GEOLOGY AND GROUND-WATER RESOURCES OF THE DALLES REGION, OREGON

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ABSTRACT

This report is based upon an investigation conducted by the United States Geological Survey in cooperation with the Oregon State Agricultural Experiment Station to determine the feasibility of pumping water from wells for irrigating orchard and produce tracts in the vicinity of The Dalles, Oreg. This investigation was carried on between May 6 and October 6, 1930.

The oldest rock formation that crops out in the Dalles region is the Yakima basalt, which is generally considered to be of Miocene age. This basalt forms the bold bluffs along the Columbia River entirely across the northern part of the Dalles region; also the high divide between Chenoweth and Mosier Creeks along the northwest side of the region. It underlies the extensive stream terrace that extends northward from Grand Dalles, Wash., to the base of Stacker Mountain and floors the lower reaches of Fivemile, Eightmile, and Fifteenmile Creeks. Its top is at shallow depth in the lower reaches of Threemile and Mill Creeks near The Dalles but is as much as 1,500 feet below the upland. The Yakima basalt is made up of many layers 35 feet to more than 100 feet thick, and its total thickness in the vicinity of The Dalles is at least 2,000 feet. Most of the basalt is black, dense, and fine grained and is characteristically divided into massive columns, which extend from top to bottom of each layer. The Yakima basalt contains two water-bearing zones, which are moderately well defined. The upper zone includes several water-bearing beds less than 10 feet thick interleaved with the uppermost 100 feet of the basalt. The lower zone, the top of which is 300 to 375 feet below the top of the basalt formation, comprises one or more layers of extremely porous or granular rock.

The Yakima basalt is overlain by the Dalles formation, of Miocene or lower Pliocene age, which is the bedrock of most of the interstream tracts east of Chenoweth Creek. The Dalles formation is made up of semiconsolidated stream-laid sandstone, sandy shale, and conglomerate, together with fine-grained volcanic tuff, tuffaceous sandstone, and coarse andesitic pyroclastic rocks. The pyroclastic rocks consist of angular and subangular fragments as much as 6 feet across embedded in a matrix of dense fine-grained tuff. Generally the strata are less than 5 feet thick, and the several rock types interfinger and grade laterally into one another. In general, also, both the coarse pyroclastic rocks and the thick beds of coarse sandstone and conglomerate are most abundant in the lower part of the formation. The Dalles formation is separated from the underlying Yakima basalt by a slight unconformity in the vicinity of The Dalles, but there is inconclusive evidence that the lowest part of the Dalles formation interfingers with the uppermost part of the basalt farther to the south and east. Most of the Dalles formation is not highly permeable, for only the beds of sandstone that are free from clayey matrix yield water in appreciable quantities, and these beds are generally thin and discontinuous.

The rock formations younger than the Dalles formation are not extensive in the Dalles region. They include tongues of andesite lava that fill the bottoms of former valleys in the upper reaches of Mill and Eightmile Creeks, ice-rafted boulders of crystalline rock that are not native to the Dalles region, and deposits of sand and gravel laid down by the Columbia River and its tributaries in at least three epochs.

In general, the geologic structure of the region is simple, its elements being open major folds and associated secondary folds and faults. These folds and faults deform the Yakima basalt and the overlying Dalles formation together. The principal structural feature of the region is the Dalles syncline, an asymmetric troughlike fold whose axis trends roughly eastward through Grand Dalles, Wash. At the lowest point along this axis, about 2 miles northwest of The Dalles, the top of the Yakima basalt is about 200 feet above sea level, or nearly 150 feet above the Columbia River. From this axis the strata rise gently northward for 3 to 4 miles, the dip being 1°–2° S. to S. 60° W., and then steepen to 18°–25° S. 20°–40° E. South of the axis of the syncline the strata dip 1°–2° N. 30° E. to N. 30° W. as far south as Tygh Ridge, 25 miles from The Dalles. The principal faults are normal and follow or cut acutely across the steeper flanks of the major folds. Folding probably began after middle Miocene time and was nearly complete before the middle (?) of the Pliocene epoch. Faulting, on the other hand, began somewhat before the middle (?) of the Pliocene but was most active after that epoch and has continued at intervals almost to the present time.

There are two possible sources of ground water for irrigating the existing orchards—the upper and lower water-bearing zones of the Yakima basalt. The existing truck gardens can be irrigated from wells of moderate capacity in the alluvium or from wells of larger capacity drawing from the lower water-bearing zone of the basalt. The Dalles formation generally has so small a water-yielding capacity that it is not a feasible source of water for irrigation.

The water in the upper water-bearing zone of the basalt has a much higher head than that in the deeper zone and can be raised to a large part of the existing orchards by lifts between 150 and 450 feet. Two irrigation wells were drawing water from this zone in 1930. The stronger of these two wells, which is operated by the Cherry Hill District Improvement Co., is 301 feet deep. It was first used in 1926 and since that time has been pumped 110 to 405 gallons a minute for 957 to 1,826 hours each season, the annual consumption ranging from 38 to 113 acre-feet. The greatest pumping lift at this well is approximately 350 feet. The geologic and hydrologic conditions and the performance of the existing wells indicate that the safe yield, or the quantity of water that can be pumped each year from this zone through a long period, is not very great and that the supply is insufficient to irrigate all of the existing orchard land. The supply in the vicinity of the present irrigation wells is probably sufficient for the land now under irrigation in that vicinity if no additional wells are put into service there. It is, however, altogether unlikely that the wells now in existence salvage all the water available in this permeable zone, so that it seems justified to put down a moderate number of additional wells at a distance from the present wells. So far as is practicable such wells should be about a mile from one another. A few wells in the valley of Threemile Creek both upstream and downstream from the present irrigation wells and in the lower part of the valley of Mill Creek would probably salvage practically all the water available in this zone.

The lower water-bearing zone of the basalt will yield water in much larger quantities than the upper zone, as is shown by the performance of the municipal well at The Dalles and by several wells along the Spokane, Portland & Seattle Railway on the north bank of the Columbia River. These wells yield from 45 to 450 gallons a minute for each foot of drawdown. The municipal well at The Dalles is pumped almost continuously for about three months each summer at a rate ranging from 750 to perhaps 2,000 gallons a minute. The static level of the water in the lower zone is nearly 400 feet below that of the water in the upper zone, and therefore the cost of pumping from this zone to the orchards will be greater. This additional cost of pumping will, however, be offset to some extent by economies that will result from having wells with larger yields and less drawdown. It is possible that with adequate pumping equipment water could be raised within permissible limits of cost from the lower zone to the orchards on the lowest lands, thereby supplementing the supply available from the upper zone, but certainly it is not practicable to pump from the lower zone to the orchards unless a well of large capacity is obtained. The most favorable sites for such wells are on the alluvial plains of Threemile and Mill Creeks 2 to 3 miles south of The Dalles, where the top of the lower water-bearing zone is 350 to 500 feet below the land surface and where the lift to the lowest existing orchards would be about 425 feet. This zone is also a feasible source of water for irrigating the existing truck gardens, most of which lie along a terrace of the Columbia River or on the plains of tributary creeks near The Dalles, 100 to 250 feet above the river. At these localities the top of the lower water-bearing zone is 200 to 300 feet below the land surface, and the pumping lift would be about 75 to 200 feet. The safe annual yield of this zone is believed to be several times the quantity of water heretofore pumped from the city well each summer.

INTRODUCTION

LOCATION AND EXTENT OF AREA

Most of the region described in this report lies in north-central Oregon, in Wasco County, but a small part is in Klickitat County, Wash. (See fig. 30.) The area represented by the geologic map (pl. 11) covers about 300 square miles in Ts. 1 and 2 N. and 1 S., Rs. 11 to 15 E. Willamette meridian.

The Dalles, which according to the census reports had a population of 5,883 in 1930, is the largest city and chief commercial center of the region; it is also the county seat of Wasco County. Dufur, with a population of 382, is the next largest community.

PURPOSE AND SCOPE OF INVESTIGATION

The investigation upon which this report is based was made to determine the feasibility of recovering water from wells for irrigation of orchard and produce tracts in the vicinity of The Dalles, Oreg. Several hundred acres of orchards are cultivated in this region, mostly by dry-farming methods, but it has been found that the natural supply of moisture is not adequate after the trees reach maturity. Hence it is desired to supplement the natural supply and thereby to control the soil moisture so that the optimum condition for crop growth may be maintained. The investigation was conceived by the Oregon State Agricultural Experiment Station and was carried on by the United States Geological Survey. The two organizations have shared in the cost of the field investigation and in the preparation and publication of this report.

The writer carried on the field investigation between May 6 and October 6, 1930, but was occupied by other duties from July 5 to July 25 and from August 4 to September 3. The stratigraphy and geologic structure were traced in moderate detail within the area represented by the geologic map (pl. 11) and were examined in a cursory manner over a more extensive contiguous region in order to discriminate the possible water-bearing strata. Data to indicate the water-yielding capacity of these strata were gathered from observations on springs and wells. Samples of water for chemical analysis were taken from the Columbia River and from seven wells and springs to determine the chemical character of the water with respect to its proposed use for irrigation.

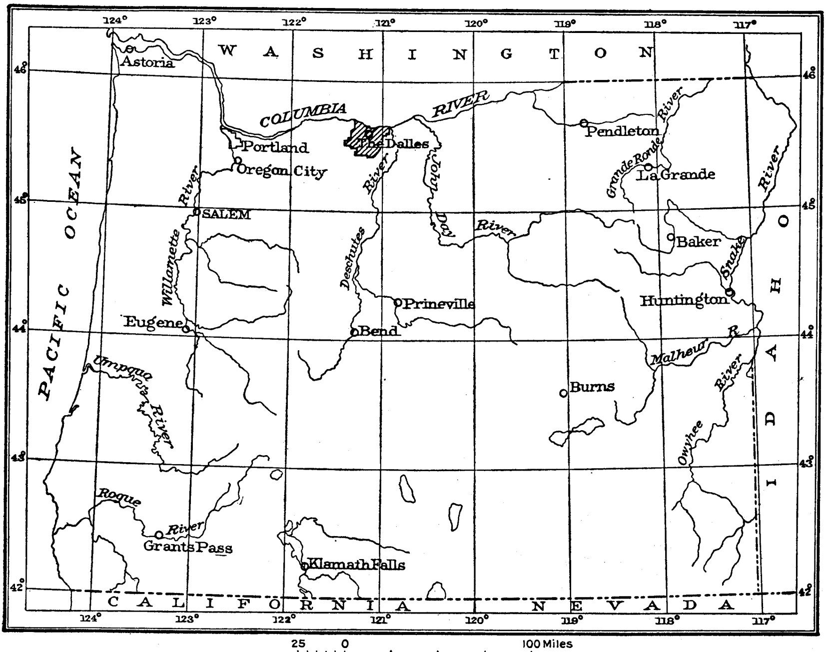

FIGURE 30.—Map of Oregon showing location of the Dalles region

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to O. E. Meinzer, geologist in charge of the division of ground water, United States Geological Survey, for constructive criticism during the field investigation and the preparation of this report. He is further indebted to J. T. Jardine, director of the Oregon State Agricultural Experiment Station, and to W. S. Nelson, executive secretary of The Dalles-Wasco County Chamber of Commerce, for courtesies which furthered the investigation materially. While the field studies were being conducted, L. O. Newsome, of the topographic branch, United States Geological Survey, was sketching the topography of parts of The Dalles and Dufur

quadrangles; he assisted the writer by furnishing data that facilitated the geologic mapping. S. K. Love, of the division of quality of water, United States Geological Survey, analyzed the eight samples of water (p. 162). The United States Forest Service and the Corps of Engineers, United States Army, furnished copies of unpublished maps of parts of the region about The Dalles, and the Oregon State Highway Commission supplied alinement plats of the principal highways in the region. The Spokane, Portland & Seattle Railway and the Oregon-Washington Railroad & Navigation Co. supplied data concerning ground-water supplies along their rights of way, both within and outside of the region.

The field investigation was facilitated greatly by the whole-hearted cooperation of residents in giving information pertaining to ground-water conditions and to the geography and geology of the region. Among those whose assistance is especially praiseworthy is the City Water Commission of The Dalles, which contributed data from its files, kept a special record of pumpage from the municipal well, and gave the writer permission to install a water-stage recorder over the well when it was not in use. D. G. Glass, city engineer of The Dalles, supplied pertinent data and granted the use of his office and equipment for preparing maps. The Cherry Hill District Improvement Co., through W. W. Starkey, president, and J. E. Thorndike, water master, opened its files of data and made special observations pertaining to recovery of ground water for irrigation. R. F. Kelly also kept for the writer a record of pumping from his irrigation well. J. F. Austin, W. E. Kretzer, and W. W. Rawson & Son, well drillers, contributed records of wells drilled by them and discussed freely with the writer conditions pertaining to the occurrence of ground water and to the drilling of wells.

SURFACE FEATURES AND DRAINAGE

The region considered in this report (fig. 30) lies near the western edge of the Walla Walla Plateau section of the Columbia Plateaus physiographic province, the eastern flank of the Cascade Range being about 12 miles southwest of The Dalles. The region is by no means a plain, however, for it is deeply dissected and has a relief of nearly 3,000 feet. The most conspicuous features of the topography are the broad, flat summits of the divides between the tributary streams in the southern part of the region, of which Mount Hood Flat and Pleasant Ridge (pl. 11) are typical examples. These flats are about 1,900 to 2,050 feet above sea level just south of The Dalles, but rise southwestward and are nearly 3,000 feet above sea level near the southwest corner of the region. They are parts of a plain, once continuous throughout the region, which is believed to be a part of the Ochoco erosion surface (p. 141).

The master stream, the Columbia River, flows westward across the region near its northern boundary, but in the vicinity of The Dalles it traces a rude semicircle convex toward the south and nearly 6 miles in diameter. Its low-water surface is about 130 feet above sea level at the mouth of the Deschutes River, which is at the eastern edge of the region, but only about 45 feet above sea level at The Dalles, 16 miles downstream. The average gradient in this portion of the stream, which is commonly known as The Dalles of the Columbia River, is therefore about 5 feet to the mile, a gradient which is unusually steep for a major stream. The actual gradient is by no means uniform, however, but comprises a sheer drop of 20 feet at Celilo Fall, three rapids, and intervening reaches of relatively quiet water. Each of the rapids is a narrow but deep rock chute. The principal one, Fivemile Rapid (pl. 12), is about 1½ miles long and only 150 to 375 feet wide; just below its upstream end the water is as much as 165 feet deep.[1] Downstream from The Dalles the gradient of the river is but a small fraction of a foot a mile as far as Cascade Locks, a distance of 40 miles.

The valley of the Columbia River near The Dalles is nearly 2,000 feet deep below the remnants of the Ochoco (?) erosion surface (p. 141). Where it is cut in the resistant Yakima basalt (p. 118), the valley is commonly narrow, V shaped, and without prominent terraces. On the other hand, where it is cut in the relatively weak Dalles formation (p. 120) the valley may be several miles wide, is generally bordered by a belt of rolling topography 3 to 5 miles wide, and commonly has well-defined terraces at several levels. The most prominent terraces near The Dalles are about 300 and 150 feet above sea level, or 250 and 100 feet above the river; remnants of these terraces are as much as 1¼ miles wide and 3 miles long. The flat north of the river at The Dalles is about 4 miles wide (pl. 12) and is compounded from stream terraces of this sort; this flat is 175 to 200 feet above sea level near the river but about 325 feet above sea level along the main valley wall.

The largest tributaries of the Columbia River in the Dalles region are the Deschutes River, which drains an area of 9,000 square miles in central Oregon, and the Klickitat River, which drains about 1,200 square miles in south-central Washington. These streams enter the Columbia River 16 miles upstream and 9 miles downstream from The Dalles, respectively; both are perennial. The other tributaries, which enter the river from the south, are, from east to west, Fifteenmile, Eightmile, Fivemile, Threemile, Mill, and Chenoweth Creeks. (See pl. 11.) Of these, all but Fifteenmile and Eightmile Creeks are intermittent in their lower courses. Fivemile Creek is tributary to Eightmile Creek, which in its turn flows into Fifteenmile Creek about

[1] Harza, L. F., Columbia River power project near The Dalles, Oreg.: U. S. Recl. Service, Rept. of Board of Review, fig. 10, p. 23, 1914.

3 miles above its mouth. The drainage area of these three is about 300 square miles; the other tributaries drain less than 100 square miles each. These creeks are nearly parallel for most of their length and flow N. 45°–75° E., but Fifteenmile and Eightmile Creeks swerve and flow northwestward for several miles before joining the Columbia River.

The tributary creeks of the region are trenched to a depth of 1,500 feet below the remnants of the Ochoco (?) erosion surface, their valleys being typically V shaped near their heads but submature in their lower reaches. In many places there are remnants of a prominent terrace 50 to 200 feet above the creeks and declining downstream 50 to 100 feet to the mile. (See pl. 13.) These terrace remnants are in part cut on rock and in part constructed from alluvium; they are adjusted to the 300-foot terrace along the Columbia River. On them are most of the orchard tracts. The middle reaches of the creeks are trenched into this terrace, are approximately graded, and are bordered by flood plains less than a quarter of a mile wide. These graded portions of the creeks slope 50 to 75 feet to the mile and are adjusted to the 150-foot terrace along the Columbia River. On them are most of the truck gardens. For half a mile to 3 miles above their mouths the creeks are not graded but flow in narrow rock trenches cut below the 150-foot terrace and imperfectly adjusted to the present stage of the river. The gradients of the creeks in these trenches are 125 to 200 feet to the mile.

The pattern of the streams and the topography express in a moderate degree both the differences in resistance of the rocks to erosion and the geologic structure. Along both the Columbia River and its intermittent tributaries the topography in the resistant Yakima basalt (p. 118) is youthful—that is, the changes in slope are abrupt, there are many precipitous bluffs, and most of the slopes are concave upward except where they are determined by the geologic structure. In the less resistant Dalles formation (p. 120), however, the river and all but its weakest tributaries have wider valleys and the topography may be submature or rolling—that is, the changes in slope are gradual, and many of the slopes are convex upward. For most of their courses the tributary creeks follow the strike of the rocks, even in the resistant basalt, and Fifteenmile and Eightmile Creeks swerve northward as they cross the axis of the Dalles syncline (p. 134) and then northwestward along the strike of the northern flank of that fold. In part their courses have the same trend as certain well-defined faults and may have originated along low fault scarps or along fault zones where the rocks were brecciated. Commonly the valley slopes on the northwest sides of these tributary creeks are the steeper, as if the streams had been deflected down the dip of the strata as they deepened their valleys, even though they continued to follow the strike. In most places the course of the Columbia River does not express the geologic structure but trends across even the major folds. The great meander of the river at The Dalles, however, is a slip-off meander on the north flank of the Dalles syncline.

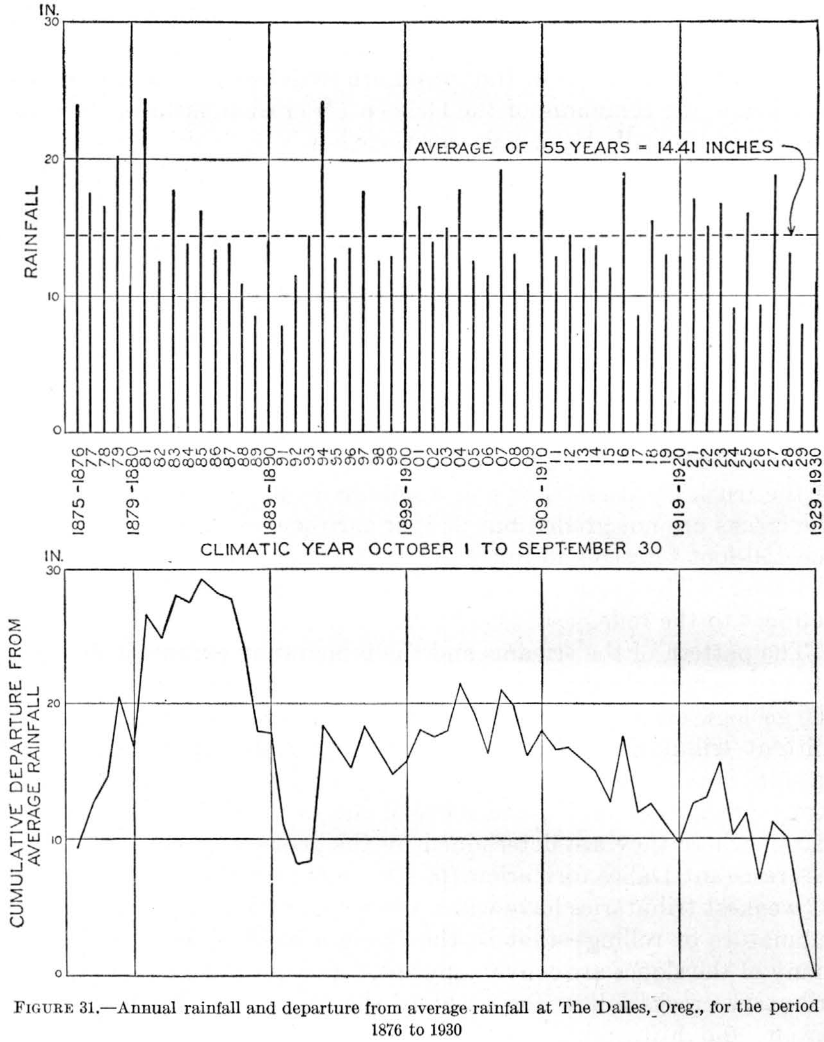

FIGURE 31.—Annual rainfall and departure from average rainfall at The Dalles, Oreg., for the period 1876 to 1930

CLIMATE

The Dalles region is semiarid, and is characterized by warm dry summers but rather cold, wet winters. At The Dalles the mean maximum temperature is 85.9° F. in July, which is generally the warmest month; the mean minimum temperature is 26.2° F. in January, which is generally the coldest month; and the mean annual temperature is 52.7° F. For the period 1875 to 1922 the highest recorded temperature was 111° F., the lowest −30° F.

The average growing season or frost-free period is 196 days, from April 11 to October 24. However, in the 47-year period 1876 to 1922, the frost-free period has ranged from 145 days in 1916 to 245 days in 1921. In the same period the latest killing frost in the spring has ranged from March 3 to May 12, and the earliest killing frost in the autumn from September 25 to November 26.

As is shown by the following table, the average rainfall in the climatic year (October 1 to September 30) at The Dalles during the 55-year period 1876 to 1930, is 14.41 inches, of which 9.56 inches falls in the winter, from November to February, and 1.37 inches in the summer, from May to August. The average annual snowfall is 34.1 inches. On the average there are 78 days each year in which the rainfall is 0.01 inch or more; of these, 42 days occur in the four winter months and 12 days in the four summer months. As is brought out by the accompanying table and diagram (fig. 31), the yearly rainfall during the 55-year period of record has ranged from 24.39 inches in 1880-81 to 7.80 inches in 1890–91, but the cycle of fluctuation is long.

