime before or during this period of downcutting, the uplands in the Ahtanum-Moxee subbasin were covered by a nearly continuous mantle of windblown silt, or loess, of which there are only remnants today.

WATER RESOURCES

Of the precipitation that falls within the drainage basin of Ahtanum Creek, part evaporates directly or is transpired by vegetation, part begins its return to the Pacific Ocean as direct runoff, and the remainder infiltrates into the soil and rocks to the zone of saturation, the surface of which is called the water table. This ground water moves slowly toward the streams and either is discharged into them, forming most of their dry weather (base) flow, or is evaporated and transpired as it approaches the land surface.

Ground water in the unconsolidated alluvium in the area is freely interconnected with the streams. Water may alternately rise to or sink below the land surface several times during its course eastward through the valley. During most of the year, the flows of the streams are maintained largely by ground-water discharge; conversely, much of the recharge to both the shallow and the deep ground-water bodies occurs by direct infiltration from stream channels and by infiltration of irrigation water derived from streams. Therefore, any quantitative study of the ground-water resources of the area necessarily must include an appraisal of the surface-water supplies.

SURFACE WATER

The surface runoff in the Ahtanum Valley varies widely from year to year and from season to season. The amount of annual runoff is determined mainly by the total yearly precipitation in the drainage basin, but other influencing factors are the type and seasonal distribution of precipitation, air temperature, soil conditions, and evaporation. Seasonal distribution of the runoff is determined mostly by the amount and melting rate of snow in the headwaters area. About one-fifth of the total precipitation falls as snow; consequently, years of high total precipitation usually are years of above-normal snowfall.

The runoff is greatest during years in which the snowfall is excessive, especially if the melting of accumulated snow is rapid. Conversely, the runoff is least during years of scanty snowfall, especially if the melting is slow. During years of rapid melting and quick runoff, the loss of water through evaporation is considerably less than in years of slow melting of the snow and correspondingly slow runoff.

The Geological Survey maintains two stream-gaging stations in the area studied. One is on the North Fork and the other is on the South Fork of Ahtanum Creek above all major diversions. Three other Geological Survey gaging stations have been discontinued—at the Narrows, at the mouth of Ahtanum Creek near Union Gap, and on the South Fork near Tampico. (See pl. 1 for location of gaging stations.) Complete streamflow records from these stations have been published by the U.S. Geological Survey.[4]

The U.S. Bureau of Reclamation formerly maintained a gaging station on Wide Hollow Creek near its mouth (pl. 1). The records from that station have not been published, but they are available for inspection at the office of the Bureau of Reclamation in Yakima.

[4] U.S. Geol. Survey Water-Supply Papers 252, 272, 292, 492, 812, 832, 862, 870, 882, 902, 932, 962, 982, 1012, 1042, 1062, 1092, 1122, 1152, 1182, 1216, 1246, 1286, 1346, 1396, 1446, 1516.

SURFACE-WATER INFLOW

More than half the water that supplies the area of the investigation enters as streamflow in the North and South Forks of Ahtanum Creek. The remainder consists of precipitation falling within the area, irrigation water supplied from outside the area, streamflow entering the lower valley in the channel of Wide Hollow Creek, and probably ground-water inflow from Wide Hollow.

The streamflow entering the valley in the North and South Forks of Ahtanum Creek may be at a maximum during any of the months from March through June. The runoff in both streams during those 4 months usually constitutes about two-thirds of the year's total. Flows are at a minimum in the fall and winter; yearly minimums have been recorded at least once in each of the months from August through February. The following table shows that the average annual inflow (North Fork plus South Fork Ahtanum Creek) to the upper Ahtanum Valley during the periods 1909–14 and 1931–55 was about 62,000 acre-feet. It shows also that May was the month of greatest average runoff, and September was the month of minimum average flow.

January	2, 920	May	15, 000	September	1, 530
February	2, 840	June	12, 000	October	1, 630
March	4, 930	July	4, 340	November	2, 170
April	9, 520	August	2, 010	December	3, 210
				Avg annual	62, 100

A considerable amount of surface water passes through the northeast corner of the lower valley in the channel of Wide Hollow Creek, which discharges into the Yakima River about half a mile upstream from the mouth of Ahtanum Creek. Wide Hollow Creek is a perennial stream that is fed principally by runoff, unused canal water, and return flow from irrigation in the area north of the lower valley. The flow of Wide Hollow Creek undoubtedly is related to ground water in much the same manner as are the flows of other streams of the area, in that it supplies some recharge to the shallow ground-water bodies during flood stages and in turn is supplied by ground water during low stages. However, the role of the creek in the hydrologic regimen of the area is not clearly known because of a lack of concurrent streamflow records and water-level data covering a period great enough for dependable analysis.

The only continuous record of the flow of Wide Hollow Creek was obtained from a gaging station near the mouth of the creek and, therefore, does not indicate the amount of surface water entering the lower Ahtanum Valley, but only the outflow from the stream.

Some additional surface water enters the area from the Tieton canal, which brings in almost the entire water supply for the terrace known as Wiley Heights, north of the lower Ahtanum Valley. Of this, perhaps as much as 1,000 acre-feet per year eventually reaches the Ahtanum Creek drainage system or recharges the water-bearing formations, within the Ahtanum Valley.

Near the east end of the Narrows, the flow of Ahtanum Creek splits into three principal channels which rejoin downstream before Ahtanum Creek empties into the Yakima River. The surface water is further distributed throughout the valley by a complex system of irrigation distributaries. Thus, the surface runoff, and particularly the flood-stage runoff, of Ahtanum Creek is spread widely over the floor and on the lower slopes of the valley.

Of the total surface-water inflow, part is used beneficially by crops, part recharges the ground-water reservoir, part evaporates directly from streams and irrigation canals, and part is evaporated and transpired by stream-bank vegetation and other water-loving plants; the remainder leaves the valley by surface runoff and underflow to the Yakima River.

SURFACE-WATER OUTFLOW

Records of surface-water outflow from the Ahtanum Valley include those for Ahtanum Creek near Union Gap and for Wide Hollow Creek near its mouth. The records on Ahtanum Creek were collected by the Geological Survey during three short periods—March–October 1910, April 1911–September 1914, and June 1951–March 1953. Records of the flow of Wide Hollow Creek were collected by the Bureau of Reclamation during the periods April 1911–March 1915 and May 1922–February 1933.

Records of the outflow of Ahtanum Creek at its mouth (near Union Gap) and the inflow to the west end of the valley, in the North and South Forks of Ahtanum Creek, are shown together for corresponding months of record in table 1. A comparison of the figures in this table shows that, during the period of record, Ahtanum Creek lost about 22 percent of its annual inflow in its course through the area. However, downstream loss occurred mainly during the months April through November, and a slight to moderate downstream gain occurred during the months December through March.

The period of downstream loss coincides approximately with the growing season. During this period, large amounts of water are diverted from Ahtanum Creek. More water is lost by evapotranspiration and by ground-water outflow from the east part of the valley than is gained by the Ahtanum Creek system from irrigation return flow, from ground-water discharge, or from other sources such as runoff. Seasonal differences in the inflow-outflow relationship are due to variations in the relative magnitudes of these losses and gains.

TABLE 1.—*Monthly surface-water inflow to and outflow from the Ahtanum Valley by way of Ahtanum Creek*

[Upper figure is inflow, lower figure is outflow; both are in acre-feet]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1910	--------	--------	27, 520	16, 970	20, 440	9, 000	3, 370	1, 690	2, 010	2, 000	--------	--------
	--------	--------	35, 700	14, 600	22, 800	6, 070	646	498	476	547	--------	--------
1911	--------	--------	--------	8, 900	11, 290	15, 650	4, 140	1, 450	1, 610	1, 540	1, 900	1, 260
	--------	--------	--------	3, 770	4, 590	9, 940	1, 310	430	476	450	601	1, 150
1912	2, 680	3, 410	4, 910	12, 650	26, 860	13, 840	3, 720	2, 190	1, 850	1, 800	2, 170	2, 030
	2, 080	3, 390	3, 460	5, 950	10, 000	6, 190	953	577	583	592	1, 030	1, 630
1913	2, 750	2, 550	3, 070	8, 720	17, 440	18, 970	6, 440	2, 390	1, 980	20, 070	1, 810	1, 590
	2, 660	3, 240	4, 460	6, 610	9, 860	14, 910	2, 150	637	563	918	956	1, 690
1914	3, 400	2, 500	11, 640	18, 960	21, 880	11, 850	4, 000	1, 890	1, 700	--------	--------	--------
	5, 740	5, 380	11, 500	12, 300	14, 300	7, 740	637	504	569	--------	--------	--------
1951	--------	--------	--------	--------	--------	17, 240	5, 650	2, 870	2, 030	2, 270	2, 020	2, 490
	--------	--------	--------	--------	--------	16, 170	1, 940	1, 170	1, 640	2, 250	2, 900	3, 710
1952	1, 740	2, 730	4, 070	11, 810	15, 410	10, 120	3, 870	2, 030	1, 590	1, 350	1, 160	1, 390
	3, 160	6, 190	7, 370	9, 370	8, 890	6, 300	1, 890	1, 260	1, 300	1, 230	1, 470	1, 950
1953	6, 020	4, 490	3, 290	--------	--------	--------	--------	--------	--------	--------	--------	--------
	9, 330	7, 430	4, 050	--------	--------	--------	--------	--------	--------	--------	--------	--------
Average	3, 320	3, 140	9, 080	13, 000	18, 890	13, 810	4, 460	2, 070	1, 820	1, 840	1, 810	1, 750
	4, 590	5, 130	11, 100	8, 770	11, 700	9, 620	1, 360	725	800	1, 000	1, 390	2, 030

Downstream gain occurs during the period of high precipitation and low evaporation, and it probably represents chiefly runoff from precipitation within the valley.

The data in table 1 indicate that, for a given inflow into the valley, the surface outflow during the months of August, September, October, and November in recent years has been appreciably higher than it was during the earlier years of record. For example, the inflow dur ng September 1951 was about the same as it had been during September 1910; however, the outflow during September 1951 was 1,640 acre-feet, or about 3½ times the 476 acre-feet recorded for the same month in 1910. The same general relationship is shown for each of the autumn months during the two periods of measurement. The periods of record are too short to allow any definite conclusion regarding the validity of this indicated increase in autumn outflow. If the increase is truly representative, it could be due to one or more changes in conditions affecting the seasonal gain or distribution of the water supplies in the valley, such as (1) increased utilization of Ahtanum Creek water for irrigation, resulting in a delay in the down-valley transit of some of the water and a correspondingly greater return flow to the stream during autumn; (2) an increase in unmeasured surface inflow to the area, such as water reaching the area via the Tieton canal; and (3) an increase in the amount of irrigation water, pumped from the deep ground-water bodies, that ultimately reaches the channel of Ahtanum Creek during and after the irrigation season.

The outflow in Wide Hollow Creek was measured by the U.S. Bureau of Reclamation during the periods 1911–15 and 1922–33 at a gaging station near the mouth of the creek. Unpublished records from that station show that the average annual runoff was about 20,000 acre-feet and that the seasonal variation in flow was much less than that in Ahtanum Creek.

Because Wide Hollow Creek was gaged only near its mouth, it is not possible to determine the amount of gain or loss in the flow of the stream as it passes through the area. However, the relatively small range between maximum and minimum flow suggests that the stream receives substantial amounts of ground-water effluent throughout most of the year.

UTILIZATION OF SURFACE WATER

The most important use of surface water in the Ahtanum Valley is for irrigation. Water from Ahtanum Creek is used and reused for irrigation a number of times between the creek's entrance into the valley above Tampico and its confluence with the Yakima River at Union Gap. The lower valley in particular is served by a maze of interlacing irrigation canals and stream channels, so complex that tabulation of the flow in individual channels is impractical for this report.

Perhaps 17,000 acres of arable land in the area could be irrigated with water from Ahtanum Creek if the supply were sufficient throughout the irrigation season. However, because the available surface-water supplies are not adequate during late summer, much of the land in the valley is not cultivated, is irrigated only during the first 2 or 3 months of the irrigation season (when the creeks are at high stage), or is irrigated partly or completely with ground water. Although no quantitative records of surface-water use are available, it is estimated that the water of Ahtanum Creek constitutes the entire irrigation supply for about 10,000 acres. Kinnison (1952, p. 31) reported, however, that only 2,600 acres is irrigated under water rights of a priority high enough to assure a supply of surface water throughout the irrigation season of an average year.

The above estimates do not include an unknown amount of land that is irrigated partly with surface water and partly with ground water, nor do they include an undetermined acreage that is irrigated with water brought into the area by the Tieton canal.

GROUND WATER

That portion of subsurface water that fills voids or interstices in the rocks under hydrostatic pressure is ground water. The water above the zone of saturation is under less than atmospheric pressure, whether or not it completely fills the interstices in which it occurs, and is not considered to be ground water. This water is called vadose, and the zone in which it occurs is called the zone of aeration.

AQUIFER PROPERTIES

Because ground water occurs in the interstices in the rock materials—that is, in the spaces not occupied by solid material—the ability of a soil or rock to transmit water is determined by the abundance, character, and degree of interconnection of the interstices. A rock material that is capable of transmitting and yielding appreciable quantities of water to a well is called an aquifer.

The interstices in the rock materials of the Ahtanum Valley vary widely in size, shape, and arrangement. They range in size from the minute pore spaces in clay of the Ellensburg formation to the larger openings between coarse gravel particles and crevices in the basalt. Likewise, the shapes of the interstices range from the simple nearly round vesicles in basalt and thin, tabular joints in the consolidated and semiconsolidated rocks to the complex interstices in poorly sorted granular rocks. In most of the sedimentary rocks the interconnection between interstices is good. Conversely, interconnection of interstices, particularly vesicles, in the basalt often is poor or lacking.

The porosity of a rock or soil is the ratio of the volume of its interstices to its total volume. Thus, it is a measure of the ability of the rock to contain water. Natural rock materials differ greatly in porosity. The porosity of some consolidated rocks, such as tightly cemented sandstone or massive lava flows, is only a few percent or even a fraction of a percent, whereas the porosity of some clays may exceed 50 percent. In unconsolidated rocks, the well-sorted materials, such as clay or clean even-textured sand or gravel, have very high porosity. Poorly sorted materials, in which the smaller particles fill the openings between the larger grains, have low porosity.

Soil or rock may have a high porosity and yet yield little water. For example, a clay having a porosity of 50 percent or more might yield virtually no water because of the smallness of the pore spaces. Also, water may be retained in isolated or poorly interconnected pore spaces, such as the vesicles in basalt flows. Saturated vesicular zones of most basalt flows will not yield appreciable amounts of water unless the walls between adjacent vesicles are broken down by weathering or shattering. The ratio of the volume of water a saturated rock will yield by gravity to the total volume of the rock is known as the specific yield and usually is stated as a percentage. If water moves freely through a rock material under ordinary conditions, the material is said to be permeable, or pervious. Material described as impermeable, or impervious, allows relatively little movement of water through it. Another convenient term, closely related to permeability, is transmissibility. It, also, refers to the ability of a rock material to transmit water, but of the whole thickness of an aquifer rather than a unit thickness such as 1 foot.

WATER TABLE

The upper surface of an unconfined saturated zone is known as the water table. The level at which water stands in a well penetrating an unconfined zone of saturation represents the water table at that place.

The water table in most places is a sloping surface. It is highest in areas of recharge, where water is added to the aquifer, and slopes downward to areas of discharge, where water leaves, or is removed from, the aquifer. The slope of the water table (hydraulic gradient) adjusts automatically to the velocity of the moving water and the permeability of the rock. Rocks of low permeability require a steeper gradient than more permeable rocks to transmit water at a given rate.

The water table has irregularities that are generally comparable with the configuration of the land surface, although more subdued. Additional irregularities are caused by local differences in the permeability of the rock materials and by local differences in ground-water discharge and recharge. The water table fluctuates chiefly in response to variations in recharge to, and discharge from, the ground-water body.

A saturated zone may be held above an unsaturated zone by a relatively impermeable rock stratum. Such a saturated water zone is called perched, and its upper surface is a perched water table.

CONFINED GROUND WATER

Water moving in an unconfined aquifer may pass between relatively impermeable beds and become confined there under a pressure due to the weight of the water in the unconfined part of the aquifer. Such water will rise higher in a well than the bottom of the overlying confining bed and is called confined, or artesian. The imaginary surface coinciding with the level to which confined water will rise in wells is called the piezometric surface. The piezometric surface is similar to the water table of an unconfined aquifer in that it usually is a sloping, irregular, fluctuating surface. It is highest in areas of ground-water recharge and lowest in areas of discharge. Fluctuations and irregularities in the piezometric surface are caused by variations in recharge and discharge and by differences in permeability within the aquifer.

Water which flows naturally from the top of a well, particularly a deep well, is commonly called artesian water. However, in the Geological Survey the term is used to mean water that is under pressure sufficient to raise it above the top of the confined aquifer. If the top of the well is at a lower elevation than the piezometric surface, the well is called a flowing artesian well. Of the examples shown in figure 5, wells A, C, and D are artesian wells, although only wells A and C flow. There are many artesian wells in the Ahtanum Valley, but relatively few of them flow.

RECHARGE TO AQUIFERS

Aquifers receive natural replenishment (recharge) chiefly by downward seepage from the surface, either from rain and melting snow or from streams and lakes which themselves are supplied by precipitation. Irrigation may be considered a form of artificial recharge, inasmuch as part of the water that is spread over the land surface commonly seeps downward to a zone of saturation.

Streams that cross permeable zones above the water table contribute to the ground-water reservoirs. On the other hand, streams that flow at a level lower than the water table receive contributions from the ground-water body. At places within the report area, Ahtanum Creek and its principal distributaries recharge the aquifers during their flood stage, when stream levels are higher than the adjacent water table, but receive virtually their entire flow from ground-water discharge during the low-flow periods, when streams are below the water table.

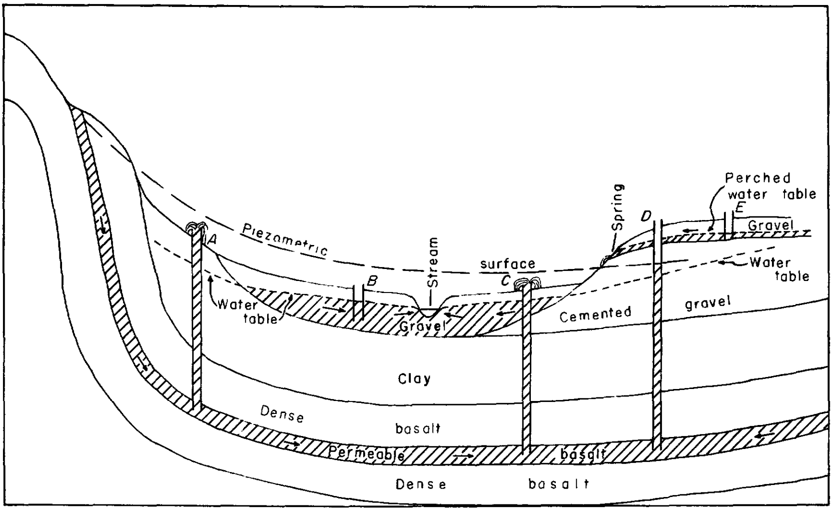

FIGURE 5.—Diagrammatic cross section showing various occurrences of ground water. Water in the aquifers and wells is indicated by crosshatching. Arrows show the direction of ground-water movement. Wells A, C, and D are artesian wells tapping a basalt aquifer confined by impermeable basalt and clay. At wells A and C the land surface is below the piezometric surface of the confined aquifer, and these wells flow. Well B taps an unconfined (water-table) gravel aquifer. Well E taps an unconfined aquifer perched above the regional water table by impermeable strata within the cemented gravel.

When a permeable zone is completely saturated, the rate of recharge cannot exceed the rate of discharge. Any water available for recharge in excess of the amount of discharge will be rejected and will flow off as direct runoff. Generally, the ground-water system tends toward a state of equilibrium wherein annual recharge equals annual discharge.

MOVEMENT OF GROUND WATER

Ground water moves in response primarily to the force of gravity. Therefore, areas of discharge from an aquifer are necessarily lower than areas of recharge, and ground water moves down the hydraulic gradient, even though it may locally move upward toward a point of discharge, such as in a confined aquifer or in an unconfined aquifer near a stream. The rate of movement varies directly with the hydraulic gradient—that is, if all other factors remain the same, doubling the hydraulic gradient doubles the velocity.

GROUND-WATER DISCHARGE

Ground water is discharged naturally through springs and seeps (either at the land surface or into streams, lakes, or the sea), by evaporation or transpiration, and artificially by withdrawal from wells or drains.

Evaporation directly from the zone of saturation can take place where the water table is close to the land surface. Discharge by transpiration takes place where the roots of plants extend to a shallow zone of saturation or to the "fringe" water drawn up from it by capillarity; the water is drawn up through the plants and is evaporated from the leaves.

HYDRAULICS OF A WELL

As soon as a well begins discharging water, the water table (or piezometric surface) around the well is drawn down in a shape similar to an inverted cone, which is called the cone of depression. Thus, a hydraulic gradient is established, and water moves downgradient into the well. As the pumping of the well continues, the cone of depression expands, but more and more slowly, and water moves toward the well from greater distances. The drawdown in the well also continues at a decreasing rate. Eventually, the cone of depression may become so large that the aquifer receives recharge at the rate at which the well is being pumped. The cone of depression then remains virtually stable so long as all conditions remain unchanged. Conditions in the vicinity of a discharging water-table well are shown in figure 6.

