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DANIEL J. EVANS, Governor

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DIVISION OF WATER RESOURCES
MURRAY G. WALKER, *Supervisor*

Water Supply Bulletin No. 21

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By
R. C. NEWCOMB

Prepared in cooperation with the U. S. Geological Survey, Ground Water Branch, the Office of the State Engineer of Oregon, and the Board of County Commissioners of Walla Walla County, Washington.

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FOREWORD

A demand for more water than was available from presently developed surface and ground water sources for irrigation, domestic, and industrial use in the Walla Walla Basin led the State Division of Water Resources and the Walla Walla Board of County Commissioners to request the U. S. Geological Survey, Ground Water Branch, to make a comprehensive geohydrologic study of that part of the Walla Walla Basin lying within the State of Washington. Since the Walla Walla Basin also includes a large area in Oregon, the Oregon State Engineer agreed to cooperate in the program in order that the study would cover the entire Walla Walla Basin as a unit. The study is a part of the State Division of Water Resources' overall geologic mapping and water resource inventory program for the State of Washington.

Field work for the Walla Walla Basin study was started in 1946 and culminated with a preliminary report being released to open-file in 1951. Since that time, the author has collected additional basic data for hundreds of wells which have been drilled since the open-file report was released. In addition, the author has updated certain geologic interpretations and incorporated some new ideas based upon findings made during his continuing study of the geohydrology of the area.

Although the report was prepared primarily to assist water resource planners and developers, the data and material are presented in a manner which will make it useful for all geologists, engineers, architects and others who are to take an active part in the evaluation, design and maintenance of structures to be constructed on or below the earth's surface in the Walla Walla Basin.

The Division of Water Resources is pleased with the results of the author's findings and interpretations and wishes to convey its appreciation for an outstanding contribution to a better understanding of the geology and ground water conditions of the Walla Walla Basin.

-Robert H. Russell
Assistant Supervisor
Division of Water Resources

CONTENTS

	Page
Abstract	1
Introduction	2
Purpose of the investigation	2
Location and extent of the area	3
Cooperation and personnel	3
Acknowledgments	5
Location symbols	5
Climate	6
Physiography and streams	9
Physiography	9
Blue Mountains section	9
Secondary upland elements	11
Valley section	11
Alluvial slopes	11
Terraces	12
Streams	14
Geology	18
Consolidated rocks--Columbia River Basalt	18
Unconsolidated rocks	20
Old gravel and clay of Pleistocene age	20
Ringold(?) Formation	22
Palouse Formation	23
Deposits of the upper valley terraces	24
Touchet beds	25
Recent alluvium	26
Loess, undifferentiated	26
Glaciofluviatile deposits, undifferentiated	26
General structure of the rocks	27
Postbasalt deposits	27
Columbia River Basalt	27
Occurrence of ground water	28
Ground water in the Columbia River Basalt	28
Nature of the permeable zones	28
Transmission of water	30
Structural control	30
Folds	31
Faults	31
Joints	32
The top of the ground water	32
The base of the ground water	35

CONTENTS

	Page
Occurrence of ground water (continued)	
Ground water in the Columbia River Basalt (continued)	
Average yield of the basalt aquifers to wells	35
Nonproductive wells in the basalt	35
Permanence of water levels in basalt wells	36
Ground water in the old gravel of Pleistocene age	37
Lithologic characteristics of the gravel	37
Regimen of the ground water in the gravel	40
General features of the ground water	40
Recharge	40
Transmission	44
Discharge	45
Form of the water table in the old gravel	45
Hydraulic condition of the ground water	46
Minor ground-water occurrences	47
Ground water in the Palouse Formation and other loess deposits	47
Ground water in the deposits of the upper valley terraces	47
Ground water in the Touchet beds	48
Ground water in the Recent alluvium	48
Chemical quality of the ground water	48
Hardness	49
Sodium and potassium	49
Chloride	50
Fluoride	51
Other constituents	51
Other published data on water quality	54
Temperature of the ground water	54
In the Columbia River Basalt	54
In the old gravel	57
Use of the ground water	58
Types of use	58
Irrigation	58
Public supply	59
Domestic supply	60
Industry	61
Annual use of ground water	61
Development of the ground water	62
"Shallow" ground water of the old gravel	62
History of development	62
Future developments of ground water in the old gravel	62
Future development of other shallow-zone ground-water bodies	64
Ground water in the Columbia River Basalt	64
History of development	64

CONTENTS

Page

Development of the ground water (continued)
  Ground water in the Columbia River Basalt (continued)
    Nature and extent of present ground-water development ------ 66
    Construction of wells in the basalt ---------------------- 67
    Future development of ground water from the basalt --------- 69
      Indications of amount of water available annually from the basalt -- 69
      Areas subject to ground-water development ------------- 70
      Precautions to preserve high ground-water levels ------- 71
      Artificial recharge to the basalt aquifers --------------- 71
      Ground water in structural traps on the Blue Mountains slope --- 72
      Ground-water supplies for the future ------------------ 72
Tables of ground-water data ------------------------------------ 73
References cited -- 74

ILLUSTRATIONS

Plate 1. Geologic and hydrologic map of the Walla Walla River basin, Washington-Oregon.
2. Map showing altitude of Columbia River Basalt (bedrock surface) beneath the Walla Walla Valley.
3A. Geologic section along line A-A'.
3B. Geologic section along line B-B'.
Plates 1, 2, 3a and 3b in pocket

Figure 1. Index map of the Walla Walla River basin --------------- 4
2. Precipitation records showing increase of precipitation with greater altitude eastward ------------------------- 7
3. Precipitation and cumulative departure from average precipitation at Walla Walla during water years ending on September 30, 1891-1959 ---------------------- 8
4. View of the Blue Mountains slope --------------------- 9
5. View south across a characteristic part of the alluvial plain of the Walla Walla River from the Whitman Monument 13
6. View northeast across the Walla Walla River canyon at the confluence of the North and South Forks---------------- 15
7. Average monthly discharge of principal streams in the Walla Walla River basin------------------------------ 17
8. Old gravel in the east bank of the Walla Walla River at Milton-Freewater ----------------------------------

ILLUSTRATIONS

		Page
Figure 9.	Water levels in three wells in the basalt	36
10.	Water levels in five basalt wells at Milton-Freewater, Oregon	38
11.	Water levels in four wells of the city of Walla Walla, Washington	39
12.	Water levels in three wells in the gravel aquifer	41
13.	Water levels in three wells in the gravel aquifer	42
14.	Water levels in two wells in the gravel aquifer	43
15.	View east up Mill Creek valley and across the Walla Walla reservoir	65

TABLES

Table 1.	Records of representative wells in the Walla Walla River basin	76
2.	Drillers' logs of representative wells	103
3.	Analyses of water from wells, springs, and surface waters of the Walla Walla River basin	142
4.	Representative springs in the Walla Walla River basin	146

GEOLOGY AND GROUND WATER RESOURCES

OF THE

WALLA WALLA RIVER BASIN, WASHINGTON-OREGON

By

R. C. Newcomb

ABSTRACT

The Walla Walla River, whose drainage basin of about 1,330 square miles lies astride the Washington-Oregon boundary, drains westward to empty into the Columbia River. The basin slopes from the 5,000-foot crest of the Blue Mountains through a structural and topographic basin to the terraced lands adjoining the Columbia River at an altitude of about 340 feet. The main unit of the topographic basin is the valley plain, commonly called the Walla Walla Valley, which descends from about 1,500 feet at the foot of the mountain slopes to about 500 feet in altitude where the river cuts through the bedrock ridge near Divide. In the Blue Mountains the streams flow in rockbound canyons. Beyond the canyons, near Milton-Freewater and Walla Walla, they pass onto the broad alluvial fans and the terrace lands of the valley.

The growing season is long and the climate dry but equable. The average annual precipitation ranges from more than 40 inches on the higher uplands to less than 10 inches on the lower parts of the basin. The storm runoff is highly seasonal and typical of drainage from a maturely dissected upland. In consequence of the small amount of rainfall in summer, the streamflow is far short of irrigation requirements in the late summer months. Storage is a prime water problem; aside from some short-term storage as snow, ground water supplies the only storage of water within the basin.

The only consolidated rock in the basin is the Columbia River Basalt. These accordantly layered lava flows are the bedrock exposed in the canyons and other declivities. Beneath the valley plains the bedrock is covered by unconsolidated sedimentary deposits. The basalt dips westward from the Blue Mountains, southward down the "Touchet slope," northward from the Horse Heaven ridge, and eastward from a divide ridge in the lower valley. These dips converge into a synclinal trough whose bedrock surface extends below sea level in at least two places west of Walla Walla. In places faults cut the basalt and cause displacements in the even slopes that characterize the basalt of most of the basin.

The basalt is overlain by unconsolidated deposits of Pleistocene and Recent age. The oldest, thickest and most extensive unit of these deposits consists of the old clay, up to 500 feet or more thick, that partly fills the Walla Walla synclinal trough. The old clay is interfingered with the old gravel which descends in a tabular stratum from the mouths of the canyons. Successively younger depcsits--the Palouse Formation, the deposits of the upper valley terraces, the Touchet beds, and the Recent alluvium--in places overlie the basalt as well as the old gravel and clay of Pleistocene age.

Significant ground-water storage occurs in two rock units--in the old gravel, which in places has a mantle of water-bearing alluvium of Recent age, and in the basalt. The regimen of the ground water in the two materials is considerably different. The ground water in the gravel is recharged directly by the infiltration of precipitation, by water from the surface streams, and by water infiltrated from irrigation; it percolates downvalley below the surface of the alluvial fans to its discharge points in springs and seepage areas. The ground water in the permeable parts of the basalt is recharged through the outcrops of permeable rock and by percolation of water from the overlying sedimentary deposits.

Most of the ground water in the old gravel is unconfined, but that in the basalt is largely confined (artesian). The water in the top part of the basalt is confined beneath the old clay in the central part of the valley. In its downgradient progress the ground water in the basalt is dammed in places by impermeable zones along structural barriers created by faults and sharp folds.

Annually about 48,000 acre-feet of ground water from the gravel and 16,000 acre-feet from the basalt is taken for irrigation, industry, domestic, or public use. The annual basinwide recharge to the aquifers is much greater than the present ground-water withdrawal, but overdrafts now occur locally.

Largely to appraise the size of the ground-water resources of the river basin, some estimates of recharge and storage are made. The average annual total basinwide recharge to the ground water is about 300,000 acre-feet of water--125,000 acre-feet of this is recharged in the Blue Mountains and discharges to the streams. An estimated 500,000 acre-feet of water stored is in the old gravel and in the top saturated 100 feet of the basalt. The pumping lift is commonly less than 200 feet.

In the downvalley part of the old gravel some additional ground water in storage is available for use.. Much greater use can be made of the space ready for storing water in the old gravel. More water than is now used can be developed from the basalt. Plans for development of large quantities of additional water from the basalt should provide for proper dispersement of well draft and the utilization of geologic and hydrologic knowledge to obtain the optimum benefits.

INTRODUCTION

Purpose of the Investigation

The valley was endowed with sufficient surface and ground water for the pioneer irrigators, but, after more extensive use, the natural supply locally fell short of the increased requirements.

The shortage of water for irrigation during late summer and fall has been a chronic problem for 60 years. The narrow, steeply graded valleys do not afford prospects for cheap surface storage. The best of the plans for the sites of small canyon reservoirs on Mill Creek seem to require a minimum original capital outlay of $350 and a yearly operational cost of $16 per acre-foot of storage capacity (unpublished data, the District Engineer, Walla Walla District, U.S. Engineer Dept., public hearing at Walla Walla Air Base, June 28, 1960). Storage of the plentiful winter and spring supplies to meet the requirements of summer and fall is still a prime need of the basin. Aside from some delay in runoff afforded by snow, ground water forms the only water storage.

Ground water has been increasingly used to supply part of the water needs, but locally the development has been illogical. Problems of local overdraft, conflicts between withdrawals for public-supply and irrigation purposes, and uncertainties as to the adequacy of the ground-water supplies prompted the request for this study.

The size and extent of the water-bearing units, their probable recharge and their discharge areas, and the general regimen of the ground water form the basis of a ground-water appraisal. This report outlines the broad aspects of the geology and hydrology that govern the amount of ground water available for development. The report lays a base for subsequent quantitative ground-water studies.

Location and Extent of the Area

The Walla Walla River basin is a roughly triangular area of about 1,330 square miles that extends 45 miles eastward from the Columbia River to the crest of the Blue Mountains in southeastern Washington and northeastern Oregon (fig. 1). The main stream and tributaries drain an area nearly 40 miles wide athwart the Oregon-Washington State boundary. The basin is crossed by the boundary between the Walla Walla Plateau and the Blue Mountain section of the Columbia Plateaus physiographic province (Fenneman, 1931).

As used in this report, the term "Walla Walla River basin" excludes the tributary Touchet River drainage basin. That tributary basin was excluded in order to concentrate on the diverse ground-water situations of the main valley area.

Cooperation and Personnel

The work was done by the Ground Water Branch of the United States Geological Survey in cooperation with the Washington State Department of Conservation, Division of Water Resources, the Board of Commissioners of Walla Walla County, and the office of the State Engineer of Oregon.

The canvass of representative wells and springs was begun in the fall of 1946, completed largely in 1948, and maintained thereafter. The mapping and study of geologic formations were done during 1947-48. The well canvass was made by John Manning, Frederick D. Trauger, Frank A. Watkins, Jr., and the writer. Available data, such as drillers' logs, water-level data, and chemical analyses were collected, organized, and incorporated in the report. The geologic mapping of the Blue Mountains slope was done by Sherwood D. Tuttle during the summer of 1947; the Horse Heaven upland, the Touchet slope, and the details of the valley floor were mapped by the writer during 1947-48.

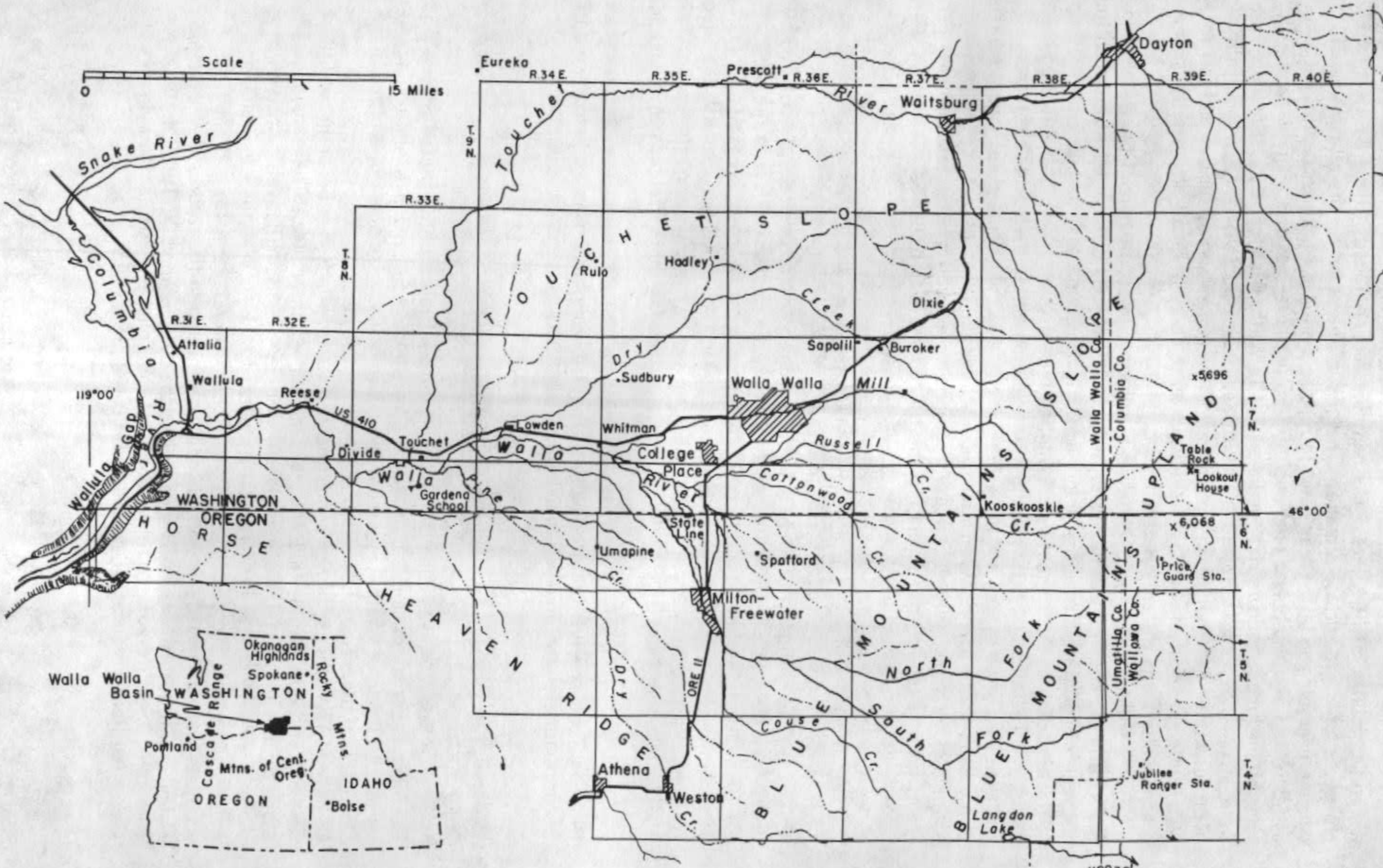


Figure I.- Index map of the Walla Walla River basin.

Compilation of the information in the report was done in 1962. A preliminary report (Newcomb, 1951) was released to the open file in 1951.

Acknowledgments

People connected with the construction and operation of water wells were cooperative and helpful. Special acknowledgment of generous help is due A. A. Durand and Paul Durand, Harry H. Harding, and Harold Yager. Help from drill records also was given by Earl Shortridge and W. E. Ruther, who contributed their well records and those gathered by their fathers. Records were obtained also from George Scott, Ted VanVoorst, L. W. Marlatt, and the firms of Moore and Anderson and Heistuman Brothers. The Soil Conservation Service furnished aerial photographs and records of wells. The district office of the Bureau of Reclamation, under the direction of M. Boyd Austin, was very helpful, and its measurement of an extensive well net weekly for nearly a year aided greatly during the early part of the study. The supervisors of the city water departments contributed records of water level and other data regarding their wells.

Many of the data on ground-water levels were obtained by Harlow Barney, Watermaster of Walla Walla County, and W. C. Mason, Deputy Watermaster of Umatilla County.

A report by A. M. Piper and others (Piper, Robinson, and Thomas, 1935) described the geology and ground water of the shallow ground-water zone beneath the valley floor. Charts and tables of that report, as well as the ground-water-level and spring-discharge measurements, continued since that study, were used in the present work.

Location Symbols

In this report, wells and springs are designated by symbols which indicate their locations according to the rectangular survey of public lands. For example, in the symbol for well 6/35-12P2, the fraction preceding the hyphen indicates township and range; because all parts of the river basin are in the northeast quadrant of the Willamette base line and meridian, this part of the symbol indicates T. 6 N., R. 35 E. The number following the hyphen indicates the section (sec. 12); the letter denotes the 40-acre subdivision of the section, according to the following diagram; and the final digit is a serial number among wells and springs in that particular 40-acre tract. Thus, well 6/35-12P2 is in the SE¼SW¼, sec. 12, T. 6 N., R. 35 E., and is the second well or spring to be listed in that tract.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

In tables 1 and 4, these location symbols are not given in full for each well. Rather, the symbols are grouped by townships under appropriate subheads and only that part of the symbol is tabulated which indicates the section, 40-acre tract, and serial number. All wells and springs listed in the tables are located on plate 1.

In a few places, such as for the location of the sample points of surface water whose analyses are listed in table 3, the part of this number giving the township, range, and section is used only for brevity in location of the sampling site.

Climate

In general, the type of climate is continental, but some oceanic storms from the west occur in winter. The climate varies with the altitude--from warm and semiarid at the western, lower part of the river valley to cool and less arid at the headwaters in the Blue Mountains.

The precipitation comes mainly in the winter; ordinarily 70 percent falls in the 6-month period October-March. It increases progressively eastward with the altitude--from an average annual total of 10 inches for the 500-foot level at Lowden to 42 inches for the 4,200-foot level in the Blue Mountains (fig. 2).

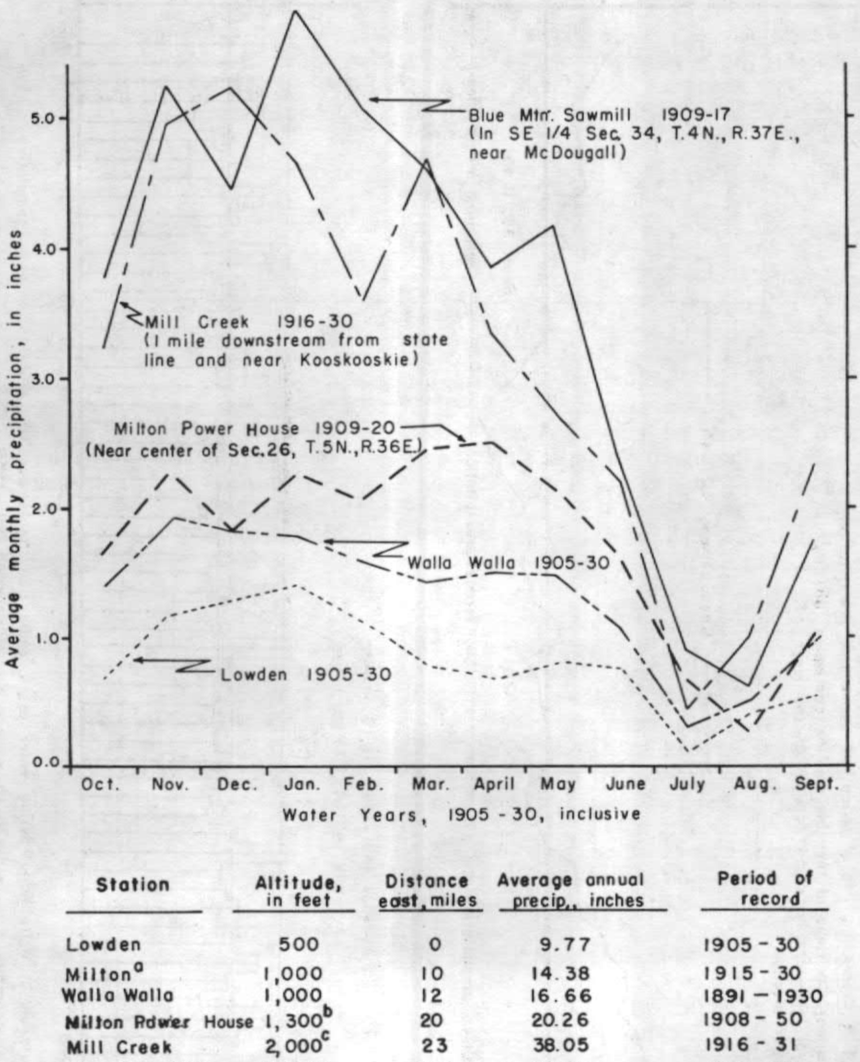
The annual precipitation for the region is remarkably constant; the lowest year of the 69-year record at Walla Walla (1891-1959) having 61 percent, and the highest but 153 percent, of the average 16.1 inches. The record of the annual rainfall (fig.3) shows a general below-average condition in the 1920's and 30's and a gradual above-average condition since 1941.

In the lower parts of the drainage basin the precipitation comes mainly as rain and in the upper parts, as rain and snow. Snow does not often accumulate to a depth of more than 1 foot on the valley floor at Walla Walla, but it builds up to depths of several feet in the Blue Mountains during most winters.

According to the Weather Bureau records, the average annual temperature at Walla Walla for the 45 years ending with 1929 was 53.5°F. The highest temperature recorded each year is rarely higher than 100°F., and the lowest seldom reaches 0°F. The average relative humidity is 71 percent at 8:00 a.m. (43 years of record), 50 percent at 12 noon and 53 percent at 8:00 p.m. (15 years of record). The monthly average relative humidity has ranged from 84 percent at 8:00 a.m. during the winter months to 25 percent at 8:00 p.m. in July.

The wind at Walla Walla is recorded as prevailingly from the south. That may in part be due to local terrain control, because a more southwesterly direction is common for the region as a whole. There is good movement of air through the valley; monthly average wind velocities at Walla Walla, for the 45-year period 1885-1930, range from 5.7 to 7.2 miles per hour. March and April were months of highest wind velocities, and October of lowest. Maximum annual wind velocities are recorded as 32 to 51 miles per hour and their occurrence seems evenly spread through the year. Winds of tornado velocities are virtually unknown. A mild wind, though prevalent and often rather continuous in the daylight hours, is not usually strong enough to bother the application of irrigation water by sprinklers.

The sky is usually clear. An average of only 56 days per year were called cloudy during one 26-year period when this weather element was recorded at Walla Walla.



Station	Altitude, in feet	Distance east, miles	Average annual precip., inches	Period of record
Lowden	500	0	9.77	1905 - 30
Milton[a]	1,000	10	14.38	1915 - 30
Walla Walla	1,000	12	16.66	1891 — 1930
Milton Power House	1,300[b]	20	20.26	1908 - 50
Mill Creek	2,000[c]	23	38.05	1916 - 31
Blue Mtn. Mill	4,200	30	42.75	1910 - 17

[a] Not shown on graph.
[b] Adjacent hills are above 3,000 feet.
[c] Adjacent hills are above 4,000 feet.

Figure 2.- Average monthly precipitation for five stations and average annual precipitation for six stations, showing greater precipitation with increase in altitude eastward in the Walla Walla River basin.

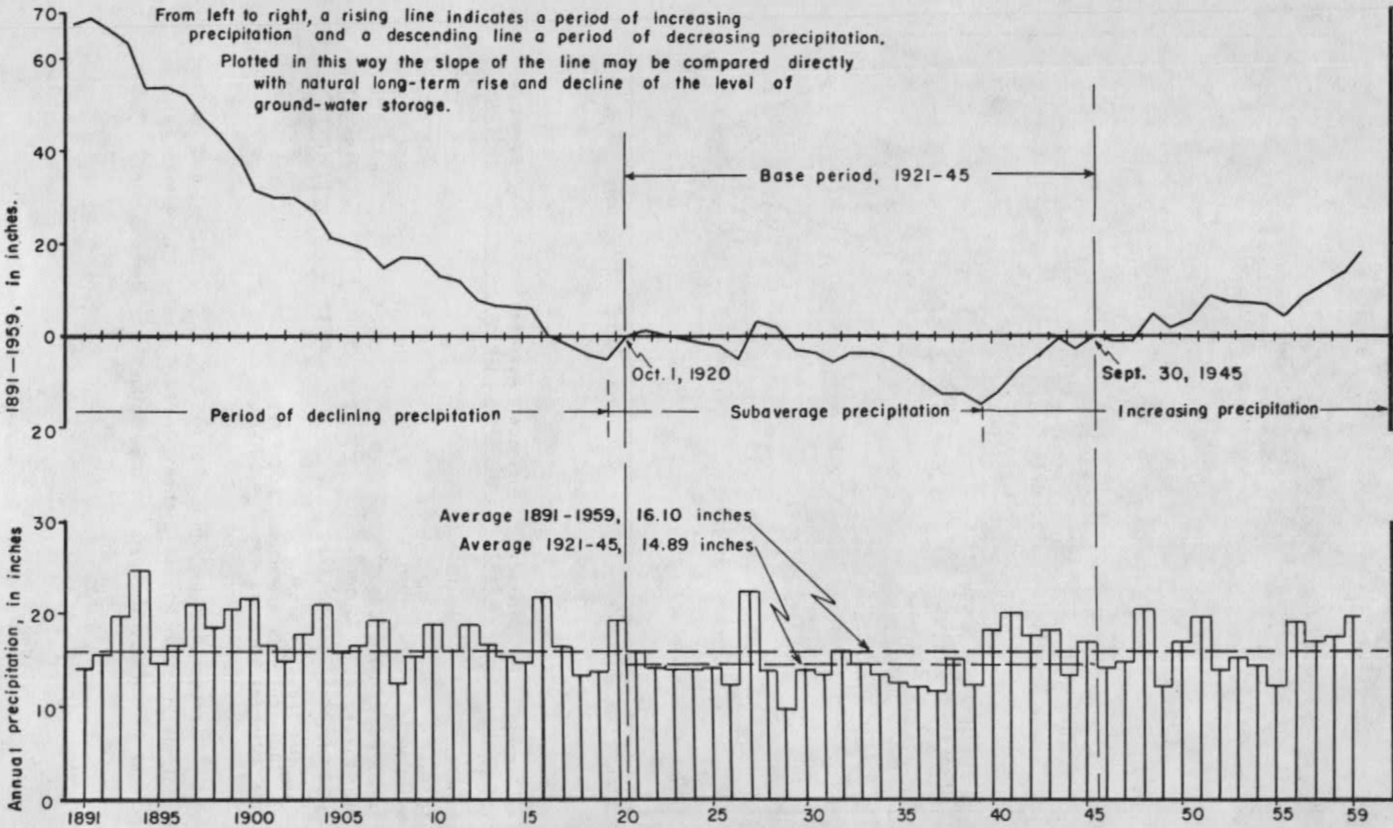


Figure 3. – Precipitation at Walla Walla during water years ending on September 30, 1891–1959 and cumulative departure from the 1921–45 average over the period 1891–1959.

The growing season is long--averaging 218 days at Walla Walla for the 46 years, 1885-1930. The average date of the last frost was March 31, and the average date of the first frost in the fall was November 1. Unseasonal frosts during the growing season are rare, though killing frosts are listed as having occurred as late as May 9 and as early as September 24.

PHYSIOGRAPHY AND STREAMS

Physiography

The principal physiographic elements of the Walla Walla Basin are the Blue Mountains section, consisting of a deeply canyoned upland surface and a ramplike slope called the Blue Mountains slope, and the valley section composed of plains and terraces. These two main elements join rather abruptly where the upper limit of the valley floor intersects the Blue Mountains slope. Secondary physiographic elements are the north slope of the Horse Heaven ridge and the southerly inclined Touchet slope which flank the valley plains on the southwest and north respectively.

Blue Mountains Section

An inclined surface, formed on the Columbia River Basalt, rises from beneath the unconsolidated deposits at the eastern edge of the Walla Walla Valley. In its lower altitudes of 1,200 and 2,000 feet, stream-valley notches set off the ramplike ridges, which ascend eastward at about 3° to 5° (figs. 4 and 5). The

Figure 4.--View of the Blue Mountains slope with upper part of the valley plains along Cottonwood and Russell Creek valleys in foreground.

even interstream surfaces narrow progressively as the ridges gain greater altitudes; nevertheless, in the headwater areas at the crest of the Blue Mountains several broad upland areas remain undissected. The broad crests of the mountainous heights reach a rather common altitude of 5,000 feet along the drainage divide, and a maximum of just over 6,000 feet at Table Rock (pl. 1 and fig. 15). The even surfaces of the ramp slope and the upland levels have a smoothly curved profile which is mostly parallel to the dip of the underlying basalt flows.

One of the largest undissected remnants of the upland surface is nearly 10 square miles in area. It lies between the canyons of the North Fork of the Walla Walla River and Mill Creek. Its smoothly undulating surface has less than 50 feet of local relief. The old surface is covered by a deep silty-clay soil on which fir, pine, yew, and associated conifers stand in dense thickets interspersed with occasional glades and more open stands of trees. The depth of the soil cover in the central parts of this upland is apparently greater than the 10 to 20 feet exposed in the banks of some of the road grades. The high precipitation results in wet areas at poorly drained places, and mountain meadows are common.

Shallow valleys of what once must have been large creeks remain on this upland surface. Probably they are modified remnants of the gentle valleys that drained this basalt surface prior to its uplift and dissection. Two of these are narrow and branched grassy swales that wind about for a mile or more and are known as Little Meadows and Big Meadows.

Blalock Mountain, lying between the forks of the Walla Walla River, and Table Glade, in which Langdon Lake and Tollgate Ranger Station are located, are two other remnants of this old upland surface.

Small springs occur about the edges of the upland plateaus. Most are the seepage outlets of water that has infiltrated the soil and moved laterally perched on the basalt. Such seepage outlets occur at Dusty, Bone, Husky, Deduck, and many other springs.

The valleys that dissect the upland surface are steep-sided, mostly narrow, canyons which are as much as 1,500 feet deep in places. The canyon walls are marked by the stairlike edges of stratified basalt flows. The South Fork and Mill Creek canyons are the deepest and grandest.

In valleys cut parallel to the direction of the strike of the basalt, as are the upper parts of Mill Creek and South Fork, the canyon profiles are asymmetrical--the wall on the west, the downdip side, is steeper. In reaches of the canyons that trend downdip, perpendicular to the strike of the basalt, cross-section profiles of the valleys are more symmetrical and generally V-shaped. The transverse profiles of the valleys of both Mill Creek and the South Fork, as well as of most other valleys, have "two-story" shapes--a narrower inner gorge of several hundred feet depth has been cut below an older, wider valley. Travel into and out of many of the canyons is difficult except at certain places and for those experienced in the area. These canyons are one place where the old admonition to go downslope when lost may well lead the uninitiated hiker into difficult, if not dangerous, circumstances.

The dominant directions of the stream canyons correspond to the direction of the structural elements of the basalt. In the upper, more gently dipping part of the arch, as in South Fork of the Walla Walla River and Mill Creek, the canyons generally follow the strike of the basalt flows. A consequent, downdip, direction of the stream canyons is more common in the lower parts of the Blue Mountains slope. Most of the reaches that trend parallel to the strike of the basalt layers seem to have inherited their ancestral locations from preuplift streams. Those which course straight down the dip seem to occupy canyons that are subsequent to the tilting of the surface. The regional jointing and the fault zones exert some control on the intrenchment of the streams–both by providing softer zones for downcutting and by bringing out ground water to nourish the streamflow. The large Hite fault seems to have played an important part in the location of the upper part of the North Fork as well as part of Mill Creek and its branches (pl. 2).

In longitudinal profile, the stream channels are rather evenly graded and have few noteworthy falls or plunges. In their lower parts the mountain canyons are partly choked with bouldery alluvium. At the present time, tributary streams from the side canyons are building fans of coarse alluvial debris into the larger valleys faster than the main streams can carry the material downstream. The canyon valley of the South Fork is backfilled in places to a depth of 60 feet or more, as far upstream as the mouth of Elbow Creek. Mill Creek valley is backfilled to a lesser degree.

Secondary Upland Elements

The eastern part of an elongate upland, known as the Horse Heaven ridge, separates the lower part of the Walla Walla River drainage basin from the Umatilla River valley to the south. Within but 2 or 3 miles of the valley floor, the north side of the Horse Heaven ridge rises a thousand feet over a series of steplike escarpments connected by "flat" stretches or by short ramp slopes. The Horse Heaven ridge itself is a rather even plateau which, in contrast to its abrupt descent northward, slopes southward evenly and gently in the Umatilla Valley.

The fourth topographic unit is the undulating plateau surface that descends in 12 miles from the 2,100-foot divide just south of the Touchet River to 1,200 feet in altitude at Dry Creek and, still farther southwest, to an altitude of 600 or 700 feet where it overlooks the floor of the Walla Walla valley near the mouth of the Touchet River. This gentle slope, which forms the north side of the Walla Walla Basin, is herein referred to as the "Touchet slope."

Valley Section

Alluvial slopes.--From the Horse Heaven ridge at Milton-Freewater [1] northeastward to the Prospect Point Ridge and from the foot of the Blue Mountains slope at Tracy northwestward to Dry Creek near Buroker, an old gravelly surface on coalescent alluvial fans formerly sloped uniformly downvalley. The old surface and its present thinly covered "reflection" descend from an altitude that ranges between 1,200 and 1,500 feet in the canyons of Mill Creek, Walla Walla River, and their main tributaries. Downstream from Whitman that ancient surface became flatter and was underlain by silt and fine-grained deposits, but it formed the lower part of the valley floor. The upper part of this alluvial surface was buried by later unconsolidated materials which now thinly overlie it. Its covered form is the main physiographic feature in the upper part of the Valley.

[1] The formerly separate cities of Milton and Freewater are now combined in Milton-Freewater, but in places within this report the upper part, Milton, and the lower part, Freewater, are referred to separately for brevity.

The valley floor slopes at a rate of 50 to 100 feet per mile to the center of the valley near Whitman. It wraps around the west end of the basalt bedrock ridge (known as Prospect Point Ridge) that extends from the Blue Mountains slope westward nearly to Walla Walla.

The unconsolidated deposits which overlie and mantle the original alluvial surface do not mask its larger features. In the west part of the Prospect Point Ridge and in the Tracy area, that old alluvial-fan surface is covered by a deposit whose composition and topographic expression are quite similar to the Palouse Formation of eastern Washington and northeastern Oregon. In the Cottonwood, Birch, Reser, and Russell Creeks section and in the Sapolil-Sudbury section this old alluvial-fan surface is overlain by a silty clay that is somewhat like the Palouse Formation, and in the lower valley-floor area it is covered by glaciofluviatile and Recent alluvial deposits. These deposits that overlie the old alluvial surface are described beyond, in the section on unconsolidated deposits.

Near Freewater and Walla Walla, much of the present land surface is believed to be close to the former level of the old fan surface. It is a sloping gravel plain upon which the streams run in shallow channels. The ground-water level is near the surface during much of the year and springs in the swales are fed by ground water whose interplay with the surface streams is readily evident. Where the overlying deposits have been swept from the old fan surface, the gravel is exposed in strips between the interstream terraces or along the front of the terraces at the edges of the valley floor. These alluvial strips and interstream terraces are prominent physiographic features in the central parts of the valley plains.

Terraces.--Low terraces form the upper part of the valley floor at an altitude of 1,300 to 1,500 feet. They remain along the sides of the valley plains, or as islandlike remnants among the stream-swept flood plains all the way down the valley to an altitude of 400 feet at the bedrock canyon near Divide. The terrace fronts range in height from a few feet to the 150-foot escarpment at the lower end of the Gardena Terrace.

A slightly different type of terrace predominates along the lowest part of the Walla Walla River and the Columbia River in the Pasco Basin downstream from Divide.

In the upper part of the valley pieces of the older terrace lie at an altitude of 1,250 feet on the ridge just south of Dry Creek below Buroker and on the Prospect Point Ridge south of Mill Creek. These terrace remnants are underlain by soil that is typical of that formed on the Palouse Formation. They are eroded into hilly topography, such as also is typically of the Palouse Formation. The Palouse Formation beneath these old terraces is in part underlain by a gravel and conglomerate belonging to the old gravel of Pleistocene age, which in turns lies upon the basalt bedrock. Much of the higher part of the valley lands in the Birch-Cottonwood-Reser-Russell Creeks area also may belong to this older terrace level.

A second and lower terrace level abuts against the older "1,250-foot terrace" and extends farther downvalley. It slopes downvalley from the 1,500-foot level above Tracy in Mill Creek valley. A remnant of this second and lower terrace occurs on the end of the Prospect Point Ridge east of Walla Walla. It is well preserved in the broad area northeast of Milton, from where it slopes uniformly downstream and passes, nearly imperceptibly, into the wide-spread terrace level of the lower valley, which is typified by the plain around Gardena and is there known as the Gardena Terrace.

Below 1,150 feet altitude, this second terrace is underlain almost entirely by silt or clayey silt which is part of a glaciofluviatile deposit.

The surface of the second terrace is but slightly eroded. It occurs as broad inclined plains south of Spofford and northeast of Walla Walla. The Walla Walla City-County Airport utilizes a part of it. In places, the materials underlying the second terrace have been completely removed by the tributaries and distributaries of the Walla Walla River near Freewater and, in strips, downstream from Freewater, and by Mill Creek and associated streams east and west of Walla Walla.

The Gardena Terrace consists of the main broad remnant of this second terrace on the south side of the Walla Walla River. It slopes from about 800 feet altitude at the State Line district to about 500 feet, 14 miles farther west near Gardena School. Several fairly large remnants of this terrace level lie at equivalent altitudes on the north side of the Walla Walla River. In places at its upper end the Gardena Terrace tapers evenly from the level of the stream-swept gravel surface of the Freewater district. It extends downstream with progressively higher escarpments separating it from the Recent flood plains of the Walla Walla River (fig. 5).

Figure 5.--View south across a characteristic part of the alluvial plain of the Walla Walla River from the Whitman Monument on an erosional remnant of the Gardena Terrace, near center sec. 32, T. 7 N., R. 35 E. The low bluff at the right upper center is one scarp near the upper end of the Gardena Terrace.

The terraces are underlain by some of the best soils of the Walla Walla Basin. The loess of the Palouse Formation beneath the older, higher terrace and beneath the uppermost part of the younger second terrace, has different water-absorbing and water-transmitting characteristics than the Touchet beds which underlie most of the lower and main part of the younger, second terrace. The two main soil types are recognized by soil surveyors as the Palouse and Sagemoor types with many gradational changes between the two type specimens in opposite ends of the Walla Walla Valley (Newcomb, 1961).

Streams

The main Walla Walla River is formed by the confluence of the South and North Forks. The South Fork [1/] is the principal tributary and is actually the upstream continuation of the main stem. The North Fork is a smaller, shorter river that progressively is being robbed of both surface- and ground-water drainage by headward extension of the tributaries of the larger and more deeply cut South Fork. Together these two tributaries drain the southern part of the Blue Mountains slope (fig 6).

The headwaters of the South and North Forks both flow southwestward along the strike of the layered basalt for 5 or 6 miles before taking a more westerly direction down the dip of the rock layers, which are inclined from 1/2° to 5° toward the Walla Walla Valley. At the apex of its alluvial fan at Milton, the Walla Walla River divides into 2 main distributaries, the Tum-a-lum Channel (main stem) and the Little Walla Walla River. The latter in turn gives forth another distributary called the East Fork of the Little Walla Walla River. Below where the main stem, Tum-a-lum Channel, turns westward in the swale between the alluvial fans of the Walla Walla River and Mill Creek, it is rejoined by the other distributaries, the flow of many spring-fed creeks, and the distributaries of Mill Creek (pl. 1).

Mill Creek, which heads in the high central part of the Blue Mountains slope, is the largest of the continuously flowing tributaries, all of which rise in the Blue Mountains. It passes northwestward onto its alluvial deposits in the lower part of its mountain canyon, and joins the main stream on the valley floor below Walla Walla. It also has several distributaries. These distributaries course southwestward off the south slope of the alluvial fan and are augmented by spring-fed branches, locally called "spring branches," through which the outflow of ground water augments the creek.

The Touchet River is formed by the confluence of several large creeks draining the northern part of the Walla Walla River basin. At the foot of the mountain slope the river abruptly changes direction to follow an unusual type of course westward to the Eureka Flats, from where it flows southward to the Walla Walla River at Touchet. The divide between the Touchet River drainage and the other parts of the Walla Walla River drainage is part of the northern limit of this investigation.

[1/] For brevity the South Fork and the North Fork of the Walla Walla River are referred to hereafter as the South Fork and the North Fork.

Figure 6.--View northeast across the Walla Walla River canyon at the confluence of the North and South Forks. The eroded upland surface and the flow layers of the basalt both rise about 150-300 feet per mile eastward toward the Blue Mountains upland. (Photo by A. M. Piper.)

Creeks whose headwater areas are in the lower part of the Blue Mountains slope are mostly nonperennial, though streams like Pine, Dry (Oregon), Couse, Birch, Cottonwood, Reser, Russell, and Dry (Washington) Creeks carry some water in parts of their courses throughout some years. Blue Creek, a tributary of Mill Creek, has a permanent flow.

Most, if not all, of the mountain-fed streams lose water while crossing unconsolidated deposits underlying the upper parts of the valley floor. That infiltrating water returns again to the streams in the middle and lower parts of the alluvial fans, as described below under "Ground-water occurrence in the old gravel of Pleistocene age."

The Horse Heaven ridge and the Touchet slope have no perennial streams; only storm water or snowmelt runoff reaches the valley floor from the dry washes of those uplands.

The discharge of water by each of the through-flowing tributaries is characterized by topographic and hydrologic conditions that provide: (1) a headwater area of rockbound canyons wherein the streams that are deepest cut receive a steady perennial spring supply, (2) a large storm-water and snowmelt runoff, and (3) a downstream course across the alluvial slopes of the valley floor wherein the streams first lose and then regain water. Farther downstream the main stem of the Walla Walla River follows, in succession, a normal meandering flow through a valley section that reaches past the mouth of the tributary Touchet River and a more rapid passage through a shallow, partly rockbound, gorge in which it descends to the level of the Columbia River.

The gradient, in feet per mile, of the main Walla Walla River decreases from more than 200 on the South Fork above Elbow Creek, to 100 near the mouth of the North Fork, to 50 near Milton in the mountain canyons and across the alluvial fan, and to 25 along the terrace lands as far as the mouth of the tributary Touchet River.

The discharge of the Walla Walla River comes from three principal sources. These are (1) storm water (precipitation shed directly or nearly directly to the streams and not lost to infiltration from the channels), (2) snowmelt conveyed entirely without infiltration, and (3) ground-water discharge. The discharge from each of these sources appears as characteristic parts of the annual discharge curves shown in figure 6. The storm runoff is especially dominant in early winter; the snowmelt, in the spring and early summer, and the ground-water outflow is dominant during the summer and the long cold periods of winter.

The flow of the South Fork during the year ranges from about 400 to 500 cfs (cubic feet per second) down to a base flow of about 100 cfs. The North Fork flows in a shallower canyon that does not reach down to the regional water table; consequently its summer base flow amounts to only about 5 cfs compared to an annual peak flow of about 275 cfs. In discharge per unit of surface area, the annual peak flow (surface runoff) of the North Fork is comparable to that of the South Fork (fig. 7). Mill Creek has basin discharge characteristics similar to those of the South Fork. It has a base flow in summer of about 40 to 50 cfs coming from springs where the canyons reach down to the regional water table or to some of the zones of perched ground water deep in the basalt.

Much of the precipitation runs off the mountainous section. The total discharge of Mill Creek at a station half a mile downstream from the State boundary for the climatic years of 1914 and 1915 was equivalent to 30.8 and 26.6 inches of precipitation, respectively, on the drainage area (Johnson, 1933, p. 18). Johnson also reported the discharge of the South Fork above the Pacific Power & Light Co.'s intake (half a mile above the mouth of the North Fork) equaled a basinwide yield of 30.4 and 28.2 inches respectively for those same years. The precipitation recorded at Blue Mountain Sawmill on the upland at McDougal (altitude 4,200 feet) was 43.14 and 33.09 inches respectively for those years. If this precipitation is taken as representative for that part of the drainage basin, the percentage of the precipitation that passed the gaging station during those years would have been 71 and 80 for Mill Creek and 70 and 85 for South Fork. These quantities are rude, but still they would suggest remarkably high basin yields and would indicate that only 15 to 30 percent of the precipitation had been taken from the basins by evapotranspiration.

The contribution of ground water to the total yields of the basin in 1914 and 1915 may be approximated from parts of the discharge records shown on figure 6. The infiltration to ground water represents a considerable part of the precipitation on the mountain areas. Published records of streamflow in the Touchet River to the north, the Grande Ronde to the east, and the Umatilla River to the south indicate the summer base flow of those rivers per unit area of drainage basin is similar to that of the Walla Walla River and Mill Creek. This similarity between basins indicates that the ground-

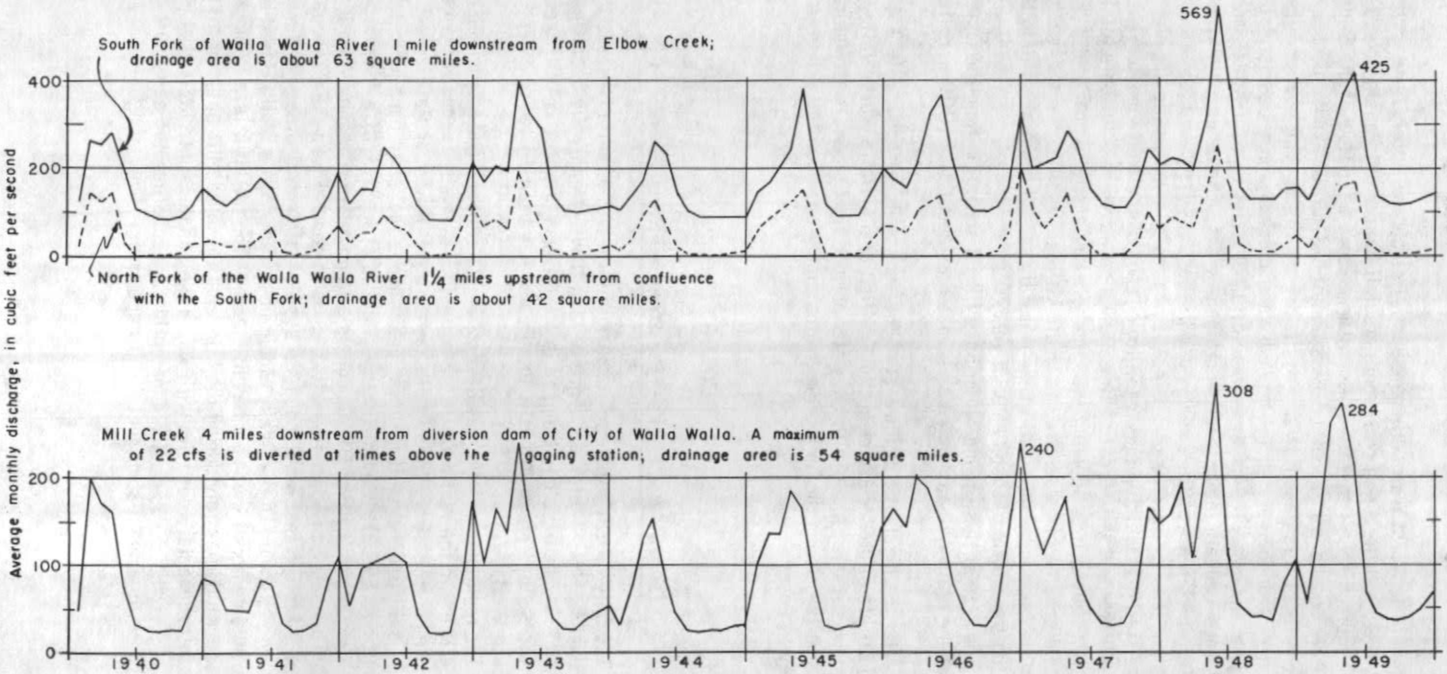


Figure 7. – Average monthly discharge of principal streams in the Walla Walla River basin.

water divide of the Walla Walla drainage basin lies approximately beneath the surface drainage divide, and the runoff represents precipitation on this basin only.