Monthly and annual rainfall at The Dalles, Oreg., 1876–1930

[Data from publications of U. S. Weather Bureau]

Climatic year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Departure from average
1876	4.80	6.18	4.80	2.76	1.39	2.20	1.09	0.20	0.34	0.07	0.02	0.13	23.98	+9.57
1877	2.37	4.31	.46	.78	1.68	3.66	1.21	1.03	.15	.48	.10	1.24	17.47	+3.06
1878	1.66	4.18	1.58	2.96	2.32	1.99	.20	.26	.02	.08	.13	1.01	16.39	+1.98
1879	.53	1.22	1.61	1.43	6.32	3.15	1.34	2.94	.11	.31	.48	.79	20.23	+5.82
1880	.88	1.24	2.57	2.04	1.33	.16	1.03	.94	.02	.02	.43	.08	10.74	−3.67
1881	.12	.69	6.75	6.37	6.23	.38	1.29	.14	1.82	.11	.23	.26	24.39	+9.98
1882	2.62	.75	1.76	1.49	2.92	.23	.53	.27	.60	.12	.72	.43	12.44	−1.97
1883	2.30	.75	5.14	4.85	.61	2.32	1.21	.54	.01	.00	.00	.01	17.74	+3.33
1884	.46	2.19	1.77	1.33	3.10	.74	1.33	.69	.93	.44	.12	.65	13.75	−.66
1885	1.27	.82	7.04	1.10	2.88	.14	.31	.81	1.01	.00	.00	.87	16.25	+1.84
1886	1.28	1.78	2.65	5.45	.53	.95	.30	.11	.07	.00	.02	.14	13.27	−1.14
1887	.70	.21	5.06	4.01	1.13	.79	.46	.32	.67	.00	.18	.36	13.89	−.52
1888	.15	1.06	3.01	3.36	.41	.94	.05	.70	.92	.29	.00	.02	10.91	−3.50
1889	.95	1.34	2.71	.51	.04	1.26	.42	.66	.29	T.	T.	.16	8.34	−6.07
1890	.90	1.27	2.00	2.97	4.33	1.89	.24	.02	.27	.06	.04	.11	14.10	−.31
1891	1.16	.00	1.19	1.13	2.47	.53	.01	.32	.51	.24	.11	.13	7.80	−6.61
1892	1.14	1.39	4.14	1.35	.68	.70	1.00	.67	.06	.27	T.	.14	11.54	−2.87
1893	.90	1.16	5.04	.69	1.84	.96	1.69	.69	.06	.30	.00	1.21	14.54	+.13
1894	4.40	4.36	1.77	4.84	1.83	3.73	.64	.47	1.15	.10	T.	1.02	24.31	+9.90
1895	2.08	.51	1.65	4.72	.47	.65	.24	.94	.00	.32	.05	1.14	12.77	−1.64
1896	.00	1.20	4.15	3.45	.72	1.00	.95	.63	.10	T.	.28	.42	12.90	−1.51
1897	.60	5.87	2.74	1.14	2.98	1.94	.23	.27	1.07	.24	.08	.54	17.70	+3.29
1898	.24	3.84	4.03	.82	.98	.30	.11	.03	.90	.17	.02	.85	12.29	−2.12
1899	.12	2.13	1.14	2.82	2.19	.94	1.05	.45	.20	.00	.86	.81	12.72	−1.69
1900	1.56	3.57	2.29	1.90	1.94	1.62	.42	.03	.47	T.	.55	1.09	15.44	+1.03
1901	2.02	2.25	1.33	3.46	4.15	.68	.09	.39	.20	T.	.16	1.84	16.57	+2.16
1902	.13	1.69	3.04	1.61	3.79	.52	1.82	.63	.13	.26	.00	.36	13.98	−.43
1903	.78	3.53	4.00	2.87	.47	.56	.23	.05	2.11	.12	.11	.15	14.98	+.57
1904	1.10	4.44	.56	1.52	4.50	3.10	.98	.09	.46	.40	.04	.61	17.80	+3.39
1905	1.44	1.01	1.79	3.27	.51	.63	.18	.66	1.27	.19	.10	1.19	12.24	−2.17
1906	1.88	.84	1.07	1.90	1.67	1.21	.11	.95	1.05	T.	.31	.35	11.34	−3.07
1907	.23	3.99	3.07	3.92	3.08	1.30	1.67	.41	.42	.22	.74	.29	19.34	+4.93
1908	.29	2.22	5.50	1.06	.77	1.50	.17	.92	.10	.36	.16	.03	13.08	−1.33
1909	1.42	.48	1.21	4.06	1.41	.33	.08	.13	.13	.39	.00	1.05	10.69	−3.72
1910	.83	4.55	3.09	1.87	2.67	.41	.83	1.31	.72	T.	.00	.05	16.33	+1.92
1911	1.01	4.18	1.51	1.23	.56	.22	.21	.80	.30	.00	.00	2.92	12.94	−1.47
1912	.33	1.19	1.23	6.30	2.03	1.03	.28	.82	.43	.02	.55	.31	14.52	+.11
1913	.47	1.62	2.86	3.88	.28	.71	.69	.92	1.55	.09	T.	.46	13.53	−.88
1914	1.65	2.21	1.72	3.33	1.06	.30	1.15	.35	.73	.01	.00	1.24	13.75	−.66
1915	1.22	1.06	.91	2.24	2.05	1.59	.42	1.63	.00	.76	.00	.22	12.10	−2.31
1916	.52	3.95	2.49	2.28	3.33	2.89	.60	.66	.98	1.28	.01	.18	19.17	+4.76
1917	.30	1.20	1.83	.68	1.08	.71	2.05	.33	.10	.00	.00	.37	8.65	−5.76
1918	.00	2.53	4.99	2.42	1.87	.14	.24	1.16	.00	.24	.30	1.40	15.29	+.88

Monthly and annual rainfall at The Dalles, Oreg., 1876–1930—Continued

Climatic year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Departure from average
1919	2.18	1.03	1.01	2.57	2.97	1.11	.87	.21	.15	.22	.05	.60	12.97	−1.44
1920	.66	2.86	2.92	2.22	.00	.82	.98	.07	.69	.10	.54	1.05	12.91	−1.50
1921	0.65	2.82	2.94	2.58	4.12	1.93	0.65	0.36	0.34	0.00	0.01	0.71	17.11	+2.70
1922	.46	9.41	1.13	1.00	.74	1.12	.50	.01	.09	.00	.58	.17	15.21	+.80
1923	1.30	1.05	2.95	4.40	.57	1.58	1.20	.34	.65	1.18	.70	.93	16.85	+2.44
1924	.58	1.04	3.05	1.81	1.39	.35	.02	.00	.41	.15	.18	.20	9.18	−5.23
1925	1.32	3.35	1.15	4.04	2.49	.52	.80	1.47	T.	T.	.01	.81	15.96	+1.55
1926	.03	1.94	1.11	1.71	3.06	T.	.18	.62	.00	.00	.23	.44	9.32	−5.09
1927	.75	5.50	1.42	4.19	3.35	.45	T.	.40	.30	T.	T.	2.51	18.87	+4.46
1928	.81	3.02	.87	3.50	.23	2.92	1.04	T.	.54	.12	.00	.09	13.14	−1.27
1929	.15	1.81	2.61	2.24	.02	T.	.40	T.	.55	.00	T.	.13	7.91	−6.50
1930	.23	.02	4.96	2.18	1.85	.88	.20	.12	.12	.00	.03	.21	10.80	−3.61
Average	1.05	2.34	2.64	2.63	1.95	1.14	.66	.54	.48	.18	.17	.63	14.41	

STRATIGRAPHY

GENERAL CHARACTER AND AGE OF THE ROCKS

The rocks of the Dalles region include interbedded clastic rocks and lavas of Tertiary and possibly Quaternary age and unconsolidated stream deposits of Quaternary age. Each of the rock units is described in succeeding pages in so far as its characteristics enter into the interpretation of those stratigraphic and structural conditions that control the occurrence of ground water. The areal extent of the rock units is shown on Plate 11, and their water-bearing properties are described on pages 144 to 160.

TERTIARY SYSTEM

EAGLE CREEK FORMATION

The oldest of the Tertiary rock units here described consists of about 500 feet of semiconsolidated andesitic pyroclastic rocks which crop out in the vicinity of Bonneville, Multnomah County, at the axis of the Cascade Locks anticline. At this locality, which is about 45 miles west of The Dalles, the base of the formation is not exposed. Intercalated with the pyroclastic rocks are lentils of tuffaceous sandstone and clay and of volcanic ash and seams of carbonaceous shale that represent the former soil zones of intraformational disconformities. These rocks have been designated Eagle Creek formation by Williams [2] and "Warrendale formation" by Smith and Packard.[3] Eagle Creek is recognized by the United States Geological Survey as having priority and is used in this report.

The Eagle Creek formation does not crop out within the area represented on Plate 11, but it is inferred that the top of the formation

[2] Williams, I. A., Columbia River gorge; its geologic history as interpreted from the Columbia River highway: Mineral Resources of Oregon, vol. 2, No. 3, pp. 66–77, Oregon Bur. Mines and Geology, 1916.

[3] Smith, W. D., and Packard, E. L., the salient features of the geology of Oregon: Oregon Univ. Bull., new ser., vol. 16, No. 7, pp. 97–98, 1919.

may not be far below the level of the Columbia River at the axis of the Ortley anticline. This inference is drawn from the bold landslide topography in the Yakima basalt of that locality (p. 138), the slumping of the basalt presumably being due to failure of underlying incompetent rocks.

As the Eagle Creek formation is a useful horizon marker in correlating the rock units of the Dalles region and adjacent areas, it is desirable to fix its geologic age as closely as possible. The sandy and calcareous shale members of the formation, according to Chaney,[4] carry a fossil flora of 72 species, which are distributed among 10 or more horizons and are intermediate in age between the Bridge Creek and Mascall floras [5] of the John Day Basin. Recently Chaney has assigned the Eagle Creek flora to the uppermost Oligocene or lower Miocene on the basis of his reclassification of the Bridge Creek flora.[6] Berry,[7] however, considers the Eagle Creek flora to be wholly Miocene. Furthermore, if Knowlton and Berry [8] are correct in assigning the Florissant flora of Colorado to the upper Miocene, and if Chaney [9] is correct in his implication that the Bridge Creek and Florissant floras are essentially contemporaneous, it would follow from paleobotanic evidence alone that the Eagle Creek formation may be as young as uppermost Miocene. However, additional evidence as to the age of the Eagle Creek formation may be derived from the fauna of the John Day formation, which in its type locality, the John Day Basin of central Oregon, is underlain by the leaf-bearing Bridge Creek shale and is overlain by the Mascall formation. The John Day formation is probably in part of the same age as the Eagle Creek formation.

The John Day formation consists of three members that are lithologically distinct. It contains an extensive mammalian fauna, which has been listed by Merriam and Sinclair [10] and classified by them as mainly Oligocene. Osborn,[11] in his provisional graphic correlation of the upper Tertiary, assigns the lower part of the John Day formation to the middle Oligocene, the middle part to the upper Oligocene, and the upper part to the lower Miocene. In his final correlation Osborn [12]

[4] Chaney, R. W., The flora of the Eagle Creek formation: Chicago Univ. Walker Mus. Contrib., vol. 2, No. 5, pp. 115–181, 1920.

[5] Knowlton, F. H., Fossil flora of the John Day Basin, Oregon: U. S. Geol. Survey Bull. 204, pp. 103–108, 1902.

[6] Chaney, R. W., Geology and paleontology of the Crooked River Basin, with special reference to the Bridge Creek flora: Carnegie Inst. Washington Pub. 346, pp. 95–97, 1927.

[7] Berry, E. W., A revision of the flora of the Latah formation: U. S. Geol. Survey Prof. Paper 154, p. 235, 1929.

[8] Idem, p. 234.

[9] Chaney, R. W., op. cit. (1927), pp. 95–96.

[10] Merriam, J. C., and Sinclair, W. J., Tertiary faunas of the John Day region: California Univ. Dept. Geology Bull., vol. 5, pp. 172–195, 1907.

[11] Osborn, H. F., Tertiary mammal horizons of North America: Am. Mus. Nat. Hist. Bull., vol. 23, fig. 3, p. 248, 1907.

[12] Osborn, H. F., Cenozoic mammal horizons of western North America: U. S. Geol. Survey Bull. 361, fig. 10, pp. 64–69, 1909.

repeats this graphic correlation but in his text greatly restricts the range of the fauna by the following statements:

The time of the beginning of the John Day deposition appears to correspond with that of the close of the *Leptauchenia* zone in the South Dakota region—namely, the upper Oligocene.

The lower John Day fauna is so little known that no deductions can be made from it, except that it appears to be closely related to that of the middle John Day.

The conclusion is that the middle John Day deposition partly overlaps and is partly sequent to the deposition of the upper part of the Brule clay and the "*Protoceras* sandstones" [upper Oligocene, first or earliest stage].

The upper John Day fauna, he points out, is the oldest part of a faunal stage which covers the transition between the Oligocene and Miocene epochs, as those divisions are used in the European type sections. He concludes that "the upper part of the John Day, for the present, may be somewhat arbitrarily separated as the [highest part of the] American upper Oligocene." Still later, Osborn[13] states that the fauna of the upper John Day is regarded by many as lowest Miocene but that "as compared with the Old World * * * [it] is still characteristically Oligocene, rather than Miocene." Hence it seems that Osborn's correlations can be summarized by the statement that the John Day epoch is essentially coextensive with the upper Oligocene.

Chaney[14] concludes that the leaf-bearing shale of Bridge Creek is the lowermost part of the John Day formation and that it is separated from the underlying Clarno formation by an erosional break. If these stratigraphic relations and Osborn's correlation of the Tertiary fauna are sound, the Bridge Creek flora is not younger and is little if any older than lowermost upper Oligocene. Consequently, the Eagle Creek flora may be as old as upper Oligocene. If the Mascall epoch occupied all of middle Miocene time (p. 126) the Eagle Creek flora is not younger than lower Miocene. This range in age is essentially the same as that ascribed to the Eagle Creek formation by Chaney[15] on the basis of paleobotanic evidence.

YAKIMA BASALT

The andesitic pyroclastic rocks of the Eagle Creek formation are overlain by a series of basalt layers, the Yakima basalt, whose aggregate thickness in the vicinity of The Dalles is at least 2,000 feet. The individual layers range in thickness from about 35 feet to more than 100 feet. Most of the basalt is dense, black on fresh fractures, and fine grained, but in some places the upper parts of the layers are slightly vesicular. It is characteristically divided by columnar joint-

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[13] Osborn, H. F., The age of mammals in Europe, Asia, and North America, pp. 232–233, New York, Macmillan Co., 1921.

[14] Chaney, R. W., Geology and paleontology of the Crooked River Basin, with special reference to the Bridge Creek flora: Carnegie Inst. Washington Pub. 346, p. 95, 1927.

[15] Idem, pp. 95–96.

ing into prisms 3 to 10 feet in transverse dimension extending from top to bottom of each layer. Commonly the basalt is quite unweathered, but just below its contact with the overlying Dalles formation (p. 120) and beneath some of the Pleistocene terrace deposits (p. 129) it is disintegrated to a depth of 20 feet or less. In a few places it has even been oxidized to a laterite.

In many places the basalt layers are separated by former soil zones or by discontinuous lentils of stream-borne sediment from a few inches to 3 feet thick. Sediments are reported to be interbedded with the basalt in two deep wells drilled near The Dalles (Nos. 18 and 45, p. 170). Well 18, about 3½ miles northwest of The Dalles, 1,710 feet deep, penetrated several feet of leaf-bearing shale or fine sandstone somewhere between 1,200 and 1,500 feet below the surface; it did not reach the bottom of the basalt. Well 45, about 1 mile east of The Dalles, penetrated 836 feet of basalt, then 42 feet of clay shale, and finally 125 feet of basalt; it also did not pass through the basalt series. The tops of these sedimentary beds are about 1,250 to 1,500 feet and 1,050 feet, respectively, below the top of the basalt series. In view of the imperfect record of well 18, it is possible that the two occurrences represent one stratum. These and other wells near The Dalles also pass through a rather persistent layer of extremely vesicular or granular basalt as much as 20 feet thick, whose top is from 300 to 375 feet below the top of the basalt series. Other layers of similar physical character undoubtedly occur.

At and near The Dalles a layer of pillow basalt as much as 40 feet thick is exposed in cuts along the Columbia River highway on the south side of the river and along the Spokane, Portland & Seattle Railway on the north bank. The top of the layer is about 125 to 250 feet below the top of the basalt series. This pillow basalt consists of spherical masses and ropy tongues of dense glassy basalt as much as 5 feet in diameter embedded in an incoherent matrix of granulated glass, and the whole mass is presumably due to extrusion of fluid basaltic lava into ponded water. About 6 miles northwest of The Dalles this pillow basalt seems to grade laterally into ropy vesicular basalt which rests upon an intraformational soil zone. In several places, as in a cut on the Columbia River highway in the E. ½ sec. 17, T. 2 N., R. 13 E., this soil zone contains silicified or carbonized stumps of former trees, pieces of limbs as much as 12 inches in diameter, and much thoroughly carbonized vegetable matter. No fossil leaves or fruits were found by the writer in this soil zone, but time was not available for a thorough search of its outcrops.

The basalt of the Dalles region is underlain by the Eagle Creek formation, of uppermost Oligocene or lower Miocene age (p. 117), and overlain by the Dalles formation, of Miocene or Pliocene age (p. 126).

From the age ascribed to the underlying and overlying formations, the basalt is generally considered to be Miocene. It is correlative with the Columbia lava or Columbia basalt as that term is restricted by Merriam[16] and also with the Yakima basalt of south-central Washington as defined by Smith.[17] The term Columbia basalt, though commonly applied to the Miocene extrusive rocks here described, has been so loosely used that it is ambiguous as a stratigraphic name. This rock unit is therefore designated Yakima basalt in this report.

The Yakima basalt crops out in bold bluffs along the Columbia River entirely across the northern part of the Dalles region. (See pl. 11.) It also forms the high divide between Chenoweth and Mosier Creeks along the northwest side of the region, underlies the extensive stream terrace that extends northward from Grand Dalles, Wash., to the base of Stacker Mountain, and floors the lower reaches of Fivemile, Eightmile, and Fifteenmile Creeks. It also crops out at the axes of secondary anticlines near the head of the North Fork of Mill Creek and on Threemile Creek in secs. 27, 28, 32, and 33, T. 1 N., R. 13 E. South of the area represented on Plate 11 the Yakima basalt forms most of the gentle northwestern slope of Tygh Ridge and of the other high ridges north of Tygh Creek.

DALLES FORMATION

The Yakima basalt is overlain by a heterogeneous series of semiconsolidated sandstone, sandy shale, conglomerate, fine-grained tuff, fine-grained tuffaceous sandstone, and coarse andesitic pyroclastic rocks. These rocks constitute the Dalles formation. They are composed almost entirely of particles derived from dense bluish-gray porphyritic andesite; generally this characteristic distinguishes the formation from clastic rocks associated with the underlying Yakima basalt. Some of the coarse-grained beds resemble certain facies of the stream terrace deposits in texture and petrography but are relatively much more indurated and somewhat more deeply weathered under like conditions of topography. Some beds of the Dalles formation contain pebbles and grains derived from metamorphic and crystalline rocks which are not known to occur in place in or near the Dalles region, and locally the sandstone members are micaceous. However, neither the presence nor the absence of such pebbles is a trustworthy guide in discriminating the formation from other stratigraphic units of the region.

Generally the strata that constitute the Dalles formation are less than 5 feet thick, and the several lithologic types interfinger and grade

[16] Merriam, J. C., A contribution to the geology of the John Day Basin: California Univ. Dept. Geology Bull., vol. 2, pp. 303–304, 1901.

[17] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), 1903; Mount Stuart folio (No. 106), 1904.

laterally into one another, so that no one section is strictly representative of the whole. The three partial sections that follow, however, indicate the general character of the formation.

Partial section of the Dalles formation in the south bank of Mill Creek about 7½ miles southwest of The Dalles, in the E. ½ sec. 28, T. 1 N., R. 12 E., Oregon

[Beds dip 1° N. 40° E.; base of measured section is about 935 feet above sea level, or 425 feet above the top of the underlying Yakima basalt]

	Feet
Concealed; top of section.	
20. Tuff, buff, massive, consisting of fragments of pumice as large as 1½ inches in diameter in fine-grained matrix	2+
19. Tuffaceous sandstone, buff, in rude beds 6 inches to 2½ feet thick; discontinuous conglomeratic lentils with poorly rounded cobbles of andesitic rocks as large as 6 inches in diameter	21
18. Conglomerate, poorly rounded boulders as large as 2 feet in diameter in matrix of tuffaceous sandstone	2½
17. Sandstone and conglomerate, in beds as much as 5 feet thick; poorly sorted rounded cobbles of andesitic rocks as large as 8 inches in diameter in sandy matrix. Uppermost bed grades upward into pumiceous tuff	37
16. Boulder conglomerate; poorly rounded cobbles and boulders 2 inches to 2 feet in diameter in sandy matrix; rude foreset beds dip northeastward	33
15. Sandstone, buff and light gray, medium and coarse grained; local cross-bedding dips northeastward; some beds in part tuffaceous; others contain isolated boulders as large as 1 foot in diameter	30
14. Tuff, buff, massive, containing fragments of pumice as large as 1½ inches long	7
13. Sandstone, buff and drab; waterworn grains 1 to 5 millimeters in diameter, moderately well assorted; true beds 6 inches to 3 feet thick with pebbly and tuffaceous lentils	46
12. Concealed; boulder conglomerate in part	28
11. Agglomerate; angular fragments of andesitic rocks as large as 2 inches in diameter in tuffaceous matrix; boulder conglomerate band at base	3
10. Sandstone, conglomerate, and tuff in lenticular interfingering beds 1 to 4 feet thick; ranges from medium-grained sandstone of uniform texture to conglomerate with boulders as large as 3½ feet in diameter and to volcanic agglomerate with angular fragments 1 foot in diameter	35
9. Conglomerate; poorly assorted pebbles and subangular boulders as large as 2½ feet in diameter in sandstone matrix	17
8. Concealed	59
7. Sandstone and pebble conglomerate, buff to drab, in beds 1 to 4 feet thick; in part cross-bedded, the foreset beds dipping northeastward. Boulder conglomerate about 3 feet thick at center	66

	Feet
6. Tuff and agglomerate, in beds 1 to 4 feet thick, each of which ranges from fine-grained tuff to agglomerate; 50 per cent of agglomerate consists of angular and subangular fragments as large as 12 inches in diameter	12
5. Sandstone, medium to coarse grained, in beds 1 to 4 feet thick, inclosing lentils of boulder conglomerate 2 to 4 feet thick	17
4. Tuff, purplish gray, pumiceous fragments in fine-grained matrix; beds about 3 feet thick	9
3. Sandstone and pebble conglomerate, in beds 6 inches to 3 feet thick, some of which grade upward into sandy tuff; local clusters and single boulders as large as 18 inches in diameter	23
2. Tuff and agglomerate, dark gray, in beds 6 inches to 4 feet thick; dense tuffaceous matrix with angular fragments of felsitic and porphyritic andesite as large as 6 inches across; small lentils of clay and water-laid conglomerate at top	20
1. Concealed	12
Base of slope and bottom of measured section.	
Thickness of measured section	479½

Partial section of the Dalles formation in the south bank of Chenoweth Creek about 2½ miles northwest of The Dalles, in the SW. ¼ sec. 29, T. 2 N., R. 13 E., Oregon

[Beds horizontal; base of section about 200 feet above sea level, or 50 feet above the top of the underlying Yakima basalt]

	Feet
Top of bluff and top of measured section.	
20. Volcanic agglomerate, massive; felsitic and glassy andesite and basalt fragments as much as 3 feet in greatest dimension in matrix of fine ejectamenta	38
19. Sandstone, in part tuffaceous, white, gray, and tan, in rude beds 1 to 5 feet thick; contains small lenses of pebbles about a quarter of an inch in diameter	23
18. Tuff, ejected fragments as large as 6 inches in diameter	2
17. Sandstone and sandy siltstone, light gray, in interfingering lentils 1 to 6 feet thick; locally conglomeratic with rounded cobbles as large as 2 inches in diameter	58
16. Tuff and tuffaceous siltstone, brownish gray, rudely bedded and massive	25
15. Sandstone, gray, massive and rudely bedded; medium-grained pebbly bands and lenses as much as 1 foot thick	23
14. Concealed; in part covered with sandstone débris	24
13. Sandy clay, massive and tuffaceous (?) at top, laminated at bottom	23
12. Concealed; hill wash contains many rounded pebbles as large as 2 inches in diameter, possibly derived from conglomeratic sandstone	29
11. Tuff, light gray; fragments of felsitic and scoriaceous basalt and andesite less than 1 inch in diameter in fine-grained matrix	11

		Feet
10.	Tuffaceous sandstone, gray; grains as large as 2 millimeters in diameter; grades downward into tuff	2
9.	Tuff, light gray, massive; fragments of andesitic rocks as large as 6 inches in diameter and smaller shreds of pumice in fine-grained matrix	82
8.	Concealed	65
7.	Tuff and agglomerate, light gray; ejectamenta smaller than half an inch in diameter in fine-grained matrix; poorly exposed	19
6.	Agglomerate, massive; consists of angular fragments of porphyritic, felsitic, and pumiceous andesite and basalt as large as 6 feet across and a few rounded cobbles as large as 5 inches in diameter in matrix of fine-grained tuff	21
5.	Concealed	53
4.	Agglomerate, massive; consists of subangular fragments of andesitic and basaltic rocks as large as 5 inches in diameter in matrix of dense fine-grained tuff; top not exposed	3½
3.	Sandy tuff, creamy white, massive, grains less than half a millimeter in diameter	10
2.	Sandstone, gray and buff; generally true bedding is distinct, but locally cross-bedding dips northeastward. Generally grains are of uniform size and less than 1 millimeter in diameter; locally there are pebbly bands less than 1 foot thick. Not well exposed	26
1.	Largely concealed; small scattered outcrops of sandstone similar to that overlying	42
	Base of slope and bottom of measured section.	
	Thickness of measured section	597½

Small outcrops in the vicinity of this measured section disclose the lowest part of the formation, which consists of clay with distinct varves (annual laminations).