The shape and the rate of expansion of a cone of depression are determined almost entirely by the rate of withdrawal, the ability of the aquifer to transmit water, and the rate at which water can be

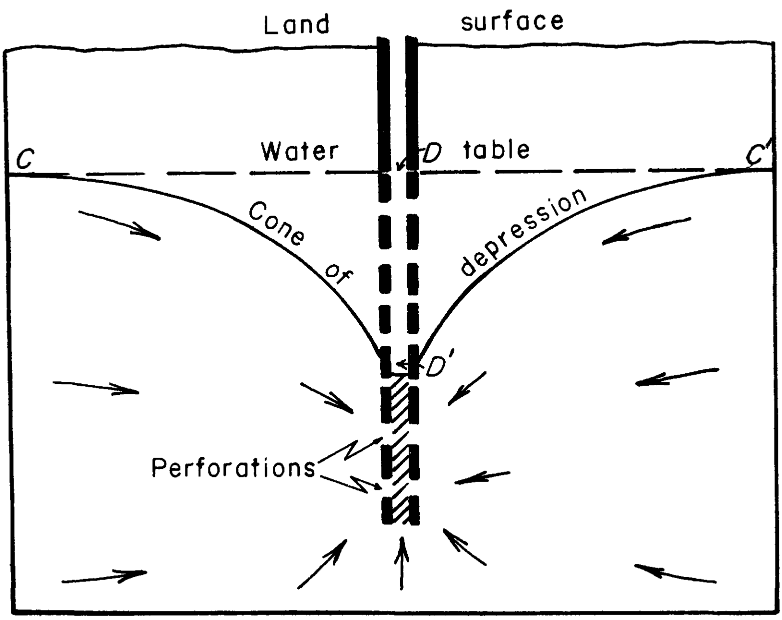

FIGURE 6.—Diagrammatic section through a discharging water-table well. *C–D′–C′* is a section through the cone of water-table depression. *D–D′* represents the drawdown from the static (nonpumping) water level. Arrows indicate direction of water movement.

removed from storage in the rock material during the withdrawal. A higher gradient (steeper cone of depression) is required to transmit water in material of low permeability at the same rate as in more permeable material. Similarly, a cone of depression expands more rapidly in material that has a low storage capacity than in material that has a high storage capacity. When the rate of pumping from a well is increased, the hydraulic gradient at every point on the cone of depression must become steeper so that water can move to the well at the increased rate.

The area of influence of a well is the land area beneath which the water table (or piezometric surface) is perceptibly lowered by withdrawal of water from the well. In the area of influence of a well that is being pumped, water levels are lowered in all other wells tapping the same aquifers.

The rate at which a well will yield water can be called its capacity. The amount of water it will yield with a given drawdown is the specific capacity and usually is expressed in gallons per minute per foot of drawdown.

OCCURRENCE OF WATER IN THE ROCK UNITS

Locally within the Ahtanum Valley each of the major rock units (the Yakima basalt, the Ellensburg formation, the cemented basalt gravel, and the unconsolidated alluvium) yields ground water. At most places in the valley, however, only one or two of these units will yield supplies adequate for substantial uses.

YAKIMA BASALT

The basalt sequence contains the most productive aquifers in the Ahtanum Valley. It supplies ground water to at least 14 irrigation wells in the area, some of which yield more than 1,000 gpm (gallons per minute) by pumping. Of the wells, 6 are in the upper valley or in the Narrows, 2 are on the upland bench north of the upper valley, and 6 are in the lower valley, between the Narrows and Wiley. Most of the ground water in the basalt is under artesian pressure, controlled by the troughlike structure of the subbasin and confined by the overlying Ellensburg formation or by adjacent, less permeable layers of basalt. About half the wells that penetrate basalt either flow or have water levels standing less than 10 feet below the surface.

At least locally near the east end of the Narrows, the uppermost basalt flows, the Wenas(?) member of the Yakima basalt, may contain an important aquifer. In that area, well 12/16–13D1 was drilled to a depth of 146 feet, reportedly without penetrating the interbedded sedimentary layer that overlies the main body of the Yakima basalt. (For location of this well and others cited in text or tables, see pl. 1.) That well has a reported pumping yield of 850 gpm and is used regularly for irrigation. Farther west, however, the Wenas(?) member apparently contains no significant aquifers. Without exception, wells in the upper valley that penetrate the Wenas(?) flows have failed to yield water from that unit in quantities sufficient for irrigation. Most of the wells have been drilled deeper, through the underlying sedimentary layer, into the main body of the Yakima basalt in order to produce enough water for irrigation.

The basalt aquifers of the Ahtanum Valley are recharged partly within the area mapped, partly north of the area along the south side of the Cowiche Mountain anticline, and partly just west of the area along the valley of the South Fork of Ahtanum Creek between Sedge Ridge and Ahtanum Ridge. Sources of recharge to the basalt are infiltration from precipitation, influent seepage from the intermittent streams on the slopes and upland benches, and influent seepage from Ahtanum Creek in 1 or 2 localities where the piezometric surface of the basalt aquifers is below stream level. The relative amounts of recharge received from each of these sources is not known. Some recharge from streamflow probably goes on throughout the year, but the infiltration from precipitation is limited to the wetter seasons of the year.

Most of the direct infiltration to the basalt from precipitation takes place on the slopes bordering the west half of the Ahtanum-Moxee subbasin, where the beveled flow layers are exposed at the surface or covered only by a thin mantle of slope wash; however, some infiltration from precipitation probably occurs at most places where the basalt is at or near the land surface. Some of the recharge from precipitation that occurs within the subbasin, but outside the area mapped—for example, in the valley of the South Fork and on the slope of Cowiche Mountain—reaches the basalt aquifers in the Ahtanum Valley as ground-water inflow. Most of the recharge to the basalt from streamflow probably takes place in the Narrows, where Ahtanum Creek flows directly on basalt of the Wenas(?) member or through a shallow layer of permeable gravel overlying the basalt, and where the piezometric surface of the basalt aquifers is about 30 to 40 feet lower than the stream. The streams probably contribute some recharge also in the vicinity of Tampico during the irrigation season, when the large-yield irrigation wells in that area draw the artesian levels down below the stream levels. The basalt undoubtedly recieves additional recharge by infiltration from the intermittent streams around the margins of the subbasin.

In the lower valley, few wells tapping basalt aquifers have penetrated more than about 200 feet into the basalt. In the western part of the lower valley, this upper part of the basalt sequence probably corresponds to the Wenas(?) flows exposed in the Narrows. Ground water entering the Wenas(?) basalt member as influent seepage from Ahtanum Creek in the Narrows may migrate eastward and provide part of the supply for wells that penetrate the upper part of the basalt sequence.

Movement of ground water in the basalt consists of slow percolation across the beds, through joints in the massive parts of the flows, and lateral flow through the interflow zones, toward areas of discharge. In general, ground water in the basalt moves from the intake areas on higher slopes toward the axis of the subbasin and eastward toward the Yakima River. Locally, however, the movement may be toward a discharging well, or away from a localized area of recharge such as the Narrows. Because of the extremely wide range in permeability of the basalt, the rate of ground-water movement through it also ranges widely. Percolation across the flow layers undoubtedly is very slow, but the amounts of water removed each year from wells indicate that lateral movement through some of the water-bearing zones may be comparatively rapid—perhaps several feet per day—under the hydraulic gradients occurring naturally within the area. Under conditions of pumping, the movement near wells is still more rapid.

Ground water is discharged from the Yakima basalt principally by seepage to streams, through seeps and minor springs at the surface, and from wells. The basalt loses water also by upward leakage to shallower aquifers.

Some ground water from the Yakima basalt undoubtedly discharges directly into the Yakima River (or into the unconsolidated alluvium) in Union Gap. Also, some ground water undoubtedly is discharged from the basalt to streams in the upper valley. As this effluent seepage cannot be seen or measured directly, the actual amount is unknown, but it is believed to be only a few thousand acre-feet per year or less.

Small seeps and springs issuing from the basalt are common on the lower slopes in the area. Few of these seeps and springs flow perennially, however, and this form of discharge is believed to account for only a small percentage of the total ground-water discharge from the basalt.

Ground water is withdrawn from about 20 wells tapping basalt aquifers in the area mapped. At least 14 of those wells are used for irrigation. Possibly as much as 1,500 acres is irrigated partly or completely with ground water from the Yakima basalt. The maximum withdrawal from basalt aquifers may be as much as 4,000 acre-feet per year, but the average withdrawal probably is closer to 3,000 acre-feet per year. The rate of withdrawal is influenced by variations in climate and streamflow and by the market demand for agricultural products. As much as one-quarter or one-fifth of the ground water withdrawn from the Yakima basalt (and also from the Ellensburg formation) eventually may reach the shallow aquifer or discharge into the small streams as return flow from irrigation.

Perhaps the largest discharge of ground water from the Yakima basalt in the Ahtanum-Moxee subbasin is that by interformational leakage to the overlying rock units and thence to the Yakima River and the smaller streams. Ground water in the basalt beneath the lower valley is under pressure sufficient to raise it 50 or more feet above the land surface in many places. For example, well 12/17-16D3, which is 384 feet deep and penetrates 59 feet of basalt, had a shut-in pressure of 25 pounds per square inch in 1952. That pressure is sufficient to raise a column of water about 58 feet above the land surface. Thus, where the water table is 10 feet below the land surface, the differential upward pressure exerted upon the confining bed between the artesian and water-table aquifers is about 30 pounds per square inch. Even though the confining beds have a very low permeability and are several hundred feet thick, it is believed that thousands of acre-feet of ground water leaks upward each year from the Yakima basalt, through the small pores and joints in the confining strata, into the unconsolidated alluvium or into permeable zones in the Ellensburg formation or the cemented gravel unit. From these more permeable rock bodies, the ground water may then be discharged into the streams or through wells.

ELLENSBURG FORMATION

Within the Ahtanum Valley the Ellensburg formation is important as an aquifer only in the lower valley and northwest of Wiley on the terrace known as Wiley Heights. West of the Narrows—that is, throughout the upper valley and on the adjacent upland benches—the Ellensburg formation generally is too impervious, too thin, or too discontinuous to yield appreciable amounts of water to wells.

Of the wells tapping the Ellensburg formation, the most productive are in the center of the valley east of Wiley. Seven wells in that part of the valley are known to obtain water from the Ellensburg formation, and only 2 are reported to have yields smaller than 100 gpm. Well 12/18-1M1, at the Yakima Farm Labor Camp, is the most productive well tapping this aquifer. It is 620 feet deep and in 1939 was reported to flow at a rate of 560 gpm. In contrast, the wells on Wiley Heights that tap the Ellensburg formation usually yield less than 100 gpm, although larger yields might be obtained by deeper penetration into the aquifer. Seven wells on the floor of the lower valley between Wiley and the Narrows have failed to obtain water from the Ellensburg formation in amounts sufficient for irrigation and were drilled deeper, into the underlying Yakima basalt, to obtain economic yields.

The principal aquifers in the Ellensburg formation consist of weakly cemented, permeable layers of gravel and well-sorted sand which are interbedded with less permeable layers of clay and shale. The aquifers are confined by the less permeable strata in the Ellensburg formation and by the underlying basalt. The structure of the formation (the rock layers of the sides of the valley dip inward toward the center of the valley and eastward toward the Yakima River) and the alternation of permeable and impermeable strata produce artesian pressure in the confined aquifers, so that several of the wells tapping the Ellensburg formation in the center of the lower valley are flowing wells.

The water-bearing properties of the Ellensburg formation within the valley are not well known, for only a few wells in the area are known to obtain all their water from that rock unit, and the information derived from these wells is sufficient for only general conclusions. It is believed, however, that the water-bearing zones in the Ellensburg become generally deeper downvalley (eastward) from the vicinity of Wiley. Also, the records indicate that the permeability of the Ellensburg formation, at some places, changes rather abruptly within short distances. Records of several of the wells indicate that the basal layer of the formation, which is about 10 to 20 feet thick and lies directly above the uppermost basalt flow, may be one of the most productive of the water-bearing zones in the Ellensburg formation.

The Ellensburg formation is recharged by infiltration from precipitation and irrigation, by influent seepage from streams, and by upward leakage from the Yakima basalt. The principal intake areas probably are those in which the Ellensburg formation is exposed at the surface, as on the upland bench northwest of the Narrows and along the north flank of Ahtanum Ridge in the lower valley. In these areas, infiltration from precipitation, from irrigation, and from streams undoubtedly contributes much of the recharge. Some recharge to the Ellensburg formation probably takes place by downward percolation from the alluvium in a small area of the valley floor near the east end of the Narrows (secs. 8, 17, and 18, T. 12 N., R. 17 E.) where the saturated alluvial gravels directly overlie the Ellensburg formation (pl. 1, *A–A′*). At least locally in that area, the lower part of the Ellensburg formation is somewhat permeable, and water levels in that part of the formation apparently are below stream levels. For example, in well 12/17–8K1 (tables 4 and 5), which reportedly derives its water entirely from a 20-foot-thick layer of permeable sand directly overlying the basalt, the water level is about 20 or 30 feet below local stream level. Here the ground water in the alluvial gravel is able to percolate downward into the Ellensburg formation.

At other places where the Ellensburg formation contains significant aquifers, the pressure head in those aquifers generally is above the levels of the streams and the local water table; hence, no water moves downward to the aquifers. The Ellensburg formation receives additional recharge to the north of the area mapped, where the formation is exposed along the south flank of the Cowiche Mountain anticline. The amount of recharge that normally migrates from outside the area to aquifers beneath the Ahtanum Valley proper is not known, but it probably does not constitute a major source of ground water for the valley. One reason is that most of the water that is recharged to the Ellensburg formation from north of the area probably migrates toward Wide Hollow, where a large part of it is intercepted by wells. Also, the postulated small buried upfold (see p. 23) in the beds of the Ellensburg formation between Wide Hollow and the lower Ahtanum Valley (pl. 1, sections *E–E′* and *F–F′*) doubtless would retard the southward movement of ground water from Wide Hollow. However, unless additional information becomes available through future drilling of deep wells in the Wiley Heights area, this hypothetical structure cannot be affirmed.

Probably one of the most important sources of recharge to the Ellensburg formation is upward leakage from the Yakima basalt. In parts of the lower valley, ground water in the basalt is under pressure sufficient to cause appreciable upward leakage, and it doubtless contributes to the ground water available for withdrawal from aquifers of the Ellensburg formation.

Although the overall movement of ground water in the Ellensburg formation is toward the center of the subbasin and eastward toward the Yakima River, the hydraulic gradient may be modified by pumping so that locally the water may be diverted to a discharging well. No measurements or estimates have been made of the velocity of ground-water movement in the formation, but the water probably moves very slowly in the dense, clayey strata and moderately slowly even in the more permeable zones.

In the Ahtanum Valley, ground water from the Ellensburg formation probably is discharged mainly by withdrawal from wells and by upward leakage to the cemented gravel and unconsolidated alluvium.

The Ellensburg formation may yield as much as 800 acre-feet of ground water each year to wells. More than 95 percent of that total comes from irrigation wells, and most is withdrawn between July 1 and October 1.

Perhaps the largest part of the natural discharge from the Ellensburg formation is the upward seepage to the overlying cemented-gravel unit and unconsolidated alluvium, from which the water then discharges into the Yakima River. Of course, such upward leakage can occur only where the pressure is sufficient to raise the confined water in the Ellensburg formation above stream levels or the water table. Near the center of the subbasin in the eastern part of the lower valley, the relatively high transmissibility of the cemented-gravel unit and the high head in the underlying aquifers favor upward leakage.

Although the total amount of ground-water discharge from the Ellensburg formation has not been estimated, it is believed to be approximately balanced by recharge.

CEMENTED BASALT GRAVEL

The cemented basalt gravel is important as a source of ground water only in the eastern part of the lower valley and on the upland bench north of the lower valley. Elsewhere in the area, wells generally have failed to obtain water from the cemented-gravel unit in amounts sufficient for either domestic or irrigation use.

Although at most places part or all of the cemented gravel is saturated, the interstices generally have been so nearly filled with cementing material that the unit has low permeability and will yield very little water to wells. Even on the upland bench north of the lower valley, where supplies of water adequate for domestic use are obtained from the cemented gravel, the yields of individual wells are small (commonly less than a gallon per minute) and apparently are derived from discontinuous sandy or poorly cemented lenses. However, beneath the eastern part of the lower valley, an abrupt change in the character of the materials constituting the cemented-gravel unit is indicated by the logs of wells. In that part of the area, the unit contains more and thicker layers of sand and gravel, some of which are only weakly cemented and constitute productive aquifers. Well 12/19–5N1, a municipal well of the city of Union Gap, is the most productive of several large-yield wells that tap the cemented gravel unit in that part of the area. The well is 370 feet deep and produces as much as 970 gpm from gravel and sand.

The cemented gravel on the slopes and upland benches is recharged entirely by infiltration of precipitation, irrigation water, and water from intermittent streams. The more permeable zones beneath the eastern part of the lower valley, however, may be recharged mostly by upward leakage from the underlying artesian aquifers.

In general, movement of water in the cemented gravel is very slow. Even the presence of permeable lenses within the gravel may increase its overall permeability only slightly, as most of these sandy or poorly cemented lenses are discontinuous or poorly connected hydraulically. On the upland benches, the direction of movement generally is toward the edges of the benches. On the south side of the lower valley, where beds of cemented gravel have been tilted along with the underlying rock units, some water, recharged from local precipitation and irrigation, probably moves northward toward the center of the valley. Beneath the eastern part of the valley floor, ground water in the unit moves generally toward the Yakima River.

Ground water is discharged from the cemented gravel on the upland benches mainly as seeps along the bluffs and terrace faces and by withdrawal from wells. At the east end of the valley, a considerable amount of ground water undoubtedly seeps directly from the unit into the Yakima River, but in that area also the withdrawal from wells constitutes a major form of discharge. It is estimated that about 500 acre-feet of ground water is pumped from the unit each year for industrial uses in and around the city of Union Gap, and another 300 acre-feet per year supplies the water system of that city.

UNCONSOLIDATED ALLUVIUM

The unconsolidated alluvium is the second most productive aquifer in the Ahtanum Valley, being surpassed in total yield only by the Yakima basalt. Most of the wells in the area tap the alluvium, and even though many of these are small-yield domestic wells, the alluvium produces about a third of the ground water used. The alluvium provides nearly all the domestic water for the entire valley, and in the lower valley it is an important source of irrigation water. Yields as great as 400 gpm have been reported from shallow dug wells and, at most places in the floor of the lower valley, yields of more than 100 gpm can reasonably be expected from a properly constructed dug well. The unconsolidated materials making up the alluvial slope on the south side of the lower valley also yield moderate supplies of ground water, but the depth to water there is somewhat greater than beneath the flood plain of Ahtanum Creek, and the yields of individual wells generally are less. The water table in the alluvium of the valley floor is generally less than 10 feet below the surface.

Ground water in the alluvium generally is unconfined, although at places lenses of silt and clay within the gravel body doubtless retard the movement of water and create small bodies of confined water.

The unconsolidated alluvium is recharged by infiltration from streams, irrigation canals, and irrigated fields; by precipitation; and by upward leakage from underlying artesian aquifers.

During the freshet stage, water from the swollen creeks percolates downward to the water table, filling the interstices of the alluvium and gradually replenishing the ground-water reservoir. During the rest of the year, the streams are at levels so low that ground water

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from the alluvium seeps into the stream channels and helps maintain the flow of the streams.

Throughout the irrigation season, the slow draining of the valley alluvium is partly offset by more or less continuous recharge from irrigation ditches and irrigated fields. It should be noted that a considerable part of the ground water withdrawn from both the shallow and the deep aquifers eventually recharges the shallow alluvium, and some of this flows into the streams.

During the wetter seasons of the year, local precipitation is an important form of recharge to the unconsolidated alluvium. Precipitation is greatest when evaporation is low, and much of the rainfall or melt water percolates downward to the shallow water table. During the summer months, however, the meager precipitation (usually less than 1 inch for the period July–August) is largely intercepted by vegetation or evaporates directly from the soil without reaching the water table.

On much of the gentle alluvial slope south of the lower valley, the elevation of the water table is higher than the highest possible stage of Ahtanum Creek. Therefore, the alluvium on those slopes cannot receive recharge from Ahtanum Creek; instead, ground water from the alluvial slopes discharges slowly but continuously into Ahtanum Creek. The water table beneath the lower alluvial slope is, in many places, maintained at fairly high levels by recharge from local irrigation, by seepage from irrigation canals and drainage courses from the higher slopes, and by precipitation that falls directly on the slope.

In the lower valley, and particularly in its eastern part, the alluvium that forms the valley floor doubtless is recharged to some extent by upward leakage from the underlying artesian aquifers. The difference in head between the water table and the piezometric surface of the artesian aquifers may be as much as 70 feet at places. Even though the rock materials that separate the alluvium from the artesian aquifers are relatively impermeable, they do not prevent entirely the upward movement of ground water, and it is possible that thousands of acre-feet of water per year leaks upward into the alluvium in this manner.

Ground water in the valley alluvium moves generally downstream, toward the Yakima River, but the movement at any given place may be toward or away from a stream or toward a discharging well, according to the local gradient of the water table.

It is obvious from the records of the shallow wells in the area that at most places the alluvium is at least moderately permeable, and that water readily moves through it. However, in order to estimate the velocity of ground-water movement and to make other quantitative estimates, it was necessary to make some quantitative determination of the ability of the alluvium to transmit water. To this end, pumping tests were made in September 1951 on four wells that tap the valley alluvium. In these tests, the wells were pumped at a constant rate, and water-level measurements were made in them during and after the periods of pumping. The data were then analyzed by the recovery method developed by Theis (1935, p. 522; see also Wenzel, 1942, p. 95). Under certain conditions, this method, when applied to data obtained from a pumping test of a well tapping an ideal aquifer, affords a satisfactory means of determining the coefficient of transmissibility of the aquifer. The coefficient of transmissibility may be defined as the number of gallons per day of water, at the prevailing water temperatures, that will pass through a vertical section of the aquifer 1 mile wide (measured normal to the direction of flow) under a hydraulic gradient of 1 foot per mile. The coefficient of transmissibility, when divided by the thickness of the aquifer in feet, gives the field coefficient of permeability, which is the rate of flow of water, in gallons per day, through a section of the aquifer 1 foot thick and 1 mile wide under a hydraulic gradient of 1 foot per mile, at the prevailing water temperature.