Figure 6 shows that the uniform summertime base flow of the South Fork and North Fork combined is about 100 cfs and of Mill Creek about 50 cfs. Based on the continuity of this base flow during the dry months of each year and its uniformity from year to year, such a ground-water discharge may be postulated for the whole year and computed as an average depth of water that infiltrates and reaches the ground water beneath the respective drainage areas. The resulting outflow of ground water which reaches the streams and passes these measuring stations annually is equal to an average of 13 inches of precipitation on the drainage basins above these stations, which are near the lower ends of the canyoned courses of the Walla Walla River and Mill Creek. Thus, when compared to Johnson's total yield figures, given above, it is apparent that ground water supplies nearly half of the total annual discharge of these streams to the Valley. Also it is clear that ground water supplies much more than half of the water these streams discharge to the Valley during the growing season of each year.

The size of this ground-water base flow discharging from the Blue Mountains part of the drainage basin may be estimated as about 125,000 acre-feet of water per year.

After the discharge of the last of the snowmelt, by about July 1 of each year, the 150 cfs of ground-water outflow carried to the Walla Walla Valley by these two main streams, along with the water pumped from ground-water storage beneath the valley, forms the bulk of the water supply on which the economic life of the valley is based.

GEOLOGY

Consolidated Rocks--The Columbia River Basalt

The only consolidated rock exposed in the Walla Walla Basin is the Columbia River Basalt, a thick sequence of lava flows of generally basaltic composition (pl. 2). The basalt is exposed in a thickness of about 2,000 feet in the canyons of the South Fork and of Mill Creek, and has been drilled to a depth of 2,500 feet at Walla Walla.

The rock on which the basalt rests is not exposed and has not been reached in drilling in the Walla Walla River basin. In the Tucannon River canyon, about 35 miles northeast of Walla Walla, a few small inliers of Paleozoic(?) and Mesozoic(?) sedimentary, metamorphic, and igneous rocks are exposed beneath the basalt (Huntting, 1942), which in that vicinity is at least 3,000 feet thick.

The Columbia River Basalt covers a large area in Oregon, Washington, and Idaho. The main body of the basalt extends in general from the Okanogan Highlands southward to the east-west mountain systems of central Oregon and from the Cascade Range eastward to the Rocky Mountains. The Walla Walla Basin lies southeast of the center of that vast basaltic area. The basaltic lava is considered to have been extruded largely during the Miocene Epoch, on the basis of fossils gathered from sedimentary deposits with which the basalt is interlayered at places about its margins, but its extrusion apparently continued into the early part of the Pliocene Epoch in at least some parts of its occurrence.

The basalt is a dense dark-gray, brown, or black rock with very finely felted crystallites set in a glassy groundmass. Vesicular texture is common in most flows; the tops of some flows are spongy in places.

Characterically, the basalt flows have three main sets of joints resulting from shrinkage during cooling. Two of the joint sets are generally vertical and one horizontal. One vertical set separates the basalt into polygonal, usually hexagonal, columns that extend perpendicular to the cooling surface of each flow. These columns range from about 6 inches to 5 feet or more in diameter and in some thick flows extend from top to bottom. The second vertical set separates the basalt into straight-sided, irregularly shaped blocks only 6 inches or so in diameter. That joint structure is often called "cubical" or "brickbat." The third joint set embraces the horizontal platey cracks. The three types of cooling joints may occur in the same flow, but when they do one always seems to be more strongly developed than the others. Besides the cooling cracks, or joints, which separate the basalt into columns, blocks and platey slabs, as described above, there are master joints, sometimes called regional joints. The regional joints are linear cracks, or multiple cracks in a band a few inches wide, cutting nearly vertically through the basalt of a flow and continuing for a distance of several hundreds or thousands of feet. In some places these master joints continue vertically into the overlying and underlying flows. In many places these master joints are aligned with fault planes and may be a part of the structural accommodation of the rock to deforming stress, but elsewhere they may be a gross feature of the cooling and solidification of the individual lava flow. Generally there is little displacement of the sides of these regional joint planes, but displacements of several inches or a few feet occur locally.

The basalt sequence is composed of successive flows of lava, built up accordantly one over the other, with relatively few interflow deposits or soils. A few dikes of basaltic lava cut across the layers. On the whole, the interflow planes are remarkably parallel and uniform, although locally the contacts are irregular, particularly near the tapering ends of individual flows. In the South Fork canyon above Elbow Creek and in Mill Creek canyon, as well as at other places in the Blue Mountains, sections nearly a thousand feet thick are well exposed, and have accordant inclination of interflow planes throughout the vertical section in which the layered structure extends uniformly as far as the individual flow lines can be followed laterally. One angular discordance of about 1° is present between prominent flow lines in the cliff along the South Fork in sec. 21, T. 5 N., R. 36 E. The discordance described by Erdmann (1933, p. 28 and fig. 4B) was not verified in the field. Instead, the apparent discordance may represent differences on opposite sides of a fault displacement or between flow layers and a low angle dike rather than a discordance in the dip of successive lava flows.

Individual flows range in thickness from 5 to 150 feet. Individual flows exposed in the South Fork canyon average about 40 feet thick (Erdmann, 1933, p. 16).

Only a few sedimentary interbeds are visible in the basalt outcroppings. A few thin buried soil zones between the lava flows are exposed in the thick sections in Mill Creek and South Fork Canyons. Though sedimentary deposits may be present between flows in canyon exposures and be hidden from view except in the sheerest slopes, it seems evident that sedimentary interflow deposits are thin and rare. Logs of deep wells in the basalt (table 2) show that, on the average, only one interflow "clay," "shale," or tuffaceous zone averaging 10 feet in thickness was logged by drillers for each 340 feet of drilling. Some reddish interbeds were listed in those logs but no extensive interflow zones are identified from drilling records. The tuffaceous beds commonly encountered 100 to 300 feet below the top of basalt in the Yakima River valley, the Richland area, and the Pasco district to the west were not identified in the basalt beneath the main part of the Walla Walla River basin. However, such extensive interflow deposits may be penetrated by wells as far east as Wallula. Also, one 10-foot-thick volcanic ash or tuff bed is exposed over a wide area near the top of the basalt section in the south side of the canyon of the South Fork.

The tops of many lava flows are oxidized to a deep red color that diminishes progressively downward for 2 or 3 feet--into the normal dark rock of the flow. The tops of some flows show a rather rough "cooling-breccia" type of fragmentation, the pore spaces of which were not closed by the lava of the overlying flow. These cracks and vuggy spaces are large in the tops of some flows; however, cavernous conditions are rare. The rock texture indicates that the basalt in the Walla Walla Basin largely solidified after the fluid lava came to rest. Flow brecciation, resulting from self-fragmentation by movement after partial solidification, is very rare in these flows.

Unconsolidated Rocks

Old Gravel and Clay of Pleistocene Age

The oldest of the unconsolidated deposits that lie below the plains of the Walla Walla Basin consists of clay as much as 500 feet thick, and of gravel 10 to 300 feet thick. The gravel was laid down as coalescent alluvial-fan deposits whose materials were washed from the mountain canyons of Mill Creek, the Walla Walla River, and their tributaries.

These deposits are referred to locally as the "old gravels and clays" or the "cemented gravels" and the term "old gravel and clay" is used here informally in conformance with local custom.

So far as known, the old clay does not crop out at the surface. Drilling records show it lies upon the basalt bedrock in the deep parts of the Walla Walla syncline (plate 3A and 3B). At depth it extends across the valley from Mill Creek to the bedrock near Umapine. Longitudinally it extends down the valley from Freewater to the rock rim at Divide. The old clay may be the time equivalent of part of the Ringold Formation which lies on the basalt in the broad synclinal area of the Pasco Basin west and northwest of the rock rim of the Divide anticline.

The old gravel occurs as remnants at the valley floor level, as a widespread layer beneath most of the valley floor, and as narrow trains buried beneath later deposits and extending far down the southern part of the lower valley floor. Locally, near the margins of the valley, as at the top of the river bluff just below the Milton powerhouse and in the road banks in sec. 5, T. 5 N., R. 36 E., the gravel rests on the tilted surface of the basalt. The main gravel deposit is exposed beneath a thin soil cover in parts of the Walla Walla city and Freewater areas (fig. 8).

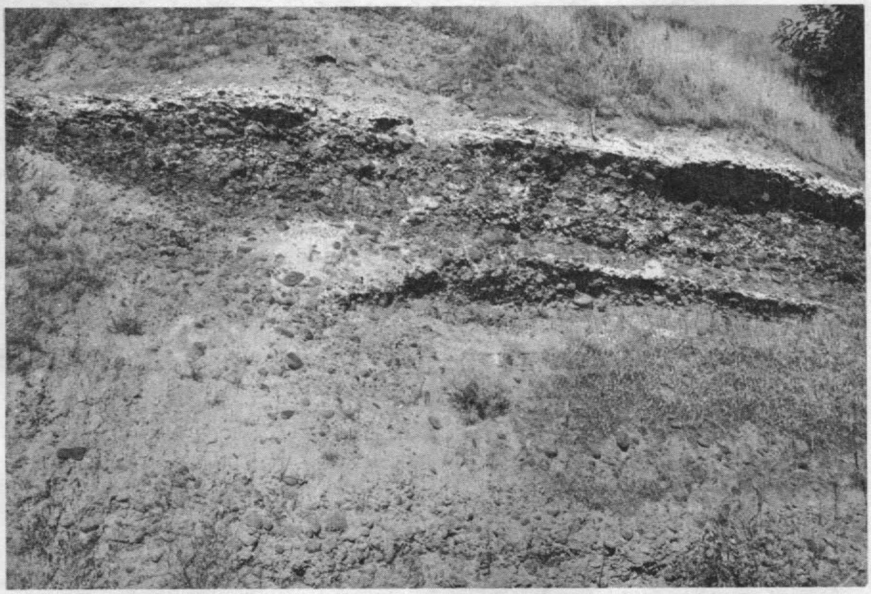


Figure 8.--Old gravel exposed to a height of 20 feet and overlain and silt in the east bank of the Walla Walla River at Milton-Freewater, just north of center of sec. 1, T. 5 N., R. 35 E.

Some of the old gravel deposit lying on the basalt in the upper part of the valley may be older than Pleistocene. However, because of the apparent Pleistocene age of the main stratum of the old gravel, and in the absence of other age data, this possibly older gravel is included with the gravel of Pleistocene age because they are similar.

The old gravel is composed largely of well-rounded, undecomposed pebble, cobble, and boulder gravel entirely of basaltic material. The gravel materials in most places are set in a matrix of sandy and silty material, although beds and irregular flat zones without such matrix do occur. Sand constitutes a minor part of the gravel zone. In some places considerable calcareous cement is present. Exposures of gravel in the sides of dug wells show that compaction and imbedding of silt and sandy matrix is of greater importance than cementation in making the gravel semiconsolidated. Much of the footage drilled in the old gravel is recorded as "cemented gravel." The gravel is so compacted that in most places it stands unsupported in the walls of dug wells; loose gravel, or gravel sufficiently free to transmit water readily, forms but a small part of the material observed or reported in wells.

From an irregular thinly tapered edge on the lower slopes of the Blue Mountains the old gravel thickens downvalley into a 200-foot stratum in the area between Walla Walla, Milton-Freewater, and Whitman Station. The gravel extends in narrow trains farther downvalley along the southern side and apparently thickens and widens in places beneath the area south of Gardena School. Downvalley from College Place and the State line, the gravel is interlayered with clay and silt of the old clay described above. Along the northern side of the lower part of the valley the gravel largely terminates upstream from Lowden, where wells penetrate only a few layers of sand and fine gravel interbedded with silt and clay.

Downvalley from the common western limits of the main stratum of the old gravel, some coarse sand and fine gravel are penetrated by wells in the Mud Creek and Pine Creek areas as well as beneath the Gardena Terrace itself. Those sand and gravel layers are largely interstratified with finer materials, in which respect they contrast with the continuous thicknesses of the old gravel that occur beneath areas farther upstream.

Laterally across the valley, the old gravel may be followed in wells from the bouldery zone found above bedrock in the Buroker and Sapolil districts on Dry Creek southwest to the Horse Heaven escarpments southwest of Umapine. The main bulk of the deposit lies beneath the alluvial fans of the Walla Walla River and Mill Creek where it has a general thickness of 100 to 300 feet. Downvalley, the old gravel tapers out, in both vertical and horizontal planes, as tongues that extend into the old clay. The long trains that extend beneath the Umapine area, widening and thickening again beneath the south side of the lower valley, are the most important among these tonguelike extensions.

The old clay is apparently the quiet-water equivalent of the old gravel and was deposited where the gravel-bearing currents were unable to reach. The general downslope limit of the main body of this old gravel occurs along an arc about a mile beyond the outer spring zone (pl. 1). This outer limit of the main body of the old gravel extends northeastward from a mile or so west of Umapine, crosses the State line northward to where the old gravel strata of the Walla Walla River merge with those that originated in the Mill Creek valley. The limit of this main body of the old gravel then extends northeastward about through Whitman Station.

Ringold(?) Formation

In the railroad cut along the north bluff of the Walla Walla River 2½ miles west of Reese the westward-descending top of the Columbia River Basalt is overlain by layers of silt and conglomerate. These deposits may be part of the Ringold Formation which underlies a large part of the Pasco Basin north and west from the bedrock ridge at Reese.

The exposed section is:

	Feet
Siltstone, yellowish-gray, semicompact (eroded top is overlain by Touchet beds and by slope rubble from basalt croppings higher on slope)	10

	Feet
Conglomerate, weakly indurated, 70 percent of pebbles and cobbles are basalt, 30 percent exotic types. Basaltic particles have a decomposition rind. Siliceous sand fills interstices..........................	50
Siltstone, similar to 10-foot bed at top, lies on basalt	20
Exposed thickness	80

Deposits of this type were not seen elsewhere in the Walla Walla River basin. These beds probably continue beneath the glaciofluviatile deposits to the west and north and form part of the water-bearing gravel deposits above the basalt bedrock in the Wallula area to the west.

Palouse Formation

The Palouse Formation is an extensive deposit of loess in eastern Washington, northeastern Oregon, and northwestern Idaho. The gentle slopes of the uplands, particularly the higher parts of the Touchet slope, Prospect Point Ridge, the foothill slopes east of Milton, and the higher parts of the Horse Heaven ridge, are mantled largely with this thick cover of fine-grained massive light- to dark-buff silty loess.

Most of the constituent grains are microscopic in size. The loess has a mealy cohesion and is of low or low-medium plasticity when wet. Temporarily it stands steeply in cut banks. In general, the loess is progressively finer grained and more clayey to the eastward within the Walla Walla River basin. Where observed on Prospect Point Ridge, it is a massive clayey silt with some irregular caliche lines that follow sandy streaks. The deposit ranges in altitude from about 1,100 to 3,000 feet. The upper parts constitute a prominent soil type.

Exposures up to 50 feet in height occur in road banks and adjacent hill slopes but the maximum thickness locally may be more than 100 feet. The deposit has characteristics of grain size, color, structure, and mineralogical composition distinct from that of the Touchet beds of Flint (1938)--a widespread glaciofluviatile deposit of the lower part of the valley (Newcomb, 1961).

In the western part of the basin the Palouse Formation is overlain by Touchet beds. A younger loess, wind-worked largely from the Touchet beds, extends beyond the Touchet beds as a mantle of light pink-gray silty loess on the type Palouse Formation. North of Touchet and Lowden this mantle of Touchet-derived loess is visibly distinct, but in the uplands farther east it thins and becomes progressively less distinct.

In much of the foothill and upland land south, east, and north of the Walla Walla Valley the Palouse Formation lies directly on the basalt. Beneath the upper terrace the Palouse Formation lies on the old gravel of Pleistocene age. This relation is well known (at 1,200 feet) in the vicinity of the flood-control reservoir on the Prospect Point Ridge in sec. 26, T. 7 N., R. 36 E., east of Walla Walla (pl. 3B). This higher terrace south of Buroker on the Dry Creek-Mill Creek divide is also formed upon the Palouse Formation. The Palouse at this place is underlain by a coarse basaltic boulder stratum that is apparently continuous with the old gravel in the Mill Creek valley to the south. At those two localities the Palouse is typical of the formation in the so-called type, or core, area of the "Palouse region" (Newcomb, 1961). This type area is commonly taken as the Colfax-Pullman-Moscow area 80 miles northeast of Walla Walla. The erosion of the Palouse Formation underlying this upper (1,250-foot) terrace has produced the billowing rounded convex-upward hill slopes characteristic of the "Palouse topography."

Deposits of the Upper Valley Terraces

Downslope from the lower areas underlain by definite Palouse Formation, several terraces and alluvial plains are underlain by deposits which pass imperceptibly beneath the younger Touchet beds. These deposits, here referred to as "deposits of the upper valley terraces," are composed largely of clay and silt. They may be in part equivalent to the Palouse; generally they contain a large amount of reworked Palouse material. For the most part, the deposits of the upper valley terraces overlie the old gravel. In places they overlie the Palouse Formation or, as in the Birch and Cottonwood Creek districts east of Freewater, the Columbia River Basalt.

Westward from both these localities of the Palouse Formation to and beyond Prospect Point, and down the Mill Creek-Dry Creek divide, the Palouse Formation is present at progressively lower altitudes. In many of these lower places its upper part has been altered by reworking and by incorporating post-Palouse loess and volcanic ash, which become progressively more evident westward. An arbitrary line on plate 1 was used to separate the Palouse from the later loess to the west.

The isolated upland occurrences of the Palouse Formation, as well as the undifferentiated loess, are roughly outlined on plate 1 between the bedrock exposures on the Blue Mountains Slope, Touchet Slope, Divide ridge, and Horse Heaven ridge. Boundaries are arbitrarily drawn where the loess gets only 5 to 10 feet thick and rock is mixed with the loess. In the mapping of the margins of the loess on the Horse Heaven ridge, the soil maps (Harper and others, 1948) were consulted frequently to expedite the work.

For the most part these deposits of the upper valley terraces seem to be loess of the Palouse Formation, which was deposited on valley plains, underwent some reworking in places by streams and had some streamborne debris incorporated in the deposit. Because of these stream-laid features in part of these deposits the unit is separated from the Palouse Formation in this report, although the deposit resembles the Palouse in many respects.

The lowest terrace in Mill Creek valley is formed on an extensive part of these deposits. This terrace descends about 50 feet per mile from an apex nearly 1,500 feet in altitude near Tracy. It broadens to about 3 miles in width north of Walla Walla. The same general terrace level continues in a considerably more eroded condition along the north side of the valley to the vicinity of Whitman and Lowden where it matches the altitude of the broad Gardena Terrace on the south side of the river. In its western part, below 1,150-foot altitude, the terrace is formed on progressively thicker deposits of the Touchet beds until in the Whitman area no materials comparable to the "deposits of the upper valley terraces" are visible. It is difficult to escape the inference that this lowest terrace in Mill Creek valley, underlain by the complex fine-grained materials of "deposits of the upper valley terraces," was a gravel-free alluvial slope aggraded to one of the levels of Lake Lewis during deposition of the Touchet beds in the lake.

In the most massive phases of the materials, stratification is poor or is entirely lacking in the deposits of the upper valley terraces. At the Walla Walla Air Force Base, the deposits beneath the Mill Creek valley terrace may well be reworked Palouse Formation or material of Palouse type laid over a valley plain late in the first phases of the Palouse deposition. South of the Prospect Point Ridge these deposits apparently underlie the broad terraces of the Russell Creek-Birch Creek area. The materials there also appear to be partly reworked deposits of loess of the Palouse-Formation type.

The "deposits of the upper valley terraces" in general transmit only minor quantities of water, sufficient for domestic wells. The deposits underlie much of the best land in the basin.

Touchet Beds

A deposit of horizontally bedded silt and fine sand, marked by distinctive gravel, cobble, and boulder inclusions and by peculiar structural features, overlies all other Pleistocene and older materials. The Touchet beds[1] are more than 100 feet thick beneath the terrace lands in the lower part of the Walla Walla Valley. They extend upslope to a taper edge at a maximum altitude of about 1,150 feet. These beds are principally light-gray silt and very fine sand with some clay, diatomaceous earth, and volcanic ash. Considerable sand and a little gravel occur interbedded, particularly in the lower parts of the deposits, and is exposed in deep cuts in the thicker sections, such as that along the north front of the Gardena Terrace just south of Touchet. Distinctive of these deposits is some pebble-to-boulder debris of granitic and metamorphic rock that has come from the upper part of the Columbia River basin. The presence of large erratics of such material is ascribed to rafting by icebergs. These deposits apparently were laid down in glacial Lake Lewis at a time when a lava flow, ice jam, or landslide dammed the Columbia Gorge near Hood River, Oregon, to an altitude of about 1,150 feet (Allison, 1933, p. 675-722). They underlie the Gardena Terrace and other similar terraces that line the Walla Walla Valley and its tributary stream valleys, such as those of Dry Creek and Spring Valley Creek. Upvalley, this material tapers to a few scattered erratics like those found on the terrace west (but not east) of the Walla Walla Air Force Base. Downstream below the bedrock rim at Divide, the deposits underlie the rolling terrace lands and form much of the surficial material around the margins of the Pasco Basin.

The Touchet beds, like the "deposits of the upper valley terraces," are significant mainly from the standpoint of soils and topography and only in a lesser way are significant to the ground-water situation in the lower part of the valley.

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[1] The name "Touchet beds" was applied first to these deposits by Flint (1938, p. 494).

Recent Alluvium

The gravel and silt laid down by the present streams comprise the Recent alluvium. Recent alluvial material now above the reach of the streams is called "older alluvium"; that submerged by the streams in flood is referred to in this report as "younger alluvium." Sandsize material forms only a very minor fraction of the deposits of the streams of the Walla Walla River basin. It is mostly pebbles, cobbles, and silt. On the Walla Walla River alluvial fan in the State Line district considerable course alluvium is carried by the present river. Farther upstream, the coarse alluvium is backfilled 50 to 60 feet deep up its mountain canyon, and is spewed out near the apex of the alluvial fan for several miles in a thin layer lying on the old gravel.

Most of the streams that cross the valley floor have cut into or through the Touchet beds, deposits of the upper valley terraces, and the Palouse Formation and are temporarily base leveled on the exhumed gravel surfaces of the old gravel and clay of Pleistocene age or on the basalt bedrock. Across this exhumed surface the alluvial materials are being transported or have been thinly deposited.

Loess Undifferentiated

A sandy silt loess, light gray in color, mantles the Palouse Formation in the uplands of the western and lower parts of the valley. In places it also covers the Touchet beds to a thickness that ranges from 1 to 10 feet. This distinctly sandier loess is apparently derived largely from wind working of the Touchet beds and glaciofluviatile deposits in the westernmost part of the Walla Walla River basin and in the terrace lands along the Columbia River farther northwest. Lines separating this loess from the Palouse Formation and other adjacent deposits were arbitrarily and tentatively drawn on plate 1. The true distinction of this loess deposit was not possible during this investigation. The deposit has little or no significance to the ground-water situation.

Glaciofluviatile Deposits, Undifferentiated

Gravel and sand with some interbedded silt underlie broad terraces in the lowest part of the Walla Walla River basin and along the Columbia River farther northwest and west.

These materials are glaciofluviatile and fluviatile deposits of the ancestral Columbia River. A part of them may be remnants of the Touchet beds, or time equivalents of the latest part of the Touchet beds. They have little significance to the ground-water occurrences in the Walla Walla River basin and are shown on the geologic map (pl. 1) largely to complete the basin coverage.

General Structure of the Rocks

Postbasalt Deposits

The latter Quaternary deposits, at least those from the Palouse Formation to the Recent alluvium, lie in the essentially horizontal position of their deposition.

The earliest part of the old clay and old gravel may have been tilted in some of the last of the main deformations of the bedrock. A few scattered remnants of gravel exposures, too small to map, on the upland a few miles east of Milton suggest that the early part of the old gravel in places may have preceded the last of the bedrock warping.

Columbia River Basalt

The bedrock is deformed in broad open folds and in local lines of more intense displacement. The broad warpings have determined the large elements of the basin's geography.

The principal upwarped (anticlinal) segments of the region form the Blue Mountains anticline, Horse Heaven anticline, a broad but low arch whose axis lies to the north side of the Touchet River and the small north-south warp, known as the Divide anticline, west of Touchet. The downwarped (synclinal) unit, which is a counterpart to these anticlines, is the broad and slightly complex Walla Walla syncline. The traces of the axes of these folds, except the one north of the Touchet River, are shown on plate 1.

The largest fold is the broadly arched anticline of the Blue Mountains. The basalt is elevated about 3,000 feet above its relative position at the western foot of the mountains. In generalized cross section the arch is simple and symmetrical. A 5- to 10-mile-wide belt of nearly horizontal basalt in the axial crest is flanked on each side by a 10- to 20-mile-wide slope wherein the basalt layers dip basinward at 2° to 4°. Locally the uniform dips and even ridge crests give way to steeper descents or interruptions where more intense displacements, faults, or sharp folds mark the basalt. The anticline extends into other river basins to the northeast and southwest.

A second large fold forms the Horse Heaven ridge which extends eastward from the Cascade Range for 130 miles to where its diminishing end forms a spurlike prominence on the west flank of the Blue Mountains anticline just east of Weston. Where the fold is crosscut by the Columbia River Gorge, in the Wallula Gap just south of the mouth of the Walla Walla River, it is a symmetrical anticline. The basalt is elevated about 1,000 feet in the anticlinal crest of the 10-mile-wide fold. Farther east the north limb is marked by an en echelon series of northwest-trending normal faults along each of which the basinward block is tilted and displaced downward as a part of the drag toward the Walla Walla syncline to the north. Vansycle Canyon is the southwesternmost of these fractures and is not itself a fault, although its lower part follows a linear fracture away from which the block on the northeast side has rotated so that its basalt dips basinward about 3°.

The low arch north of the Touchet River is apparent in the Walla Walla Valley only as a monoclinal dip of the basalt southward from the Touchet River beneath the Touchet Slope and on down into the Walla Walla syncline beneath the valley floor. The poorly exposed bedrock beneath the Touchet Slope seems to have a rather even monoclinal dip and fewer lines of severe deformation than are present in the basalt at many other places in the Walla Walla River basin.

The Divide anticline is a minor warp in which the basalt is arched up about 300 to 500 feet in a belt 1 to 3 miles wide trending north-south across the lower part of the Valley. The basalt seems to be rather uniformly arched and to lack intense deformation except along its southern edge where a normal fault separates it from the Horse Heaven uplift. The main importance of the Divide anticline arises from its functions as a bedrock closure across the lower part of the Valley where it forms a rock boundary between the Walla Walla Valley and the Pasco Basin farther west.

The inward dip of the basalt from the anticlines on all four sides, as described above, terminates in the Walla Walla syncline, a broad and irregularly boat-shaped downwarp beneath the unconsolidated deposits that underlie the valley floor. The approximate axial trend of this downwarp is shown on plate 1, the bedrock surface is reproduced by contours on plate 2, and cross sections are given on plates 3A and 3B. Apparently the top of the bedrock where it is deeply covered within the syncline, as elsewhere in much of the drainage basin, rudely follows the structure of the flow layers.

Drilling records indicate that the top of the basalt continues underground at even dip and slope for considerable distances beneath some parts of the valley floor, but in other places it is marked by abrupt changes in altitude. The best known of these abrupt changes is the College Place flexure, the subsurface escarpment of a fault or sharp fold, is shown on plates 1 and 2. Its importance as a ground-water barrier in the basalt is described beyond. Other such subsurface escarpments are indicated as probably present and important to the ground-water situation. The faults extending northwest from the north side of Horse Heaven ridge continue as abrupt changes in the altitude of the bedrock beneath the unconsolidated deposits, but few of these displacements can be shown accurately by the bedrock contours with the sparse data now at hand.

OCCURRENCE OF GROUND WATER

Ground Water in the Columbia River Basalt

Nature of the Permeable Zones

The discharge of ground water from the basalt in its canyon and hill exposures occurs almost entirely along the line of contact between one basalt flow and another. These permeable parts of the rudely tabular zones of contact are the principal water-bearing parts of the basalt. Vesicles in the basalt increase the porosity by enlarging the fracture planes, but, because the vesicles generally are not connected, they do not in themselves greatly increase the permeability of the rock. The openings in these interflow zones are mainly cracks and crevices produced primarily by the incomplete closure of one flow over another and by the unhealed fragmentation and the inflated character of the basalt at the top of some of the flows.

Fractures and vuggy texture make some thin flows permeable through their whole thickness. When such a basalt flow lies between porous interflow zones the thickness of the water-bearing zone may be 25 feet or more. The thickness of any one porous water-bearing zone can vary greatly in a lateral direction, but many of the zones are fairly extensive. Some individual porous zones crop out continuously for a mile or so. Though the individual flows seldom can be traced in outcrop for as much as a mile, some of the individual porous zones are penetrated by wells in more or less uniform thickness for even greater distances underground.

The permeability and transmissive qualities of even the thickest aquifers differ from place to place. Tight, nonporous places are present at intervals along most aquifers. Stratigraphic discontinuities--the pinching out, overlapping, and fusion of flows and interflow zones--are present. Stratigraphic traps, in which the permeable zones taper out between less permeable strata, in places cause ground water to be impounded back to a point of overflow or leakage around the obstruction. These stratigraphic reservoirs are well known above the regional water table where they create many of the small bodies of perched ground water tapped by upland stock and domestic wells.

The type of lava flow that is massive throughout, or at least in its central part, commonly does not allow water to pass vertically across it. Water can pass vertically through the fractured "brickbat" type of flow--as is evident especially near the surface in wells and excavations. Many of the open joints and fractures visible in nearly all flows at and near the land surface (in even the most massive flows), apparently are at least partly closed deep underground. Vertical separation of ground water by the nonpermeable massive zones is common. In outcrop this separation is shown by the perched nature of the water in surficial deposits like the Palouse Formation and by the layered character of seeps and springs in the basalt canyons and hillsides.

Changes in the static water level, as found during the drilling of some wells, are a direct expression of the tabular separation of the ground-water zones in much of the basalt. (See table 2, particularly logs of wells 4/37-9H1, 5/35-1E1, 6/34-35D1, 6/35-10P1, 6/36-13C1, 6/37-5F1, 7/36-19R1, 22N1, 31J1, and 7/37-18R2.) In some upland places the perched water found in the upper part of a well commonly drains into lower porous zones as an uncased well is drilled deeper. Also, in valley areas, as a well is deepened below the water table it is common for successively deeper aquifers to contain water under greater pressure and for this water to rise and flow out into any uncased permeable zones higher in the well. A change of static water level of as much as 100 feet within a few feet of drilling through the massive confining parts of the basalt is a well-known drilling circumstance.

Thus, the fundamental pattern of aquifers in the Columbia River Basalt is that of separate tabular zones, each of which is interrupted in many places but is of rather widespread lateral extent. "Brickbat" and other types of fractured basalt allow hydraulic continuity in places between nearby permeable zones. The water of some aquifers is completely separated by the impervious and massive parts of flows. In all, the tabular permeable zones--the aquifers-- make up about one-tenth of the average vertical section of the basalt.

Transmission of Water

From points where it infiltrates, water spreads down the hydraulic gradient through the openings in the rock. The passage of this saturated or unsaturated transfer of water follows the permeable paths, especially those of the porous interflow zones, as gravity takes it downward. In places the water descends to lower porous zones until it is brought to a water table, beneath which the pores of the rocks are filled with water. Directly below a water table the ground water is under the pressure of the atmosphere only and is called unconfined. The upper surface of large bodies of perched ground water may be referred to as a water table, but the water surface beneath which the pores of the earth's crust are saturated universally is commonly referred to as the water table or the regional water table.

In unconfined conditions the ground water travels by mass movement downward and laterally as permeable openings in the basalt permit. Where erosion has provided an outlet, the water discharges as seeps, or springs. Residents of the Walla Walla region are familiar with the many such seeps and springs that flow from the Columbia River Basalt in ravine and canyon sides. Most of those which flow permanently are topographically low and are at the intersection of a water table with the land surface. Few of the higher seeps discharge large volumes of water; discharges of as much as 50 to 100 gallons a minute are exceptional. The large springs are those whose discharging level is considerably below the level of the regional water table. The main mass of the unconfined water below the regional water table moves laterally toward the lowest opening available to that body of water--generally an outcrop of the aquifer in the bed of the principal local stream or an opening of the aquifer into overlying gravels. Beds of the streams are mostly rubble- or gravel-covered and the regional ground-water body commonly feeds the perennial streams in an inconspicuous manner.

Where enclosed aquifers pass below the level of the principal local drainage, or where inclined aquifers pass beneath an impervious confining layer with which they terminate against a barrier, the water becomes confined under hydraulic pressure, and is commonly called artesian if it flows from wells. The two conditions of ground-water travel in the basalt--confined and unconfined--are hydraulically distinct, but confined and unconfined water can occur in different parts of some aquifers. Most of the confined water in the Walla Walla River basin occurs in the basalt where inclined porous zones conducted it beneath a confining cap of less permeable rock, or beneath the old clay, where its aquifer terminates. The movement of confined water, even more conspicuously than that of unconfined water, is by hydraulic pressure whose force is commonly stated as a hydraulic gradient (feet drop per unit of distance) between horizontally separated points.

Structural Control

The flowing or pumping level of confined water where wells tap it in the basalt beneath downwarped areas, is a dynamic condition that is also an expression of the resistance a given quantity of water meets while it is percolating in the aquifer. Thus, the flowing or pumping level at places is a reflection of the structural as well as the petrologic and stratigraphic conditions the water meets in the aquifer.

Folds.--Because ground water moves down the hydraulic gradient in tabular zones, the synclines, the downwarped areas, are the "lows" where ground water accumulates and are the most important areas of ground-water storage in the basalt. Conversely, the anticlines underlie areas away from which water percolates downdip, and are areas where the water table lies at relatively greater depth. The lands between the axial areas of the synclines and anticlines are underlain by inclined basalt with ground water moving toward the synclines. In general, localities high on the monoclinal slopes and on the upland, share the ground-water deficiencies of the anticlinal areas, and localities on the lower slopes have some access to the large ground-water supplies of the synclinal areas. It is in these lower parts of the monoclinal slopes around the edges of the valley floor where many of the ground-water supplies are most desired and where the data presented in this report may be of greatest service.

Faults.--Master or regional joints, along which slippage or shearing may be present, are common in most areas of deformed rock. These impede or block percolation at many places. Even more effective as ground-water barriers are the longer lines of fracturing. These are similar to the master joint planes, but the rocks at the sides have had much greater displacement. Zones of rock-crushing "gouge" at places occupy the planes of minor displacement, and wide zones of crushed rock occur along some faults.

Both the regional joints and the fault displacements, though in many places difficult to detect and to map, are believed to have a much more important place in the ground-water regimen than has been accorded them heretofore. Most of the faults are effective barriers to ground-water movement. At places they are known to control ground-water levels, and to affect such aspects of the ground water as recharge, discharge, spring location, temperature, chemical quality, static and pumping water levels, and many other related factors.

Sharp folds in the basalt also may form complete or partial ground-water barriers. Observations made on ground-water levels at places like the O'Sullivan Dam site and elsewhere outside the Walla Walla Basin indicate that sharp flexures, especially where the bending is accompanied by interflow sliding and shearing, may be effective ground-water barriers. Together the fault and sharp fold barriers form the class known as structural barriers (Newcomb, 1959). The fault of large displacement typically contains a wide zone of crushed and decomposed rock that forms an impervious barrier. The barrier effect of fault and shear zones commonly impedes lateral more than vertical percolation. Many of these steeply inclined planes of crushed rock permit small amounts of water to pass vertically, parallel to the direction of the planes of shear in the fault zone, and the outcrops of transverse faults in creek valleys are commonly sites of seepage springs.

The width of the impermeable parts of fault zones may range from a few inches to many hundreds of feet wide. Crushed and sheared gouge zones as much as 1,000 feet wide have been observed along faults of the Walla Walla Basin. (An outcrop of a wide fault zone is well exposed southward from the Walla Walla River at "The Slide" 3 miles west of Gardena School.)

A few of the older faults contain basalt dikes that follow the walls. Such a dike is exposed in the Mill Creek valley a mile above Kooskooski (pl. 1).

Joints.--The joints, cracks which resulted from a shrinkage of the rock while cooling from the fluid melt, are a means of water penetration, although in some places they may be too narrow to permit rapid percolation.

In some tunnels, wells, and other excavations where the natural conditions have not been greatly disturbed, the slow percolation of water downward solely in joint planes can be observed as an important transfer of water in the basalt.

The Top of the Ground Water

In the uppermost part of the Walla Walla drainage basin a partly dissected upland about 5 miles wide is underlain by basalt whose layers are essentially horizontal. At all altitudes on the edges of this area of horizontal basalt small springs discharge to the slopes or into the river's tributaries. Some of these small springs are located at the edges of the upland soil where the water seeps out along the top of the basalt bedrock. This is perched water many hundreds of feet above the water table. In other places and at other altitudes small bodies of ground water occur perched on impervious layers in the basalt above the regional water table.

In the Blue Mountains slope a 10-mile-wide section of the basalt has a general 2°-4° dip toward the Walla Walla Valley. This downslope dip of the basalt causes ground water to move westward down the dip wherever permeable paths are available.

As shown by the location of the stronger springs at low altitudes in the stream canyons and by the few wells in that area, the regional water table beneath the interstream ridges of the Blue Mountains slope lies near the level of the most deeply cut streams. There are many places where aquifers are intercepted by part of a stream which follows along the strike of the basalt. In the South Fork of the Walla Walla River such a large spring outflow occurs in secs. 19, 30, and 31, T. 5 N., R. 39 E. An instance of overflow of water from an aquifer cut in a down-dip segment of the same canyon was told by Erdmann (1933, p. 55) who described a spring near the center of sec. 14, T. 4 N., R. 37 E., as issuing "... on the top of a basalt flow (B-1) on the right bank *** about 50 feet above the valley floor. Water moves up the dip ... indicating that there is a slight head. The temperature of the water is about 70°F., and is in decided contrast to the very cold surficial waters."

Because, in this basalt bedrock, fault zones generally form barriers to ground-water movement, it seems evident that in parts of the basalt in the Blue Mountains slope ground water in each aquifer must be dammed. This damming raises the pressure level of the ground water to where the water can percolate either around the barrier or to the surface. Above a fault barrier conspicuous outflows of ground water at or near the barrier do not occur everywhere; rather, each dammed aquifer probably remains full to its point of intake, which in most cases is some distance upstream from the barrier. The Hite fault and Elbow Bend fault in the South Fork Canyon and the fault near Kooskooski in Mill Creek and Blue Creek canyons are known as probable ground-water dams (Newcomb, 1962, fig. 5).

A ground-water reservoir system, such as is formed in aquifers terminated by fault barriers, probably occurs in and around the Russell and Reser Creek districts just east of the foot of the Blue Mountains slope. Wells 6/37-4B1, -5F1, -7Q1, and -7Q2 show extraordinarily high pressure levels with progressively greater pressure in aquifers of successively greater depth, whereas wells just west of that barrier--beyond the sharp topographic break at the foot of the mountain slope (wells 7/37-32P1 and 6/36-10E1)-- have much lower pressure levels and find successively lower pressure with greater depth. Similar ground-water reservoirs behind structural barriers may occur at many other places above the several faults that cross the dip in the Mill Creek and Walla Walla River canyons (pl. 2).

Above the Cause Creek fault the ground water in the shallow layers of the basalt is confined and flows from the few wells that have been drilled into the basalt, but the deeper aquifers may have water at levels low enough to be in agreement with normal ground-water slope to the water in the basalt farther west. The natural static water level in the basalt was 100 feet below river level in the southern part of Milton, 70 feet in the northern part of Milton, and 40 feet in the northern part of Freewater. Downvalley from the sharp drop in the bedrock north of Freewater (pl. 3) the ground water in the basalt is largely confined beneath the old clays as far downstream as the barrier zone in the bedrock along the College Place flexure, at the northern part of College Place.

The levels of the water surface in the basalt at Freewater indicate a ground-water high or "mound." Whether that mound on the water-pressure surface is due to recharge, damming, or to artificial depression of the water level in surrounding areas is not yet known.

Westward from about the longitude of Prospect Point the water table in the basalt passes under the "blue clay" strata of the old gravel and clay of Pleistocene age, and the water becomes confined. The maximum natural pressure level of the ground water in the basalt at College Place was at about the same altitude as the unconfined water level in the basalt and overlying gravel at the upper edge of the confining clay. The pressure (piezometric) surface of the confined water now has an average gradient of 25 or 30 feet per mile downvalley to the abrupt 200-foot rise in the bedrock, the College Place flexure, that runs east-northeast beneath the northern part of College Place and the junction of the Little and the main Walla Walla Rivers in sec. 31, T. 7 N., R. 35 E. (pls. 2 and 3). Northwest of this flexure the water-pressure surface is now 50 to 100 feet lower than on the southeast side, and a free flow from wells does not occur. Under the natural conditions, when wells were first drilled, the difference in ground-water pressure on opposite sides of this barrier was about 200 feet. Downvalley from the College Place flexure, the ground water in the basalt is mostly unconfined and has a static water level about equal to the level of the Walla Walla River except in a few subordinate districts where some structural confinement is present. Such areas occur southwest of Touchet (well 6/33-5B1) and along the foot of the Horse Heaven slope (well 6/34-35D1).

The east-northeast-trending College Place flexure, which terminates this confined water and causes the high water pressure in the basalt at College Place, must have some complementary barriers. Northwest-trending barriers must pass through the area between Whitman and Umapine, intersect the College Place flexure, and form a southwestern limit to this high-pressure water best known at College Place. Such a northwest-trending lateral barrier would fit the fault patterns common to the north slope of the Horse Heaven ridge (pl. 1), but so far the barriers that close this area of high-pressure ground water on the southwest have not been located specifically.

Water levels in a few scattered wells on the Touchet slope show that the pressure level of the ground water in the basalt in the hill lands south of the Touchet River is inclined about 50 feet per mile southwestward through the Hadley-Sudbury district and about 25 feet per mile southward in the Rulo-Lowden district. The water table is considerably below the level of all the intermittent streams but above the level of the Touchet River. Where the Touchet Slope merges into the valley floor of the Walla Walla River, the level of the ground water in the basalt descends in 10 miles from an altitude of about 550 feet near Whitman to about 400 feet just west of Touchet.

The ground-water level in the basalt was not observed along the Walla Walla River downstream from the Divide anticline, the bedrock ridge west of Touchet. Near Reese it undoubtedly lies close to the level of the Columbia River, which, at the mouth of the Walla Walla River, has a usual reservoir altitude of about 340 feet. Three miles west of Reese the basalt descends below river level and for 40 miles to the northwest is covered by the Ringold Formation, glaciofluviatile deposits and alluvial materials.

The tilted blocks of basalt that make up the en echelon steps and the escarpments of the north slope of the Horse Heaven ridge contain ground water under diverse conditions. As indicated by a few wells and springs, the different blocks of the slope contain ground water under more or less separate hydrostatic conditions. Some of these separate units of the ground water are trapped in the tabular interflow aquifers by the relatively impermeable fault zones which mark these escarpments. (Some of the prominent faults are shown on pl. 1.)

Wells 6/34-33C1 and -34C1, near the foot of the slope from Horse Heaven ridge, have remarkably high water levels, possibly representing perched ground water. Well 6/34-35D1 was started on the downthrown side of a north-dipping normal fault, crossed the fault, and obtained flowing artesian water from the upthrown (upgradient) side of the fault (pl. 1). That well is not cased in the fault zone, and water leaked upward along the fault zone to the surface nearby when the control valve of the well was closed. Ten years after the well was drilled, the flowing pressure head had declined, largely because of discharge within the well.

Thus, the overall shape of the top of the saturated zone, or of the piezometric surface of the ground water, in the basalt bedrock is a subdued replica of the valley floor and its mountainward extensions up the main stream canyons. However, local details of the topography and the water-transmitting characteristics of the basalt cause the piezometric level of the ground water, in places, to range from 300 feet below to more than 100 feet above the land surface of the valley floor. Because the shape and position of the top of the ground-water body in the basalt is of prime importance to pumping levels and economic withdrawal of the water, extensive data on it are presented in the tables (1 and 2) and descriptions of it are given in the text.

The Base of the Ground Water

So far as is known, the overall average permeability of the basalt persists throughout its thickness of 2,500 plus feet. Thus the shape of the bottom of the ground-water body in the basalt bedrock may be assumed to be determined by the top of some underlying less permeable rock. The underlying metamorphic rocks that crop out in the Tuocannon River canyon to the northwest and the sedimentary, metamorphic, and granitic rocks that crop out beneath the basalt in the Umatilla River basin to the south could form, at some now unknown depth, such a lower limit to the ground water in the basalt.

Average Yield of the Basalt Aquifers to Wells

A tabulation of all available information on properly constructed wells in the Columbia River Basalt indicates that, over its regional extent as a whole, the basalt yields to a 10- or 12-inch percussion-drilled well an average of 1 gallon per minute per foot of penetration below the regional water table, when it is pumped at such a rate as to produce a drawdown of 50 to 100 feet (Newcomb, 1959, p. 14). That average is a little low for wells in the upper part of the valley--above College Place, but is about in agreement with yields obtained in the few wells located down-valley from Whitman. In general it is low for the better designed and engineered wells that have been drilled in recent years.

Nonproductive Wells in the Basalt

Records are incomplete for many of the older wells drilled into the basalt, but the writer knows of only one inadequate well among the 40 or more large wells constructed according to modern methods during the period since 1940. That inadequate well was the Walla Walla Memorial Park well (7/36-17K1). The reason why the rock penetrated by the Memorial Park well was so exceptionally barren is not known. Among many possible explanations is the one that the site may unfortunately mark a place where the juxtaposition of the horizontally changing permeable zones has resulted in a vertical zone devoid of good aquifers. Such vertical sections, lacking water-bearing strata known to be present in adjacent wells, are numerous, but such "blank" (aquifer-deficient) zones are usually only a few hundred feet thick. In few places would such an aquifer-devoid spot be considered statistically possible for the full depth of the well cutting more than two thousand feet of the basalt.

The linear continuation of either the sharp bedrock flexure that terminates the area of flowing artesian wells at College Place (pl. 3), or the possible bedrock displacement beneath Mill Creek along the north side of Prospect Point Ridge (pl. 4B) could, beneath the deep alluvial cover, pass through or near the site of the Memorial Park well. Such a fault or sharp flexure, with its associated vertical zones of sheared rock, may have caused a nonwater-yielding condition in the aquifer zones that would elsewhere have yielded water to a well. Among other causes mentioned for the nonproductiveness of the Memorial Park well was the excessive use of cement to hold raveling rock in the well during drilling. Such cementing, in places, can prevent water from entering a well.

Some other wells yield less than the average. Wells 6/35-2E1, -3N1, -23D1, 7/35-35G1, and 7/36-33A1 afford below-average yields. Wells 6/35-2E1 and 7/35-35G1 do not penetrate the basalt deeply and the other three are small-diameter (6-inch) wells.

It is apparent, from an overall tabulation of the production for known wells in the Valley above Whitman, that not more than one out of each ten wells fails to provide at least the average water-yielding capacity ascribed above to the Columbia River Basalt as a whole. Nevertheless, the investor should bear in mind that such chances do exist for obtaining an inadequate well in the basalt.

Permanence of Water Levels in Basalt Wells

The water levels observed in basalt wells (table 1 and figs. 9, 10, and 11) show that in some areas the ground water moves actively from areas of infiltration and sustains a perennial water level in the pumped wells, but in other areas the transmission of water is sufficiently restricted that water levels are not entirely restored after each year's withdrawal.