Partial section of the Dalles formation along The Dalles-California highway in secs. 5 and 6, T. 1 S., R. 14 E., Oregon

[Beds dip 2° N. 15° W.; base of section about 952 feet above sea level]

		Feet
	Concealed, top of section.	
11.	Clay and volcanic ash, laminated, white and light gray; some fragments of pumice as much as half an inch in diameter	6+
10.	Tuff, generally massive; brown at top, grading downward to light gray or white; fragments of pumice and felsitic and glassy andesite as large as 12 inches across make up 10 to 65 per cent of the whole by volume; rudely laminated at base and center	14
9.	Clay, black (decomposed basalt scoria?)	1
8.	Basalt, black, with glassy upper surface; granular and pillow facies as much as 3 feet thick at base	5

	Feet
7. Sandy clay, white and brownish gray, in rude beds 3 to 10 inches thick; contains imprints of leaf and twig fragments at top	6
6. Sand, white and buff, in interfingering beds 1 to 8 inches thick, locally cross-bedded; composed largely of water-worn quartz grains as large as 3 millimeters in diameter; some black laminae about a quarter of an inch thick cemented by oxides of iron and manganese	8½
5. Sand, white and light gray, fine grained, micaceous; no true bedding	6
4. Clay, white, massive; upper part poorly exposed but seems to grade into overlying sand	4½
3. Concealed, in part massive andesitic agglomerate	6
2. Tuffaceous sandstone, light gray, fine grained at top	5½
1. Tuffaceous sandstone or clay, white, fine grained, in part rudely laminated	1½
Top of Yakima basalt and bottom of measured section.	
Thickness of measured section	64

In general both the massive coarse pyroclastic rocks and the thick beds of coarse sandstone and conglomerate are most abundant in the lower part of the formation (pl. 14, *A*), as in the measured section on Chenoweth Creek. However, these rock types are not equally abundant in all sections. At places in the southeastern part of the area represented on Plate 11 a discontinuous layer or layers of basalt (member 8 of section measured along The Dalles-California highway) occurs about 40 feet above the base of the formation; this may be a correlative of one of the agglomerate layers that are so prominent in the Chenoweth Creek section. The thick beds of sandstone, such as member 2 of the Chenoweth Creek section, are commonly cross-bedded, and the foreset beds dip northward or northeastward at most places near The Dalles.

At some places, especially along the bluff south of the Columbia River in T. 2 N., Rs. 14 and 15 E., the lowest member of the formation is a cross-bedded fluviatile conglomerate composed of well-rounded pebbles and cobbles as large as 6 inches in diameter in a matrix of slightly calcareous sand. Locally this member is as much as 125 feet thick. Most of the constituent pebbles are basic extrusive rocks such as might be indigenous to the region; these are generally somewhat decomposed as much as 2 inches inward from the surface of the particle. A few pebbles, at most places less than 1 per cent of the whole, are composed of white or pink quartzite, silicified rhyolite, chalcedony, or other material which is not known to occur in place in or near The Dalles region. Elsewhere in the region coarse pyroclastic rocks or massive tuffs occur at the horizon of the conglomerate. Other beds of conglomerate that contain pebbles of quartzite occur in the lower part of the formation and are separated from the underlying Yakima basalt by pyroclastic rocks; they are especially conspicuous in the eastern part of the area. (See pl. 14, *B*.) These beds of conglomerate are discontinuous and seem to grade laterally into fluviatile sediments of finer grain or to pinch out between layers of tuff or agglomerate. They are clearly stream deposits which represent but one phase of the Dalles epoch of sedimentation.

The Dalles formation is chiefly fluviatile in origin, much of the finer volcanic ejectamenta having been sorted and bedded by streams. However, certain of the coarse massive pyroclastic rocks are undoubtedly subaerial, and some of the finer tuffs may have been laid down by wind or as mud flows. Beds of lacustrine origin are not abundant in the formation, though some occur locally at or near its base; these include laminated (varved?) clay and laminated sandy clay in discontinuous masses.

Within the area represented on Plate 11 the Dalles formation occupies a zone about 12 miles wide in the deepest part of the Dalles syncline (p. 134), its principal outcrop being bounded roughly by Chenoweth Creek on the northwest, the Columbia River on the north, and Fifteenmile Creek on the southeast. Its maximum known thickness within this zone is about 1,500 feet along the divide between Mill and Threemile Creeks, but its original top is not exposed there and the original thickness is not known. Beyond the area represented by the geologic map the Dalles formation crops out in small areas north of the Columbia River along the base of Stacker Mountain. It also extends southwestward in the Dalles syncline to and beyond Mosier Creek and mantles parts of the southern flank of the syncline south of Fifteenmile Creek. Still farther south rocks that resemble the strata of the Dalles formation crop out in the structural depression which forms Tygh Valley (p. 137).

The Dalles formation is separated from the underlying Yakima basalt by an erosional unconformity whose relief is about 100 feet in the Dalles region. The Dalles strata, however, are nearly if not exactly parallel to the layers of the basalt, and the relief of the unconformity and the degree of weathering of the underlying basalt are little if any greater than in some of the erosional breaks within the basalt series. Hence the unconformity may not indicate a long time interval between the two formations. Certain stratigraphic relations suggest that the lowest part of the formation may interfinger with the upper part of the Yakima basalt outside the area here described. Of course, if it does, the lowest part of the Dalles formation is contemporaneous with the uppermost part of the Yakima basalt.

Only a few fossils have been found in the Dalles formation, and these do not indicate the geologic age precisely. Mrs. McCornack [18]

[18] McCornack, E. C., A study of Oregon Pleistocene: Oregon Univ. Bull., new ser., vol. 12, No. 2, p. 15, 1914. Hay, O. P., The Pleistocene of the western region of North America and its vertebrated animals: Carnegie Inst. Washington Pub. 322-B, p. 102, 1927.

lists a part of a metacarpal of an undetermined species of pre-Pleistocene camel from a "quarry of coarse-grained volcanic rock, just south of The Dalles." Buwalda [19] found the tooth of a horse of upper Miocene or lower Pliocene age together with a proboscidian fragment and the fused metapodial of an artiodactyl. These fossils were found in place in the Dalles formation in massive gray tuff about 500 feet above the base of the formation; the locality is described as 2 miles southeast of The Dalles and a quarter of a mile southeast of the Charles Calkins residence on the southwest side of the road and about 75 feet above it. Knowlton [20] correlates tentatively three species of leaves "from the so-called Dalles group" with the Bridge Creek (lowermost John Day) flora, the correlation being based on unpublished drawings of the leaves by Newberry. However, these three species of leaves or others which are closely related to them occur in both the Eagle Creek and the Mascall formations, so that they are not an adequate basis for fixing the age of the Dalles formation.

The lithology of the Dalles formation and its stratigraphic relation to the Yakima basalt are the same as for the Mascall formation [21] of the John Day Basin of Oregon and the Ellensburg formation [22] of central Washington. It seems extremely probable that the three formations—the Dalles, Mascall, and Ellensburg—are approximately if not strictly correlative. The Mascall formation contains a mammalian fauna which is listed by Merriam and Sinclair [23] and is ascribed by them to the middle or late Miocene. However, it is ascribed by Osborn [24] to the middle Miocene with the qualification that it may prove to be older because of its close relation to the lower Miocene faunas of Europe. The Mascall formation also contains a well-known fossil flora which Knowlton [25] considers to be "fixed with much certainty as middle Miocene," whereas Berry [26] believes it to be "somewhat younger than middle Miocene." It follows from the published faunal and floral classifications, therefore, that the Dalles formation may be as old as lower Miocene or as young as lower Pliocene; more precise correlation must await the discovery of fossils that are more diagnostic as to geologic age.

The writer believes that part or all of the Dalles formation is correlative with the fluviatile beds which overlie the Yakima basalt in

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[19] Buwalda, J. P., The Dalles and Hood River formations, and the Columbia River gorge: Carnegie Inst. Washington Pub. 404, p. 17, 1929.

[20] Knowlton, F. H., Fossil flora of the John Day Basin, Oregon: U. S. Geol. Survey Bull. 204, p. 112, 1902.

[21] Merriam, J. C., A contribution to the geology of the John Day Basin: California Univ. Dept. Geology Bull., vol. 2, pp. 305–310, 1901.

[22] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), 1903.

[23] Merriam, J. C., and Sinclair, W. J., Tertiary faunas of the John Day region: California Univ. Dept. Geology Bull., vol. 5, pp. 195–197, 1907.

[24] Osborn, H. F., The age of mammals in Europe, Asia, and North America, pp. 288–289, 1921.

[25] Knowlton, F. H., Flora of the Latah formation of Spokane, Wash., and Coeur d'Alene, Idaho: U. S. Geol. Survey Prof. Paper 140, p. 20, 1926.

[26] Berry, E. W., A revision of the flora of the Latah formation: U. S. Geol. Survey Prof. Paper 154, p. 235, 1929.

the gorge of the Columbia River west of the Dalles region and which Bretz[27] and Williams[28] have correlated with the Satsop formation of Washington. He believes further that the beds of quartzite-bearing conglomerate in the lower part of the Dalles formation in the region described in this report are in whole or in part correlative with the Hood River formation of Buwalda[29] and that these formations are phases of one stratigraphic unit. This interpretation of the stratigraphy is the same as that held by Bretz and suggested as a possibility by Buwalda.

ANDESITE

Tongues of andesite extend in two places into the area represented on Plate 11—in the valley of Mill Creek in Ts. 1 N. and 1 S., R. 12 E., and in the valley of Eightmile Creek in T. 1 S., R. 12 E. Both are northeastward extensions from a lava field whose source is in volcanic vents in the vicinity of Mount Hood. Both tongues lie in abandoned valleys eroded to a depth of several hundred feet in the Dalles formation and have been trenched through by subsequent erosion. The andesite tongue in Mill Creek Valley was originally from a quarter of a mile to a mile wide and as much as 250 feet thick, and the remnants of its upper surface are about 1,600 feet above sea level in secs. 27 and 28, T. 1 N., R. 12 E. Its present remnants form prominent benches on one or both sides of the valley and 500 to 700 feet above the bed of the stream. It consists of a single layer of massive dense andesite which is bluish gray on fresh fracture, glassy at its contact with the underlying Dalles formation but somewhat porphyritic in its central part. In some places the andesite is slightly vesicular. The present remnants of the andesite tongue in the valley of Eightmile Creek cap a bench between the two forks of the creek and extend downstream into sec. 26, T. 1 S., R. 12 E.

These andesite tongues were extruded after the Dalles formation and the underlying Yakima basalt had been folded (pp. 134–136), planed off in the Mount Hood Flat cycle (p. 141), and trenched by erosion about 750 feet below the Mount Hood Flat. Hence they are relatively young. They are probably not older than late Pliocene and may be as young as middle Pleistocene.

QUATERNARY SYSTEM

GENERAL FEATURES

The unconsolidated Quaternary rocks of the Dalles region include gravel, sand, and silt on stream bars and terraces, hill wash and fans

[27] Bretz, J. H., Satsop formation of Oregon and Washington: Jour. Geology, vol. 25, pp. 446–458, 1917.

[28] Williams, I. A., The Columbia River gorge; its geologic history interpreted from the Columbia River highway: Mineral Resources of Oregon, vol. 2, No. 3, pp. 24–128, Oregon Bur. Mines and Geology, 1916.

[29] Buwalda, J. P., The Dalles and Hood River formations, and the Columbia River gorge: Carnegie Inst. Washington Pub. 404, pp. 11–26, 1929.

of alluvium, scattered erratic boulders, and sand dunes. With the exception of the erratic boulders and sand dunes, these rock units seem to be largely the products of normal processes of erosion and sedimentation by the Columbia River and its tributaries, the hill wash and alluvium being genetically related to the terrace deposits. The sand dunes occur only on the flood plain and terraces of the Columbia River near The Dalles.

ERRATIC BOULDERS

Boulders that have been transported from distant points were found at 10 localities in the Dalles region and are described in the following table. None of them are similar petrographically to any of the rocks known to occur in place in the Dalles region or in the Oregon section of the Cascade Range.

Erratic boulders in the Dalles region, Oregon

No.	Location	Altitude (feet above sea level)	Description
1	NE. ¼ sec. 25, T. 2 N., R. 12 E., south slope of valley of north branch of Chenoweth Creek.	700–800	15 or more angular and subangular pieces of coarse-grained quartzose granite, 1 to 3 feet in greatest dimension, scattered among local boulders of basalt and andesite.
2	NW. ¼ NW. ¼ sec. 25, T. 2 N., R. 12 E., on remnant of stream terrace, about three-quarters of a mile southwest of locality No. 1.	775	20 or more subangular pieces of quartzose granite and granodiorite; the largest is 3 feet in greatest dimension.
3	NW. ¼ SE. ¼ sec. 24, T. 2 N., R. 12 E., on north slope of valley of north branch of Chenoweth Creek.	925	Angular fragments of coarse-grained porphyritic hornblende granite, aggregate volume about 5 cubic feet, evidently freshly broken from one or more larger pieces.
4	NW. ¼ sec. 36, T. 2 N., R. 12 E., in bed of ephemeral drain entering Chenoweth Creek from the north across terrace of older alluvium about a quarter of a mile wide.	500–550	6 subangular boulders and 8 angular fragments of medium-grained biotite granite 4 to 24 inches in greatest dimension; 1 subangular boulder of biotite gneiss 12 inches in diameter; 2 well-rounded cobbles of pinkish-white granite 5 inches in diameter; 2 well-rounded cobbles of banded quartzite. Mingled with local boulders of andesite and basalt.
5	NE. ¼ SW. ¼ sec. 25, T. 2 N., R. 14 E., on north bank of Fifteenmile Creek.	460	Subangular boulder of granodiorite 2 feet in greatest diameter at base of erosion scarp in older alluvium.
6	NW. ¼ NW. ¼ sec. 24, T. 1 N., R. 12 E., on terrace remnant on south bank of Mill Creek.	790	4 tabular pieces of medium-grained granite 6 to 16 inches long, among local boulders of andesite and basalt.
7	NW. ¼ SW. ¼ sec. 18, T. 1 N., R. 13 E., on remnant of same terrace as locality 6.	775±	2 subangular pieces of medium-grained granite about 12 inches long.
8	Near the west quarter corner of sec. 27, T. 1 N., R. 13 E., on terrace remnant on west bank of Threemile Creek.	900	Angular granite cobble 6 inches in diameter.
9	NE. ¼ NE. ¼ sec. 32, T. 1 N., R. 14 E., on terrace remnant on south side of Eightmile Creek.	850	4 subangular boulders of medium-grained granodiorite 2 to 5 feet in greatest dimension, among local boulders of basalt and andesite.
10	NE. ¼ SW. ¼ sec. 28, T. 1 N., R. 14 E., on terrace remnant on south side of Eightmile Creek near junction of Wrentham market road with The Dalles-California highway.	875	2 angular pieces of medium-grained granite 2 and 3 feet in greatest dimension in pile of boulders cleared from field; may have been broken by blasting.

Of these 10 localities, 4 are on remnants of terraces of the older alluvium, 3 are on higher terraces, and 3 can not be correlated with any terrace stages of the Dalles region. They were presumably rafted into the area on floating ice, but it does not follow that all were deposited in the same physiographic epoch. Inasmuch as there seem not to be any shore terraces or high-level deltas in the tributary valleys of the Dalles region, water was probably not ponded therein for long periods. At what stage or stages of the physiographic history the Columbia River was ponded is not known.

OLDER ALLUVIUM

Distribution and character.—Along the creeks that enter the Columbia River near The Dalles (pl. 11) there are in many places prominent terraces 50 to 200 feet above the present creek beds. These terraces are from 350 to 500 feet above sea level near the Columbia River and rise upstream about 50 to 100 feet to the mile. They are widest and most persistent where the Dalles formation constitutes the bedrock and are only imperfectly developed on the underlying Yakima basalt. In Threemile Creek, for example, the terrace is as much as 1 mile wide (pl. 13) where it has been formed in the massive tuffs and tuffaceous sandstone of the Dalles formation. These terraces of the tributary creeks are adjusted to a discontinuous terrace along the Columbia River, the master terrace being about 300 feet above sea level at The Dalles and rising upstream 25 to 50 feet in each mile. The unconsolidated rocks that cover parts of these terraces constitute the older alluvium.

The older alluvium consists of gravel, sand, and silt. The finer material is more abundant where the terrace is cut on the Dalles formation, as in the western part of the region. The thickness of the alluvium ranges from about 10 to 150 feet and generally increases downstream; where thinnest, it is only a veneer upon a rock-cut terrace. Along Chenoweth Creek in sec. 36, T. 2 N., R. 12 E., and sec. 30, T. 2 N., R. 13 E., the older alluvium consists largely of sandy silt, in part rudely bedded in layers 2 to 8 inches thick and cross-bedded. Locally its lower part contains poorly sorted sand with beds of pebbles and cobbles as large as 4 inches in diameter; these pebbles and cobbles consist of andesite such as is common in the Dalles formation. Farther east, on Mill and Threemile Creeks, the older alluvium is also mostly rudely stratified and cross-bedded sandy silt inclosing pebbly lentils and a few rounded cobbles; the cross-bedding is not constant in orientation. Generally this sandy silt contains many grains of quartz and feldspar and some flakes of mica—minerals that are also characteristic of some of the sandstone members of the Dalles formation.

Along the lower part of Fifteenmile Creek on the other hand, the older alluvium consists largely of coarse sand, gravel, and boulders. In the SW. ¼ sec. 25, T. 2 N., R. 14 E., in the vicinity of Fairbanks station of the Great Southern Railroad, it consists in part of lenticular beds of pebbly sand from 4 to 18 inches thick interfingering with beds of poorly rounded gravel as large as 3 inches in diameter. Other strata are cross-bedded, and the foreset layers are separated by sand partings 1 to 3 inches thick. Still other parts consist of poorly sorted subangular and poorly rounded pebbles, cobbles, and boulders from half an inch to 24 inches in diameter forming rude and nearly horizontal beds as much as 10 feet thick. The older alluvium at this place is at least 100 feet thick; most of its constituent particles are derived from the Yakima basalt. About 3 miles downstream, in the W. ½ SE. ¼ sec. 28, the older alluvium is exposed to a height of about 50 feet in a gravel pit. The lower 20 feet exposed at this place consists of cross-bedded gravel from 1 to 4 inches in diameter, the true beds being nearly horizontal and 2 to 10 feet thick and the foreset layers dipping eastward or southward; boulders as large as 24 inches in diameter make up a few of the foreset layers. This gravel is overlain in turn by rudely cross-bedded sand and gravel and by stratified sand and fine gravel in beds 2 inches to 4 feet thick. About half a mile farther downstream, in the N. ½ SW. ¼ sec. 33, the older alluvium is exposed in another gravel pit. At this place the older alluvium is composed largely of angular and subangular pebbles, cobbles, and boulders of basalt, but about a fourth of the whole consists of rounded cobbles of basalt and perhaps 10 per cent of pieces of tuffaceous sandstone or andesite cobbles from conglomerate members of the Dalles formation. (See pl. 15, *A*.) It is in part cross-bedded, with the foreset layers dipping southwestward, and is mostly unsorted. Such coarse gravel and boulder deposits seem to be characteristic of the older alluvium where its terrace is cut across the resistant Yakima basalt. They also occur along the lower part of Chenoweth Creek, as in the SE. ¼ sec. 30, T. 2 N., R. 13 E., where fans of coarse angular wash from the Yakima basalt of the valley sides seem to interfinger with the sandy silt that makes up most of the older alluvium farther upstream.

The coarse gravel and boulder deposits on the lower part of Fifteenmile Creek have been interpreted by Bretz[30] as river-bottom bars built in virtually their present form by the Columbia River during the so-called "Spokane flood"; as such they would be younger than the terrace deposits of the other tributary creeks. The writer, however, believes them to be a coarse facies of the older alluvium.[31]

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[30] Bretz, J. H., Bars of channeled scabland: Geol. Soc. America Bull., vol. 39, No. 3, pp. 693–695, 1928.

[31] Piper, A. M., Observations in the Dalles region, Oregon, bearing on the history of the Columbia River [abstract]: Washington Acad. Sci. Jour., vol. 21, pp. 371–372, 1931.

In the main valley of the Columbia River the older alluvium covers extensive areas on the broad terrace north of the river opposite The Dalles (pls. 11 and 12) and a few small areas on terrace remnants south of the river.

Age.—The finer facies of the older alluvium have been rather completely decomposed by chemical weathering to a depth of several feet, and the terraces of which the older alluvium forms a part have been dissected to the stage of early maturity. These general features suggest that the older alluvium is probably not younger than Pleistocene.

Finds of mammalian remains of Pleistocene age have been reported from four localities near The Dalles,[32] as listed below.

Bison antiquus. Skull, 5 or 6 miles east of The Dalles. "*Bos latifrons*" in original description.[33]

Camelops vitakerianus Leidy. Distal extremity of radius, "beneath glacial drift" 2 or 3 miles southeast of The Dalles.

Elephas boreus. Tooth and part of shoulder blade from terrace deposit resting on the Dalles formation on Eightmile Creek, near The Dalles.

Elephas columbi. Lower right molar, near The Dalles. University of Oregon catalog No. 310.

According to Hay's classification[34] these four species are probably not younger than the third or Sangamon interglacial stage (later Pleistocene). The locality of *Elephas boreus* is probably in the older alluvium as described in this report. The localities of the other three species are not known exactly but also are probably in the older alluvium, for the older alluvium is the oldest terrace deposit resting on the Dalles formation (lower Pliocene or older) at these localities and is the only unconsolidated deposit likely to be as old as the Sangamon.

Origin.—The older alluvium of the Dalles region rests in valleys eroded in both the Dalles formation and the Yakima basalt, the rock floors of these buried valleys being adjusted to the Columbia River at a stage when the river was about 150 feet above sea level at The Dalles. On the other hand, the upper surface of the older alluvium seems originally to have been continuous with a prominent rock shelf along the Columbia River, the present altitude of which at The Dalles is about 300 feet above sea level, and its gradient nearly 50 feet to the mile. Hence the older alluvium is clearly older than a 150-foot stage of the Columbia River but presumably in part contemporaneous with a 300-foot stage. Furthermore, the upper surface of the older allu-

[32] McCornack, E. C., A study of Oregon Pleistocene: Oregon Univ. Bull., vol. 12, No. 2, p. 15, 1914; Contributions to the Pleistocene history of Oregon: Oregon Univ. Leaflet ser., Geol. Bull., vol. 6, No. 3, pt. 2, pp. 16, 23, 1920. Hay, O. P., The Pleistocene of the western region of North America and its vertebrated animals: Carnegie Inst. Washington Pub. 322-B, pp. 24, 30, 102, 124, 1927.

[33] Condon, Thomas, The two islands and what came of them, p. 153, Portland, Oreg., J. K. Gill & Co., 1902.

[34] Hay, O. P., The Pleistocene of North America and its vertebrated animals from the States east of the Mississippi River and from the Canadian Provinces east of longitude 95°: Carnegie Inst. Washington Pub. 322, p. 14, 1923.

vium is approximately continuous with the floors of two rock-floored wind gaps that cross the divide between the Columbia River and the lower course of Fifteenmile Creek. It is also continuous with well-defined rock shelves in the tributary valleys. The more prominent of the two wind gaps lies in secs. 21 and 28, T. 2 N., R. 14 E. (pl. 11); its floor is nearly a mile wide, is about 550 feet above sea level, and is trenched nearly 200 feet into the Yakima basalt. The smaller of the two is in secs. 24 and 25; its floor is about 250 yards wide, is 700 feet above sea level, and approximately follows the top of the Yakima basalt. The rock shelves of the tributary creeks are cut on both the weak Dalles formation and the resistant basalt. A third wind gap in sec. 20, T. 2 N., R. 13 E., may originally have been continuous with the terrace of older alluvium in Chenoweth Creek. These rock shelves indicate a relatively long period when the Columbia River and its tributaries were planing laterally and widening their valleys. The continuity of the rock shelves with the upper surface of the alluvium suggests that the streams planed their courses across the alluvial fill at the same time as on the bedrock.

The stratification of the older alluvium and the range in size of its constituent particles suggest that much of the older alluvium was transported by and deposited in flowing streams of moderate velocity and moderate but not excessive load. The approximate correlation between the coarseness of the alluvium and the petrographic character of its particles indicates that much of the alluvium probably has not been transported far. The occurrence of ice-rafted boulders of distant origin at a few places on or near the terraces of the older alluvium suggests that some of the alluvium may have been deposited in static water.

The writer has suggested[35] the following sequence of events as a tentative explanation of the origin of the older alluvium. First, the Columbia River and its tributary creeks eroded rock channels along their present courses, the river cutting down to an altitude of about 150 feet above sea level at The Dalles. Downcutting was rapid, for the rock channels of the tributaries in the weak Dalles formation are relatively steep. Second, these channels were filled with alluvium up to or above the wind gaps in the divide between Fifteenmile Creek and the Columbia River. Third, the Columbia River, superposed upon the alluvial fill, cut the 300-foot terrace by lateral planation in the Yakima basalt; the tributary creeks widened their valleys by cutting laterally, both in the Yakima basalt and in the less resistant Dalles formation. One or both of the wind gaps were presumably occupied by Fifteenmile Creek or by the Columbia River during part of this stage. This third or planation stage was relatively long, for the terraces then cut were more extensive than those formed in any

[35] Piper, A. M., op. cit.

other stage of the physiographic history except the Mount Hood Flat stage (p. 141). Fourth, the streams again deepened their valleys and reoccupied their former courses, because the alluvium could be swept therefrom more rapidly then the superposed parts of the meandering courses could be eroded in the resistant basalt.