The characteristics of the alluvium and the conditions under which the aquifer tests in the area were made differ greatly from the ideal conditions assumed in the derivation of the recovery method. For example, the recovery method assumes a homogeneous artesian aquifer, of infinite areal extent, bounded above and below by perfectly impervious confining beds; the well is assumed to penetrate the aquifer completely. In contrast, the alluvium in the area is typically heterogeneous in character, and the ground water is unconfined. None of the wells completely penetrates the aquifer, and all undoubtedly have less than perfect efficiency. Furthermore, the wells were pumped for only short periods—2 hours or less—in order to prevent recirculation of the discharge water; thus, the cone of pumping depression of the water table in the vicinity of the well could not spread far enough from the well to test a large area. All these differences between theoretical and field conditions tend to cause inaccuracies in the results of an aquifer test. Their overall effect on the tests in the Ahtanum Valley is not known, but the results of the tests are considered to represent only the general magnitude of transmissibility in the permeable gravels of the alluvium, and they are the best basis presently available for quantitative estimates of ground-water movement in the alluvium.

The four tests and the results derived therefrom are summarized in table 2. As the table shows, the indicated coefficients of transmissibility range from about 30,000 to 90,000 gpd (gallons per day) per foot, and the coefficients of permeability from about 5,000 to

6,000 gpd per square foot. However, each of the wells tested derives all or most of its water from coarse gravel, and the values obtained from the tests do not apply to the lenses and discontinuous layers of the finer grained materials, such as sand and silt. It is concluded, therefore, that the average transmissibility and permeability are less, but how much less is not known.

TABLE 2.—*Summary of pumping tests on wells tapping sand and gravel aquifers of alluvium, in lower Ahtanum Valley*

Well	Distance (miles) from—	Depth (feet)	Thickness of producing zone (feet)	Duration of test		Depth to water level before pumping (feet)	Average yield (gpm)	Maximum drawdown (feet)	Specific capacity (gpm per ft)	Coefficient of transmissibility (gpd per ft)	Coefficient of permeability (gpd per sq ft)
				hr	min						
	WILEY										
12/17-2R2	In Wiley	9	[1] 15	2	0	3.66	69	0.74	93	90,000	6,000
12/17-10C1	1½ W	8	6	1	9	1.18	64	2.27	28	30,000	5,000
	AHTANUM										
12/18-4F1	2½ E	12	--------		52	6.45	64	1.00	64	(2)	--------
12/18-5J1	1½ E	18	9	1	42	7.54	62	.85	73	51,000	5,700

[1] Estimated.
[2] Data derived from test not suitable for calculation of coefficient of transmissibility.

It is assumed, however, that the average permeability of the least permeable body of alluvium of substantial size is 100 gpd per square foot. Doubtless there are pods of clay having extremely low permeability, but any such pods are believed to be small and not of consequence in affecting areal movement of ground water. The value of 100 is believed to be reasonable for bodies of mixed sand and silt.

With these data, the probable range of velocity of water moving in the shallow alluvium can be calculated by the use of the following formula based on Darcy's law and adapted from Tolman (1937, p. 215):

$$V_e = \frac{(2.532 \times 10^{-5} P_f)h}{p},$$

where V_e is the effective velocity of the water, in feet per day,
P_f is the field coefficient of permeability, in gallons per day per square foot,
h is the hydraulic gradient, in feet per mile,
p is the porosity.

As stated, the field coefficient of permeability (P_f) of the valley alluvium is estimated to range from about 6,000 to 100 gpd per square foot. The hydraulic gradient in the upper valley and through the Narrows averages about 85 feet per mile, and in the lower valley the gradient between Wiley and Union Gap averages about 40 feet per mile. The average porosity of the valley alluvium probably is between 0.15 and 0.25.

Substituting the values above so as to obtain the widest numerical spread for the sections of the valley where alluvium is present, the results indicate the limits of the downvalley velocity at which ground water in the shallow alluvium might be expected to move.

Upper valley:

$$V_e(\text{max})=\frac{2.532\times10^{-5}\ (6{,}000)\ (85)}{0.15}=86 \text{ ft per day}$$

$$V_e(\text{min})=\frac{2.532\times10^{-5}\ (100)\ (85)}{0.25}=0.9 \text{ ft per day}$$

Lower valley, Wiley to Union Gap:

$$V_e(\text{max})=\frac{2.532\times10^{-5}\ (6{,}000)\ (40)}{0.15}=40 \text{ ft per day}$$

$$V_e(\text{min})=\frac{2.532\times10^{-5}\ (100)\ (40)}{0.25}=0.4 \text{ ft per day}$$

Thus, in the upper valley, ground water in the inconsolidated alluvium might be expected to move downstream at a velocity approaching 100 feet per day in the permeable coarse gravels, and less than a foot per day in the bodies of mixed sand and silt. The rates in the lower valley would be expected to be roughly half as great. Thus, in the floor of the lower valley, using the highest calculated velocity, several months would elapse while ground water in the very permeable gravel of the unconsolidated alluvium moved a mile downstream. In the least permeable material a considerable number of years would be required for water to move the same distance.

In the lower valley, the profile across the valley floor is much flatter than the downvalley gradient, and the gradient at which water moves laterally toward the small streams probably is lower also. Therefore, the average velocity of ground water moving laterally across the lower valley floor probably is considerably less than the downvalley movement, on the order of a few feet or less per day. In the upper valley, the gradient across the valley is much steeper, and in many places the velocity of ground water moving laterally through the alluvium may be equal to, or greater than, the downvalley velocity.

Ground water is discharged from the unconsolidated alluvium naturally by effluent seepage to the Yakima River and the smaller streams, by evapotranspiration, and probably, in the Narrows and the upper valley, by seepage to the deeper aquifers. It is also discharged artificially by means of wells and drainage systems. Of these modes of discharge, effluent seepage is one of the more important.

That part of the seepage discharge from the unconsolidated alluvium which reaches the small streams, including Ahtanum Creek, helps to maintain their low-level flow (p. 44). That part which discharges directly to the Yakima River results in a contribution of perhaps 5,000 acre-feet per year to the flow of the river in its course past the mouth of Ahtanum Valley. (See p. 63.)

It is not known how much ground water migrates downward from the alluvium to the lower aquifers. However, the water table in most parts of the area is lower than the piezometric surfaces of deeper aquifers, and there could be no downward leakage from the alluvium at these places. In a few rather small areas in the upper valley and the Narrows, the alluvium is underlain at shallow depth by basalt and the Ellensburg formation, in which the piezometric surfaces are lower than the water table. In these areas, water from the alluvium moves downward probably at rates depending on the transmission capabilities of the underlying materials.

Evapotranspiration from the shallow alluvium includes (a) consumptive waste of shallow ground water by phreatophytes of low economic value, (b) consumptive use by crops, and (c) direct evaporation of moisture from the capillary fringe where the water table is near the surface.

The group of phreatophytes, or "well plants," that grow within the Ahtanum Valley includes cottonwood, willows and associated shrubs, and marsh grasses. Alfalfa is an economic plant that acts as a phreatophyte in areas where it can send its roots down to the water table. Where phreatophytes grow near streams, their roots may withdraw water from both the surface- and ground-water bodies.

The amount of water used by a unit area of phreatophytes may be as much as, or more than, the evaporation from a free water surface covering the same area. In an extensive study made in the Safford Valley, Ariz. (Gatewood and others, 1950, p. 203), careful measurements showed that dense stands of cottonwood use as much as 6 acre-feet of water per acre in the year ended September 30, 1944. It cannot be stated whether the year of the estimate was typical, but the estimate gives at least a good general idea of the magnitude of transpiration by cottonwood.

The amount of stream-bank vegetation growing in medium to dense stands in the Ahtanum Valley has been estimated from aerial photographs at about 1,200 acres. The average consumptive waste by that vegetation is assumed to be half that for cottonwood in the Safford Valley, or 3 acre-feet per acre, to allow for both the lower temperature in the Ahtanum Valley and the fact that not all the vegetation grows at maximum density. On the basis of this estimate, about 3,600 acre-feet of water is lost each year. No attempt has been made to determine the evapotranspiration losses from marshy or waterlogged land between the streams. However, the annual non-beneficial discharge of ground water by evapotranspiration throughout the valley probably exceeds 4,000 acre-feet. This consumptive waste may represent a large reclaimable source of water in the Ahtanum Valley. Even though not all the wasted water could be salvaged, the possibility of reclaiming a part of it to alleviate the water shortage certainly warrants a careful study of the problem.

Withdrawals from wells tapping the alluvium are estimated to average about 1,800 acre-feet per year. Of that total, about 1,300 acre-feet is used for irrigation, about 400 acre-feet for domestic supplies, and less than 100 acre-feet for industrial purposes.

In addition to that withdrawn from wells, some ground water is discharged artificially from the unconsolidated alluvium in the lower valley by drainage systems. Several large drains were constructed beneath the Yakima Airport and at the east end of the lower valley, in the vicinity of Union Gap. In addition, experiments were started about 1950 on the effectiveness of drainage systems for use on farms in some of the waterlogged areas of the lower valley (A. L. Dickinson, U.S. Soil Conservation Service, oral communication, September 1952). The quantity of ground water that is discharged through these drains is not known. Apparently, however, the systems are effective in lowering the water table only in very localized areas near the drains.

WATER-LEVEL FLUCTUATIONS

During the investigation, levels in 9 wells in the area were measured at intervals of 1 or 2 months for periods of a year or more, and levels in several other wells, in the lower valley and in Wide Hollow, were measured for shorter periods. In addition, during part of the time, recording gages were maintained on wells 12/17–2R2 and 12/17–9J3. Hydrographs from 11 wells in the Ahtanum Valley are shown on plates 2 and 3.

Of these wells, 2 tap the Yakima basalt, 1 the Ellensburg formation, and 8 the unconsolidated alluvium. The location of the wells are shown on plate 1, and descriptions of the wells are given in table 4.

Water-level fluctuations in the alluvium are moderate. In the observation wells tapping the alluvium, the maximum observed change in water levels was 6.96 feet in well 12/16–18A1, from 14.02 feet (Oct. 18, 1951) to 7.06 feet below the land surface (May 19, 1952). The minimum observed change was 1.24 feet in well 12/17–16Q1, from 6.02 feet (Aug. 10, 1951) to 4.78 feet below the land surface (Feb. 20, 1952).

The water-level measurements indicate that fluctuations of ground water in the alluvium are related principally to variations in stream levels, in irrigation and the flow of canals, and in local precipitation. The water level fluctuates less in response to withdrawals from wells and differences in evapotranspiration discharge from the shallow ground-water body. Of the major fluctuations the largest are those related to changes in the level of Ahtanum Creek and its major branches. The highest recorded water levels of the shallow wells in the valley floor usually are in the spring, coinciding with the high stages of Ahtanum Creek. Other important seasonal fluctuations are caused by differences in irrigation and in the flow of water through the irrigation canals, and by precipitation within the valley. Smaller, more localized fluctuations apparently are caused by different rates of pumping from irrigation wells in the shallow alluvium and by sharp decreases in the consumptive use of the shallow ground water by vegetation when crops are harvested or after the first killing frost of fall. Minor fluctuations of a few hundredths of a foot are caused during the summer months by the differences in the nighttime and daytime rates of evapotranspiration of ground water by vegetation. An example of such diurnal fluctuations is shown in figure 7, which is a copy of a portion of an original chart from the recording gage on well 12/17–2R2, at Wiley. Figure 7 also shows the drawdown in well 12/17–2R2 caused by pumping of a nearby well.

Because the water table beneath much of the alluvial slope south of the lower valley is higher in elevation than the maximum stage of Ahtanum Creek, the seasonal variations in the level of Ahtanum Creek probably have little effect on its position except in the immediate vicinity of the creek. For example, the hydrograph of well 12/17–16Q1 (pl. 2) shows no fluctuations that can be correlated with streamflow. In fact, the only marked fluctuation was a downward trend that probably was related to evapotranspiration and to pumping from the well itself during the summer months. The highest level, during February 1951, probably was the result of recharge from local precipitation.

Well 12/18–7J1, owned by A. W. Knight, is the only well tapping the Ellensburg formation that was measured regularly during the investigation. It is a 362-foot drilled irrigation well that penetrates 22 feet into the Ellensburg. Fluctuation of the water level in that well is shown in plate 2. The measured range in water level was only about 2 feet, but the actual range is greater by an unknown amount because the well flowed during the summer months and the water level was not measured. The lowest observed level, 1.56 feet below the land surface, was recorded in March 1952, and the highest level probably was in July. In 1951 the well was pumped only during August.

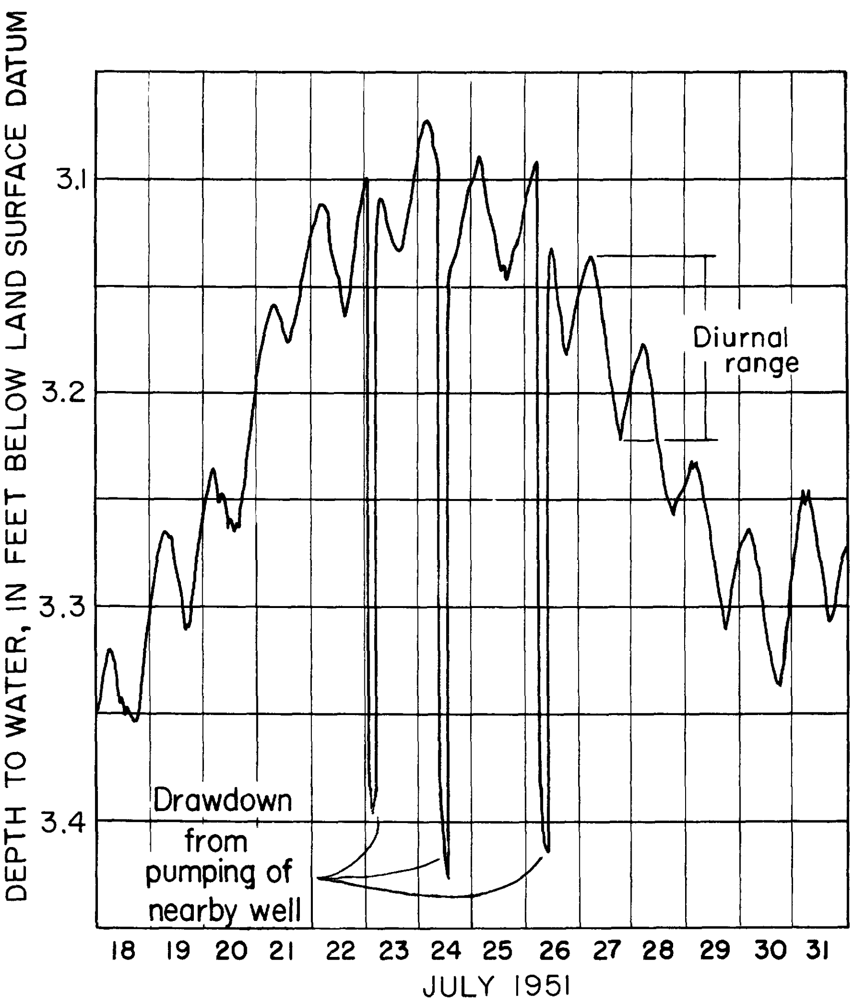

FIGURE 7.—Hydrograph of well 12/17-2R2, showing diurnal water-level fluctuations and drawdown from pumping of a nearby well.

The water-level fluctuations in well 12/18–7J1 probably are controlled chiefly by differences in the recharge to the formation. However, in other parts of the lower valley, the water-level fluctuations may be controlled mainly by withdrawals from wells tapping the Ellensburg formation.

The two observation wells that tap basalt aquifers are 12/16–13D2, at the east end of the Narrows, and 12/17–9J3, 2 miles west-southwest of Wiley.

Well 12/16–13D2, owned by Herke Bros., was drilled as a test well. It is about 8 feet from a very productive irrigation well that probably withdraws water entirely, or mostly, from the Yakima basalt. As its hydrograph shows, the water level in well 12/16–13D2 is controlled primarily by pumping from the irrigation well. The water levels in both wells respond immediately to pumping, which usually is begun in July, and continue to decline throughout the period of pumping which usually continues steadily for 60 or 70 days at the rate of about 850 gpm. The maximum drawdown during a season of pumping usually is less than 40 feet. After pumping is stopped, the water levels in the wells do not recover as rapidly as might be expected from the specific capacity of the pumped well. Instead, the aquifer requires about 10 months, or until the next irrigation season, to be replenished, and in some years the water levels do not fully recover before pumping is resumed. It is therefore assumed that, although the transmissibility of that particular water-bearing zone in the basalt is rather high, the recharge is limited by adjacent materials of low permeability, so that a period of 10 months is required to replenish the ground water that is discharged during 2 months of heavy pumping.

Well 12/17–9J3, owned by Walter McInnis, is 575 feet deep and also taps aquifers in the Yakima basalt. The well originally supplied water for a school, but it has been used exclusively for observation since the U.S. Geological Survey installed a recording gage in January 1953.

On July 20, 1953, the water level in this well was 66.80 feet below the land-surface datum. This level represented the seasonal high for that year. On July 19, 1957, the approximate seasonal high was 80.98 feet below the datum. Hence, the overall decline was 14.18 feet, or about 3½ feet per year, for the 4-year span. The year-to-year decline was not consistent however. In the years 1954, 1955, and 1956 the seasonal highs were as much as 10 feet below the 5-year average trend, but the reason for these inordinately low levels is not known. Major water-level fluctuations in the McInnis well probably are caused largely by the pumping of four large-yield irrigation wells, which tap basalt aquifers and are located within 1.5 miles of the McInnis well. The water level doubtless is affected also by other factors, such as seasonal variations in recharge and natural discharge.

The hydrographs of wells 12/17–9J3 and 12/16–13D2 suggest that at least locally in the western part of the lower valley, there may be a declining trend in the artesian pressures in the basalt aquifers. However, the length of record is not adequate to determine whether pumping has reached, or is approaching, an optimum balance with recharge.

In the Pullman area (Foxworthy and Washburn, 1957, p. 56–58), increased pumping withdrawals and the attendant decline in ground-water levels have resulted in an increase in natural recharge to basalt aquifers—recharge that otherwise would have been rejected. In the Ahtanum Valley, therefore, moderate drawdown of water levels in the basalt aquifers may not necessarily be detrimental to the hydrologic regimen of the area but could result, as in the Pullman area, in increased recharge to the aquifers.

DEVELOPMENT

UPPER VALLEY

The ground-water resources of the upper valley are developed on a moderate scale. Virtually all domestic water is derived from wells, and the irrigation water from streams is supplemented to a considerable extent by ground water. The Yakima basalt and the unconsolidated alluvium are the principal sources of ground water; the Ellensburg formation and the cemented gravel are not important aquifers. The estimated withdrawals of ground water from the upper valley, and also from other parts of the area, are presented in table 3.

All the large-yield wells in the upper valley derive water from basalt aquifers which yield as much as 1,700 acre-feet of water per year to 6 irrigation wells. The irrigation wells range in depth from 146 to 598 feet, and a pumping yield of 1,300 gpm has been reported for one of them (12/16–13D1). All 6 wells tap artesian aquifers, and 4 of the wells either flow or have flowed in the past.

The unconsolidated alluvium is an important aquifer in the upper valley, although not a highly productive one at present. It supplies nearly all the domestic wells, the total withdrawal from which is about 15 acre-feet per year. At some places, as in the Narrows, the alluvium may be generally thinner than in the lower valley, but its similarity in appearance to the unconsolidated gravel in the lower valley suggests that it may be capable of yielding much larger quantities of water than are presently withdrawn.

Any sizable increases in ground-water withdrawals from the upper valley probably would come mostly from wells in the main body of the Yakima basalt. Withdrawals from the basalt aquifers probably could be increased somewhat without exceeding the long-term yield. However, any additional irrigation wells that tap the basalt should be spaced as far as possible from other wells in the same aquifer, in order to minimize interference—that is overlapping of the cones of depressions of the discharging wells.

Although properly constructed wells tapping the unconsolidated alluvium of the upper valley might produce as much as several hundred gallons per minute each, continued pumping of several such wells throughout an irrigation season might cause at least slight decreases in streamflow. The floor of the upper valley is so narrow that on most farms it would be difficult to locate a well more than a few hundred yards away from a branch of Ahtanum Creek, and after several months of pumping the cone of depression around the discharging well probably would spread far enough to affect the flow of the stream—either by inducing direct infiltration from the stream channel or by intercepting appreciable amounts of ground water that normally would discharge into the stream. The possible effects of increased withdrawals from the alluvium are discussed more fully in a subsequent part of this report.

UPLAND BENCHES

Ground water on the upland bench north of the upper valley is developed by means of three irrigation wells and half a dozen domestic wells. All the irrigation wells derive water from the basalt, which is the only source available in that part of the area for the development of large supplies of ground water. The maximum withdrawal from the irrigation wells is estimated to be about 800 acre-feet per year. The domestic wells, of which some have barely adequate yields, derive water from cemented gravel or from the Ellensburg formation, overlying the basalt.