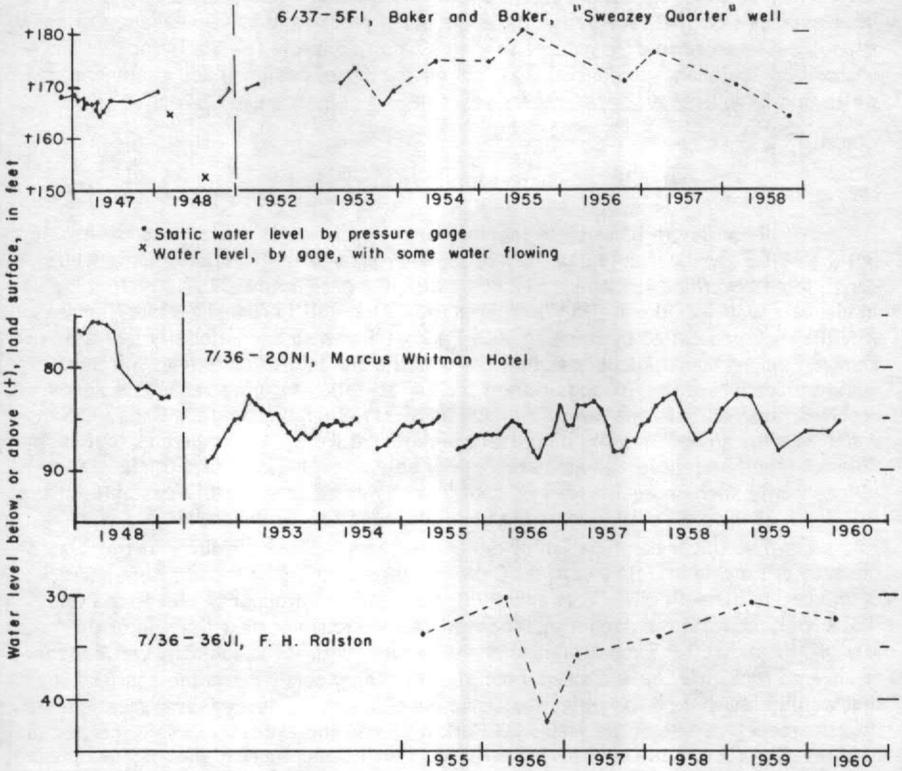

Figure 9. — Water levels in wells in the basalt. Two wells are in the Russell Creek area and one is near the center of Walla Walla.

Figure 9 shows the water level in well 6/37-5F1 has remained constant, about 172 feet above the land surface, since the well was constructed and the amount of water withdrawn has been restored to the aquifer each year by natural recharge. Also, that wells 7/36-36J1 and 7/36-20N1 have had a nearly constant water level since 1955 and 1952, respectively, when the annual recharge had established a balance with the withdrawal from wells of their localities. The water levels in these two wells in recent years were a few feet below their original levels.

Figure 10 shows water levels observed in five public-supply wells at Milton-Freewater. A persistent decline is evident in the level of water in three wells which are in localities of extensive pumping from these and other wells. The two wells with stable water levels are in places where there is less pumping from other wells. The records show that the transmission of ground water through the basalt into parts of the Milton-Freewater area has not equaled the withdrawal from some of the wells; however, the decline of water level in the three wells is distinctly due to inadequate spacing of wells drawing water from similar stratigraphic zones in the basalt.

Figure 11 shows the persistent decline in three wells (7/36-13F1, -F2, and 7/35-18F1) of the city of Walla Walla. These records indicate that the three "Mill Creek valley" wells of Walla Walla are in an area of the basalt that has been receiving sufficient water from the surrounding areas.

Ground Water in the Old Gravel of Pleistocene Age

Lithologic Characteristics of the Gravel

Although a matrix fills the interstices of the gravel, in most places there are some beds, streaks, and zones of openwork, partly loose, gravel. As seen in the sides of the dug wells, strata of openwork gravel were mostly flat, thin zones through which water travels rapidly; but they are highly irregular in horizontal extent and occur at haphazard levels in any vertical section. On the average, probably less than 10 percent of the gravel exposed in the sides of wells may be called loose, relatively free of intergranular matrix, and available for the rapid passage of ground water.

In the upper parts of the alluvial fans the old gravel is mantled thinly by gravelly alluvium of Recent age. Apparently the shallow cover of Recent gravel plays an important function in spreading the water from the streams outward through the old gravel. However, these Recent gravels do only a small part in the transmission of the main bulk of the ground water downvalley in the gravel unit.

It is important to the correct understanding of the ground-water regimen that one grasp the longitudinal section view of a flat gravel stratum tapering upvalley to pointed ends in the stream canyons and separating downvalley principally into thin strata which pinch out in the old clays. In plan, the gravel stratum lies in the shape of several coalescent fans whose "handles" are the gravel trains extending up the canyons from the apices.

The tabular gravel mass has a complex permeability that differs greatly in detail but averages rather uniform overall.

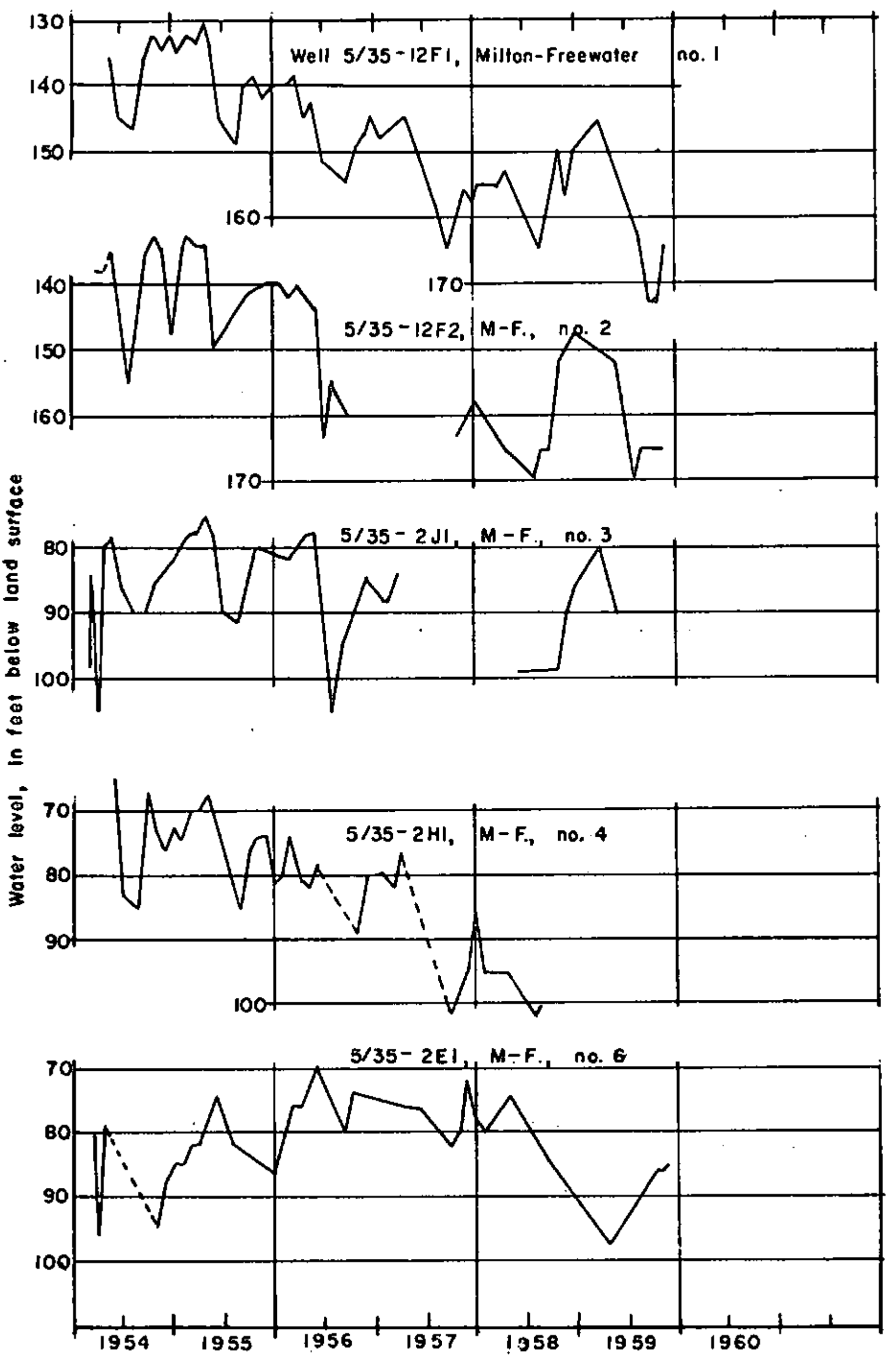

Figure 10.— Water levels in five basalt wells at Milton-Freewater, Oreg.

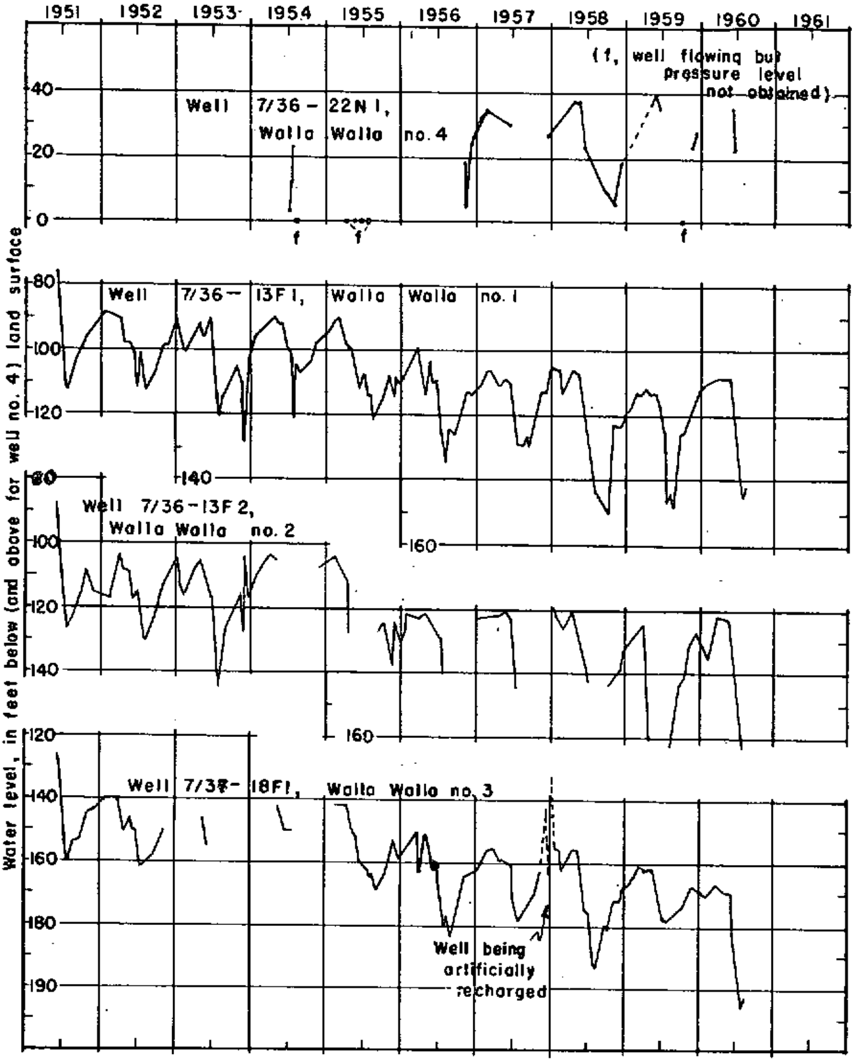

Figure 11.— Water levels in four basalt wells of the City of Walla Walla. Wells 1, 2 and 3 show a progressive decline in the water levels of that area, while well no. 4 shows a water level rise since it was drilled in 1953.

The factors of (1) variable permeability in the gravel mass, (2) relatively low overall average porosity, (3) restricted local continuity of individual permeable zones, (4) irregular vertical and horizontal distribution of the more permeable zones, (5) general downstream decrease both in grain size, width, thickness, and permeability of the deposit, and (6) a steep (50-feet-per-mile) inclination of the deposit, all contribute to the complexity of the ground-water occurrence.

The principal part of the ground-water body in the gravel occurs beneath the Walla Walla River alluvial fan, the largest of the separate parts which form the coalesced deposit. The part under the Mill Creek fan stores and yields less water. Subordinate parts of the ground-water body occur in the Russell, Cottonwood, and Pine Creek areas.

Regimen of the Ground Water in the Gravel

General features of the ground water.--Beneath the alluviated sections of the downstream parts of the mountain canyons, the level of the water table coincides with the level of the adjacent Walla Walla River, Mill Creek, and the other associated creeks. At these places the water table in the gravel is in balance with the streams.

Farther downstream, where the gravel fan widens, the water table in places stands below the level of the adjacent surface water as the ground water spreads out and adjusts itself to a flatter gradient in the larger area of gravel. In crossing these areas where the water levels are lower, the streams lose substantial amounts of water to the gravel. This infiltration increases greatly when the streams are high. With the water table standing a little below creek level, the infiltrated water moves downslope until its level intersects the surface. The outflow to the surface occurs where the underground passage of the water is impeded by the progressively decreasing permeability and size of the gravel aquifers.

Recharge.--Because, during average years, there is little surface runoff from the area underlain by the old gravel, about 3 to 4 inches, or nearly one-third of the annual precipitation is estimated to percolate to the ground water. That recharge comes mainly as rain during the fall, winter, and spring months or as melting snow and ice--mostly in the late winter and spring months. By estimating such recharge as 3 inches of water over 50 or more square miles, an approximate annual recharge of 8,000 acre-feet of water is computed as entering the old gravel from direct precipitation on the alluvial fans of Walla Walla River and Mill Creek. In some years the additions to the ground-water body in the gravel from in situ precipitation cause distinguishable rises in the water levels in some wells.

During periods of low stream discharge across the upper part of the alluvial fans, where the water table normally lies below stream level and where water infiltrates from the streams in large quantities, a large part of the river's flow may percolate to ground water. During the high water of spring and winter particularly, large additions are made to the ground water. On Mill Creek and the small creeks of the basin, such infiltration does not involve so great a volume or so great a percentage of the streamflow as it does on the Walla Walla River. Nevertheless, the infiltration on the upper part of the Mill Creek fan was, under natural conditions, sufficient to maintain a substantial ground-water body of great importance to the economy of the valley area about Walla Walla and College Place.

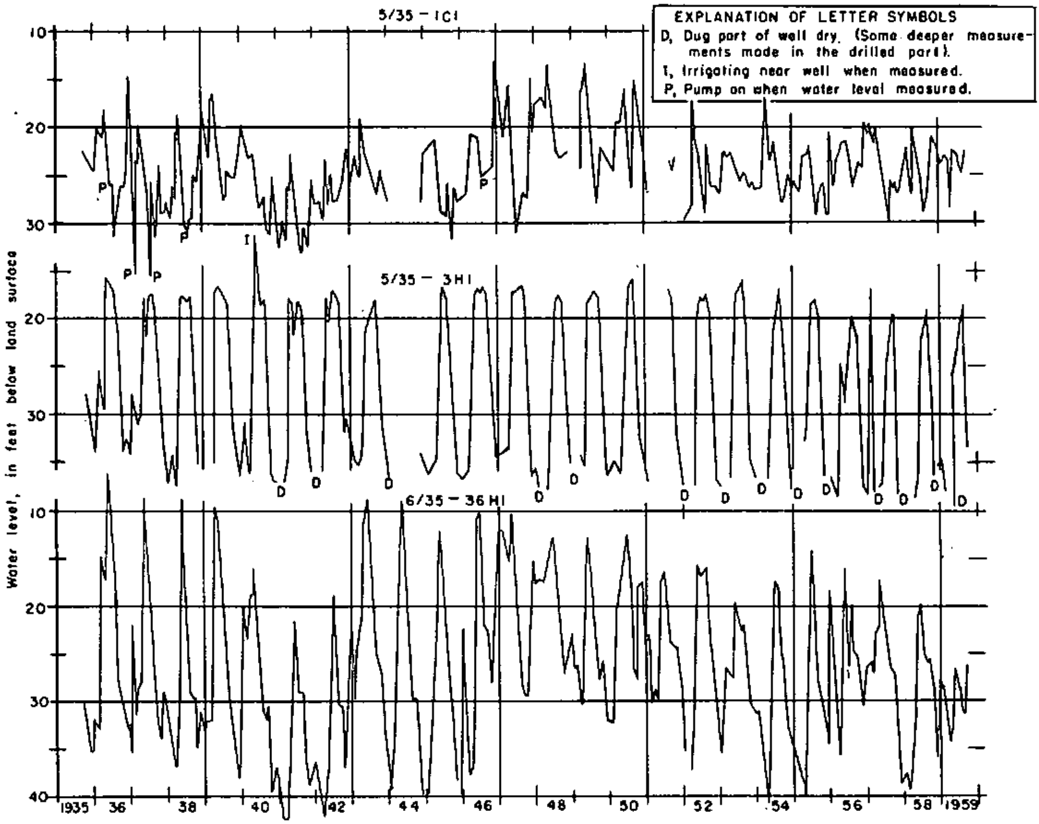

Figure 12. — Water level in three wells in the gravel aquifer near the upper part of the alluvial fan of the Walla Walla River.

Figures 12, 13, and 14 give graphically the water-level records in eight wells that tap gravel aquifers beneath the alluvial fan of the Walla Walla River. The winter and spring peak levels produced by infiltrated recharge during high stages of the river are evident, as are the summer and fall rises due to recharge from infiltrated irrigation water. In some wells one recharge source produces much higher levels than the other recharge source. The wells near the apex of the fan (fig. 12) show a predominance of the river-infiltration recharge. Records of wells 5/35-1C1 and 6/35-36H1 indicate a rather constant average rate of annual recharge except for the years 1940-42, when the recharge was less in agreement with the smaller river discharge for those years (fig. 6), and for the years since 1951 when the infiltration from the river has not raised the ground-water levels so high as their former annual high levels.

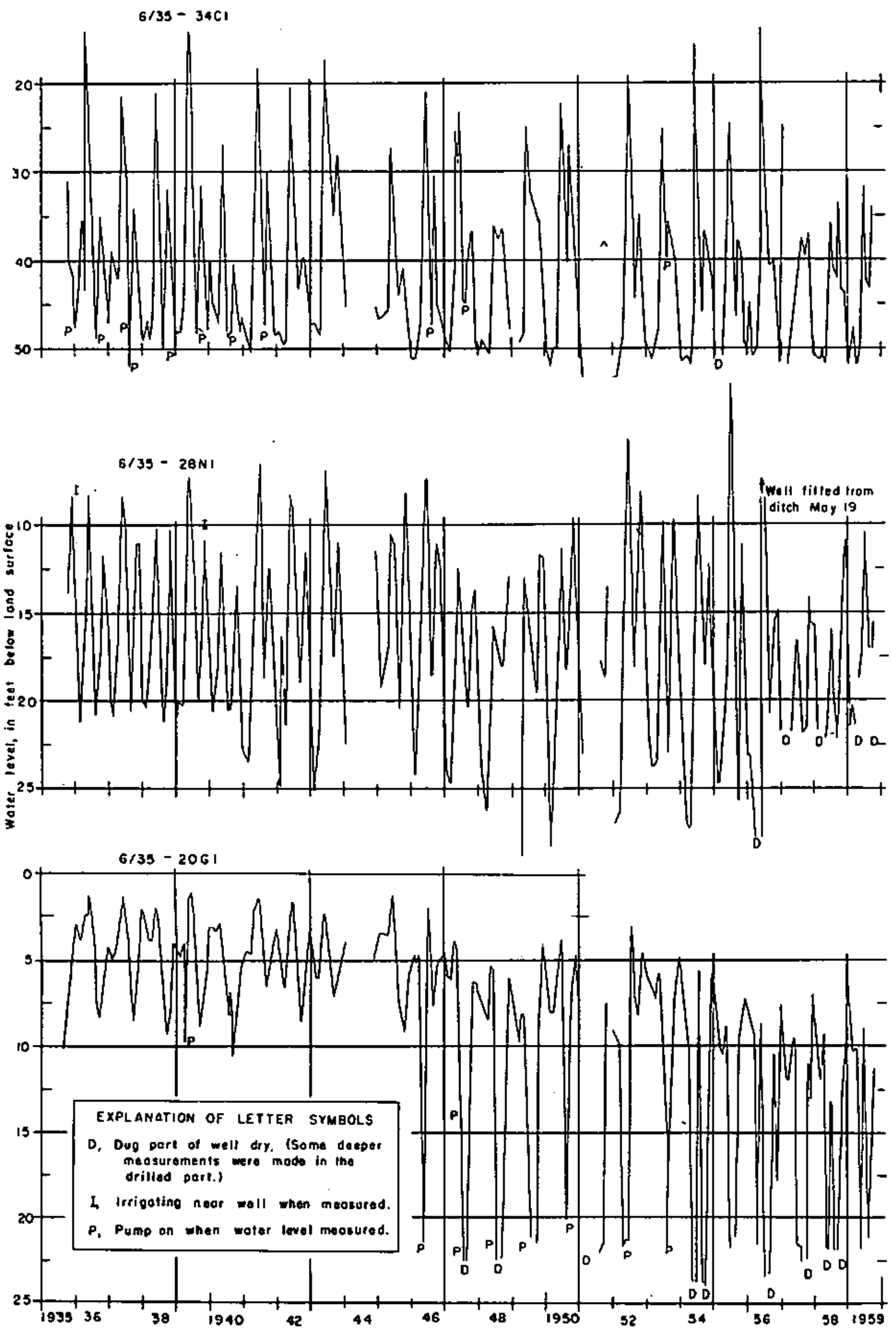

Figure 13. — Water levels in three wells in the gravel aquifer beneath the alluvial fan of the Walla Walla River between the upper edge of the fan and the lower spring zone.

The higher levels of the ground water are particularly important because of the great increase they induce in the yields of many irrigation wells. The arrival time and duration of the high levels are vital factors in the capability of the wells for meeting the irrigation requirements. Figure 13 gives the water levels in three wells alined downgradient on the alluvial fan. A progressively later time of arrival down the slope is shown for most water-level peaks. Also evident in these graphs is the downslope increase in the relative size of the water-level rise produced in summer by recharge from the infiltration of irrigation water. The plot of water levels in wells 6/35-24Q1 and -14L1 on figure 14 shows the lesser range of water-level change and the more uniform upper peak levels that occur near the discharge outlets of the ground water.

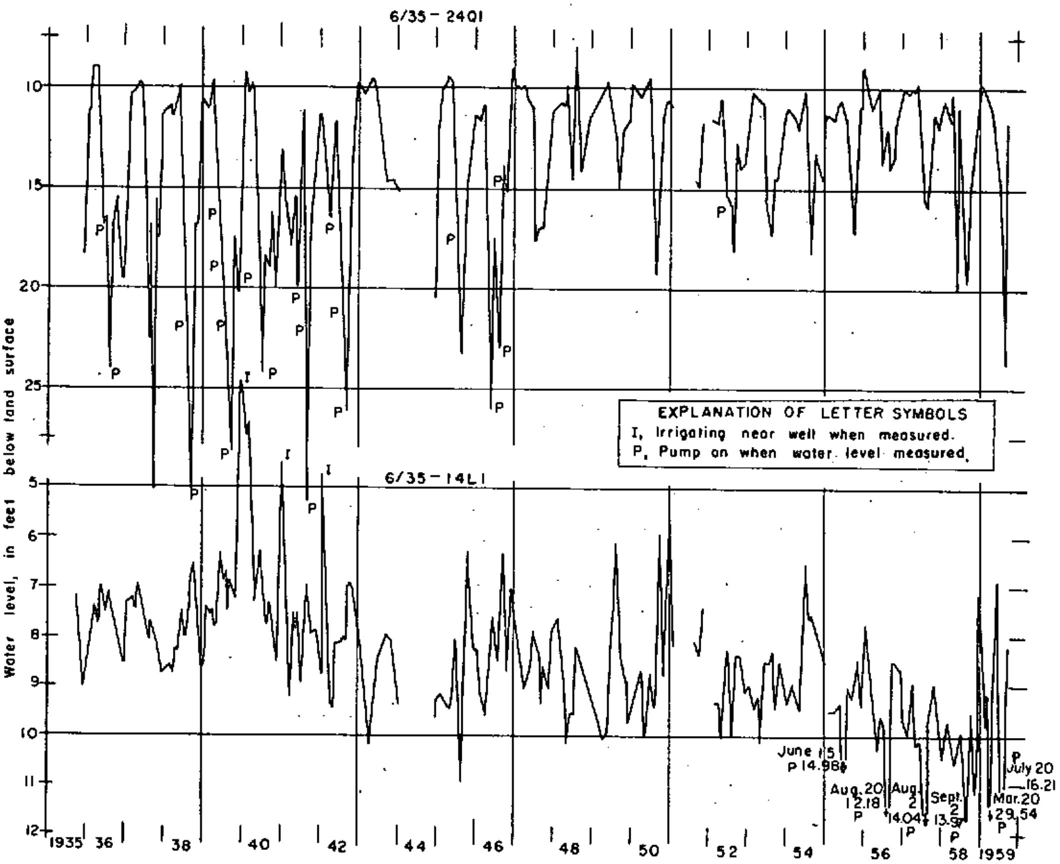

Figure 14. — Water levels in two wells in the gravel aquifer beneath the east central part of the alluvial fan of the Walla Walla River.

Several hundred acre-feet of water for irrigation is diverted each year from Mill Creek above Walla Walla and an estimated average of 60,000 acre-feet is taken from the Walla Walla River, mostly at and just below Milton-Freewater. A large part of that irrigation water, probably half on the average, infiltrates to the ground-water body. Another 20,000 acre-feet of water is diverted by the Burlingame ditch from the river below State Line. It is used for irrigation on the Gardena Terrace; a much smaller percentage of this water infiltrates to the ground water because of the finer grained soils and subsoils of the Gardena Terrace where the irrigation is done.

Waste water, industrial wastes, and sewage water do not make up a large return to the ground water in the gravel. Though it has occurred in the past, return of large amounts of objectionable fluids to the ground water is being diligently avoided. The treated effluent from the Milton-Freewater sewage plants is turned into Dry Creek or used for irrigation on land in Dry Creek valley west of Milton; the fully treated effluent from the Walla Walla sewage plant and some untreated industrial wastes are returned to Mill Creek or used for irrigation below the city. There are many suburban homes using septic tank disposal, and health authorities doubt if the gravel stratum can be used much longer for domestic water supplies in some of the more thickly settled suburban areas.

Transmission.--The ground water moves downslope in the old gravel largely by pressure transfer and also by downgradient percolation along porous and permeable zones of loose gravel. After each separate addition of water, the ground-water level rises nearer the surface; the "rise" progresses outward and down the gradient as a wave. Each transmittal of ground water down the comparatively steep hydraulic gradient shows as a wave in the water table. Within each year the largest of these waves beneath the Walla Walla River's alluvial fan are commonly as much as 20 to 30 feet high. Across the slope of the water table above the upper spring zone (see pl. 1), the gravel newly saturated by each main annual ground-water wave has a width of about 4½ miles and an average thickness of about 20 feet. The waves in the water table spread out from beneath the streams during periods of great streamflow and move downgradient at an average rate estimated to be about a mile per week. Downgradient about three miles from the main points of recharge, the large waves still show on the records of water level in the wells, but, beyond about two miles, much of the individuality of each wave is obscured and only the seasonal high ground-water levels attest to the period of great recharge which had occurred along the streams farther upslope.

Under the natural and irrigation recharging of the 1930's and 1940's about 50,000 acre-feet of water passed through the gravel unit and flowed from the outlets during the average water year (year ending on Sept. 30). Water diverted by pumping from wells has modified this formerly normal discharge as have changes in the recharge resulting from irrigation and other water regulation practices.

Downvalley from the outer spring zone of the Walla Walla River alluvial fan, the ground water--especially that within the isolated tongues of gravel within the old clay--is in a less transient condition. There, as shown by observations in wells 6/35-4B1 and 6/34-3M1, the ground-water level remains more nearly constant through the year.

Beneath the Mill Creek fan, the comparable gravel section newly saturated by each annual main wave of transmission has a width of 2½ miles (between Shelton and Butcher Springs shown on pl. 1 and table 4) and a height of 2 to 10 feet. It is estimated that not more than 6,000 or 7,000 acre-feet of ground water was transmitted down the Mill Creek alluvial fan section during each of the recent years. The smaller ground-water transmission of the Mill Creek fan, as compared to the Walla Walla River fan, is also illustrated by the fewer wells and springs of large yield. The main conduits of the shallow ground water seem to be in the form of a composite of smaller and shorter subsurface courses that are of lower permeability than those beneath the alluvial fan of the Walla Walla River.

Discharge.--The ground water in the old gravel beneath the Mill Creek fan discharges mainly to two spring zones, known as the inner (upper) and the outer (lower) spring zones. The inner zone extends southward from Butcher Springs to Shelton Springs (table 4. pl. 1) in the eastern part of Walla Walla. The inner spring zone contains the springs which feed Shelton, Yellowhawk, Stone, and the other creeks that drain through the southeastern part of Walla Walla. The outer zone includes the springs in the western part of Walla Walla and in College Place.

From beneath the Walla Walla River fan the ground water emerges in springs, most of which lie within two belts known as the inner and outer spring zones. Other springs lie outside or between these zones, and some ground-water discharge occurs undistinquished in stream channels. These main spring zones arc across the surface of the fan (pl. 1). Study of the lithologic continuity of the old gravel as recorded in drillers' logs (table 2) indicates that outwardly descreases in the permeability and in the thickness of the gravel stratum may determine the amount of water that can be transmitted at a given gradient (water level) and thus cause the average water table to intersect the surface at these two principal levels. The fact that the upper end of the fine-grained terrace-forming deposits, such as the Touchet beds, overlie the gravel downvalley from the inner spring zone is probably only a result or a coincidence, but it may indicate that the mantle of fine-grained deposits--overlying the gravel downgrade from that level--is a factor in bringing the shallow ground water out at the level of the inner spring zone.

On both the Walla Walla and Mill Creek fans the location of the principal spring orifices has remained fairly stable in recent years. However, at times of high water table, other low places, normally dry, become spring orifices and some of the established spring zones become widespread bogs lacking distinctive orifices. Likewise, during periods of low levels of the water table, flow from some springs diminishes and even stops.

Form of the water table in the old gravel.--Upgrade above both Milton and Walla Walla, ground water fills to stream level the pore spaces of the gravel deposits that underlie the alluviated parts of the stream canyons. Downstream to and beyond Milton and Walla Walla, the water table lies close beneath the surface of the two main alluvial fans. The main body of shallow ground water occupies the gravel beneath the fans which trend into the valley floor at right angles, coalesce in the Walla Walla-College Place district, and terminate irregularly in the valley floor a short distance downvalley. Also, the ground water fills to stream level the smaller gravel bodies associated with Russell, Cottonwood, Reser, and other tributary creeks originating in the Blue Mountains slope. The lower limit of the ground-water body in the gravel is the base of the gravel where it overlies the basalt in the mountain canyons and in the upper parts of the valley and overlies the old clay farther downvalley. At places in the canyons and the upper parts of the alluvial fans, the ground water in the gravel is in contact with the ground water in the basalt and there is considerable interplay of water, but at other places the water in the gravel is perched above the basalt and there is little connection.

Farther downvalley the basalt passes beneath the old clay which forms the base of the ground water in the old gravel beneath the main part of the valley. The upper edge of the old clay lies at depth beneath the valley floor in an arc passing about through Prospect Point and Freewater. In the lower part of the main valley area the clay zone separates the ground water in the overlying, and interfingering, gravel from the ground water in the underlying basalt.

From the upvalley end of the old clay downslope as far as an irregular terminus near longitude 118°30' west, the ground water in the old gravel extends laterally under essentially all the valley floor. Vertically, this ground water in the old gravel extends upward from the top of the old clay to the level of the streams (pl. 3A and 3 B). In places downvalley from College Place and Umapine the thinner and less widespread continuation of the old gravel is overlain by later deposits, particularly the Touchet beds, up to a maximum of about 100 feet thick. These younger deposits lie mostly above the water table.

Thus, the shape of the ground-water body in the old gravel is that of a flat stratum whose top is largely parallel to the lowest of the valley plains and whose base is 20 to 300 feet lower on the top of the underlying old clay or basalt bedrock. In the approximately 90 square miles of its occurrence the gravel aquifer may be estimated to have a saturated thickness of about 100 feet and to have an average effective porosity of 5 percent. This would indicate storage space is occupied by at least 250,000 acre-feet of water in the gravel.

A basis for an estimate of recharge is given by the water-level records during the last 30 years, the measurements of spring discharge, the estimates previously compiled for some types of recharge, and the estimates and measurements of the water withdrawn. From these factors an estimate of about 75,000 acre-feet of water may be deduced for the average annual recharge to the old gravel of the Walla Walla Valley during the period 1933-1960.

Hydraulic condition of the ground water.--The water in the old gravel occurs under unconfined or water-table conditions, with exceptions in a few places. Near the upvalley edge of the old clay, where gravel beds tongue into it, there is some ground water under confinement (artesian pressure) in the gravel tongues interfingered with the old clay. Such water in the gravel, under sufficient pressure to flow, was found in wells along the Walla Walla River near the State boundary (wells 6/35-12N1, -12P2, and -13H1). Likewise, water from some of the old gravel in the Russell Creek and Cottonwood Creek areas is under sufficient confining pressure to flow at the land surface (wells 7/37-31R1 and 6/36-13C2). In these latter places the ground water in the gravel aquifers may have become confined in isolated gravel strips that have been buried beneath later less pervious deposits. In places near the mouths of the mountain canyons, such as downstream from Couse Creek to Freewater and downstream from Tracy to Walla Walla, the ground water in the old gravel stands perched above the piezometric level of the ground water in the underlying basalt, as mentioned above.

Minor Ground-Water Occurrences

Ground Water in the Palouse Formation and Other Loess Deposits

At some places the Palouse Formation, and to a lesser extent the other loess deposits, receive more moisture than they can retain against the pull of gravity. Under these conditions water passes either into, or laterally outward over, the underlying materials. Such an excess of water over the retention capacity of the loess is seen along low places in gentle slopes where the stratum of ground water in the Palouse Formation may reach the surface. Where loess lies on a relatively impervious material, such as the dense centers of some of the flows of the Columbia River Basalt; or, where it is at or below the local drainage level, a small body of ground water may be accumulated. The level of such ground water is subject to marked fluctuation with the annual and periodic rainfall cycles, as well as with the effects of local soil management. Marks on the curbing of well 7/37-6D1, which taps shallow ground water in alluvium, which is reworked material of the Palouse Formation, show that its water level has declined about six feet concurrently with an equally deep erosional entrenchment of the adjacent small branch of Dry Creek.

The small amounts of ground water in the Palouse Formation occur mostly in the uplands and are perched. Many of these perched-water zones crop out at sharp changes in the slope where the top of the basalt bedrock is exposed. These outlets of perched ground water form the small springs developed for farmstead supplies over much of the region underlain by the Palouse Formation.

As is typical with loess deposits, the vertical permeability of the Palouse Formation is greater than its horizontal permeability. This is evident in the soil-moisture, drainage, and sprinkler-irrigation characteristics of the Palouse Formation. It makes the Palouse Formation a relatively efficient collector of small increments to ground water wherever water exceeds the retention capacity of the loess.

Ground Water in the Deposits of the Upper Valley Terraces

Much of the area of the "upper valley terrace deposits" is underlain by old gravel, and the upper valley terrace deposits at many places lie above the level of the ground water. However, beneath the alluvial slopes about Birch and Cottonwood Creeks northeast of Milton-Freewater some of these terrace deposits lie sufficiently low that their gravel and sand members contain small amounts of ground water. Wells 6/36-10J2 and -33B1 are believed to tap ground water in these deposits.

The level of the ground water in these upper valley terrace deposits rises to approximately the level reached by the nearby streams during the wet season and recedes about 5 feet to an annual low point during the fall of each year. The observed water levels indicate that the lows and highs in some of these small ground-water bodies do not occur at the same time as similar levels of the nearby streams.

Ground Water in the Touchet Beds

Beneath the Gardena Terrace and the equivalent terrace northeast of Touchet, the water table is at or near river level. Some of the sand and gravel in which the ground water occurs apparently belongs to the lower part of the Touchet beds and some to part of the downvalley extensions of the old gravel deposit. Farther east there are small amounts of ground water within the Touchet beds; for example, the quicksand reported at 90-110 feet in well 6/34-5F1 is a saturated sand stratum of the Touchet beds. The ground water in this well stands considerably above river level; apparently the ground water drains to the north into the ravine at old Mud Creek School (N½ sec. 5, T. 6 N., R. 34 E.).

The upper part of the Touchet beds is composed mostly of fine-grained materials whose horizontal laminations have a water-shedding or lateral-directing effect that tends to bring water out to the slope surfaces--a characteristic that contrasts with the ease of vertical movement of water in the loess of the Palouse Formation and other loess deposits. Near irrigated areas, the evaporation of this lateral seepage in late summer leaves mineral incrustations on the slopes of knobs and on escarpments of the Touchet beds. In some places these white mineral incrustations give the Touchet beds the appearance of being much more alkali-impregnated than they actually are.

Ground Water in the Recent Alluvium

The bulk of the ground water in Recent materials occurs along streams in the Blue Mountains section of the drainage basin. In the Walla Walla River and Mill Creek canyons the water table in the alluvium is at the level of the streams and its level rises and falls simultaneously with the level of the streams.

The most important ground-water function of the Recent alluvium of the main valley floor seems to be the acceleration of infiltration recharge to the larger aquifers below.

CHEMICAL QUALITY OF THE GROUND WATER

Comprehensive chemical analyses were obtained or made of water samples taken from 27 representative wells and partial analyses were made of water samples from about 140 representative wells and springs. All are listed in tables 1 and 3. The ground water was examined, where possible, for color, odor, sediment, or iron precipitates.

The ground waters of the Walla Walla River basin are of generally excellent chemical quality. With few exceptions, the sources sampled yield water that is low in mineral content, soft to only moderately hard, and free of undesirable concentrations of detrimental elements.

Hardness

The average hardness of water from 72 wells drawing water from the Columbia River Basalt was 66 ppm (parts per million). That hardness is in the low part of the moderately hard designation on the scale given below.

Hardness as CaCo (parts per million)	Degree of Hardness
0- 60	Soft
61-120	Moderately hard
121-180	Hard
181-	Very hard

The hardness of the water is rather uniform within a given locality but differs from place to place and differs slightly with depth. Thus, the hardness of the water from 15 wells in the basalt at College Place ranges from 45 to 62 ppm; from 6 wells in the basalt on Dry Creek below Sudbury it ranges from 90 to 130 ppm; and from 5 wells in the basalt on Russell Creek it ranges from 40 to 65 ppm. Hardness seems to decrease with depth. Three wells exceeding 1,000 feet in depth near the State Line district yield water having a hardness in the range from 25 to 35 ppm. Of 14 wells in the basalt (table 3), only 1 shows any noncarbonate hardness; the rest have solely the carbonate, or temporary, type of hardness.

The hardness of the water from the old gravel averages 63 ppm for samples from 59 wells. The extreme range of hardness is from 30 to 219 ppm, but most of the wells yield water within the range of 30-95 ppm. The average hardness is equivalent to the designation of moderately hard on the above scale. The fact that the old gravel and the Columbia River Basalt yield ground water of similar chemical qualities is logical in view of the lithology of the gravels--they are composed almost entirely of the basaltic materials.

The ground water from the silt, sand, and gravel beneath the Gardena Terrace is harder (generally having a hardness that ranges from 75 to 200 ppm) than the water in the basalt and the old gravel.

Sodium and Potassium

Sodium and potassium occur dissolved in most ground waters and when their content is small, or is not greatly more than that of the other common chemical bases, their effect on water use is negligible. However, when they are present in excessive quantities they may be detrimental to use of the water for irrigation, industry, and even domestic supply.

The usual means of indicating the relative abundance of sodium in water are by the two criteria called percent sodium and sodium-adsorption ratio.

Percent sodium of a water is the percentage sodium forms in the total of the common bases, all expressed as equivalents per million. In 16 analyses of water from the basalt (table 3), the percent sodium ranged from 12 to 60 and averaged 30; in the 3 analyses from the sedimentary deposits above the basalt, the range was from 11 to 60 and the average was 30. The percent sodium is used along with the dissolved solids and the boron content in appraising the probable suitability of a water for irrigation of alkali-sensitive crops. The content of dissolved solids is approximated by the electrical conductivity (specific conductance) of the water. When the 19 analyses of water are plotted on the usual diagrams (Wilcox, 1948, p. 26) combining percent sodium and electrical conductivity, all fall in the excellent to good category.

The sodium-adsorption ratio is the index most commonly used to show the degree of alkali hazard of an irrigation water. The ratio for a given water sample may be calculated from the formula

$$SAR = \frac{Na^{++}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the cations are expressed in equivalents per million (Richards, 1954). The sodium-adsorption ratios (table 3) computed for the 12 samples of water from the basalt range from 0.3 to 2.3. The sodium-adsorption ratio of one sample from the old gravel near College Place is 0.4 and of one sample from the alluvial deposits at Touchet is 4.2.

In appraising the suitability of water for irrigation, the sodium-adsorption ratio is plotted against the electrical conductivity to determine the salinity and the sodium (alkali) hazards of the water to crops on average soils. When the sodium-adsorption ratios and the specific conductances for 14 analyses are plotted on the standard diagram (Richards, 1954), the 12 samples from the basalt show both a low sodium (alkali) hazard and a low salinity hazard, sample (7/35-33J1) from old gravel shows a low sodium and a low-to-medium salinity hazard, and sample (7/33-34P2) from shallow alluvium at Touchet shows low sodium and high salinity hazards. Apparently, sodium hazards are generally significant only in the ground water in the alluvium and in other near-surface materials beneath the lowest part of the valley. Downvalley from Whitman, the sodium and the salinity hazards, even in this ground water, are generally moderate, but great enough to warrant extensive sampling and analysis before the water is used on some crops.

Chloride

The chloride content of the water from 82 wells in the basalt ranged from 1 to 14 ppm and averaged 5 ppm. The chloride content of water from 63 wells in the old gravel was similar--ranging from 3 to 23 ppm and having an average of 5 ppm.

The water from the Touchet beds beneath the Gardena Terrace south of Touchet and from some of the alluvium beneath the flood plains of the lower valley is relatively high in chloride for this valley but still low as chloride concentrations go some places. Two wells in the Touchet beds yield water that have chloride contents of 11 and 65 ppm, and one in the alluvium yields water that has a chloride content of 17 ppm.

Fluoride

The average fluoride content of the water from the basalt in nine wells situated in the central part of the valley floor is 0.6 ppm. It averages 0.57 and 0.17 ppm, respectively, in four public-supply wells of Walla Walla and three wells of Milton Freewater (table 3). Of the available fluoride determinations on ground water, the lowest figures (0.1, 0.2 and 0.3 part) were for water in wells (5/35-2H1, 7/36-13F1, and 5/35-12L1) that are either comparatively near the edge of the valley lowland or have water of otherwise slightly different quality than the rest of the ground water in the basalt. Water from three wells (7/35-33J1, 7/36-35R1, and 7/37-18G1) in the old gravel contains fluoride in the amounts of 0.2, 0.6, and 0.2 ppm, respectively. The maximum fluoride content analyzed, 1.0 ppm, is near the concentration generally recommended for the optimum effect in prevention of tooth decay, but the average (0.6) is somewhat less than the recommended content for optimum benefits to children's teeth. However, the experience with tooth decay shows that even this average content of fluoride is better than if the fluoride content were zero (Dean, 1942, p. 1176-77). The two cities, Walla Walla and College Place, whose primary domestic water supplies are from Mill Creek and from the basalt respectively--one nearly fluoride-free and the other containing approximately 0.5 ppm of fluoride--might furnish contrasting backgrounds for study of the relative rates at which dental caries afflict children who live in otherwise similar environmental and nutritional circumstances.

Other Constituents

Ground water from the basalt and from the old gravel generally has an iron content of only a few hundredths of a part per million. The maximum iron content determined in this study (see table 3) was 0.17 ppm, a concentration that generally is not troublesome.

In places, the ground water at depth within the basalt has a faint sulfurous odor. The odor seems much more prevalent in new wells. Either the odor decreases with time and pumping or the users become accustomed to it, for the complaints tend to diminish with use. The consensus of well users is that the odor decreases with the pumping of the well. Odor may, in some cases, make it desirable to include aeration in the preparation of supplies for domestic use. The gaseous content is not known to have any detrimental effect; in fact, it has been suggested by some irrigators that any sulfur content would have a beneficial effect.

Adams' description		Location obtained during this work					
No.	Owner	Township and Range	Section	40-acre tract	County	State	Aquifer
5	Dillard York #1	7/35	34	NW¼NW¼	Walla Walla	Washington	Old gravel
11	White Bros.	Indeterminate					
12	Baker & Baker	(?)6/36	9	NE¼SW¼	Walla Walla	Washington	Basalt
13	Dwelly Jones	7/36	25	SE¼NW¼	Walla Walla	Washington	Old gravel
21	Dillard York #3	7/35	34	SE¼NW¼	Walla Walla	Washington	Old gravel
24	Lawrence McBride #1	6/35	20	NE¼NW¼	Umatilla	Oregon	Old gravel
25	Ed Seeholt (Czyhold)	6/35	15	NE¼NE¼	Walla Walla	Washington	Old gravel
29	Grant York	(?)5/35	4	NE¼NE¼	Walla Walla	Washington	Old gravel
31	Miller Bros.,	(?)6/34	1	NE¼NW¼	Walla Walla	Washington	Old gravel
34	Hubbs (nursery)	6/35	25	NE¼NW¼	Umatilla	Oregon	Old gravel
35	Edwards	6/35	29	NE¼NE¼	Umatilla	Oregon	Old gravel
36	Gibbons	(?)6/35	18	SE¼SE¼	Umatilla	Oregon	Old gravel
40	D. York #1	7/35	34	NW¼NW¼	Walla Walla	Washington	Old gravel
41	D. York #2	7/35	34	SW¼NW¼	Walla Walla	Washington	Old gravel
77	L. McBride #2	6/35	18	NE¼SE¼	Umatilla	Oregon	Old gravel
85	E. Key #3	5/35	5	NE¼NW¼	Umatilla	Oregon	Basalt
86	E. Key #4	6/34	36	NW¼SE¼	Umatilla	Oregon	Basalt
87	E. Key #2	6/34	36	SW¼SE¼	Umatilla	Oregon	Basalt
88	E. Key #1	6/34	36	SW¼SW¼	Umatilla	Oregon	Basalt
125	Archie Harris #2	6/33	23	NW¼NE¼	Umatilla	Oregon	Basalt
140	Well #1, Walla Walla	7/36	13	SE¼NW¼	Walla Walla	Washington	Basalt
142	Well #4, Walla Walla	7/36	22	SW¼SW¼	Walla Walla	Washington	Basalt
273	Dillard York #2	7/35	34	SW¼NW¼	Walla Walla	Washington	Old gravel
275	V. Weitz	7/35	23	NW¼SW¼	Walla Walla	Washington	Old gravel
276	W. W. College Farm	7/33	33	SE¼NE¼	Walla Walla	Washington	Basalt

Adams' description		Location obtained during this work					
No.	Owner	Township and Range	Section	40-acre tract	County	State	Aquifer
277	J. Harding	7/35	33	NE¼NE¼	Walla Walla	Washington	Old gravel
278	E. Burlingame	6/33	14	SW¼SE¼	Umatilla	Oregon	Old gravel
279	O. Helberg	(?)6/34	14	NE¼SW¼	Umatilla	Oregon	Old gravel
280	White Bros. (at house)	6/34	20	SW¼NW¼	Umatilla	Oregon	Old gravel
281	White Bros. (NE house)	6/34	20	SE¼NW¼	Umatilla	Oregon	Old gravel
282	White Bros. (W house)	6/34	20	SW¼NW¼	Umatilla	Oregon	Old gravel

Boron in very small amounts in the soil or water is essential to the growth of many crops, but in slightly greater amounts it may be detrimental or even injurious. Water with boron concentrations of less than 0.33 ppm is considered excellent for the sensitive plants and water with more than 3.75 ppm is regarded as unsuitable even for the boron-tolerant plants. Two water samples from the basalt in the Walla Walla River basin had 0.07 ppm (well 5/35-12F2) and 0.04 ppm (well 7/37-18F1) boron. (See analyses in table 3.) From these determinations and from the general lack of boron in the normal-temperature ground waters of the Columbia River Basalt of this region, boron is believed present in the ground water in only negligible or beneficial amounts.

Other Published Data on Water Quality

The only other group of analyses of water from wells in the Walla Walla River basin is contained in the lists of Adams (1957). Because Adams did not specifically locate his sources, a tabulation is given on page 52 to show the location and the aquifer source of the ground-water samples for which he lists analyses, as these sources were reestablished by the writer.

Temperature of the Ground Water

In the Columbia River Basalt

The measured temperatures of the ground water, compared with the earth temperature normally to be expected in the zone reported as the main basalt aquifer of the respective wells, are listed on the following pages.

Ground water having a temperature lower than the assumed normal earth temperature is found in wells about the edges of the valley--at Milton, Weston, Pine Creek, and on Russell Creek above Maxson School. The low temperatures found in those wells suggest that recharge with cold surface waters is probably taking place nearby and the water does not become completely warmed before being withdrawn.

Most of the wells in which the ground water is warmer than normal are in a strip that extends northeastward toward Walla Walla from about the State Line crossing of the Walla Walla River, but some also are located near College Place. The ground water may pass through a warmer zone of basalt that extends northeastward past the southeast corner of Walla Walla. The warmest water is from a flowing artesian well (7/37-31R1) that may tap ground water near a fault zone or water that has circulated more deeply than that tapped by most wells.