Faulting has occurred in the Dalles region in very late geologic time (pp. 137–139) and may have played a principal part in bringing about the second or aggradational stage postulated in the preceding paragraph.

INTERMEDIATE ALLUVIUM

Along the south bank of the Columbia River near The Dalles there are remnants of a terrace from a quarter of a mile to nearly a mile wide and about 100 feet above the river, or 150 to 175 feet above sea level. To this terrace are adjusted the graded portions of the tributary creeks. The unconsolidated rocks that cover parts of this terrace and the beds of the creeks adjusted to it constitute the intermediate alluvium. (See pl. 11.)

The intermediate alluvium of the tributary creeks consists of poorly sorted sandy and pebbly silt and in most places is probably less than 20 feet thick. Generally the plains which it forms are less than 250 yards wide. Along the Columbia River, however, the intermediate alluvium commonly comprises beds of stratified sand from 1 to 10 inches thick and cross-bedded sand and gravel containing cobbles as large as 3 inches in diameter. Generally the stratified sand is relatively uniform in size of grain, whereas the coarse cross-bedded facies are composed of particles of many different sizes. (See pl. 15, *B*.) At most places in this part of the area the intermediate alluvium is between 10 and 35 feet thick.

The intermediate alluvium is very little weathered and is clearly younger than the older alluvium, although both of these unconsolidated rock units seem to rest on parts of the same bedrock platform. It seems unlikely that this common platform, the most prominent part of which is the rock terrace 150 to 175 feet above sea level along the Columbia River, was cut in one erosion stage. More probably it was begun before the deposition of the older alluvium but was greatly widened through planation by the river after most of the older alluvium had been swept from the valley and before the intermediate alluvium was deposited.

YOUNGER ALLUVIUM

In its latest partial erosion cycle the Columbia River has cut a relatively narrow trench in the Yakima basalt about 100 feet below the 150-foot terrace. The unconsolidated materials that form the stream bars and cover the low discontinuous terraces of this trench constitute the younger alluvium. (See pl. 11.)

The younger alluvium consists of sand, fine gravel, and coarse gravel of unknown thickness. It is in large part covered by the river during flood stages and hence is reworked periodically. Most of the constituent particles are of local origin and derived from the Yakima basalt, but there is in most places a minor portion derived from granular and crystalline rocks from the head of the drainage basin.

STRUCTURE

GENERAL FEATURES

In general, the structure of the Dalles region is simple, its elements being open major folds and associated secondary folds and faults. However, it is somewhat difficult in places to trace the structure in detail, because trustworthy horizon markers are wanting in both the Dalles formation and the underlying Yakima basalt. Furthermore, in many places the regional structure is concealed by superficial landslides, especially in the weak Dalles formation. Although the Dalles region lies only a short distance east of the Cascade Range, it may not be a part of the Cascade structural province, because the trend of its folds and major faults is discordant with the trend of the Cascade arch. The major folds and some of the secondary faults of the western part of the Cascade structural province have been described by Williams,[36] but the structure of the Dalles region has not been described heretofore except in general terms.

DALLES SYNCLINE

The major structural feature of the Dalles region is the Dalles syncline, an asymmetric trough whose axis trends roughly eastward through Grand Dalles, Wash. (See pl. 11.) From this axis the beds of the Dalles formation and the Yakima basalt rise northward for 3 to 4 miles, the dip being 1°–2° S. to S. 60° W. Farther north the dip steepens and becomes 18°–25° S. 20°–40° E. on the flank of the Ortley anticline. The axis of this anticline, which bounds the Dalles syncline on the north, crosses the north bank of the Columbia River in sec. 7, T. 2 N., R. 13 E. From the axis of the Dalles syncline the beds rise southward to the summit of Tygh Ridge, about 12 miles south of the area represented on Plate 11, the dip being generally 1°–2° N. 30° E. to N. 30° W. At the south flank of Tygh Ridge the strata are downfaulted with accompanying sharp drag folds. In this area, therefore, the Dalles syncline is about 26 miles wide and is approximately 2,500 feet deep below the axes of the anticlines that bound it on the north and south. Farther east, however, the syncline seems to decrease in depth and to become much less prominent.

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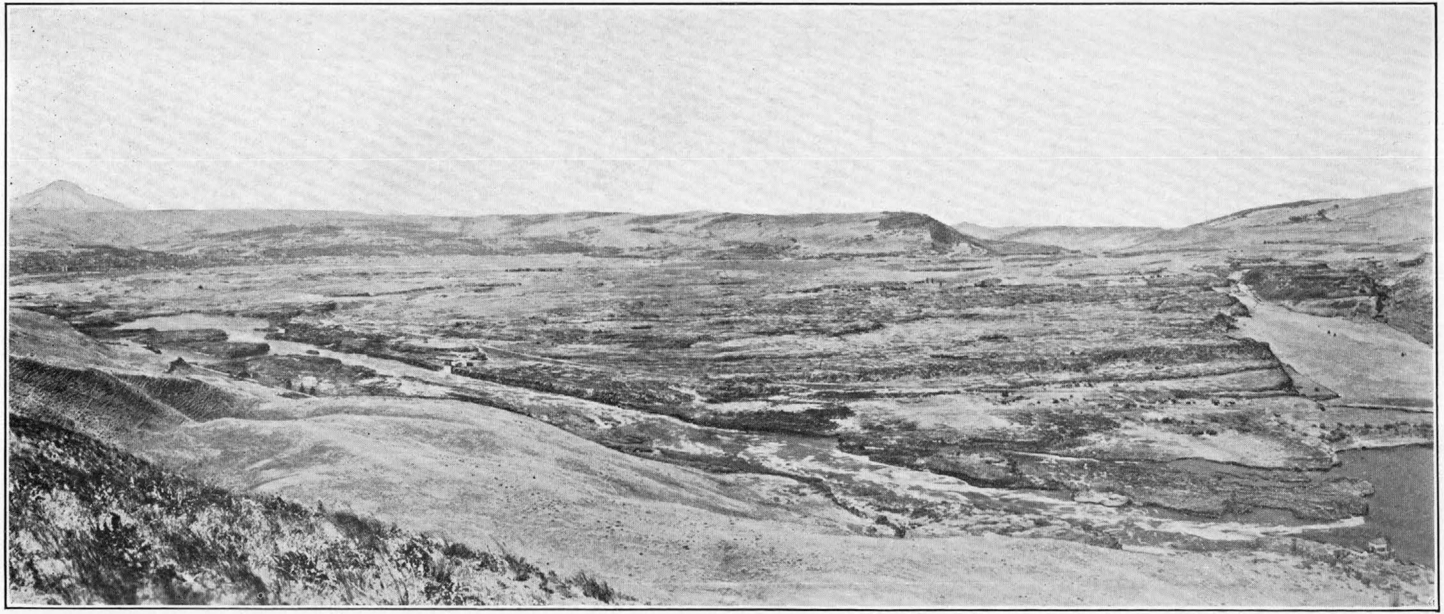
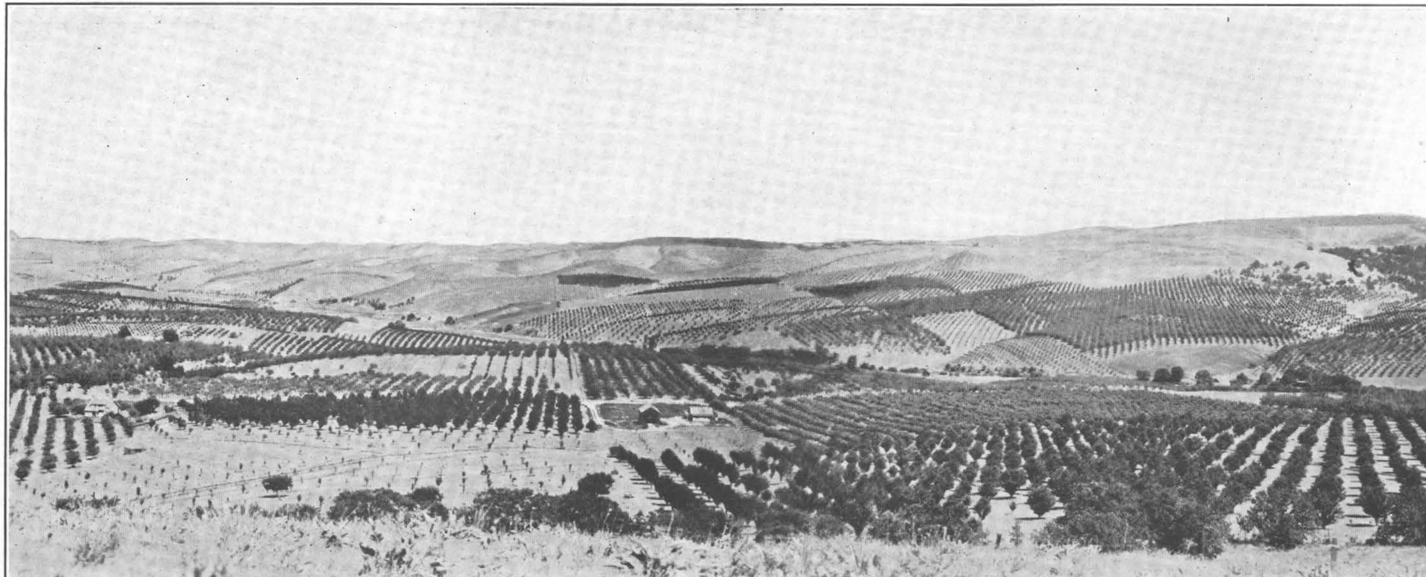
[36] Williams, I. A., The Columbia River gorge: its geologic history interpreted from The Columbia River highway: Mineral Resources of Oregon, vol. 2, No. 3, pp. 85–86, 104–108, 111–112, 121–122, Oregon Bur. Mines and Geology, 1916.



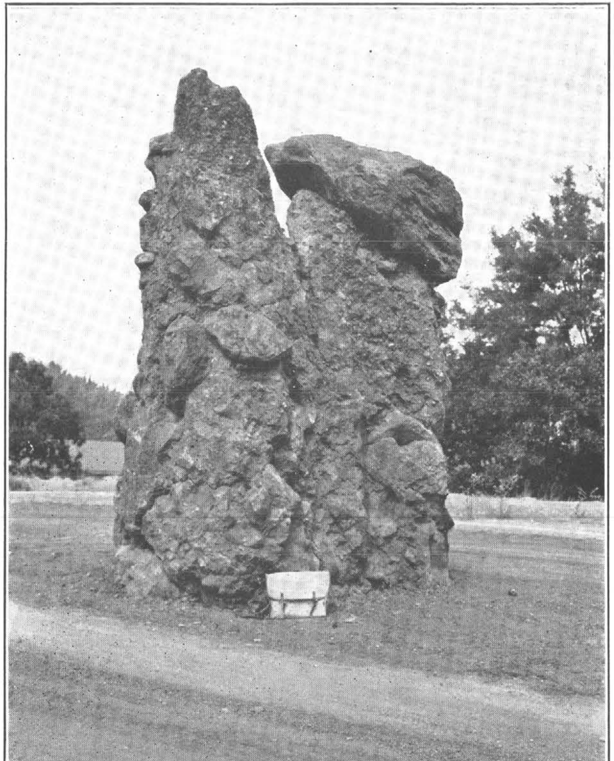
VALLEY OF COLUMBIA RIVER AT THE DALLES, OREG., SHOWING FIVEMILE RAPID AND STREAM TERRACE NORTH OF THE RIVER

View downstream from NE. ¼ sec. 29, T. 2 N., R. 14 E.



VALLEY OF THREEMILE CREEK SHOWING TERRACE OF OLDER ALLUVIUM, ON WHICH MOST OF THE ORCHARD TRACTS ARE LOCATED

View eastward from NE. ¼ sec. 15, T. 1 N., R. 13 E.

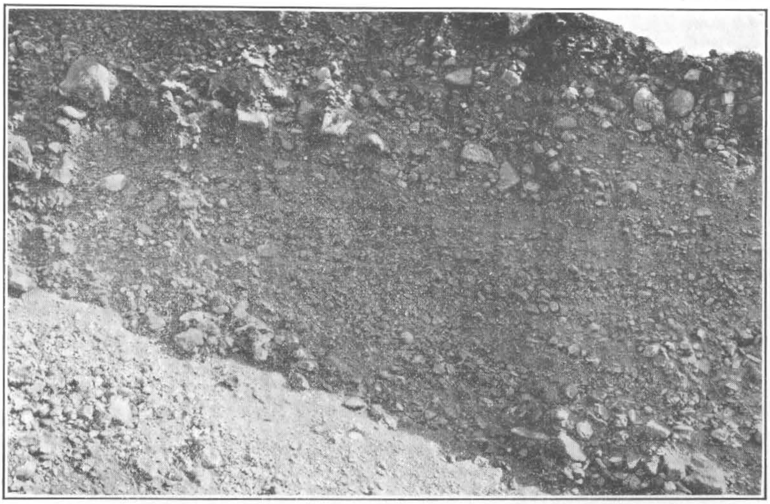


A. COARSE ANDESITIC AGGLOMERATE ABOUT 35 FEET ABOVE THE BASE OF THE DALLES FORMATION

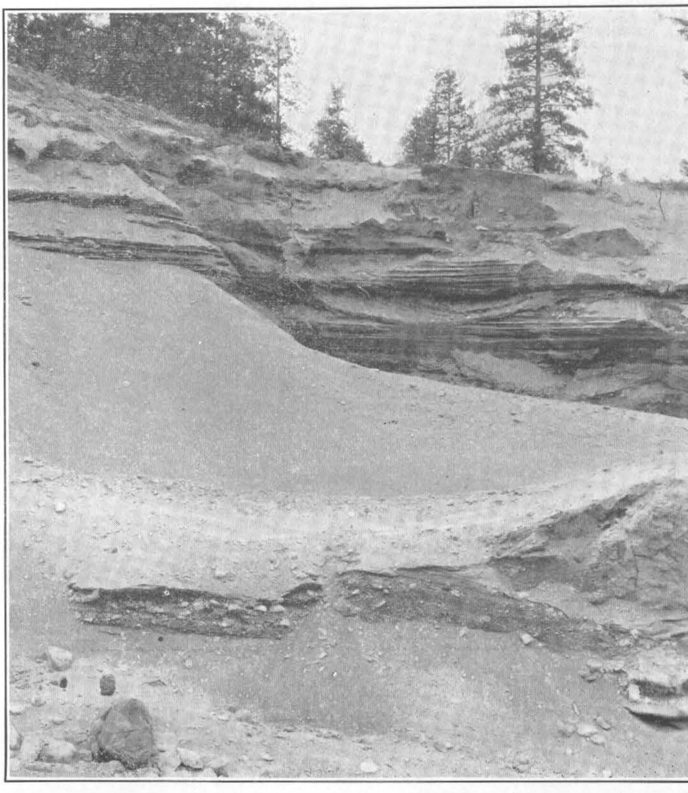
Pulpit Rock, at intersection of Court and Twelfth Streets, The Dalles, Oreg.

B. CROSS-BEDDED CONGLOMERATE ABOUT 175 FEET ABOVE THE BASE OF THE DALLES FORMATION

Gravel pit in NW. ¼ NE. ¼ sec. 3, T. 1 N., R. 14 E.



A. CROSS-BEDDED SAND, GRAVEL, AND BOULDERS OF THE OLDER ALLUVIUM
Gravel pit in SW. ¼ sec. 33, T. 2 N., R. 14 E., in the northwest bank of Fifteenmile Creek.



B. SAND AND GRAVEL OF THE INTERMEDIATE ALLUVIUM
Gravel pit on terrace of Columbia River, in SW. ¼ sec. 29, T. 2 N., R. 13 E.

At the lowest point along the axis of the Dalles syncline, about 2 miles northwest of The Dalles, the top of the Yakima basalt is approximately 200 feet above sea level. The axis rises toward the east, however, so that the top of the basalt is about 535 feet above sea level where the axis crosses Eightmile Creek near its junction with Fivemile Creek. The altitude of the top of the basalt at points on the flanks of the syncline is shown by the following table.

Approximate altitude of top of Yakima basalt on flanks of Dalles syncline

	Feet
Lot 1, sec. 33, T. 2 N., R. 13 E., Grand Dalles, Wash	200
NE. ¼ sec. 16, T. 2 N., R. 13 E	475
NE. ¼ sec. 17, T. 2 N., R. 13 E	650
SW. ¼ sec. 21, T. 2 N., R. 14 E., bluff south of Columbia River	750
E. ½ sec. 24, T. 2 N., R. 14 E., bluff south of Columbia River	785
N. ½ sec. 36, T. 2 N., R. 14 E., south wall, valley of Fifteenmile Creek	600
SW. ¼ sec. 31, T. 2 N., R. 14 E., Seufert flag station, Oregon-Washington R. R. & Navigation Co	400
SW. ¼ sec. 2, T. 1 N., R. 13 E., The Dalles	285
SW. ¼ sec. 9, T. 1 N., R. 13 E., well 51 (see p. 178)	230
NE. ¼ sec. 12, T. 1 N., R. 13 E., well 55 (see p. 178)	280
NW. ¼ sec. 23, T. 1 N., R. 13 E., well 65 (see p. 180)	435
SE. ¼ sec. 28, T. 1 N., R. 12 E., well 42 (see p. 174)	500±
N. ½ sec. 19, T. 1 N., R. 14 E., north wall, valley of Fivemile Creek	580
NW. ¼ sec. 33, T. 1 N., R. 14 E., south wall, valley of Eightmile Creek	950
S. ½ sec. 36, T. 1 N., R. 13 E., Jap Hollow	800±
SW. ¼ sec. 2, T. 1 S., R. 14 E., south wall, valley of Fifteenmile Creek	1,200±
N. ½ sec. 20, T. 1 S., R. 14 E., south wall, valley of Fifteenmile Creek	1,340
NW. ¼ sec. 25, T. 1 S., R. 13 E., north wall, valley of Fifteenmile Creek at Dufur	1,390

SECONDARY FOLDS AND FAULTS

The most prominent secondary folds of the Dalles region are two anticlines, one on each flank of the Dalles syncline. The northerly one lies just north of Chenoweth Creek and is separated from the southern flank of the Ortley anticline, one of the major folds of the region, by a comparatively narrow syncline, as is shown by the structure section on Plate 11. Although its continuity is broken by faulting, the anticline trends about S. 70° W. for 4½ miles from the Columbia River and extends eastward about half a mile beyond the river. The fold is asymmetric, its southern flank dipping 15°–20° S. 20° E. and its northern flank about 10° N. 20° W. The other secondary anticline is well defined in the valley of the North Fork of Mill Creek near the southeast corner of T. 1 N., R. 11 E., where the Yakima basalt is exposed below the Dalles formation. At this place the strata on the northeastern flank dip 10°–15° nearly due east. Farther east the Yakima basalt is also exposed at the crest of this anticline in the valley of Threemile Creek in secs. 27, 28, 32, and 33, T. 1 N., R. 13 E., and on Fivemile Creek in sec. 25. The top of the Yakima basalt at the crest of this fold is about 2,750 feet above sea level in the Mill Creek valley, 1,200 feet above sea level on Threemile Creek, and 1,100 feet above sea level on Fivemile Creek. The amplitude of the fold and the inclination of its flanks decrease toward the east, so that the fold is not well defined where the projection of its axis crosses Eightmile Creek. The axis of the fold strikes roughly eastward as far as Fivemile Creek and then swerves N. 70° E. across that stream. As is brought out by a subsequent paragraph, both of these secondary anticlines are faulted locally along their southern flanks.

In addition to the two secondary anticlines described in the preceding paragraph, there are many very small undulations superposed on the flanks of the Dalles syncline, some of which are suggested by differences in the direction and amount of the dip as plotted on Plate 11. The strata are also deformed by minor drag folds along some of the faults.

Faults are common in the Dalles region. One of the largest is a normal fault that strikes about N. 70° E. along the south flank of the Ortley anticline and across the secondary anticline just north of Chenoweth Creek. The vertical displacement along this fault is at least 1,000 feet at the divide between Chenoweth and Mosier Creeks, near the west boundary of the region, where the block south of the fault is thrown down. Farther east, near the Columbia River, the fault branches as it crosses the secondary anticline, and the net displacement is a downthrow of about 700 feet on the north. However, this apparent reversal of the vertical component of the displacement is probably due largely to horizontal slip or shove along the fault plane rather than to hinge movement. Still farther east, across the river, this fault joins a major fault zone that trends about N. 70° W. along the base of Stacker Mountain, but its trace is concealed by unconsolidated rocks.

Another normal fault, which is roughly parallel to the one described in the preceding paragraph, follows the south flank of the secondary anticline that crosses Threemile and Fivemile Creeks near the south boundary of T. 1 N., R. 13 E. The south block is downthrown 150 to 200 feet where the fault crosses Fivemile Creek, but the displacement diminishes eastward and is small or lacking where the projection of the fault trace crosses Eightmile Creek. Still farther south, beyond the area represented on Plate 11, a major normal fault, which also strikes about N. 70° E., passes along the north side of Tygh Valley. Along this fault likewise the south block is thrown down and the displacement diminishes eastward; the displacement due to faulting and drag folding is more than 2,000 feet at the town of Tygh Valley.

The major fault or fault zone that follows the south base of Stacker Mountain north of the Columbia River was not traced in detail. However, it trends about N. 70° W. across sec. 15, T. 2 N., R. 13 E. (see pl. 11), and the south block is thrown down several hundred feet. The projection of its trace westward coincides with the Columbia River for several miles downstream from Skadat flag station of the Spokane, Portland & Seattle Railway, but the actual extent of the fault in that direction is not known. The fault that strikes through sec. 24, T. 2 N., R. 13 E., and secs. 19 and 20, T. 2 N., R. 14 E. (see pl. 11), is either a component part of the major fault zone or a secondary fracture branching from it; the block southwest of this fracture is thrown down at least 200 feet. In the vicinity of The Dalles this fault zone appears to comprise several en échelon or braided fractures, along each of which the vertical displacement diminishes eastward. This fault pattern is superposed, at least locally, on the south flank of the Ortley anticline and may cross the axis of that fold at an acute angle.

Several secondary faults of small displacement cross the Columbia River near The Dalles; others probably exist in many parts of the region but are not apparent because of the absence of trustworthy horizon markers in the Yakima basalt and the overlying Dalles formation. One of these secondary faults crosses the river at the head of Threemile Rapid, in sec. 36, T. 2 N., R. 13 E., where its strike is about N. 25° W. The vertical component of the displacement, as indicated by the contact between the Dalles formation and the Yakima basalt and by a layer of pillow lava in the basalt, is about 40 feet, with the western block downthrown. However, the original displacement must have been at least 100 feet, for the bed of the river has been raised about 60 feet by upward movement of the western block in late geologic time. This rebound movement along the fault plane has caused the formation of Threemile Rapid, which is a narrow cleft eroded by the river across the upstream edge of the rising fault block. Another minor displacement, which might be either a sharp flexure or a fault, strikes N. 70° W. across the river at the head of Big Eddy, in sec. 25, T. 2 N., R. 13 E., and sec. 30, T. 2 N., R. 14 E. The net stratigraphic downthrow is about 50 feet on the north. As is pointed out in the preceding paragraph, the fault that crosses the river in secs. 19 and 20, T. 2 N., R. 14 E., at the head of Fivemile Rapid, may be a secondary fracture of this same class. Here also there has been rebound movement along the fault, for the western block is downthrown stratigraphically at least 200 feet but has moved upward about 100 feet in comparatively recent time. The rapid at this place is the narrow cleft eroded by the Columbia River across the rising block. The essential features of this fault have been described by Harza.[37] Still farther upstream another secondary fault crosses the river at Celilo Fall, about 200 yards upstream from the Oregon Trunk Railway bridge in sec. 20, T. 2 N., R. 15 E. This fault strikes N. 20° W.; the net stratigraphic displacement is not known, but late movement has raised the eastern block about 20 feet.

LANDSLIDES

Landslide topography is prominent at many places in the Dalles region, generally along the Columbia River and the lower reaches of its tributaries and generally also in the weak rocks of the Dalles formation. The most striking example is perhaps a landslide scarp about a mile long which trends nearly due east across secs. 11 and 12, T. 1 N., R. 13 E., about 2 miles east of The Dalles. At this place a large mass of conglomerate and tuff of the Dalles formation has slumped vertically about 200 feet. Smaller slides are numerous along the bluff of the Dalles formation that faces the 150-foot terrace of the Columbia River in secs. 29 and 32, T. 2 N., R. 13 E., and along the base of the Dalles formation in the bluff south of the river and east of Fifteenmile Creek. The bluffs in which all these landslides are situated are the scars of high-level meanders of the river.