East of the Narrows the basalt dips below the surface, and the upland bench or terrace north of the lower valley is formed mostly by cemented gravel, underlain at depths of about 50 to more than 100 feet by the Ellensburg formation. During the investigation, wells were canvassed in the southern part of this terrace. (See pl. 1.) Most of the wells range in depth from 90 to 200 feet; they completely penetrate the cemented-gravel units and tap aquifers in the upper part of the Ellensburg formation. A few deeper wells penetrate farther into the Ellensburg formation, and a few shallower wells evidently derive small supplies of water from the cemented gravel. In general, the wells tapping the cemented gravel are the least productive of those in the southern part of the terrace and have yields of not more than a few gallons per minute. Somewhat larger yields, up to perhaps 50 gpm, usually are obtained from the wells that penetrate a short distance into the Ellensburg formation, and yields of more than 50 gpm have been obtained from the deeper wells. Well 12/17–3M3, owned by F. T. Tissell, about 2 miles west of Wiley, is the most productive well in that part of the area. This drilled well, which is 262 feet deep, penetrates more than 100 feet into the Ellensburg formation and reportedly was pumped at a rate of 90 gpm for 4 hours, with a drawdown of 33 feet. In the southern part of the terrace, the estimated ground-water withdrawal is 65 acre-feet per year, most of which is derived from the Ellensburg formation (table 4).

No wells have been drilled on the bench south of the Narrows, although it probably is potentially as good an area for ground-water development as the bench on the north side. The structure of the basalt layers that underline the upland benches on both sides of the upper valley is generally favorable for the occurrence of ground water under artesian pressure.

Well records indicate that any additional large-capacity wells that are drilled on the upland benches must penetrate a considerable distance into the older rock units—that is, the Yakima basalt (adjacent to the upper valley) and the Ellensburg formation (on the terrace north of the lower valley). Yields of more than 100 gpm probably will require wells at least 200 feet deep. Recharge to those deeper aquifers probably is sufficiently great that a few additional large-capacity wells located on the upland benches would not withdraw ground water in excess of the long-term average intake.

LOWER VALLEY

PRESENT DEVELOPMENT

In the lower Ahtanum Valley, sizable amounts of ground water are withdrawn from all the rock units; however, the degree of development of the various aquifers differs widely from place to place. Estimated withdrawals of ground water from the rock units in the lower valley are given in table 3.

In the lower valley between the Narrows and Wiley, the unconsolidated alluvium and the Yakima basalt are the only productive sources of ground water. Neither the cemented-gravel unit nor the Ellensburg formation is known to yield more than small amounts of water to wells. Basalt aquifers yield as much as 1,050 acre-feet per year to 5 wells in the lower valley; individual well yields range from 210 gpm (well 12/17–8R3) to 640 gpm (well 12/17–16D3). The wells range in depth from 243 feet (well 12/17–17C1) to 1,078 feet (well 12/17–16R1).

Farther east the Yakima basalt plunges deeper beneath the valley floor; its upper surface may be as much as 1,500 feet below the land surface near the city of Union Gap. Its depth in the eastern part of the lower valley makes the cost of drilling to the basalt prohibitive, and no wells have been drilled deep enough to reach it. Well 13/18–29Q1, in Wide Hollow, penetrated basalt at a depth of 1,250 feet, but it apparently was not drilled far enough into the basalt to tap a productive aquifer (table 4). Fortunately, the Ellensburg formation contains productive aquifers east of the Wiley-Ahtanum district, and the cemented-gravel unit is a productive source of ground water at the mouth of the lower valley. The Ellensburg formation yields about 730 acre-feet per year to 10 wells in the lower valley. The wells produce up to 1,100 gpm (well 12/18–2E1), and range from less than 100 to more than 600 feet in depth. The cemented-gravel unit yields about 800 acre-feet per year, mostly to wells in and near the town of Union Gap.

The unconsolidated alluvium yields most of the domestic water used in the lower valley and is a productive source of irrigation water in most of that area. Most of the wells tapping the alluvium are dug or driven and are less than 30 feet deep. Yields as great as 400 gpm have been reported for some of the shallow dug wells, and the total withdrawal from the alluvium in the lower valley is estimated to be about 1,750 acre-feet per year.

POTENTIAL DEVELOPMENT

Recharge to the Ellensburg formation, the cemented-gravel unit, and the unconsolidated alluvium probably is sufficient that additional withdrawals could be made from those aquifers in the lower valley without lowering the water levels excessively. However, in any additional development of the ground-water resources, wells should be spaced to minimize interference, and observations of water levels should be made regularly to give early warning of any overdraft.

Because of the trend toward declining water levels in wells tapping basalt aquifers, any additional development of these aquifers should be planned carefully, and the plan should include a program for the collection of hydrologic data.

Each of the aquifers in the lower valley, in localities favorable for development, is capable of yielding several hundred gallons of water per minute to a properly constructed well. The unconsolidated alluvium is, of course, the most easily developed of the aquifers. In most parts of the lower valley, a properly constructed dug well can be expected to produce more than 100 gpm. However, the probable depth, yield, and construction cost of wells in the other aquifers differ widely in different parts of the lower valley. In general, the withdrawal of additional ground water from aquifers other than the alluvium will require drilled wells ranging in depth from a few hundred feet to 1,000 feet, or even more.

Some of the probable results of increased withdrawal from the alluvium would be a lowering of the water table; a decrease, at least temporarily, in effluent seepage to streams, with a corresponding temporary increase in ground-water recharge; and possibly a slight increase in the consumptive use by vegetation if the water is used for irrigation. In order to estimate the overall effects of such increased withdrawal, it is necessary to consider not only the individual results but also the interrelation of all foreseeable results.

Any increase in the withdrawal of ground water from the unconsolidated alluvium of the lower valley would tend to lower the water table in the vicinity of the wells. This effect, by itself, would be desirable in some waterlogged areas, but along the banks of streams a lowering of the water table might be considered undesirable, as it would decrease the gradient, and therefore the amount, of water moving to the streams or, if the water table locally were lowered below the stream levels, would induce local infiltration from the stream. In either event it would decrease the streamflow. Unless the wells were located close to the streams, however, the resulting decrease in streamflow would not occur until some time after pumping was increased. On the basis of the yields from existing wells and the probable rates of ground-water movement in the alluvium, it is believed that withdrawals from shallow irrigation wells located more than a mile or two west of the town of Union Gap would have no direct effect upon the seepage of ground water directly to the Yakima River during the same irrigation season, but the cones of depression of most irrigation wells in the valley alluvium probably would be extensive enough during the latter part of the irrigation season to cause at least slight decreases in the flow of the smaller streams (Foxworthy, 1953, p. 18).

These effects—that is, the decrease in streamflow and the lowering of the water table—would be partly offset by return flow from the additional irrigation. Under normal conditions, an estimated 25 percent of the water applied returns to the streams or to the shallow ground-water body.

Additional cultivation and irrigation in the lower Ahtanum Valley would of course increase the consumptive use of water by crops. Evaporation losses also would be increased during the period of application of irrigation water. On the other hand, the nonbeneficial evapotranspiration loss would be virtually eliminated on the tracts brought under cultivation. Also, if the water table were lowered generally by increased pumping, the consumptive waste by phreatophytes in surrounding areas probably would be decreased somewhat, because in general the deeper the water table the smaller the waste by phreatophytes. The net effect that increased irrigation would have upon the amount of annual evapotranspiration discharge depends upon the degree to which these factors would balance each other.

On much of the reclaimable land in the lower Ahtanum Valley, the annual nonbeneficial evapotranspiration loss doubtless is as much as 2 acre-feet per acre, and in localities having rather dense phreatophytic growth, it probably reaches or exceeds 3 acre-feet per acre. If reasonably efficient irrigation methods were used, any crop suitable to the lower Ahtanum Valley probably would not require the application of more than about 3.5 acre-feet of irrigation water per acre, and of this amount perhaps 1 acre-foot would return to streams or the ground-water body. If this irrigation water were applied to land that is now wasting 2 or 3 acre-feet per acre, little or no additional water would be lost by evapotranspiration. Hence, the proper reclamation of a considerable area in the lower Ahtanum Valley probably would require little, if any, additional water. Any decrease in streamflow resulting from the withdrawal of ground water to irrigate the reclaimed land would be only temporary, occurring partly during the latter part of the irrigation season but mostly later in the year when the demand on streams is no longer critical.

SUMMARY OF WITHDRAWALS

The estimated withdrawal of ground water in the subareas of the Ahtanum Valley, the amounts withdrawan from the various rock units, and the utilization of the ground water in the area are summarized in table 3.

TABLE 3.—*Estimated ground-water withdrawals, in acre-feet per year, in subareas of the Ahtanum Valley, according to use and principal aquifer*

	Upper valley	Lower valley	Upland benches	Total
(USE)				
Domestic	15	400	45	460
Industrial	0	700	20	720
Irrigation	1,100	3,000	800	4,900
Public supply	0	220	0	220
Stock [1]	[2] <5	10	[2] <5	10
Total	1,115	4,330	865	6,310
(AQUIFER)				
Yakima basalt	1,100	1,050	800	2,950
Ellensburg formation	0	730	60	790
Cemented gravel	0	800	5	805
Unconsolidated alluvium	15	1,750	0	1,765
Total	1,115	4,330	865	6,310

[1] Includes supplies for dairies.
[2] Not included in total.

Most of the estimates are based on data gathered during the canvass of wells in the area. Estimates of irrigation withdrawals, however, were based largely on ground-water certificates issued by the Washington State Department of Conservation. The average irrigation withdrawal undoubtedly is considerably less than the maximum allowable under the water-right certificates, as some of the irrigation wells are not operated during years of above-average streamflow, and many others are not utilized to the extent of their water rights. Therefore, to estimate average withdrawals from wells for which certificates have been granted, the maximum allowable withdrawals have been arbitrarily reduced by one-third. For irrigation wells for which water-right certificates have not been issued, such as those south of Ahtanum Creek on the Yakima Indian Reservation, the averages were based on reported or estimated irrigated acreages.

Irrigation demands of course vary greatly from year to year, depending on such factors as climate, the availability of surface water, and market prices for crops. All the ground water used for irrigation is withdrawn during the period from May to October, and most of the large-scale pumping is done after July 1.

CHEMICAL QUALITY

Comprehensive chemical analyses of samples of water from 7 wells in the area were made by the U.S. Geological Survey in 1951 and 1952. Of these, 3 tap the unconsolidated alluvium, 2 the basalt, 1 the Ellensburg formation, and 1 the cemented basalt gravel. The results of the analyses are given in table 6. In addition, field determinations of hardness and chloride content were made of samples from about a tenth of the wells visited. The results of determinations of hardness and chloride are given in table 7. These data indicate the general character of water from the various aquifers.

RANGE IN CHEMICAL CONCENTRATION

The overall range in chloride concentration was from 0.7 to 26 ppm (parts per million), and the range in hardness was from 49 to 265 ppm. The chloride content and hardness of samples from the various aquifers range as follows:

Source of samples	Number of samples	Chloride (ppm)	Hardness as $CaCO_3$ (ppm)
Yakima basalt	6	1.2–8	54–95
Ellensburg formation	9	6 –26	75–240
Cemented gravel	10	5 –26	120–265
Unconsolidated alluvium	19	.7–14	49–148

The range in concentration of all dissolved constituents was not determined for the area as a whole because the scope of the investigation did not warrant an extensive geochemical study. In the analyses shown in table 6, the dissolved solids ranged from 113 ppm (well 12/16–17J1, tapping unconsolidated alluvium) to 235 ppm (well 12/18–11E1, tapping the Ellensburg formation). Values for pH indicated all samples to be slightly alkaline; the bicarbonate content ranged from 74 to 180 ppm.

GENERAL CHARACTER

The analyses show that the concentrations of chemical constituents in the ground water are related much more closely to the rock material in which the water occurs than to the depth of the aquifer or the geographic location of the well. Water from basalt aquifers generally has a lower concentration of chloride and lower hardness than water from the other aquifers. Water from both the basalt and the alluvium is lower in concentration of chloride and hardness than water from

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either the Ellensburg formation or the cemented gravel. Hardness of water in the alluvium apparently increases slightly downvalley, and shallow ground water in the alluvial slope south of Ahtanum Creek generally is harder than water from the alluvium north of the creek.

Differences in the chemical character of the ground water from different aquifers can be seen more clearly in figure 8, which is a graph upon which the seven comprehensive analyses have been plotted. In general, the position of each point on the graph is dependent upon the chemical character of the water with respect to proportions of 2 groups of major cations (calcium and magnesium, and sodium and potassium) and 2 groups of major anions (bicarbonate and carbonate, and sulfate and chloride) (Piper, 1944). Analyses of water samples of nearly identical chemical character plot closely together, but analyses of samples of different chemical character plot in different parts of the graph. The analyses of water from the basalt and the alluvium, represented by points 1, 3, 5, 6, and 7, all plot in a fairly close group in a part of the graph that indicates they are all of the calcium magnesium bicarbonate type. In contrast, the analyses of water from the Ellensburg formation and the cemented gravel, points 2 and 4, are entirely separate from the other group, apparently owing largely to a higher proportion of sulfate and chloride in these two water samples.

An important chemical characteristic of water for irrigation is the proportion of sodium to the principal basic constituents (calcium, magnesium, sodium, and potassium)—the "percent sodium." The U.S. Department of Agriculture (Wilcox, 1948, p. 25–27) commonly rates water as to its suitability for irrigation according to the percent sodium and the concentration of dissolved solids. By this classification, all samples analyzed rated "excellent to good" for irrigation.

The temperature of water in shallow aquifers is controlled largely by the mean annual temperature of the area. Water from deeper aquifers usually is warmer, in response to the effect of the geothermal gradient. The type of material that yields the water usually has very little influence upon the temperature of ground water. In the Ahtanum Valley, the water from the shallow wells, as much as about 40 feet deep, showed a considerable range of temperatures—from 43° to 55° F. In wells deeper than 50 feet, the temperature increases about 1° F for every 45 feet of depth, with no apparent relation to the type of material from which the water is derived. For example, well 12/17–3D1, which is 125 feet deep, yields water at 54° F, whereas well 12/18–1M1, which is 620 feet deep, yields water about 11° warmer, or at 65° F. Measurements of the ground-water temperatures in the area are given in table 4.

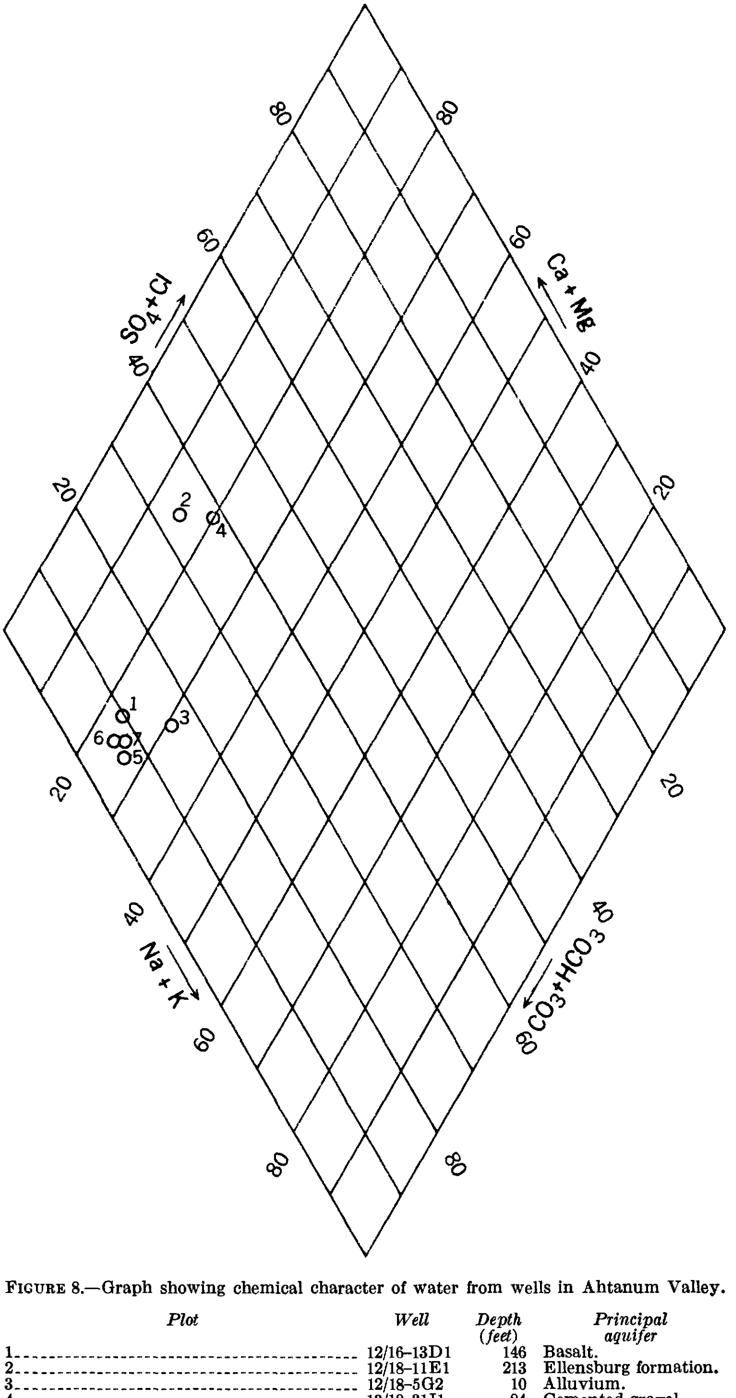

FIGURE 8.—Graph showing chemical character of water from wells in Ahtanum Valley.

Plot	*Well*	*Depth (feet)*	*Principal aquifer*
1	12/16-13D1	146	Basalt.
2	12/18-11E1	213	Ellensburg formation.
3	12/18-5G2	10	Alluvium.
4	13/19-31J1	84	Cemented gravel.
5	12/18-5J1	18	Alluvium.
6	12/16-17J1	11	Alluvium.
7	12/17-16R1	1,078	Basalt.

SUITABILITY FOR USE

The analyses, together with information supplied by residents during the canvass of wells in the area, show that the chemical quality of ground water in the Ahtanum Valley generally is satisfactory for most purposes, although water from many wells is harder than desirable for domestic use. The water generally is clear and cool and has no objectionable taste or odor. A few wells that tap basalt aquifers reportedly yield water that has a slight odor of hydrogen sulfide, but this odor usually disappears if the water is allowed to stand in an open vessel.

GROUND-WATER DISCHARGE TO THE YAKIMA RIVER

Analyses of available streamflow records indicate that the flow of the Yakima River increases substantially as it traverses the Ahtanum-Moxee subbasin. This increase is attributable partly to direct runoff from tributary streams and partly to ground-water discharge. It is possible to estimate the amount of ground-water discharge to the Yakima River within the subbasin provided that concurrent records of the flow of the river as it enters and leaves the subbasin and of streams tributary to the river within that reach are available for study.

Streamflow records have been collected concurrently at stations on the Yakima and Naches Rivers at Selah Gap, the Yakima River at Union Gap, and Ahtanum and Wide Hollow Creeks near their mouths during only two brief periods, July–October 1911 and July–September 1912. Additional measurements were made at all these stations except Wide Hollow Creek during the period May–November 1904.[5] These periods are too short to allow more than a tentative estimate of ground-water discharge.

The records show that the flow of the Yakima River nearly doubles between Selah Gap, where it enters the Ahtanum-Moxee subbasin, and Union Gap, where it leaves the subbasin. Most of the increase comes from the Naches River, which discharges into the Yakima just below Selah Gap, and from Ahtanum and Wide Hollow Creeks. The rest enters the river as ground-water seepage and intermittent surface runoff.

On the basis of records for the period cited above (but omitting those for May and June 1904, which reflect flood stages that apparently mask the effect of ground-water discharge), the average monthly ground-water increment to the Yakima River between Selah Gap and Union Gap is estimated at 9,000 acre-feet per month.

[5] Records cited above, except those for Wide Hollow Creek, have been published in U.S. Geological Survey Water-Supply Paper 1316. The records for the station on Wide Hollow Creek have not been published but are available for examination at the office of the U.S. Bureau of Reclamation at Yakima.

Ground-water contributions from specific areas within the subbasin also may be estimated from the total discharge, provided that certain additional assumptions are made. It is assumed that more than half the ground-water increment to the Yakima River, perhaps 5,000 acre-feet per month, came from the west side of the Ahtanum-Moxee subbasin, where precipitation and surface discharge are greater. If it is assumed further that the contribution from the west side of the subbasin is evenly distributed throughout the 8-mile reach, the yearly total for each mile would amount to about 7,500 acre-feet. Because of lack of precise data on elevations of the land surface and on water levels in wells and streams, no ground-water drainage divide between wide Hollow Creek and the Ahtanum Creek system has been located. Hence, the ground-water contribution from the area drained by Ahtanum Creek cannot be determined directly. However, for the 3-mile reach of the Yakima River shown on figure 1 the effluent seepage directly into the Yakima River and to the short intermittent streams and drains which empty into the river may be on the order of 20,000 to 25,000 acre-feet per year. Doubtless a part of that ground-water discharge is from Wide Hollow, but the proportion cannot be determined on the basis of available data.

The preceding estimate of ground-water discharge to the Yakima River constitutes the total for all the aquifers. The discharge from the unconsolidated alluvium may be estimated separately, using the transmissibility data derived from aquifer tests and the gradient of the water table, according to the following modification of the gradient formula:

$$Q = Thl$$

where Q is the quantity of water discharged, in gallons per day,
T is the coefficient of transmissibility, in gallons per day per foot,
h is the hydraulic gradient, in feet per mile,
l is the length of the discharging area, in miles.

The gradient of the water table (h) in the lower valley near the Yakima River is about 25 feet per mile, and the length of the discharging area (l) is 3 miles. If the average coefficient of transmissibility (T) is assumed to be 60,000 gpd per foot on the basis of the results of the aquifer tests previously described (table 2), the discharge (Q) is on the order of 4.5 mgd (million gallons per day), or about 5,000 acre-feet per year. Thus it is estimated that the alluvium discharges as much as one-fourth of the total ground-water discharge from the area to the Yakima River.

PROBLEMS OF FUTURE WATER SUPPLY

The foregoing discussion outlines the ground-water conditions in the Ahtanum Valley during 1951–58, insofar as avaliable data permit. This period has been marked by continuing construction of wells for irrigation and by a major lawsuit concerning apportionment of the inadequate summertime flow of the streams. If the productivity of the land and the economy of the population are to reach optimum levels, a comprehensive plan must be established for the systematic development and management not only of the ground water but also of the total water resources of the area.