Besides the above two general exceptions to the normal temperatures of the ground water, some of the deep wells, such as 6/36-9P1, 6/36-31L1, and 7/36-31J1, obtain cooler water than might be expected, while others, such as 7/36-19R1, obtain water whose temperature agrees with the assumed earth gradient. Overall, the ground water from the basalt in depth seems to be a few degrees warmer than would be expected from a normal earth-temperature gradient--a fact that may indicate a slightly higher than normal earth-temperature gradient in the basalt.

Well	Water temp (°F)	Expected earth-gradient increase[a]	Observed deviation[b]
4/35-15P1	63[c]	11	None
15P2	70c	20	4-
5/35-2D1	56c	4.5	2-
1E1	55	4	2+
2H1	55	4	2+
6C1	63	5	3+
12F1	61	5	3+
12G1	62c	11	2-
6/33-23B1	72	6	11+
6/34-35D1	63.5c	11	None
6/35-1C1	67	8	6+
1M1	67	11	2.5+
3N1	68	9	5+
4G1	67	13	None
10P1	76	18	4.5+
12H1	71	9	8+
12N1	73	8	11+
13P1	62	5	4+
33J1	64c	6	5+
34P3	62.5c	5	4+
6/36-5G3	58	5	None
5M1	70.5	8	9+
5R2	81	17	11+
6M1	71.5	8	10+
7D1	72c	9	10+
9L1	71.5	16	None
9P1	74	33	12-
31L1	77	32	8-
6/37-4B1	54.5c	2	None
5F1	54	9	8-
7/33-32M1	65	3	8+
33N1	60	4	2.5+
34N2	67	3	10+
7/34-25N1	68	16	None
7/35-4H1	58	1	4+
23M1	68	7	7+
25F1	68c	10	4+
25G2	68	10	4+
25N1	67	8	6+
25P1	69	9	6+

Well	Water temp (°F)	Expected earth-gradient increase a/	Observed deviation b/
7/35-26Q1	67	8	6+
35A1	68c	9	5+
36C1	69	9	7+
36F1	68c	9	6+
36F2	70c	9	7+
36F3	69c	11	4+
36R1	70	7	9+
7/36-19F1	76	16	6+
19R1	82c	27	None
22N1	61	5	3+
31J1	70c	21	4-
31N1	68c	9	6+
35D1	62c	2	7+
36J2	62c	6	2.5+
7/37-18F1	59	6	None

a/ Normal earth gradient is taken as 1.8°F for each hundred feet of depth beyond the first 100 feet below the surface. Ordinarily the temperature of ground water in the 10- to 100-foot zone should approximate the mean annual air temperature, which is 53.5°F at Walla Walla.

b/ Observed deviation less than (−), and more than (+), assumed normal earth gradient temperature. The word "none" means variation less than 2 degrees from normal earth gradient, as nearly as can be determined.

c/ Depth of aquifers not reported. Total depth of well used in calculation.

In the Old Gravel

The temperature of the ground water in the old gravel agrees generally with the mean annual temperature plus the assumed normal earth gradient for the depth of the aquifer. The temperature of the water in the upper 50 feet is generally 54°F and that at 200 feet is about 57°F. Some observed temperatures of the ground water of the old gravel are listed below:

Well	Depth (feet)	Aquifer (in feet below land surface)	Water temp (°F)	Normal earth gradient	Date water temp measured	Observed deviation [a]
6/35-4Q1	107	20-63	54.5	53.5	7-15-48	
15A1	42	20-36	52.5	53.5	7-16-48	
15B1	60	9-60	54.5	53.5	7-15-48	
15P1	130	0-130	53	54	7-19-48	
19L1	140		52.5	54	7-19-48	2.5-
19R1	20		53	53.5	7-19-48	
21H1	19		52	53.5	7-19-48	1.5-
22F1	300	175-275	54	55	7-19-48	4-
23M1	12		52	53.5	?	1.5-
24M1	50	9-50	48	53.5	7-16-48	5.5-
25B1	25	0-27	48	53.5	7-23-48	5.5-
25P1	90	0-90	51	53.5	7-23-48	2.5-
26Q1	64	18-64	56	53.5	7-23-48	2.5+
27B1	220		52	55	7-21-48	3-
27H1	56	0-34	51	53.5	7-21-48	2.5-
27Q1	73	19-73	54.5	53.5	7-21-48	
28R1	200		55	55	7-20-48	
29B1	29		56	53.5	7-20-48	2.5+
29K1	35		52.5	53.5	7-20-48	1.5-
33M1	81		54.5	53.5	7-20-48	
34C1	54		54	53.5	5-6-33	
34P1	34		56	53.5	7-20-48	2.5+
34R2	35		55	53.5	7-21-48	
7/35-33J2	85	15-85	56	53.5	10-29-59	2.5+
7/36-19H1	216	0-9	56	55	5- -33	
7/37-31R1	220		58	55	10-19-46	3+

[a] Water temperature less than (−) and more than (+) assumed normal earth gradient temperature.

The gravel wells, whose water temperature deviation is greater than 1°F, are mostly cold-water wells and are located principally in the area north of Freewater. Upvalley from and within that district there is much irrigation and natural recharge of the ground water with cool water from the Walla Walla River. It seems probable that this cooler ground water is the recently recharged water which has not yet become heated to normal ground temperature.

USE OF THE GROUND WATER

Types of Use

At least a roughly derived figure for the quantity of the ground water withdrawn was obtained from most of the users. From those reports, some measurements, and some projected estimates, an approximation was made on the total ground-water withdrawals for an average year in the period 1948-60. Domestic, public-supply, irrigation, and food processing purposes are the most common and wide-spread uses for which the ground water is withdrawn.

Irrigation

Ground water drawn or flowing from the old gravel of Pleistocene age in the Milton-Freewater and State Line areas, and, to a lesser extent, in the Walla Walla and College Place areas, provides a principal supply for irrigation. On the Walla Walla River alluvial fan from Milton to Umapine, wells in the old gravel are present on an average of one for each 40-acre tract. They furnish supplemental or primary water supply to about half the land irrigated. In addition, an average of about 50,000 acre-feet (Piper et al, 1935, p. 132A) of water flows from the springs in the inner and outer spring zones of that alluvial fan. Practically all the spring flow during the period May through September each year, or 60 percent of the annual flow from these springs, is used for irrigation. Thus, on the Walla Walla River alluvial plain, approximately 30,000 acre-feet of spring water and about 10,000 acre-feet of well water is derived mainly from the old gravel.

On the Mill Creek alluvial plain about 1,000 acre-feet of ground water is taken from the old gravel in the area above Walla Walla; about 1,500 acre-feet is taken from springs, and 2,500 acre-feet from wells--in the area downstream from Walla Walla to Whitman. For irrigation west of Whitman about 1,500 acre-feet of ground water is taken from the alluvium and from permeable beds that may be equivalent to the old gravel.

Other than on the Mill Creek and Walla Walla River alluvial fans and in the Umapine-Gardena area, the ground water from the old gravel aquifer is little used for irrigation. Thus, the total irrigation use of water from the old gravel is in the order of 45,000 acre-feet per year in the Walla Walla River valley.

From the Columbia River Basalt, the water used for irrigation is derived from wells clustered around College Place and others distributed around the margins of the valley plain near Weston, Milton-Freewater, Maxson School, Walla Walla Air Force Base, and Whitman. Near Weston, wells supply about 200 acre-feet of water for irrigation. In the Milton-Freewater district, the wells numbered 6/35-34P3, 33J1, and -J2, and 5/35-2D1 withdraw about 100 acre-feet of ground water for irrigation each year. Farther north, wells 6/35-23C1 and 10P1 furnish about 200 acre-feet of water, though the latter, the old Jaussand well, is capable of much greater yield. Eight wells in the Dry Creek-Pine Creek area southwest of Umapine supply about 1,000 acre-feet of water per year. In the Maxson School and Cottonwood Creek districts, the three Baker wells and the Reser and other wells are drawn upon for a total of about 1,000 acre-feet and the strongly flowing "Sweazy Quarter" well (6/37-5F1) for about 500 acre-feet. Near the Air Force Base in Mill Creek valley, two wells supply 200 acre-feet of water most years. Near Whitman, the Charles Baker well and Bergevin wells are drawn upon for 300 acre-feet of water per year, and several wells near Lowden and on Dry Creek obtain about 300 acre-feet of water.

Most of the remainder of the irrigation water drawn from the Columbia River Basalt comes from 30 wells near College Place. During 1958, about 2,000 acre-feet of ground water from the basalt was being applied to 1,200 acres in the College Place district. Thus, a total of about 5,600 acre-feet of ground water was being drawn for irrigation annually from wells in the Columbia River Basalt during 1958 and 1959.

The crops grown are mainly fruits and vegetables, grain, hay and forage, peas, and sugar beets. The farms in the Freewater district use an especially diversified crop plan, with emphasis on crops of early summer maturity like cherries and apricots. The largest farm-irrigation operations in recent years were those using the Baker and Baker wells, 6/36-9L1, 9P1, and 5R2, and the "Sweazy Quarter" well, 6/37-5F1.

Most irrigators use the sprinkler method of water application. With sprinkler application, water, averaging about 2 feet per year for the irrigation of some crops, is spread during about 150 days of the growing season. Management of the water application requires that a minimum of about 5 gallons of water per minute per acre be available throughout the season. The greatest stretching of the available water is done by some farmers who are raising sugar beets on small fields of silty soil with a supply of only 3 gallons of water per minute per acre. However, most authorities in agronomy advise that a capacity of 7 to 8 gpm per acre is necessary for most crops on average soils. Particularly is this greater capacity, or even one as great as 10 gpm per acre, advisable on crops like alfalfa that draw heavily on their water supply during certain periods of exceptionally rapid growth. Also, irrigation specialists advise that the total annual water requirement for full irrigation of most crops during the average growing season on the average loam soil is 3 feet.

Public Supply

Of the incorporated communities, Walla Walla and Milton-Freewater use wells for standby supply during periods of excess turbidity or of low streamflow in Mill Creek and the Walla Walla River, their primary supplies. The College Place Water Company obtains its supply from 2 wells, and Weston uses spring water augmented by a well supply. Several suburban public-supply districts near College

Place operate wells, most of which are used for both public supply and irrigation. Nearly all the ground water, both from the wells and from the Weston springs, is derived from the basalt. Other, smaller communities do not have central municipal water systems but are supplied by private installations that utilize springs or wells.

The water withdrawn for public supply by the largest systems during 1957, 1958, and 1959 is tabulated below from information supplied by the water departments of those cities:

	Wells in use	1957	1958	1959
Walla Walla	4 and 5	554	400	467
Milton-Freewater	6	1,126	1,099	1,098
College Place	2	165	182	164
Suburban public-supply districts near College Place (estimated)	8±	200	200	200
Total, million gallons		2,045	1,881	1,929
Total, acre-feet		6,280	5,560	5,920

Weston annually uses about 100 acre-feet of spring water and an additional 50 acre-feet of water is pumped from a well during the summer months of the year.

The U.S. Veterans Administration Hospital at Walla Walla, the State Penitentiary, and the Walla Walla College at College Place are the principal institutions using ground water for institutional supply. The hospital annually withdraws about 200 acre-feet of ground water, about three-fourths of which is from the old gravel of Pleistocene age and the remainder from the basalt. The college well annually takes from the basalt an estimated 150 acre-feet of water for domestic supply in addition to the approximately 100 acre-feet that the well furnished for irrigation. The State Penitentiary used three basalt wells for water supply in addition to the water received through its connection with the Walla Walla city distribution net. About 200 acre-feet of water is estimated as the average annual withdrawal from the three wells.

Thus, for public supply purposes during the years 1957 to 1959, an annual average of about 6,370 acre-feet of ground water was taken from the basalt wells, 100 acre-feet from springs, and 150 acre-feet from wells in gravel aquifers.

Domestic Supply

Outside the incorporated cities and towns the household water is almost entirely from wells and springs. Most suburban houses have an individual domestic supply, though some are connected to the municipal systems. It is estimated, on the basis of visits to many of these domestic installations, that a total of about 1,800 individual domestic systems using ground water are in use to furnish the private domestic water supply in the Walla Walla River basin. Of those domestic sources, about 1,600 are wells and 200 springs. There is only a small difference between shallow wells and springs in some of the spring-zone areas of the valley plain--in some cases the difference is only a matter of the current position of the water table, which varies greatly during any one year and differs some between wet and dry years.

Of the wells, about 1,350 obtain ground water from the old gravel and the hydraulically continuous Recent alluvium, 180 from the basalt, and 70 from other water-bearing materials, such as the lower part of the Touchet beds, the Palouse Formation, and the deposits of the upper valley terraces. An estimated total of about 1,000 acre-feet of ground water is used for domestic purposes in the Walla Walla Valley, divided about equally between the two states. Of this total, about 830 acre-feet of ground water is extracted from the old gravel, 130 acre-feet from the basalt, and 40 acre-feet from the various other water-bearing materials.

Industry

Food canning and processing plants, particularly pea canneries, are by far the largest industrial users of ground water in the Walla Walla River basin. Very minor users include creameries, hatcheries, fruit-boxing plants, railroads, electric-power stations, and lumber-processing plants.

The canning companies pump large quantities of water during the summer packing season. The nine cannery wells in 1958 and 1959 withdrew from the basalt a total of about 2,200 acre-feet of water. This withdrawal supplemented the water they obtained from the public-supply systems. The combined annual total withdrawal of the other minor industries using ground water is not over 200 acre-feet--all but a small part of which comes from the basalt. Most of the industrial processing water is released to private conduits or to the surface streams after treatment and is reused for irrigation.

Annual Use of Ground Water

The annual use made of the ground water in 1958 and 1959, with its aquifer origin, is as follows:

	Old gravel (acre-feet)	Basalt (acre-feet)	Total (acre-feet)
Irrigation	46,500	5,800	52,300
Public supply	150	6,570	6,720
Domestic supply	870	130	1,000
Industrial	100	2,300	2,400
Totals	47,620	14,800	62,420

Of the acre-feet of water used from the old gravel, 40,000 is in Oregon and 7,620 in Washington; and from the basalt, 7,000 acre-feet of water is in Oregon and 8,800 is in Washington.

DEVELOPMENT OF THE GROUND WATER

"Shallow" Ground Water of the Old Gravel

History of Development

The early settlers found the springs and spring-fed creeks of the alluvial plains readily adaptable to diversion for irrigation. This period was mainly concerned with use of the spring flows and development of the ground water by shallow wells.

Household wells were dug and, as techniques of well construction were perfected, a number of infiltration galleries of tile and wooden conduits were laid in deep trenches and led downslope to bring the ground water out at the surface level without pumping. Walla Walla used an infiltration gallery system for municipal supply in 1897; it was located near Mill Creek above the town. After the increasing density of the nearby settlement made these local shallow ground waters difficult to protect from pollution, the main cities, Walla Walla and Milton, constructed conduits to stream sources farther upvalley.

As demand increased for more irrigation water and for irrigation of dry lands higher upon, and around, the alluvial fan, large ditch diversions were made at the apex of the alluvial cone at Milton. The discharge of the springs of the inner and outer spring zones increased greatly after the enlargement of the irrigated acreage on the upper part of the alluvial fan. Subsequently, the unused part of this discharge from springs and other excess water was diverted to the lower part of the valley by the Burlingame Ditch (pl. 1).

About the time of World War I, dug wells, a type that previously had been used mainly for domestic and stock-watering purposes, were put into irrigation service with centrifugal pumps. That system of well construction and pumping of ground water from the old gravel remained dominant until World War II. The recent period of development has resulted in the drilling to greater depth within many of the old dug wells, a practice that has not produced much additional water from some wells, and in the drilling of many new wells for irrigation on the terrace lands downvalley from Freewater and College Place. Many wells were drilled for suburban homes. In recent years some irrigation wells, such as 6/34-13A1 and 14G1, have been drilled into the downvalley extensions of the old gravel in the Whitman and Umapine districts; also, the ground water in the extension of the old gravel beneath the Gardena Terrace has been extensively developed.

Future Developments of Ground Water in the Old Gravel

The tracts of good soil underlain by the old gravel in the Milton-Freewater-to-State Line and Walla Walla-College Place districts are now partly irrigated by a system of combined surface water and ground water, the principal supplies being obtained from the Walla Walla River and Mill Creek. Because of the shortage of surface water, much of the land does not receive a full irrigation in the latter part of the growing season.

Monthly measurements made in 1942 and 1943 showed total annual discharge of the springs on the alluvial fan of the Walla Walla River to be about 50,000 acre-feet, as it was in 1933. The less frequent measurements since 1943 do not permit comparison of total annual discharge as of 1960. There is some evidence that the total annual discharge from the springs on the alluvial fan of the Walla Walla River has decreased progressively during the period 1950-60. All spring discharge is used in the growing season by holders of water rights downstream. Some holders of water rights to spring outflow find the springs no longer yield the amount of water they did 10 and 20 years ago.

Some preliminary plans have sought means to augment or prolong the early summer high level of the ground water in the old gravel. Such plans, to have practical effect, must take into account (1) the rapidity with which the ground-water level declines after its annual crest passes and (2) the large volume of river flow or artificial recharge necessary to produce great infiltration to the ground water. Some initial tests at artificially recharging the gravel aquifers by placing excess surface water into gravel pits and onto unused gravelly fields have reportedly helped raise temporarily the water level in wells of their vicinities. A comprehensive plan for the systematic management of the old gravel as a water reservoir is an obvious need that will surely come about ultimately. Such a comprehensive plan and systematic management will need to include all phases of natural and artificial recharge in order to obtain the maximum benefits from this important natural water-storage facility.

There is some feeling by many water users that the future will see a different type of water management for the water-storage space in the old gravel. Those making this prediction note the gradual and progressive change from the former use of the gravel as a full reservoir, from which only the overflow from the springs was used. They contend that the progressively greater pump withdrawal from wells in the summer has obtained full-season water and utilized "dead" storage space of the entire gravel stratum with bonus benefits from increased recharge opportunity, the salvage of winter runoff, and other advantages. There is little doubt that this type of transition has come about progressively. In the long run, the amount of water that can be gotten underground to sustain the summer draft may be the critical factor that determines the optimum utility of the old gravel as a reservoir.

Protection and increase of the water resources of the old gravel are vital to the established economy of the Walla Walla Valley. Actions that might permanently decrease the natural infiltration recharge from the surface or the artificial recharge by irrigation and other means may be detrimental to full use of this water-storage resource.

As is amply shown by the water-level graphs previously discussed, the greatest infiltration of water from the Walla Walla River and Mill Creek occurs during and just after their highest rates of runoff. This type of peak recharge to the ground water is commonly attributed to the cleaning and scouring of the channel and the greater height, hence greater pressure downward, of the river during its periods of greatest runoff. Artificial changes in stream regimen, such as some types of storage in upstream impoundments or alterations in channel-scour and water-depth situations, can diminish the infiltration to recharge the ground water. Consequently, any such plans for changes in river regimen could well be required to provide for compensatory recharge or to sustain counter charges for their diminution of natural recharge and storage.

The vulnerability of this ground water to contamination by noxious wastes is an ever-present threat. The prevention of such contamination should be aided by the public's constant appreciation of the value of the resource provided by the water which uses this ground route on its way down the valley.

Future Development of Other Shallow-Zone Ground-Water Bodies

In the lower central part of the Walla Walla Valley, some gravel aquifers occur beneath the Gardena Terrace and its extensions. The ground water in these gravels may, in the future, support a slightly larger withdrawal. Beneath the area south of Gardena School sand and gravel aquifers occur in places. Until recent years they have been used solely for domestic and stock purposes. By 1950, the records of wells showed enough permeable material had been encountered in wells like 6/33-10J1 and 11H1, respectively 1 mile southeast and 2 miles east of Gardena School, to warrant test wells for supplemental irrigation water. Since then, about a dozen irrigation wells have been constructed having average yields of about 800 gpm from the gravel aquifer.

Beneath the isolated segments of the Gardena Terrace north of the Walla Walla River a 20-foot-thick horizontal sand aquifer has long supplied each year a few hundred acre-feet of ground water for irrigation (wells 7/33-35C1, C2, E1, and others). So far the water levels in that aquifer have not been drawn down and the aquifer seems capable of sustaining some additional withdrawal by properly constructed and managed wells. Quantitative studies of this aquifer may be required to determine actual amounts of water available perennially. Such careful inventory of the storage capacity of the shallow aquifers will become the normal order of water management as the optimum withdrawal of ground water is progressively approached.

Ground Water in the Columbia River Basalt

History of Development

During the earliest period of development, prior to 1900, some ranches on the flanks of the Walla Walla Valley were equipped with wells in the basalt for domestic and stock water.

The well (7/35-26Q1) that resulted in the discovery of flowing artesian[1] conditions in the College Place district was drilled in 1903 on the Blalock place, apparently in response to Russell's (1897, p. 85) suggestion of the possibility of artesian conditions in the valley. During the ensuing 20 years about 30 wells were drilled for flowing artesian water in that vicinity. Well 7/36-36H1 is reported by the driller, A. A. Durand, to have had a pressure of 60 pounds per square inch at the surface when drilled in 1910. It was early determined that wells northwest of

[1] The reader may note that hydrologists in general, as well as those of the Geological Survey, use the work "artesian" to mean any confined ground water whether or not its level stands above the surface. Some dictionaries define artesian water as ground water that flows at the surface.

a certain line (herein called the "College Place flexure" and located on pl. 1. Also, on pl. 2, see line of sharp bedrock rise running east-northeast through the northern part of College Place) did not yield flowing artesian water. Most of the wells drilled in that area of non-flowing artesian water were abandoned or destroyed because the water did not flow from them. Of these, only the Ganni well (7/35-26P1) was found during this investigation. Farther west, well 7/34-29C1 at Lowden and well 7/35-8A1 on Dry Creek were left unused because the water failed to flow at the surface.

During the years 1920 to 1940 a few wells were drilled to obtain water from the basalt and some of those for municipal or industrial supply were equipped with deep-well turbine pumps (fig. 15). Many of the originally flowing artesian wells were equipped with centrifugal pumps to augment their lessened flow. Except for the water from the flowing or near-flowing artesian wells in the College Place vicinity, little or no ground water from the basalt was being used for irrigation.

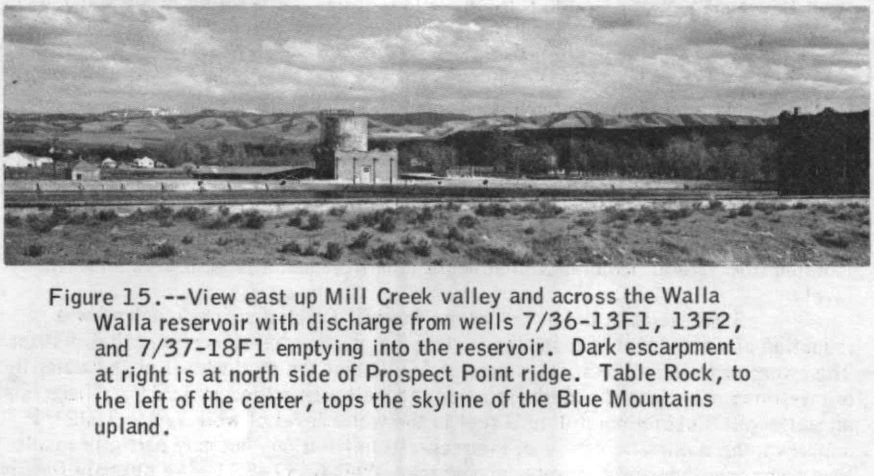

Figure 15.--View east up Mill Creek valley and across the Walla Walla reservoir with discharge from wells 7/36-13F1, 13F2, and 7/37-18F1 emptying into the reservoir. Dark escarpment at right is at north side of Prospect Point ridge. Table Rock, to the left of the center, tops the skyline of the Blue Mountains upland.

The advent of the pea-canning industry during the decade of the 1930's necessitated the drilling of a few wells into the basalt. The increase in population and the industrial activity during and just after World War II brought about the drilling of additional public-supply wells at Walla Walla, College Place, and Milton-Freewater.

Nature and Extent of Present Ground-Water Development

As shown by the records of water levels in the wells, the withdrawals of ground water from the basalt do not approach the total amount of water that each year naturally recharges and reaches the basalt below the valley floor. Locally, close-spaced wells, as in the College Place and Milton areas, interfere by drawing down their mutual water level. Also, one area of persistent decline of the water level exists east of Walla Walla, but the basinwide situation shows an annual excess of recharge over pumped withdrawal from the basalt.

So far, the withdrawal of water from wells has not resulted in the water level of unpumped wells being drawn down beyond a general level about 50 feet below the surface during the summer in the College Place district, where the water level is normally at or near the surface. Also, it has not resulted in the water level being drawn generally more than 160 feet below the surface in the Milton district, where the water level was originally about 100 feet below the surface.

The water level in the Whitman Hotel well in Walla Walla declines a few feet each year about when the heavy pumping is begun from the large cannery wells (7/36-19F1 and 19R1) (see fig. 9), but the few pumping wells in the basalt at Walla Walla apparently produce a drawdown in only that locality. The three Walla Walla City wells in Mill Creek valley (7/37-18F1 and 7/36-13F1 and F2) along with several other basalt wells in that area have drawn the water level down about 40 feet during the period 1950-60. That area of the basalt seems to be partly isolated from lateral percolation that might otherwise maintain a near-natural water level.

Some wells in the basalt of the Russell Creek district do not show a reduction of water level in response to pumping of other basalt wells of that district. The owner of well 7/36-35D1 stated in 1948 that the static level of the water in the well had not changed materially since the well was drilled in 1910. There is an annual cyclic fluctuation of 1 to 2 feet in the water level of well 7/36-36J2. It appears to be a climatic effect on the recharge infiltration, but may partially result from summer withdrawals of water elsewhere. Well 6/37-5F1, the strongly flowing "Sweazy Quarter well," has an unusually stable static water level. It stands at about 75 pounds (172.5 feet above the surface) at all times--even a few minutes after flowing for several months at the rate of 600 or more gallons per minute. Such behavior indicates that some water source keeps the aquifer full to the overflow point at all times.

The withdrawals from the early wells during the period 1903-20 apparently used nearly as much water as is now taken from the basalt in the College Place area. In effect, those wells drew all the water that the aquifers in the upper part of the basalt could provide when the water level was drawn down to the surface throughout each summer. Judging from the drillers' reports of the original static water levels, that amount of annual water use drew the average static water level down something between 20 and 50 feet throughout College Place. Thus, at this place, we can get an appreciation of one hydrologic characteristic of the top part of the basalt. By 1948, a 30-foot cone of depression in the regional piezometric surface was needed to maintain a supply of 3,000± acre-feet of ground water from the wells scattered through a 2,500-acre area. During the ten-year period 1948-58 the increased pumping had induced an average additional decline of about 15 feet in the water level of the basalt wells in the College Place area.

Measurements of the water level in well 7/35-36H1 just east of College Place show that the water level varies from about 10 feet below the land surface in winter and spring to 30 feet in the late summer and fall--an annual decline that accompanies the summertime withdrawal of about 2,500 acre-feet of water from the basalt in an area 1 to 1½ miles wide arcing around the north, west, and south of this well (36H1). The wintertime pressure level in this well is largely restored by December, 4 months after the cessation of heavy summertime pumping.

The development that has evolved for the ground water in the basalt thus comprises one area of heavy development and overdraft around College Place, one locality of concentrated heavy pumping from one depth zone of the basalt at Milton, a few areas where wells are drawing down their mutual water level, several areas of well-separated and efficiently constructed and operated wells, a number of places that the public seems to consider disproved for ground-water development, and several extensive areas of untested ground-water potential. On a valleywide basis the basalt wells are withdrawing less water than the annual recharge. The technology of artificially recharging the basalt aquifers with excess surface water is just getting started (Price, 1960 and Paul F. Meyer, personal communication).

Construction of Wells in the Basalt

Essentially all the wells in the basalt have been drilled by standard cable tool (churn) drilling. A few have been drilled to shallow depths by rotary machines of the normal mud circulation type, but the rotaries have not been economically competitive with churn drills. One deep diamond drill hole (6/34-22G1) was put down as an "oil and water test."

One water well (7/36-17K1) was drilled to a depth of 3,000 feet, one (6/36-9P1) to 2,061 feet, and about fourteen to more than 1,000 feet. Most of the basalt wells penetrate a few tens of feet below the water level for domestic and stock supplies and from 100 to 1,000 feet for irrigation, industrial, and public water supplies.

The diameter of the early wells was commonly 6-, 7-, 10-, or 12-inch for irrigation wells and 4-, 5-, and 6-inch for domestic water supply. Recent practice utilizes larger and heavier casing pipe--6- and 8-inch for domestic and stock wells and 10- and 20-inch for irrigation, public-supply, and industrial wells.

A drill diameter greater than 12 inches in the water-bearing zones is difficult to justify for wells which are designed to produce 1,000 gpm or less. Greater diameter in the upper, pump-occupied, part of the well is for pump accommodation only and the diameter of this upper part of the well is generally dictated by the specifications of the pump and water-level measuring facilities. The water-bearing parts of the basalt commonly "over break" while being drilled and slough out to a diameter greater than the well bore through the more massive parts of the basalt; this overbreakage can be induced if it does not occur normally. Thus, the effective diameter of the well bore at the water entrance is generally greater, or can be made greater, than the tool-diameter with which the well was drilled. This circumstance accounts for the fact that test wells of 6- or 8-inches diameter have yielded virtually as much water per foot of drawdown as they did after they were reamed to much larger diameter.

The factor of frictional resistance to the flow of water, as it affects the selection of the well diameter, can be stated in part by analogy to water movement in steel pipe of similar size. The frictional resistance which must be overcome in forcing 1,000 gpm through 500 feet of steel pipe is equal to 15 feet of water pressure in a pipe of 8-inch diameter, to 10 feet in one of 10-inch, and 4 feet in one of 12-inch diameter. Though a well bore in basalt presents greater frictional resistance than steel pipe, it is plain from the comparison that the frictional resistance, expressed as increased pumping lift for water entering the well 500 feet below the pump, is only a foot or so more for 1,000 gpm rising in a 12-inch than in a 16- or 18-inch well bore.

The wells are commonly cased to, or slightly into, the bedrock and left open-wall in the basalt, except for caving interbeds or fractured zones in the basalt. In these unstable parts of the wells, liner sections or the complete extension of casing from the surface may be required. Only one well (penetrating the fault-sheared rock in the roadside park at the Wallula highway junction, outside the primary area covered by this report) is known to have required casing support for its entire depth (295 feet) in the basalt. Casing was run for the entire 1,590 feet depth of the well (7/36-19R1) of the Walla Walla Canning Co. and perforated opposite the water-bearing strata so far as they could be determined.

The proper casing of some basalt wells demands careful attention to many factors, particularly to the static level of the water in each important water-bearing zone penetrated by the drill. In wells where the water is found to occur perched, and the water in successively deeper aquifers stands successively farther below the surface, the well bore will serve as a conduit toward the deeper permeable zones and may even drain all water away to a dry, but permeable zone. Casing off, or otherwise sealing, all except the best water-bearing zone may be necessary to secure the maximum yield in such perched-water situations, which characterize the domestic and stock well sites of some of the upland areas. In wells where the water occurs with successively higher static level as deeper aquifers are encountered, a sealed casing to the deepest aquifer is required to prevent wasteful leakage into the upper permeable zones which may have been dry or had water of lower pressure level. Such within-well leakage has helped to dissipate the natural pressure head in many flowing and nonflowing artesian wells in the Walla Walla Basin. In wells where no significant changes in the static level of the water occur throughout its depth, as was the case in the Charles Baker well (7/34-25N1) north of Whitman, casing can be limited to that necessary for sanitary and pump protection needs.

The basalt is not an easy rock in which to drill a good straight well. The massive centers of some of the lava flows are tough and hard, and drill progress in places may not exceed 2 or 3 feet per 8-hour drilling shift. The tops and bottoms of the flows are considerably less tenacious, and the average drill progress is commonly about 10-15 feet per shift of drilling.

Irregular hard and soft parts of the rock cause difficulty in drilling some of the lava flows because the drill may in places persist in deflecting towards the side of the well bore which is drilling the easier. Most drill operators agree that the primary cause of crooked wells lies in attempting to make the hole too rapidly and that deflections of the well bore are corrected most readily at their first inception. Many drillers undertake corrective measures as soon as the drilling cable is seen to be drifting consistently from the center of the casing at the surface.

The upper part of the well, in which the pump is to be set, is the part for which alignment requirements are most rigid. Contract specifications usually require that these sections pass tests such as visual check, with drop light or reflected light as far as the water level; persistence of the drilling cable to the casing center while full-gauge tools are being lowered slowly in the well; barrel gauge alignment surveys; passage of rigid "dummy" sections of the next smaller pipe; or other alignment-testing methods.

As engineering design of water wells and better drilling equipment and methods have come into use a number of improvements have come to well construction in the basalt. The cement sealing of the casing into the massive center part of a lava flow at some depth below the top of the basalt has become common practice. Excessive cement grouting of minor areas of rock slough in the water-producing section of a well are no longer done unless absolutely necessary for the construction of the well. The old belief that water-bearing zones are always identified by a clearing of the drilling sludge or a disappearance of the drill cuttings has been amply disproven; prolonged bailing and pumping tests are now considered the only valid demonstrations of the potential yield of a well.

Future Development of Ground Water from the Basalt

Indications of amount of water available annually from the basalt.--In one area of some 2,500 acres at College Place, ground-water withdrawals from the top part of the basalt totaled about 3,000 acre-feet annually and is producing further progressive decline of the static water levels. This ground water is brought to the locality by keeping the water level about 50-100 feet below its original natural position. This is an unusual condition and the annual withdrawal of 1½ acre-feet of water per acre at College Place, since the water level was reduced about 70 feet below its natural position, may be much more than double the quantity that could be withdrawn perennially throughout the basin.

An estimate of the amount of ground water stored in the top 1,000 feet of the basalt, the part commonly tapped by wells, can be made empirically by applying some rude quantities observed in various dewatering operations. These observations estimate the average drainable porosity as 10 percent within water-bearing zones which form about 10 percent of the rock beneath 400 square miles of the valley floor. For the uppermost 100 feet of basalt, such empirical reasoning would indicate about 250,000 acre-feet of water would be removed when the water levels in the basalt were lowered 100 feet throughout the valley floor area. This rude estimate is similar to that obtained above for the gravel aquifers, and along with the ground water in the gravel it gives 500,000 acre-feet of water as an estimate of the storage in the first 100 feet of the two water-bearing units beneath the Walla Walla Valley.

When Price's (1960, p. 29) value of 400,000 gpd for the transmissibility [1/] of the 1,000 feet of basalt in Walla Walla well 3 (7/37-18P1) is extended to a yearly basis for a section of the basalt 40 miles long surrounding the valley floor above Lowden, and the smaller factor for an average ground-water gradient of 5 feet per mile is introduced, the transmission capacity of the basalt through this peripheral plane is computed as about 90,000 acre-feet of water per year. This theoretical projection of too meager data gives a value nearly 6 times the present withdrawal of ground water from the basalt.

A precise, or even preliminary, figure will have to be based on much more quantitative work than could be included in this investigation. Nevertheless, the records of the present wells, and the structure and transmission characteristics of the basalt, indicate that, as a whole, the basalt beneath the valley will afford, to properly spaced wells, much more ground water without exceeding the annual amount naturally recharged and transferred laterally beneath the valley floor. In addition, increasing water storage in the basalt by artificial recharge holds promise for the future.

The water-level information in table 1 and figures 10 and 11 show that about 30 wells near College Place have drawn down the pressure level of the water in basalt, as have about 10 wells at Milton-Freewater and 5 wells on Mill Creek northwest of Walla Walla. Elsewhere the levels of the water in the basalt are comparable to the native conditions or are due to the temporary lowering inherent to the annual reestablishment of ground-water levels depressed by pumping.

Areas subject to ground-water development.--Some valley areas where the basalt obviously warrants exploration of ground water for irrigation are described below:

Around Spofford Station, and particularly to the north and northeast, the water level in the basalt aquifer should stand within 100 feet of the land surface. The wells marginal to this area (6/36-31L1, 19B1, 9P1) are good producing wells.

In the Russell Creek district below Maxson School and southward to Cottonwood Creek the static ground-water level is less than 100 feet below the surface. Wells 7/36-36J2, 6/37-5A1, and 7/37-32P1 are marginal wells of good yield.

Other districts where the basalt obviously warrants exploration of the ground water for irrigation include Spring Valley in secs. 1, 2, 10, and 11, T. 8 N., R. 36 E.; lower Dry Creek northeast and southwest of Sudbury station; the dissected terrace lands north of Whitman, for which 7/34-25N1 and 7/35-23M1 are the marginal wells; the lower few miles of the Touchet River valley; the Blue Mountains foothill strip of high static ground-water levels between wells 6/37-4B1, 5F1, and 7Q1; many other localities where few wells now tap the basalt aquifers; and many localities of reservoired water behind structural barriers in the upland valleys of the basin (Newcomb, 1962). When the technology of recharging excess surface water to the basalt is worked out, many other districts, even those now deemed to have too high a water lift, may become feasible areas for development of the ground water in the basalt.

[1/] The coefficient of transmissibility is defined as the number of gallons that will pass in 1 day through a vertical strip 1 foot wide extending the height of the aquifer under a hydraulic gradient of 1 foot in 1 foot.

Precautions to preserve high ground-water levels.--The continued availability of adequate ground water ordinarily is indicated by a relatively high static water level. It is imperative that everything possible be done to maintain water levels commensurate with optimum use of the ground water. If developments are started to withdraw large amounts of ground water they should incorporate judicious spacing of the wells to avoid undue local drawdown of the water level. Such developments may wisely plan to provide irrigation water at first for only about one-eighth or one-fourth of each section until sustained ground-water levels indicated that more water is available without persistent overdraft. At best, the ultimate capacity of the basalt aquifers without excessive decline of water levels probably will not permit the withdrawal of irrigation water for more than half the acreage in any given locality.

Where wells have been overcrowded, as at College Place, additional or replacement wells should extend the casing and explore to horizons deeper in the basalt in an effort to avert further overdraft on the aquifers near the top of the basalt.

Every well should be provided with both an air gauge-air line assembly, which can be used to indicate water level, and an entry port through which the water level in the well may be checked by means of a measuring tape. These should be provided by the well driller or pump installer as a regular part of the well's construction and equipment, as has long been done in many other parts of the nation.

Artificial recharge to the basalt aquifers.--The possibility of augmenting ground-water storage in the basalt by artificially recharging wells with excess surface water during the winter months has long been foreseen as a future practice of great promise. Its feasibility was thought to depend upon several important considerations. Theoretically, a well should accept the same amount of water under a given pressure head of application as it will produce with an equal amount of drawdown. In practice, however, certain reactions may occur to reduce the recharge capacity of a well. Any sediment may ultimately plug the pores of the aquifers, chemical deposition or exchange may also take place to reduce porosity, and dissolved air or other gases may come out of solution and air-lock the pores of the rock. Water used for recharge by injection through basalt wells should be quite clear, chemically stable, and preferably as warm and air-free as the water in the basalt.

The first experiments have yielded optimistic results. The second stage, the design and operation of permanent but still-experimental recharge plants, is close at hand.

In 1957 and 1958 the city of Walla Walla, the Washington State Department of Conservation, Division of Water Resources, and the Ground Water Branch of the Geological Survey conducted an artificial recharge test on Walla Walla well 3 (7/37-18P1) (Price, 1960). Water from the city's Mill Creek conduit was injected at the rate of about 660 gpm from December 11 to 20, 1957, and from December 23, 1957, to January 8, 1958, during which time 71.3 acre-feet of water was placed in the basalt aquifers. The artificial recharge raised the water level in the recharged well by about 8 feet and the water level in Walla Walla well 1 (7/36-13F1) by at least several feet. However, some temporary reduction in the well's yield occurred because of the greater viscosity of the cold water recharged or because of air entrained and dissolved in the recharged water. Some technological improvements were planned for subsequent tests of these recharging experiments.

In the winter of 1961-62 the city of Walla Walla carried on further experiments in artificially recharging the ground water in the basalt through their No. 3 well. It was found that the practice of pumping the well after only 1 to 5 days of recharging was effective in preserving the normal specific yield of the well (Paul F. Meyer, personal communication). By the end of the recharge period in April they had recharged 65 million gallons, about 200 acre-feet, of water which had raised the static level of the well (7/37-18P1) by about 5 feet.

Favorable results from similar recharge experiments in wells in the same basalt rock were carried out in 1961 and 1962 at The Dalles and South Salem, Oregon (B. L. Foxworthy, personal communication).

Ground water in structural traps on the Blue Mountains slope.--The prevailing westward inclination of the basalt flows causes the westward-flowing streams to cross the outcropping edges of the flows. In the main stream valleys the interflow zones, some of which are aquifers, remain full of water. Apparently the level of the water in each aquifer slopes laterally toward the streams from the interstream areas. When tapped by wells farther downstream, the water entering the well from an enclosed aquifer will rise to the level of the aquifer's outcrop. Such wells are the small one (4/37-9H1) at the boys' camp on the South Fork and the Bureau of Reclamation exploratory drill holes at proposed dam sites on the South Fork and the main stem of the Walla Walla River (4/37-12Q1 and 5/36-18P1).

Some faults cut transversely across the Blue Mountains slope (see pl. 2). Their shear zones provide barriers that dam up the water in some of these inclined aquifers. Wells drilled on the upslope side of those barriers should tap stored ground water under pressure. The yield of such wells might be used to augment the flow of the stream during the low-water months. Some of the water taken from a well (and delivered to the stream) would be offset by some loss from the stream to the aquifer at its outcrop farther upstream. However, it is likely that the removal of ground water from storage and from flanking areas would secure a "new" source of water that would substantially exceed any dimunition of the streamflow. Such a ground-water withdrawal probably would be replaced by recharge during the winter months. The system recommends itself for trial; its workability should be determined in an effort to augment late summer streamflow with otherwise unused ground-water storage (Newcomb, 1962). The preliminary estimates indicate that augmentation of the ground storage may be far cheaper and more advantageous than some of the surface storages now under consideration.

Ground-water supplies for the future.--The water in the ground will be the main part of the water resources of the basin in the future as it is now. The ground-water sotrage in the mountainous part of the basin will provide the base flow of the streams--the average 150 cfs of water that Mill Creek and the Walla Walla River deliver to the valley floor in the vital growing months of summer and fall. Also, storage and transmission to points beneath the sites of water use will continue to be provided by the gravel stratum and the basalt aquifers. The approximate 250,000 acre-feet of storage space in the uppermost saturated 100 feet of the basalt and a similar storage space in the old gravel will continue as the principal operational reservoir of the Walla Walla Valley.

A transition in the use of the water-storage space of the old gravel is underway. From a more or less static concept of the "full tank" from which only the overflow was used, development of the water is progressing toward a more dynamic situation in which the reservoired water is drawn down in months of need and refilling permitted during the winter and spring months. Providently, measures to retain all the present opportunities for recharge and for augmenting them with artificial recharge could be included in the planning of this transition.

The ground water in the basalt will support greater withdrawals than now prevail in many parts of the basin. In some localities the water in some zones of the basalt is already overdrawn by crowded wells. The whole basalt reservoir also is susceptible to operation on a dynamic basis with recharge enhanced by a judicious lowering of the water level during months when the extracted water has the greatest value. Also, like the gravel reservoir, the increased use of the basalt reservoir will need a planned and managed basinwide operation.

The greatly increased use of ground water and of the ground-storage space for water in the future is bound to require more management and operation based on more and better information than has been customary under the near-native conditions of the past. The serious neglect, which in the first 100 years witnessed a basin-wide expenditure of less than $50,000 for study of this principal water resource, must give way to considerate management and husbandry.

Certainly the ground-water resources in all their occurrences are of such importance to the economy of the Walla Walla Valley that the determination of their optimum utility and their wise management are worthy objectives with progressive and perpetual rewards.

TABLES OF GROUND-WATER DATA

Some detailed information on the ground water, wells, and springs is condensed in tables 1 to 4. The tabulated data contains the basis for many statements of the preceding text; also, it contains additional information beyond the text presentation. The tables and the maps and cross sections (pls. 1 to 3) supplement each other in presenting this additional ground-water information. The wells listed in table 1 and the springs listed in table 4 are located on the map, plate 1. The ground-water and geologic data given in tables 1 and 2 and on the geologic map (pl. 1) also form the basis for the geologic cross sections (pls. 3A and 3B) and the bedrock contour map (pl. 2).

Table 1 (p. 76-102) lists the pertinent data on wells chosen as representative of the wells in their respective localities. This selection for representativeness is not strictly followed for the larger and deeper wells which obtain water in the bedrock basalt--most all of those wells are listed in table 1. For each well that has additional information in the other tables or in the figures, the pertinent references are given in the remarks column of table 1.

Table 2 (p. 103-141) contains drillers' logs that record the general geologic and ground-water conditions observed by the drillers in many parts of the river basin. In general, the logs were selected for their representation of subsurface conditions in certain parts of the valley; however, several logs of wells are included for each of a few well groups--such as the Milton-Freewater group of deep wells (which includes 5/35-1E1, 2H1, 2J1, 12F1, 12F2, and 12G1), the Russell Creek group (including 6/36-9L1, 9P1, and 10E1), the Walla Walla group (including 7/36-19F1, 19R1, and 20N1), and the College Place cluster (including 6/35-K1, 1D1, 1M1, 2E1, 7/35-23M1, 25F1, 25P1, 26Q2, 33D1, 36A1, and 36 D1). The drillers' logs show the main stratigraphic divisions, but within the main rock groups the logs do not identify specific beds or strata as is commonly done in subsurface exploration done specifically for stratigraphic detail. Some of the logs include the static levels of the ground water as observed during drilling, in further illustration of the text description of this factor in ground-water occurrence. Some of the logs describe well-casing installations in addition to the casing bottom locations given in table 1.

Table 3 (p. 142-145) gives the chemical analyses obtained on ground waters of the basin and contains a few analyses of surface water for comparison. These data form the basis for the text generalizations on the quality of the ground water. To supplement table 3, the hardness and chloride determinations in table 1 are given from field analyses of samples taken at some wells during the data collections of this investigation.

Table 4 (p. 146-151) lists data on representative springs which are located on plate 1. It lists nearly all of the main permanent orifices of the ground water that flows from the gravel aquifers of the alluvial fans in the valley floor part of the basin. The discharge from these valley springs is described in the text under the sections dealing with ground water in the old gravel and with the development of the ground water. Also included are data on a few springs that illustrate types numerous in the upland and slope areas.

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Table 1.—Records of representative wells in the Walla Walla River basin

(Location of wells is shown on plate 1)

Topography where well is located: Ap, alluvial plain; Fp, flood plain of river; S, slope to major valley; T, terrace; Td, terrace dissected; U, upland; Uv, upland valley of minor stream. Altitudes interpolated from topographic maps or from barometric traverses.

Type of well construction: Bd, bored; Dg, dug; Dn, driven; Dr, drilled.

Ground-water occurrence: U, unconfined; C, confined; P, perched.

Water-level information: Depths and water levels expressed in feet and decimals were measured by the Geological Survey or cooperating personnel; those in whole feet were reported by owner or driller; those with plus and minus signs were estimated. "F," flowing well, static level not known; "+" measurement, static level above land surface. Datum is land surface.

Type of pump: B, bucket; C, centrifugal; J, jet; N, none; P, plunger; R, rotary; Sy, syphon; T, turbine.

Use of water or well: D, domestic; E, exploration; Ind, industrial; Irr, irrigation; N, none; O, observation; PS, public supply; S, stock.

Chemical data given in remarks column were determined in the field. Hardness and chloride of water given in remarks column with only one use of the ppm abbreviation.

Abbreviations used in remarks column: Ca, analyses of water in table 3; L, log of well in table 2; WL fig. 7, water-level record in figure 7; Dd, drawdown of water level; Gpm, gallons of water per minute; Ppm, parts per million; Tpd, test pumped.

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
									T. 4 N., R. 35 E.						
11G1	Geo. Winn	Uv, 1,500	Dr	280	10	----	89	209	Basalt	C	F	9-26-53	-------	Irr	
12C1	Geo. Lieuallen	Uv	Dr	346	8	165	152	194	------Do------	U	40	3-24-59	-------	Irr	Tpd 108 gpm with dd of 100 ft.
15P1	Lamb-Weston Inc.	Uv, 1,775	Dr	737	20-12	471	---	-----	------Do------	C	-----	------	T, 1,500	Ind	
15P2	Lamb-Weston Inc.	Uv, 1,775	Dr	1,200	----	----	---	-----	------Do------	C	-----	-------	T, 1,200	Ind	L.
22A1	Weston Cemetery	Uv	Dr	1,000	16-8	893	---	-----	------Do------	U	252	3-26-55	-------	Irr	
22Q1	City of Weston	Uv, 1,790	Dr	534	10	40	508	26	------Do------	C	100	1939	T, 500	PS	Water level reported drawn down by pumping of well 15P1; L.
									T. 4 N., R. 36 E.						
7R1	Don Olinger	Uv	Dr	70	8	36	59	11	Basalt	U	37	2-28-59	-------	---	
									T. 4 N., R. 37 E.						
9H1	William Coleman	Uv, 1,950	Dr	97	5	61	87	10	Basalt	C	1.0	11-23-48	P	D, S	Hardness, 40; chloride, 3 ppm; L.
12Q1	Bureau of Reclamation	Uv, 2,290	Dr	156	5-2	55	137	19	------Do------	C	+22	7-23-51	-------	E, O	Test hole at damsite. A 380-ft test hole to northwest and higher on canyon wall had water level at similar altitude.