More extensive landslides occur in some of the tributary creeks. For example, the entire tip of the divide between the two principal forks of Chenoweth Creek, an area of at least 1 square mile in secs. 2, 3, and 11, T. 1 N., R. 12 E., has slumped 150 feet or more. In the lower part of the valley of Threemile Creek, in T. 1 N., R. 13 E., there is a landslide amphitheater half a mile in diameter in section 13, south of the creek, and a smaller amphitheater in section 11, north of the creek. Slides of small extent are common in most parts of the region.

Two prominent landslide scarps, each about a mile long, occur in the Yakima basalt in the south wall of the Columbia River Valley where it crosses the Ortley anticline. One forms the east face of Rowena Point, in secs. 3 and 10, T. 2 N., R. 12 E., the other forms the bold northward-facing bluff just north of the Dalles Country Club, in sec. 17, T. 2 N., R. 13 E. Slides of this magnitude in rocks as competent as the Yakima basalt imply the presence at relatively shallow depth of incompetent strata, such as the Eagle Creek formation.

The landslides of the Dalles region are presumably superficial features, which do not affect the strata that lie below the level of the streams. However, some of the more prominent landslide scarps are

[37] Harza, L. F., Columbia River power project near The Dalles, Oreg.: U. S. Recl. Service, Rept. of Board of Review, p. 22, San Francisco, Technical Pub. Co., 1914.

so nearly straight that they resemble fault scarps; some of the slides, therefore, may be due to slump along secondary faults that are not otherwise indicated at the surface.

EPOCHS OF DEFORMATION

Both the folding and the faulting in the Dalles region have deformed the Yakima basalt and the overlying Dalles formation as a unit. The secondary folding has not deformed appreciably the erosion terrace known as Mount Hood Flat (p. 141) or the tongues of andesite that fill high-level valleys eroded in that terrace (p. 127), but the faulting has deformed the present flood plain and bed of the Columbia River. It follows that the folding began after the Dalles formation had been deposited and therefore may have begun as early as the middle or upper Miocene; it had essentially ceased before the Mount Hood Flat erosion stage, which is regarded tentatively as lower or middle Pliocene (p. 141). Whether or not there has been further movement of the major folds in late geologic time is not known, for the successive erosion terraces were not traced over so extensive an area as to prove or disprove that any have been warped after they were formed. Inasmuch as the major faults follow the steeper flanks of the asymmetric major folds it is presumable that both folds and faults were produced by the same forces, the faults originating in a later stage of the deformation. Hence the faults may be essentially as old as the folds. However, movement along both the major and minor faults has recurred in relatively late geologic time, after the folds were essentially at rest, and movement may be going on at present. This recurrence of movement is shown by the low fault scarps that at several places traverse the present flood plain and bed of the river. These low scarps are due to reversed displacement or rebound along old faults. (See p. 137.)

East of the Dalles region, in the John Day Basin of central Oregon, the probable correlatives of the Yakima basalt and the Dalles formation—the Columbia lava and Mascall formation of Merriam [38]—were folded, faulted(?), and eroded before the overlying Rattlesnake formation, of Pliocene (middle Pliocene?) age, was deposited. Subsequently the Rattlesnake formation was tilted gently and faulted, in part at least, by renewed movement along old faults.[39] In that area, therefore, the major folding began after the middle Miocene and was nearly complete before the middle (?) Pliocene; faulting probably began before the middle (?) Pliocene but was most active after that epoch. It is altogether likely that the epochs of folding and of faulting in the

[38] Merriam, J. C., Contribution to the geology of the John Day Basin: California Univ. Dept. Geology Bull., vol. 2, pp. 303–310, 1901.

[39] Idem, pp. 311–312. Merriam, J. C., Stock, Chester, and Moody, C. L., The Pliocene Rattlesnake formation and fauna of eastern Oregon, with notes on the geology of the Rattlesnake and Mascall deposits: Carnegie Inst. Washington Pub. 347, pp. 57–58, 1925.

John Day Basin were approximately contemporaneous with the analogous deformations of the Dalles region.

SUMMARY OF GEOLOGIC AND PHYSIOGRAPHIC HISTORY

After the deposition of the andesitic pyroclastic materials and fluviatile beds of the Eagle Creek formation, which does not crop out in the Dalles region but is thought to be at shallow depth where the Columbia River crosses the Ortley anticline (p. 134), the Dalles region was subjected to erosion for a relatively short period. Upon the erosion surface thus formed, whose relief is unknown, was extruded in lower (?) Miocene time the Yakima basalt. This rock unit comprises as many as 20 distinct layers in the Columbia River gorge,[40] 23 layers in the John Day Basin,[41] and possibly more in other localities, each layer representing a distinct epoch of extrusion. Commonly the layers are separated by old soil zones, which in places contain fossil plants, by thin sheets of fluviatile sediment, or by volcanic tuff. Hence the epochs of extrusion were separated by intervals of erosion from which minor intraformational unconformities resulted.

The Yakima epoch was followed promptly by deposition of the andesitic pyroclastic materials and tuffs and fluviatile beds that constitute the Dalles formation, the earliest of these clastic rocks perhaps interfingering with the latest extrusions of the Yakima epoch. At the beginning of the Dalles epoch there were ponds and lakes here and there on the basalt surface, and stratified clay and sand were deposited in them, but such conditions were neither widespread nor of long duration. In many parts of the region andesitic tuff and agglomerate accumulated on the basalt at the same time that stream-borne gravel, sand, and sandy silt were laid down elsewhere, the several rock types interfingering with or grading laterally into one another. Gradually the quantity of coarse pyroclastic material and of uniform-sized stream sediment diminished, and the quantity of fine eolian tuff, unsorted stream sediments, and nonhomogeneous material increased. Throughout the epoch the type of rock material deposited at any one time differed greatly from place to place. The Dalles epoch was of considerable duration and may have continued through the upper Miocene into the lower Pliocene. The original maximum thickness of its rocks is not known but is more than 1,500 feet. Rocks whose petrologic and lithologic characters are very similar to those of the Dalles formation were deposited at many places in central Oregon and Washington—if not everywhere in that region—at about the time of the Dalles epoch. The source of the great volume

[40] Smith, W. D., A summary of the salient features of the Oregon Cascades: Oregon Univ. Bull., vol. 14, No. 16, p. 38, 1917.

[41] Merriam, J. C., op. cit. (1901), p. 304.

of andesitic pyroclastic rocks and of gravel and sand from andesitic rocks that were laid down at that time is not known. If, as is not unlikely, the Dalles epoch of sedimentation was in part contemporaneous with the post-Yakima volcanism of the Cascade Range, much of the rock-forming material may have originated in the ancestral Cascade Range.

The Dalles epoch was succeeded by a period of folding about axes that trend about N. 70° E., and the folding was probably accompanied by faulting and was essentially completed before lower (?) Pliocene time. Subsequently the region was subjected to erosion, and an extensive erosion surface of low relief was cut across the folded rocks. On the weak rocks of the Dalles formation this surface was a well-developed terrace or peneplain; where it was cut across anticlines of the resistant Yakima basalt it was somewhat undulating. Its most prominent remnant in the Dalles region is the flat divide between Mill and Threemile Creeks, which is known locally as Mount Hood Flat. Consequently the erosion cycle that produced this surface is herein called the Mount Hood Flat erosion cycle, and the surface the Mount Hood Flat erosion surface. The Mount Hood Flat erosion surface is correlated tentatively with the Ochoco erosion surface in central Oregon, which is described by Buwalda [42] and ascribed by him to the early or middle Pliocene.

After the Mount Hood Flat erosion cycle the Columbia River and its tributaries became established in courses that are essentially the same as those they occupy to-day and began dissecting the Mount Hood Flat erosion surface. In the Dalles region dissection has proceeded through the Pleistocene and until the present time by several partial cycles of stream erosion, each of which terminated in lateral planation and cutting of a local stream terrace. At the same time there was recurrent movement along old faults, possibly further warping along the old folds, and, in the near-by Cascade Range, vigorous volcanic activity and alpine glaciation. One of the earlier partial cycles was interrupted by extrusion of andesite lava which flowed down the ancestral valleys of Mill and Eightmile Creeks from the vicinity of Mount Hood. Some partial cycles may have been terminated or started by faulting, but no correlation between stages of erosion and epochs of faulting is made. Other partial cycles may have resulted from variations in climate in the Pleistocene epoch, but here again no correlation seems possible at present.

By middle Pleistocene time the Columbia River had cut down to a surface that is now about 150 feet above sea level at The Dalles, but it had not cut an extensive terrace at that altitude, and its tributaries were not cut down to grade. It has been postulated by the writer

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[42] Buwalda, J. P., A Neocene erosion surface in central Oregon: Carnegie Inst. Washington Pub. 404, pp. 1–10, 1929.

that subsequently the valleys were filled with alluvium to or above a surface that is now about 300 feet above sea level at The Dalles and that the streams were superposed on the alluvial fill and by lateral planation cut rather broad and continuous terraces on both the weak Dalles formation and the resistant Yakima basalt. At about this time some changes in the stream pattern took place, Chenoweth Creek being diverted from the north side to the south side of the butte in sec. 20, T. 2 N., R. 13 E., and Eightmile and Fifteenmile Creeks being diverted from the wind gaps in the present divide between the Columbia River and Fifteenmile Creek. The terraces formed in this partial erosion cycle are the most extensive of the Dalles region below the remnants of the Mount Hood Flat erosion surface; they are regarded tentatively as not younger than the third or Sangamon interglacial stage. Subsequently movement was renewed along some of the old faults, and the streams swept the alluvium from their old channels, perfected their grades at about the level they stood before the deposition of the alluvium, and then cut prominent terraces by lateral planation. During this planation the surface forms caused directly by the renewed fault movement were almost completely eroded away. In the present partial erosion cycle the Columbia River and its larger tributaries have intrenched themselves about 100 feet below the terraces just described, but the small tributary streams have been unable to cut down in pace with the master stream. Very late in this present cycle there has been still further movement along old faults that cross the river, but the direction of movement is the reverse of the original displacement. At present the river is cutting its bed to grade across the rising fault blocks.

OCCURRENCE AND RECOVERY OF GROUND WATER

GENERAL FEATURES

Essentially all the water that occurs in the rocks of the Dalles region is of meteoric origin—that is, it is rain or snow water that has percolated through the soil down to a level below which the permeable rocks are saturated with water. This level is commonly called the water table, and the water in the saturated zone below is called ground water. None of the ground water of the Dalles region is so warm or contains so much dissolved matter that it can be considered connate or juvenile.

Where the space between the water table and the surface is occupied by permeable rocks the body of ground water exists as if impounded in a reservoir, and its upper surface—the water table— is free to rise or to fall. The water table may rise during or after protracted heavy rainfall or melting of snow as more of the rock is saturated, and it generally falls during the warm growing season as part of the rock is unwatered by evaporation, by transpiration of vegetation, or by spring discharge. It also declines and a certain volume of the permeable rock is unwatered as water is pumped from wells that tap the body of unconfined ground water. The unwatering is temporary if, over any long period, the rate of ground-water discharge by natural causes and by pumping is not greater than the rate of recharge, but it is permanent if the natural discharge plus the pumpage exceeds the recharge. A part of the natural discharge can be recovered by pumping and thereby lowering the water table below the root zone of plants and below the outlet of springs.

Commonly, however, the rocks are not permeable throughout but consist of alternate permeable and impermeable layers. Under such conditions the permeable layers are generally saturated with ground water and the impermeable beds confine the water under hydrostatic pressure, the water entering each permeable bed at its outcrop and the pressure being limited by the height to which the bed is saturated. The confined ground water may be discharged through springs or wells, by leakage through the confining beds, or by deep percolation. Therefore, each permeable bed is a conduit through which ground water moves under hydrostatic head to points or areas of discharge, much as water moves under pressure through the mains of a municipal water-supply system. Wherever a well taps a body of confined ground water the hydrostatic pressure causes water to rise in the well a certain distance, which is a measure of that pressure; under certain conditions the pressure may be so great that the water will rise to the land surface and flow from the wells. As the hydrostatic pressure in the water-bearing bed fluctuates, the water surface in the well rises or falls accordingly, but such fluctuations, unlike the fluctuations of the water table, do not indicate commensurate unwatering of the rocks. Rather, the fluctuations indicate variations in the rate at which ground water is moving through the permeable beds.

When a well that taps a body of confined ground water is pumped, the pressure at and near it is reduced, the water level declines, a hydraulic gradient toward the well is created, and the water is caused to flow into the well. Other things being equal, the quantity of water flowing into the well is proportional to the drawdown, or the amount the water level is lowered. It follows that the permissible draft upon the body of ground water is limited by the drawdown, which is established by the maximum economic lift. If the capacity of the water-bearing bed to transmit water is small, this permissible draft may be small, even though the quantity of ground water stored in the permeable bed is large.

Ground water exists in each of the rock units of the Dalles region, but the mode of occurrence differs with the lithologic character, geologic structure, topography, and areal extent of the several units.

WATER IN THE UNCONSOLIDATED ROCKS

The unconsolidated rocks of the Dalles region include the younger alluvium, intermediate alluvium, and older alluvium (pp. 129–134; see also pl. 11). As these rock units underlie all or nearly all the areas that are cultivated in truck crops, they are the most accessible of the possible sources of ground water for irrigation. Commonly the alluvium is moderately to highly permeable on the terraces along the Columbia River, where it contains in many places beds and lenses of uniform-sized sand and gravel. Also, along the river it commonly contains unconfined ground water, which originates as rainfall and snowfall on the alluvial plains and saturates the lower part of the alluvium just above the underlying bedrock platform. Much of this ground water percolates laterally along the top of the bedrock and is discharged in intermittent and perennial springs, such as Nos. 6, 7, 13, 15, 28, and 30 (p. 188), on the north side of the river, and Nos. 11 and 19 on the south side. These springs issue at or just above the contact between the alluvium and the bedrock, which is generally the Yakima basalt. In years of subnormal rainfall extensive deposits of the alluvium are probably in large part unwatered by the springs, so that the zone which is perennially saturated is thin and probably discontinuous and is likely to follow the concealed depressions in the bedrock platform. In years when the rainfall is considerably more than the average, however, the quantity of ground water retained in storage may be large. Generally in the valleys of the tributary creeks and even at some places on the terraces along the river the alluvium contains much silt, is not highly permeable, and does not contain much recoverable ground water.

Heretofore water has been recovered from the alluvium for farm water supplies from springs and from some dug wells, which are small in capacity but entirely reliable. A few wells, such as Nos. 8, 17, and 27, have been dug in the intermediate alluvium to furnish supplies for irrigating truck gardens. These wells are pumped intermittently as much as 100 gallons a minute during the growing season but draw in part upon water stored in the well pits, for the rate of inflow to the wells is as low as 10 gallons a minute in a dry season such as that of 1930. There is little doubt that in places where the intermediate alluvium consists of clean sand or gravel and where the water table is as much as 10 feet above the bottom of the alluvium, if wells were sunk to the bedrock platform, adequately screened, and thoroughly developed they would yield larger supplies. In the favorable places such wells should be reliable for irrigating small truck gardens in years of normal rainfall, but it is doubtful whether they would prove adequate in very dry years. In many places, moreover, the zone of saturation in the intermediate and older alluvium is so thin that those rock units are not likely to yield perennial supplies adequate for economical irrigation, even though they may be highly permeable. A considerable part of the younger alluvium also rests on bedrock platforms that are above the mean high stage of the Columbia River, so that in it also the zone of saturation is commonly thin.

WATER IN THE DALLES FORMATION

The Dalles formation, which comprises interfingering beds of semi-consolidated sandstone, sandy shale, conglomerate, fine-grained tuff, tuffaceous sandstone, and andesitic pyroclastic rocks (p. 120), is on the whole not highly permeable. In fact, the beds of massive tuff and agglomerate and the fine-grained tuffaceous clay and tuffaceous sandstone, which together constitute most of the formation, are essentially impermeable, and only the beds of sandstone that are free from tuffaceous or clayey matrix have an appreciable water-yielding capacity. Permeable beds of this sort occur at intervals from top to bottom of the formation but are somewhat more numerous in its lower part. Generally, they are less than 10 feet thick and are lenticular.

Within the area represented on Plate 11 the valleys of Fifteenmile, Eightmile, and Fivemile Creeks cut entirely through the Dalles formation and its permeable beds, and those of Threemile and Mill Creeks cut almost entirely through it. All these streams follow the strike of the strata. Hence the permeable beds may be largely unwatered except where they grade into less permeable material in the direction of dip or where minor folds form traps that impede percolation.

Commonly the permeable beds of the Dalles formation are saturated and retain ground water under slight or moderate hydrostatic head, the water being derived from rainfall or snowfall on their outcrops. However, as many of these water-bearing beds lie far above the near-by surface drainageways and beneath the crests of narrow ridges their catchment areas are of small extent; consequently, their recharge is correspondingly small. In many parts of the region several water-bearing beds are commonly penetrated by each drilled well, and the shallowest bed in each well is referred to generally as the "first flow," the next underlying bed as the "second flow," and so on. It is commonly assumed by residents of the region that all "first flows" are parts of one water-bearing stratum, that all "second flows" are parts of another water-bearing stratum underlying the first, and so on, but this assumption is entirely false.

Inasmuch as the strata of the Dalles formation are characteristically lenticular, the water-bearing beds are discontinuous and any one or several that are penetrated in a given well may be represented by impermeable material in another well not far away. These relations are brought out by Plate 16. Also, wherever several bodies of ground water occur at different depths in the Dalles formation but above the level of near-by surface drainageways each of the bodies is invariably perched above those underlying it. In other words, each body of ground water is separated from all others by impermeable or unsaturated material, and the static level of each body—that is, the level to which the water would rise under its hydrostatic pressure—is higher than the static level of each underlying body of ground water. (See pl. 16.) Hence, whenever a well is drilled through the "first flow" the level at which the water stands in the well drops sharply when the "second flow" is tapped and drops again when each succeeding water-bearing bed is tapped. For example, in well 64 (p. 180) three water-bearing beds were penetrated; these are 55, 100, and 158 feet below the land surface, whereas the respective static levels of the ground water are 35, 60, and 112 feet below the surface. In this well the static level of the third or 158-foot water-bearing bed is below both the upper two water-bearing beds, so that water from the upper beds trickles down the walls of the well to the static level of the third bed. (See pl. 16.) Other examples of bodies of perched water are shown by the tabulated well data (pp. 170–183).

Generally the bodies of ground water that are perched in the Dalles formation above the level of the principal surface drainageways yield supplies that are adequate for household and stock-watering demands, but commonly two or more such bodies must be tapped by a well to obtain a sufficient yield. The wells that tap these bodies of perched water commonly range in depth from 100 to 450 feet. So far as the writer is aware none of the wells yield more than 20 gallons a minute, and their specific capacity is commonly only a fraction of a gallon a minute for each foot of drawdown. On some of the higher ridges wells fail to find water within practicable depths—for example, wells 41 and 67.

Commonly the most permeable members of the Dalles formation occur at or just above its base. Where these beds lie below the principal surface streams they may retain water under moderate pressure and yield as much as 100 gallons a minute to drilled wells, such as Nos. 3, 21, 22, and 23 (pp. 170–174). The specific capacity of these wells is as much as 5 gallons a minute for each foot of drawdown.

These same water-bearing beds supply flowing wells in the lower part of the valley of Threemile Creek in the vicinity of well 55 and in the valley of Chenoweth Creek about wells 20 and 21. Each of these localities is near a fault (p. 136), and at each the artesian condition probably results in part from faulting of the water-bearing stratum against impermeable rock. In the valley of Threemile Creek the area in which such flowing wells may be obtained is limited to the floor of the valley, approximately within sec. 12, T. 1 N., R. 13 E.; in this area the artesian stratum is about 75 to 100 feet below the valley floor. In the valley of Chenoweth Creek also the area of flowing wells is limited to the valley floor, approximately between well 21 and the road junction in the SW. ¼ NW. ¼ sec. 29, T. 2 N., R. 13 E. It seems likely that these same strata would also yield flowing wells in the alluvial plain of Mill Creek in sec. 8, T. 1 N., R. 13 E., where they are 50 to 100 feet below the land surface. At none of these three localities are flowing wells likely to yield more than a few tens of gallons a minute. Furthermore, the body of ground water that supplies these flowing wells is perched above the deeper ground water, so that whenever a well is drilled through the lower confining bed into the Yakima basalt without a seal, the artesian head is dissipated and the bed that supplies the flowing wells is drained into underlying permeable rocks, as in well 20.

In view of the lithologic character of the Dalles formation, it is altogether possible that the formation contains lentils of very permeable rock which may be found to be water bearing. However, it is improbable that any such water-bearing lentils have catchment areas of sufficient size to yield much water perennially.

Springs issue from the Dalles formation in many places, especially from its lowermost part, just above the underlying Yakima basalt, and from landslide débris (p. 138). Those that issue from the base of the formation are most numerous where the basal members are conglomerate or sandstone, as along the bluff south of the Columbia River between the Fairbanks wind gap, in sec. 24, T. 2 N., R. 14 E., and the Deschutes River. They discharge from a fraction of 1 gallon to as much as 5 gallons a minute and presumably fluctuate with the season. It is reported that many such springs originally issued along the base of the Dalles formation in the southwestern part of The Dalles but that most of them have been drained or diverted as the streets were graded and dwellings built in that section. Spring 49 (p. 188) is typical. Other springs occur along the lower outcrops of permeable beds that are cut through by the creek valleys; these are commonly on the southeast sides of the valleys, such as No. 56. In part they issue under slight hydrostatic head, but few discharge more than 1 gallon a minute perennially. Springs that discharge as much as 5 gallons a minute issue from landslide débris and from brecciated facies of the formation along fault zones in several parts of the region, especially in the valley of Chenoweth Creek in secs. 34 and 35, T. 2 N., R. 12 E., and in the sector between the principal two forks of that stream in the northeastern part of T. 1 N., R. 12 E. These are gravity springs that are supplied from rainfall in the immediate vicinity; they do not indicate the presence in the formation of water confined under high pressure.

WATER IN THE YAKIMA BASALT

GENERAL CONDITIONS

Two major permeable zones exist in the Yakima basalt near The Dalles—an upper zone, which comprises several thin water-bearing beds intercalated in the uppermost 100 feet of the formation, and a lower zone, which comprises one or several layers of extremely vesicular or granular basalt and whose top is 300 to 375 feet below the original upper surface of the formation. These two permeable zones of the Yakima basalt are the most promising sources of ground water for irrigation in the area. However, the strata that compose them, being of fluviatile or volcanic origin, are inherently discontinuous, so that their water-yielding capacity may differ greatly from place to place. With the exception of these two zones the formation consists largely of dense massive rock, which is impermeable except where it is jointed.

Like the bodies of water that exist in the Dalles formation above the level of the streams, the water in the upper water-bearing zone of the Yakima basalt near The Dalles is perched above the main body of ground water, which is contained in the lower water-bearing zone (p. 156) of that formation. Consequently, if a well should be drilled through the upper zone its static level would drop sharply when it entered the lower zone. In order to avoid such a circumstance, a well by which it is sought to develop only the upper water-bearing zone should not be drilled much more than 150 feet below the top of the basalt; otherwise it may prove necessary to plug the well in order to maintain the static level. On the other hand, because of the great difference between the static levels of the water in these two zones (p. 158) it is impracticable to draw from both by one well. Consequently, any well that is drilled through the upper zone in order to draw from the lower zone should be tightly cased where it passes through the upper zone, in order that the pressure of the water in that zone may not be uselessly dissipated.

UPPER WATER-BEARING ZONE

The upper permeable zone of the Yakima basalt generally comprises one, two, or possibly more water-bearing beds, which are from 35 to 100 feet below the top of the formation, and commonly also includes the lowermost stratum of the Dalles formation. These beds are described in the driller's log of well 65 (p. 187) as porous basalt and in the log of well 60 as sand associated with layers of shale interbedded with the basalt. Each of them is less than 10 feet thick and is presumably discontinuous; however, they seem to be interconnected, for they contain water under approximately the same hydrostatic head, and the reduction in head caused by pumping seems to affect all of them equally. These relations suggest that they may be fingers of fluviatile sediment belonging to the Dalles formation interleaved with the uppermost layers of the Yakima basalt, the sediments thickening and coalescing toward the south and east. (See p. 125.) However, it has not been possible either to prove or to disprove this suggestion because of the lack of accurate and detailed well logs and because the contact zone between the Dalles formation and the Yakima basalt is commonly concealed by hill wash. The water-bearing properties of these beds are discussed herein as if they were an integral part of the basalt.