Efficient management requires a comprehensive inventory of the water resources of the area. This report provides estimates for some of the factors pertinent to such an inventory; the available data allow only tentative conclusions about other critical factors. Also, some of the quantitative estimates presented in this report may require revision as new data become available or if the use of water changes materially. To complete a comprehensive water-resources inventory, insofar as possible, to refine and check the conclusions reached during the present investigation, and to evaluate the long-term effect of water use upon the hydrologic regimen, the investigative studies outlined in the following paragraphs are recommended, to begin as soon as possible.

STREAMFLOW

For a continuing evaluation of the inflow-outflow relationship of Ahtanum Creek, the records from the existing gaging stations on the North and South Forks of the creek need to be supplemented by additional streamflow data at its mouth. Therefore, permanent reestablishment of the former gaging station on Ahtanum Creek near Union Gap is recommended. In addition, a station at the Narrows would provide data for determining seasonal gains and losses in streamflow within the upper or lower parts of the valley.

Additional data are needed also on the flow of Wide Hollow Creek to determine gains or losses in the stream as it traverses the lower Ahtanum Valley and to establish its relation to the water table in that part of the area. A gaging station located near its mouth would be required to provide adequate data on the outflow from the creek; another gaging station near the Yakima Airport would be required to measure the surface inflow to the lower valley.

The present estimate of ground-water discharge from the Ahtanum Valley to the Yakima River probably could be refined if additional data were available on the gain in flow of the river in the reach adjacent to the valley. This would necessitate at least one additional gaging station, on the river upstream from the project area and below the confluence with the Naches River, to provide records to supplement those from the existing station at Parker. However, much better results would be obtained if the downstream record were collected in Union Gap (below the mouth of Ahtanum Creek) rather than at Parker.

GROUND WATER

Periodic field canvasses should be made of newly constructed wells, particularly those of moderate or large yield, to fill gaps in current information on the availability of ground water in various parts of the area, on the extent and yield of the aquifers, and on ground-water levels.

The network of observation wells used in this investigation should be expanded and maintained on a continuing basis to define more accurately the seasonal fluctuations of water levels and artesian pressures and to give early warning of any possible overdraft from the aquifers. The network should include at least a few wells tapping each aquifer and as many of the irrigation and other large-yield wells as possible. The elevations of the measuring point at each well on the network should be established precisely by leveling. In the eastern part of the lower valley, relatively close spacing of observation wells tapping the unconsolidated alluvium will be necessary to determine whether a clearly defined ground-water divide exists between the lower Ahtanum Valley and Wide Hollow.

WATER USE

Inasmuch as the amount of water used in the Ahtanum Valley varies from year to year, a continuing appraisal of water use for all purposes from both surface- and ground-water sources is needed for effective management of the water resources. Data on annual withdrawals from wells are especially important as a possible means of determining optimum yields of some of the aquifers where the withdrawal can be related to water-level changes.

PRECIPITATION

In order to determine the total amount of water entering the Ahtanum Valley, it will be necessary to refine the estimates, made in this report, of the distribution of precipitation throughout the valley. Operation of additional precipitation gages on the floor and slopes of the upper valley for at least a few years probably would yield the data required.

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BASIC DATA

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*

[Locations of wells are shown on pl. 1]

Topography:
Ap, alluvial plain; As, alluvial slope; S, slope; Ub, upland bench; V, valley.
Land-surface datum: Approximate altitude of land-surface datum at well interpolated from topographic maps.
Type of well: Bd, bored; Dg, dug; Dn, driven; Dr, drilled.
Depth to water level: Measurements made by the Geological Survey expressed in feet and decimal fractions; depths reported by owner, tenant, or driller expressed in feet. In flowing wells, "+" preceding the water-level measurement indicates static head in feet above land-surface datum. "Flows" indicates unmeasured static head.
Type of pump: B, bucket; C, centrifugal; J, deep-well jet; N, none; P, deep-well piston; S, suction; T, turbine.
Use of water: D, domestic; F; fire protection; Ind, industrial; Inst, institutional; Irr, irrigation; PS, public supply; S, stock; NU, not in use. Symbol in parentheses indicates former use.
Remarks: C, comprehensive chemical analyses in table 6; Cp partial chemical analyses in table 7; dd, drawdown; gpm, gallons per minute; H_2S, hydrogen sulfide gas; L, log in table 5; temp, temperature. Aquifer tests are discussed on p. 46.

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s)			Water level		Pump		Use of water	Remarks
								Depth to top (feet)	Thickness (feet)	Formation and Material	Depth (feet below land-surface datum)	Date measured	Type	Horsepower		
T. 12 N., R. 15 E.																
13R1	William Monder	Ap	2,180	Dr	329	16	50	53		Yakima basalt	Flows	5-1-51	T	36	Irr	Reportedly flowed 160 gpm in 1945; pumped 900 gpm for 4 hr, dd 80 ft; temp 56° F; Cp, L.
T. 12 N., R. 16 E.																
4H1	W. H. Shuck	Ub	2,180	Dg	48	48	4			Ellensburg formation (clayey sand).	24.29	6-20-51	P		D	Clayey sand from 4 to 25 ft.
4J1	Anna G. Aumiller	Ub	2,180	Dg	51	54				Ellensburg formation (clayey sand).	4.9	6-13-51	P		NU(D)	Soil to 1 ft, cemented basalt gravel to 2.5 ft, and clayey sand to 5+ ft.
4R1	M. D. Spohn	Ub	2,160	Dg	19	2	19				4.3	6-13-51	S		D	
8H1	Vernon Mondor	Ub	2,250	Dr	380	10-8	380			Yakima basalt			T	20	Irr	Reported originally flowed 180 gpm; not flowing 6-13-51; L.
8N1	W. Mondor	Ub	2,200	Dg	30	48				Cemented basalt gravel(?).	10.9	6-13-51	S		NU(D)	Cp.

9H1	James Edwards	Ub	2,080	Dg	16	36				Alluvium	7.5	6-13-51	S		D	Reported to go dry in late summer.
9M1	Vernon Mondor	Ub	2,150	Dg-Dn						Cemented basalt gravel(?).			S		D	Cp.
10N1	Charles Bows	S	1,990	Dg	18	6				do	7.8	6-13-51	N		NU	
11K1	M. A. Lesh	V	1,850	Dr	230	6	72			Yakima basalt	1	4-11-48	T	15	Irr	Gravel to 60 ft, basalt to 230 ft. Pumped 168 gpm for 1 hr, dd 154 ft; temp reported 60° F.
13D1	Herke Bros	Ap	1,750	Dr	146	14	27	130	10±	do	55	4-22-51	T	30	Irr	Pumped 850 gpm for 1½ hr, dd 20 ft, "full" recovery in 30 sec; A, C, L.
13D2	do	Ap	1,750	Dr	130	8				do	51.8	5-7-51	N		NU(D)	Originally irrigation test well.
13H1	Lee Boatman	Ap	1,690	Dg	9	36				Alluvium (gravel)	4.0	5-7-51	S		D	
13K1	Benjamin Phillips	Ap	1,700	Dg	13	24				do	5.3	5-7-51	S		D	
14F1	Herke Bros	Ap	1,830	Dr	160					Yakima basalt			S	½	D	Sand from 156 to 158 ft.
15D1	Arthur Hanses	S	1,960	Dn	8	1½				Alluvium	5.6	5-4-51	S		NU(D)	
15E1	Hiram White	Ap	1,900	Dr	598	12	255	235		Yakima basalt	60	6- -29	T	20	Irr	"Slight flow" at 235 ft, which stopped as drilling proceeded to approximately 500 ft; pumped 360 gpm in 1945; 8-inch perforated liner 155-255 ft.
15F1	Arthur Hanses	S	1,900	Dr	544	10-6	278	411		Alluvium	52.9	4-24-46	T	20	Irr	Pumped 335 gpm, dd 27.5 ft; L.
15M1	do	Ap	1,870	Dr	43	12	42+			do	3.7	5-4-51	N		NU	Cp.
17D1	Mrs. Henry Lesh	Ap	2,160	Dg	20	1½				do			S		D	Cp.
17J1	S. A. Mondor	Ap	2,050	Dg	11	60	0			Alluvium (gravel, coarse, unsorted).	6.4	5-2-51	B		D	Gravel to bottom; C.
17K1	Nicholas Schuller	Ap	2,050	Dg	12	24	12			Alluvium (gravel)	3	5-2-51	S		D	Cp.
17L1	R. E. Knox	Ap	2,080	Dr	100	6	90±				11.1	5-2-51	S		D	Reported inadequate for irr.
18A1	W. Mondor	Ap	2,110	Dr	16	6				Alluvium	9.0	5-1-51	S		D	
18B4	Frank Mayfield	Ap	2,120	Dr	196	8				Cemented basalt gravel(?).	.6	5-21-51	N		NU	Filled with rocks to 2 ft; L.
18C1	Garrison & Hazen	Ap	2,200	Dr	287	14-7	287	210	58	Yakima basalt			T	40	Irr	Originally flowed; pumped 1,260 gpm for 4+ hr, dd 140 ft; L.
18G1	Frank Mondor	Ap	2,110	Dr	384	12	40				2.4	5-1-51	T	5	Irr	Slight initial flow; pumped 350 gpm, dd 70 ft; L.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 16 E.—Continued																
18K1	Herke Bros	Ap	2,110	Dr	343	8–5	315			Yakima basalt	Flows	5–1–51	T	20	Irr	Flow started at depth of 320 ft; reported flow 90 gpm, 2-20-46; pumped 220 gpm, dd 115 ft; Cp, L.
18L1	W. Mondor	Ap	2,130	Dg	18	36	15±	4	14	Alluvium (sand and gravel).	3		S	⅛	D	Supplies 5± families. Soil to 4 ft, sand and gravel to 18 ft.
T. 12 N., R. 17 E.																
1B2	Lane Ferguson	Ub	1,310	Dg	17	72	6	10	7	Cemented basalt gravel.	9.0	6–29–51	S	¾	D, S	Cemented basalt gravel from 6 to 17 ft.
1D1	H. C. Wilson	Ub	1,350	Dr	180	6	180			Ellensburg formation.	65	10– –48	P	¾	D	Supplies 2 families.
1E1	G. J. Bayle	Ub	1,360	Dg	47	48					2.2	6–29–51	S		S	
1E3	Lyman Lennington.	Ub	1,360	Dr	159	6	100±			Ellensburg formation.			T	3	D	
1G2	B. E. Snelling	Ub	1,280	Dr	200	6–5	200	197±	3±	Ellensburg formation (coarse sand).	60		J	1	D	L.
1J4	Ira Gray	Ap	1,280	Dn	15	1½				Alluvium	5.3	5–29–51	S	1	D, Irr	
1L1	Lyman Lennington.	Ap	1,320	Dr	33	6	20	29		Alluvium (sand and gravel).	9.6	7–2–51	S	1½	D	Cp.
1M2	R. Shaw	Ap	1,360	Dg	4	96				Alluvium	.9	6–1–51	S	¼	D, Irr	
1N1	Arthur Fulbright	Ap	1,350	Dr	77	6				Cemented basalt gravel.	5.0	5–16–51	S	⅓	D, Ind	Supplies 3 stores and 3 families.
1P1	Springbrook Dairy.	Ap	1,300	Dr	79	6				Alluvium(?)	2.1	6–22–51	S	½	D, Irr, Ind	Supplies 3 families, 3 sprinklers, and small dairy; temp 51° F; Cp.
2A1	S. T. Ray	Ub	1,400	Dr	198	6				Ellensburg formation.	70	1951	P	¾	D	

2J2	Floyd Willard	Ub	1,400	Dr	92	6	40	90±		Ellensburg formation (black sand).	55.6	7- 6-51	P		UN (Irr)	Cemented gravel to about 90 ft.
2J3	do	Ub	1,400	Dr	94	6	40	90±		do	50		J	1	D	Cemented gravel to about 90 ft. Water reported to have slight odor of H_2S.
2K1	Gilbert Orchards, Inc.	Ub	1,450	Dr	150	6				Ellensburg formation(?)	50+	6-29-51	P	⅓	D	Supplies 2 families; formerly used for irrigation; pumped 50 gpm, dd 90 ft.
2N1	Gilbert Orchards, Inc.	Ub	1,390	Dr		6				Ellensburg formation (?).	36.8	5-16-51	P	½	D	Supplies 3 families; Cp
2P1	Conrad Kuhl	Ap	1,380	Dg	11	4				Alluvium (gravel)	2.4	6-16-51	S	¼	D, Irr	Irrigates about ½ acre of berries.
2P2	J. A. Richartz, Jr.	Ap	1,380	Dg	16	6				do	5.7	5-17-51	S	¼	D, Irr	Irrigates 1 acre of pasture.
2Q1	Ruth Kerl	Ap	1,390	Dr	75	6				Cemented basalt gravel(?).			C S	1 ⅓	D	Cp.
2Q3	E. Spohn	Ap	1,380	Dg	16	36		13		Alluvium (sand and gravel).	5.0	5-17-51	T	3	Irr	Tested at 150-200 gpm early in irrigation season, dd 10 ft; sand and gravel to bottom.
2R1	Floyd Willard	Ap	1,350	Dr	48	6	42			Alluvium(?) (coarse gravel).	20	9- -50	J	1	D, Ind	Supplies frozen food lockers, tavern, and garage; pump capacity reported 30 gpm.
2R2	Frank Glaspey	Ap	1,325	Dg	9	36				Alluvium (gravel)	2.5	5-24-51	C	1½	Irr	Temp 55° F; aquifer test; Cp.
3A1	Olaf Lawrie	Ub	1,510	Dr	107	6				Ellensburg formation(?).	20.1	6-29-51	S	⅓	D	
3B1	Henry Carlson	Ub	1,540	Dr	92	6	60	90±		Ellensburg formation (sand).	11.4	6-27-51	S	½	D	Cemented gravel to about 90 ft.
3C1	M. W. Beecham	Ub	1,550	Dr	319	5½	90	300±		Cemented gravel (?).			P	1	D, S	Pump capacity reported 3⅓ gpm.
3D1	N. S. Kelly	Ub	1,580	Dr	125	6	40±			Ellensburg formation(?).	15	1948	S	½	D	Temp 54° F.
3E1	E. H. Lovestrand	Ub	1,580	Dr	90	6	50			do	11.3	12- 5-51	S	¼	D	
3J1	G. E. Clasen	Ub	1,510	Dr	160	6				Ellensburg formation.	17.6	6-28-51	S	½	D	
3M2	A. V. Anderson	Ub	1,560	Dr	118	6	60				20	6- -51	S	¼	D	Pumped 3⅓ gpm, dd 1½ ft.
3M3	F. T. Tissell	Ub	1,600	Dr	262	6				Ellensburg formation.	182	1946	P	3	D	Supplies 3 families; pumped 90 gpm for 4 hr, dd 33 ft.
3N1	Carl Nystrom	Ub	1,600	Dr	100	6					2.8	6-28-51	S	½	D	Pumping when measured; supplies 2 families.
4F1	C. R. Holtzinger	Ub	1,630	Dr	80	6-4				Ellensburg formation(?) (sand and gravel).			S	½	D	Reported to have pumped sand occasionally.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 17 E.—Continued																
4H1	J. R. Borton & Sons.	Ub	1,600	Dr	360			110	"Few feet"	Ellensburg formation (sand).	172	8–16–46	T	5	D, Ind	Supplies fruit packing plant. Pumped 72 gpm for 10 min, dd 15 ft.
4H2	do	Ub	1,590	Dr	235					do			T	3	Ind	Supplies fruit packing plant.
4J1	L. H. Mansperger	Ub	1,590	Dr	101	6	80			Ellensburg formation(?).	9		J	1	D, Ind	Supplies fruit packing plant; pumped 13⅓ gpm, dd 54 ft.
4K1	C. E. Kuhnke	Ub	1,630	Dr	240	6				Ellensburg formation (sand).			P	1	D	Supplies 2 families.
4N1	Cohodas, Lancaster, Frank Co.	Ub	1,600	Dr	397	6	235			do			P	2	D	Supplies several families; pump capacity reported 50 gpm.
4P1	do	Ub	1,600	Dg	39	48	0			Cemented gravel (?).	11.9	6–26–51	S	½	D	Supplies 2 families; cemented gravel to about 15 ft.
5B1	E. L. Lenington	V	1,560	Dr	170	6	77	160	10	Ellensburg formation (sand).	6	6–25–51	T	5	D, Irr	Pumped 300 gpm, dd 35 ft; temp 54° F; Cp, L.
5E1	Otis Bailey	V	1,620	Dr	117	6				Ellensburg formation.	79	9– 2–47	P	½	D, S	Pumped 48 gpm for 1½ hr; dd 35 ft.
5H1	Peter Pan Arendonk.	Ub	1,650	Dr	215	6	10	204		Ellensburg formation (sand and gravel).	190		P	1½	D, Irr	
5N1	Gilbert Orchards, Inc.	Ub	1,740	Dr	315	6	294	306		Ellensburg formation.	200	6– –51	P	1½	D	Pumps 9.6 gpm.
6F2	R. F. Morozzo	V	1,680	Dr	159	6	44	140	10	Ellensburg formation (sand).	30	6–19–51	N		NU	To be used for irrigation; L.
6J1	George Weaver	V	1,680	Dr	140	6	140			Ellensburg formation.	55	1950	J	¾	D	Penetrated mostly clay with 3 or 4 thin water-bearing sand layers; casing perforated from 120 to 140 ft; Cp.

6J2	do	V	1,680	Bd	35	6	0	37		do	2.7	6-25-51	N		NU	
7R1	E. E. Crosno	Ap	1,620	Dg	12	1½				Alluvium	5.1	5- 7-51	S		S	
8C1	John Austin	Ub	1,700	Dr	320	6				Ellensburg formation.			P	2	D	Reported inadequate.
8G1	Volney Eglin	Ap	1,560	Dg	12	8	12			Alluvium	2	5- 9-51	S	¼	D	
8J1	do	Ap	1,550	Dg	14					do			S	⅓	D	Cp.
8K1	Merle Carson	Ap	1,570	Dr	100	16	60	70	25	Ellensburg formation (sand).	30	5- 8-51	S	¼	D	Cp, L.
8R2	A. W. Grissom	Ap	1,530	Dr	22	8				Alluvium	1.6	5- 8-51	S	¼	D	
8R3	James Bowers	Ap	1,550	Dr	410	8	245	248	159	Yakima basalt	124	2- 6-53	T	20	Irr	Pumped, 185 gpm for 4 hr, dd 76 ft; temp 60° F; water reportedly contains H_2S. Flowed at depths of 248 and 400 ft; L.
9C1	F. M. Stull & Son.	Ub	1,610	Dr	91	6	68			Cemented basalt gravel.	23	1948	S	½	D	Reported inadequate.
9E1	Dean Rutherford	Ap	1,520	Dr	80	6							S	½	D	Cp.
9H1	R. J. Schmella	Ap	1,460	Dr	15	6				Alluvium	6.6	5- 9-51	S	⅓	D	
9J1	Walter McInnis	Ap	1,450	Dg	7	36				Alluvim (gravel)	3.9	5- 9-51	S	¼	D	Reportedly goes dry when Ahtanum Creek fails.
9J3	Walter McInnis (formerly Marks School).	Ap	1,470	Dr	575	4¼		522	53	Yakima basalt	86.4	1-20-53			NU (Inst)	L.
10A2	C. L. Lester	Ap	1,400	Dr	33	6	30			Alluvium	3.9	5-16-51	C	3	Irr	Pumped 100 gpm for 4 hr, dd 14 ft.
10B1	Claude Ekland	Ap	1,420	Dr	35	8				do	3.9	5-14-51	S	1	D, S	
10C1	do	Ap	1,420	Dg	8	36	8	4		Alluvium (coarse gravel).	2.4	5-14-51	C	1	Irr	Aquifer test. Well 10C2 drilled inside this well.
10C2	do	Ap	1,420	Dr	470	8	33			Ellensburg formation (clay and shale).			N		NU	Reported inadequate; L.
10E1	Marian and Irene Hall.	Ap	1,450	Dg	10	48	0			Alluvium (coarse gravel).	5.7	5-15-51	S	¼	D	Reportedly goes dry in late summer.
10H1	Alex Iriarte	Ap	1,380	Dg	13	48				Alluvium	4.9	5-11-51	S	¾	D (Irr)	
10J1	C. R. Holtzinger	Ap	1,390	Dr	100	8	80			Cemented basalt gravel(?).			S	¼	D	Reported inadequate for irrigation; Cp.
10N1	William Bunger	Ap	1,450	Dg	30	36	30			Alluvium	4.4	10-20-52	S	⅙	D	
10N3	Leland Torson	Ap	1,440	Dg	11	36	11			Alluvium (gravel)	4	1946	S	½	D	"Hardpan" at bottom; Cp.
10R1	C. R. Karney	Ap	1,390	Dn	18	2				Alluvium			S	⅓	D	Cp.
11A1	Gilbert Orchards, Inc.	Ap	1,347	Dr	786	10	787	805	12	Cemented basalt gravel, Ellensburg formation.			T	20	D, Ind	Supplies cold storage plant and several families. Filled from original 1,025-ft depth to reduce water temp; pumped 250 gpm, dd 140 ft; L.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 17 E.—Continued																
11A8	School District 128.	Ap	1,330	Dr	30	6				Alluvium	9	6- -51	T	10	Inst	Supplies 2 school buildings.
11A9	do	Ap	1,330	Dr	101	6-4				Cemented basalt gravel.	25	6- -51			NU	Reported inadequate for school supply.
11B2	W. H. Neumiseter.	Ap	1,360	Dn	11	2				Alluvium			C	5	Irr	
11C1	Shirley Ward	Ap	1,370	Dg	14	36				do	4.5	5-17-51	S	¼	D	
11D1	Manuel McCully	Ap	1,380	Dg	10	96				Alluvium (gravel)	1.2	5-16-51	C	1	Irr	Irrigates 5½ acres when surface water fails.
11D3	Shirley Ward	Ap	1,370	Dr	390	10				Ellensburg formation(?).	10	3- -46	T	20	Irr	Originally flowed but stopped in 1930; reported filled from 800-ft depth in 1946; at present depth, pumped 510 gpm, dd 42 ft.
11D4	Ernest Bitz	Ap	1,390	Dr	30	6	30	26	4+	Cement basalt gravel (gravel and sand).	4	4-24-53	C	2	Irr	Pumped 50 gpm for 8 hr, dd 2 ft; L.
11M1	Shirley Ward	Ap	1,380	Dg	10	30				Alluvium	4.4	5-16-51	S	¼	D	Cp.
11N2	—Lindsey	Ap	1,360	Dr	35	6	35	33±		Alluvium (gravel)	4.3	7-16-58	S		NU (D)	Penetrated 13± ft of "hardpan" above aquifer.
12C1	Phillip Meyer	Ap	1,300	Dg	8	36-6	4	3		do	3.1	5-25-51	C	1	Irr	Irrigates ¼ acre.
12D6	Henry Dinzl	Ap	1,330	Dg	8	36				Alluvium	.9	5-25-51	C	3	Irr	Irrigates ¾± acre.
12E1	Otis Goode	Ap	1,320	Dr	26	6				do	5.8	5-28-51	S	⅓	D	Temp 49° F. Cp.
12H3	H. E. Brownley	Ap	1,280	Dr	25	8				do	1.6	5-29-51	N		NU	Well filled by caving to 25 ft; originally 192 ft deep; pumped 1800± gpm for 48 hr, dd 32 ft.
12K1	Allen Shockley	Ap	1,290	Dg	12	6				Alluvium	3	5-29-51	S	⅙	D	Cp.
12L1	E. S. Shockley	Ap	1,300	Dn		2				do	1.1	5-29-51	S	¼	D	