									T. 5 N., R. 35 E.						
1C1	John Clark	Ap, 996	Dg	37	84	---	----	----	Gravel	P	14.4	5-8-33	C, 100	Irr	WL fig. 12.
1D1	Henry Betts	Ap, 994	Dg	20	72	---	----	----	Gravel	P	11.2	5-8-33	C	Irr	
1E1	Utah Canning Co.	Ap, 1,010	Dr	528	16	109	468	60	Basalt	U	49	2-16-45	-------	Ind	Ca; L.
2C1	C. Townsend	Ap, 976	Dg	23	60	---	----	----	Gravel	P	12.8	8-22-32	C, 100	Irr	
2D1	Gus Seibold	Ap, 950	Dr	344	8	100	308	23	Basalt	U	53	3- -46	T, 150	Irr	Hardness, 60; chloride, 14 ppm; L.
2E1	City of Milton-Freewater, No. 6	Ap	Dr	952	16-12	61	----	----	------Do------	U	77	1952	T	PS	L; WL fig. 10.
2G1	City of Milton-Freewater, No. 4	Ap	Dr	374	?-8	---	----	----	------Do------	U	-----	------	-------	PS	
2H1	City of Milton-Freewater, No. 5	Ap, 995	Dr	502	18-12	172	435	67	------Do------	U	47(?) 82	1936 1953	T, 850	--	Water level 47 ft below surface when pumping 750 gpm (1936); Ca; L; WL fig. 10.
2J1	City of Milton-Freewater, No. 3	Ap, 1,010±	Dr	550	20-16	100	---	----	------Do------	U	50(?) 78	6- -46 2-26-53	T, 1,500	PS	L; WL Fig. 10.
3C1	P. S. Gibbons, Jr.	Ap	Dg, Dr	141	8	---	75	66	Basalt	U	17.4	7-21-48	C, 100	Irr	
							16	16	Gravel	P					
3H1	Walter Miller	Ap, 959	Dg	36.5	42	---	---	----	------Do------	P	22.3	5-17-33	P	--	WL fig. 10.
4A1	Grant York	Ap, 889	Dg	62	48	---	---	----	------Do------	U	33.9	5-8-33	N	N	Penetrated to basalt bedrock. Later destroyed.
4D1	---- Coffman	T	Dr	110	8	---	---	----	Sand	U	60	1948	T, 100	Irr	
5A1	Nellie Smith	T	Dg	60	72	---	---	----	------Do------	U	47.0	7-21-48	J, 5	D	Hardness, 120; chloride, 16 ppm.
6C1	Ernest Key	S	Dr	777	12	202	572	20	Basalt	U	36	3- -56	-------	Irr	Tpd 730 gpm with dd of 113 ft.
12F1	City of Milton-Freewater, No. 1	Ap, 1,070	Dr	651	12	100	---	----	------Do------	U	85 107 136	5-28-37 7- -45 5- -52	T, 1,000	PS	Water level reported dd 10 ft when well 12Q1 is pumping; Ca; L; WL fig. 10.
12F2	City of Milton-Freewater, No. 2	Ap, 1,065	Dr	902	12	99	---	----	------Do------	U	105	9-21-45	T, 1,000	PS	Ca; L; WL fig. 10.
12G1	Rogers Canning Co.	Ap, 1,080	Dr	702	20-16	65	---	----	------Do------	U	105 132	9-21-45 9-17-52	T, 1,200	Ind	L.
12G2	Rogers Canning Co.	Ap, 1,075	Dr	700±	18	---	---	----	------Do------	U	-----	------	T	Ind	Tpd 1,000 gpm.
13L1	Umatilla Canning Co.	S, 1,170	Dr	918	18-16	286	286	632	------Do------	U	222	6- -51	T, 950	Ind	Tpd 920 gpm with dd of 46 ft.
23P1	Lowell Steen	S, 1,300	Dr	1,000	14	---	800	200	------Do------	U	152	8- -52	------	Irr	Tpd 1,000 gpm; in basalt entire depth.
									T. 5 N., R. 36 E.						
1N1	Baker Estate	S, 2,750	Dg, Dr	600	60-6	105	---	----	----------	---	-----	------	------	--	Basalt was dry 20-600 ft.
2F1	H. A. Miller	S, 1,550±	Dr	450	6	50	200 450	1± 4±	Basalt ------Do------	P U	375	1912	P, 10	D, S	
5A1	C. O. Whiteman	S, 1,150±	Dr	500	6	---	---	----	------Do------	C	180	1946	P, 5	D	
8D1	Von Der Ahe	S, 1,170	Dr	240	6	---	---	----	------Do------	---	-----	------	P	D, S	Hardness, 65; chloride, 6 ppm.
9D1	G. S. Cockburn	S, 1,220	Dr	400	6	---	---	----	------Do------	U	380(?)	1948	P	D, S	
18P1	Bureau of Reclamation	Ap, 1,177	Dr	204	4-3	155	6 90	43 114	Gravel Basalt	U C	6 +5	1951	------	E, O	Foundation test well at dam site.
18P2	Bureau of Reclamation	Ap, 1,371	Dr	210	5-2	43	209	1	------Do------	C	95	1951	------	E, O	Foundation test well at dam site; reported drilled in faulted rock, on left abutment.
26G1	H. Poulsen	Ap, 1,515	Dr	10	18	---	6	4	Gravel	U	6.0	11-23-48	C, 10	D	Typical well of river canyon floor above Milton; hardness, 40; chloride, 3 ppm.

Table 1.--Records of representative wells in the Walla Walla River basin--Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Thickness (feet)	Character of material	Ground-water occurrence	Water level: Feet below datum	Date	Type of pump and yield (gpm)	Use	Remarks
									T. 5 N., R. 37 E.						
14L1	Emmett Lynch	U, 3,500	Dr	502	6	---	200	2	Basalt	P	300±	1939	P	D	Water about at level of adjacent canyon's floor.
							490		------Do------	U					
									T. 6 N., R. 32 E.						
9G1	John Ankeny	Uv, 720	Dr	170	8	---	160	10	Basalt	C(?)	80	1936	P	D	Gives small yield.
21Q1	---- Rogers	U, 1,720	Dr	827	6	80	540	2	------Do------	P	540	1950	P	D,S	Located on drainage divide. Inadequate yield for full supply of farmstead.
									T. 6 N., R. 33 E.						
5B1	Wayne Martin	Ap, 425	Dr	174	8	---	170±	4	Basalt	C	12.03	10-27-48	P	D	Flowed at surface until about 1930. Drilled in sand to about 75 ft; basalt below.
5M1	Wm. Martin	T, 425	Dr	214	6	---	150	10	------Do------	C	6	1935±	------	Irr	Upper water zone cased off.
							210	4	------Do------	C	4				
6L1	Wm. Martin	T, 460	Dr	250±	6	---	---	----	--------------	--	55.75	3-19-49	N	N	
7J1	A. Demaris	S, 500	Dr	150	10	138	138	12	Basalt	C	16	12- -56	T	Irr	Only loose basalt above 118 ft; Tpd 350 gpm with dd of 140 ft.
8L1	A. Demaris	Td, 500	Dr	60	10	53	33	20	Slope rubble	C	14	10- -56	T	Irr	Tpd 540 gpm with dd of 55 ft.
8Q1	Nelson (formerly)	Td, 525	Dr	177	5	---	175	2	Basalt	C	-----	------	P	D	L.
9A1	Hugh Snider	T, 535	Dr	154	4½	150	150	4	Coarse black sand	C	75	7- -33	P, 4	D	Aquifer overlaid by 150 ft of medium and fine sand interlayered.
9F1	A. Munns	T, 510	Dr	170	12-10	120	129	19	Gravel	U	39	11- -53	------	Irr	Well filled with sand to 120 ft during pump test; 10-inch screen set inside perforations 102-120 ft; Tpd 550 gpm with dd of 102 ft.
10A1	U. Mousser	T, 550	Dr	184	5	---	---	----	Black sand	C	75	11- -47	P, 3	D,S	
10C1	---- Wagner	T, 560	Dr	200	6	---	190	10	Gravel	C	75	11- -46	J, 3	D	Clay and silt overlies aquifer.
10H1	B. J. Johnson	T, 560	Dr	256	8	223	170	86	------Do------	U	61	10- -55	------	Irr	Tpd 420 gpm with dd of 28 ft.
10J1	D. Gilkerson	Td, 545	Dr	225	6	---	175	50	------Do------	C	20(?)	12- -39	20	D,S	L.
11H1	Dan Fiske	T, 565	Dr	230	6	200	180	10	Silty sand	C	40	1945	P, 12	D,S	
							200	30	Pea gravel						
12K1	H. M. Ahlquist	T, 570	Dr	211	5	---	---	----	Coarse black sand	C	-----	------	P, 6	D,S	Water from lower part of well.
13G1	E. C. Burlingame	T, 560	Dr	185	5	---	---	----	Black sand	C	-----	------	------	--	Three similar wells on farm.
14J1	Jess Sutherland	T, 550	Dr	300	6	---	---	----	--------------	--	-----	------	P, 5	D,S	Hardness, 200; chloride, 20 ppm.

14Q1	E. C. Burlingame	T, 560	Dr	220	12	---	---	----	Gravel	U	------	-------	T, 1,000	Irr	Irrigates about 100 acres.
15C1	A. L. Farley	T, 510	Dr	180	5	---	175±	5±	Sand and gravel	C	------	-------	J, 5	D, S	Well bottomed on bedrock or large boulder.
16A1	J. Herman	S, 550	Dr	730	8	720	275(?)	----	Rubble	U	16	-------	-------	Irr	Bedded silt and sand drilled to 140 ft and broken basalt rubble and clay to bottom; Tpd 340 gpm with dd of 40 ft.
							450								
20N1	A. Campbell	S, 1,200	Dr	778	----	---	---	----	Basalt	P	650	3-8-58	-------	D	
23B1	A. Harris	T, 610	Dr	700	10	129	---	----	-----Do-----	C	78	1-7-58	-------	Irr	Tpd 330 gpm with dd of 190 ft.
24A1	J. L. Geyer	T, 570	Dr	250	12-8	250	198	20	Gravel	U	45	4-2-56	-------	Irr	Tpd 600 gpm with dd of 27 ft.
31J1	A. Campbell	Uv, 1,350	Dr	130	8-6	---	100	30	Basalt	C	60±	1929	P, 3	D, S	Alluvium 15 and basalt 85 ft thick overlie aquifer.
									T. 6 N., R. 34 E.						
2R1	Frog Hollow School District	Ap, 580	Dr	480	6	---	470±	----	Silty sand	C	3	1932	P	D	No other water strata encountered.
3D1	R. B. Melton	Ap, 525	Dr	40	6	40	40	1±	Gravel and sand	C	8	1947	J, 6	D, S	Hardness, 95; chloride, 10 ppm.
3M1	H. Halverson	T, 620	Dr	187	8-6	172	122	3	Sand and gravel	C	92.2	10-23-47	-------	D, S	
							152	3							
4C1	Minnie A. Williams	Ap, 525	Dr	42	6	41	41	1	Gravel	C	-----	1946	-------	D, Irr	
4E1	Charles Mang	T, 600	Dr	800	8	---	700	100	Basalt	C	101.0	10-23-47	N	N	Bedrock overlain by 150 ft of silt and sand and 550 ft of mostly cemented gravel (?).
5B1	Jim Kelly	Td, 555	Dg	26	36	---	25	1	Gravel	U	5	8- -49	C	Irr	
5F1	Jim Kelly	Td, 550	Dr	66	4	---	---	----	------------	--	.9	1945	-------	--	Former Mud Creek School well.
5F2	Gardena Farms Dist. 13	T, 610	Dr	189	5	---	---	----	Sand	U	90	1930	P, 5	D	
5K1	L. J. Noland	T, 660	Dr	166	5	---	90	20	Quicksand	--	-----	------	P, 5	D, S	Reported 90 ft of silt at top and 50 ft of blue clay between aquifers.
							160	6	Cemented gravel						
5N1	Ed Tucker	T	Dr	312	12	224	102	210	Gravel	U	35	11- -58	T, 400	Irr	Tpd 400 gpm with dd of 200 ft.
6C1	R. C. Moore	Td, 510	Dr	500	14	---	---	----	Cemented gravel	U	35.6	10-23-47	N	--	Drilling stopped on basalt bedrock.
6N1	R. C. Moore	Td, 500	Dr	180	8	175	125	175	Sand and gravel	U	-----	------	-------	--	
6N2	R. C. Moore	Td	Dg	31	36	28	29	2	Gravel	U	4	12-11-51	-------	Irr	Tpd 350 gpm with dd of 14 ft.
7B1	John Merry	Td	Dr	68	12	53	29	24	-----Do-----	U	7	1-30-52	T, 425	Irr	
8F1	W. F. Dolling	T, 525	Dr	618	10	485	505	113	Sandstone (basalt?)	C	42	1-2-51	-------	Irr	Tpd 450 gpm with dd of 197 ft; entered basalt(?) bedrock at 505 ft.
9A1	B. F. Gibson	Td, 600	Dg	33	60	---	---	----	Sand	U	25.0	5-12-33	P, 5	D, S	
9F1	Clayton Prusia	Td, 610	Dr	196	12	98	28	93	Gravel	U	+2	12-15-53	-------	Irr	Tpd 300 gpm with dd of 14 ft; L.
11B1	Roy Kelly	Ap, 570	Dg	65	5	---	60	5	Sand and gravel	U	7	1947	-------	D, Irr	
11M1	A. P. Fredrickson	T, 775	Dr	190	12	166	51	130	Gravel	U	32	1-14-54	T	Irr	Tpd 35 gpm with dd of 104 ft; typical of many similar wells in this immediate area.
12B1	Floyd Miller	Ap, 590	Dr	140	6	---	---	----	Gravel	U	13	10-16-47	J	D	Iron-bearing water encountered above 80 ft.
12C1	J. Miller	Ap, 585	Dr	100	6	---	93	7	-----Do-----	U	9	1945	C, 5	D, S	
13A1	R. M. Emigh	T, 700	Dr	310	10	125	170	10	------------	U	60	1945	T, 500	Irr	L.
							220	4							
13E1	---- Krumbaugh	Td, 700	Dr	300	6	---	---	----	------------	--	-----	------	-------	--	Dry hole, all silt and clay.
13M1	---- Krumbaugh	Ap, 630	Dr	300	10	---	---	----	------------	--	-----	------	-------	--	---------Do---------
13M2	---- Krumbaugh	T, 655	Dr	300	10	---	---	----	Gravel	--	-----	------	N	N	Yield 100 gpm from one gravel bed.
13M3	---- Krumbaugh	T, 640	Dr	300	10	---	---	----	------------	--	-----	------	-------	--	Dry hole, clay and silt only.
13R1	M. O. Beauchamps	Ap, 649	Dg	11	18	---	---	----	Gravel	U	4.1	5-31-33	-------	D	
13R2	M. O. Beauchamps	Ap, 655	Dr	100	10	---	---	----	-----Do-----	U	5.4	11-8-47	C, 400	Irr	
14C1	O. L. Hellberg	Td, 610	Dr	100	10	---	---	----	Gravel and sand	U	14.7	11-7-47	------	Irr	
14G1	O. L. Hellberg	Td, 600	Dr	80	8	---	---	----	-----Do-----	U	16.1	11-7-47	C, 300	Irr	
14Q2	S. C. Weatherman	Ap, 600	Dr	200	12	84	18	189	-----Do-----	U	26	1948	------	Irr	Tpd 290 gpm with dd of 140 ft.

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 6 N., R. 34 E.—Continued								
15K1	K. Dickerson	Td	Dr	225	8	70	120 170	8 25	Gravel	U	25	12-10-51	------	Irr	Tpd 300 gpm with dd of 50 ft.
16K1	Grant Low	Ap, 548	Dg	12	60	---	---	----	------------	U	8.4	5-12-33	------	D	
17A1	H. V. Dickerson	Ap, 520	Dr	12-8	350	320	37	183	Gravel	U	28	2-11-53	------	Irr	Tpd 400 gpm with dd of 200 ft.
17L1	R. Bevan	Td, 550	Dr	10	292	125	67	151	-----Do-----	U	7 8.2 6.7 11.6	3-15-51 11-26-54 12-23-54 3-5-58	T, 500	Irr	Penetrated mostly clay below 218 ft; tpd 500 gpm with dd of 63 ft.
18C1	Dale Jacobs	T, 530	Dr	200	12	109	60	----	-----Do-----	U	30	1-8-54	------	Irr	Tpd 900 gpm with dd of 50 ft.
20E1	O. A. White	Ap, 550	Dr	195	10	105	38	153	Gravel and sand	U	28	1951	T, 600	Irr	Owner's no. 2 of 5 wells.
20F1	O. A. White	Td, 560	Dr	210	10	102	35	175	-----Do-----	U	29	1951	T, 650	Irr	Owner's no. 3.
22C1	Lane Hune	Ap, 565	Dr	79	5	---	75	4	-----Do-----	U	10±	1947	P	D, S	
22G1	Lane Hune	Td, 590	Dr	3,000	4-2	---	---	----	------------	--	-----	------	N	N	Oil-test well; L.
22R1	Dan Kinney	Ap, 600	Dn	16	1½	---	---	----	Gravel	U	9.7	5-31-33	P	D	
24A1	Roy Huffman	T, 675	Dg, Dr	80	48-6	---	---	----	-----Do-----	U	30	1947	J, 5	D	
24F1	J. L. Richarts	Ap, 650	Dr	50	10	---	---	----	-----Do-----	U	-----	------	C, 300	Irr	
24G1	J. T. Roberts	Ap	Dr	217	10	80	80 190	4 20	-----Do-----	U	15	9-20-58	------	Irr	Tpd 400 gpm with dd of 140 ft.
24P1	Roy Trump	Ap, 650	Dg	22	30	---	---	----	-----Do-----	U	4.5	11-6-47	C	D	Pumps dry in late summer.
26A1		Ap, 640	Dg	35	48	---	29	6	-----Do-----	U	6	11- -47	C, 175	Irr	Silty clay overlies aquifer.
26A2	H. C. Franklin	Ap, 640	Dr	60	10	50	50	10	Sand	U	8	11- -47	C, 200	Irr	
33C1	W. W. Schubert	Ur, 800	Dr	----	5	---	---	----	------------	--	-----	------	------	--	
34C1	W. W. Schubert	Uv, 750	Dr	150	8	---	---	----	------------	--	49.8	11-6-47	P, 5	D, S	
35D1	M. A. Cockburn	Ap, 650	Dr	650	18-12	60	500	200	Basalt	C	F 22	7- -48 5-5-49	N T, 1,000	Irr	Flowing 400 gpm; hardness, 60; chloride, 5 ppm; L.
36K1	Clark Key	Ap, 640	Dr	970	12-8	748	---	----	-----Do-----	C	+34 100	1951 1954	T	Irr	
36N1	E. Key	S, 740	Dr	300	12	255	255	45	-----Do-----	C	+16	1953		Irr	Flowed 1,200 gpm when drilled in 1953; owner's No. 1.
36Q1	E. Key	S, 800	Dr	402	12	---	354	----	-----Do-----	C	29 44.2	1953 3-5-58	T	Irr	Tpd 1,500 gpm with dd of 6 ft.
							T. 6 N., R. 35 E.								
1C1	Frank Daccio	T, 810	Dr	535	8-6	535	529	----	Basalt, porous	C	+30 +15	1- -48 4-12-55	C, 400	Irr	Known as old Kelly well; hardness, 62; chloride, 4 ppm; L.

												33.8 +15 +14	10-4-56 2-26-57 2-22-58				
1D1	Tony Lampeiti	T,	800	Dr	549	6	400	524	25	Basalt, porous	C	F +28 30 +28 +23	1- -48 4-12-55 9-15-55 4-17-56 5-10-60	C,	300	Irr	Former Nelson well; hardness, 60; chloride, 4 ppm; L.
1E1	L. Fanciullo	T,	800	Dr	618	6	---	535	83	Basalt, porous	C	+35 +31 +5 +24 +29 +31	1- -48 4-12-55 10-26-55 4-17-56 2-26-57 2-22-58	N		Irr	Known as Harmon well.
1G1	L. Davin	T,	800	Dr	650	6	---	540	110	Basalt, creviced	C	F	1951	------		Irr	
1M1	Harold Wagoner	T,	805	Dr	703	6	600	700	----	-----Do-----	C	+20	1- -48	C		Irr	Former Hansen well; hardness, 60; chloride, 4 ppm; L.
										T. 6 N., R. 35 E.							
1P1	D. A. McAuslan	Ap,	780	Dr	610	6	---	---	----	Basalt	C	F +36 +29 21 +22 +30	1- -48 4-12-55 4-17-56 10-4-56 2-26-57 2-22-58	N		D	Former Russell well.
2E1	Mrs. Mary Seeliger	Ap,	730	Dr	814	10-6	540	800 40	14 40	Basalt Gravel	C U	6.5	7-15-48	N		N	L.
2J1	Casey Hatchery	Td,	780	Dr	95	8	---	93	2	-----Do-----	U	11	1947	J,	20	D, Ind	Well penetrates quicksand below upper gravel zone.
3C1	C. W. Zwanzig	Ap,	730	Dr	140	8	---	73	2	-----Do-----	U	5	Winter 1945	T,	200	Irr	Hardness, 60; chloride, 6 ppm.
3E1	Mojonnier and Sons	Ap,	690	Dg	30	144	---	6	24+	Sand and gravel	U	6.3	7-15-48	P,	30	D, Irr	Hardness, 65; chloride, 9 ppm.
3E3	Ernest Freepons	Ap,	680	Dg, Dr	190	60-10	---	10	80	Gravel	U	10	------	J,	10	Irr	One of two wells drilled in a 30-ft dug well.
3N1	----------------	Ap,	685	Dr	1,365	6	---	625	20	Basalt	C	34.1 37.2 58.5 32.3 53.8 32.5 33.7	7-15-48 4-13-55 9-22-55 4-18-56 10-4-56 2-26-57 2-22-58	J,	10	D	Former E. C. Burlingame well. Barely flowed when drilled 1914±; hardness, 35; chloride, 6 ppm.
4B1	F. R. Travoille	Ap,	680	Dr	92	8	90	15	52	Gravel and sand	U	8.1	1-21-48	T,	200	Irr	L.
4G1	C. E. Shaw	Ap,	680	Dr	796	6	792	792	----	Basalt	C	10±	1946	T,	400	D, Irr	Reported to flow in wintertime, 1948.
4H1	G. J. Helser	Ap,	685	Dr	165	12	---	---	----	Gravel	U	14	Summer 1947	C,	200	Irr	
4N2	William Resor	Ap,	675	Dn	9.5	1½	---	---	----	Sand and gravel	U	7.8	5-11-33	P,	2	D	
4Q1	D. D. Wright	T,	685	Dr	107	12-8	107	20	43	-----Do-----	U	10	6- -45	T		Irr	Hardness, 55; chloride, 4 ppm; L.
6A1	R. Rimpler	Td,	630	Dr	75	6	43	56	17	Gravel	U	13	9- -46	J,	25	D, S	L.
7B1	V. Hastings	T		Dr	189	12	86	18	136	-----Do-----	U	18	4-26-56	------		Irr	Tpd 290 gpm with dd of 124 ft.
7R2	L. Locker	Ap,	660	Dr	220	12	---	17	----	-----Do-----	U	16	6- -56	------		Irr	Tpd 370 gpm with dd of 152 ft.

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 6 N., R. 35 E.—Continued								
8E1	Dale Hastings	Td, 690	Dr	84	4	83	83	1	Gravel	U	0.5	1940	C, 10	D	Aquifer overlain by 29 ft cemented gravel beneath 54 ft of quicksand.
9D1	C. H. McGilvray	Ap, 670	Dg	26½	30	---	---	---	---Do---	U	10	1948	C, 300	Irr	Water draws down 10 ft when well is operated at pump capacity; hardness, 60; chloride, 4 ppm.
9R1	Fentress and Malden	Ap, 740	Dr	190	8	---	14	64	Gravel in clay	U	15	1946	T, 100	Irr	Penetrated only thin gravel beds.
10H2	Mrs. M. Rosor	Ap, 730	Dr	205	8	91	58	14	Gravel	U	10	3-13-48	---	Irr	Tpd 85 gpm with dd of 135 ft.
10P1	Frank Berard	Td, 735	Dr	1,145	8	1,100	1,120	2	Basalt, porous	C	+25	4-13-55	N	D, Irr	Retains much of its original pressure. Known as old Jaussand well; hardness, 35; chloride, 4 ppm; Ca; L.
											+24	9-22-55			
											+38	4-17-56			
											+23	10-4-56			
											+41	2-26-57			
											+32	2-22-58			
10Q1	Mrs. Bussel	Ap, 740	Dn	8	1½	---	---	---	Gravel	U	5.7	5-12-33	P	D	
11C1	R. L. Carr	Ap, 740	Dg	28	48-10	28	20	8	---Do---	U	5.7	12-17-46	C, 25	D, Irr	
11D1	Ivor Williams	Ap, 730	Dr	51	10	51	15	17	---Do---	U	6.5	3-25-48	C, 250	Irr	L.
							35	38	---Do---						
11E1	M. Toal	Ap, 731	Dn	13	1½	---	---	---	---Do---	U	6.1	5-9-33	P	D	
11G1	Ed Melich	Ap, 750	Dr	142	10	43	18	1	---Do---	U	9	3- -48	T, 300	Irr	
							60	60							
11J1	U.S. Dept. of Agriculture	Ap, 760	Dr	642	8-6	---	630	12	Basalt, porous	C	+20	Winter 1948	C, 100	PS	Old Webb farm well; hardness, 47; chloride, 6 ppm; L.
11J2	M. A. Harrah	Td, 780	Dr	58	8	---	15	43	Gravel	U	6.8	7-17-48	---	Irr	
12H1	D. A. McAuslan	Ap, 800	Dr	700	8	---	---	---	Basalt, porous	C	F	1948	C, 200	D, Irr	Old McCall well; hardness, 62; chloride, 4 ppm.
											15	10-28-59			
											0	5-10-60			
12N1	A. A. Durand	Ap, 775	Dr	590	10-8	495	345	5	Gravel	C	+46	1913	C, 300	Irr	Former Juvenal well; Ca; L.
							565	25	Basalt, porous	C	+100±				
12P1	G. H. Thomas	Td, 776	Dg	25	120	---	---	---	Gravel	U	10.8	5-12-33	N	N	Located just east of well 12P2.
12P2	G. H. Thomas	Ap, 770	Dr	650	8	91	135	177	---Do---	C	F	3-25-48	N	Irr	Found basalt at 366 ft depth. The 8-inch casing carries flow from gravel aquifer interbedded in blue clay.
					6	420	550	130	Basalt	C	F				
13H1	O. O. Black	Ap, 790	Dr	---	8	---	---	---	---	C	9.5	1-16-48	N	Irr	
13J1	D. D. Nicholas	T, 810	Dg	59	38	---	---	---	Gravel	U	28.09	12-9-46	P	S	
13M1	George Metz	T, 830	Dg	65	60	---	45	20	---Do---	U	45	1947	C	D	
13P1	Grandview Irrigation Tracts	T, 835	Dr	400±	6	---	---	---	Basalt	C	20	1933	T, 300	Irr	Formerly flowed during wintertime.
13R1	D. D. Nicholas	T.	Dr	1,030	10-8	---	---	---	---Do---	C	F	2- -52	T, 500	Irr	Flows during wintertime.

14C1	Ray Eiffert	Ap,	775	Dr	160	8	---	70	3	Gravel	U	10.0	7-16-48	N		Irr	Other water occurs in gravel at 23, 35, and 160 ft depth.
14L1	Conrad Miller	Ap,	790	Dg	15	84	---	---	----	----Do----	U	5.05	8-22-32	C		D	WL fig. 14.
												7.43	7-19-48				
15A1	S. T. Cauvel	Ap,	760	Dr	42	8	42	20	16	Sand and gravel	U	7.06	7-16-48	C,	100	Irr	Water level fluctuates from 2 ft down; hardness, 35; chloride, 6 ppm; L.
15B1	Mrs. Carro Chapman	Ap,	740	Dr	60	8	---	9	51	Gravel	U	12	Summer 1947	C,	220	Irr	Tpd 220 gpm with dd of 3 ft; hardness, 50; chloride, 4 ppm.
15L1	E. C. Babcock	Ap,	768	Dg	25	48	---	12	13	----Do----	U	12.73	5-11-33	B		D	
												15.15	7-19-48				
15N1	Mrs. L. Weiss	Ap,	770	Dg, Dr	90	60-6	---	---	----	----Do----	U	26.84	7-19-48	J,	5	D	Drilled in bottom of 30-ft well.
15P1	K. Babcock	Ap,	770	Dr	130	8	---	---	----	----Do----	U	35	Winter 1947	T,	150	Irr	Gravel drilled for full depth of well; hardness, 45; chloride, 5 ppm.
16A3	Knowles and Calhoon	Ap,	740	Dr	80	8	---	---	----	----Do----	U	7.52	7-15-48	C,	100	Irr	Hardness, 42; chloride, 5 ppm.
16B1	Claude Winn	Ap,	740	Dg, Dr	74	48-8	---	---	----	----Do----	U	3.91	5-1-33	T,	100	Irr	Dug 13 ft, later drilled to 74 ft; hardness, 45; chloride, 4 ppm.
16K1	P. E. Oliver	Td,	755	Dg, Dr	171	60-8	---	---	----	----Do----	U	25	1948	T,	180	Irr	
16K2	J. B. Rencken	Ap,	745	Dg	24	60	---	10	14	----Do----	U	10-17	1947	C,	300	Irr	
16N2	F. E. Kralman	Ap,	750	Dr	46	8	43	12	10	----Do----	U	7.4	11-7-47	C,	130	Irr	L.
								32	9	----Do----							
								44	2	----Do----							
16P2	William Rand	Ap,	749	Dr	71	8	48	62	9	----Do----	U	9	9-5-52	T		D, Irr	Tpd 400 gpm with dd 65 ft.
17E1	C. A. Burggaff	Ap,	680	Dg, Dr	60	8	---	50	10	Gravel, loose	U	-----	-----	J,	5	D	Cemented gravel 30-50 ft is "dry."
17F1	V. M. Anderson	Ap,	675	Dr	220	10	---	---	----	----Do----	U	20	1948	C,	100	D, Irr	
17G1	L. Davin	Ap,	670	Dr	95	10	17	60	35	----Do----	U	6	1948	N		Irr	Only gravel drilled below 16-ft depth.
18B1	George Locker	Ap,	674	Dg	25	36	25	---	----	----Do----	U	20.25	5-11-33	------		D	
18B2	George Locker	Ap,	674	Dr	226	12-10	204	20	11	----Do----	U	32	11- -56	------		Irr	Tpd 350 gpm with dd of 150 ft.
								169	13	----Do----							
18M1	R. E. Bean	Ap,	666	Dg	26	48	26	---	----	----Do----	U	18.07	11- -56	C,	10	D	
18Q2	D. Christerson	Ap		Dr	290	12-10	290	68	217	Gravel	U	67	9-1-57	------		Irr	Clay underlies aquifer; tpd 250 gpm with dd of 112 ft.
19G1	Harp Estate	Ap,	683	Dg	12	24	12	---	----	----Do----	U	4.35	6-6-33	P		D	
19K1	J. E. Myers	------		Dr	200	8	81	18	182	----Do----	U	50	3-18-58	------		Irr	Tpd 128 gpm with dd of 95 ft.
19L1	J. B. Heitsuman	T,	685	Dr	170	8	---	---	----	----------	--	------	------	T,	200	Irr	Hardness, 80; chloride, 8 ppm.
19N1	Mrs. M. Graves	T,	685	Dr	58	8	---	56	2	Gravel	U	------	------	J,	35	D	Cemented gravel 26-ft thick and 30 ft of soil and silt above aquifer. Shallow well typical of Umapine district.
19R1	J. E. Myers	T,	727	Dg	20	84	---	---	----	----Do----	U	3.39	5-6-33	C,	250	Irr	Tpd 250 gpm with dd of 15 ft; hardness, 50; chloride, 5 ppm.
20G1	J. E. Courtney	T,	734	Dg, Dr	22-?	60-?	---	---	----	----Do----	U	1.25	5-15-33	C		D, Irr	WL fig. 13.
20Q1	R. P. Lile	T		Dg	38	60	---	---	----	----Do----	U	27.11	7-26-33	C		Irr	
21B1	Fruitvale School Dist.	Ap,	758	Dr	41	6	---	---	----	----Do----	U	16.76	6-23-33	J,	10	PS	
												23.0	7-19-48				
21D1	D. E. Kralman	------		Dr	67	8	67	58	9	----Do----	U	10	5-12-58	------		Irr	Gravel from 4 ft to bottom, all compact except in aquifer.
21H1	---- Behnke	Ap		Dg	19	66	---	12	7	----Do----	U	14.94	5-15-33	T,	200	Irr	Hardness, 70; chloride, 5 ppm.
22F1	T. Ferhenbacher	T,	800	Dr	300	12	90	175	5±	Gravel, cemented	C	80	1933	T,	200	Irr	Owner reports basalt bedrock struck at 300 ft; hardness, 45; chloride, 4 ppm.
								275	5±	[illegible]							

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
23C1	E. E. Stevens	Ap, 800	Dg, Dr	50	60-8	---	49 33	1 2	Gravel -----Do-----	U	6	1933	J	D	
23D1	E. E. Stevens	T, 825	Dr	1,007	8-4	800	687	48	Basalt	C	+21	1948	T, 150	Irr	Hardness, 25, chloride, 4 ppm; L.
23M1	B. J. Owen	Ap, 826	Dr	12	1¼	---	---	----	Gravel	U	3.7	6-1-33	P	S	
24C1	William Pomeringin	Ap, 851	Dg	34	108-48	---	---	----	-----Do-----	U	29.84	8-22-32	N	D	
24M1	W. K. Nixon	Ap, 845	Dr	60	8	---	9	51	-----Do-----	U	1.42	7-16-48	C, 100	Irr	Well located in spring area; hardness, 25; chloride, 4 ppm.
24P1	George Nelson	Ap, 851	Dg	11	48	---	---	----	-----Do-----	U	3.46	6-2-33	P	D	Well located in spring area.
24Q1	George Ransom	Ap, 860	Dg, Dr	165	72-10	45	28	47	-----Do-----	U	14	7- -46	C	D, Irr	WL fig. 14.
25B1	D. Goodman	Ap, 870	Dg, Dr	402	60-8	54	15	12	-----Do-----	U	-----	------	C, 180	D, Irr	Hardness, 30; chloride, 3 ppm; L.
25C3	H. M. Williams	Ap, 868	Dg, Dr	56	48-6	---	---	----	-----Do-----	U	9.90 7.85	7-24-33 7-23-48	C, 100	Irr	
25D1	M. Clarkin	Ap, 870	Dg	24	60	8	---	----	-----Do-----	U	10.17 5.55	7-21-33 7-23-48	C	D, Irr	
25E1	---- Duff	Ap, 888	Dg	26	60	12	---	----	-----Do-----	U	19.85 15.33	7-24-33 7-23-48	C	Irr	
25M2	---- Strumpler	Ap, 902	Dg	46	72	14	---	----	-----Do-----	U	28.80	7-27-33	C	Irr	
25N1	Demaris (formerly)	Ap, 919	Dg	36	48	---	---	----	-----Do-----	U	32.60 28.57	7-24-33 7-24-48	P	D	
25N2	Jerome Hill	Ap, 920	Dg	58	72	15	---	----	-----Do-----	U	39.43 30.06	8-22-32 7-23-48	C	Irr	
25P1	Hayden Estate	Ap, 907	Dg, Dr	90	72-8	---	40	50	-----Do-----	U	11.58	5-9-33	T, 100	Irr	Hardness, 32; chloride, 3 ppm.
25R1	Starkel (formerly)	Ap, 906	Dg	25	72	12	---	----	-----Do-----	U	1.24	5-8-33	J, 5	D	Well is in spring area.
25R3	George Ransom	Ap, 910	Dr	458	8	56	122	38	-----Do-----	U	10	4-17-45	------	Irr	Drill penetrated clay 150-262 ft, cemented gravel and boulders to 400 ft, and clay and rock (basalt bedrock?) on to bottom.
26C1	John Starkel	Ap, 858	Dg	19	60	12	---	----	-----Do-----	U	12.55 1.50	8-22-32 7-23-48	C, 300	Irr	
26C2	Earl Ransom	Ap, 868	Dg, Dr	46	72-8	---	---	----	-----Do-----	U	14.82 13.48	5-8-33 7-21-48	C, 250	Irr	
26E1	Dan Finley	Ap, 860	Dg, Dr	63	72-8	---	---	----	-----Do-----	U	17.02 14.29	7-26-33 7-21-48	------ C, 100	-- Irr	
26F1	A. Avey	Ap, 880	Dg	32	60	---	---	----	-----Do-----	U	24.94 18.78	8-22-32 7-21-48	C	Irr	
26P1	C. Morse	Ap, 909	Dg	74	42	8½	---	----	-----Do-----	U	38.75	8-22-32	C	D	Deepened from 42-ft level, in 1944.

26Q1	---- Propeck	Ap,	910	Dg, Dr	64	60	18	---	----	Gravel	U	33.95	7-31-33	C,	300	Irr	Hardness, 32; chloride, 3 ppm.
27B1	E. A. Knopf	Ap,	845	Dg, Dr	220	60-8	---	---	----	-----Do-----	U	-----	-------	C,	300	Irr	Hardness, 45; chloride, 6 ppm.
27D1	C. M. Bixby	Ap,	832	Dg	12	72	---	---	----	-----Do-----	U	2.55 2.82	5-8-33 7-21-48	C		Irr	
27H1	J. E. Kessler	Ap,	860	Dg, Dr	56	48-6	46	15	19	-----Do-----	U	15.56	7-26-33	C,	400	Irr	Drilled 6-inch to 56 ft; yielded no additional water; now plugged; hardness, 45; chloride, 4 ppm; L.
27L1	M. E. Moon	Ap,	852	Dg, Dr	31	30-6	---	---	----	-----Do-----	U	12.68 12.69	5-8-33 7-21-48	C		D	
27N2	Mrs. C. B. Harris	Ap,	865	Dg, Dr	114	72-8	17 110	30 4±	----	-----Do-----	U	17.17	6-7-33	C,	200	Irr	Two drilled wells in dug well. Older "dry" one passed through blue clay from 350 to 450 ft and into basalt bedrock to 701 ft.
27Q1	John Budd	Ap,	885	Dg, Dr	73	72-8	---	---	----	-----Do-----	U	32.62	8-22-32	C,	300	Irr	Hardness, 50; chloride, 6 ppm.
27Q3	C. Feigner	Ap,	890	Dr	480	8	60	---	----	-----Do-----	U	30	8-20-58	--------		Irr	Tpd 400 gpm with dd of 5 ft; L.
27R1	Frank Derrick	Ap,	890	Dg	34	60	11	---	----	-----Do-----	U	25.80 23.20	7-26-33 7-21-48	N		N	
28D1	Mrs. C. Smiley	Ap,	800	Dr	1,050	12	---	---	----	-----Do-----	--	-----	-------	N		N	Entered clayey and broken bedrock about 840 feet; no water obtained in basalt.
28H1	W. J. Rand	Ap,	830	Dg	16	48	12	11	4	-----Do-----	U	-----	-------	-------		--	
28K1	George Preston	Ap,	824	Dg	15	60	---	9	6	-----Do-----	U	7.50 9.01	6-5-33 7-20-48	J,	5	D	Water level same as nearby spring.
28N1	McKnight Estate	Ap,	817	Dg	37	84	16	---	----	-----Do-----	U	18.35 14.72	8-22-32 7-20-48	------		N	WL fig. 13.
28Q1	C. O. Wheeler	Ap,	820	Dr	73	8	---	---	----	-----Do-----	U	-----	------	T,	250	Irr	
28R1	J. M. Hanson	Ap,	825	Dr	200	8	---	---	----	------------	--	-----	------	T,	200	Irr	Hardness, 60; chloride, 10 ppm.
29B1	C. E. Eyller	Ap		Dg	29	72	---	---	----	Gravel	U	-----	------	C,	200	Irr	Drill hole in well to 80 ft yielded no additional water; hardness, 65; chloride, 6 ppm.
29D1	Everett Miller	Ap		Dr	340	14	---	---	----	------------	--	14	7-24-46	T,	250	Irr	Hardness, 55; chloride, 5 ppm.
29J1	R. E. Edwards	Ap		Dg,	57+	60-6	---	---	----	Gravel	U	12.92	7-20-48	C,	200	Irr	Drill hole extends beyond the 57-ft dug well.
29K1	L. R. Edwards	Ap		Dg, Dr	30	60	---	---	----	-----Do-----	U	9.58	7-26-33	C,	200	Irr	Hardness, 65; chloride, 6 ppm.
30C1	A. F. Riggle	Ap,	700	Dr	240	8	61	35 212	7 18	-----Do-----	U	14	5-11-55	------		--	Tpd 160 gpm with dd of 89 ft; L.
30L1	J. Linebaugh	Ap		Dg	29	72	13	---	----	-----Do-----	U	6.36 9.17	5-6-33 7-20-48	N		N	
30M1	T. Shepherd	Ap,	690	Dg	30	60	10	---	----	-----Do-----	U	19.16	5-6-33	J		D	
30M2	G. L. Simmons	Ap,	695	Dr	40	6	39	---	----	-----Do-----	U	21.11	5-6-33	------		D	
31A1	Fred Phillips	T		Dr	118	8	---	---	----	-----Do-----	U	53.0	7-20-48	J		D	Hardness, 155; chloride, 4 ppm.
31A2	Fred Phillips	Td		Dr	700	6	---	---	----	Basalt	C	-----	1910±	N		N	Capped and not used because of failure to flow; known as "Old John Hall" well.
31B1	Fred Sommers	Td		Dr	62	6	---	---	----	Gravel	U	-----	------	J		D	
31K1	Clark Key	Ap		Dr	970	12-8	748	625	----	Basalt	C	+20 5-10	1951 11- -54	T,	400	--	Entered basalt at 362 ft, basalt badly fractured; lost flowing pressure and part of yield in 1954.
32D1	Robert Dickerson	Td		Dr	140	----	---	---	----	------------	--	-----	------	D		--	Nearby 340-ft well obtained less water.
32E1	Ivor Williams	-------		Dr	715	10-8	635	697	18	Basalt	--	-----	------	------		Irr	Tpd 500 gpm with dd of 28 ft; entered basalt at 520 ft.
32H1	Harry Phillips	Ap		Dg	34	66	---	---	----	Gravel	U	14.59	7-26-33	C,	300	Irr	

Table 1.--Records of representative wells in the Walla Walla River basin--Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 6 N., R. 35 E.--Continued								
33J1	J. Nelson	Ap, 875	Dr	442	8	---	415	27	Basalt	C	15.12	6-10-33	T, 200	Irr	Hardness, 45; chloride, 5 ppm; L.
33K1	H. O. Yates	Ap, 865	Dg, Dr	66	8	---	62	4	Gravel	U	------	------	------	—	L.
33M1	Harry Phillips	Ap, 833	Dg, Dr	81	60-8	---	---	----	-----Do-----	U	32.31	5-6-33	C, 300	Irr	One of three wells that irrigate 100 acres; hardness 65; chloride, 4 ppm.
34C1	Roose Estate	Ap, 882	Dg	54	96	20	---	----	-----Do-----	U	32.33	5-6-33	C, 250	Irr	WL fig. 13.
34H1	F. Feigner	Ap, 900	Dg	34	96	9	---	----	-----Do-----	U	16.39	7-21-48	C, 150	Irr	
34K1	C. W. Rasmussen	Ap, 910±	Dg, Dr	225	8	225	52	8	-----Do-----	U	37	1-19-48	C, 100	D, Irr	L.
34P1	F. Wollenschlaeger	Ap, 916	Dg	36	48	15	35	1+	Gravel, loose	U	16.10	5-8-33	C, 300	Irr	Penetrated 15 ft loose and 20 ft cemented gravel over aquifer; nearby drilled well logged cemented gravel with clay interbeds from 20 to 112 ft.
34P3	Alex Duff	Ap, 895	Dg, Dr	410	60-8	410	410	1+	Basalt	C	10	1925±	C, 300	D, Irr	Hardness, 50; chloride, 5 ppm; L.
34R1	Carl Philpott	Ap	Dg	35	48	---	---	----	Gravel	U	14.30	7-22-33	C, 200	Irr	Goes dry each December.
34R2	Fred Bull	Ap	Dg	35	48	12	---	----	-----Do-----	U	------	------	C, 200	Irr	Hardness, 75; chloride, 24 ppm.
35G1	Elba Rogers	Ap, 933	Dg, Dr	98	54-6	---	---	----	-----Do-----	U	32.37	8-22-32	T, 200	Irr	
35L1	J. L. Anderson	Ap, 947	Dg	27	48	---	---	----	-----Do-----	U	18.10 13.96	5-8-33 7-21-48	------	D	
35L2	Mrs. C. H. Ansbach	Ap, 953	Dg, Dr	135	48-6	---	1	60	-----Do-----	U	12.92 11.91	8-22-32 7-21-48	------	Irr	Penetrated gravel to 60 ft and clay to bottom.
36C1	J. Busch	Ap, 928	Dg	40	60	---	---	----	-----Do-----	U	33.54	7-21-33	------	Irr	
36D1	John Roloff	Ap, 930	Dr	700	10	---	---	----	------------	--	------	------	------	--	Old well, largely caved in.
36E1	M. Grogan	Ap, 935	Dr	740	8	500	550	190	Basalt	C	100	1931	T, 150	Irr	Penetrated thick zone of blue clay; basalt struck at 450 ft.
36H1	Walter Hermann	Ap, 932	Dg	44	48	18	---	----	Gravel	U	13.20	5-8-33	------	D	WL fig. 12.
									T. 6 N., R. 36 E.						
1C1	C. O. Levin	S, 1,200	Dr	210	6	---	---	----	------------	--	20	10-26-46	J, 15	D	Hardness, 80; chloride, 3 ppm.
3A1	B. D. Rosor	S, 1,060	Dr	290	18	286	284	5	Basalt	C	44 50 54	7-11-51 4-15-55 4-18-56	T	Irr	Tpd 1,500 gpm with dd of 54 ft; L.
4A2	V. V. Duff	S, 1,000	Dr	295	8	140	290	----	Gravel or rubble	U	59	6- -47	T	Irr	Tpd 40 gpm with dd of 140 ft.

4D1	J. W. Henderson	S,	990	Dr	150	8	---	---	----	------------	--	----	------	C		Irr	
4D2	Ralph Titus	S,	996	Dg	23	96	---	---	----	Gravel	U	13.30	10-29-46	C,	5	D	
4F1	O. M. McCubbins	S,	970	Dr	115	6	---	---	----	----Do----	U	48.75	11-19-46	J,	7	D	Hardness, 60; chloride, 3 ppm; Ca.
4L1	C. W. Hoss	S,	984	Dg	48	60	---	---	----	------------	U	44.04	5-16-33	P		D	Hardness, 80; chloride, 4 ppm.
4N1	William Hill	S,	940	Dg	43	48	---	---	----	Gravel	U	34.90	11-19-46	J,	12	D	Hardness, 55; chloride, 3 ppm.
4P1	W. E. Morrison	S,	955	Dr	280	6	---	---	----	----Do----	--	14	1946	J,	15	D, Irr	Hardness, 55; chloride, 3 ppm.
4P2	L. O. Long	S,	970	Dg, Dr	96	60-6	---	---	----	----Do----	U	8	1945	C		D, Irr	Tpd 50 gpm with dd 7 ft.
4P3	W. E. Morrison	S,	955	Dr	838	8	553	547	291	Basalt	U	10 130	6- -47 9-4-50	T,	300	Irr	Tpd 270 gpm with dd of 108 ft; basalt found at 547 ft.
5F2	Franco Veneri	Ap,	880	Dg	40	36	---	---	----	------------	U	30	12-5-46	C,	30	Irr	
5G1	Frank L. Rizzuti	Ap,	890	Dr	108	6	---	---	----	------------	U	5	12-5-46	C,	80	Irr	
5G3	Frank L. Rizzuti	-------		Dr	675	10-6	585	630	45	Basalt	--	----	------	T		Irr	Tpd 380 gpm with dd of 4 ft; reached basalt at 538 ft.
5M1	R. E. Richardson	Ap,	875	Dr	616	8	510	500	116	----Do----	C	50	6- -48	T,	450	Irr	Hardness, 50; chloride, 6 ppm.
5R1	Baker & Baker	Ap,	930	Dg	36	96	---	---	----	------------	P	29.94	12-11-46	C		Irr	
5R2	Baker & Baker	-------		Dr	1,817	16-12	814	---	----	Basalt	--	115.25	2-22-58	T		Irr	Tpd 1,580 gpm with dd of 44 ft.
6C1	Eugene Tausick	Ap,	870	Dg	20	72	---	---	----	------------	U	12.63	12-19-46	C		D, Irr	
6C2	Eugene Tausick	Ap,	870	Dr	954	8	---	---	----	Basalt	C	----	------	------		Irr	Tpd 500 gpm with dd of 50 ft.
6D1	Eugene Tausick	Ap,	860	Dg	30	84	---	---	----	Gravel	U	16.56 15.55	12-19-46 3-24-48	N		N	
6D2	Eugene Tausick	Ap,	880	Dr	641	6	---	---	----	Basalt	C	30 41.7 41.1 39.4 40.1 40.4 40.9 40.9 41.3	1940 4-20-55 9-21-55 4-17-56 2-27-57 2-21-58 4-24-59 10-28-59 5-11-60	------		Irr	Flowed when drilled in 1912.
6F1	Milo Gray	Ap,	860	Dr	835	8	---	810	25	----Do----	C	18 36.9 28.8 26.2 27.6 26.0 26.3 25.3 27.0	1940 4-20-55 9-21-55 4-12-56 10-6-56 2-27-57 2-21-58 4-24-59 5-11-60	T		Irr	Did not flow when drilled.
6M1	Jess Courtney	Ap,	806	Dr	610	6	---	565	25	Basalt	C	F +.1 50.9 7.4 7.0	3-25-48 4-17-55 10-6-56 2-26-57 2-21-58	C,	500	Irr	Had 70 pounds pressure when drilled in 1910, now sealed up; hardness, 60; chloride, 4 ppm.
6P1	Alfonzo Curcio	Ap,	840	Dr	680	6	---	---	----	----Do----	C	20 21.2 71.0 26.5	12-6-46 4-20-55 9-22-55 4-17-56	T,	120	Irr	Flowed from 1908, when drilled, until about 1930.
6Q1	J. W. Yenny	Ap,	870	Dr	59	8	30	---	----	Gravel	U	12	1945	J,	32	Irr	L.
6R3	County School Dist. No. 9	Ap,	877	Dr	100	6	---	---	----	----Do----	U	25	12-6-46	J,	10	D	Braden School well.