This upper permeable zone lies below the level of the streams on part of the southern flank of the Dalles syncline (p. 134), within an area that is bounded by the outcrops of the Yakima basalt (see pl. 11)—that is, approximately by Chenoweth Creek on the northwest, by the Columbia River on the north, by Fifteenmile and Fivemile Creeks on the east, and by the secondary anticline that lies just north of Fivemile Creek (p. 135) on the south. Within these boundaries lie practically all the orchard tracts in the vicinity of The Dalles. Within them also the permeable zone receives water from local precipitation and retains it under moderate hydrostatic head.

The altitude of the top of the Yakima basalt at several points within this region is given in the table on page 135; these figures indicate approximately the altitude of the top of the upper permeable zone. Within 3 miles of The Dalles the top of the zone is 50 to 100 feet below the alluvial plains of Threemile and Mill Creeks and as much as 600 feet below the crests of the ridges. The static level of the water is a few tens of feet above the plains of Mill and Threemile Creeks in secs. 8 and 12, respectively, T. 1 N., R. 13 E., but probably as much as 500 feet below the ridge crests.

Of the typical wells described in the data tabulated on pages 170 to 183, Nos. 51, 55, and 64 and probably also Nos. 58, 61, and 62 end at the top of the Yakima basalt and consequently may tap the uppermost bed of the zone. Wells 42, 57, 60, and 65 draw their supplies chiefly from the lower beds of the zone. The 503-foot water-bearing bed tapped by well 66 and the 374-foot water-bearing bed of well 50 may also belong to the zone. On the other hand, wells 20 and 50 and probably well 42 pass entirely through the upper permeable zone and tap deeper water-bearing beds. Plate 16 presents a tentative correlation of the water-bearing beds in several of these wells.

The water-yielding capacity of the upper permeable zone in the Yakima basalt is well shown by the history of the irrigation well of the Cherry Hill District Improvement Co. (No. 65, p. 180), in the NW. ¼ sec. 23, T. 1 N., R. 13 E. According to the driller's log of this well (p. 187) the principal water-bearing bed is 7 feet thick; its top is 281 feet below the land surface, 93 feet below the projected top of the Yakima basalt, and 342 feet above sea level. The static level of the ground water when the well was drilled, in July, 1926, was reported by the driller to be 147 feet below the land surface, which is 134 feet above the top of the water-bearing bed and 476 feet above sea level. Prior to 1930 this well was equipped with a deep-well turbine pump, which was set with the lower end of its suction pipe 180 feet and the bottom of its impeller bowls 162 feet below the collar of the well. Water is delivered to five weir boxes, which are from 704 to 791 feet above sea level, or 81 to 168 feet above the collar of the well. With this equipment the greatest drawdown attainable would have been 33 feet below the static level reported by the driller, and the maximum pumping lift, not including friction losses, would have been 348 feet to the highest weir box. It is reported by J. E. Thorndike, watermaster, that while being operated under these conditions the well yielded as much as 280 gallons a minute for 10 to 16 hours each day during the first four to six weeks of the irrigation season; that thereafter the yield attainable declined gradually until at the end of the season it was only about 140 gallons a minute for as much as 24 hours a day. As is brought out below, this decrease in yield was undoubtedly due to gradual decline in the hydrostatic head. The total quantity pumped in each of the irrigation seasons is shown by the following table:

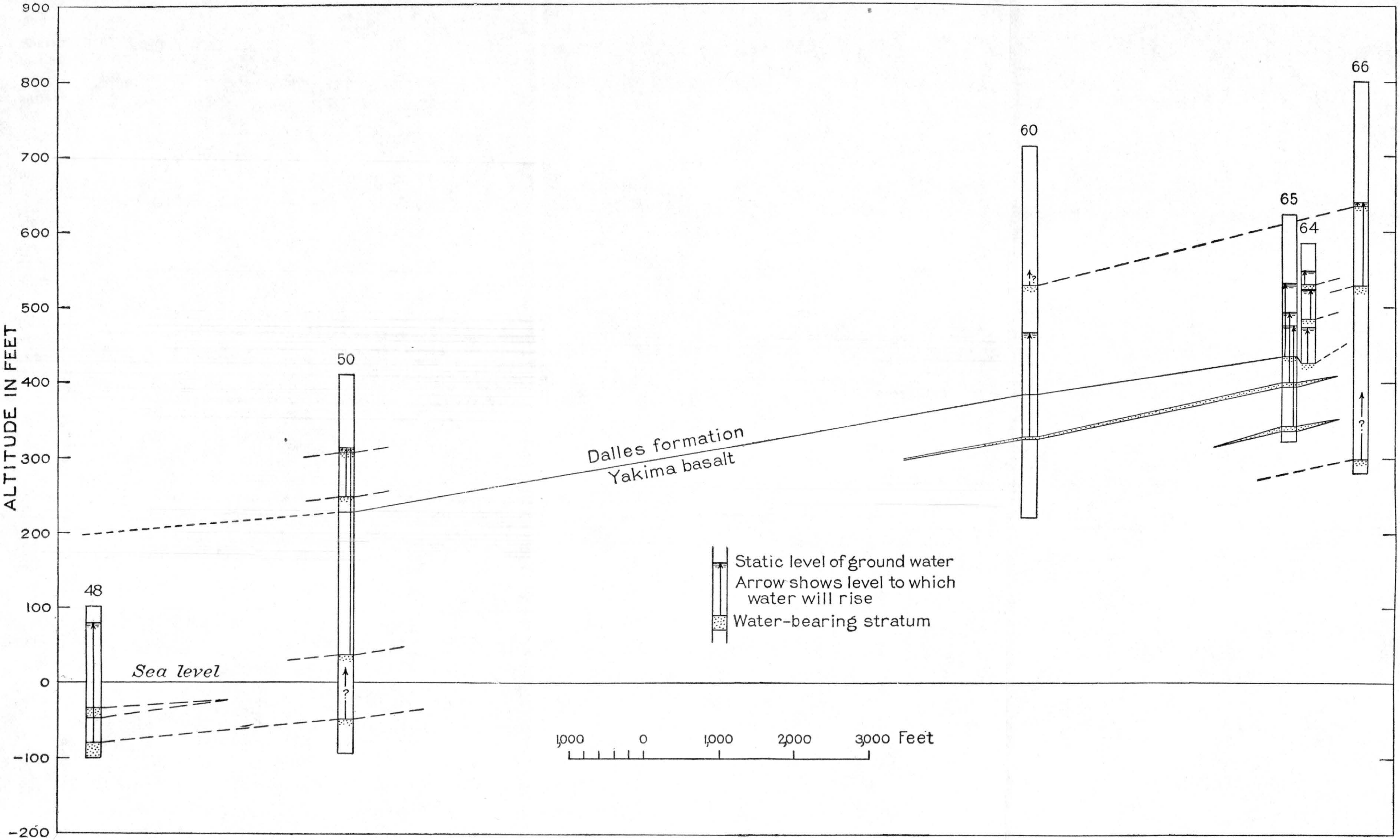
Summary of pumpage from well of Cherry Hill District Improvement Co. (well 65)

[Data summarized from records of Cherry Hill District Improvement Co.]

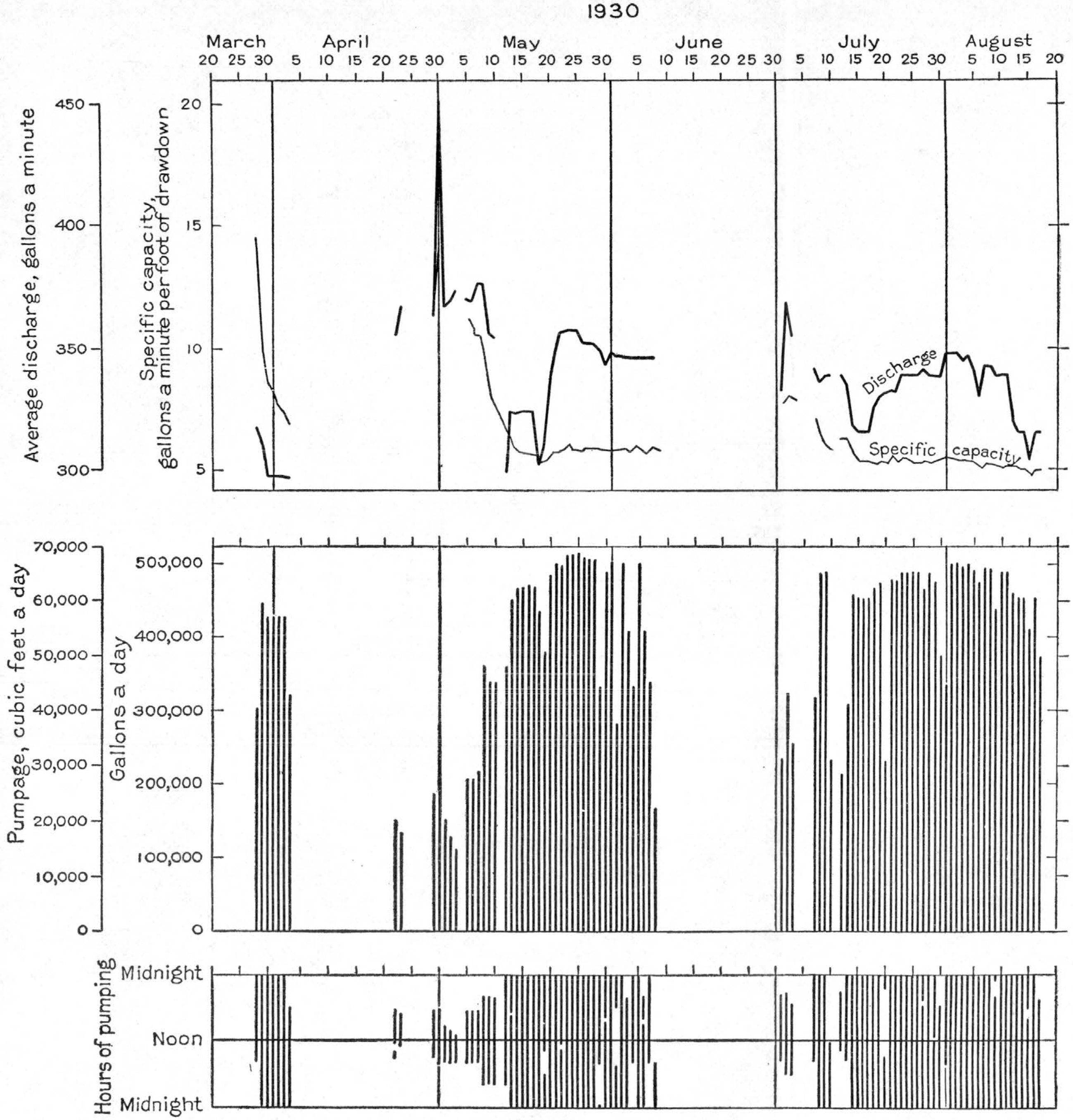
Year	Irrigation season	Total period of pumping (hours)	Daily average rate of pumping (gallons a minute)	Quantity pumped	
				Cubic feet	Gallons
1926	Season ended Sept. 11	293	160–405	639,000	4,780,000
1927	Apr. 29 to Sept. 10	1,015	175–390	2,120,000	15,850,000
1928	Apr. 29 to Sept. 3	957	110–325	1,657,000	12,390,000
1929	Mar. 22 to Aug. 27	1,218	130–315	1,963,000	14,690,000
1930	Mar. 28 to Aug. 17	1,826	[a] 295–375	4,915,000	36,760,000

[a] Average reported rate on April 30, 465 gallons a minute, may be in error.

In preparation for the irrigation season of 1930 the turbine pump was rebuilt so that it had 14 impellers, was set with the lower end of its suction pipe 245 feet and the bottom of its impeller bowls 224 feet below the collar of the well, and was equipped with a 60-horsepower direct-connected electric motor. By these means the possible drawdown was increased to 98 feet below the original static level as reported by the driller or to 87 feet below the static level as measured by Mr. Thorndike on January 9, 1930. Under these conditions the rate of pumping was increased to 295 to 375 gallons a minute and the quantity of water pumped during the season was increased to 4,915,000 cubic feet, or 36,760,000 gallons. The accompanying diagram (pl. 17) shows the average discharge, hours of operation, and quantity of water pumped on each day of the season. It also shows that the



TENTATIVE CORRELATION OF WATER-BEARING BEDS PENETRATED BY TYPICAL WELLS NEAR THE DALLES, OREG.



DIAGRAMMATIC SUMMARY OF OPERATION OF WELL OF THE CHERRY HILL DISTRICT IMPROVEMENT CO., IN THE 1930 IRRIGATION SEASON specific capacity of the well—that is, its discharge in relation to the distance the water level was depressed by pumping—declined from about 15 to 7 gallons a minute for each foot of drawdown during the first week of the pumping season and decreased gradually thereafter until it reached about 5 gallons a minute at the end of the season. It follows, even though the draft was moderate and though no other wells were drawing from the upper permeable zone of the Yakima basalt during most of the period, that the area from which well 65 drew water was being extended throughout the four and one-half months of the irrigation season and that hydraulic equilibrium was not attained at any time.

The well of the Cherry Hill District Improvement Co. and that of Ray F. Kelley (No. 60, pl. 11) interfere mutually when pumped, though they are approximately 3,800 feet apart. The degree of this interference also indicates the capacity of the upper permeable zone to transmit water, as is brought out in the following paragraphs.

It is reported that the principal water-bearing bed of Mr. Kelley's well is 2 feet thick and that its top is 387 feet below the collar of the well, or 326 feet above sea level. The static level of the water was 247.5 feet below the collar on January 9, 1930, according to a measurement with cord and float by J. E. Thorndike; this level is 465 feet above sea level and approximately the same as the static level in well 65 on the same date. In 1930 the Kelley well was equipped with a deep-well turbine pump driven by a direct-connected electric motor, with the bottom of the impeller bowls 335 feet and the lower end of the suction pipe 366½ feet below the collar of the well. Water was delivered to three weir boxes, of which the highest was 97 feet above the well, or 345 feet above the static level of January 9. Under these conditions the well delivered 230 gallons a minute during a pumping test on May 10, 1930. The depth to water while the pump was in operation was 350 feet, as read from the detector tube and depth gage which were attached to the pump. This pumping level was 107 feet below the static level of April 28, 1930, but only about 55 feet below the pumping level in well 65 at the time of the pumping test. The pump on well 60 was operated about 12 hours a day from May 12 to May 21 and intermittently from June 21 to July 5. During these periods the discharge was 175 to 215 gallons a minute and the drawdown 72 to 91 feet below the static level of April 28, but, as before, only about 55 feet below the pumping level in well 65. If, as seems likely, the drawdown would have been about 55 feet had the pump on well 65 been idle, the specific capacity of well 60 is 3.5 to 4.0 gallons a minute for each foot of drawdown.

The extent of the interference between the two wells is indicated by the accompanying diagram (fig. 32), which is based upon the measurements of depth to static water level tabulated below.

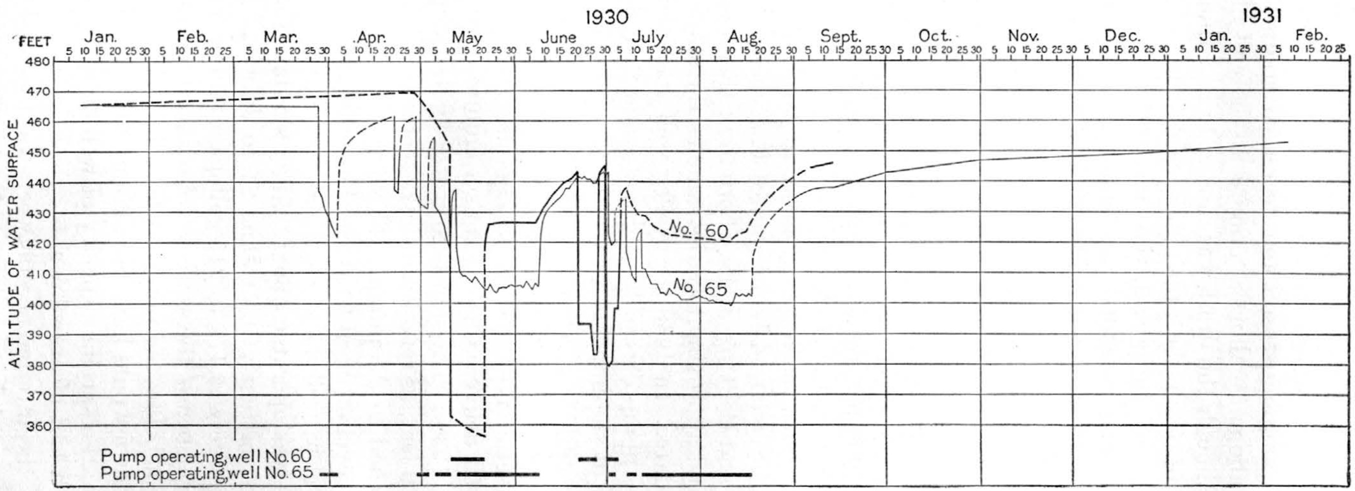


Figure 32.—Fluctuations of water surface in wells of Ray F. Kelley (No. 60) and the Cherry Hill District Improvement Co. (No. 65) in relation to periods of pumping. (Static levels were plotted only after the respective pumps had been idle 24 hours or more)

Measurements of depth to static level of water in well of Ray F. Kelley (No. 60, pl. 11)

[Unless otherwise noted measurements made by detector tube and depth gage attached to pump. Datum of measurements is base of pump, 0.2 foot above concrete floor of pump house, 713.1 feet above sea level]

Date	Hour	Depth to water	Altitude of water surface	Remarks
1930		*Feet*	*Feet*	
Jan. 9		247.5	465.6	Cord and float measurement by J. E. Thorndike.
Apr. 28		243.3	469.8	Tape measurement by contractor installing pump.
May 10	11.45 a. m.	350.0	363.1	Pump operating.
May 23	9.45 a. m.	287.0	426.1	Pump idle 33 hours prior to measurement.
May 27	3.25 p. m.	286.5	426.6	
June 7	11.35 a. m.	286.5	426.6	
June 10	5.00 p. m.	281.0	432.1	
June 13	5.45 p. m.	277.0	436.1	
June 16	7.00 p. m.	274.0	439.1	
June 17	7.10 p. m.	273.0	440.1	
June 19	5.15 p. m.	272.0	441.1	
June 20	6.50 p. m.	271.0	442.1	
June 21	3.10 p. m.	[a] 270.0	443.1	Resumed pumping about 3.15 p. m., after 1 month shutdown.
Do	6.15 p. m.	[a] 320.0	393.1	
June 23	6.30 p. m.	[a] 320.0	393.1	
June 24	7.00 p. m.	[a] 320.0	393.1	
June 25	6.00 p. m.	[a] 320.0	393.1	
June 26	5.30 p. m.	[a] 330.0	383.1	
June 27	6.00 p. m.	[a] 330.0	383.1	
June 28	6.10 p. m.	271.0	442.1	Pump idle about 24 hours prior to measurement.
June 30	8.00 a. m.	[a] 268.0	445.1	Pump idle about 54 hours prior to measurement.
Do	7.00 p. m.	[a] 330.0	383.1	
July 1	do	[a] 334.0	379.1	
July 2	do	[a] 332.0	381.1	
July 3	do	[a] 315.0	398.1	
July 4	7.00 a. m.	[a] 315.0	398.1	
Sept. 6		268.8	444.3	Tape measurement.
Sept. 13		267.1	446.0	Do.

[a] Measurement by R. F. Kelley.

Measurements of depth to static level of water in well of Cherry Hill District Improvement Co. (No. 65, pl. 11)

[Measurements on and after March 28, 1930, made by detector tube and depth gage installed with turbine pump. Datum of measurements is top of concrete pump base, 622.7 feet above sea level]

Date	Hour	Depth to water	Altitude of water surface	Remarks
1926		*Feet*	*Feet*	
July		147	475.7	Depth reported by driller.
1930				
Jan. 9		157.5	465.2	Cord and float measurement by J. E. Thorndike.
Mar. 28	8.05 a. m.	158.0	464.7	Start of irrigation season.
Do	10.40 a. m.	[a] 186.0	436.7	
Mar. 29	6.00 p. m.	[a] 188.0	434.7	
Mar. 30	8.00 p. m.	[a] 192.0	430.7	
Mar. 31	5.30 p. m.	[a] 194.0	428.7	
Apr. 1	10.00 p. m.	[a] 197.0	425.7	
Apr. 2	7.30 p. m.	[a] 199.0	423.7	
Apr. 3	6.00 p. m.	[a] 201.0	421.7	
Apr. 22	8.45 a. m.	162.0	460.7	Pump idle 18 days prior to measurement.
Do	5.30 p. m.	186.0	436.7	Pump operating.
Apr. 23	10.50 a. m.	164.0	458.7	Pump idle 17 hours prior to measurement.
Apr. 29	8.55 a. m.	162.0	460.7	Pump idle 5 days prior to measurement.
Apr. 30	8.00 a. m.	166.0	456.7	Pump idle 14½ hours prior to measurement.
May 2	7.55 a. m.	168.0	454.7	Pump idle 17 hours prior to measurement.
May 5	5.30 p. m.	191.0	431.7	Pump operating.
May 6	8.00 a. m.	169.0	453.7	Pump idle 14½ hours prior to neasurement.
May 7	do	170.0	452.7	Do.
May 8	4.00 a. m.	173.0	449.7	Pump idle 10 hours prior to measurement.
May 9	do	176.0	446.7	Pump idle 8 hours prior to measurement.
May 10	do	180.0	442.7	Do.
May 12	do	186.0	436.7	Pump idle 32 hours prior to measurement.
Do	11.15 a. m.	[a] 204.0	418.7	
May 13	3.15 p. m.	[a] 213.0	409.7	
May 14	5.00 p. m.	[a] 214.0	408.7	

[a] Measurement by J. E. Thorndike.

Measurements of depth to static level of water in well of Cherry Hill District Improvement Co. (No. 65, pl. 11)—Continued

Date	Hour	Depth to water	Altitude of water surface	Remarks
1930		*Feet*	*Feet*	
May 15	4.50 p. m.	[a] 214.5	408.2	
May 16	5.15 p. m.	[a] 215.5	407.2	
May 17	3.30 p. m.	[a] 216.0	406.7	
May 18	6.15 p. m.	[a] 214.5	408.2	
May 19	5.50 p. m.	[a] 215.5	407.2	
May 20	4.30 p. m.	[a] 217.0	405.7	
May 21	5.00 p. m.	[a] 218.5	404.2	
May 22	11.25 a. m.	[a] 219.0	403.7	
May 23	5.30 p. m.	[a] 217.0	405.7	
May 24	5.45 p. m.	[a] 219.0	403.7	
May 25	6.45 p. m.	[a] 219.5	403.2	
May 26	5.45 p. m.	[a] 217.5	405.2	
May 27	4.00 p. m.	[a] 217.5	405.2	
May 28	8.00 a. m.	[a] 218.0	404.7	
May 29	4.00 p. m.	[a] 216.0	406.7	
May 30	6.00 p. m.	[a] 217.0	405.7	
May 31	8.05 a. m.	[a] 217.5	405.2	
June 2	8.10 a. m.	[a] 217.0	405.7	
June 3	7.40 p. m.	[a] 217.5	405.2	
June 4	5.00 p. m.	[a] 216.0	406.7	
June 5	6.00 p. m.	[a] 217.5	405.2	
June 6	4.05 p. m.	[a] 218.5	404.2	
June 7	4.30 p. m.	[a] 216.5	406.2	
June 8	8.00 a. m.	[a] 217.0	405.7	
June 10	5.25 p. m.	194.0	428.7	Pump shut down at 8 a. m. June 8, 1930, after operating almost steadily for 39 days; idle until 8.15 a. m. July 1.
June 11	6.25 p. m.	192.5	430.2	
June 13	5.50 p. m.	190.0	432.7	
June 15		188.5	434.2	
June 16	7.15 p. m.	187.0	435.7	
June 17	7.25 p. m.	185.5	437.2	
June 18		185.5	437.2	
June 19		184.0	438.7	
June 20	7.05 p. m.	182.5	440.2	
June 21	5.30 p. m.	181.5	441.2	Well 60, 3,800 feet N. 28° W. from well 65, pumped 3.15 to 6.15 p. m. June 21 and about 6 a. m. to 6 p. m. June 22–27.
June 22		182.0	440.7	
June 23	5.30 p. m.	181.5	441.2	
June 24	5.10 p. m.	182.5	440.2	
June 25	do	182.5	440.2	
June 26	5.20 p. m.	183.5	439.2	
June 27	7.31 p. m.	183.5	439.2	
June 28	5.53 p. m.	181.5	441.2	
June 29	8.05 p. m.	180.5	442.2	
June 30	6.15 p. m.	181.0	441.7	
July 1	8.10 a. m.	180.0	442.7	Pump started at 8.15 a. m. and operated almost steadily until 7.40 p. m. Aug. 17.
Do	5.30 p. m.	[a] 201.0	421.7	
July 2	8.40 p. m.	[a] 204.0	418.7	
July 3	6.00 p. m.	[a] 203.0	419.7	Pump idle 6 p. m. July 3 to 8.25 a. m. July 7.
July 7	8.20 a. m.	[a] 189.0	433.7	
Do	5.00 p. m.	[a] 206.0	416.7	
July 8	6.10 p. m.	[a] 211.0	411.7	
July 9	5.40 p. m.	[a] 214.5	408.2	
July 10	11.35 a. m.	[a] 216.5	406.2	Pump idle 11.35 a. m. July 10 to 10.15 a. m. July 12; also 8.50 p. m. July 12 to 8.30 a. m. July 13.
July 12	10.10 a. m.	[a] 198.0	424.7	Pump idle 47 hours prior to measurement.
Do	10.20 a. m.	[a] 212.0	410.7	
July 13	9.00 a. m.	[a] 212.0	410.7	
July 14	2.30 p. m.	[a] 214.0	408.7	
July 15	5.45 p. m.	[a] 216.5	406.2	
July 16	5.30 p. m.	[a] 216.5	406.2	
July 17	8.30 a. m.	[a] 217.0	405.7	
July 18	5.15 p. m.	[a] 220.0	402.7	
July 19	5.30 p. m.	[a] 220.0	402.7	
July 20	9.15 a. m.	[a] 220.5	402.2	
July 21	5.15 p. m.	[a] 218.5	404.2	
July 22	5.30 p. m.	[a] 220.0	402.7	
July 23	5.50 p. m.	[a] 220.0	402.7	
July 24	5.30 p. m.	[a] 221.0	401.7	
July 25	8.30 a. m.	[a] 222.0	400.7	
July 26	8.00 a. m.	[a] 222.0	400.7	
July 27	do	[a] 222.0	400.7	
July 28	8.10 a. m.	[a] 222.0	400.7	
July 31	5.15 p. m.	[a] 221.0	401.7	
Aug. 1	1.45 p. m.	[a] 221.5	401.2	
Aug. 2	5.00 p. m.	[a] 222.0	400.7	
Aug. 3	do	[a] 222.0	400.7	

[a] Measurement by J. E. Thorndike.