13H1	Frank Cortel	Ap	1,310	Dr	31	6				Cemented basalt gravel(?).	4.0	5-28-51	S		D	Cp.
13J1	Schwarzmiller Bros.	As	1,370	Dr	100±					do			P	¼	D	Reported inadequate.
14H2	Adaline Um-Tuch	Ap	1,350	Dr	31	6	22			Alluvium	11.8	6-22-51	S		D	
15G1	E. E. Brownlee	Ap	1,395	Dr	17	6				do	3.4	5-10-51	S	¼	D	
15N1	B. S. Borton & Sons.	As	1,510	Dr	140	6				Cemented basalt	60	1950	P		D	Water reported to contain H_2S.
16A1	Robert F. Wiley	Ap	1,460	Dg	12	12				Alluvium (gravel)	3.9	5-10-51	S	¼	D	
16D1	A. Merrit	Ap	1,530	Dg	10	1½				do	4.3	5- 8-51	S		D	
16D3	Jack Schreiner	Ap	1,510	Dr	384	10	312	325	59	Yakima basalt	59	5-15-52	C	7½	Irr	Irrigates 60± acres of pasture. Flows 640 gpm; temp 61° F; L.
16Q1	Kenneth Withers	As	1,530	Dg	11	1				Alluvium	4.8	5-15-51	S	¼	D, S	Cp.
16R1	B. S. Borton & Sons.	As	1,550	Dr	1,078	12-6½	940	1035	38	Yakima basalt	Flows	3-19-51	T	20	Irr	Irrigates 80-acre orchard; reported to contain H_2S, pumped 525 gpm, dd 160 ft; reported flow 92 gpm in 1944; C, L.
17C1	Carl Sheneberger	Ap	1,570	Dr	243	8-6	243	204	36±	do	Flows	5- 7-51	T	10	D, Irr	Slight H_2S odor; pumped 200 gpm, dd 23 ft; Cp, L.
17C2	do	Ap	1,570	Dr	56	6	30±	16	14	Alluvium and cemented basalt gravel.			S	½	D	Reported to have caved from 80-ft depth; reportedly well goes dry August and September.
17G2	George Bak	Ap	1,570	Dr	6	82				Ellensburg formation (sandstone).	11.4	7-14-58	T		D	Aquifer encountered near bottom.
17H1	J. R. Rutherford	Ap	1,540	Dg	8	1½					+.2	5- 9-51	N		NU(D)	Flood water ponded around casing when measured.
17J1	do	Ap	1,540	Dg	15	60	15	15		Alluvium (sand and gravel).	1.3	5- 9-51	N		NU(Irr)	Formerly irrigated 35 acres of hops; pumped 360± gpm, dd 13 ft; temp 43° F; L.
18H1	Paul Bak	Ap	1,610	Dg	4	36	4	1		Alluvium (gravel).	3.0	5- 7-51	S	½	Irr	
18H2	Joseph Bak	Ap	1,610	Dr	58	6	40			Alluvium(?) (sand and gravel).	20		S	¾	D, S	Supplies 2 families.

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TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 18 E.																
1C1	Elsa Schroeder	Ap	1,020	Dg	10	36	0			Alluvium (silt)	6.6	7-31-51	B		D	Silt to bottom.
1D1	Frederick Batt	Ap	1,030	Dr	23	4	23	13	10	Alluvium (gravel)	4		S	½	D	
1E1	Galvin Guadulupe.	Ap	1,030	Dn	18	1½				Alluvium	5.9	7-27-51	S		D	
1G2	R. C. Evans	Ap	1,020	Dg	8	48	0			do	6.2	7-27-51	S		NU(D)	Silt to bottom.
1H1	C. G. Bach	Ap	1,000	Dr	39	6	40±	6		Alluvium (sand and gravel).		8- 7-51	S	¼	D	Soil to 6 ft, sand and gravel to 40 ft.
1M1	Yakima Farm Labor Camp.	Ap	1,020	Dr	620	10-8	555	600	20±	Ellensburg formation (sand).	+4.5	11- -39	C	10	PS	Flowing 560 gpm, Nov. 1939; has supplied domestic water for approximately 300 cabins since 1939; temp 65°F, Cp, L.
1Q1	Earle McKissick	Ap	1,000	Dr	42	6				Alluvium (sand and gravel).	2.2	7-31-51	S	½	D	
1R1	U.S. Geological Survey.	Ap	995	Dn	9	1½	9	8		Alluvium (gravel, unconsolidated).	5.6	12-18-52	N		NU	Observation well; silt to 8 ft, gravel to 9 ft.
2E1	LeRoy Schreiner	Ap	1,080	Dr	405	10-6	376	370		Ellensburg formation (sand and gravel).	+0.2	7-26-51	T	15	Irr	Also flowed at depths of 125 ft and 170 ft; L.
2G1	do	Ap	1,050	Dr	43	6	43	12		Alluvium (sand and gravel).	7		S C	½ 1	D, Irr	Soil to 12 ft, sand and gravel to 43 ft.
2H1	— Davis	Ap	1,040	Dn	17	1¼				Alluvium	5.0	7-27-51	S		D	
2J1	Glaspey Sawmill	Ap	1,030	Dg	21	48	13	16		Cemented basalt gravel.	10.9	7-27-51	C C	3 15	Ind	Both pumps operating when measured; supplies sawmill; reported inadequate; soil to 17 ft, cemented gravel to 21 ft.
2K1	L. W. Maybee	Ap	1,040	Dn	17	1¼				Alluvium	5.0	7-26-51	S		D	

2L1	Riley Kelly	Ap	1,050	Dg	15	48	15			Alluvium (silt?)	6	5-30-52	C	7½	Irr, S	"Soil" to bottom; pumped 200 gpm for 4 hr, dd 6 ft; perforated every 1.5 ft to bottom.
2N1	L. C. Moorehead	Ap	1,060	Dn	13	1¼				Alluvium	8.0	7-26-51	S		D	
2Q1	H. C. Detloff	Ap	1,040	Dr	41	8	41			Alluvium(?)	5.4	7-27-51	S	½	D, Ind	Supplies home and dairy.
3D1	Roy Purviance	Ap	1,105	Dg	11	16				Alluvium	5.5	7-18-51	S	¼	NU(D)	
3E3	Harold Armstrong	Ap	1,100	Dn	13	1¼				do	4.7	7-18-51	S		S	
3F1	D. F. Woerner	Ap	1,100	Dg	9	30	11	6		Alluvium (gravel)	5.8	7-18-51	S	⅓	Irr	Reported inadequate; soil to 6 ft, gravel to 9 ft.
3H1	R. E. Davis	Ap	1,070	Dn	18	1¼				do	5.2	7-26-51	S		D	
3K4	Herman Center	Ap	1,080	Dg	9	48				do	5.9	7-20-51	C	2	Irr	Pumped 50 gpm for 4 hr, dd 2 ft.
3M3	David Pattison	Ap	1,100	Dg	15	48±				Alluvium	5.9	7-18-51	N		NU (Irr)	Caving badly.
4F1	A. H. Lust	Ap	1,130	Dg	12	36	12			Alluvium (gravel and sand).	3.8	7-14-51	C	1	Irr	Aquifer test.
4R1	R. B. Shoemaker	Ap	1,100	Dn	27	2	27			Alluvium	4.8	7-18-51	S		D	
5A1	J. H. Rettig	Ap	1,180	Dg	11	48	12	3	9	Alluvium (gravel and sand).	4.5	7-20-51	N		Irr	Pumped 100 gpm for 4 hr, dd 8 ft; reported seldom used.
5C2	Claire Van Eaton	Ap	1,190	Dg	13	24				Alluvium (gravel?)	6.8	7- 9-51	C	3	Irr	
5C3	do	Ap	1,190	Dr	285	8	205			Cemented basalt gravel.	9.4	7- 9-51	N		NU (Irr)	Drilled inside well 5C7. Cemented gravel to 285 ft. Reported inadequate for irrigation.
5C7	do	Ap	1,190	Dg	15	14				Alluvium gravel(?).	7.0	7- 9-51	N		NU (Irr)	Well 7C3 drilled inside this well.
5D1	Maurice Renville	Ap	1,210	Dn	20	2				Cemented basalt gravel(?).			S	½	D	
5E2	A. J. Mowatt	Ap	1,205	Dg	17	36		5	12	Alluvium (sand and gravel).	5.6	7- 9-51	T	2	Irr	Pumped 200 gpm for 4 hr, dd 2 ft.
5E3	J. C. Hansen	Ap	1,200	Dr	27	6				do	8.4	7- 9-51	C	1	D, S	
5G1	Mrs. Flora Rush	Ap	1,190	Dn		1¼				Alluvium			S	¼	D	Cp.
5G2	H. E. Anderson	Ap	1,190	Dg	10	30		3	9	Alluvium (sand and gravel).	2.5	7-18-51	T	2	Irr	Soil to 3 ft; pumped 250 gpm, dd 2 ft; C.
5H1	C. L. Cook	Ap	1,180	Dn	20	1¼				Alluvium	4		S	½	D, S	Pumped 16 gpm, dd "small."
5J1	Joel Richwine	Ap	1,170	Dg	18	30	18	17		Alluvium (sand)	7.5	9-26-51	T	3	Irr	Aquifer test; C, L.
5J3	Oral Brown	Ap	1,165	Dr	280	8	203	275	5	Ellensburg formation (sand).	21	2- 3-53			Irr	Bailed 50 gpm; L.
5M1	G. E. Stewart	Ap	1,210	Dg	16	72		6	10+	Alluvium (gravel)	7.6	7-11-51	T	3	Irr	Soil to 6 ft; pumped 250 gpm for 4 hr, dd 14 ft.
5M2	George Ashbaugh	Ap	1,205	Dg	9	36				do	Flooded	7-11-51	C	1½	Irr	Yield less than 90 gpm.
5M3	Benjamin Wagner	Ap	1,210	Dg	15	72				Alluvium	7.1	7-12-51	C	1	Irr	Reported dd 0.5 ft.
5M5	Eva Gohl	Ap	1,210	Dg	14	48		7	15+	Alluvium (silt and gravel).	5.6	7-12-51	C	1	Irr	Soil to 6 ft, "hardpan" to 7 ft.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 18 E.—Continued																
5M9	Louis George	Ap	1,205	Dr	23	6	22	4±	19+	Alluvium (sand and gravel).	6.2	7-12-51	N		NU	Soil to 4± ft; bailer test 15 gpm.
6A1	Kurt Tabert	Ub	1,240	Dr	80	6	68			Cemented basalt gravel (sand layers).			J	1	D	Penetrated mostly cemented gravel with some water-bearing sand layers.
6D1	Charles Roberts	Ap	1,290	Dg	39		5			Cemented basalt gravel (sand layer?).	24	11- -49	S	⅙	D	Soil to 5 ft, penetrated some cemented gravel above aquifer.
6E2	Clasen Fruit Co.	Ap	1,270	Dg	9	48	7			Alluvium	3.8	7- 3-51	C	1	Ind	Supplies fruit warehouse.
6F4	Albert McPheeters.	Ap	1,270	Dg	11	18	11			Alluvium (gravel)	7.7	7- 2-51	S S S	¾ ¼ ¼	D	Cp.
6G1	Wesley H. Hansen.	Ap	1,260	Dg	14	36		3	17+	do	3.8	7- 9-51	N		NU	Soil to 3 ft; pumped 160 gpm, dd 12½ ft.
6G2	do	Ap	1,260	Dg	15	36		7	9+	do	8.3	7- 9-51	T	3	Irr	Pumped 400± gpm for several hours, dd 4.93 ft; soil to 7 ft; temp 49°F; Cp.
6H1	Cecil R. Weston	Ap	1,240	Dg	16	60				do	8.6	7- 9-51	S	¾	S, Irr	Pumped 300± gpm for 43 days.
6H2	J. R. Pittman	Ap	1,240	Dg	12	60				do	2.0	7- 9-51	T		NU (Irr)	
6K1	Riley Tyler	Ap	1,240	Dg	11	60	11	5	6	do	4.4	7- 6-51	T	2	Irr	Pumped 200 gpm for 4 hr, dd 9 ft.
6K3	Ernest Estes	Ap	1,230	Dn	17	2	17			Alluvium			S	¾	Irr	Irrigates large garden.
6L2	J. W. Mudd	Ap	1,250	Dg	12	48	14	5±	9±	Alluvium (gravel, loose).	6.1	7- 6-51	S	⅓	Irr	Soil to 6 ft, gravel to bottom.
6P2	W. G. Campbell	Ap	1,250	Dg	10	60				Alluvium	3.0	6- 2-51	C	1	Irr	
6Q1	Mrs. Lillian Woodcock.	Ap	1,240	Dg	19	30				do	6.6	7-11-51	N		NU (Irr)	

6R2	do	Ap	1,230	Dg	12	36	12			do	7.5	7-11-51	C	1	D, Irr	Pumping when measured.
6R3	Fred X. Savage	Ap	1,225	Dr	21	3	21			Alluvium (gravel)			S S	¼ ⅛	D	Supplies 2 families; penetrated 2 "hardpan" layers above aquifer.
7A1	Peter Solem	Ap	1,225	Dg	14	36	16			Alluvium (gravel)	7.9	7-11-51	C	3	Irr	Irrigates 12 acres of pasture and 7 acres of alfalfa.
7B2	Gene Woodcock	Ap	1,240	Dg	15	37				Alluvium	4.9	7-11-51	S	⅙	D	
7D2	Ira Gano	Ap	1,260	Dg	12	30	15			do	4.4	6-2-51	S	⅓	Irr	Irrigates 1 acre.
7E1	Mrs. Mary Snyder.	Ap	1 260	Dr	30	6	30			Alluvium (gravel)	2.6	6-2-51	S	¼	D	Soil to 3½ ft, gravel to 23½ ft, cemented gravel to 27± ft.
7J1	A. W. Knight	Fp	1,230	Dr	362	8-6	324	340±		Ellensburg formation (sand).	.3	5-15-51	T	10	Irr	Irrigates 40 acres during dry summers; may flow occasionally; pumped 280 gpm for several hours, dd 110 ft; cemented gravel to 340 ft.
7K1	H. B. Fairbanks	Ap	1,240	Dg	15	72	20	10	10+	Alluvium (gravel)	6.9	6-1-51	C	5	Irr	Originally 20 ft deep; soil to 10 ft; pumps 120± gpm; temp 52° F; Cp.
7M1	Mrs. Tony Coupal.	Ap	1,260	Dg	16	36	16+	6	9+	do	6.5	6-2-51	N		NU (Irr)	Pumped 250 gpm for 4+ hr, dd 15 ft; soil to 6 ft.
7Q2	Vernon Mondor	Ap	1,260	Dg	20	60				do	8.4	6-1-51	C		Irr	
8A1	Carrel Morton	Ap	1,180	Dr	100	10	20	98±	2+	Ellensburg formation (sand).	4.3	7-13-51	J	1	D	Pumped 85 gpm, dd 27 ft; L.
8B1	do	Ap	1,180	Dr	635	12	22			do	12		T	5	Irr	Irrigates 30 acres of nursery and pasture; pumped 300± gpm, dd 43± ft; Cp, L.
8D2	Charles Eller	Ap	1,210	Dg	17	48				Alluvium	8.0	7-11-51	S	¾	D	
8G1	Louis Vetsch	Ap	1,200	Dr	103	6	50±			Ellensburg formation (sand).			S	½	D	Penetrated sand and 1 or 2 layers of "hardpan" for entire depth.
8J1	Louis Vetsch	Ap	1,200	Dg	38	5				Alluvium(?)	8.6	7-18-51	S		Irr	
8K1	P. J. Vetsch	Ap	1,210	Dr	85	6	85			Ellensburg formation (sand).			S	½	D	
8N1	William Adam	Ap	1,270	Dg	60	36	0				22.2	7-12-51	P	¼	NU(D)	Water reported polluted.
9L1	Walter S. Ready	As	1,210	Dr	49	6	49			Cemented basalt gravel(?) (sand and gravel).	20	10- -50	J	½	D	Temp 61° F; Cp.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s)			Water level		Pump		Use of water	Remarks
								Depth to top (feet)	Thickness (feet)	Formation and Material	Depth (feet below land-surface datum)	Date measured	Type	Horsepower		
T. 12 N., R. 18 E.—Continued																
10D1	Axel Erickson	As	1,150	Dr	300	8	68			Ellensburg formation (sandy clay).	15.9	7–18–51	T	10	Irr	Cemented gravel above aquifer; casing perforated 8–68 ft.
10D2	do	As	1,150	Dg	24	96				Alluvium	13.8	7–18–51	C	10	NU (Irr)	
10H1	Masterson Pahosta & Parchese Wolloack.	As	1,200	Dr	100	6					65.6	7–20–51	P		NU (D)	
11D1	R. L. McDougal, Sr.	Ap	1,100	Dg	17	6				Alluvium	10.6	7–27–51	P	¼	D, Ind	Supplies 2 homes and dairy.
11E1	S. H. Schreiner	As	1,170	Dr	213	5	151	205	8	Ellensburg formation (sand and gravel).	85	9– 9–46	T	5	D, Irr	At 127-ft depth water level 85 ft, pumped 36 gpm, dd 35 ft; supplies 3 families and irrigates 8 acres of orchard; C, L.
11E2	Fred Westburg	As	1,185	Dr	183	6	165	180	3+	Ellensburg formation (sand).	105	7–25–52			D	L.
11J1	A. W. Sapp	As	1,190	Dg, Dr	127	6	80			Cemented basalt gravel(?).	66.6	7–31–51	J	¾	D	Dug to 60 ft. Top of "cement rock" layer at 60 ft.
12C1	Harry Gimmaka	Ap	1,110	Dr	245	8	45	245		Ellensburg formation (sand).	25	5– –50	T	3	Irr	Soil to 15 ft, cemented gravel to 245 ft. Pumped 120 gpm for 1 hr, dd 15 ft, "full recovery" in 5 sec.
12E1	Thurman Schuttle.	As	1,105	Dr	72	6	55	60	8+	Ellensburg formation (sand).			S	½	D, S	Cp.
12K1	Wade Langell	As	1,140	Dr	225	5	220±			Ellensburg formation(?).			P	1½	D	