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
								T. 6 N., R. 36 E.—Continued							
7A1	J. W. Yenny, et al	Ap, 860	Dr	778	6	---	---	----	Basalt	C	25	12-5-46	T, 300	Irr	Former Rizzuti well. Irrigates 100 acres.
											41.7	4-20-55			
											88.0	9-22-55			
											46.2	4-17-56			
7D1	Earl Prusia	Ap, 790	Dr	560	6	400	---	----	-----Do-----	C	+34	5- -53	C, 300	Irr	Flows from both casings.
					5	500			-----Do-----		+4.3	4-17-55			
											16.3	10-26-55			
											12.6	4-17-56			
											16.6	10-6-56			
											13.6	2-26-57			
											13.6	2-21-58			
											13.9	4-24-59			
7E1	John Schumacher	------	Dr	750	8-6	532	---	----	-----Do-----	C	25.9	4-17-55	T, 250	Irr	Entered basalt at 511 ft; tpd 250 gpm with dd of 50 ft.
											70.9	9-21-55			
											31.1	4-17-56			
											71.2	10-6-56			
											32.1	2-26-57			
											31.7	2-21-58			
											56.7	10-28-59			
7M1	Hancock & Yenny	Td, 850	Dr	680	6	---	---	----	-----Do-----	C	F	12-6-46	C, 450	Irr	Drilled in 1912; in 1953 tpd 266 gpm with dd of 3 ft.
											2	1953			
8D2	---- Hahn	Ap, 870	Dr	670	14-6	500	500	170	-----Do-----	C	57.66	7-14-48	N	Irr	Reported 355 ft blue clay overlying basalt; in 1953 tpd 740 gpm with dd of 93 ft.
8M1	B. E. Hiller	Ap	Dr	641	12	495	589	52	-----Do-----	C	108	8-22-54	------	Irr	Entered basalt at 482 ft; tpd 750 gpm with dd of 50 ft.
8N1	Ed Lyday	Ap, 905	Dr	115	6	115	---	----	Gravel	U	50	12-7-46	J, 5	D	Hardness, 50; chloride, 4 ppm.
9B1	B. M. Van Donge	S	Dr	617	8	362	590	25	Basalt	C	35	5-7-48	T	Irr	Entered basalt at 358 ft; tpd 500 gpm with dd of 200 ft.
9L1	Baker & Baker	S, 1,000	Dr	1,155	12-10	939	986	1,155	-----Do-----	C	92	11-5-45	T, 1,200	Irr	Fix Farm well No. 1' hardness, 45; chloride, 4 ppm; L.
											89	4-16-55			
											110	5-1-56			
											130	10-6-56			
											100	4-24-59			
											104	5-10-60			
9P1	Baker & Baker	S, 1,000	Dr	2,061	16-5	---	---	----	-----Do-----	C	97	12-4-46	T	Irr	Fix Farm well No. 2; Ca; L.
											101	4-16-55			
											145	10-5-56			

											125	2-28-57			
											148	10-21-58			
											115	4-24-59			
10E1	Lawrence Frazier	S, 1,050	Dr	807	12-10	224	46	176	Gravel	C	126	4-10-46	T, 300+	Irr	L.
							224		Basalt						
10J1	Mrs. Eva Moss	S, 1,122	Dr	184	6	---	---	----	-------------	--	100(?)	1946	P, 3	D	Hardness, 55; chloride, 3 ppm.
10J2	Mrs. Eva Moss	S, 1,135	Dg	60	36	---	---	----	Gravel	P	13.97	10-29-46	P, 2	O	Hardness, 40; chloride, 3 ppm.
10J3	J. D. Garred	--------	Dr	640	10	221	147	----	Basalt	U	117	8- -55	------	Irr	Tpd 1,200 gpm with dd of 21 ft.
					8	516-46									
12H1	G. Copeland	S, 1,320	Dr	795	16	263	250	----	-----Do-----	U	145	3- -53	------	Irr	Tpd 850 gpm with dd of 84 ft.
13C1	Emmett Lynch	S, 1,300	Dr	135	6	62	---	----	-----Do-----	--	80	8-10-44	J, 6	D	Ca; L.
13C2	C. R. Hagert	S, 1,320	Dr	67	8	65	60	----	Basalt (?)	C	F	10-23-46	------	Irr	Flowing at estimated rate of 70 gpm in 1946; hardness, 45; chloride, 3 ppm.
15C1	August Erdman	S, 1,080	Dr	100	6	---	---	----	------------	--	65	1946	P, 3	D	Hardness, 65; chloride, 4 ppm.
16A1	Otto Erdman	S, 1,050	Dr	160	6	---	---	----	------------	--	32	1946	------	D	
16N1	J. M. Buchanan	Uv	Dr	110	6	---	---	----	------------	--	20	1946	J, 10	D	
17G1	J. M. Buchanan	S, 930	Dg, Dr	76	60-10	---	---	----	------------	U	47.30	5-12-33	------	N	Well partially filled and dry in 1946.
18K1	J. E. Wiseman	S, 880	Dr	112	6	---	---	----	------------	--	-----	------	J, 3	D	
19B1	Elmer Ferguson	Ap, 860	Dr	712	14-10	400	600	112	Basalt	C	24	3- -49	T, 1,760	Irr	Dd 7 ft at pump capacity.
19C1	Elmer Ferguson	Ap, 838	Dg	24	60	---	---	----	Gravel	U	17.42	6-7-33	P, 2	D, S	Hardness, 75; chloride, 5 ppm.
19M2	D. D. Nicholas	Fp, 837	Dn	11	1¼	---	---	----	Gravel and sand	U	6.91	7-21-33	------	N	
20Q1	W. H. Till	S, 935	Dr	385	6	359	360	----	Basalt	C	90	7-30-45	T, 80	D, Irr	Hardness, 65; chloride, 5 ppm; L.
22N1	Kirk Casper	Uv	Dr	367	4	---	---	----	------------	--	125	1946	P, 7	D	Hardness, 95; chloride, 5 ppm.
23N1	Harry Struthers	Uv, 1,300	Dr	238	6	12	100	----	Basalt	U	228	1946	P, 3	D	Hardness, 85; chloride, 7 ppm.
25A1	A. E. Nibler	U, 1,653	Dr	155	6	---	---	----	-----Do-----	P	55	1940	P, 1	D, S	Hardness, 30; chloride, 4 ppm.
29L1	G. M. Fulton	S, 915	Dr	163	6	---	---	----	-----Do-----	C	20	1946	P, 5	D	Flowed when first drilled in 1905. Hardness, 80; chloride, 5 ppm.
30E1	---- Heidenrich	Ap, 855	Dr	747	8	400	740±	7±	-----Do-----	C	19.0	6-7-33	T	Irr	Entered basalt at about 300 ft; some water in basalt cased off.
30E2	---- Heidenrich	Ap, 865	Dr	285	6	285	---	----	-----Do-----	C	19.5	6-7-33	------	N	Basalt entered at 285 ft.
30N1	Dan Colley	Ap	Dr	60	6	58	---	----	------------	U	-----	1946	J, 10	D	
30N2	Dan Colley	Fp	Dg	32	72	---	---	----	Gravel	U	11.59	12-9-46	C, 300	Irr	
30N3	Laura E. Davis	Fp	Dg, Dr	90	6	90	13	1	-----Do-----	U	12.8	12-9-46	C	Irr	
31D1	John Hickman	Fp, 907	Dg	22	60	---	---	----	-----Do-----	U	0.09	5-8-33	------	Irr	
31D2	John Hickman	Td	Dr	100	8	---	---	----	-----Do-----	U	30	12- -46	J, 6	D	
31E1	K. C. Turner	Ap	Dg, Dr	140	6	---	---	----	------------	--	24.84	12-9-46	J, 6	D	Hardness, 200; chloride, 12 ppm.
31L1	Milton Nursery	Ap, 955	Dr	2,000	12-8	537	---	----	Basalt	C	115	1930	T, 800	Irr	L.
							140	25	Gravel						
33B1	---------------	S, 1,052	Dg	81	40	---	---	----	------------	U	62.47	12-7-46	J, 10	D	
34R1	John Casper	S	Dr	306	6	---	---	----	Basalt	--	200	1948	P	N	
									T. 6 N., R. 37 E.						
4B1	E. Pribilsky	Uv, 1,700	Dr	200	8-6	118	194	6	Basalt	C	+46	7-16-47	N	D	Hardness, 45; chloride, 10 ppm.
4J1	Steve Maxson	Uv, 1,950	Dg	35	24	---	---	----	------------	U	8.95	10-22-46	P, 1	D	Hardness, 75; chloride, 3 ppm.
4K1	Delbert Barger	Uv, 1,770	Dr	240	6	---	---	----	Basalt	U	50	1917	P, 5	D, S	Used to supplement spring.
5A1	L. C. Lyons	S, 1,700	Dr	814	14	103	87	727	-----Do-----	U	75	6- -48	T	Irr	Tpd 630 gpm with dd of 75 ft.

Table 1.—Records of representative wells in the Walla Walla River basin--Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s)			Ground-water occurrence	Water level		Type of pump and yield (gpm)	Use	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material		Feet below datum	Date			
								T. 6 N., R. 37 E.--Continued							
5F1	Baker & Baker	S, 1,560	Dr	612	12	125	417	195	Basalt	C	+176 +169 +177 +182 +179	12-10-46 3-25-52 2-22-55 2-28-57 2-22-58	N	Irr	Well on former Sweazy quarter section; test flow 2,390 gpm in 1947; hardness, 45; chloride, 2 ppm Aug. 2, 1946; hardness, 40; chloride, 9 ppm Oct. 1947; hardness, 37; chloride, 5 ppm July 15, 1948; WL fig. 9; Ca; L.
5R1	E. L. Forest	Uv, 1,700	Dr	103	6	---	---	----	------------	U	-----	------	P, 10	D, S	Hardness, 70; chloride, 3 ppm.
6C1	O. M. Shelton	S	Dr	300	8	150	158	142	Basalt	C	13	1952	T, 200	Irr	Tpd 220 gpm with dd of 19 ft.
7F1	M. J. Lee	S, 1,440	Dg	60	48	---	---	----	Gravel (?)	U	23.57	10-23-46	C, 10	D, S	Hardness, 90; chloride, 4 ppm.
7Q1	Clyde Garland	S, 1,650	Dr	290	12	---	---	----	Basalt	C	38	10-23-46	T, 600	D, Irr	Reported to pump 700 gpm.
7Q2	Clyde Garland	S, 1,620	Dr	208	8	---	---	----	-----Do-----	C	F	10-23-46	Sy	D	Hardness, 45; chloride, 4 ppm.
18P1	E. R. Davis	Uv, 1,500	Dr	162	6	73	152	10	Gravel	U	130	1945	J, 7	D	Hardness, 75; chloride, 6 ppm; L.
20L1	Steven Ringhofer	S, 2,000	Dr	200	6	---	---	----	Basalt	C	-----	------	P, 3	--	Owner reports water level is near surface.
								T. 7 N., R. 33 E.							
10A1	DeRuwe and Weber	Ap, 550	Dr	159	6	30	144	15	Basalt	C	90	1940	P, 5	D, S	L.
24A1	H. Colley	S, 505	Dr	160	6-4	---	50	110	-----Do-----	C	25	1944	P, 5	D, S	Pumps dry in 3 hours.
24M1	---- Hailson	U, 610	Dr	265	6	---	---	----	-----Do-----	--	-----	------	P, 5	D, S	Pumps dry in 3 hours.
25P1	R. Taylor	T	Dr	100	10	73	70 79	5 11	Gravel	U	70	9-18-51	T, 100	Irr	One of 4 similar wells.
26P1	William Schiffman, Jr.	T	Dr	80	8	80	60	18	Sand and gravel	U	55	5-1-55	------	Irr	Tpd 220 gpm with dd of 23 ft.
26Q1	A. A. Long	T, 500	Dr	125	10	125	70	55	Gravel	U	63.2	10-24-47	N	N	Pumped only 25 gpm on test; L.
28G1	R. L. Andrews	T	Dr	126	10	126	22 119	43 7	-----Do----- -----Do-----	U	24	1957	------	Irr	Tpd 400 gpm with dd of 60 ft.
31R1	---------------	Td, 500	Dr	97.5	7-4	---	---	----	------------	--	96.1	11-24-48	N	N	Old homestead well.
32M1	X. Michellod	Td, 475	Dr	300	----	---	200	100	Basalt	C	10	1940	------	D, S	
33K1	E. Carlson	Ap, 435	Dr	60	6	---	---	----	Gravel	U	5±	1935	C, 300	Irr	Supplies water for 30 acres. Very good shallow well.
33L1	E. Carlson	Ap, 435	Dr	135	6	---	---	----	Basalt (?)	C	6	1948	------	D	
33N1	W. P. Workman	Ap, 430	Dr	275	5	---	265±	----	Basalt, porous	C	F	11-24-48	J	D, S	Water level estimated as 4 or 5 ft above surface; former Stockdale well.
34H1	W. J. Webb	Td, 470	Dg, Dr	97	60-10	78	16	12+	Sand	U	15.7	10-24-47	C, 150	Irr	L.
34L1	Union Pacific Railroad	Ap, 442	Dr	387	6	387	260 387	10	Gravel Basalt	C	----	10-29-48	C, 75	Ind	Hardness, 30; chloride, 7 ppm; L.

34L2	Harry Nulph	Ap,	440	Dr	280	6	---	275	5	Basalt	C	4	1920	C,	10	D	Entered basalt at 275 ft.
34N2	R. R. Dodd	Ap,	435	Dr	285	8-6	255	248	37	-----Do-----	C	6	1940	T,	7	D	L.
34P1	Darigold Creamery	Ap,	440	Dr	65	6	---	60	5	Gravel	U	-----	------	J,	10	Ind	Water said less alkaline than shallower wells nearby. Hardness, 75; chloride, 11 ppm.
34P2	H. H. Taylor	Ap,	440	Dr	30	1½	30	---	8	-----Do-----	U	-----	------		10	D	Co.
35B1	N. A. Davis	Td,	475	Dg, Dr	70	60-10	70-	40	30	Sand	U	40	1947	C,	100	Irr	
35C1	Ruby May	T,	500	Dg, Dr	90	60-10	90	70	20	-----Do-----	U	70	1947	C,	150	Irr	Used for irrigation of 50 acres.
35E2	Clarence Hansen	Td,	460	Dg, Dr	55	60-20	55	37	21	-----Do-----	U	34.2	10-24-47	C,	220	Irr	
35F1	Christina Hansen	Ts,	490	Dg	85	60-10	85	70	85	-----Do-----	U	70	1947	C,	200	Irr	
36C1	R. Taylor	Ap		Dr	65	10	54	4	61	Sand and gravel	U	4	2-4-52	T		Irr	Tpd 110 gpm with dd of 44 ft.
										T. 7 N., R. 34 E.							
3B1	C. R. Coyle	Uv,	820	Dr	500	6	---	---	----	Basalt	--	-----	------	P,	5	D,S	Hardness, 65; chloride, 6 ppm.
13P1	P. F. Hedger	Ap,	605	Dr	190	6	---	---	----	Basalt (?)	--	-----	------	P,	5	D,S	Hardness, 100; chloride, 10 ppm.
20J1	J. B. Buckley	Td,	550	Dr	240	8	40	35	5	Gravel	P	20	1943	P,	5	D,S	Hardness 60; chloride, 8 ppm.
								50	50	Basalt	P	50	1943				
									140	-----Do-----	U	100	1943				
22F1	R. L. Talbot	Ap,	560	Dg	20	60	---	---	----	Alluvium	U	8.3	10-20-47	P,	5	D,S	Hardness, 160; chloride, 12 ppm.
22M1	J. B. Buckley	Ap,	550	Dr	187	6	---	---	----	Basalt	U	18	1945	J,	5	D,S	
22N1	J. B. Hall	Ap,	540	Dr	60	8	57	32	2	Gravel	U	13	12-28-53	T		--	Tpd 465 gpm with dd of 20 ft; 32 ft soil and clay overlies 28 ft of sand and gravel.
								54	6	Sand							
24R1	W. P. Wallace	Tp,	690	Dr	325	6	250	280	45	Basalt	C	80	7- -47	T,	40	D,S	Sand, clay, and gravel drilled to reach basalt at 280 ft. Hardness, 45; chloride, 6 ppm.
25N1	Charles Baker	Td,	600	Dr	1,102	10	180	340	762	Basalt	C	20	Summer 1947	T,	450	Irr	At 300 ft and 800 ft well yielded 35 and 100 gpm, with dd of 100 ft; and 442 gpm with dd of 70 ft at full depth; L.
26Q1	D. Bergerin	Td,	600	Dr	460	12	186	288	172	-----Do-----	C	22	12- -57	T		Irr	Entered basalt at 249 ft; tpd 455 gpm with dd of 146 ft.
27L1	Ray Nibler	Td,	555	Bd	20	6	---	---	----	Sand	U	7.95	10-21-47	P,	5	D,S	Hardness, 130; chloride, 10 ppm.
27L2	Ray Nibler	Td,	555	Dr	87	10	57	9	68	Gravel	U	6	8- -55	------		Irr	Tpd 315 gpm with dd of 38 ft.
28A1	Patrick O'Brien	Ap,	550	Dr	117	6	90	90	27	Basalt	U	102	1945	J,	5	D,S	Hardness, 130; chloride, 8 ppm.
28B1	J. B. Hall	Ap,	520	Dr	88	10	70	35	49	Gravel	U	33	1955	------		Irr	
28C1	J. B. Hall	Ap,	530	Dr	180	6	---	---	---	-----Do-----	--	-----	------	J,	5	D,S	Hardness, 115; chloride, 5 ppm.
29C1	Lowden Johnson	T,	500	Dr	1,200	12-6	610	610	590	-----Do-----	C	73.5	10-21-48	T		Irr	Not used for years because didn't flow; rehabilitated and drilled 12-inch to 800 ft in 1956; tpd 1,056 gpm with dd of 14 ft; L.
29G1	County School Dist. No. 4	Ap,	490	Dr	180	6	---	---	----	-----Do-----	--	-----	------	P,	5	PS	Hardness, 110; chloride, 5 ppm.
29J1	Harold Buckley	Ap,	490	Dr	200	6	---	175±	----	Gravel and sand	U	10	1947	J,	5	D,S	Reported to have entered basalt bedrock for a few ft; hardness, 115; chloride, 9 ppm.
29M1	J. P. Dodd	Ap,	475	Dr	260	6	190	200±	60±	Gravel, cemented (?)	U	32	1940	J,	5	D,S	
31M1	H. Stockdale	Ap,	500	Dr	157	10-6	93	72	6	Sand	U	6	9- -47	P,	35	D,S	
32C1	---- Burgess	Ap,	485	Dr	300	6	---	---	----	------------	--	-----	------	J,	5	D,S	Hardness, 125; chloride, 9 ppm.
33E1	J. E. Talbot	Ap,	510	Dr	115	12	62	53	55	Gravel	U	5	3-1-59	------		Irr	Tpd 525 gpm with dd of 16 ft; L.

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
									T. 7 N., R. 34 E.—Continued						
34N1	G. Dow	Ap, 530	Dr	115	12	85	40	44	Gravel beds in clay	U	10	8-12-59	T	Irr	Tpd 75 gpm with dd of 100 ft.
35A1	Clem Bergevin	Ap, 550	Dr	220	6	200	170	30	Sand, silty	U	1	7- -33	C, 10	D,S	Well penetrated gravels and sand to about 50 ft, mostly blue clay below; hardness, 90; chloride, 8 ppm.
35J1	Clem Bergevin	Ap, 550	Dr	200	6	200	---	----	-----Do-----	U	6.1	10-22-47	N	N	Well drilled in only blue clay and silt.
35N1	D. Bergevin	Td, 550	Dr	428	12-10	428	410	----	Basalt	C	9	5-31-59	T, 600	--	Entered basalt at 365 ft; obtained water at 410 ft; lower part of casing is perforated.
36A2	B. B. Cooley	T, 600	Dr	290	10	91	17	78	Sand and gravel	U	17	10-16-50	------	Irr	Drilled only clay below 95 ft; Tpd 143 gpm with dd of 103 ft.
									T. 7 N., R. 35 E.						
4H1	Ralph Riley	Fp, 725	Dr	173	6	70	170	3	Basalt	C	25	1933	J, 8	D	Sand and silt drilled in upper 45 ft; hardness, 90; chloride, 8 ppm.
7F1	G. Cavalli, et al	Fp, 650	Dg	32	120	25	14	18	Gravel	U	15	5- -27	C, 200	Irr	Tpd 110 gpm with dd of 6 ft.
7Q1	County School Dist. No. 59	Fp, 630	Dr	285	6	---	---	----	Basalt	--	1.7	4-14-55	P	PS	
											10.1	4-18-56			
											10.0	2-26-57			
											45.8	5-10-60			
8A1	Mrs. John Ankeny	Fp, 700	Dr	1,000	12	---	---	----	-----Do-----	C	47.90	10-18-47	R, 10	D	Hardness, 95; chloride, 7 ppm.
8B1	T. Bodmer	Fp, 680	Dr	780	8	---	---	----	-----Do-----	C	55	1957	T	Irr	Tpd 600 gpm with dd of 120 ft.
18D1	Clarence Bergevin	Fp, 625	Dr	275	4	---	180	90	-----Do-----	C	10	1947	J, 5	D,S	Silt and black sand overlies aquifer; hardness, 90; chloride, 7 ppm.
											9.8	2-26-57			
											12.4	2-22-58			
											12.2	10-27-59			
23J1	Remo Fausti	Ap, 810	Dg	21	72	---	12	9	Gravel	U	12.34	5-9-33	C, 5	Irr	
23J2	Hydro-Irrigation Dist. No. 9	Ap, 810	Dr	618	6	535	535	83	Basalt	C	+20	Winter 1948	T, 7	PS	Serving 30 houses in 1948; old Goss well drilled in 1909; has flowed in winter since 1936 quake; log shows gravel to 165, clay and gravel 165-220, clay 220-535; hardness, 45; chloride, 5 ppm.
23K1	B. W. Blair	Ap, 810	Dg, Dr	350	48-6	350	200± 35	---- 5	Gravel	--	18	3- -48	C, 75	Irr,D	
23M1	Bonneville Power Adm.	Ap, 772	Dr	515	10-8	464	464	51	Basalt	C	59.51	9- -41	50	Ind	Ca; L.
24M1	R. Gluck	Ap, 825	Dr	572	12-8	507	498	74	-----Do-----	C	75	8-10-54	T	Irr	Tpd 255 gpm with dd of 26 ft; drilled mostly in gravel to 150 ft and clay 150-498 ft.

25A1	Artesian Irrigation Dist. No. 8	Ap,	890	Dr	640	6	---	545	107	Basalt	C	+13 36 3 18	1914 7-1-36 8-1-36 3- -48	T,	50	PS	Drilled in 1909; hardness, 90; chloride, 8 ppm.
25A2	Artesian Irrigation Dist. No. 8	Ap,	890	Dr	772	10-8	538	637	772	-----Do-----	C	29	5- -46	T,	250	PD	Drilled in gravel with some clay beds to 220 ft, and clay to 538 ft, where basalt entered; Tpd 495 gpm with dd of 5 ft, when drilled in 1946.
25C1	Joe Aliverti	Ap,	860	Dg	37	72	---	---	----	Gravel	U	12	1945	C,	50	Irr	
25C2	Joe Aliverti	Ap,	860	Dr	250	8	---	---	----	Gravel and sand	C	45	1947	T,	50	Irr	
25F1	James Arbini, et al	Ap,	880	Dr	680	10-8	539	539	141	Basalt	C	8.59 10 61 14 61 16	10-24-46 4-13-55 9-21-55 4-17-56 10-6-56 2-26-57	T,	300	Irr	Hardness, 55; chloride, 4 ppm; L.
25G3	Charles Criscola	Ap,	875	Dg	30	60	---	25	3	Cobble gravel	U	1.53	3-22-48	C,	3	Irr	Supplies water for 18 acres.
25G4	Remo Grassi	Ap,	875	Dr	563	8	511	502	61	Basalt	C	55	7-28-51	T		Irr	
25K1	Green Tank Irrigation Dist. No. 11	Ap,	880	Dr	628	6	600	620	8	-----Do-----	C	20	Winter 1948	T,	350	PS, Irr	About 75 households and 100 acres of irrigation supplied by 2 wells.
25K2	Green Tank Irrigation Dist. No. 11	Ap,	875	Dr	752	10-8	645	555	97	-----Do-----	C	32	5- -58	T;	500	PS, Irr	
25P1	Ponti and Columbo	Ap,	820	Dr	618	6	—	610±	8	-----Do-----	C	F 5.4 9.9 10.2 10.0	3-18-48 4-18-55 4-17-56 2-26-57 2-22-58	C,	350	Irr, S	Hardness, 60; chloride, 4 ppm; L.
25Q1	Green Tank Irrigation Dist. No. 11	Ap,	840	Dr	618	6	590	---	----	-----Do-----	C	-----	-------	T		PS	Used as stand-by; drilled in 1910; originally flowed.
25R1	Louise Satori (former)	Ap,	840	Dn	16½	1¼	16½	13	3¼	Sand	U	13.4	5-16-33	P		D	Water table at level of swale to south.
25R2	A. W. Hawkins	Ap,	845	Dr	214	6	206	---	----	Gravel	U	26	7-28-58	------		D	
26C1	Frank Garrett	Ap,	780	Dg	15±	84	---	8	7	-----Do-----	U	10.1	1-23-48	C,	300	Irr	
26F1	Blalock Irrigation Dist. No. 12	Ap,	780	Dr	650	8	---	---	----	Basalt	C	+35	3- -48	------		--	Supplies 30-40 houses; casing sealed in 1950; hardness, 55; chloride, 4 ppm.
26H1	Orchard Irrigation Dist. 10	Ap,	800	Dr	635	6	---	535	100	-----Do-----	C	5-10(?) F	3- -48 Winter 1952	C		PS	Supplies 24 houses; flowed for one year after the 1936 earthquake; entered basalt at 535 ft; hardness, 52; chloride, 3 ppm.
26M1	---- Lamb	Ap,	760	Dg	19	120	---	8	11	Gravel	U	10.0	5-9-33	C,	250	Irr	Irrigates 10-acre orchard.
26P1	I. C. Ganni	Ap,	760	Dr	550	10	220	---	----	Basalt	C	F	Winter 1920	N		N	Now covered over.
26P2	L. Robinson (former)	Ap,	770	Dg	25	72	---	---	----	Gravel	U	15±	Wintertime	N		N	
26Q1	College Place Irrigation Dist. No. 14	Ap,	780	Dr	570	6	540	535	40	Basalt	C	F	3- -48	------		--	Original artesian discovery well; former Dist. 3 well; casing sealed in 1950; hardness, 55; chloride, 4 ppm.
26Q2	College Place Irrigation Dist. No. 14	Ap,	780	Dr	625	10	546	539	86	-----Do-----	C	F	3- -52	C,	1,000	PS	Replaced 26Q1; L.
26R1	College Place Irrigation Dist. No. 14	Ap,	790	Dr	650	6	---	---	----	-----Do-----	C	30±	1- -48	C,	150	PS	Former Dist. 7 well; hardness, 60; chloride, 4 ppm.
27G1	W. Williams	Ap,	740	Dg	25	30	---	10	15	Gravel	U	10±	1- -48	J		D, Irr	
27K1	J. Freeburn	Ap,	730	Dr	300	8	---	280±	----	-----Do-----	C	-----	------	J		S	
27Q1	Young's Dairy	Fp,	725	Dr	90	6	---	80	----	-----Do-----	C	6	1- -48	J,	10	DS, Ind	

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 7 N., R. 35 E.--Continued								
28K1	H. M. Brown	Fp, 745	Dg	15	48	15	8	7	Gravel	U	9.3	5-17-33	C	D, S	
28N1	R. O. Spenser	Fp, 730	Dr	30	6	30	20	10	-----Do-----	U	10.5	11-5-47	J	D, PS	Clay and sandy clay over aquifer.
28R1	C. A. Logan	Ap, 740	Dr	134	8	111	119	15	-----Do-----	U	5	2-2-51	T	Irr	Tpd 180 gpm with dd of 120 ft.
29P1	Ed Stiller	Ap, 650	Dr	64	4	64	---	----	-----Do-----	U	16.5	5-17-33	C	D, S	
29Q1	J. F. Kamm	Ap	Dr	165	10	58	34	126	-----Do-----	U	27	8-8-44	T	Irr	Tpd 120 gpm with dd of 90 ft.
30M1	---------------	Td, 640	Dr	52	8	---	---	----	-----------	--	25.0	10-20-47	------	--	Well at abandoned farmstead.
31E1	H. Ringhofer	Fp, 590	Dn	16½	1¼	16½	---	----	Sand	U	10.54	5-17-33	N	N	Water at level of river nearby.
31E2	H. Ringhofer	Fp, 590	Dr	43	6	43	---	----	-----------	--	8.73	6-19-33	P, 5	D	
31J1	---- Myers	Fp, 600	Dr	450	6	450	---	----	-----------	C	2±	1- -48	P, 5	D, S	Believed to bottom in sand above basalt.
32N1	Roy C. Shelden	Fp, 610	Dr	89	6	89	70	19	Gravel	U	5	1- -48	P, 5	D, S	
32R1	R. C. Nelson	Ap, 645	Dr	108	6	---	---	----	Sand and gravel	U	10±	1- -48	J, 10	D, S	
33D1	Fred Fuller	Ap, 660	Dr	760	10-6	617	700	60	Basalt	C	20	9-19-46	T, 300	Irr	L.
											25.9	4-14-55			
											34.1	10-27-55			
											25.1	4-20-56			
33H1	Walla Walla College	Ap, 695	Dr	710	8	---	---	----	-----Do-----	C	15	1- -48	T, 300	Irr	Tpd 400 gpm with dd of 71 ft.
33J1	Walla Walla College	Ap, 700	Dr	89	8	---	---	----	Gravel	U	15	10- -59	-------	S	Ca.
33L1	Frank Nelson	Ap, 680	Dr	618	6	550	---	----	Basalt	--	F	10- -59	N	N	
											28.9	4-12-55			
											38.5	10-25-55			
33L2	Frank Nelson	Ap, 685	Dr	650	6	550	---	----	-----Do-----	--	F	1- -48	C, 300	Irr	Partial irrigation for 160 acres.
											23.6	4-18-56			
											24.5	2-26-57			
34A1	Herman Martin	Ap, 730	Dr	750±	6	---	---	----	-----Do-----	C	30±	9- -47	N	N	Old well recently uncovered.
34G1	Herman Martin	Ap, 720	Dr	143	8	77	30	62	Gravel	U	8	9-22-44	T	D, Irr	L.
35A1	Walla Walla College	Ap, 778	Dr	600	6	---	---	----	Basalt	C	+46	1953	------	--	Drilled in 1916, capped about 1958; hardness, 55; chloride, 4 ppm.
35A2	Walla Walla College	Ap, 778	Dr	1,010	12-7	700	700	310	-----Do-----	C	F	------	T	PS, Irr	Located 250 ft south of 35A1.
35G1	C. N. Tillman	Ap, 775	Dr	730	8	---	---	----	-----Do-----	C	8	3- -48	T, 280	--	Did not flow when drilled in 1910; hardness, 90; chloride, 8 ppm.
35H1	Walla Walla College	Ap, 785	Dr	100	12-10	100	32	10	Gravel	C	18.1	3-24-48	------	--	L.
							49	15							
							70	28							
35P2	E. L. Keech	Fp, 760	Dg	137	120	---	---	----	-----Do-----	U	9.28	5-9-33	C, 150	Irr	Irrigates 5 to 10 acres of garden.
											8.77	3-22-48			
35R1	---- Franciullo	Fp, 780	Dg	37	96	---	6	31	-----Do-----	U	8.38	3-22-48	C, 100	Irr	Irrigates 20 acres of garden.

36A1	A. Zaro	Fp,	825	Dr	635	8-6	554	563	57	Basalt	C	2.0	3-19-48	T	Irr, D	Hardness, 52; chloride, 4 ppm; L.
												21.3	4-13-55			
												79.2	9-22-55			
												26.1	4-18-56			
												26.0	2-26-57			
												26.0	2-22-58			
												66.4	10-22-58			
												57.4	10-28-59			
												39.9	5-10-60			
36C1	G. Magnoni	Ap,	810	Dr	640	6	---	---	----	----Do----	C	F	1948	C, 100	Irr	Former Immanuel well; leaks badly; hardness, 62; chloride, 4 ppm.
36D1	College Place Water Co	Ap,	790	Dr	640	6	535	600	40	----Do----	C	+20	3-18-48	------	N	Former Cady well; sealed with cement, 1951; hardness, 60; chloride, 4 ppm; L.
36F1	College Place Water Co	Ap,	800	Dr	810	6	500	600	25	----Do----	C	+37	3-18-48	C, 150	PS	Former Maple Street Water Co. well; recased and drilled to 810-ft depth about 1951; Ca; sample from 36F1 and F3.
												+15	4-18-55			
												33	9-21-55			
												+13	4-1-56			
												+12	2-26-57			
												19	10-27-59			
												3.1	5-11-60			
												62	8-2-60			
36F2	Richards, et al	Ap,	805	Dr	610	6	100(?)	---	----	----Do----	C	F	3-19-48	------	PS	Former Campbell well; leakage around casing sealed about 1951; hardness, 62; chloride, 4 ppm; L.
												+8	4-19-55			
36F3	College Place Water Co	Ap,	800	Dr	708	20-12	552	620	80	----Do----	C	F	3-18-48	T, 1,800	PS	Free flow 2,000 gpm, July 1947; pumping level 83 ft, Aug. 10, 1960; Ca.
36G1	Virgil Davin	Ap,	820	Dg	15	60	---	---	----	Gravel	U	13.4	12-17-46	B	D	
36H1	Wahluke Investment Co	Ap,	845	Dr	600	6	---	---	----	Basalt	C	6.7	3-24-48	T, 200	Irr	Reportedly had pressure head of 138 ft when drilled in 1910.
												24.9	4-19-55			
												77.4	9-21-55			
												31.4	4-18-56			
36P1	D. H. Kinzer	T,	845	Dr	600	6	---	---	----	----Do----	C	15±	3-19-48	C, 200	Irr	Hardness, 60; chloride, 4 ppm.
36R1	Stone Creek Sanitarium	Ap,	845	Dr	618	8-6	---	500+	----	----Do----	C	F	3-24-48	C, 150	D, S	Water level reportedly lowered by pumping of well 7/36-31N1.
												20	6-7-54			
												28	7-28-54			
												51.9	9-2-54			
										T. 7 N., R. 36 E.						
2J1	R. L. Moore	T,	1,250	Dr	810	12	164	182	528	Basalt	--	65	8-8-55	------	Irr	Tpd, 1,160 gpm with dd of 83 ft; L.
												74.8	4-25-58			
												81.3	8-20-58			
												79	4-23-59			
												94	8-26-59			
												76	11-29-59			
												64	5-10-60			
4E1	Roy Richmond	T,	1,030	Dg	80	48	---	45	30	Cobbles	U	61.95	10-15-47	P, 15	D, S	Silt or loess overlies aquifer; hardness, 75; chloride, 7 ppm.
								75	5	Basalt (?)						
4P1	W. E. Morrison	T,	1,050	Dr	205	8	77	105	17	Gravel	U	13	3-16-48	------	Irr	Drilled in gravel containing some clay beds.
								184	13	----Do----						
9E2	Baker & Baker	T,	1,025	Dr	162	10	53	47	115	----Do----	U	55	5-11-49	P, 4	D, S	

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 7 N., R. 36 E.—Continued								
10D1	Walter Minnick	T, 1,110	Dr	241	8	145	104	132	Gravel	U	93	9- -46	------	D	
11B1	Roy Frazier	T, 1,200	Dr	807	16-12	170	170	637	Basalt	C	20 49	2-1-47 1-8-58	T, 1,000	Irr	Gravel, containing clay beds, overlies basalt; tpd 1,500 gpm with dd of 33 ft.
13F1	City of Walla Walla, No. 1	Td, 1,260	Dr	810	12-10	363	363	447	----Do----	C	64	4-4-42	T, 1,500	PS	Ca; L; WL fig. 11.
13F2	City of Walla Walla, No. 2	Td, 1,270	Dr	808	16-12	140	140	668	----Do----	C	82	1942	T, 1,200	PS	WL fig. 11.
13J1	R. R. Brunton	Ap, 1,280	Dg	14	36	14	---	----	Cemented gravel	P	10.71	10-18-47	P, 4	D	Hardness, 35; chloride, 3 ppm.
15C1	City of Walla Walla	T, 1,135	Dr	515	10(?)	35	90	----	Cobbles and gravel	U	90	1931	N	N	Gave poor yield; now covered near runway of airport; L.
15Q1	Mrs. E. B. Feathers	Ap, 1,115	Dr	435±	6	110	300 125	135± 175(?)	Basalt Gravel	U	35	1947	------	--	
16N1	J. H. Schurr	Ap, 1,035	Dg, Dr	60	60-6	---	40	----	----Do----	U	32	1946	C, 10	D	Typical of many wells nearby; 35 ft of silt overlies aquifer; hardness, 70; chloride, 8 ppm.
16R1	Elmer Markham	Ap, 1,060	Dr	122	8	48	112	10	----Do----	C	34.5	12-10-46	J, 5	D	L.
17K1	City of Walla Walla	Ap, 1,000	Dr	3,000	20-8	---	---	----	----------	--	40 49.6 54.2 80.8 74.7 49.5	3-24-48 4-24-59 6-25-59 8-26-59 10-27-59 5-10-60	N	--	Yielded but 180 gpm; top of basalt at 481 ft.
18M1	Washington State Penitentiary	T, 915	Dr	1,004	24-16	525	405	599	Basalt	C	74	3-18-56	T	Irr	
18P1	-------Do-------	T, 920	Dr	920	---	525	525	----	----Do----	C	100	1933	T, 700	PS	Aquifer overlain by 40 ft of silty soil and 425 ft of sand and gravel.
18P2	-------Do-------	Td, 920	Dr	915	---	525	525	----	----Do----	C	100	1933	T, 300	PS	Located 60 ft south of 18P1.
18P3	-------Do-------	T, 950	Dr	640	12	100 250 600	---	----	Gravel ----Do---- Basalt	U	87	1933	T, 400	PS	Located 700 ft east of 18P1 and P2.
19C1	-------Do-------	Td, 900	Dr	225	12	220	25	200	Gravel, cemented	U	38	7- -33	C, 250	Irr	
19C2	-------Do-------	Td, 915	Dg	57	240	---	---	----	Gravel	U	37	1946	C, 150	D, Irr	Tpd 150 gpm with dd of 19 ft.
19E1	Mrs. Nina Anderson	Ap, 880	Dg, Dr	84	6	55	71	13	----Do----	U	27	7- -46	J, 10	D, S	L.
19F1	General Food Corp.	Ap, 890	Dr	1,125	20-12	836	836	289	Basalt	C	59	5- -46	T, 1,000	Ind	Ca; L.
19H1	Walla Walla Meat Co.	Ap, 940	Dg, Dr	216	----	190	210±	6± 90	Sand, white; gravel	U	-----	1933	P, 15	Ind	Dug well taps upper aquifer.
19M1	Joe Pratto	Ap, 880	Dg	26	60	20	20	6	Gravel	U	17.61	5-16-33	P, 3	D	

19R1	Walla Walla Canning Company	Ap, 920	Dr	1,590	12-6	1,590	---	----	Basalt	C	94	12-7-42	T, 1,100	Ind	Ca; L.
20A1	Sid McCool	Ap, 995	Dn	16	1¼	16	---	----	Sand	U	14.93	5-16-33	N	N	
20G1	Whitman College	Ap, 985	Dr	1,202	20-16	425	---	----	Basalt	C	64	6-1-62	T	Ind	Tpd 700 gpm with 100 ft dd. Temp of water 72°F.
20N1	Marcus Whitman Hotel Assoc.	Ap, 940	Dr	700	18-	---	402	298	----Do----	C	76.3	1-20-48	N	--	L; WL fig. 9.
							20	207	Gravel	U	45				
20P1	Union Bulletin Publishers	Ap, 950	Dr	224	----	---	---	----	----Do----	U	-----	------	------	Ind	L.
21G1	Roy Mindemann	Ap, 1,030	Dr	55	6	54	44	11	----Do----	U	24	8-30-45	------	D	L.
21K1	Frank Wright	Ap, 1,050	Dr	60	6	---	---	----	----Do----	U	20	1946	C, 50	Irr	
22H1	City of Walla Walla, No. 6	Ap, 1,130	Dr	1,330	24-16	285	284	1,046	Basalt	C	71	10-24-61	T	PS	Tpd 900 gpm with 180 ft dd when at 900 ft depth, 1,400 gpm at 1,200 ft depth, and 2,600 gpm with 100 ft dd at final depth.
22N1	City of Walla Walla, No. 4	Ap, 1,045	Dr	789	30-20	400	400	389	----Do----	C	+16	1953	T	PS	Tpd 2,800 gpm with dd of 116 ft. 9-4-53; Ca; L; WL fig. 11.
											+42	4-18-55			
											5	9-21-55			
											+7	10-5-56			
											+34	4-23-59			
											17	10-28-59			
											+27	5-10-60			
22Q1	O. O. Crites	Ap, 1,090	Dr	98	6	---	90	8	----Do----	P	20	1948	J, 5	D	Cemented gravel overlies aquifer.
23B1	Dwelly Jones	Ap, 1,175	Dr	190	6	---	---	----	Gravel	P	16.40	10-28-48	J, 5	D	
											15.5	4-14-55			
											18.1	2-27-57			
											14.5	2-22-58			
											16.6	5-10-60			
23C1	United States of America	Ap, 1,160	Dr	100±	----	---	---	----	----Do----	P	-----	------	------	D	Near flood-control diversion gates; hardness, 45; chloride, 3 ppm.
23E1	Elmer Murray	Ap, 1,150	Dr	88	6	---	80	8	Gravel, loose	P	16	1948	J, 5	D	Well penetrated boulders near surface and cemented gravel down to aquifer.
23E2	Garry Huff	Ap, 1,140	Dr	100	6	98	56	40	Gravel	P	18	8-24-48	J, 5	D	Hardness, 35; chloride, 4 ppm; L.
23M1	William Hauber	Ap, 1,135	Dr	103	6	---	95	5	Sand and gravel	P	14	1945	J, 5	D	Cemented gravel overlies aquifer.
25F1	Dwelly Jones	S, 1,270	Dr	1,100	12	157	---	----	Basalt	C	225	8- -45	T, 500	Irr	L.
											235	4-19-56			
											283	10-6-56			
											259	12-19-56			
											249	2-27-57			
											245	2-22-58			
											243	4-24-59			
											253	5-10-60			
26G1	United State of America	Ap, 1,140	Dr	75	6	---	10	52	Gravel, cemented	U	-----	------	------	--	Test well penetrated Palouse-type loess (10 ft) above, and basalt (3 ft) beneath, aquifer.
26K1	Dwelly Jones	Ap, 1,120	Dg, Dr	49.1	30-8	---	---	----	----------	U	27.1	10-28-48	J, 5	D, S	Hardness, 75; chloride, 3 ppm.
27D1	---- Fields	Ap, 1,060	Dr	50	6	49	48	2	Gravel	U	24	7- -45	J	D	L.
28A1	Charles F. Baker	Ap, 1,030	Dr	100	6	72	95	5	Sand and gravel	U	6.54	12-9-46	C, 10	D	L.
28A2	C. A. McKenzie	Ap, 1,035	Dr	55	6	52	43	2	Gravel	U	18	8- -45	J, 5	D	Hardness, 45; chloride, 4 ppm.
28C3	B. Campbell	Ap, 1,005	Dr	90	6	71	71	19	----Do----	U	8	7- -45	J, 5	D	L.
28G1	L. D. Felch	Ap, 1,000	Dr	215	8	---	208	7	----Do----	U	-----	------	J, 10	D	
							193	2	----Do----						

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Thickness (feet)	Character of material	Ground-water occurrence	Water level: Feet below datum	Date	Type of pump and yield (gpm)	Use	Remarks
							T. 7 N., R. 36 E.—Continued								
28K1	Wilson and Messer	Ap, 1,020	Dr	217	8	65	200	17	Gravel	U	29.3	11-18-48	J, 20	D	Supplies two houses; hardness, 35; chloride, 3 ppm; L.
28R1	City of Walla Walla, No. 5	Ap, 1,020	Dr	1,090	30-16	567	---	----	Basalt	C	86.1	2-22-58	T	PS	Entered basalt at 462 ft; tpd 1,600 gpm with dd of 23 ft in 1958; Ca.
											95	4-23-59			
											118	10-28-59			
29J1	Ambrose Aliverti	Ap, 960	Dr	94	8	48	35	2	Gravel	U	6	5- -46	20	Irr	
30J1	U.S. Veterans Administration	T, 900	Dr	550	16-8	540	64	186	----Do----	C	25	2- -34	T, 400	PS	L.
							450	100	Basalt						
30K1	U.S. Veterans Administration	T, 895	Dr	275	----	---	230	15	Gravel, loose	U	23	1933	T, 500	PS	L.
31H1	A. J. Mathison	Ap, 900	Dr	60	12-10	55	17	48	----Do----	U	22	5- -45	J	D	
31J1	Walla Walla Country Club	Ap, 880	Dr	1,715	12	538	538	1,279	Basalt	C	75	9- -46	T, 1,500	Irr	Supplies water for irrigation of about 160 acres; L.
											78	4-17-56			
											131	10-6-56			
											79	2-27-57			
											86	4-24-59			
											106	10-22-59			
31N1	J. J. Chisholm	Ap, 840	Dr	600	6	519	---	----	----Do----	C	F	3-24-48	C, 400	Irr	Supplies water for about 40 acres; hardness, 50; chloride, 5 ppm.
31P1	J. J. Chisholm	Ap, 850	Dr	142	8-6	140	130	12	Gravel, cemented	U	16	5- -45	J	D, S	Hardness, 60; chloride, 5 ppm; L.
31R3	John Yenny	Ap, 880	Dr	47	8	46	40	2	Gravel	U	12	4- -46	C, 70	Irr	L.
							28	4	----Do----						
32A1	J. C. Phillips	Ap, 960	Dg	33.5	36	---	23	33	----Do----	U	32.4	12-11-46	B	D	
32A2	J. R. Nestell	Ap, 960	Dg, Dr	435	8	89	110	10	----Do----	U	35.5	12-11-46	J, 5	D	Well plugged back to 120 ft; L.
							35	37	----Do----	U					
32F1	W. S. McColley	Ap, 920	Dr	85	10	80	35	44	----Do----	U	33.6	11-18-48	T, 200	Irr	Supplies water for about 10 acres.
32L1	L. Taruscio	Ap, 920	Dg	39.0	96	---	39	1	----Do----	U	31.2	11-18-48	C, 100	Irr	--------Do--------
32P1	A. L. Smith	T, 960	Dr	150	6	64	65	85	----Do----	U	30	3- -45	J, 10	D	L.
33A1	H. E. Studebaker	T, 1,020	Dr	762	8-6	546	---	----	Basalt	C	70	1945	T, 100	Irr	Hardness, 72; chloride, 3 ppm; Ca; L.
33A2	H. E. Studebaker	T, 1,000	Dr	152	8	152	---	----	Gravel	U	12.5	2-8-41	J, 10	D	Hardness, 150; chloride, 5 ppm; L.
33B1	R. W. Stevens	Ap, 960	Dr	668	8-6	---	535	----	Basalt	C	40	8-1-50	T, 75	Irr, D	
33D1	J. O. Parkins	T, 960	Dg	36	----	---	34	2	Gravel	U	34.1	5-16-33	P	D	
33H1	---- Storey	T, 1,000	Dr	106	6	100	100	6	Gravel, cemented	U	30	1947	J, 5	D	Upper water stands at about level of the creek from Shelton Springs.
							25	5	Sand, silty	U					
33P1	G. A. Kralman	Ap, 950	Dr	575	8	435	256	25	Gravel	U	2½	5-25-48	T, 150	Irr	Did not reach the basalt.
34B1	Karl Depping	Ap, 1,050	Dg, Dr	130	40-6	130	---	----	----Do----	U	18	1948	C	Irr	Supplies water for 11 acres.