Measurements of depth to static level of water in well of Cherry Hill District Improvement Co. (No. 65, pl. 11)—Continued

Date	Hour	Depth to water	Altitude of water surface	Remarks
1930		*Feet*	*Feet*	
Aug. 4	5.30 p. m.	[a] 222.5	400.2	
Aug. 5	5.45 p. m.	[a] 222.5	400.2	
Aug. 6	5.40 p. m.	[a] 223.0	399.7	
Aug. 7	4.45 p. m.	[a] 223.0	399.7	
Aug. 8	8.00 a. m.	[a] 223.0	399.7	
Aug. 9	6.00 p. m.	[a] 223.5	399.2	
Aug. 10	10.30 p. m.	[a] 224.0	398.7	
Aug. 11	8.30 a. m.	[a] 223.5	399.2	
Aug. 12	9.15 a. m.	[a] 220.0	402.7	
Aug. 13	do	[a] 221.0	401.7	
Aug. 14	6.00 p. m.	[a] 220.5	402.2	
Aug. 15	10.25 a. m.	[a] 221.0	401.7	
Aug. 16	5.25 p. m.	[a] 220.5	402.2	
Aug. 17	7.35 p. m.	[a] 220.5	402.2	
Sept. 1		[a] 188.0	434.7	
Sept. 6		186.0	436.7	
Sept. 10		[a] 185.0	437.7	
Sept. 13		[a] 185.0	437.7	
Oct. 1		[a] 180.0	442.7	
Oct. 17		[a] 178.0	444.7	
Oct. 31		[a] 176.0	446.7	
Dec. 21		[a] 174.0	448.7	
1931				
Feb. 8		[a] 170.0	452.7	

[a] Measurement by J. E. Thorndike.

It will be noted from Figure 32 and from the data in the tables that although the pump at well 60 was stopped May 21, the water level in that well failed to rise appreciably from May 22 until June 8, when pumping of well 65 was also stopped. Seemingly, the relatively steady pumping of well 65 from April 29 to June 8 (see pl. 17) had depressed the water level in well 60 nearly 40 feet below its normal level and had held it in approximate equilibrium at that depressed position. This condition implies that the area of influence of well 65 may have extended northward—that is, in the general direction of the ground water movement—nearly if not quite to the outcrop of the zone along the Columbia River. In the period June 9 to 21 neither pump was operated and the static levels in the two wells rose at approximately the same rate, that in well 60 being 2 to 3 feet higher. From June 21 to 27 well 65 was not pumped but well 60 was pumped 9 to 12 hours each day, between 6 a. m. and 7 p. m. Although the draft on well 60 was intermittent and only about 200 gallons a minute, the static level in well 65 not only ceased to rise but was depressed approximately 2 feet. On June 38 and 29, when both wells were again idle, the static level in well 65 rose at nearly the same rate as in the period June 9 to 21.

Inasmuch as well 65 failed to reach hydraulic equilibrium during the irrigation season of 1930 and recovered only slowly after pumping was stopped, and inasmuch as wells 60 and 65 interfere rather seriously with each other, although they are 3,800 feet apart, it is clear that the transmission capacity of the upper water-bearing zone is not large.

Heavy pumping of these two wells alone during each irrigation season would doubtless eventually produce considerable further drawdown. If several additional wells are drilled in the same locality and are also pumped heavily the water levels are likely to be lowered to the bottoms of the wells, and the yields of the wells, even with such maximum drawdown, may be seriously reduced. Wells drilled in other localities, however, at considerable distances from the existing wells, will produce less drawdown and, moreover, will salvage water that can not be recovered through the two existing wells. If it is desired to explore this water-bearing zone more adequately and to bring about the full utilization of its water supply, a few additional wells should be drilled in other localities, as widely distributed as possible.

LOWER WATER-BEARING ZONE

The lower permeable zone of the Yakima basalt consists of one or more layers of extremely vesicular basalt or granular tuff, in some places as much as 30 feet thick. The top of the zone is about 300 to 375 feet below the original upper surface of the basalt. Strata of this character are commonly discontinuous and change greatly in texture within a horizontal distance of a few hundred feet or less, so that their water-yielding capacity may differ greatly in adjacent wells. However, such rocks seem to occur rather generally at this horizon within the area represented on Plate 11 and to constitute a relatively continuous permeable zone which may comprise several interwoven lentils. In the Dalles region, at least, these permeable members are saturated with water under moderate hydrostatic head, this being a part of the main body of ground water in the region. Above it are perched all the bodies of ground water heretofore described. If other water-bearing zones exist below it, they are under essentially the same hydrostatic head, for two deep wells near The Dalles were drilled to a level several hundred feet below the lower permeable zone without any appreciable change in the static level of the water. These two wells are Nos. 18 and 45 on Plate 11 (see also pp. 170 and 176); they end about 1,500 and 900 feet, respectively, below the horizon of the lower permeable zone.

Rocks at the horizon of the lower permeable zone crop out along both flanks of the Dalles syncline (p. 134), for the most part beyond the limits of the area represented on Plate 11. On the south flank of the fold they crop out at several places in the valley of Fifteenmile Creek near Dufur, and probably on the north fork of Mill Creek where that stream cuts across the secondary anticline (p. 135) shown on the geologic map; the most extensive outcrop, however, is along the flanks of Tygh Ridge (p. 134). On the north flank of the fold these beds crop out along the northwest slope of the divide between Chenoweth and

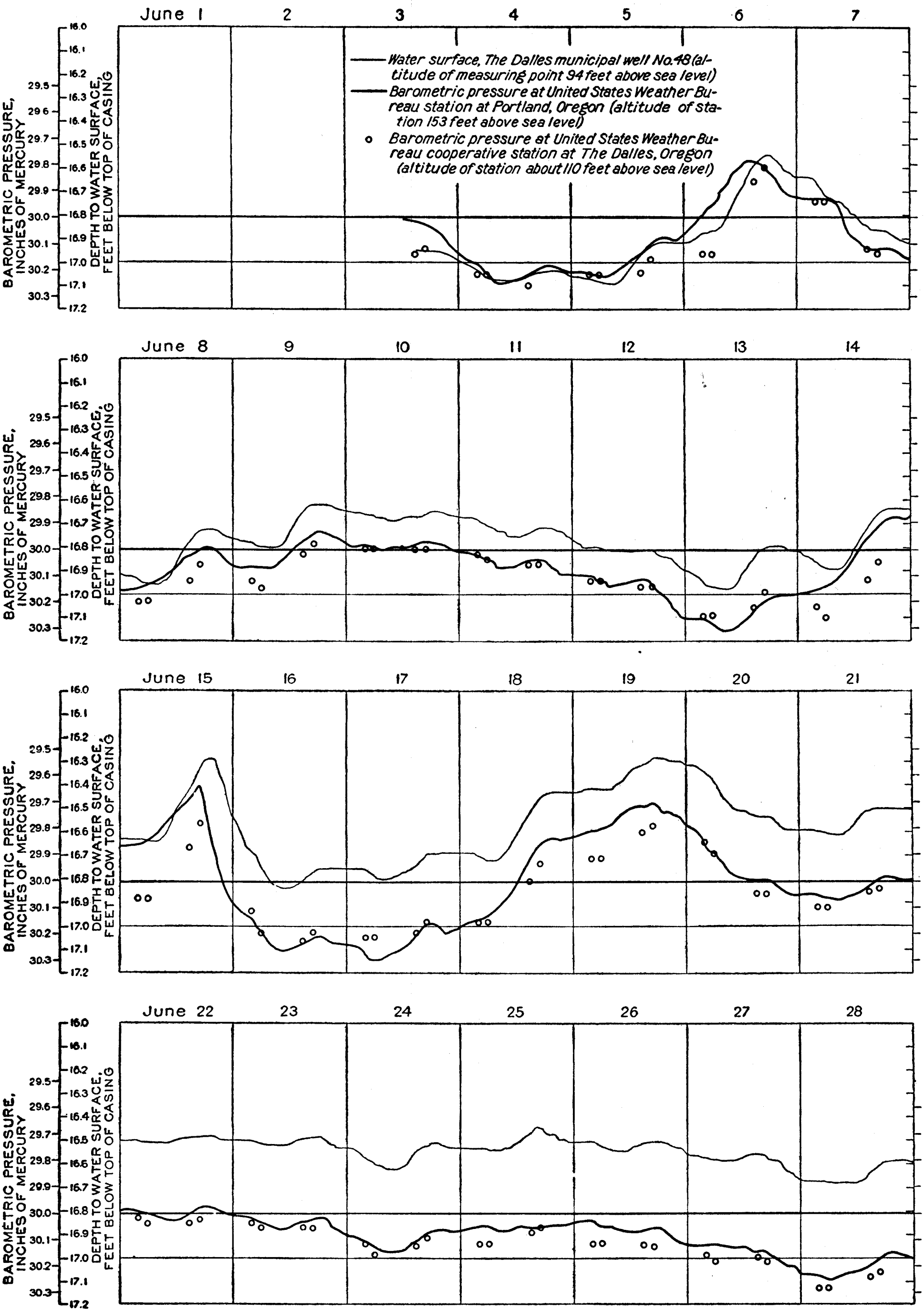
Mosier Creeks, cross the Columbia River about in sec. 17, T. 2 N., R. 13 E., and presumably follow the crest or northern slope of Stacker Mountain toward the east; the outcrop also crosses the river again about at Big Eddy, in sec. 31, T. 2 N., R. 14 E., and extends eastward from that point in each of the river bluffs. To the east of the area represented by the geologic map the beds at the horizon of the lower permeable zone are probably trenched through by the canyon of the Deschutes River at the prolongation of the axis of the fold; to the west they pass beneath the younger rocks that form Mount Hood. Within the area bounded by these outcrops, the permeable zone is below the land surface and is deformed into a synclinal basin about 26 miles wide and fully 20 miles long, whose axis plunges gently westward. This synclinal form is modified by some secondary folds and faults (p. 135). The top of the zone is about 300 to 375 feet below the top of the upper permeable zone and is therefore 350 to 500 feet below the alluvial plains of Mill and Threemile Creeks within 3 miles of The Dalles and is as much as 1,000 feet below the ridge crests in the same locality. It is 200 to 300 feet below the surface between Grand Dalles and Skadat flag station, on the terrace of the Columbia River north of The Dalles (see pl. 12), and is only about 100 feet beneath the surface farther east in parts of sec. 24, T. 2 N., R. 13 E.

The lower permeable zone of the Yakima basalt is the principal water-bearing bed in wells 1, 9, 12, 18, 29, and 44 to 48 (pl. 11, also pp. 170–176) and probably also in wells 37, 38, and 39. Drillers' logs of several of these wells are given on pages 184–187. All these wells are located along the Columbia River near the axis of the Dalles syncline and fully 20 miles from the southern outcrop of the water-bearing zone. The test well of The Dalles City Water Commission at Wick's reservoir, on the south fork of Mill Creek (well 42), probably ends just above the horizon of the permeable zone. Another test well, which is just south of the reservoir near Sixteenth and Lincoln Streets, The Dalles (well 50), ends in the permeable zone after penetrating three higher bodies of perched water.

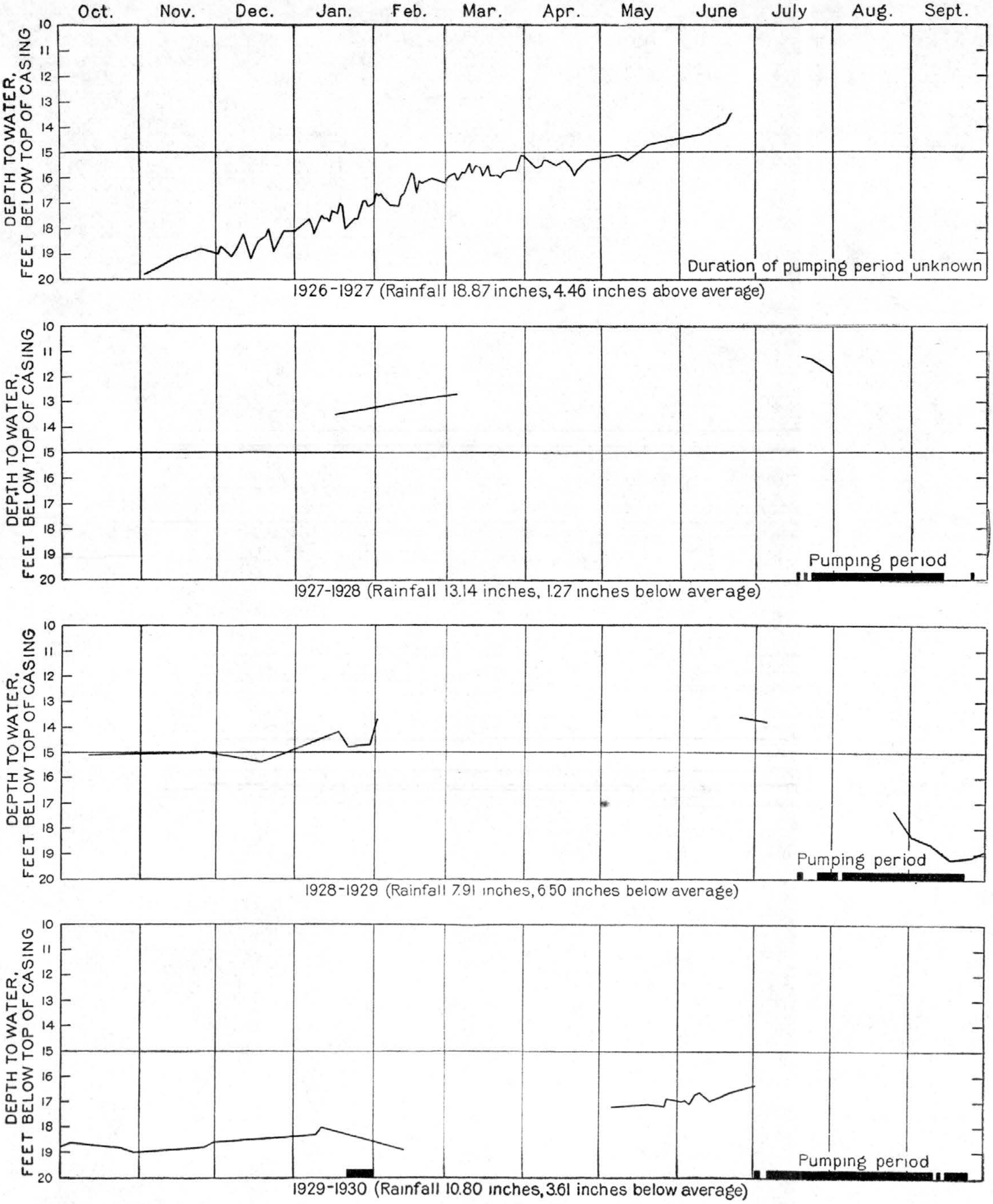
The capacity of the lower permeable zone to transmit water is large, the specific capacity of the wells ranging from about 450 gallons a minute for each foot of drawdown in the municipal well at The Dalles (No. 48) through 125 gallons a minute in well 1 to about 40 gallons a minute in wells 38 and 39. The specific capacities are 10 to 100 times as great as those of wells in the Dalles formation or the upper permeable zone of the Yakima basalt. In well 48, on which the draft is reported to be about 1,000,000 to 2,000,000 gallons a day for 8 to 12 weeks each summer, hydraulic equilibrium is attained within a comparatively short time after the pump is started, and the pumping level of the water remains essentially constant thereafter, the drawdown being about 5.5 feet. The transmission capacity being so large, the rate at which water can be recovered perennially from the basin is likely to be conditioned by the rate of recharge rather than by the drawdown involved in the permissible lift.

The static level of the water in the lower permeable zone of the Yakima basalt was about 77 feet above sea level during June, 1930, in adequately cased wells at The Dalles. The static level in the other wells along the Columbia River declined downstream about 3 feet to the mile, but the hydraulic gradients in other directions are not known. This level is about 30 feet above the mean low stage of the river. It is also about 250 feet below the static level of the upper water-bearing beds of well 50 and is nearly 400 feet below the static level of the water in the upper permeable zone in the vicinity of wells 60 and 65. Hence, in wells that tap the lower permeable zone the static level of the water may be expected to be about 300 to 425 feet below the alluvial plains of Mill and Threemile Creeks close to The Dalles but as much as 900 feet below the ridge crests. It may be expected to be 50 to 125 feet below the surface along the southern edge of the stream terrace opposite The Dalles (pl. 12), and 200 feet or more below the surface about 3 miles farther north. The static level is above some of the low terraces along the river, so that flowing wells, such as No. 45 (p.176), can be obtained in those areas. However, most of these potential areas of flowing wells lie below flood stages of the river.

The magnitude of the potential safe draft upon this body of ground water is indicated in a rough way by fluctuations in the static level as disclosed by the municipal well at The Dalles (No. 48). As is shown by Plate 18, the free water surface of the well rises as the atmospheric pressure decreases and falls as the atmospheric pressure increases, the fluctuations of the water surface being strictly of the same magnitude as the fluctuations of the atmospheric pressure when expressed as a water barometer. This condition indicates that the water is confined under artesian pressure. The diagram shows further that the fluctuations due to changes in atmospheric pressure were superposed upon a very gradual rise of the water surface amounting to 0.40 foot during the period of record, June 3 to 28, 1930, or about 0.015 foot a day. The nature and magnitude of the fluctuations of the water surface due to barometric fluctuations and other causes combined are shown roughly by Plate 19, which is based upon the measurements of depth to water in the following table:



FLUCTUATIONS OF WATER SURFACE IN THE DALLES MUNICIPAL WELL, ALSO FLUCTUATIONS IN BAROMETRIC PRESSURE AT THE DALLES AND PORTLAND, OREG., JUNE 3 TO 28, 1930



FLUCTUATIONS OF WATER SURFACE IN THE DALLES MUNICIPAL WELL IN THE PERIOD 1926-1930

Measurements of depth to static level of water in municipal well at The Dalles, Oreg. (No. 48, pl. 11)

[Measurements prior to May 26, 1930, by The Dalles City Water Commission. Measuring point is top of 12-inch casing, which is 5.7 feet below sill of pump house door and 94.0 feet above sea level]

Date	Depth to water	Date	Depth to water	Date	Depth to water
1926	*Feet*	1927	*Feet*	1927	*Feet*
Nov. 2	19.8	Feb. 9	17.1	June 9	14.3
Nov. 10	19.4	Feb. 10	17.1	June 19	13.8
Nov. 15	19.1	Feb. 11	16.7	June 21	13.4
Nov. 29	18.8	Feb. 12	16.6		
Dec. 1	19.0	Feb. 14	16.1	1928	
Dec. 2	18.7	Feb. 15	15.8	Jan. 16	13.5
Dec. 3	18.8	Feb. 16	15.9	Feb. 13	13.0
Dec. 6	19.1	Feb. 17	16.6	Mar. 5	12.7
Dec. 8	18.8	Feb. 18	16.1	July 19	11.2
Dec. 11	18.2	Feb. 19	16.2	July 23	11.3
Dec. 13	18.8	Feb. 23	16.0	July 30	11.8
Dec. 14	19.2	Feb. 28	16.2	Oct. 11	15.1
Dec. 15	18.9	Mar. 1	16.0	Nov. 26	15.0
Dec. 17	18.5	Mar. 2	15.9	Dec. 18	15.4
Dec. 20	18.3	Mar. 4	15.8		
Dec. 21	18.0	Mar. 5	16.1	1929	
Dec. 23	18.9	Mar. 7	15.7	Jan. 17	14.2
Dec. 27	18.6	Mar. 8	15.7	Jan. 21	14.8
Dec. 31	18.6	Mar. 10	15.4	Jan. 29	14.7
		Mar. 11	15.8	Feb. 1	13.7
1927		Mar. 12	15.5	June 24	13.6
Jan. 3	17.9	Mar. 14	15.6	July 5	13.8
Jan. 4	17.8	Mar. 15	15.9	Aug. 25	17.3
Jan. 5	17.7	Mar. 17	15.5	Sept. 1	18.3
Jan. 6	17.6	Mar. 18	15.9	Sept. 8	18.6
Jan. 7	17.8	Mar. 21	15.9	Sept. 16	19.2
Jan. 8	18.2	Mar. 22	16.0	Sept. 25	19.1
Jan. 10	17.7	Mar. 23	15.8	Oct. 4	18.6
Jan. 11	17.5	Mar. 25	15.7	Oct. 24	18.8
Jan. 12	17.6	Mar. 26	15.7	Oct. 29	19.0
Jan. 13	17.6	Mar. 28	15.7	Nov. 26	18.8
Jan. 14	17.7	Mar. 30	15.1	Nov. 30	18.6
Jan. 15	17.3	Mar. 31	15.1		
Jan. 17	17.4	Apr. 2	15.3	1930	
Jan. 18	17.0	Apr. 4	15.5	Jan. 9	18.3
Jan. 19	17.1	Apr. 5	15.6	Jan. 11	18.0
Jan. 20	18.0	Apr. 7	15.5	Feb. 13	18.9
Jan. 24	17.6	Apr. 8	15.3	May 5	17.2
Jan. 25	17.6	Apr. 9	15.3	May 19	17.1
Jan. 26	17.3	Apr. 11	15.4	May 26	17.16
Jan. 27	16.9	Apr. 12	15.5	May 27	16.89
Jan. 28	16.9	Apr. 13	15.5	June 2	16.99
Jan. 29	17.1	Apr. 16	15.3	June 3	16.95
Jan. 31	17.0	Apr. 19	15.6	June 5	17.09
Feb. 1	16.6	Apr. 20	15.9	June 7	16.74
Feb. 2	16.7	Apr. 21	15.7	June 9	16.62
Feb. 3	16.6	Apr. 23	15.5	June 13	16.97
Feb. 4	16.8	Apr. 25	15.3	June 17	16.80
Feb. 5	16.9	May 7	15.1	June 21	16.61
Feb. 7	17.1	May 11	15.3	July 1	16.35
Feb. 8	17.1	May 19	14.7		

In the period November 2, 1926, to June 21, 1927, the water surface in the well rose 6.4 feet—from 19.8 to 13.4 feet below the top of the casing. The minor fluctuations in the same period are of such magnitude that they may be considered as due to changes in atmospheric pressure and independent of the progressive rise shown by the diagram. A similar rise seems to have occurred in the climatic year 1927–28 and to have culminated in the highest recorded static level—11.2 feet below the measuring point on July 19, 1928. In the following year the static level also rose gradually until February but was no higher in late June and early July, just before the start of the pumping season. In the year 1929–30 the water level rose even more slowly. In the period represented by Plate 19 practically all the draft upon the lower water-bearing beds of the Yakima basalt occurred during the period July to September, inclusive, of each year, and little water was pumped from wells other than No. 48. Consequently, the diagram and tabulated data are not complicated by the cumulative effects of pumping several wells.