17C1	R. L. Olsen	As	1,280	Dr	60	4	65	60±	5+	Ellensburg formation (sandstone).	47.3	7-13-51	J	¾	D, S	Originally 65 ft deep; soil to 8 ft, sandstone to 65 ft; reportedly drilled in 1 day.
18D1	Mary Tom	Ap	1,300	Dr	28	6				Cemented basalt gravel(?).	9.3	5-28-51	P		D	Cp.
								T. 12 N., R. 19 E.								
5E1	La Casa Motel	Ap	980	Dg	8	36				Alluvium (sand and gravel).	5.3	6-22-51	S	¼	Irr	Irrigates lawn and flowers; pumping when measured.
5E2	F. E. Devoe	Ap	980	Dr	68	6	68			Alluvium (gravel).	6	7- 3-46	J	3	Ind	Supplies refrigeration equipment for cold storage warehouse; pumped 104 gpm for 1 hr, dd 11 ft.
5F1	State of Washington, Dept. of Highways.	Ap	980	Dr	26	6	26			do	6		P	3	Irr	
5F2	do	Ap	980	Dr	75	6	75			Cemented basalt gravel(?).	20		P	3	D	Casing probably perforated.
5M1	City of Union Gap.	Ap	980	Dr	215	12-10	215			Cemented basalt gravel.	10	7-22-49	T	30	PS	Alternate pumping with well 5M2; pumped 450 gpm, dd 56 ft; temp 57° F; L.
5M2	do	Ap	980	Dr	217	12-10	198			do	10	7-10-47	T	30	PS	Pumped 750 gpm, dd 80 ft; either well 5M1 or 5M2 yields approximately 192,000 gpd in winter; L.
5N1	City of Union Gap.	Ap	975	Dr	370	12	370	187	174	Cemented basalt gravel (sand and gravel).	Flows	10-10-51	T	40	PS	Reported flowing 62 gpm, 1950; reported dd 72 ft pumping 970 gpm; reported pH 7.3, hardness 31 ppm; L.
6A1	N. C. Root	Ap	990	Dg	7	3	9			Alluvium (gravel).	4.2	6-22-51	S	¼	Irr	Irrigates lawn and garden; casing slotted 7-9 ft.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 12 N., R. 19 E.—Continued																
6E1	Elmer Close	Ap	1,000	Dr	50	4	52	10±	43+	Alluvium(?) (sand)	5.1	5–3–51	S	⅓	D	Soil to 7 ft, "hardpan" to 10 ft; pumped 3 gpm for 2 hr, dd 4.5, "full recovery" in 1 hr; Cp.
6E2	do	Ap	1,000	Dn	6	1¼				Alluvium silt(?)	1.1	6–15–51	S		S	
6M1	H & H Packing Co.	Ap	1,000	Dr	85	8	85			Cemented basalt gravel(?).	4	10–15–47	T	10	Ind	Supplies meat packing plant 40 hr per week; pumped 195 gpm for 2 hr, dd 56 ft.
6M2	do	Ap	1,000	Dr	38	6	39			Alluvium (gravel)	6.2	8–8–51	C	2	Ind	Pumping when measured; supplies refrigeration water for meat packing plant.
17C1	Miocene Petroleum Co.	Fp	950	Dr	3800	12½–10	1045			Yakima basalt	.3	8–7–51	N		NU	Oil test well; flows intermittently; L.
T. 13 N., R. 18 E.																
28L1	Congdon Orchards.	Ap	1,160	Dr	1252	10½–5¼	1227	873	60	Ellensburg formation (sandstone, blue).	+39	1–11–33			Irr	At 873 ft flowed 13 gpm; at 1220 ft flowed 112 gpm; at 1252 ft flowed 300 gpm in 1912; flowed 50 gpm in 1956; L.
								1220		(sandstone)						
								1250	2	(sandstone)						

29Q1	George Wilson	Ap	1,190	Dr	1267	6-3.5		800 1,000 1,050		Ellensburg formation. (sandstone?). (sandstone?).	+42	8- -1898			Irr	Basalt penetrated at about 1,250 ft; flowed 336 gpm in April 1901; temp 80°F.
32J1	Mrs. W.L.Lemon Estate.	Ap	1,190	Dr	257	6				Ellensburg formation(?).			T	5	D, Irr	Supplies 3 homes.
32P1	Paul Johnson	Ap	1,220	Dr	39	6					9.9	8- 1-51	S	⅓	D	
32R1	E. Hazard	Ap	1,190	Dg	9	48				Alluvium	4.6	8- 1-51	S	½	D	Formerly irrigation well.
33L1	Raymond Hess	Ap	1,180	Dg,Dn	22	72-4	22			Alluvium (gravel).	10		S C	⅓ 2	D, Irr	Pumped 100 gpm for 4hr, dd 8 ft; temp 54°F; Cp.
33L2	G. E. Stewart	Ap	1,170	Dg	17	36	20			do	12.0	8- 1-51	T	3	Irr	Pumped 300 gpm, dd 7 ft; L.
33L3	do	Ap	1,170	Dr	137	10	49.5	119	18+	Ellensburg formation (sand and gravel).	16	4- 9-48	T	7½	Irr	Pumped 300 gpm for 4 hr, dd 80 ft; L.
33L4	do	Ap	1,160	Dr	34	6	35	5	30+	Alluvium (gravel).	9.8	8- 1-51	S	½	D	Soil to 5 ft.
33L5	Victor Kohls	Ap	1,170	Dg	30	3				Alluvium (sand and gravel).	10		C	2	Irr	Pumped 100 gpm.
33M1	Rainier State School.	Ap	1,180	Dr	613	8	600			Ellensburg formation (sand and gravel).	2	12- -45	C	5	Inst	Supplies school and hospital; pumped 275 gpm, dd 8 ft; L.
33N1	R. H. Crow	Ap	1,180	Dg	15	30		3	17+	Alluvium (gravel).	4.9	12- 6-51	T	3	Irr	Pumped 275 gpm, dd 18 ft.
33N2	G. F. Rossow	Ap	1,180	Dg	17	30		3	17+	do	11.4	12- 6-51	C	1	Irr	Pumped 120 gpm for 4 hr, dd about 4 ft.
34J1	E. J. Crawford	Ap	1,100	Dr	10	8				Alluvium	6.2	8- 2-51	S	¼	D	
34M1	Edgar A. Pearson	Ap	1,130	Dg	17	30	17	4±	14	Alluvium (sand and gravel).	1.7	12- 6-51	C	10	Irr	Pumped 450 gpm for 3 hr, dd to 17 ft; L.
35J1	McAllister Flying Service.	Ap	1,070	Dr	69	8					6.9	8- 2-51	S	⅓	Irr	Irrigates large lawn.
35R1	State of Washington Fish Hatchery.	Ap	1,060	Dr	65	6		55	8	Cemented basalt gravel(?).	55		J		D	
36J1	Kenneth Goddard	Ap	1,040	Dr	87	6				do	6.1	8- 3-51	S	¾	D	Supplies 3 families.
36J2	H. P. McGlothern	Ap	1,030	Dn	28	6				Alluvium (sand and gravel).	6.2	8- 3-51	C	2	PS	Pumping continuously, dd 3¾ ft; reportedly this well and well 13/19-31M1 supply 38 homes.
36K1	R. L. Epperson	Ap	1,040	Dg	16	18	16	12	4+	Alluvium (gravel).	7.5	8- 2-51	S	¾	Irr	
36M1	Albert Wellner	Ap	1,050	Dg	15	18				Alluvium	10.9	8- 2-51	S	¼	D	
36P2	Thomas H. Pollock.	Ap	1,040	Dr	45	6				Cemented basalt gravel(?) (sand and gravel).	7.7	8- 2-51	N		NU	Reported inadequate for irrigation.

TABLE 4.—*Records of representative wells in Ahtanum Valley, Yakima County, Wash.*—Continued

Well	Owner or Tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Formation and Material	Water level: Depth (feet below land-surface datum)	Water level: Date measured	Pump: Type	Pump: Horsepower	Use of water	Remarks
T. 13 N., R. 19 E.																
31J1	Yakima Farmers Supply Co.	Ap	1,015	Dr	84	6	84			Cemented basalt gravel(?) (sand and gravel).	4.0	7-31-51	N		Ind	Supplies washrooms; C, L.
31K1	J. F. Scott	Ap	1,010	Dg	3	120×240	3+			Alluvium (gravel)	1.3	7-31-51	S C	½ 5	D, Irr	Pumping when measured.
31K2	George Hargraves	Ap	1,015	Dg	14	36±				do	8.0	7-31-51	S C	¼ 1	D, Ind	Supplies 1 home and spray water for orchard.
31K3	Niagara Chemical Corp.	Ap	1,010	Dr	38	6	38			do	5.7	12- 6-51	J	2	Ind	
31M1	H. P. McGlothern	Ap	1,025	Dr	20	6				Alluvium (sand and gravel).	10.5	7-31-51	C	5	PS	Pumping when measured; reportedly this well and well 13/18-36J2 supply 38 homes.
32L1	Frederick Mercy	Ap	990	Dr	36	6	39			Alluvium (gravel)	5.0	7-31-51	S	½	D, S	
32M1	Yakima Cooperative Association.	Ap	1,005	Dr	40	6	38	31	9+	Cemented basalt gravel(?) (sand and shale).	3.7	6-25-51	S	½	Ind	Supplies small office building, pumped 45± gpm, dd 20 ft; L.
32M2	Forney Fruit & Produce Co.	Ap	1,005	Dr	125	8	82			Cemented basalt gravel.	4	12- 1-47	C	5	D, Ind	Supplies fruit packing plant, auto freight company, and paving company: pumped 360 gpm, dd 38 ft; Cp.
32M3	Cascade Casting Co.	Ap	1,005	Dr	42	6	42±			do	4.3	8- 6-51	C	1	D, Ind	Gravel to bottom; supplies small foundry and farm equipment company.
32M4	Sears Lumber Market.	Ap	1,000	Dr	42	6	42			do			S	½	D, F	Supplies small lumber yard.

32M5	Honeymoon Auto Court.	Ap	1,000	Dr	45	4	45	32	13+	do			S	¼	D	Supplies auto court; pumped 30 gpm, dd ¾ ft; L.
32P1	W. B. Edmiston & Sons.	Ap	990	Dr	46	6	46			do			C S	1½ ½	D	Supplies small office building.
32P2	Lulsi Union Oil Station.	Ap	990	Dr	47	6	47			do	8	8– –49	S	½	D	Supplies service station and small restaurant.

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*

Most of the information in this table was obtained from records made by well drillers at the time the wells were constructed, although some information was supplied from memory by drillers and well owners. A few of the wells were visited during construction, and samples were examined by the writer. The records were edited for consistency of terminology and presentation and for conformance with the stratigraphic units described in the text but were not changed otherwise. For the purpose of clarity, the writer's interpretations have been added in parentheses after some of the drillers' designations.

12/15-13R1

[William Mondor. About 1 mile southwest of Tampico. Altitude about 2,180 ft. Drilled by N. C. Jannsen, 1939. Casing, 16-in to 50 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation (unamed member):		
Gravel, large	9	9	Clay, yellow	38	178
Cemented basalt gravel:			Yakima basalt:		
Gravel, cemented, and boulders	43	52	Basalt	20	198
Yakima basalt (Wenas? basalt member):			"Rock," brown (basalt)	5	203
			Basalt	45	248
Basalt, porous and broken	30	82	"Rock," brown (basalt)	9	257
Basalt, hard	5	87	Basalt, broken	23	280
Basalt, broken	53	140	Basalt, hard	49	329

12/16-8H1

[Vernon Mondor. About 1 mile northeast of Tampico. Altitude about 2,250 ft. Drilled by N. C. Jannsen, 1926. Casing, 10-in to 200 ft, 8-in to 380 ft; no perforations]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Yakima basalt:			Yakima basalt—continued		
Basalt	300	300	Basalt	60	380
Shale, blue	20	320			

12/16-13D1

[Herke Bros. About 6 miles west-southwest of Wiley. Altitude about 1,800 ft. Drilled by Oscar Boehler. Casing, 14-in to 27 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Yakima basalt (Wenas? basalt member):		
Soil	17	17	Basalt, black	111	130
Boulders	2	19	Basalt, black, water-bearing	10	140
			Basalt, black	6	146

12/16-15F1

[Arthur Hanses. About 2.5 miles east of Tampico. Altitude about 1,900 ft. Drilled by A. A. Durand, 1945. Casing, 10-in to 71 ft, 6-in to 278 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	5	5	Yakima basalt—Continued		
Yakima basalt (Wenas? basalt member):			Basalt	15	331
			Sandstone(?)	25	356
"Rock" (basalt)	18	23	Basalt	55	411
Basalt, broken	12	35	Basalt, water-bearing	1	412
Basalt, solid	6	41	Basalt, hard	14	426
Basalt, broken, water-bearing	21	62	"Good water-bearing formation" (basalt?)	6	432
Basalt	8	70	Basalt	20	452
Basalt, water-bearing	11	81	Basalt, creviced	8	460
Basalt	93	174	Basalt, water-bearing	13	473
Basalt, with some clay	19	193	Basalt	12	485
Ellensburg formation (unnamed member):			Basalt, hard, black	49	534
Clay and sandstone	77	270	"Granite" (basalt?)	1	535
Yakima basalt:			Basalt, hard, black	9	544
"Rock" (basalt?)	15	285			
Basalt, hard	31	316			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/16-18B4

[Frank Mayfield. Tampico. Altitude about 2,116 ft. Drilled by N. C. Jannsen. Casing, 8-in.]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel—Con.		
Boulders	9	9	Clay, sandy	21	114
Boulders and gravel	41	50	Clay and boulders	41	155
Cemented basalt gravel:			Clay and sand	11	166
Gravel, cemented	10	60	Clay and boulders	30	196
Clay and boulders	33	93			

12/16-18C1

[Garrison and Hazen. About 0.5 mile west of Tampico. Altitude about 2,200 ft. Drilled by A. A. Durand, 1945. Casing, 14-in to 80 ft, 10-in to 250 ft, 7-in to 287 ft. Perforated from 165 ft to 287 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium and cemented basalt gravel, undifferentiated:			Yakima basalt (Wenas? basalt member)—Continued		
Boulders	17	17	Basalt, black	10	137
Boulders and gravel	3	20	Basalt, broken	23	160
Rock (cemented basalt gravel?)	3	23	Basalt	29	189
Boulders	18	41	Ellensburg formation (unnamed member):		
Boulders and cemented basalt gravel	16	57	Clay	21	210
Basalt (gravel?)	13	70	Yakima basalt:		
Boulders	7	77	Basalt, broken, water-bearing	11	221
Boulders and clay	20	97	Basalt, solid	15	236
Yakima basalt (Wenas? basalt member):			Basalt, broken	27	263
Basalt, brown, broken	30	127	Basalt, broken, water-bearing	5	268
			Basalt, solid	19	287

12/16-18G1

[Frank A. Mondor. About 0.25 mile south of Tampico. Altitude about 2,107 ft. Drilled by N. C. Jannsen, 1926. Casing, 12-in to 40 ft, perforated from 20 ft to 40 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel—Con.		
Sand and gravel	37	37	Gravel, cemented, and boulders	8	234
Cemented basalt gravel(?):			Clay	3	237
Gravel, cemented, and boulders	74	111	Gravel, cemented	10	247
Clay, blue, and gravel	20	131	Clay	6	253
Clay, brown, boulders and gravel	8	139	Gravel, cemented	14	267
Clay and cemented gravel	10	149	Sand and hardpan	6	273
Gravel, cemented	54	203	Gravel, cemented	97	370
Clay, cemented gravel, and boulders	8	211	Clay	7	377
Gravel, cemented	7	218	Clay, blue	4	381
Gravel, cemented, and "hardpan"	8	226	Gravel, cemented	3	384

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/16-18K1

[Herke Bros. About 0.5 mile south of Tampico. Altitude about 2,110 ft. Drilled by A. A. Durand, 1946. Casing. 8-in to 55 ft, 6⅝-in from 59 ft to 208 ft, 5-in from 170 to 315 ft; perforations from 162 ft to 164 ft, from 166 ft to 170 ft, from 200 ft to 204 ft, and from 208 ft to 315 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium and cemented basalt gravel(?), undifferentiated:			Yakima basalt (Wenas? basalt member):—Continued		
Soil and gravel	35	35	Sandstone (basalt?)	13	249
Sand, brown, and black, coarse	14	49	"Rock," brown (basalt?)	14	263
Shale, blue	17	66	Ellensburg formation (unnamed member?):		
"Slaterock"	9	75	Clay, brown, and sandstone	23	286
Gravel and "rock"	18	93	Clay, blue	7	293
Shale, blue	16	109	Yakima basalt:		
Yakima basalt (Wenas? basalt member):			"Rock" (basalt?)	2	295
Basalt, hard, gray	23	132	Boulders (basalt)	25	320
Shale	7	139	Basalt, hard, black	8	328
"Shaley rock" (basalt?)	25	164	Sand, black	1	329
Basalt, brown	14	178	Basalt, brown, and "soapstone"	9	338
Clay, brown, and sandstone	24	202	Basalt, brown	5	343
Basalt, gray	34	236			

12/17-1G2

[B. E. Snelling. About 0.5 mile west of Ahtanum. Altitude about 1,280 ft. Drilled by F. Riebe & W. G. Ludwig. Casing, 6-in to 60 ft, 5-in to 200 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Cemented basalt gravel and Ellensburg(?) formation undifferentiated:			Cemented basalt gravel and Ellensburg(?) formation undifferentiated:—Continued		
Cemented gravel	80	80	Clay with some "rock"	--------	197
Clay	20	100	Sand, coarse, water-bearing	3	200
Sand	--------	--------			

12/17-5B1

[E. L. Lenington. About 3.5 miles west-northwest of Wiley, in Cottonwood Canyon. Altitude about 1,560 ft. Drilled by F. Riebe. Casing, 6-in to 77 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium and cemented basalt gravel, undifferentiated:			Ellensburg formation:		
			Clay, brown, pumiceous	122	160
Gravel, river and cement	38	38	Sand	10	170

12/17-6F2

[R. F. Morozzo. About 5 miles west of Wiley, in Cottonwood Canyon. Altitude about 1,680 ft. Drilled by Oscar Boehler, 1950. Casing, 6-in to 44 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Ellensburg formation:			Yakima basalt (Wenas? basalt member):		
Clay, blue, sandy	30	30			
Sand	2	32	Gravel, coarse, black	--------	--------
Clay and sand	108	140			
Sandstone	10	150			
Clay and sand	9	159			

12/17-8K1

[Merle Carson. About 3.5 miles west of Wiley. Altitude about 1,570 feet. Drilled by N. C. Jannsen. Casing, 6-in to 60 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Yakima basalt:		
Gravel, surface	20	20	Basalt	5	100
Ellensburg formation:					
Clay, blue	55	75			
Sand, water-bearing	20	95			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/17-8R3

[James Bowers. About 3.5 miles west-southwest of Wiley. Altitude about 1,550 ft. Drilled by Boehler and Huber, 1953. Casing, 8-in to 245 ft, open end, no perforations]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Yakima basalt:		
Soil	2	2	Basalt, black (flow started at 248 ft, increasing to 290 ft)	60	300
Gravel, river	9	11	Basalt, black (lost flow at 400 ft)	100	400
Cemented basalt gravel:			Crevice (cuttings washing away)	7	407
Gravel, cemented	9	20	Basalt, black	3	410
Ellensburg formation:					
Clay	220	240			

12/17-9J3

[Walter McInnis, (formerly Marks School). About 2 miles west-southwest of Wiley. Altitude about 1,470 ft. Drilled by Hughett. Casing, 4.25-in]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium and cemented basalt gravel, undifferentiated:			Ellensburg formation—Con.		
Soil	12	12	Sandstone	100	345
"Hardpan"	8	20	Clay, yellow	60	405
Gravel	10	30	Clay, blue	20	425
Gravel, cemented	70	100	Yakima basalt:		
Ellensburg formation:			Basalt	5	430
Clay	30	130	"Rock" (basalt), water-bearing	23	453
Sandstone	10	140	Clay	6	459
Gravel	25	165	"Rock" (basalt), black	45	504
Sandstone	20	185	"Rock" (basalt), gray	18	522
Clay	25	210	"Rock" (basalt), water-bearing	53	575
Gravel	10	220			
Clay	25	245			

12/17-10C2

[Claude Ekland. About 1.5 miles west of Wiley. Altitude about 1,420 ft. Drilled by F. Reibe, 1952. Drilling suspended, yield inadequate. Casing, 8-in to 33 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	5	5	Ellensburg formation:		
Cemented basalt gravel:			Clay, sticky, gray	381	415
Gravel, cemented, and boulders	29	34	Shale, blue	55	470

12/17-11A1

[Gilbert Orchards, Inc. Wiley. Altitude about 1,347 ft. Drilled by Hughett. Casing, 10-in to 787 ft; intermittent perforations from 103 ft to 725 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation—Con.		
Soil and gravel	16	16	Clay	56	311
Cemented basalt gravel:			Sandstone, hard	4	315
Gravel and cement	16	32	Clay	108	423
Gravel, cemented	10	42	"Rock"	8	431
Clay	7	49	Clay, gray	7	438
Clay and gravel	11	60	Clay	2	440
Gravel, cemented	37	97	Gravel, cemented	20	460
Clay	6	103	"Rock," hard	6	466
Gravel, cemented, with some water at 110 ft	45	148	Clay	10	476
Clay, yellow, and gravel	12	160	Clay and sandstone	61	537
Ellensburg formation:			Clay	24	561
Clay and sand	15	175	Clay and sand	22	583
Sandstone	6	181	Clay	62	645
Clay and sand	39	220	Clay, brown	20	665
Gravel, cemented	11	231	Clay	20	685
Clay, yellow	4	235	Clay, brown, sandy	8	693
Sandstone	5	240	Clay, light, and yellow	23	716
Gravel, cemented, hard	15	255	Clay, blue	4	720
			Clay, blue, and sandstone	21	741

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/17-11A1—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Ellensburg formation—Con.			Yakima basalt—Continued		
Clay, blue	18	759	"Rock," gray (basalt)	90	959
Clay, blue, and sandstone	26	785	Sandstone, gray	4	963
Clay and sand	20	805	"Rock," gray (basalt)	22	985
Clay and sandstone, water-bearing	12	817	Shale, blue, and "rock," black (basalt)	6	991
Yakima basalt:			"Rock," black (basalt)	9	1,000
Basalt, gray	33	850	Shale, black (basalt)	13	1,013
"Rock" (basalt)	8	858	Shale, soft	6	1,019
"Rock," gray (basalt)	3	861	"Rock," black (basalt)	3	1,022
"Rock," black (basalt)	8	869	Shale and "rock" (basalt)	3	1,025

12/17-11D4

[Ernest Bitz. About 1 mile west of Wiley. Altitude about 1,390 ft. Drilled by J. E. White, 1953. Casing, 6-in to 30 ft. Perforated with 1 slot per ft for entire depth]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	4	4	Cemented basalt gravel:		
			Gravel, cemented	22	26
			Gravel and sand	4	30

12/17-16D3

[Jack Schreiner. About 3 miles west-southwest of Wiley. Altitude about 1,510 ft. Drilled by Ralph Cassel, 1952. Casing, 10-in to 312 ft; unperforated]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation—Con.		
Gravel, basaltic, loose	9	9	Clay	79	179
Cemented basalt gravel:			Sand, argillaceous	75	254
Gravel, basaltic, weakly cemented	23	32	Clay, sticky	46	300
Ellensburg formation:			Clay, blue	25	325
Clay, sandy	10	42	Yakima basalt:		
Clay, sticky	58	100	Basalt, weathered	42	367
			Basalt, slightly vesicular	17	384