34C1	Karl Depping	Ap, 1,025	Dr	403	8	200	200±	200±	Basalt	C	99.05	10-28-48	P, 5	D	Well has rather poor yield.
34C2	---- Williams	Td, 1,040	Dr	65	6	---	---	----	Gravel	U	26.0	10-28-48	------	--	One of three similar wells.
34F1	Mark Fowler	Td, 1,040	Dg, Dr	85	6	85	39	1	Gravel, silty	U	15.7	10-28-48	C, 100	D, Irr	Drill hole 40-85 ft obtained no additional water.
34N1	M. R. Young	Ap, 1,050	Dr	505	8	409	388	----	Basalt	C	14	7- -55	------	Irr	Tpd 340 gpm with dd of 148 ft.
34Q1	Philip Reser	Ap, 1,030	Dr	234	6	---	---	----	----------	--	27	1946	P, 4	D	Hardness, 50; chloride, 3 ppm.
35D1	Petrus DeBoer	Td, 1,080	Dr	240	6	---	230±	-----	Basalt	C	F	10-22-48	T, 150	Irr, D	Owner reports (1948) same water level as when drilled in 1910.
35Q1	Baker & Baker	T, 1,160	Dr	936	16	235	225	----	----Do----	C	72	5- -54	T	Irr	Tpd 2,000 gpm.
											84	4-16-55			
											121	9-21-55			
											76.6	4-20-56			
											94	2-28-57			
											83.7	2-22-58			
											81.4	4-23-59			
											89	5-10-60			
35R1	J. E. Levin	Td, 1,150	Dr	222	6	---	---	----	----Do----	C	58.3	10-26-46	P, 5	D, S	Ca.
36F1	J. B. Mansfield	Ap, 1,200	Dr	257	6	---	255	2	----Do----	C	65	1941	J, 10	D, S	
36H1	F. M. Ralston	Ap, 1,250	Dg	25	84	---	---	----	----------	--	15.0	10-19-46	P, 3	S	Water at about level of nearby Russell Creek.
36J1	F. M. Ralston	Td, 1,270	Dr	245	8	135	220	25	Basalt	C	17.4	10-19-46	T, 100	Irr	WL fig. 9; L.
							118	63	Gravel, cemented	U					
36J2	F. M. Ralston	T, 1,310	Dr	454	15-12	273	210	244	Basalt	C	6.1	10-19-46	T	Irr	Tpd 1,250 gpm with dd of 10 ft, when drilled; L.
									T. 7 N., R. 37 E.						
5D1	Gale Kibler	Uv, 1,290	Dr	118	6	118	104	14	Gravel, loose	U	21	2-28-41	J, 12	D	Ca; L.
5K1	Albert Kibler	Uv, 1,350	Dr	106	6	44	84	19	Basalt, soft, brown	C	28	5-15-45	J, 7	D	Hardness, 135; chloride, 3 ppm; L.
6C1	Wallace Evans	Uv, 1,250	Dr	100	6	---	---	----	----------	C	-----	------	J, 5	D	Hardness, 75; chloride, 3 ppm.
6D1	A. F. Kees	Uv, 1,240	Dg	26.1	30	---	---	----	----------	U	23.52	10-19-46	P, 1	D, S	
13A1	John Meiners	Uv, 2,000	Dn	12	1¼	---	---	----	Soil, sandy	U	7.72	10-18-46	P, 1		
13J1	R. E. Meiners	Uv, 2,315	Dr	525	6	---	---	----	Basalt	C	-----	------	------	--	Ca.
14G1	E. J. Meiners	Uv, 1,900	Dr	270	6	---	200	70	----Do----	C	130	1938	P, 1	D, S	Supplements spring flow.
16L1	C. D. Hansen	Ap, 1,450	Dg	10	12	---	8	2	Sand and gravel	P	8.0	10-19-46	P, 1	D	
16Q1	Leo Gilkerson	Ap, 1,490	Dg	14	36	---	---	----	----------	P	-----	------	C, 6	D	In use since 1880; Ca.
18F1	City of Walla Walla No. 3	Ap, 1,320	Dr	1,169	20-16	176	149	----	Basalt	C	133	4-30-47	T, 1,800	PS	Ca; WL fig. 11.
											153	4-18-55			
											168	4-23-59			
18G1	David Kibler	T, 1,400	Dr	100+	6	---	---	----	Gravel and sand	P	45.88	10-19-46	P, 1	N	Thomas School well; Ca.
18H1	David Kibler	T, 1,400	Dg	50	48	---	---	----	Gravel	P	47.29	10-19-46	------	N	Hardness, 60; chloride, 4 ppm.
18R1	Henry Copeland	Ap, 1,350	Dg	12	48	---	---	----	----Do----	P	6.75	10-18-46	P, 5	D	
18R2	Olaus Filan	Ap, 1,400	Dr	770	12	102	102	----	Basalt	C	190	1949	T	Irr	L.
											218	4-16-55			
											239	2-27-57			
											243	4-25-58			
											239	4-23-59			
											255	6-25-59			
											249	10-27-59			
											236	5-10-60			
28R1	Carl Ferrel	U, 1,760	Dr	160	6	35	32	128	----Do----	U	55	11-13-45	J, 5	D	Boulders and gravel overlie aquifer up to the soil zone; hardness, 85; chloride, 3 ppm.

Table 1.—Records of representative wells in the Walla Walla River basin--Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s)			Ground-water occurrence	Water level		Type of pump and yield (gpm)	Use	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material		Feet below datum	Date			
								T. 7 N., R. 37 E.--Continued							
29F1	Ed Copeland	U, 1,525	Dg	30	36	---	26	4	Basalt	U	26	12- -44	P	D,S	Hardness, 115; chloride, 2 ppm.
29P1	John Yenny	Uv, 1,450	Dr	253	6	---	---	----	----------	--	23.54	10-19-46	C, 100	D, Irr	Hardness, 150; chloride, 4 ppm.
31C2	Leonard Garver	S, 1,350	Dr	127	6	---	---	----	Basalt	--	45±	9- -45	P, 3	D,S	Hardness, 65; chloride, 3 ppm.
31E1	Grace McGuire	Ap, 1,300	Dr	93	6	---	35	58	----Do----	C	-----	------	J, 7	D	Formerly flowed, now pumped; 35 ft of alluvium overlies basalt bedrock; hardness, 40; chloride, 2 ppm.
31J1	T. E. Wilson	Ap, 1,390	Dr	200	6	---	---	----	----Do----	C	F F	1936 10-19-46	------	D,S	Usual flow of 5 gpm; hardness, 50; chloride, 3 ppm.
31R1	H. T. McGuire	Ap, 1,410	Dr	220	10-6	171	---	----	----Do----	C	+8.5 +46 +37 +49 +44 +54 +46 +61	10-23-46 4-15-55 9-22-55 4-19-56 2-27-57 2-22-58 4-23-59 5-10-60	------	D	Estimated flow 25 gpm; Ca; L.
32E1	Maxson School	Ap, 1,390	Dr	200	6	---	---	----	Basalt (?)	C	F	-----	J, 5	D	Hardness, 55; chloride, 3 ppm.
32N1	Thomas Estate	U, 1,440	Dg	26	24	---	---	----	Gravel	U	12±	-----	------	D	Reported yield is 17 gpm.
32P1	C. N. Foster	U, 1,490	Dr	650	10-8	650	---	----	Basalt	C	20±	1946	T	D, Irr	Well flowed when first drilled in 1928; hardness, 40; chloride, 3 ppm.
33N1	W. L. Kincheloe	Ap, 1,590	Dg	12.7	48	12	---	----	Gravel	U	5.65	10-21-46	C, 7	D,S	
33P1	W. L. Kincheloe	U, 1,730	Dr	250±	6	---	---	----	----------	C	-----	-----	Sy	Irr	Water formerly syphoned to fields below wells.
									T. 8 N., R. 34 E.						
1E1	R. E. Burrows	Uv, 990	Dr	600	6	---	---	----	Basalt	C	76.7	10-22-47	P	--	Reported to be good well.
2J1	Martin Marback	Uv, 1,000	Dr	350	6	40	340	10	----Do----	C	230 200±	1905 1947	P	D	L.
12D1	R. E. Burrows	Uv, 1,000	Dr	330	6	---	---	----	----Do----	C	-----	-----	P	D,S	Reported dry after brief pumping.
13G1	Arch Collard	Uv, 950	Dr	565	6	---	550 250	15 5	----Do----	U	550	1918	P	D,S	Reported 90 ft of soil above basalt; hardness, 75; chloride, 9 ppm.
14L1	J. C. Scott	U, 1,000	Dr	531	8	135	---	----	----Do----	U	435	1947	------	D,S	Reported 131 ft of loess-type soil above basalt.
23L1	A. Drumheller	Uv, 900	Dg	40	40	---	35±	5±	Palouse Formation	P	35±	1947	P	D,S	This soil-zone well of type was once numerous in region.

25H1	Mrs. E. Donovan	Uv, 875	Dr	98	----	---	---	----	----------	--	60±	1947	P	D	
32C1	H. A. Dryer	Uv, 860	Dr	540	6	---	---	----	Basalt	C	175±	1947	P	D	Hardness, 75; chloride, 9 ppm.
33C1	Merlin Phillips	Uv, 850	Dr	1,000±	6	---	---	----	----Do----	C	-----	-----	P	N	
									T. 8 N., R. 35 E.						
34J1	Paul School Dist.	Uv, 790	Dr	75	6	---	---	----	----------	--	-----	------	P	PS	
34Q1	Don Seavy	Uv, 790	Dr	1,026	16-10	---	51	975	Basalt	C	32.4	4-14-55	T	Irr	Yield reported as 1,200 gpm; L.
											34.9	9-22-55			
											30.1	4-18-56			
											32.0	2-26-57			
											31.6	2-22-58			
											32.4	4-23-59			
											31.7	5-10-60			
35C1	---- Degg	Uv, 790	Dg, Dr	75	60-6	---	---	----	----------	--	-----	------	J	D, S	
36M1	J. Martin	U, 850	Dr	175	6	170	170	5	Basalt	C	10	1947	P	S	"Blue mud" overlies basalt to surface.
									T. 8 N., R. 36 E.						
10H1	P. L. Pentecost	Uv, 1,000	Dr	300	6	---	---	----	Basalt	C	-----	-----	P	D, S	Hardness, 80; chloride, 8 ppm.
10N1	---------------	Uv, 950	Dg	----	60	---	---	----	Silt, soil	P	24.8	10-15-47	P	N	
11A1	W. F. Spear	Uv, 1,070	Dr	160	6	---	---	----	Basalt (?)	C	-----	-----	P	D, S	
21N1	A. A. Carey	Uv, 950	Dr	703	12-10	144	252	451	Basalt	U	281	4-14-55	T	Irr	Yields about 900 gpm.
											280	4-18-56			
											286	2-26-57			
											287	2-22-58			
											311	10-21-58			
											287	4-23-59			
											286	5-10-60			
29D1	J. H. Nordheim	Fp, 890	Dr	412	10	126	410	2	----Do----	C	100	4-14-55	T	Irr	Tpd 600 gpm with dd of 87 ft.
											109	4-18-56			
											129	2-26-57			
											138	2-22-58			
30B1	Mrs. J. D. Bergerin	Uv, 910	Dr	75	6	60	---	----	----------	--	9.22	10-17-47	C, 20	D, S	Hardness, 80; chloride, 6 ppm.
35A1	Frank McInroe	Uv, 1,100	Dg	24	60	---	12	12	Cobble gravel	U	8	1947	P	D, S	Silty soil over aquifer; hardness, 100; chloride, 8 ppm.
35D1	Forest Buraker	Uv, 1,140	Dg	72	48	---	65(?)	7(?)	Basalt (?)	U	67	1947	P	D	
35M1	---- McInroe	Uv, 1,130	Dg	70	60	---	66	4	Cobble gravel	U	66	1947	P	D, S	
36E1	W. F. Kibler	Uv, 1,130	Dr	50	6	---	---	----	----Do----	U	-----	------	C, 10	D	Hardness, 100; chloride, 7 ppm.
36K1	W. R. White	Uv, 1,160	Dg	18	36	---	5	13	Silt, sandy soil	U	-----	------	C	D, S	
36L1	H. R. White	Uv, 1,155	Dr	143	8	22	125	15	Basalt	C	9.5	9- -57	------	Irr	Entered basalt at 21 ft; tpd 80 gpm with dd of 123 ft.
									T. 8 N., R. 37 E.						
26L1	---- Storey	Uv, 1,580	Dr	126	6	26	85	41	Basalt	C	-----	------	J	D	Hardness, 100; chloride, 4 ppm; L.
26M1	F. M. Walker	Uv, 1,550	Dr	215	6	35	180	25	----Do----	C	150	9- -41	P, 5	D	Has small yield; hardness, 85; chloride, 6 ppm.
26M2	Mrs. J. R. Wolfe	Uv, 1,550	Dr	96.5	6	35	---	----	----Do----	--	23.2	11-22-48	P	D	Tpd 40 gpm with dd of 15 ft.

Table 1.—Records of representative wells in the Walla Walla River basin—Continued

Well	Owner or occupant	Topography and altitude (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): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gpm)	Use	Remarks
							T. 8 N., R. 37 E.—Continued								
27R2	Dixie Pea Growers, Inc.	Uv, 1,510	Dr	267	----	—	235	4	Basalt	--	----	----	----	PS	L.
31P1	G. M. Rea	Uv, 1,210	Dr	94	6	25	69	25	----Do----	C	20.4	10-19-46	J, 10	D	Hardness, 80; chloride, 5 ppm; L.
35B1	---- Gardner	Uv, 1,650	Dr	360	6	25	275	85	----Do----	U	240	1945	P, 10	D,S	Hardness, 80; chloride, 3 ppm; L.
									T. 8 N., R. 38 E.						
32L1	Dale Sorenson	Uv, 2,350	Dr	175	6	22	---	----	Basalt	C	110	8- -42	J, 10	D	Hardness, 70; chloride, 4 ppm; L.

Table 2.--Drillers' logs of representative wells.

Tentative stratigraphic designations by R. C. Newcomb.

Materials	Thickness (feet)	Depth (feet)
Well 4/35-15P2		
Lamb-Weston. Altitude about 1,775 feet. Drilled by A. A. Durand and Son, 1946.		
Recent alluvium:		
Soil	18	18
Gravel	3	21
Columbia River Basalt:		
"Rock, brown"	5	26
Basalt, dark, hard	45	71
Basalt, porous	14	85
Basalt, medium hard and hard	35	120
Basalt, porous, with green clay	10	130
Basalt, gray, soft	13	143
Basalt, black, hard	4	147
Basalt, porous	11	158
Basalt, gray and black, hard, static water level 11 feet	67	225
Basalt, gray, porous	45	270
Basalt, gray and black, hard	31	301
Basalt, black, porous	20	321
Basalt, hard	30	351
Basalt, porous	5	356
Shale, brown and blue	16	372
Basalt, alternating porous and hard	120	492
Basalt, porous, water-bearing	35	527
Basalt, black, hard	12	539
Basalt	661	1,200
Well 4/35-22Q1		
City of Weston. Altitude about 1,790 feet. Drilled by A. A. Durand and Son, 1939.		
Recent alluvium:		
Soil	6	6
Boulders	14	20
Columbia River Basalt:		
Basalt, honeycombed, with clay seams	14	34
Basalt, black and gray, with occasional clay-seam zones	91	125
Basalt, honeycombed, with clay seams	35	160
Basalt, gray and black	25	185
Clay, blue	5	190
Basalt, gray, hard	30	220
Basalt, black, water-bearing	10	230
Basalt, gray and black	210	440
Basalt, black, with clay pockets	20	460
Basalt, very hard	26	486
Basalt, gray, water-bearing in part	22	508
Basalt, black, water-bearing	26	534

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 4/37-9H1		
Wm. Coleman. Altitude about 1,950 feet. Drilled by A. A. Durand and Son, 1940.		
No record - old dug well	28	28
Recent(?) alluvium:		
Gravel, with boulders	33	61
Columbia River Basalt:		
Basalt, water-bearing; static water level 35 feet	14	75
Basalt, gray	12	87
Basalt, red, vesicular, water-bearing; static water level 3 feet	10	97
Well 5/35-1E1		
Utah Canning Co. Altitude about 1,010 feet. Drilled by A. A. Durand and Son, 1945.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel with boulders	20	20
Gravel; static water level 22 feet	10	30
Gravel with some clay	34	64
Clay, yellow, with gravel	28	92
Columbia River Basalt:		
Basalt, black	26	118
Basalt, gray and brown, with blue clay and shale; static level of water is 15 feet	40	158
Basalt, black and red, with some yellow clay	70	228
Basalt, gray, blue and black, hard; static water level 15 feet	240	468
Basalt, black, hard and soft; static water level 41 feet	60	528
Casing, 16-inch, set to 109 feet, open 16-inch hole below.		
Well 5/35-2D1		
Gus Siebold. Altitude about 950 feet. Drilled by A. A. Durand and Son, 1946.		
Dug well, no record	28	28
Old gravel of Pleistocene age:		
Gravel, coarse, loose, 20-55 feet	67	95
Columbia River Basalt:		
Basalt, black	10	105
Basalt, brown, porous	45	150
Basalt, black, creviced 189-190 and 214-218 feet	103	253
Basalt, porous	39	292
Basalt, black, firm	16	308
Basalt, red, water-bearing at 325 feet	23	331
Basalt, black	13	344
Casing, 8-inch, set from 12 to 100 feet; 6-inch hole below 150 feet depth.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 5/35-2E1		
City of Milton-Freewater, No. 6. Altitude about 965 feet. Drilled by George Scott, 1950.		
Recent alluvium and old gravel of Pleistocene age:		
Soil and dirty gravel	6	6
Gravel, dirty, bouldery, water-bearing	55	61
Columbia River Basalt:		
Basalt, porous and broken, some water at top	20	81
Basalt, black, hard and medium, layered, water level, 20 feet	120	201
Basalt, black, creviced	13	214
Basalt, broken, sloughing, static water level 39 feet	63	277
Basalt, broken and mixed with yellowish clay	19	296
Basalt, clean, hard	55	351
Basalt, broken, with intermixed clay of varied hue, fault-zone material	601	952
Well 5/35-2H1		
City of Milton-Freewater, No. 5. Altitude 995 feet. Drilled by A. A. Durand, 1936.		
Recent alluvium and old gravel of Pleistocene age:		
Soil	3	3
Gravel, boulders, partly cemented and partly loose, water-bearing	77	80
Clay	10	90
Boulders and gravel	45	135
Clay and sand	10	145
Gravel and boulders, loose	15	160
Columbia River Basalt:		
Basalt, black, hard	85	245
Basalt, red, porous	45	290
Basalt, blue and black, hard	115	405
Basalt, red	30	435
Basalt, black, water-bearing	67	502
Casing, 18-inch, set to 40 feet; 12-inch set to 172 feet.		
Well 5/35-2J1		
City of Milton-Freewater, No.3. Altitude about 1,010 feet. Drilled by George Scott, 1946.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel with clay	43	43
Columbia River Basalt:		
Basalt, black	36	79
Basalt, reddish brown	9	88
Basalt, black, brown, and gray, hard	43	131
Basalt, black with crevices containing "greenish shale" at 176, 209, and 218 feet	108	239
Basalt, brown and black	228	467
Basalt, gray and black, broken, loose	25	492
Basalt, black	46	538
Basalt, black, porous	12	550
Casing, 20-inch, set to 43 feet; 16-inch set to 100 feet, 16-inch open hole to bottom.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 5/35-12F1		
City of Milton-Freewater, No. 1. Altitude about 1,070 feet. Drilled by A. A. Durand, 1937.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel	30	30
Gravel, cemented	7	37
Gravel, with clay	9	46
Columbia River Basalt:		
Basalt, black	14	60
Basalt, with clay	38	98
Basalt, black	42	140
Basalt, brown, soft	5	145
Basalt	57	202
Basalt, gray, soft	10	212
Basalt, brown, soft to hard	68	280
Basalt, gray	87	367
Basalt, black and gray, medium hard	284	651
Casing, 12-inch, set to 100 feet, perforated at 50 feet.		
Well 5/35-12F2		
City of Milton-Freewater, No. 2. Altitude about 1,065 feet. Drilled by A. A. Durand and Son, 1944.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel, cemented below 28 feet	63	63
Columbia River Basalt:		
Basalt, alternately brown and black	113	176
Basalt, brown and red	9	185
Basalt, black and gray	19	204
Basalt, brown, porous	5	209
Basalt, black and brown	109	318
Basalt, brown, porous	7	325
Basalt, brown and black	77	402
Clay, blue, sticky	1	403
Basalt, black and brown, porous 459-479	158	561
Basalt, gray and black, porous 583-595 and 654-668	107	668
Basalt, black, porous, static water level 114 feet	10	678
Basalt, black, static water level 105 feet	43	721
Basalt, brown, black, gray, and red	89	810
Basalt, black, static water level 103 feet	23	833
Basalt, black and brown	69	902
Casing, 20-inch, set to 41 feet; 16-inch set to 99 feet.		

Table 2.--Drillers' logs of representative wells.--Continued

Material	Thickness (feet)	Depth (feet)
Well 5/35-12G1		
Rogers Canning Co. Altitude about 1,080 feet. Drilled by A. A. Durand and Son, 1944.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel, cemented below 21 feet	46	46
Boulders	2	48
Columbia River Basalt:		
Basalt, brown and black, porous 182-185	334	382
Basalt, gray with blue shale	7	389
Basalt, black	62	451
Basalt, porous with some blue clay	11	462
Basalt, black, with blue shale 478-486	41	503
Basalt, black, porous	5	508
Basalt, gray and black, porous 569-584	195	703
Casing, 20-inch, set to 41 feet; 16-inch, to 64 feet.		
Well 6/33-8Q1		
Mr. Nelson (former owner). Altitude about 525 feet. Drilled by Nelson about 1915.		
Touchet Beds and other Pleistocene deposits undifferentiated:		
Soil	5	5
Sand, fine, water-bearing	25	30
Clay	20	50
Sand, fine, water-bearing	50	100
Clay, blue	35	135
Sand, coarse	40	175
Columbia River Basalt:		
Basalt, water-bearing	2	177
Well 6/33-10J1		
D. Gilkerson. Altitude about 545 feet. Drilled by A. A. Durand and Son, 1939.		
Touchet Beds:		
Clay, silt, "hardpan" and pea gravels	80	80
Gravel and sand	40	120
Clay, blue, mixed with sand	55	175
Gravel, loose, water-bearing	50	225
Well 6/34-9F1		
Clayton Prusia. Altitude about 610 feet. Drilled by Heitstuman Bros., 1953.		
Touchet Beds:		
Soil, sand, clay	28	28
Unclassified:		
Gravel	27	55
Clay and gravel	35	90

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/34-9F1--Continued		
Old gravel of Pleistocene age:		
Gravel, cemented with clay in center part	31	121
Clay	6	127
Gravel, cement	26	153
Clay	2	155
Gravel, loose, with some clay	8	163
Clay, with 4 feet of cemented gravels near top	33	196

Casing, 12-inch, set to 97½ feet.

Well 6/34-13A1

R. M. Emigh. Altitude about 700 feet. Drilled by T. VanVoorst, 1946.

Materials	Thickness (feet)	Depth (feet)
Touchet Beds:		
Soil	6	6
Clay, blue, with silt	94	100
Old gravel of Pleistocene age:		
Gravel, cemented	70	170
Gravel, water-bearing	10	180
Gravel, cemented	40	220
Gravel, water-bearing	4	224
Gravel, cemented	86	310

Well 6/34-22G1

Lane Hune, formerly E. C. Burlingame, Sr. Altitude about 590 feet. Drilled by Sullivan Machinery Company of Chicago, 1922.

Materials	Thickness (feet)	Depth (feet)
Touchet Beds and old clay of Pleistocene age:		
Silt, blue "mud" and fine sand	1,000±	1,000±
Columbia River Basalt:		
Basalt, fractured, no core over 4 ft long	2,000±	3,000

Well 6/34-35D1

Marion A. Cockburn. Altitude about 650 feet. Drilled by A. A. Durand and Son, 1948.

Materials	Thickness (feet)	Depth (feet)
Recent alluvium:		
Gravel and soil	11	11
Columbia River Basalt:		
Basalt, layered, water-bearing; static water level 8 feet below surface	289±	300
Basalt, faulted, sloughed badly	200	500
Basalt, layered, water-bearing; static water level about 20 feet above surface	150	650

Casing, 18- and 14-inch, set to 60 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-1C1		
Frank Decclo. Altitude about 810 feet. Drilled by A. A. Durand, 1910.		
Older alluvium and old gravel and clay of Pleistocene age:		
Soil, clay, fine sand and gravel	470	470
Sand, partly cemented	10	480
Clay, blue	47	527
Columbia River Basalt:		
Basalt, water-bearing, violent flow at land surface	8	535
Casing, 10-inch, set to 70 feet; 8-inch, set to 470 feet; 6-inch set 470-510 and 0-90 feet.		
Well 6/35-1D1		
Tony Lampeiti. Altitude 800 feet. Log from memory of Nelson, former owner. Drilled by A. A. Durand, 1914.		
Old gravel and clay of Pleistocene age:		
Soil, gravel	200	200
"Mud"	200	400
Gravel	100	500
Clay	24	524
Columbia River Basalt:		
Basalt, water-bearing, water flowing at land surface	25	549
Well 6/35-1M1		
Harold Wagoner. Altitude 800 feet. Drilled by A. A. Durand, 1911.		
Touchet Beds:		
Soil and silt	50	50
Old gravel and clay of Pleistocene age:		
Gravel, cemented	200	250
Clay, yellow, sticky	225	475
Gravel, cemented ("solid rock")	50	525
Clay, sticky	75	600
Columbia River Basalt:		
Basalt	100	700
Basalt, creviced, water-bearing	3	703
Well 6/35-2E1		
Mrs. M. Seeliger. Altitude about 730 feet. Drilled by Harding Bros., 1948.		
Recent alluvium:		
Clay	12	12
Old gravel and clay of Pleistocene age:		
Gravel, some water	188	200
Clay, blue	326	526
Columbia River Basalt:		
Basalt, creviced at 540 and 700, porous at places but not water-bearing, 800-814 little water; static level 22 feet	288	814
Casing, 10-inch and 6-inch, set to 540 feet.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-4B1		
F. R. Travaille. Altitude about 680 feet. Drilled by A. A. Durand and Son, 1946.		
Recent alluvium:		
Alluvium	17	17
Old gravel of Pleistocene age:		
Gravel and sand	11	28
Gravel, loose	17	45
Gravel	20	65
Boulders and gravel	15	80
Gravel, coarse	8	88
Sand	4	92
Casing, 8-inch, set to 90 feet, perforated 15-20, 30-40, and 50-67 feet.		
Well 6/35-4Q1		
D. D. Wright. Altitude about 685 feet. Drilled by A. A. Durand and Son, 1945.		
Recent alluvium:		
Soil, gravel and "dirt"	20	20
Old gravel and clay of Pleistocene age:		
Gravel and sand, water-bearing at 25 feet	43	63
Clay, brown with gravel	37	100
Clay, sandy	7	107
Casing, 8-inch, set to 107 feet, perforated 67-107 feet.		
Well 6/35-6A1		
R. Rimpler. Altitude about 630 feet. Drilled by Harding Bros., 1946.		
Recent alluvium (slope alluvium):		
"Soil"	18	18
Old gravel of Pleistocene age:		
Gravel, cement	20	38
Clay and gravel	18	56
Gravel, water-bearing	19	75
Well 6/35-10P1		
Frank Berard. Altitude about 735 feet. Drilled by A. A. Durand, 1922.		
Recent alluvium:		
Soil and alluvium	8	8
Old gravel and clay of Pleistocene age:		
Gravel, loose, water-bearing	17	25
Gravel, cemented, with sand and clay	155	180
Clay with some gravel interbedded, some water-bearing members; static level just above land surface	80	260
Clay, yellow	25	285
Clay, blue	295	580

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-10P1--Continued		
Columbia River Basalt:		
Basalt, water-bearing in places, first flow of water at 700, slight increased flow to 900, about 100 gpm increase in 900-910 zone	330	910
Basalt, hard	225	1,135
Basalt, porous, water-bearing, large flow of water (originally 2,200 gpm)	10±	1,145
Well 6/35-11D1		
Ivor Williams. Altitude about 730 feet. Drilled by A. A. Durand and Son, 1946.		
Old dug well	18	18
Old gravel of Pleistocene age:		
Gravel and boulders	12	30
Gravels and clay	8	38
Sand, coarse	13	51
Well 6/35-11J1		
U.S. Dept. of Agriculture. Altitude about 760 feet. Drilled by A. A. Durand.		
Recent alluvium:		
Soil	12	12
Old gravel and clay of Pleistocene age:		
Gravel and sand (some water)	210	222
Clay, blue	325	547
Columbia River Basalt:		
Basalt, black, hard	83	630
Basalt, porous, water-bearing	12	642
Well 6/35-12N1		
A. A. Durand. Altitude about 775 feet. Drilled by A. A. Durand, 1913.		
Recent alluvium:		
Soil and gravel	10	10
Old gravel and clay of Pleistocene age:		
Gravel, loose	35	45
Gravel, cemented with clay interbeds	215	260
Clay, blue	85	345
Gravel, water-bearing, static water level 25 feet above land surface	5	350
Clay, blue	185	535
Columbia River Basalt:		
Basalt, black	30	565
Basalt, black, porous, water-bearing	25	590

Casing, 10-inch, set to 180 feet, 8-inch, set to 495 feet, 6-inch to 535± feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-15A1		
S. T. Cauvel. Altitude about 760 feet. Drilled by A. A. Durand and Son, 1945.		
Recent alluvium:		
Soil	5	5
Old gravel of Pleistocene age:		
Boulders	15	20
Clay and gravel	6	26
Sand and gravel	10	36
Gravel, cemented	6	42
Casing, 8-inch, set to 42 feet, perforated 20½ to 36½ feet.		
Well 6/35-16N2		
F. E. Kralman. Altitude about 750 feet. Drilled by A. A. Durand and Son, 1945.		
Recent alluvium:		
Soil	8	8
Old gravel of Pleistocene age:		
Gravel and boulders	8	16
Gravel, loose	17	33
Gravel, cemented	11	44
Gravel, water-bearing	2	46
Casing, 8-inch, set to 43 feet, perforated 12-22 and 32-43 feet.		
Well 6/35-23D1		
E. E. Stevens. Altitude about 825 feet. Drilled by O. E. Haig and T. VanVoorst, 1933.		
Touchet Beds:		
Silt, sand, and clay	50	50
Old gravel of Pleistocene age:		
Gravel, water-bearing	50	100
No record	587	687
Columbia River Basalt:		
Basalt, dense, water-bearing	48	735
Basalt	185	920
Clay, blue, swelling	20	940
Basalt	67	1,007
Casing, 8-6-5-4½-inch, set to 1,007 feet, perforated 687-735 feet.		
Well 6/35-25B1		
D. Goodman. Altitude about 870 feet. Drilled by Shortridge, 1934.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel, old dug well	27	27
Old clay of Pleistocene age:		
Clay, yellow	20	47
Clay, with gravel	43	90
Clay, blue, with some "boulders"	312	402
Casing, 8-inch, set 27-54 feet, open at bottom.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-27H1		
J. E. Kessler. Altitude about 860 feet. Drilled by A. A. Durand & Son, 1945.		
Recent alluvium and old gravel of Pleistocene age (old dug well):		
Soil, mostly cemented	5±	5±
Gravel, cobble size, mostly cemented; water-bearing in loose gravel members	29	34
Old gravel of Pleistocene age:		
Gravel, washed	7	41
Gravel and clay	9	50
Gravel, clean, water-bearing	6	56
Casing, 6-inch, set 5-46 feet.		
Well 6/35-27Q3		
C. Feigner. Altitude about 890 feet. Drilled by Earl Shortridge, 1946.		
Dug well, no record	50	50
Old gravel of Pleistocene age:		
Gravel, cemented	265	315
Clay, reddish	7	322
Gravel, cemented	58	380
Old clay of Pleistocene age:		
Clay, red	10	390
Clay, gray and blue	90	480
Well 6/35-30C1		
A. F. Riggle. Altitude about 700 feet. Drilled by Lowell Marlatt, 1955.		
Soil and unclassified:		
Soil and gravel mixed with clay	35	35
Old gravel of Pleistocene age:		
Gravel, water-bearing	7	42
Clay and gravel	17	59
Sand, fine	1	60
Clay with some pea gravel	72	132
Clay, yellow	77	209
Gravel with clay intermixed	3	212
Gravel, clean, water-bearing	18	230
Well 6/35-33J1		
J. Nelson, Altitude 875 feet. Drilled by Haig Bros., 1933.		
Old gravel and clay of Pleistocene age:		
Gravel, cemented	230	230
Clay, blue	45	275
Shale, gray	55	330
Clay, black, sticky	45	375
Sand	25	400
Clay	2	402

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/35-33J1--Continued		
Sand	11	413
Columbia River Basalt:		
Basalt, red	2	415
Basalt, water-bearing	27	442
Well 6/35-33K1		
H. O. Yates. Altitude about 865 feet. Drilled by Haig Bros., 1933.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel, loose	30	30
Old gravel of Pleistocene age:		
Gravel, cemented with yellow clay matrix	32	62
Gravel and boulders, loose, water-bearing	4	66
Casing, 8-inch, set to 62 feet.		
Well 6/35-34K1		
C. W. Rasmussen. Altitude about 910± feet. Drilled by A. A. Durand and Son, 1946.		
No record - dug well	37	37
Old gravel of Pleistocene age:		
Gravels, cemented	14	51
Cobbles, basalt-rock, hard	5	56
Gravel, sandy, static water level 22 feet	2	58
Gravel, cemented	7	65
Clay, yellow	2	67
Gravel, cemented, static water level 37 feet	106	173
Clay, yellow, and cobbles	2	175
Gravel, cemented	25	200
Gravel, cemented, with clay	25	225
Casing, 8-inch, 0 to 87 feet; 6-inch to 225 feet; perforated 52 to 60 feet and 210 to 225 feet.		
Well 6/35-34P3		
Alex Duff. Altitude 895 feet. Drilled by Haig Bros., 1925.		
Recent alluvium and old gravel of Pleistocene age:		
Gravel, in part cemented	280	280
Old clay of Pleistocene age:		
Clay, swelling	10	290
Clay, blue	60	350
Clay, green, much sand interbedded	50	400
Columbia River Basalt:		
Basalt, black and white	5	405
Basalt, red, water-bearing	5	410

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/36-3A1		
B. D. Reser. Altitude about 1,060 feet. Drilled by Wm. E. Ruther, 1951.		
Soil	6	6
Old gravel of Pleistocene age:		
Gravel, cemented, water at 17 ft	24	30
Old clay of Pleistocene age:		
Clay, brown	52	82
Clay, blue, some intermixed gravel	193	275
Columbia River Basalt:		
Basalt	9	284
Basalt, water-bearing	5	289
Basalt	1	290
Well 6/36-6Q1		
John Yenny. Altitude about 850 feet. Drilled by A. A. Durand and Son, 1945.		
Soil	17	17
Old gravel of Pleistocene age:		
Gravel	2	19
Gravel, cemented	40	59
Casing, 10-inch, set to 30 feet; perforated 3 to 30 feet.		
Well 6/36-9L1		
Baker & Baker. Fix Farm Well No. 1. Altitude about 1,000 feet. Drilled by A. A. Durand and Son, 1945.		
Deposits of the upper valley terraces:		
Soil and clay	21	21
Old gravel and clay of Pleistocene age:		
Gravel, cemented; little water 62-70 feet	96	117
Clay with gravel and cobbles	58	175
Clay, blue	43	218
Columbia River Basalt:		
Basalt, black, soft and hard	118	336
Basalt, gray	22	358
Basalt, black, crevice at 440	84	442
Basalt, black, brown streaks at 445	16	458
Basalt, gray and black	162	620
Soapstone, green, and basalt, black, hard and soft; little water at 718 feet with static water level 77 feet, bailed out	110	730
Basalt, black and gray, hard and medium	149	879
Basalt, black, soft	7	886
Basalt, gray, very hard	53	939
Basalt, black; water-bearing at 990 feet, static water level 97 feet	61	1,000
Basalt, dark, hard	56	1,056
Basalt, soft, red; static water level 92 feet	16	1,072
Basalt, black, very hard	2	1,074
Basalt, red, soft	6	1,080
Basalt, black, hard	10	1,090

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/36-6Q1--Continued		
Basalt, brown, soft; static water level 92 feet	2	1,092
Basalt, soft, porous	20	1,112
Basalt, black, hard	19	1,131
Basalt, black, very hard	24	1,155

Casing, 12-inch, set to 229 feet; 10-inch, set 215 to 652 feet; cement-lined 485 to 673 feet; and 620 to 939 feet.

Well 6/36-9P1

Baker & Baker. Fix Farm Well No. 2. Altitude about 1,000 feet. Drilled by A. A. Durand and Son, 1946.

Materials	Thickness (feet)	Depth (feet)
Deposits of the upper valley terraces:		
Dirt and clay	22	22
Old gravel and clay of Pleistocene age:		
Gravel, cemented, with clay	49	71
Gravel, cemented, (water)	9	80
Gravel, with clay	20	100
Clay, yellow and blue	114	214
"Rock"	10	224
Columbia River Basalt:		
Basalt, black, hard	36	260
Basalt, black, soft	6	266
Basalt, black and gray	101	367
"Rock, soft"	4	371
Basalt, black, hard; static water level 88 feet	20	391
Basalt, gray and black, hard	205	596
Clay, blue, sticky	2	598
Basalt, hard	67	665
"Clay streaks"	2	667
Unreported (caving)	5	672
Basalt, hard	5	677
Basalt, black, with streaks of clay	314	1,001
Basalt, black	12	1,013
Shale, brown	19	1,032
Basalt	20	1,052
Basalt, with clay	8	1,060
Basalt	22	1,082
Basalt, soft, and shale	8	1,090
Basalt, black; static water level 120 feet	47	1,137
Basalt, gray, soft	46	1,183
Basalt; static water level 98 feet	77	1,260
Unreported	7	1,267
Clay, brown (caving)	28	1,295
"Rock, brown, hard"	11	1,306
Basalt, hard	16	1,322
"Rock, brown, soft"	28	1,350
Basalt	7	1,357
Basalt, black, porous; static water level 90 feet	18	1,375
Basalt, black, gray, and brown	195	1,570
Basalt, soft	14	1,584
Shale, brown	11	1,595
Basalt, gray, hard; static water level 90 feet	400	1,995
Basalt, porous	66	2,061

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/36-10E1		
Lawrence G. Frazier. Altitude about 1,050 feet. Drilled by A. A. Durand and Son, 1946.		
Recent alluvium:		
Soil	3	3
Gravel, with boulders	11	14
Gravel	5	19
Clay, yellow	11	30
Old gravel and clay of Pleistocene age:		
Gravel	8	38
Gravel, cemented	12	50
Clay, sandy	15	65
Gravel, coarse	7	72
Gravel, cemented	15	87
"Basalt," hard	5	92
"Hardshell"	1	93
Gravel	2	95
Gravel, cemented	17	112
Clay	6	118
Gravel, cemented	12	130
Gravel, with clay	10	140
Shale, blue	4	144
Clay, brown	11	155
Clay, blue	11	166
Gravel	17	183
Gravel, cemented	9	192
Clay, blue	20	212
Gravel, cemented	10	222
Columbia River Basalt:		
Basalt, black	82	304
Basalt, gray, hard	5	309
Basalt, brown, with clay	6	315
Basalt, hard, with porous zones	115	430
Basalt, black, hard	19	449
Basalt	21	470
Not reported	7	477
"Lime"	3	480
Not reported	14	494
Basalt, black, hard	18	512
Basalt, gray	98	610
Shale, gray	5	615
Basalt, gray and black	185	800
Casing, 12-inch, set to 59 feet, 10-inch, set to 224 feet and perforated 46 to 222 feet.		
Well 6/36-13C1		
Emmett Lynch. Altitude about 1,300 feet. Drilled by A. A. Durand and Son, 1944.		
Recent alluvium and Palouse Formation:		
Soil, sandy	10	10
"Shale and shells"	30	40
Columbia River Basalt:		
Basalt	5	45

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/36-13C1--Continued		
Basalt, broken, static water level 40 feet	15	60
Basalt	18	78
Shale, red, sandy, static water level 60 feet; water level dropped 20 feet at 122 feet	10	88
Basalt, static water level 80 feet	47	135
Well 6/36-20Q1		
W. H. Till. Altitude about 935 feet. Drilled by A. A. Durand and Son, 1945.		
Dug well, no record	64	64
Old gravel and clay of Pleistocene age:		
Gravel, static water level 65 feet	95	159
Clay, blue	86	245
Gravel and sandy clay, static water level 70 feet	45	290
Clay, blue, sandy, static water level 100 feet	55	345
Columbia River Basalt:		
Basalt, static water level 80 feet	15	360
Basalt, porous	25	385
Well 6/36-31L1		
Milton Nursery. Altitude about 955 feet. Drilled by A. A. Durand, 1929.		
Deposits of the upper valley terraces:		
Soil	20	20
Old gravel of Pleistocene age:		
Gravel, water-bearing in 140-165 zone	180	200
Columbia River Basalt:		
Basalt rock	217	417
Shale	17	434
Basalt, gray and black	278	712
Basalt, black, water-bearing	3	715
Basalt, gray	185	900
Basalt, black, with streaks of red	14	914
Basalt, gray	206	1,120
Basalt, black, water-bearing	2	1,122
Basalt, gray	268	1,390
Basalt, black, with fine white water-washed gravel, water-bearing	3	1,393
Basalt, gray	457	1,850
Basalt, black, water-bearing	6	1,856
Basalt, gray	84	1,940
Basalt, black, water-bearing	4	1,944
Basalt, gray, water-bearing	56	2,000

Casing, 12-inch, set to 39 feet; 10-inch, set to 207 feet' 8-inch, set to 348 feet; 6-inch, set 417 to 537 feet. Casing perforations not recorded, but said to be perforated in 140-165-foot zone.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 6/37-5F1		
Baker & Baker, Sweazey Quarter well. Altitude about 1,560 feet. Drilled by A. A. Durand and Son, 1946.		
Palouse Formation:		
Clay	15	15
Old gravel of Pleistocene age:		
Gravel, cemented	30	45
"Shale"	20	65
Gravel, cemented	5	70
Columbia River Basalt:		
Basalt, red	10	80
Basalt, gray and black	94	174
Basalt, black, water-bearing 185 to 190 feet; static water level 40 feet below land surface	40	214
Basalt, black, gray, and brown	177	392
Basalt, black; at 417 feet water flowed over casing head. Pumped 265 gpm with drawdown of 100 feet	66	458
Basalt, gray	44	502
Basalt, black, fractured; water overflowing at 5 gpm	13	515
Basalt, black, hard; crevice at 535 feet	20	535
Basalt, black, soft	18	553
Basalt, gray, hard	9	562
Basalt, black, soft; water-bearing 559 to 563 feet and flowing 100 gpm; static water level 60 feet above land surface	1	563
Basalt, gray and black, hard	16	579
Basalt, black; water flowing 3 inches over 12-inch casing; water has 55 pounds psi shut-in pressure	4	583
Basalt, porous, brown; water flowing 2,390 gpm and has 74 psi shut-in pressure	29	612
Well 6/37-18P1		
Elmer R. Davis. Altitude about 1,500 feet. Drilled by A. A. Durand and Son, 1945.		
Dug well	45	45
Old gravel of Pleistocene age:		
Gravel, with boulders	6	51
Gravel and sand	14	65
Sand, hard, cemented	8	73
Gravel	3	76
Gravel, cemented	46	122
"Hardshell"	4	126
Gravel, cement; static water level at land surface	26	152
"Gravel and broken rock, water-bearing"; static water level is 115 feet	8	160
Gravel, with clay	2	162

Casing, 6-inch, set to 73 feet; perforated 57-73 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/33-10A1		
DeRuwe and Weber. Altitude about 550 feet. Drilled by T. VanVoorst, 1925.		
Recent alluvium:		
Soil	12	12
Gravel, sand, silt, water-bearing	12	24
Columbia River Basalt:		
Basalt, soft	4	28
Basalt, hard, with some water	116	144
Basalt, gray, soft, water-bearing	15	159
Well 7/33-26Q1		
A. A. Lang. Altitude about 500 feet. Drilled by A. A. Durand and Son, 1945.		
Loess, undifferentiated:		
Soil	3	3
Clay	32	35
Sand, fine, "dry"	35	70
Uncorrelated, old gravel of Pleistocene(?) age:		
Gravel and clay, some water	25	95
Gravel with clay interbeds	5	100
Clay with gravel interbeds	25	125
Casing, 10-inch, set to 125 feet, perforated 83-115 feet.		
Well 7/33-34H1		
W. J. Webb. Altitude about 470 feet. Drilled by A. A. Durand and Son, 1945.		
Touchet Beds:		
Old dug well	18	18
"Soil, sandy," water-bearing	10	28
Sand and gravel	26	54
Uncorrelated, old gravel and clay of Pleistocene(?) age:		
Gravel	25	79
Clay	18	97
Casing, 10-inch, set to 78 feet, perforated 28-54 feet--later perforated by owner 16-26 feet.		
Well 7/33-34L1		
Union Pacific Railroad. Altitude about 442 feet. Drilled by A. A. Durand, 1931.		
Recent alluvium:		
Soil	12	12
Uncorrelated, old gravel and clay of Pleistocene(?) age:		
Gravel, cemented	63	75
Clay	180	255
Gravel, cemented	35	290
Clay	67	357
Columbia River Basalt:		
Rock	30	387
Casing, 6-inch, set 0-260 and 272-387 feet.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/33-34N2		
R. R. Dodd. Altitude about 435 feet. Drilled by VanVoorst Bros., 1940.		
Uncorrelated, Recent alluvium, old gravel and clay of Pleistocene(?) age:		
Soil, gravel and sand	69	69
Mud, bluish black, clayey	179	248
Columbia River Basalt:		
Basalt, partly decomposed, water-bearing	7	255
Basalt, black, water-bearing	30	285
Well 7/34-25N1		
Charles Baker. Altitude about 600 feet. Drilled by A. A. Durand and Son, 1946.		
Soil	3	3
Deposits of the upper valley terraces and other Pleistocene deposits:		
Sand, silty, with hard silt interlayers	20	23
Silt, blue, wet, static water level 8 feet	7	30
Gravel, quicksand layer 69-73 feet	44	74
Sand and clay	21	95
Clay, blue, brown and green	190	285
Sand and clay, water-bearing, static level 5 feet, pump test 35 gpm with 100 feet drawdown	10	295
Columbia River Basalt:		
Basalt, gray and broken	8	303
Sand, "water-bearing"	4	307
Clay, brown	19	326
Basalt, black	19	345
Clay, brown, static water level 8 feet	9	354
Basalt, black, broken lower 11 feet	52	406
Basalt, hard, pump test 234 gpm with 130 feet drawdown	570	976
Basalt	126	1,102
Well 7/34-29C1		
Lowden Johnson. Altitude about 500 feet. Drilled by A. A. Durand, 1907 and 1956.		
Recent alluvium:		
Soil	20	20
Pleistocene deposits, undifferentiated:		
Gravel	30	50
Clay, blue	70	120
Columbia River Basalt:		
Basalt, blue, dense, "dry" to 600 feet and water-bearing in several places below	1,080	1,200

Casing, 6 5/8-inch, to 100 feet, 6 1/4-inch to 610 feet, pulled and replaced with 12-inch when rehabilitated in 1956.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/34-33E1		
J. E. Talbot. Altitude about 510 feet. Drilled by Wm. Ruther, 1959.		
Alluvium:		
Soil	12	12
Old gravel and clay of Pleistocene age:		
Cobbles	16	28
Gravel, cemented	48	76
Gravel, sand and clay, water-bearing	16	92
Clay, brown with gravel layers, water-bearing	16	108
Clay, blue	7	115
Well 7/35-23M1		
U.S. Bonneville Power Administration. Altitude 772 feet. Drilled by A. A. Durand & Son, 1946.		
Recent and Pleistocene deposits, undifferentiated:		
Soil	13	13
Boulders	7	20
Old gravel and clay of Pleistocene age:		
Gravel, coarse	9	29
Sand, fine, mixed with gravel	8	37
Clay, brown	5	42
Boulders	82	124
Clay, brown	26	150
Sand, fine, with gravel	5	155
Gravel, coarse	15	170
Clay, brown	20	190
Clay, blue-gray	65	255
Sand, fine with gravel	10	265
Clay, blue-gray	112	377
Clay, brown	11	388
Clay, blue-gray	32	420
Clay, red	6	426
Clay, brown	37	463
Columbia River Basalt:		
Basalt, water-bearing	52	515
Casing, 10-inch, to 195 feet, 8-inch to 464 feet.		
Well 7/35-25F1		
James Arbini, et al. Altitude about 880 feet. Drilled by A. A. Durand and Son, 1946.		
Soil	4	4
Old gravel and clay of Pleistocene age:		
Gravel	26	30
Gravel, cemented	8	38
"Mud" and gravel	13	51
Gravel, cemented	20	71
Gravel	79	150
"Mud" and gravel	15	165
Gravel, cemented	2	167
"Mud," brown	8	175

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/35-25F1--Continued		
Gravel	25	200
Clay, brown	4	204
Clay, blue	205	409
"Rock" (probably angular cobbles cemented)	11	420
Gravel, cemented	10	430
Clay, sticky	5	435
Clay, blue, brown, gray	89	524
Columbia River Basalt:		
"Rock"	3	527
Basalt, gray, hard	16	543
Clay, "gumbo," tough	4	547
Clay and basalt	7	554
Basalt, gray and black, broken in places	66	620
Basalt and clay, brown	16	636
Basalt, gray and black	44	680

Casing, 10-inch, set to 129 feet; 8-inch set 127 to 539 feet.