12/17-16R1

[B. S. Borton & Sons. About 3 miles southwest of Wiley. Altitude about 1,550 ft. Drilled by Durand & Son, 1944. Casing, 12-in to 183 ft, 8-in from 180 ft to 699 ft, 6½ in from 744 ft to 940 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Clay, brown (loess?) and soil	20	20	Cemented basalt gravel—Con.		
Cemented basalt gravel:			Clay and boulders	16	353
Gravel, clay, and boulders	52	72	Ellensburg formation:		
Gravel, coarse, and boulders	21	93	Clay, brown	32	385
Boulders and sand	5	98	Gravel, large, and clay	5	390
Sand	7	105	Clay, sticky	30	420
Gravel, coarse	7	112	Clay, yellow	20	440
Sand, coarse, with a little gravel	21	133	Clay, sticky, brown	10	450
			Clay, white	30	480
Gravel with some clay	4	137	Clay, brown	15	495
Gravel, coarse	16	153	Clay, white	15	510
Gravel and boulders	28	181	Sandstone	38	548
Gravel and clay	16	197	Sandstone and clay	17	565
Gravel, water-bearing	4	201	Sandstone	71	636
Gravel and sand, cemented	14	215	Clay	3	639
Gravel and boulders, water-bearing	17	232	Sandstone	31	670
			Clay, sticky, and sandstone	21	691
Gravel, coarse, boulders, and clay	68	300	Clay	11	702
			Sandstone	4	706
Boulders, heavy	4	304	Yakima basalt:		
Clay, sand, gravel, and boulders	22	326	Basalt, weathered, blue	24	730
			Basalt, blue	23	753
Clay	3	329	Basalt, very hard, gray	7	760
Clay, sand, gravel, and boulders	8	337	Basalt, black, water-bearing	41	801
			Basalt, hard, black	5	806

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/17-16R1—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Yakima basalt—Continued			Yakima basalt—Continued		
Basalt, "honeycomb" (vesicular), black, water-bearing	9	815	Basalt, hard, black	21	893
Basalt, hard, black, water-bearing	5	820	Basalt, hard, gray	8	901
Basalt, hard, black	3	823	Basalt, hard, black	15	916
Basalt, red and black	4	827	Basalt, extremely hard, gray	19	935
Basalt, hard, black	2	829	Basalt, hard, black	19	954
Basalt, hard, gray and black	7	836	Basalt, very hard, gray	6	960
Basalt, "honeycomb" (vesicular), red	6	842	Basalt, hard, gray	29	989
Basalt, "honeycomb" (vesicular), black	4	846	Basalt, hard, gray	21	1,010
Basalt, hard, black	2	848	Clay, blue	5	1,015
Basalt, "honeycomb" (vesicular), black	3	851	Basalt, hard, gray	20	1,035
Basalt, hard, black, water-bearing	11	862	Basalt, black, water-bearing	5	1,040
Basalt, soft, black, water-bearing	10	872	Basalt, mostly hard, black	16	1,056
			Basalt, black, water-bearing	2	1,058
			Basalt, hard, black	1	1,059
			Basalt, black, water-bearing	5	1,064
			Basalt, fractured, black	3	1,067
			Basalt, black	6	1,073
			Clay, brown	2	1,075
			Clay, blue	3	1,078

12/17-17C1

[Carl Sheneberger. About 3.5 miles west-southwest of Wiley. Altitude about 1,573 ft. Drilled by Boehler and Huber, 1948. Casing, 8-in to 166 ft, 6-in to 243 ft; perforated below 166 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation—Continued		
Soil	5	5	Clay, brown and yellow, sticky	48	170
Coarse gravel	11	16	Clay, blue	23	193
Cemented basalt gravel:			Yakima basalt:		
Gravel, cemented	14	30	Basalt	1	194
Ellensburg formation:			Basalt, black	1	195
Clay	92	122	Basalt, water-bearing	48	243

12/17-17J1

[J. R. Rutherford. About 3.5 miles southwest of Wiley. Altitude about 1,540 ft. Casing, 6-in to bottom]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Soil	2	2	Clay	5	15
Gravel	8	10	Gravel and sand, water-bearing	--------	--------

12/18-1M1

[Yakima Farm Labor Camp. About 2 miles west of Union Gap. Altitude about 1,010 ft. Drilled by Durand & Son, 1939. Casing, 10-in to 366 ft, 8-in from 366 ft to 555 ft; no perforations]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel—Con.		
Soil	6	6	Boulders, large	5	147
Gravel and sand, loose	1	7	Gravel and clay	28	175
Cemented basalt gravel:			Gravel, loose	5	180
Gravel, cemented	5	12	Gravel and clay	24	204
Gravel and clay, loose and caving	19	31	Clay, sandy, and gravel	11	215
Gravel and clay	6	37	Ellensburg formation:		
Gravel, cemented	9	46	Sand, very fine	12	227
Gravel and clay, loose, caving	9	55	Clay, sandy	10	237
Clay, brown	3	58	Clay, sandy, caving	13	250
Gravel and clay, caving	15	73	Clay, sandy, little gravel	10	260
Clay, sandy, brown	12	85	Clay, sandy, more gravel	4	264
Gravel, cemented	20	105	Clay, sandy, and gravel	4	268
Clay, brown	5	110	Clay, sandy, and fine gravel; caving	4	272
Gravel and clay	22	132	Sand, brown, and gravel; caving	3	275
Gravel and clay, loose	3	135	Sand, brown, caving	35	310
Gravel and clay	7	142			

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TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/18-1M1—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Ellensburg formation—Con.			Ellensburg formation—Con.		
Sand, brown, clay, and fine gravel	5	315	Shale, gray	5	495
Sand and clay	18	333	Sand, brown	10	505
Clay, sandy, caving	15	348	Clay, yellow, and sand	15	520
Clay, sandy	62	410	Shale, gray	5	525
Sand	11	421	Sand, brown	8	533
Sand, caving, and fine gravel	4	425	Gravel, pea	2	535
Clay, sandy, caving, and gravel	5	430	Gravel, river, caving	5	540
Sand, river	13	443	Sand, brown	10	550
Sand, caving	7	450	Sand, water-bearing	5	555
Sand, caving, and yellow clay	5	455	Rock, "honeycomb" (porous), red	5	560
Clay, yellow, and sand	15	470	Sandstone	40	600
Sand, fine, black	12	482	Sand, water-bearing, and sandstone	20	620
Clay, yellow	8	490			

12/18-2E1

[LeRoy Schreiner. About 3 miles west of Union Gap. Altitude about 1,080 ft. Drilled by Ralph Cassel. Casing, 10-in to 86 ft, 8-in to 150 ft, and 6-in to 376 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel and Ellensburg(?) formation, undifferentiated—Continued		
Soil	10	10	Sand	10	150
Gravel	12	22	Gravel, cemented	25	175
Cemented basalt gravel and Ellensburg(?) formation, undifferentiated:			Sand, gravel, and rocks, loose	80	255
Gravel, cemented	23	45	"Quicksand"	40	295
"Rock," broken (gravel)	80	125	Gravel, cemented	48	343
Sand	5	130	Gravel and sand	62	405
Gravel, cemented	10	140			

12/18-5J1

[Joel Richwine. About 1.7 miles east of Ahtanum. Altitude about 1,170 ft. Dug by owner, 1932. Casing, 30-in to 18 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
No record	13	13	Alluvium—Continued		
Alluvium:			Sand, black	1	18
"Hardpan" (clay)	4	17	Sandstone, water-bearing	--------	--------

12/18-5J3

[Oral Brown. About 5 miles west of Union Gap. Altitude about 1,165 ft. Drilled by Ralph Cassel, 1953. Casing, 8-in to 203 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	10	10	Cemented basalt gravel—Con.		
Cemented basalt gravel:			Gravel, cemented	48	192
Gravel, cemented	76	86	Clay	5	197
Clay	4	90	Gravel, small, and clay	8	205
Gravel, cemented	10	100	Gravel, cemented	48	253
Gravel, small, and clay	4	104	Gravel and clay	5	258
Gravel, cemented	12	116	Ellensburg formation:		
Clay	17	133	Clay, sandy	17	275
Gravel, cemented	4	137	Sand, water-bearing	5	280
Clay	7	144			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/18-8A1

[Carrel Morton. About 2 miles southeast of Ahtanum. Altitude about 1,170 ft. Drilled by Joe Riebe, 1943. Casing, 10-in to 20 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	12	12	Ellensburg(?) formation:		
Cemented basalt gravel:			Sand, water-bearing	2	100
Gravel, cemented	8	20			
Clay and boulders	78	98			

12/18-8B1

[Carrel Morton. About 1.7 miles southeast of Ahtanum. Altitude about 1,180 ft. Drilled by Joe Riebe, 1937. Casing, 12-in to 22 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Dirt	10±	10±	Ellensburg formation:		
Cemented basalt gravel:			Sand, argillaceous, yellow	605±	635
Gravel, cemented	20±	30±			

12/18-11E1

[S. H. Schreiner. About 3 miles west-southwest of Union Gap. Altitude about 1,170 ft. Drilled by Ralph Cassel, 1946. Casing, 5-in to 151 ft; unperforated]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	10	10	Ellensburg formation—Con.		
Cemented basalt gravel:			"Rock"	15	170
Gravel, cemented, and boulders	100	110	Sand and clay	20	190
Ellensburg formation:			Sandstone	15	205
Sand and clay, brown	45	155	Sand and gravel	8	213

12/18-11E2

[Fred Westburg. About 3 miles west-southwest of Union Gap. Altitude about 1,186 ft. Drilled by W. G. Ludwig, 1952. Casing, 6-in to 165 ft; unperforated]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	6	6	Cemented basalt gravel—Con.		
Cemented basalt gravel:			Gravel, water-bearing	3	177
Gravel and boulders, poorly cemented	60	66	Basalt, black (boulders)	3	180
Conglomerate (cemented gravel)	108	174	Ellensburg(?) formation		
			Sand, water-bearing	3	183

12/19-5M1

[City of Union Gap. Altitude about 930 ft. Drilled by A. A. Durand, 1936. Casing, 12-in to 80 ft, 10-in to 208 ft; perforated from 159 ft to 214 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel—Con.		
Soil and gravel, loose	15	15	Gravel, loose, and boulders	70	175
Cemented basalt gravel:			Gravel, fine, cemented	17	192
Gravel, cemented	85	100	Gravel and sand	23	215
Boulders	5	105			

12/19-5M2

[City of Union Gap. Altitude about 980 ft. Drilled by A. A. Durand, 1936. Casing, 12-in to 83 ft, 10-in to 198 ft; perforated from 142 ft to 197 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	4	4	Cemented basalt gravel—Con.		
Cemented basalt gravel:			Gravel, washed, caving	9	159
Gravel, cemented	46	50	Gravel, cemented	31	190
Gravel and boulders	13	63	Gravel, cemented, caving	14	204
Clay	5	68	Gravel, cemented	13	217
Gravel, cemented, caving	42	110			
Gravel, cemented, and boulders	40	150			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

12/19-5N1

[City of Union Gap. Altitude about 975 ft. Drilled by N. C. Jannsen, 1949. Casing, 12-in to 370 ft; perforated from 130 ft to 138 ft and from 182 ft to 361 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel—Con.		
Earth	6	6	Rock and gravel	9	76
Gravel	15	21	Gravel, hard	6	82
Cemented basalt gravel:			Rock and gravel	105	187
Rock and gravel	6	27	Rock, hard, and sand	20	207
"Hardpan" and gravel	28	55	Gravel and sand	154	361
Rock and gravel	9	64	Clay	9	370
Gravel, hard	3	67			

12/19-17C1

[Miocene Petroleum Co. About 1 mile south of the City of Union Gap. Altitude about 950 ft. Drilled by N. C. Jannsen, 1929. Casing, 12.5-in to 711 ft, 10-in to 1,045 ft; no perforations]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Yakima basalt:		
Sand and gravel	21	21	Basalt	3,779	3,800

13/18-28L1

[Congdon Orchard. About 3 miles northeast of Ahtanum. Altitude about 1,160 ft. Drilled by N. C. Jannsen, 1912. Casing, 10.5-in to 284 ft, 8.25-in to 769 ft, 6.5-in to 1,026 ft, 5.25-in to 1,227 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation—Con.		
Soil and gravel	9	9	Granite (sandstone?)	12	694
Sand and clay	2	11	Sandstone	29	723
Boulders and mud	22	33	Clay	38	761
Cemented basalt gravel:			Rock and clay	2	763
Rock, cemented, hard	25	58	"Basalt," (sandstone?) hard, boulder on one side	9	772
Clay and boulders	26	84	Sandstone, brown	10	782
Gravel, cemented	53	137	Sandstone and clay	5	787
Clay and gravel	43	180	Sandstone, brown, soft	6	793
Gravel, cemented	2	182	Clay, sticky, stiff	7	800
Clay and gravel	28	210	Boulder, basaltic(?), hard	5	805
Sandstone	2	212	Clay, stiff	10	815
Clay and gravel	35	247	Gravel, cemented	2	817
Rock, cemented	65	312	Clay, stiff	10	827
Sandstone	12	324	Gravel, cemented	9	836
Gravel, cemented	11	335	Sandstone, brown	5	841
Ellensburg formation:			Sandstone, dark, hard	14	855
Shale, red	15	350	Sandstone, blue, first flow (small) at 837 ft, increased to 993 ft	93	948
Clay, brown	10	360	Sandstone, dark blue, coarse	46	994
Shale, yellow	20	380	Sandstone, hard, coarse, and blue shale in alternating layers	8	1,002
Clay, yellow	16	396	Shale, blue, hard	13	1,015
Clay, blue	13	409	Sandstone, blue, hard	11	1,026
Gravel and boulders, cemented and sandstone	82	491	Sandstone, dark	69	1,095
Rock and clay	11	502	Shale, blue	5	1,100
Gravel, cemented	24	526	Shale and sandstone, blue	43	1,143
Rock, cemented	12	538	Shale and sandstone	50	1,193
Clay, sticky	29	567	Sandstone with some clay, second flow (112 gpm) at 1,220 ft	27	1,220
Gravel, cemented	15	582	Sandstone, with 1 layer of white sand, and 1 layer of blue sand	32	1,252
Clay, sandy	4	586			
Rock, cemented	4	590			
Clay, sandy, soft	10	600			
(Sandstone?), hard	1	601			
Sandstone	54	655			
Sandstone and gravel, soft	21	676			
Mud, with boulders on one side of hole	6	682			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

13/18-33L2

[G. E. Stewart. About 2 miles east-northeast of Ahtanum. Altitude about 1,170 ft. Dug, 1945. Casing, 36-in to 20 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Con.		
Dirt	4	4	Gravel, cemented (weakly?)	11	20
Gravel	5	9			

13/18-33L3

[G. E. Stewart. About 2.5 miles northeast of Ahtanum. Altitude about 1,170 ft. Drilled by Fred Riebe, 1948. Casing, 10-in to 49.5 ft, perforated with torch from 10 ft to 49.5 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	4	4	Ellensburg(?) formation:		
Cemented basalt gravel:			Clay, sandy	30	99
Gravel, cemented	20	24	Clay, yellow	20	119
"Hardpan" (clay?)	30	54	Gravel and sand	18	137
Gravel, cemented	15	69			

13/18-33M1

[Rainier State School. About 1 mile east-northeast of Ahtanum. Altitude about 1,180 ft. Drilled by Hughett. Casing, 8-in to 600 ft; perforated from 500 ft to 600 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Ellensburg formation—Con.		
Soil	23	23	Sand	47	245
Clay	3	26	Clay	132	377
Cemented basalt gravel:			Sand	14	391
Gravel, cemented	19	45	Clay	61	452
Ellensburg formation:			Clay and sand	48	500
Clay	90	135	Sandstone	47	547
Sandstone	19	154	Clay	63	610
Clay	24	178	Sand and gravel	3	613
Sand and gravel	20	198			

13/18-34M1

[E. A. Pearson. About 2.5 miles east-northeast of Ahtanum. Altitude about 1,130 ft. Dug, 1948. Casing, 30-in to 18 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Silt, fine	5	5	Sand and gravel	10	18
Gravel, water-bearing	2	7	"Hardpan" (clay?)	--------	--------
Sandstone, hard	1	8			

13/19-31J1

[Yakima Farmers Supply Co. About 1 mile northwest of Union Gap. Altitude about 1,015 ft. Drilled by J. E. White, 1951. Casing, 6-in to 84 ft; perforated from 75 ft to 84 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel(?) and Ellensburg formation, undifferentiated—Continued		
Dirt and boulders	17	17	Sand, medium, water-bearing	15	46
Cemented basalt gravel(?) and Ellensburg formation, undifferentiated:			"Hardpan" (clay)	19	65
"Hardpan" (clay)	2	19	Sand, fine, getting coarser	17	82
Gravel	6	25	Gravel, getting finer, and sand	2	84
"Hardpan" (clay)	6	31			

TABLE 5.—*Materials penetrated by representative wells in the Ahtanum Valley*—Continued

13/19-32M1

[Yakima Cooperative Association. About 1 mile north of Union Gap. Altitude about 1,010 ft. Drilled by J. E. White, 1951. Casing 6-in to 38 ft; unperforated]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvium:			Cemented basalt gravel(?) and Ellensburg formation, undifferentiated—Continued		
Dirt and boulders	17	17	"Hardpan" (clay)	6	31
Cemented basalt gravel(?) and Ellensburg formation, undifferentiated:			Sand and shale, water-bearing	9	40
"Hardpan" (clay)	2	19			
Gravel	6	25			

13/19-32M5

[Honeymoon Auto Court. About 1 mile north of Union Gap. Altitude about 1,000 ft. Drilled by Shookman, 1942. Casing, 4-in to 15 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	25	25	Cemented basalt gravel(?)—Con.		
Cemented basalt gravel(?):			"Hardpan" (clay)	1	32
"Hardpan" (clay)	2	27	Gravel, river	13	45
Gravel	4	31			

TABLE 6.—*Chemical analyses, in parts per million, of ground water in the Ahtanum Valley*

[Analyses by U.S. Geological Survey]

Well	12/16-13D1	12/16-17J1	12/17-16R1	12/18-5G2	12/18-5J1	12/18-11E1	13/19-31J1
Date of collection	8/30/51	8/30/51	4/18/52	8/29/51	8/29/51	8/30/51	8/29/51
Principal aquifer	Yakima basalt	Unconsolidated alluvium	Yakima basalt	Unconsolidated alluvium	Unconsolidated alluvium	Ellensburg formation	Cemented gravel
Silica (SiO_2)	54	47	38	52	51	61	39
Iron (Fe)[1]	.02	.11	.24	.03	.02	.03	.02
Total iron (Fe)	.06	------	.27	------	------	------	------
Manganese (Mn)	.00	.00	.00	.28	.00	.00	.00
Calcium (Ca)	16	10	12	23	24	30	34
Magnesium (Mg)	9.7	5.8	6.6	12	14	16	11
Sodium (Na)	10	5.6	7.2	19	16	9.6	12
Potassium (K)	1.8	3.7	3.1	5.3	5.6	3.2	4.8
Bicarbonate (HCO_3)	116	74	85	160	180	133	116
Sulfate (SO_4)	4.4	2.4	4.4	8.0	5.1	29	21
Chloride (Cl)	3.0	.7	1.2	11	2.5	18	26
Fluoride (F)	.2	.2	.3	.2	.3	.3	.3
Nitrate (NO_3)	1.6	1.0	.2	1.5	1.8	2.7	6.0
Dissolved solids	158	113	115	211	209	235	211
Hardness as $CaCO_3$	80	49	57	107	117	141	130
Noncarbonate hardness	0	0	0	0	0	32	35
Percent sodium	21	19	20	27	22	13	16
Specific conductance (micromhos at 25° C)	194	98	136	285	284	315	320
pH	7.7	7.3	7.9	7.2	7.2	7.3	7.3

[1] In solution when analyzed.

TABLE 7.—*Field analyses, in parts per million, of water from wells in the Ahtanum Valley*[1]

Well	Depth (feet)	Principal aquifer	Chloride	Hardness (as $CaCO_3$)
12/15-13R1	329	Basalt	8	95
12/16-8N1	30	Cemented gravel(?)	4	105
9M1		do	8	180
15M1	43	Basalt	8	54
17D1	20—	Gravel	10	85
17K1	12	do	6	55
18K1	343	Basalt	8	95
12/17-1L1	33	Gravel and sand	24	265
1P1	79	Alluvium(?)	12	95
2N1		Ellensburg(?) formation	6	85
2Q1	75	Gravel	10	135
2R2	9	do	8	74
5B1	170	Sand	8	135
6J1	140	do	20	170
8J1	14	Alluvium	6	60
8K1	100	Sand	8	75
9E1	80		6	80
10J1	100	Cemented gravel	6	135
10N3	11	Gravel	8	90
10R1	18	Alluvium	6	115
11M1	10	do	6	110
12E1	26	do	5	100
12K1	12	do	6	125
13H1	31	Cemented gravel(?)	14	195
15N1	140	Cemented gravel	20	120
16Q1	11	Alluvium	8	135
17C1	243	Basalt	8	60
12/18-1M1	620	Sand	10	82
5G1		Alluvium	10	112
6F4	11	Gravel	8	130
6G2	15	do	10	120
7K1	15	do	6	110
8B1	635	Sand	10	202
9L1	49	Gravel and sand	20	266
12E1	72	Sand	26	240
18D1	28	Cemented gravel(?)	18	255
12/19-6E1	50	Sand	16	235
13/18-33L1	22	Gravel	14	148
13/19-32M2	125			103

[1] Analyses approximate only; not made under laboratory control.

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