Well 7/35-25P1

Ponti and Columbo. Altitude about 820 feet. Drilled by A. A. Durand, 1908.

Materials	Thickness (feet)	Depth (feet)
Soil	8	8
Old gravel and clay of Pleistocene age:		
Gravel, loose and cemented	202	210
Clay, blue and yellow	325	535
Columbia River Basalt:		
Basalt, water-bearing	83	618

Well 7/35-26Q2

College Place Irrigation Dist. No. 14. Drilled in 1952.

Materials	Thickness (feet)	Depth (feet)
Alluvium:		
Soil and clay	7	7
Old gravel of Pleistocene age:		
Gravel, cemented	33	40
Clay, brown, and gravel	93	133
Gravel	7	140
Clay, brown, and gravel	49	189
Old clay of Pleistocene age:		
Clay, green	263	452
Clay, gray, brown, sticky	82	534
Clay, brown, with basalt inclusions	5	539
Columbia River Basalt:		
Basalt, black, hard, water flowing	60	599
Basalt, honey-combed; water flow increased	9	608
Basalt, black, hard	17	625

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/35-33D1		
Fred Fuller. Altitude about 660 feet. Drilled by A. A. Durand and Son, 1946.		
Soil	18	18
Old gravel and clay of Pleistocene age:		
Gravel and clay, water-bearing	14	32
Sand, coarse, with pebbles	23	55
Clay and gravel	5	60
Gravel, fine and sand, fine	2	62
Gravel, cemented	10	72
"Mud" and gravel	4	76
Gravel, cemented	14	90
Sand and gravel, water-bearing	16	106
Clay	2	108
"Rock" (boulder?)	2	110
Gravel and sand	4	114
Gravel, cemented, muddy	12	126
Gravel, cemented, compact	30	156
Gravel, cemented	14	170
Clay, blue, sticky, with pebbles	35	205
Clay, yellow and blue	92	297
"Shale," blue	76	373
"Mud," green, sticky	5	378
"Shale," blue	12	390
"Shale," gray and blue, hard	45	435
"Shale," brown or yellow	55	490
"Mud," yellow and blue, sticky	43	533
"Shale," green	17	550
"Mud," blue, gray, green	23	573
"Shale," brown, black	42	615
Columbia River Basalt:		
Basalt, black and gray	99	714
Basalt, black, soft, porous	16	730
Basalt, black	29	759
Shale, black	1	760
Casing, 10-inch, set to 107 feet; 6-inch, set to 617 feet.		
Well 7/35-34G1		
Herman Martin. Altitude about 720 feet. Drilled by A. A. Durand and Son, 1944.		
Soil	10	10
Old gravel and clay of Pleistocene age:		
Gravel, cemented	20	30
Gravel	7	37
Gravel, loose	28	65
Gravel and clay	14	79
Gravel, loose	13	92
Clay and gravel	13	105
Clay, brown	23	128
Gravel	5	133
Clay and gravel, mixed	10	143

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/35-35H1		
Walla Walla College. Altitude about 785 feet. Drilled by A. A. Durand and Son, 1946.		
Recent alluvium:		
Soil and clay	17	17
Old gravel and clay of Pleistocene age:		
Gravel	26	43
Clay, brown	6	49
Gravel, cemented	5	54
Gravel, loose	11	65
Clay, brown	9	74
Gravel, cemented	26	100
Casing, 12-inch, set to 75 feet; 10-inch, perforated, set 75-100 feet.		
Well 7/35-36A1		
Ambrose Zaro. Altitude about 825 feet. Drilled by A. A. Durand.		
Not reported	14	14
Old gravel and clay of Pleistocene age:		
Gravel, loose	6	20
Gravel, with clay	20	40
Gravel	5	45
Gravel and clay	40	85
Gravel, water-bearing	10	95
Clay, brown	114	209
Gravel, water-bearing	11	220
Clay, blue	100	320
Clay, blue with some gravel	100	420
Sand, green	40	460
Clay, brown, and gravel	27	487
Clay, gray	48	535
Clay, green	14	549
Columbia River Basalt:		
Basalt, black	14	563
Basalt, gray, water-bearing	33	596
Basalt, black	34	630
Clay, gray, with sand ("crevice")	5	635
Well 7/35-36D1		
College Place Water Co. Altitude 790 feet. Drilled by A. A. Durand & Son, 1908.		
Soil	5	5
Old gravel and clay of Pleistocene age:		
Gravel, loose	20	25
Gravel, cemented; water-bearing	140	165
Clay, yellow, with some sand	20	185
Gravel, matrix of sand and silt	15	200
Clay, yellow, with some sand	60	260
Clay, blue	275	535
Columbia River Basalt:		
Basalt, dense	65	600
Basalt, porous and dense in alternating layers, water-bearing	25	625

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/35-36F2		
Richards, et al. Altitude about 805 feet. Drilled by A. A. Durand, 1910.		
Old gravel and clay of Pleistocene age:		
Soil, gravel, and blue clay	470	470
"Rock," broken, water-bearing	8	478
Clay, blue	57	535
Columbia River Basalt:		
Basalt	45	580
Basalt, water-bearing	30	610
Well 7/36-2J1		
R. L. Moore. Altitude about 1,250 feet. Drilled by A. A. Durand & Son, 1955.		
Palouse Formation:		
Soil, loam	36	36
Old gravel of Pleistocene age:		
Gravel, with some clay near base	17	53
Gravel, yellow and brown, with some clay	27	80
Gravel, cemented	8	88
Clay, yellow, soft	34	122
Gravel, cemented, with some clay	48	170
Columbia River Basalt:		
Basalt, fractured	12	182
Basalt, black, hard	380	562
Clay, blue	18	580
Basalt, brown, broken, with clay	40	620
Basalt, red, broken	37	657
Basalt, gray	153	810
Casing, 12-inch, set to 164 feet, 12-inch open hole below.		
Well 7/36-13F1		
City of Walla Walla well No. 1. Altitude about 1,250 feet. Drilled by A. A. Durand and Son, 1942.		
Deposits of the upper valley terraces:		
Dirt, gravel, and boulders	32	32
Old gravel and clay of Pleistocene age:		
Gravel, cemented	8	40
Gravel, fine, and clay, brown	11	51
Gravel, clay, and boulders	8	59
Clay, brown, and boulders	31	90
Gravel, cemented	15	105
Clay, brown, and gravel	23	128
Gravel, cemented, boulders	9	137
Columbia River Basalt:		
Basalt, black	53	190
Basalt, blue, with clay seams	57	247
Basalt, gray, hard	53	300
Basalt, softer	14	314
Basalt, black, porous	50	364
Basalt, black, gray, and brown	386	750
Basalt, black and gray, water-bearing at 733 feet and at 755 feet	60	810

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-15C1		
City of Walla Walla. Altitude about 1,135 feet. Drilled by Ebersol, 1931.		
Deposits of the upper valley terraces:		
Soil	20	20
Old gravel and clay of Pleistocene age:		
Gravel, cemented	115	135
Clay, blue	200	335
Columbia River Basalt:		
Basalt	180	515
Well 7/36-16R1		
Elmer Markham. Altitude about 1,060 feet. Drilled by A. A. Durand and Son, 1945.		
Dug pit ("gravel")	38	38
Old gravel of Pleistocene age:		
Gravel, cemented	35	73
Gravel, with yellow clay	39	112
Gravel, pea-size, water-bearing	10	122
Well 7/36-19E1		
Mrs. Nina Anderson. Altitude about 880 feet. Drilled by W. E. Ruther, 1946.		
Soil	4	4
Old gravel and clay of Pleistocene age:		
Gravel, water-bearing below 27 feet	44	48
Clay	23	71
Gravel, water-bearing	13	84
Well 7/36-19F1		
General Foods Corporation, Birdseye-Snider Division. Well No. 1. Altitude about 890 feet. Drilled by A. A. Durand and Son, 1946.		
Old gravel and clay of Pleistocene age:		
Gravel, coarse	14	14
Gravel, loose	26	40
Gravel, loose, with clay	10	50
Gravel, coarse, water-bearing, bailed dry at 53 feet	15	65
Clay and gravel	41	106
Gravel, cemented	3	109
Clay and gravel	6	115
Clay	20	135
Gravel, cemented	80	215
Clay, yellow	15	230
Clay, blue	165	395
Gravel, cemented	14	409
Clay, blue	10	419
Gravel, hard, cemented	24	443
Clay, brown, sticky	12	455
Gravel, cemented	5	460
Clay, yellow	32	492

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-19F1--Continued		
Clay, blue	3	495
Clay, blue, with broken basalt	6	501
Columbia River Basalt:		
Basalt, black, medium and very hard	129	630
Clay, blue	10	640
Basalt, fractured	95	735
Basalt, black, very hard	106	841
Basalt, broken	102	943
Basalt, black, very hard	27	970
Basalt, black, water-bearing	80	1,050
Basalt, black, hard	5	1,055
Basalt, broken	7	1,062
Basalt, black, hard and broken	28	1,090
Basalt, black, broken, water-bearing	35	1,125

Casing, 20-inch, 0-253 feet; 16-inch, 243 to 511 feet; 12-inch, 494½ to 836 feet; open at bottom.

Well 7/36-19R1

Walla Walla Canning Company. Altitude about 920 feet. Drilled by A. A. Durand and Son, 1942.

Materials	Thickness (feet)	Depth (feet)
Dug pit	9	9
Old gravel and clay of Pleistocene age:		
Gravel and clay; static water level 14 feet	96	105
Gravel, cemented, and clay; water at 125 feet	20	125
Unreported	5	130
Gravel, cemented	15	145
Clay, brown	8	153
Gravel, cemented	10	163
Clay, brown	8	171
Gravel, coarse and cemented; static water level 53 feet	19	190
Clay, yellow, blue, and gray	145	355
Shale, sandy, black and blue clay	50	405
Sandstone	4	409
Gravel, fine, water-bearing, static water level 80 feet	12	421
Gravel, fine, and caving clay	7	428
Clay, blue and brown	12	440
Gravel, fine, and sandy blue clay	40	480
Clay, yellow	30	510
Gravel, loose, and clay; static water level 90 feet	10	520
Conglomerate, brown, and sand, gravel, and clay	15	535
Clay, blue, sandy	25	560
Columbia River Basalt:		
Basalt, brown and black; static water level 150 feet	5	565
Basalt, black and gray, hard	93	658
Basalt, black; static water level changed from 135 feet to 105 feet at the 670-foot depth	22	680
Basalt, gray and black, hard and soft zones	35	715
Basalt, gray, very hard	14	729
Crevices	2	731
Basalt, black, hard, some green clay; static water level 100 feet	119	866
Basalt, hard and soft streaks; static water level 100 feet	117	983
Basalt, black; pump tested 72 gpm at 240 feet	106	1,089

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-19R1--Continued		
Basalt, gray, very hard, with crevices	114	1,203
Clay, sandy, and fine gravel; static water level 93 feet	23	1,226
Basalt, gray, very hard	19	1,245
Clay, red, brown, and green, with fine gravel	11	1,256
Sandstone, gray	4	1,260
Basalt, black and gray	66	1,326
Basalt, black, medium hard, water-bearing; static water level 100 feet	32	1,358
Basalt, black, very hard	207	1,565
Basalt, gray, porous, water-bearing at 1,578 feet	15	1,580
Basalt, black, porous; static water level 95 feet	10	1,590

Casing, 12-inch, 0 to 254 feet; 10-inch, 244 to 525 feet; 8-inch, 520 to 578 feet; 6-inch, 560 to 1,590 feet, perforated at each water-bearing stratum in basalt.

Well 7/36-20N1

Marcus Whitman Hotel. Altitude about 940 feet. Drilled by A. A. Durand and Son, 1946.

Materials	Thickness (feet)	Depth (feet)
Recent alluvium and old gravel and clay of Pleistocene age:		
Gravel with boulders	20	20
Gravel, cemented	130	150
Clay, brown, with gravel layers	77	227
Clay, gray and blue	175	402
Columbia River Basalt:		
Basalt, black, broken	38	440
Basalt, broken, and blue clay, sticky	35	475
Clay, blue	13	488
Basalt, black	7	495
Clay, gray	12	507
Basalt, black	193	700

Well 7/36-20P1

Union-Bulletin Publishers. Altitude about 950 feet. Drilled by A. A. Durand and Son, 1946.

Materials	Thickness (feet)	Depth (feet)
Recent alluvium:		
Soil	3	3
Gravel	12	15
Old gravel and clay of Pleistocene age:		
Gravel and cobbles	10	25
Gravel, cemented with cobbles	41	66
Boulders and gravel	16	82
Gravel, cemented	88	170
Clay, yellow	20	190
Gravel, cemented	33	223
Clay, yellow	1	224

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-21G1		
Ray Mindemann. Altitude about 1,030 feet. Drilled by A. A. Durand & Son, 1945.		
Dug well - no record	20	20
Old gravel of Pleistocene age:		
Boulder gravel	12	32
Gravel, cemented	12	44
Sand and gravel, water-bearing	11	55
Casing, 6-inch, set to 55 feet, perforated 40-52 feet.		
Well 7/36-22N1		
City of Walla Walla No. 4. Drilled by A. A. Durand & Son, 1953.		
Recent alluvium:		
Soil, sand, gravel, boulders	21	21
Old gravel of Pleistocene age:		
Gravel, coarse, and cobbles	3	24
Gravel, with some clay	67	91
Clay, yellow and brown, and gravel	116	207
Gravel with clay	87	294
Old clay of Pleistocene age:		
Clay, blue, sticky	70	364
Clay, with some gravel	6	370
Clay, blue, hard sticky	16	386
Gravel, fine	3	389
Clay, hard, with basalt chips	8	397
Columbia River Basalt:		
Basalt, black, hard, broken 412-422	59	456
Basalt, broken, clayey, water-bearing; static water level rose from 35 to 20-foot level at 458 feet	12	468
Basalt, black, hard; bailer test at 475 feet gave 30 feet draw-down at 250 gpm	16	484
Basalt; static water level 14 feet at 496, flowing 10 gpm from 511-519 zone	35	519
Basalt, black, medium hard, water flowing 50 gpm at 635 feet	116	635
Basalt, layered, hard and soft	31	666
Basalt, black, hard	52	718
Basalt, gray, hard; flowing 86 gpm at 763 feet	60	778
Basalt, black, hard; water flow increased to 103 gpm at 780 feet	11	789
Casing, 30-inch, set to 35 feet, 24-inch, set to 400 feet. Free flow 400 gpm Sept. 6, 1953.		
Well 7/36-23E2		
Garry Huff. Altitude about 1,140 feet. Drilled by A. A. Durand & Son, 1945.		
Recent alluvium and old gravel and clay of Pleistocene age:		
Gravel	55	55
Gravel, cemented	10	65
Gravel, with clay, water-bearing	35	100
Casing, 6-inch, set to 98 feet, perforated 59-96 feet.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-25F1		
Dwelly Jones. Altitude about 1,270 feet. Drilled by A. A. Durand & Son, 1945.		
Palouse Formation:		
Clay	50	50
Clay, yellow	50	100
Old gravel of Pleistocene age:		
Gravel, cemented	32	132
Gravel, cemented, and basalt	8	140
Columbia River Basalt:		
Basalt, gray, hard; static water level at 147 feet; well bailed 5 gpm	142	282
Basalt, blue	3	285
Basalt, dark, porous and broken zones	197	482
Basalt, blue	12	494
Basalt, hard, gray; static water level 210 feet at 510 feet	40	534
Basalt, red	5	539
Basalt, gray, hard	171	710
Basalt, black; hard; static water level 215 feet at 715 feet	35	745
Basalt, black	133	878
Basalt, black and gray, alternate streaks of hard and soft; static water level 225 feet in 1,020- to 1,100-foot zone	222	1,100
Well 7/36-27D1		
---- Fields. Altitude about 1,060 feet. Drilled by A. A. Durand and Son, 1945.		
Dug well, no record	25	25
Old gravel of Pleistocene age:		
Gravel with boulders	6	31
Gravel with clay	7	38
Clay, yellow	2	40
Gravel, water-bearing	1	41
Gravel, cemented, water-bearing	9	50
Well 7/36-28A1		
Charles F. Baker. Altitude about 1,030 feet. Drilled by A. A. Durand and Son, 1946.		
Dug pit, no record	12	12
Old gravel of Pleistocene age:		
Gravel and boulders	33	45
Gravel	5	50
Clay	5	55
Gravel, with some clay	6	61
Gravel, cemented	34	95
Sand and gravel; static water level 6 feet	5	100

Casing, 6-inch, set to 72 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-28C3		
B. Campbell. Altitude about 1,005 feet. Drilled by A. A. Durand and Son, 1945.		
Dug well, no record	13	13
Old gravel of Pleistocene age:		
Gravel, cemented	6	19
Sand	39	58
Gravel, cemented	31	89
Gravel, loose	1	90
Well 7/36-28K1		
Wilson and Messer. Altitude about 1,020 feet. Drilled by Harding Bros., 1946.		
Recent alluvium:		
Soil	8	8
Gravel and "dirt"	10	18
Old gravel and clay of Pleistocene age:		
Clay with a little gravel	22	40
Clay	10	50
Gravel, static water level 30 feet	30	80
Gravel and clay	15	95
Clay with some gravel	105	200
Gravel, water-bearing, static water level 22 feet	17	217
Well 7/36-30J1		
U.S. Veterans Hospital. Altitude about 900 feet. Drilled by A. A. Durand, 1933.		
Soil	4	4
Old gravel and clay of Pleistocene age:		
Gravel, some cementation	35	39
Gravel, hard, cemented	25	64
Gravel and boulders, some water	15	79
Gravel, cemented	15	94
Clay, yellow	24	118
Gravel, cemented with boulders, water-bearing	32	150
Clay	8	158
Gravel, cemented	48	206
Clay and gravel, water-bearing	44	250
Clay, blue	178	428
Columbia River Basalt:		
Rock, solid	10	438
Clay	3	441
Rock	2	443
Clay	5	448
Rock	10	458
Clay, yellowish	10	468
Rock; static water level 25 feet	17	485
Rock and yellow clay in thin layers(?)	18	503
Clay, white	37	540
Rock, solid	10	550

Casing, 16-inch, set to 66 feet, 12-inch, set 60-250 feet, and 8-inch, set 245-540 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-30K1		
U.S. Veterans Hospital. Altitude about 895 feet. Drilled by A. A. Durand, 1923±.		
Soil	4	4
Old gravel and clay of Pleistocene age:		
Gravel, water-bearing	31	35
Gravel, cemented	25	60
Gravel, loose, with boulders, water-bearing	10	70
Gravel, cemented	10	80
Gravel, loose	20	100
Clay, yellow	25	125
Gravel, cemented, with boulders, water-bearing	15	140
Clay, blue	8	148
Gravel, cemented with boulders	52	200
Clay, yellow, sandy	15	215
Gravel, partially cemented, water-bearing	30	245
Clay, blue, with gravel	30	275
Well 7/36-31J1		
Walla Walla Country Club. Altitude about 880 feet. Drilled by A. A. Durand and Son, 1946.		
Recent alluvium:		
Clay, yellow	12	12
Old gravel and clay of Pleistocene age:		
Gravel and boulders	48	60
Clay, yellow	4	64
Gravel	18	82
Clay, gravel and boulders	48	130
Gravel, cemented, hard	17	147
Clay, soft, yellow	13	160
Gravel, cemented, coarse	20	180
Clay, yellow	10	190
Gravel, cemented	12	202
Clay, yellow, sticky	4	206
Gravel, cemented	24	230
Clay, yellow	9	239
Gravel, cemented	6	245
Clay, yellow	5	250
Clay, blue, and gravel, coarse	20	270
Clay, blue, with pebbles	95	365
Columbia River Basalt:		
"Rock," broken	15	380
Shale, blue	20	400
"Rock," broken	10	410
Clay, dark-blue	15	425
"Rock," broken	7	432
Basalt with interbeds of "shale, green"	83	515
Basalt, dark and gray, hard, water-bearing; static level 20 feet	62	577
Basalt, broken	37	614
Basalt, gray, water-bearing; static water level 70 feet	126	740
Clay, brown, sticky	5	745
Basalt, brown, gray, and red, with four 5-foot-thick interbeds of "shale, green"	535	1,280
Basalt, "shells," and shale, dark and variegated	30	1,310
Basalt, creviced 1,655-1,679; static water level 68 feet	405	1,715

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-31P1		
J. J. Chisholm. Altitude about 850 feet. Drilled by A. A. Durand and Son, 1946.		
Dug well, no record	15	15
Old gravel and clay of Pleistocene age:		
Sand, gravel	25	40
Gravel, cemented	23	63
Clay, sandy	7	70
Gravel, sandy	20	90
Clay, sandy	40	130
Gravel, cemented	12	142
Casing, 8-inch, set to 51 feet; 6-inch, 40 to 140 feet; perforated 110 to 140 feet.		
Well 7/36-31R3		
John Yenny. Altitude 880 feet. Drilled by A. A. Durand and Son, 1946.		
Dug well, no record	10	10
Old gravel of Pleistocene age:		
Sand	12	22
Clay, blue	6	28
Gravel with cobbles, water-bearing	4	32
Gravel, cemented	6	38
Clay, yellow, with sand	2	40
Gravel, coarse, with sand, water-bearing	2	42
Gravel, cemented	5	47
Casing, 8-inch, set to 46 feet, perforated 31 to 46 feet.		
Well 7/36-32A2		
J. R. Nestell. Altitude about 960 feet. Drilled by A. A. Durand and Son, 1944.		
Dug well, no record	35	35
Old gravel and clay of Pleistocene age:		
Gravel, loose	2	37
Gravel, cemented	70	107
Clay	3	110
Gravel, loose	20	130
Gravel and sand with clay	10	140
Gravel, cemented	31	171
Clay	10	181
Gravel, cemented, and clay	19	200
Gravel, cemented	5	205
Clay, brown	10	215
Gravel, cemented	31	246

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-32A2--Continued		
Clay	38	284
No record	16	300
Clay, blue	100	400
Shale, blue, decomposed	15	415
Shale, black, soft, sandy	5	420
Shale, blue, muddy	15	435

Casing, 8-inch, set to 90 feet, perforated at 35 feet.

Well 7/36-32P1

A. L. Smith. Altitude about 960 feet. Drilled by A. A. Durand and Son, 1945.

Materials	Thickness (feet)	Depth (feet)
Touchet Beds:		
Soil	23	23
Old gravel and clay of Pleistocene age:		
Gravel, cemented	12	35
Clay, brown, sandy	15	50
Clay, brown, and gravel	15	65
Gravel, cemented	85	150

Well 7/36-33A1

H. E. Studebaker. Altitude about 1,000 feet. Drilled by A. A. Durand and Son, 1942.

Materials	Thickness (feet)	Depth (feet)
Deposits of the upper valley terraces:		
Soil and clay	25	25
Old gravel and clay of Pleistocene age:		
Gravel, cemented	25	50
Clay and gravel	7	57
Gravel, cemented	51	108
Clay, brown	2	110
Clay and gravel	2	112
Clay, brown	20	132
Clay and gravel	6	138
Clay, brown	8	146
Clay and gravel	5	151
Clay, brown	6	157
Gravel, cemented	81	238
Clay, brown and gravel	122	360
Clay, blue	28	388
Clay, brown	82	470
Columbia River Basalt:		
Basalt, black	14	484
Basalt, black, and clay	173	657
Basalt, blue, black and brown	105	762

Casing, 8-inch, set to 165 feet; 6-inch, from 150 to 546 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/36-33A2		
H. E. Studebaker. Altitude about 1,000 feet. Drilled by A. A. Durand and Son, 1941.		
Deposits of the upper valley terraces:		
Soil	27	27
Old gravel and clay of Pleistocene age:		
Gravel, fine	4	31
Sand and gravel, water-bearing	34	65
Gravel, cemented, and clay	10	75
Gravel, loose	10	85
Gravel, cemented	20	105
Clay, brown, and gravel	45	150
Gravel, cemented	2	152
Casing, 8-inch, set to 152 feet.		
Well 7/36-36J1		
F. M. Ralston. Altitude about 1,250 feet. Drilled by A. A. Durand and Son, 1943.		
Deposits of the upper valley terraces:		
Soil, clay, and gravel	27	27
Sand	3	30
Old gravel of Pleistocene age:		
"Basalt, brown" (probably cemented rubbly gravel)	61	91
Gravel, cemented	90	181
Columbia River Basalt:		
Rock and clay	39	220
Basalt, brown and gray	25	245
Casing, 8-inch, set to 136 feet, perforated 118-132 feet.		
Well 7/36-36J2		
F. M. Ralston. Altitude about 1,310 feet. Drilled by A. A. Durand and Son, 1946.		
Deposits of the upper valley terraces:		
Clay, yellow, sticky	12	12
Clay, yellow, sandy	53	65
Old gravel of Pleistocene age:		
Gravel, cemented	5	70
Clay, yellow, with scattered boulders	15	85
Gravel with little clay	5	90
Gravel, coarse, and clay, yellow	5	95
Gravel, hard, cemented	61	156
"Rock, broken"	8	164
No record	3	167
Gravel, firm, cemented	18	185
Columbia River Basalt:		
Basalt, black	25	210
Basalt	244	454
Casing, 15-inch, set to 185 feet, 12-inch, set 171-273, and 12-inch open hole to bottom.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/37-5D1		
Gale Kibler. Altitude about 1,290 feet. Drilled by A. A. Durand and Son, 1941.		
Recent alluvium:		
Soil, silty clay	16	16
Old gravel of Pleistocene age:		
Boulders	3	19
Gravel, cemented	26	45
Gravel, water-bearing	2	47
Gravel, coarse	15	62
Gravel, cemented	28	90
Gravel, clay and sand	14	104
Gravel, loose	14	118
Casing, 6-inch set to 118 feet, perforated 98 to 118 feet.		
Well 7/37-5K1		
Albert Kibler. Altitude about 1,350 feet. Drilled by A. A. Durand and Son, 1945.		
Recent alluvium:		
Soil, silty loam	17	17
Old gravel of Pleistocene age:		
Gravel, coarse, cemented	12	29
Gravel, cemented, and large boulders	11	40
Gravel, cemented	4	44
Columbia River Basalt:		
Basalt, black, water-bearing in 84-103-foot zone	62	106
Well 7/37-18R2		
Olaus Filan. Altitude about 1,400 feet. Drilled by George Scott, 1949.		
Recent alluvium:		
Soil	12	12
Gravel	5	17
Columbia River Basalt:		
Basalt, black and gray, sound rock	164	181
Basalt, black with gray layers, firm, hard, water-bearing; static water level 98 feet at the 271-foot depth, 135 at 301-foot, and 190 feet at 504-foot	589	770
Casing, 12-inch set to 102 feet.		

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 7/37-31R1		
H. T. McGuire. Altitude about 1,410 feet. Drilled by A. A. Durand and Son, 1946.		
Deposits of the upper valley terraces:		
Soil	5	5
Clay, sandy	9	14
Gravel	12	26
Clay	47	73
"Rock," black (angular cobbles)	13	86
Clay, sticky	11	97
Old gravel of Pleistocene age:		
Gravel and sand	3	100
Sand	1	101
Gravel, with boulders	9	110
Gravel, cemented	55	165
"Rock," loose	2	167
Clay, with coarse gravel; static water level above land surface	8	175
Gravel, cemented, water-bearing	24	199
Sand, with boulders	3	202
Sand, yellow, fine	8	210
Clay, with gravel	10	220
Casing, 10-inch, set to 65 feet; 8-inch to 171 feet, and 6-inch hole to 220 feet.		
Well 8/34-2J1		
Martin Marbach. Altitude about 1,000 feet. Drilled by W. S. McCausland, 1905.		
Loess, undifferentiated:		
Soil and sand, brown	35	35
Uncorrelated:		
Sand and rock particles; sand is medium and coarse "quartz"	5	40
Columbia River Basalt:		
Rock, black, hard; water seep at 60 feet	100	140
Rock, black, hard	26	166
Rock, dark, massive, hard	169	335
Rock, dark, soft, fine-grained to glassy texture, water-bearing	15	350
Well 8/35-34Q1		
Don Seavy. Altitude about 790 feet. Drilled by A. A. Durand and Son.		
Recent alluvium:		
Soil and clay	31	31
Old gravel of Pleistocene age:		
Gravel, hard, gray	13	44
Gravel, water-bearing	7	51

Table 2.--Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
Well 8/35-34Q1--Continued		
Columbia River Basalt:		
Basalt, dark brown, with clay 72-74 feet	28	79
Basalt, broken, with "clay"	36	115
Basalt, gray, black, brown, hard	457	572
Sedimentary interbed zone:		
Clay, light brown	27	599
Conglomerate	7	606
Shale, dark brown	49	655
Clay, dark brown and black	16	671
Basalt, broken, contains red and yellow clay	67	738
Basalt, black, hard	178	916
Basalt, black, with red and gray clay	14	930
Basalt, black, hard	25	955
Basalt, broken, with clay	3	958
Sedimentary interbed:		
Clay, blue, sticky	7	965
Clay, black and brown	10	975
Basalt, brown, with clay	18	993
Basalt, black	30	1,023
Clay and medium sand, brown	3	1,026
Well 8/37-26L1		
---- Storey. Altitude about 1,580 feet. Drilled by Moore and Anderson, 1946.		
Recent alluvium:		
"Dirt and soil"	20	20
Columbia River Basalt:		
Basalt, brown, soft	25	45
Basalt, gray	40	85
Basalt, brown, water-bearing	41	126
Well 8/37-27R2		
Dixie Pea Growers, Inc. Altitude about 1,510 feet. Drilled by A. A. Durand and Son, 1942.		
Recent alluvium:		
Not reported	10	10
Gravel, cemented	9	19
Columbia River Basalt:		
Basalt	42	61
Clay with boulders	24	85
Basalt, black, hard, broken 107-178 and 233-237	182	267
Well 8/37-31P1		
G. M. Rea. Altitude about 1,210 feet. Drilled by Moore and Anderson, 1944.		
Recent alluvium:		
Soil, silty clay	20	20
Columbia River Basalt:		
Basalt, brown, soft, water-bearing 69 to 94 feet	74	94

Casing, 6-inch, set to 25 feet.

Table 2.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
Well 8/37-35B1		
---- Gardner. Altitude about 1,650 feet. Drilled by Moore and Anderson, 1945.		
Recent alluvium:		
"Dirt and soil"	15	15
Columbia River Basalt:		
Basalt, black	45	60
Basalt, brown; water here gave out after sustained pumping	55	115
Basalt, gray and brown	160	275
Basalt, brown and red, water-bearing	85	360
Well 8/38-32L1		
Dale Sorenson. Altitude about 2,350 feet. Drilled by Moore and Anderson, 1942.		
Recent alluvium:		
"Dirt and soil"	10	10
Columbia River Basalt:		
Basalt, black, hard, very little water	65	75
Basalt, green, hard	85	160
Basalt, black, water-bearing	15	175

TABLE 3

Analyses of water from wells, springs, and surface waters of the Walla Walla River basin

Table 3.--Analyses of water from wells, springs,

Analyses by Geological Sur-

Number or location	Source	Date of collection	Parts per million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)
							Ground
5/35-1E1	Utah Canning Co. well	1/1945	----	--	-----	16	8.5
5/35-2H1	City of Milton-Freewater, Well 5	8-1-58	131	56	0.06	14	4.9
5/35-12F1	City of Milton-Freewater, Well 1	8-1-58	127	52	.06	14	4.4
5/35-12F2	City of Milton-Freewater, Well 2 3/	11-18-46	106	--	.0	17	7.4
6/35-10P1	Frank Berard	8-1-58	199	72	.03	12	1.7
6/35-12N1	A. A. Durand	11-19-46	238	66	-----	24	6.8
6/36-4F1	O. M. McCubbins	11-19-46	----	--	-----	--	-----
6/36-9P1	Baker and Baker Corp., Fix Farm No. 2	11-29-46	161	60	.09	16	9.8
6/36-13C1	Emmett Lynch	11-19-46	----	--	-----	--	-----
6/37-5F1	Baker and Baker Corp.	11-26-46	----	--	-----	--	-----
7/33-34P2	H. H. Taylor	10-27-59	554	43	.11	43	17
7/35-23M1	Bonneville Power Adm.	11-21-46	177	55	.03	11	2.1
7/35-33J1	Walla Walla College	10-29-59	312	58	.02	50	23
7/35-36F1 -36F3	College Place Water Co., water mixed from 2 wells	4-20-52	195	65	.03	20	5.8
7/35-36F3	College Place Water Co.	10-22-59	200	65	.04	20	5.5
7/36-13F1	City of Walla Walla, Well 1	11-26-46	145	54	-----	17	8.2
7/36-13F1	--------Do-------- 4/	4-23-53	144	43	.10	16	7.5
7/36-13F1	---------Do--------	10-27-59	140	50	.01	16	6.5
7/36-19F1	General Foods Corp.	4- -46 5/	----	--	-----	8.3	5.8
7/36-19R1	Walla Walla Canning Co.	(6/)	188	47	7/4.0	.0	4.0
7/36-22N1	City of Walla Walla, Well 4	10-9-53 4/	208	55	.17	17	6.1
7/36-22N1	---------Do--------	10-27-59	196	61	9/.06	19	5.2
7/36-28R1	City of Walla Walla, Well 5	7-29-60	200	62	.06	16	5.3
7/36-33A1	H. E. Studebaker	7-29-60	173	46	.17	19	5.8
7/36-35R1	J. E. Levin	11-21-46	221	54	-----	28	9.4
7/37-5D1	Gale Kibler	11-15-46	294	34	-----	54	20
7/37-13J1	R. E. Meiners	11-18-46	175	56	-----	22	11
7/37-16Q1	Leo Gilkerson	11-26-46	234	52	-----	35	13
7/37-18F1	City of Walla Walla, Well 3	1-28-57 4/	132	56	.0	17	6.5
7/37-18G1	David Kibler	11-18-46	175	39	-----	20	8.7
7/37-31R1	H. T. McGuire	11-19-46	----	--	-----	--	-----

and surface waters of the Walla Walla River basin.

vey, unless otherwise shown.

Parts per million												
							Hardness as $CaCO_3$					
Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Calcium, magnesium	Noncarbonate	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH
Water												
14		[2]90	-----	-----	---	---	74	--	--	---	----	---
6.5	3.2	81	2.3	4.0	0.1	0.0	55	0	19	0.4	145	7.6
8.0	2.8	80	1.8	5.0	.1	.0	53	0	23	.5	148	7.6
33		104	9.9	5.8	.3	.2	73	0	30	---	180	---
32	8.6	126	3.2	6.5	.7	.0	37	0	59	2.3	226	8.2
------	---	142	31	6.5	.6	.2	88	0	45	---	239	---
------	---	107	-----	4.5	---	---	----	--	--	---	----	---
7.8	3.4	108	5.7	3.8	.6	.4	88	0	17	.6	186	---
------	---	88	-----	2.8	---	---	----	--	--	---	----	---
------	---	72	-----	1.5	---	---	----	--	--	---	----	---
130	8.1	508	20	17	.2	5.8	176	0	60	4.2	848	7.7
31	7.8	125	3.8	3.6	.6	.1	36	0	59	2.2	214	---
13	6.0	238	16	23	.2	7.0	219	24	11	.4	501	7.3
22	5.5	141	5.8	4.2	.6	.1	74	0	13	1.1	233	8.1
21	5.2	136	5.4	4.2	.5	.0	72	0	37	1.1	229	8.2
7.1		96	9.7	1.8	.2	.2	76	0	17	---	150	---
7.4		98	3.1	2.8	.2	.2	69	--	--	---	----	7.6
6.2	2.6	97	1.7	1.0	.2	.5	67	0	12	.3	163	7.7
------	---	----	6.0	6.4	---	---	45	--	--	---	----	---
48		138	7.0	.2	---	---	142	--	--	---	----	---
29		164[8]	6.6	5.6	.7	.0	68	--	--	---	----	---
25	5.2	149	5.3	2.5	.9	.2	69	0	42	1.3	257	8.1
29	5.5	148	5.0	3.0	1.0	.1	62	0	48	1.6	245	8.2
23	3.2	142	2.8	2.5	.7	.1	71	0	40	1.2	230	8.2
22		142	30	3.2	.6	3.4	108	0	30	---	231	---
21		291	10	3.8	.6	7.0	216	0	17	---	459	---
7.4		106	19	3.2	.6	3.9	100	13	14	---	227	---
16		168	28	3.5	.4	3.8	141	4	20	---	291	---
9.3	2.6	106	2.5	1.0	.2	.2	69	--	25	.5	169	8.0
21		132	16	4.5	.2	.2	86	0	35	---	213	---
------	---	79	-----	3.0	---	---	----	--	--	---	----	---

Table 3.--Analyses of water from wells, springs, and

Number or location	Source	Date of collection	Parts per million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)
							Surface
4/37-12K1	Spring, South Fork of Walla Walla River	6-4-32	----	--	-----	---	-----
4/37-13D1	Spring, South Fork of Walla Walla River	6-4-32 10/	----	--	-----	---	-----
4/37-14D1	Spring, South Fork of Walla Walla River	6-4-32 10/	----	--	-----	---	-----
4/37-14F1	Warm Spring, South Fork of Walla Walla River	6-4-32 11/	----	--	-----	---	-----
4/37-10	South Fork Walla Walla River 10/	6-4-32	31	--	-----	---	-----
7/38-18	Mill Creek	(12/)	69	34	0.11	6.6	2.7
7/38-18	Mill Creek 13/	3-26-57	60	33	.04	4.8	2.1
7/38-18	Mill Creek 13/	12-19-57	61	28	.04	6.0	2.0

1/ Data from Oregon State Board of Health.

2/ Includes all "carbonate."

3/ Also contains 0.07 part per million of boron (B).

4/ Analysis by Charlton Laboratory, Portland (Price, 1960, p. 14).

5/ Analysis by Western Research Laboratory, National Canning Assoc., San Francisco.

6/ Analysis by Continental Can Co. laboratory.

surface waters of the Walla Walla River basin.--Continued

Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH
Parts per million												
Water												
16		35	-----	4	---	---	----	--	--	---	----	---
16		35	-----	4	---	---	----	--	--	---	----	---
16		32	-----	6	---	---	----	--	--	---	----	---
31		62	-----	11	---	---	----	--	--	---	----	---
13		30	-----	3	---	---	----	--	--	---	----	---
2.4	1.8	38	2.2	.4	---	0.1	28	--	--	---	----	--
1.8	1.5	30	.7	1.0	.0	.04	21	--	15	---	54	7.3
1.8	1.9	33	.1	1.0	.1	.2	23	--	13	---	62	7.1

7/ Iron and aluminum combined.

8/ Includes 12 ppm carbonate.

9/ Special sample taken June 28, 1960 for iron determination.

10/ "Cold," normal-temperatured spring and surface water, and 11/ "hot" spring water.

12/ Analysis obtained from Walla Walla Water Dept. in 1947. Date of collection unknown.

13/ Hart, 1957, p. 17 and Price, 1960, p. 14.

Table 4.--Representative springs in the Walla Walla River basin.

(Location of springs shown on plate 1)

Topography of spring area: Ap, alluvial plain; S, slope; T, terrace whose old alluvial level merges in places with the younger alluvial plain.

Use of water: D, domestic; F, fish propagation; Irr, irrigation; N, none; PS, public supply; S, stock.

Location	Owner or former owner of property	Name	Topography and altitude (feet) above sea level)	Water-bearing material	Occurrence	Yield: Gallons per minute	Yield: Date	Use	Temperature (°F) of the water	Remarks
T. 4 N., R. 36 E.										
16C1	Don Olinger	Earthquake Spring	---------	Basalt	Water percolates from general dank area on side of ravine; spouted strongly after 1936 earthquake.	60 3,000 1,000 1	7-14-36 7-16-36 8-14-36 8-14-60	Irr	---	Big flow started by earthquake, has now declined to weak seep and stream-laid rubble has covered site.
T. 4 N., R. 37 E.										
12K1	-------------	Unnamed	---------	--Do--	Flows from perched aquifer	-------	6-4-32	N	---	See table 3 for partial chemical analysis of the water.
13D1	-------------	---Do---	---------	--Do--	--------Do-------	-------	6-7-32	N	---	----------Do----------
14D1	-------------	---Do---	---------	--Do--	--------Do-------	-------	6-7-32	N	---	----------Do----------
14F1	-------------	Warm Spring	---------	--Do--	Seeps from basalt near fault line	-------	6-7-32	N	70	----------Do----------
T. 6 N., R. 32 E.										
11B1	Emmett Lynch	Warm Spring	S, 500	--Do--	Percolates from alluvium on basalt slope	50	11-8-47	Irr S	72	Water probably flows out along concealed fault zone.

T. 6 N., R. 34 E.

13Q1	M. O. Beauchamp	South Mud Creek	Ap,	640	Gravel	Flows at level of water table	1,000-4,000	5-31-33	Irr	52	General swampy area of effluence along creek.
23H1	Emil Mueller	North Prong Schwartz Branch Spring	Ap,	630	--Do--	--------Do------	-------	----------	Irr	---	Another spring area 1,000 feet southwest drains to this place.
23R1	--------------	---------Do--------	Ap,	635	--Do--	Percolates at level of water table through many seep areas	-------	5-31-33	Irr	52½	Flows several cubic feet per second.
25Q1	---- Keyes	Dry Creek Valley Springs	Ap,	645	--Do--	Percolates at level of water table(?) in Dry Creek plain	10-30	11-10-47	D	---	One of several springs that here rise in valley plain.

T. 6 N., R. 35 E.

4N2	--------------	-----------------	Ap,	655	Sand and gravel	Seeps from swampy area at level of water table at base of terrace escarpment	-------	----------	Irr	---	Area is an intricate maze of ditches and drains.
7K1	--------------	East Mud Creek Spring	Ap,	650	--Do--	Seeps from swampy area where water table meets surface	400±	5-26-33	Irr	52	Swampy seeps, drainage and irrigation waste water form spring flow.
10H1	--------------	Big Spring Branch Springs	Ap,	725	--Do--	-------Do---------	4,000±	---------	Irr	---	Fluctuating flowage goes into Big Spring Branch.
10K1	Jassand Livestock Co.	McEvoy Spring	Ap,	730	--Do--	Bubbles up in channel	4,000±	5-20-33	D,S	58	Number of spring openings along creek channel.
16A3	--------------	-----------------	Ap,	732	Gravel	Percolates from side of drain	1,000±	5-26-33	Irr	52	Flows from gravel channel.
16N1	Fred Kralman	East Mud Creek Spring	Ap,	740	--Do--	Percolates from three waterlogged areas	2,000±	5-24-33	Irr	---	One of main sources of East Mud Creek.
22P1	J. Hansen	East Mud Creek, East Prong Spring	Ap		Gravel	Flows from drains over area of several acres	425±	5-24-33	Irr	---	

Table 4.--Representative springs in the Walla Walla River basin--Continued

Location	Owner or former owner of property	Name	Topography and altitude (feet above sea level)	Water-bearing material	Occurrence	Yield: Gallons per minute	Yield: Date	Use	Temperature (°F) of the water	Remarks
T. 6 N., R. 35 E.--Continued										
23K2	---- Johnson	Haun Springs	Ap	Gravel	Seeps from swampy area	600±	6- -47	Irr	55½	Perennial orifice is a quarter of a mile south of the orifice used during the period of high discharge.
23P1	M. M. Dyer	Lewis Spring	Ap, 834	--Do--	Seeps from several points along low swale	400±	6- -47	Irr	---	
23P2	---- Downing	Downing Spring	Ap	--Do--	Seeps from swampy orifice and sides of channel	900	----------	Irr	---	
23Q2	O. D. Hittle, et al	Engle Spring	Ap	--Do--	Percolates from gravel along channel sides	900±	5-24-33	Irr	---	
23R1	---- Livingston	Ballou Spring	Ap	--Do--	Percolates from one bowl-shaped orifice	300±	5-24-33	Irr	---	
24P2	W. W. Higgins	East Prong Spring of Big Spring Branch	Ap	--Do--	--------Do---------	600±	5-24-33	Irr	---	
24P3	W. W. Higgins	East Prong Spring of Big Spring Branch	Ap	--Do--	--------Do---------	600±	5-24-33	Irr	---	
27C1	Ben Stanton	Crystal Spring	Ap, 820	Sand, alluvium	Seeps from swampy area	600±	5-22-33	Irr	---	
28K2	Walter Von Der Ahe	South Mud Creek Spring	Ap, 813	Gravel	Rises vertically in sharp swale	600±	5-23-33	Irr	---	

29J1	W. S. Edwards	Johnson Spring	Ap,	784	Gravel	Rises upward in main orifice and seeps into channel for 0.1 mile below	900-1,400±	5-23-33	Irr	---	
32A1	First National Bank of Milton	North Spring Dugger Creek	Ap		--Do--	Percolates upward from a main orifice	600-1,200±	5-23-33	Irr	---	
32A2	-------Do--------	South Spring Dugger Creek	Ap		--Do--	--------Do-------	600-1,200±	5-23-33	Irr	---	
32B1	-------Do--------	East Fork of South Spring Dugger Creek	Ap		--Do--	--------Do-------	600-1,200±	5-23-33	Irr	---	
32G1	Mary Hodgen	South Spring Dugger Creek	Ap		Sand, alluvium	Rises in one main orifice and several nearby seeps	-------	---------	Irr	---	Maximum yield from March to June; dry from December to March.
T. 6 N., R. 36 E.											
8D1	Harry Lasiter	Lasiter Spring	T,	885	Alluvium, gravel(?)	Seeps from low orifice area	12	12-6-46	D,S	---	
13P1	Raymond Reser	Reser Spring	S,	1,360±	Soil over basalt	Seeps from soil along rock surface	5-10	10-29-46	D,S	61	Water has hardness of 55 ppm and chloride content of 4 ppm.
19M1	D. D. Nicholas	Nicholas Spring	Ap		Gravel	Percolates from gravel	400±	7-21-33	S	---	
T. 6 N., R. 37 E.											
4G1	F. Pietrowski	Pietrowski Spring	S,	1,750±	Soil over basalt	Seeps from creek bank	5	10-21-46	S	---	Water has hardness of 60 ppm and chloride content of 3 ppm.
8M1	---- Clodius	----------------	S,	1,660	---Do--	Seeps from hillside	3	10-23-46	D,S	---	Water has hardness of 70 ppm and chloride content of 3 ppm.
10E1	Mantz Bros.	----------------	S,	2,200	Basalt	--------Do------	5	10-21-46	D,S	---	Water has hardness of 40 ppm and chloride content of 2 ppm.

Table 4.--Representative springs in the Walla Walla River basin.--Continued

Location	Owner or former owner of property	Name	Topography and altitude (feet above sea level)	Water-bearing material	Occurrence	Yield: Gallons per minute	Yield: Date	Use	Temperature (°F) of the water	Remarks
T. 7 N., R. 35 E.										
27J1	D. M. Periman	Blalock Lake	Ap, 750	Sand and gravel	Seeps from orifices in swale	-------	----------	S	---	Impounded by small dam.
35Q1	---- O'Farrel	----------------	Ap, 790	Gravel	Percolates from gravel in swale from bottom land	50	5-26-33	Irr	---	
T. 7 N., R. 36 E.										
21D1	Walla Walla General Hospital	Butcher Creek Spring	Ap, 1,010	--Do--	Flows from exposure of gravel strata	-------	----------	---	---	
21P1	City of Walla Walla	Pioneer Park Springs	Ap, 1,010	--Do--	--------Do-------	500±	1948	F	---	
28G2	----------------	Stone Creek Springs, North Branch	Ap	--Do--	--------Do-------	225	8-13-60	Irr	---	Flow has declined in summer of recent years.
28H1	----------------	Stone Creek Springs, South Branch	Ap	--Do--	--------Do-------	60	8-13-60	Irr	---	---------Do----------
30M1	U.S. Government	Veterans Hospital Spring	Ap, 860	--Do--	--------Do-------	420±	6-29-33	Irr	---	
34D1	Shelton Estate	Shelton Springs	Ap	--Do--	--------Do-------	200	8-13-60	Irr	---	Flow has declined progressively since about 1948.
T. 7 N., R. 37 E.										
1D1	Marie Ganguet	Ganguet Spring	Uv, 1,750	Alluvium	Percolates through alluvium over basalt	20	10-18-46	D	---	Water has hardness of 70 ppm and chloride content of 3 ppm.

12G1	J. R. Wolfe	----------------	Uv, 2,070	Basalt	Flows from seep in rock on sidehill	10	10-18-46	D	---	Water has hardness of 70 ppm and chloride content of 3 ppm.
14E1	---- Hayes	----------------	Uv, 1,800	--Do--	Seeps from rock in ravine	5	10-18-46	D	---	Water has hardness of 55 ppm and chloride content of 2 ppm.

T. 8 N., R. 38 E.

27A1	City of Waitsburg	Guntle Springs	Uv	--Do--	Flows from crevices of basalt at nine openings	625	1938	PS	60	Conducted by pipeline to reservoir at Waitsburg. Location is approximate.