On the basis of the facts brought out in the preceding paragraphs, several generalizations appear justified. First, the progressive rise of the water surface in the period from October to June does not seem to be due to recovery from pumping. Thus, the rise between November, 1926, and June, 1927, was probably greater than the drawdown resulting from pumping the preceding summer, and for at least two months after pumping had been stopped in September, 1929, there were no fluctuations of the water level greater than could be ascribed to changes in atmospheric pressure. Second, the progressive rise of the water surface coincides with the season of maximum rainfall and snowfall (pp. 114–116), and the rise seems to be greatest in years of heavy rainfall. Thus, in the climatic year 1926–27 the rise of the water surface from November to June was 6.4 feet and the yearly rainfall was 4.46 inches more than the average; in the three following years the water rose 2.3, 1.8, and 2.8 feet, respectively, and the corresponding yearly rainfall was 1.27, 6.50, and 3.61 inches less than the average. Third, recharge of the basin seems to be relatively rapid, but the increments to the supply are taken in over so extensive an area that individual rainstorms show no effect on the water level in well 48. Fourth, the annual decline in head during the period from July to September may be due in large part to natural artesian leakage, possibly at the two places where the rocks at the horizon of the water-bearing beds are cut through by the Columbia River and where the static level of the ground water is about 30 feet above the mean low-water stage of the river.

The present draft upon the lower water-bearing zone of the Yakima basalt by pumping seems to be much less than the rate of recharge. Probably several times as much water as is now pumped annually could be recovered each year from this source for beneficial use without causing the head to decline excessively or causing the supply to be ultimately depleted.

CHEMICAL CHARACTER OF THE GROUND WATER

The chemical character of the ground water is shown by analyses of seven samples collected from wells and springs in the Dalles region and, as a standard of comparison, one sample taken in duplicate from the Columbia River. These analyses were made by S. K. Love in the water resources laboratory of the United States Geological Survey, and the results are tabulated below. All these are moderately concentrated calcium bicarbonate waters of moderate hardness. In each the content of silica (SiO_2) is relatively large, as is characteristic of waters from volcanic terranes. No correlation seems possible between the chemical character of the waters and the geologic formations from which they are derived, except that the waters from the Yakima basalt contain somewhat more sodium (Na) than those from other sources. The water from the well of The Dalles Country Club (analysis 9) is by far the most concentrated and contains much more iron (Fe) and sulphate (SO_4) than the other samples from the Yakima basalt. However, this well is in a district in which deposits of pyrite and other metallic sulphides occur, so that the greater concentration of its water may result from solution of oxidation products of the sulphides; by hydrolysis these oxidation products would form acid ions and thereby increase the solvent power of the water toward the carbonates of calcium and magnesium. No difficulty is likely to arise from using such waters for irrigation on well-drained soils, such as are general in the Dalles region. However, the soap-consuming and scale-forming constituents are sufficiently abundant to make the waters somewhat undesirable for boiler feed, laundering, or ice making unless they are softened.

Analyses of typical waters from the Dalles region, Oregon

No.	Description	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
9	SE. ¼ sec. 17, T. 2 N., R. 13 E. 12-inch drilled well 300 feet deep owned by The Dalles Country Club. Water from Yakima basalt. Sampled July 26, 1930. Temperature 62° F	367	57	[a] 1.97	48	31	15	3.8	194	110	4.0	0.20	247
13	NW. ¼ sec. 21, T. 2 N., R. 13 E. (Klickitat County, Wash.). Perennial spring owned by M. A. Leonardo. Water from stream gravel. Sampled July 29, 1930. Temperature 57° F	171	48	.03	22	11	7.8	2.1	116	8.6	5.0	7.0	100
29	Lot 1, sec. 33, T. 2 N., R. 13 E. (Klickitat County, Wash.). 6-inch drilled well 149 feet deep owned by Spokane, Portland & Seattle Railway (Grand Dalles station). Water from Yakima basalt. Sampled July 28, 1930. Temperature 60° F	187	51	.04	20	8.3	22	4.5	137	18	4.0	.00	84
48	The Dalles, Third and Court Streets. Municipal supply, 14-inch drilled well 201 feet deep. Water from Yakima basalt. Sampled July 26, 1930. Temperature 63° F	249	70	.02	18	8.2	44	6.2	196	12	6.0	.05	79
55	NE. ¼ sec. 12, T. 1 N., R. 13 E. 8-inch drilled well 70 feet deep owned by Fred Cyphers. Water from bottom of Dalles formation. Sampled July 26, 1930. Temperature 62° F	211	62	.04	28	15	13	3.3	181	3.2	5.0	.86	132
65	NW. ¼ sec. 23, T. 1 N., R. 13 E. 12-inch drilled well 301 feet deep owned by Cherry Hill District Improvement Co. Water from Yakima basalt (?). Sampled July 26, 1930. Temperature 64° F	165	68	.01	15	8.9	11	3.0	109	2.6	5.0	.71	74
----	Columbia River at The Dalles. Mean of two samples; one from south bank ferry dock, the other from north bank ferry dock. Sampled July 29, 1930. Temperature 70° F	98	9.8	[b] .09	21	5.4	5.1	1.3	78	13	3.7	.64	75

[a] Includes 1.92 parts per million precipitated at time of analysis.
[b] Includes 0.05 part per million precipitated at time of analysis.

IRRIGATION POSSIBILITIES

GENERAL FEATURES

The principal crops now cultivated in the Dalles region for which irrigation is desirable are garden truck, cherries, and prunes. The truck gardens are situated on terraces of the intermediate alluvium (p. 133) along the Columbia River and on the alluvial plains of the tributary creeks within 1 or 2 miles of the river. They range from 150 to 300 feet above sea level. Most of the cherry orchards, on the other hand, are in the valleys of Mill and Threemile Creeks (pl. 13) on remnants of terraces that are veneered with older alluvium (p. 129); some are on higher slopes underlain by the Dalles formation (p. 120). The terrane on which the orchards are situated is maturely dissected and rolling; it ranges from about 500 to nearly 1,000 feet above sea level. Distribution of irrigation water over the truck gardens would entail no serious difficulties, for the land surface is in general fairly smooth. On the orchard tracts, however, distribution of the water is difficult on account of the irregular surface and can be accomplished only by skillful planning of flumes, ditches, and rills.

ECONOMIC PRINCIPLES

In order that the development of ground water for irrigation shall be economically sound, it is necessary that the cost of operation of the plant, including capital charges, maintenance, and current operating expense, shall be less than the increased value of the crop resulting from irrigation and that the source of water be adequate to supply the plant at least until its capital cost shall have been repaid. Obviously, the cost of operation for each unit quantity of water developed will differ greatly on different tracts, depending chiefly upon the depth of the water-bearing beds, the total lift from the pumping level in the well to the land to be irrigated, the capacity of the well, and the quantity of water used. As a rude standard of comparison, the cost of pumping water upon the land of the Cherry Hill District Improvement Co. in the irrigation season of 1927 is itemized below. These data are taken from the annual financial statement of the company made to The Dalles-Wasco County Chamber of Commerce.

Distribution of irrigation costs of Cherry Hill District Improvement Co. in 1927

	Per acre-inch	Per acre [a]
Current operating expense:		
Watermaster and labor in distributing water	$1.760	$21.82
Electric power (including "standby" charge) and lubricants	1.412	17.51
Supplies, maintenance of plant, repairs to weir boxes and flumes	.399	4.95
Capital charges:		
Depreciation in value of well, pumping plant, and pipe lines (useful life assumed to be 16 years)	1.103	13.68
Interest on unretired portion of investment, at 7 per cent	1.210	15.00
Depreciation in value of weir boxes and flumes (useful life assumed to be 4 years)	.770	9.55
	6.654	82.51

[a] Average use of water 12.4 acre-inches to an acre.

These costs are based upon a well (No. 65, pp. 180 and 187) 12 inches in diameter and 301 feet deep, equipped with a deep-well turbine pump direct-connected to a 50-horsepower (?) electric motor; the total lift is from 260 to 350 feet, and the draft for the season 2,120,000 cubic feet, or 48.9 acre-feet.

For other tracts the cost of labor for distributing each unit quantity of water would depend upon the system of flumes and rills required by the topography, but in general in this region the distribution systems would not be more complex than that of the Cherry Hill District Improvement Co. For plants of so small capacity that each irrigator is not fully occupied in distributing water, the cost of labor for each unit quantity is likely to be less the greater the capacity of the plant. The energy charge for electric power used to raise each unit quantity of water would increase roughly in direct proportion to the total lift if the mechanical efficiency of all pumping plants is assumed to be equal; under the common type of rate schedule for electric power—in which the cost of each unit of energy decreases as the quantity consumed increases—the energy charge for each unit quantity of water decreases somewhat as the total quantity increases. In 1927 the energy charge at the plant of the Cherry Hill District Improvement Co. was 59 per cent and the "stand-by" or "fixed" charge was 41 per cent of the total cost of electric power. Inasmuch as this stand-by charge is usually proportional to the horsepower of the motor, it is also roughly proportional to the total lift. The total lift being fixed, the stand-by charge for each unit quantity of water varies—for each month or other period for which charges are assessed—inversely as the total quantity of water pumped. Hence the cost of electric power for each unit quantity of water is least when the pump is operated continuously and at full capacity, provided that the drawdown of the well remains constant. The cost of maintaining the pumping plant in efficient mechanical condition generally increases somewhat as the total lift increases.

Of the capital charges, the annual depreciation in value would be directly proportional to its estimated useful life. The original cost of the well would increase with its diameter and depth, and for a given depth it would be somewhat greater for a well drilled in dense rock, such as the Yakima basalt. The charge against each unit quantity of water to repay the original cost would be inversely proportional to the water-yielding capacity of the well. The original cost of the pumping plant, on the other hand, would increase with both the lift and the capacity but not in proportion thereto; the charge against each unit quantity of water because of depreciation of the plant would increase somewhat with the lift but—within rather indefinite limits and for a given type of pump—would generally decrease somewhat as the capacity increased. The estimated useful life of the plant involves not only its mechanical life but also the possibility that the static level may be so lowered by continued draft of a number of wells that the lift may become so great as to be uneconomic.

The maximum economy in irrigating with ground water also involves applying the water as sparingly as is consistent with effecting a material increase in the crop, especially where the cost of each unit quantity of water is relatively large, as in the Dalles region. Under these conditions probably water should not be allotted to secondary uses, such as raising cover crops, unless it can be shown that the benefit from such use is greater than the cost and that the same benefit can not be derived more cheaply by some other means. Moreover, the quantity of ground water available for orchard irrigation in the Dalles region (pp. 167–169) is so inadequate that the use of water for any purpose other than raising the primary crop may cause the static level to decline considerably and may decrease the acreage that can be brought under irrigation.

To summarize, the maximum economic lift in pumping from wells for irrigation is that prevailing when the cost of raising each unit quantity of water, including charges for both current operation and repayment of the investment, is equal to the increase in value of the crop produced by efficient use of that water. If the actual lift is less than this maximum, pumping for irrigation is profitable; if the lift is more, pumping results in financial loss. The maximum economic lift is obviously not constant but varies with the cost of pumping and with the local market value of the crop.

STATUTORY PROVISIONS

Any development of ground water for irrigation in the vicinity of The Dalles will come under the statute passed by the Thirty-fourth Legislative Assembly of Oregon, 1927, providing that ground water may be appropriated for beneficial use and that the right to beneficial use may be acquired only by permit issued by the State engineer. This statute [43] is as follows:

Be it enacted by the people of the State of Oregon:

SECTION 1. Subject to existing rights, all underground waters of the State of Oregon in counties lying east of the summit of the Cascade Mountains may be appropriated for beneficial use, as herein provided, and not otherwise, but nothing herein contained shall be construed so as to take away or impair the vested right of any person, firm, corporation, or association to use the water from any existing well or source of underground supply where such water is economically and beneficially used.

SECTION 2. Any person, firm, association, or corporation hereafter intending to acquire the right to the beneficial use of any underground waters in counties lying east of the summit of the Cascade Mountains for irrigation purposes, before com-

[43] Thirty-fourth Legislative Assembly, State of Oregon, General laws of Oregon, ch. 410, pp. 576–579, 1927.

mencing the construction of any well, pit, gallery, tunnel, pumping plant, or other means of developing and securing such water, or performing any work in connection with such construction or in any manner utilizing said waters for irrigation purposes, shall make an application to the State engineer for a permit to make such appropriation.

SECTION 3. Nothing in this act shall be construed as requiring an application or permit for the developing for beneficial use of underground waters for domestic and culinary purposes, for stock, or for the watering of lawns and gardens for profit, and not exceeding one-half acre in area.

SECTION 4. Every application for a permit to appropriate underground water for irrigation purposes under this act shall be in a form which shall be prescribed by the State engineer and which shall set forth in definite terms the name and address of the appropriator and the location, the manner of development, the lands to be irrigated, the amount of water to be used per acre irrigated, the time of beginning and completion of work, and such other information as may be found by the State engineer to be necessary to properly classify and determine the feasibility of such appropriation. Where the depth and supply of water have not been fully determined in any section or area, the party so making such application shall pay the regular $3 examination fee at the time of making such application, and may have a reasonable time in which to develop and ascertain the supply of water, not exceeding three years, to be determined by the State engineer. At the time of making final report thereon the applicant shall pay the regular fees prescribed by the general laws of Oregon pertaining to fees upon permits for irrigation.

SECTION 5. Applications under this act for underground waters for irrigation purposes shall be accepted, recorded, and approved by the State engineer under the same procedure adopted for applications for diversion of surface waters, as provided in sections 5723, 5724, 5726, 5728, and 5729, Oregon laws. The same fees shall be charged and collected by the State engineer for applications and permits under this act as is provided by section 5690, Oregon laws. Permits may be assigned in the same manner as is provided by section 5725, Oregon laws.

SECTION 6. The owner of an approved application or permit to use water for irrigation purposes under this act shall annually, after the date of such application, furnish the State engineer with a detailed report of the work done, a log of wells drilled, characteristics of the underground supply, elevation of water, amount and time of use of water, and manner of utilization.

SECTION 7. No permit shall be granted for development of underground or artesian waters beyond the capacity of the underground beds or formation in the given basin, district, or locality to yield such water with a reasonable or feasible pumping lift in case of pumping water developments, or with a reasonable or feasible reduction of pressure in the case of artesian developments. The State engineer shall have the power to decide whether the granting of any such permit will injure or damage any vested or existing right or rights under prior permits, and may, in addition to the records of his office, require further evidence, proof, and testimony prior to granting or denying any such permit.

SECTION 8. Permits to use water from an underground source shall be contingent upon its use in an economical and beneficial manner. The State engineer shall have the power to fix the maximum amount which may be used per acre of land each season, and the water shall not be wasted. Artesian wells shall be provided with a suitable means for closing and conserving the flow when not actually needed or put to beneficial use.

SECTION 9. Whenever the owner of a permit to appropriate the underground waters of the State of Oregon in counties lying east of the summit of the Cascade Mountains shall fail to commence actual development within the time required by law, or shall fail or neglect to prosecute such work with reasonable diligence, or shall fail to complete such work within the time required by law, or as fixed in such permit, or any extension thereof, or, having completed development work, shall fail or neglect to apply water to a beneficial use, the State engineer may cancel such permit, in the records of his office, as provided in sections 5768, 5770, 5771, and 5772, Oregon laws, and it shall be thereupon voided and of no further force and effect.

SECTION 10. The State engineer is hereby authorized to make such investigations as may be necessary to determine the amount, the depth, the volume, and flow of all underground waters within the State, in counties lying east of the summit of the Cascade Mountains, and in making such examination hereby is authorized and directed to cooperate with the Federal Government, with any county or municipal corporation, or with any person, firm, association, or corporation, and upon such terms as may seem appropriate to him, and all fees paid upon applications for permits for underground and subterranean waters shall be placed in a special fund for the purpose of making examinations as herein provided, to be expended under the direction of the State engineer.

SECTION 11. Any person violating any of the provisions of this act shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished as provided by section 5767, Oregon laws.

Approved by the governor March 3, 1927.

SOURCES OF GROUND WATER FOR IRRIGATION

Three possible sources of ground water for irrigation exist in the Dalles region—namely, the intermediate alluvium along the Columbia River, the upper permeable zone of the Yakima basalt, and the lower permeable zone of that formation. The water-yielding capacity of the Dalles formation is so small where it is above the level of the streams that it does not constitute a feasible source of water for irrigation. The alluvium and the lower permeable zone of the basalt are feasible sources for irrigation of the existing truck gardens; the upper permeable zone and possibly the lower permeable zone of the basalt are sources for irrigating the existing orchard tracts.

As is pointed out on page 144, the alluvium may yield 100 gallons a minute or more to adequately constructed wells in favorable locations. Development of this source would be relatively inexpensive and would therefore be justified for irrigation of truck gardens. However, in most places the water table is only a few feet above the underlying bedrock, so that it is not probable that single wells adequate for large tracts can be obtained.

The water in the upper permeable zone has a much higher head than the water in the deeper zone and can be raised to the existing orchard tracts with relatively moderate lifts. However, the geologic and hydrologic conditions and the performance of existing wells indicate that the safe yield, or quantity of water that can be pumped each year from this zone through a long period, is not very great and that the supply is insufficient to irrigate all the existing orchard land. The supply in the vicinity of wells 60 and 65 is probably sufficient for the land they now serve but not for additional wells or a greatly increased rate of irrigation. It is, however, altogether unlikely that the wells now in existence salvage all the water available in this permeable zone, so that it seems justifiable to put down a moderate number of additional wells at a distance from the present wells. So far as practicable such wells should be about a mile from one another. A few wells in the valley of Threemile Creek, both upstream and downstream from the present irrigation wells, and in the lower part of the valley of Mill Creek would probably salvage practically all the water available in this zone.

It is essential that, for the guidance of future developments, the quantity of water pumped and the depth to both static and pumping levels be measured in each pumping period at every well and recorded systematically for several years. During the pumping season the depth to the static level should be measured just before the pump is started each time, and the depth to the pumping level should be measured just before the pump is stopped, or one or more times each week if the pump is operated continuously. The depth to water in the nonpumping period should be measured once a week in the first month after the irrigation season and once each month thereafter.

The geologic and hydrologic conditions and the performance of existing wells indicate that the lower permeable zone of the basalt will yield water in much larger quantities than the upper zone. However, its static level is much lower and therefore the cost of pumping from this zone to the orchards will be greater. This additional cost of pumping will, however, be offset to some extent by economies that will result from having wells with larger yields and less drawdown. The top of the lower permeable zone is about 350 to 500 feet below the alluvial plains of Threemile and Mill Creeks within 3 miles of The Dalles and about 675 feet below the surface at well 60. The static level of the water contained in this zone is probably about 300 to 400 feet below the creeks in the district, about 425 feet below the lowest of the orchard tracts, and about 525 and 625 feet below the surface at wells 65 and 60, respectively. Where the zone is very permeable, as at the site of the municipal well at The Dalles (No. 48, pp. 157–160), the drawdown in a well tapping it would presumably be small.

Deep-well turbine pumps are manufactured that would raise water from the lower zone to a considerable part of the orchard tracts. For example, a turbine pump recently installed in a well for the Etiwanda Water Co., of Etiwanda, Calif., for irrigating citrus orchards is reported to raise water 640 feet, the pumping level being 450 feet below the base of the pump and the delivery point 190 feet above it. This pump is equipped with a 350-horsepower motor. A turbine pump recently installed at Zacatecas, Mexico,[44] is set with the bottom of its bowls about 850 feet below the base of the pump. On the assump-

[44] Engineering News Record, vol. 104, No. 10, p. 419, Mar. 6, 1930.

tion that the combined efficiency of the motor and pump at Etiwanda is 60 per cent, its capacity would be approximately 1,300 gallons a minute. In other words, the energy input for each gallon a minute of capacity would be about 0.27 horsepower, whereas the energy input for each gallon a minute of capacity for the plant of the Cherry Hill District Improvement Co. in 1930 was 0.16 to 0.20 horsepower.

It is possible that with adequate pumping equipment and a well of large capacity water could be raised within permissible limits of cost from the lower permeable zone to irrigate the orchards on the lowest lands, thereby supplementing the supply available from the upper zone and in part relieving the shortage of water for irrigation of the orchard lands. This possibility has sufficient merit to justify an investigation of the costs that would be involved. The most favorable situation for development of this sort is on the alluvial plains of Threemile and Mill Creeks near The Dalles, for there the zone is at the least depth below the land surface, the cost of drilling the wells would be least, and the depth to which it would be necessary to set the bowls of a turbine pump would be least. If a well should be drilled into the lower zone for such a development, the water-yielding capacity of the well should be determined by a thorough test in order that proper specifications for an efficient pump might be written and that the unit cost of pumping might be estimated and the feasibility of the project established before expensive pumping machinery was installed. Unless a well of large capacity is obtained it will not be practicable to pump from this deep zone.

The top of the lower permeable zone of the Yakima basalt is generally less than 200 feet below the surface along the 150-foot terrace of the Columbia River near The Dalles and is less than 300 feet below the surface over a large part of the stream terrace north of the river in the vicinity of Grand Dalles. The pumping lift from this body of ground water would be 75 to 150 feet to the existing truck gardens on the south side of the river and 100 to 200 feet to tracts of arable land on the north side of the river. As has been brought out on page 158, it is likely that this source would yield a considerable supply of water for irrigation without serious loss of pressure. However, the cost of drilling wells through the overlying dense basalt would be rather large, so that the development of this source might not be economically sound if the capacity of the plants was much less than 1 second-foot each.

It is urged that in the future accurate and systematic records be preserved of the quantity of water pumped and of the fluctuations of the water level in the existing city well and any additional wells that may be drilled. Only from such data can the available supply be determined.

WELL AND SPRING DATA

Records of wells in the Dalles region, Oregon and Washington

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 2 N., R. 12 E.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
[a] 1	NE. ¼ sec. 3	Spokane, Portland & Seattle Ry.	1928	Terrace	105	Drilled	340	15	325	15	Porous basalt	Yakima basalt	270
2	do	do	1926	do	105	do	175	8	140,160		Crevices	do	59
3	NE. ¼ SW. ¼ sec. 36	H. L. Young		Valley	485	do	138	6	54			Dalles formation	
	T. 2 N., R. 13 E.												
8	NE. ¼ SE. ¼ sec. 17	Henry Readell		Terrace	201	Dug	10	[b] 8x10		10+	Sand and gravel	Intermediate alluvium.	10
[c] 9	SE. ¼ SE. ¼ sec. 17	The Dalles Country Club.	1925	do	215	Drilled	350±	12	300±			Yakima basalt	
12	Lot 1, sec. 21	Walter Klindt		do	90	do	100	4	100±		Porous basalt	do	
16	SW. ¼ NE. ¼ sec. 29	Fred Wettle		do	155	do	250	6	150		do	do	
17	NE. ¼ SW. ¼ sec. 29	P. S. Plummer		do	180	Dug	22	[b] 18		22+	Sand and gravel	Intermediate alluvium.	22
18	SW. ¼ sec. 29	J. C. Hostetler		do	180	Drilled	1,710	4½	240	2	Porous basalt	Yakima basalt	800
20	NE. ¼ SW. ¼ sec. 30	J. P. McInerny		Valley	245±	do	547	6	40			Dalles formation	

[a] Driller's log of well on p. 184.
[b] Feet.
[c] Chemical analysis of water on p. 162.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 2 N., R. 12 E.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
	NE. ¼ sec. 3	−50	When drilled	Pump	700	700	Oct. 22, 1928	5.6	3	Railway		Well at Lyle water tank. Yield and drawdown reported by owner.
2	do	−59		do		15		50±		Drinking		Well at Lyle station. Water level −70 feet before casing was cemented.
3	NE. ¼ SW. ¼ sec. 36	−20±	When drilled	None		100		20		None		Pit 5 feet in diameter and 20 feet deep with well drilled in bottom; yield reported; irrigation test.
	T. 2 N., R. 13 E.											
8	NE. ¼ SE. ¼ sec. 17	−9.1	June 21, 1930	Centrifugal pump.	150±	10–100				Irrigation		Capacity reported about 10 gallons a minute in dry years such as 1930; as much as 100 gallons a minute in wet years.
[c] 9	SE. ¼ SE. ¼ sec. 17	{ −125 −147	Nov. 23, 1925 1928 }	Turbine	440	350	1925	([d])		Sprinkling	62	Pumped as much as 14 hours a day in summer.
12	Lot 1, sec. 21	−24.55	Sept. 6, 1930	Deep well pump.	5					Domestic		Measuring point is top of casing.
16	SW. ¼ NE. ¼ sec. 29			do	50	45		15±	2	Irrigation		Ultimate capacity reported, about 75 gallons a minute.
17	NE. ¼ SW. ¼ sec. 29	−14.9	Sept. 5, 1930	Centrifugal pump.	200±					do		Pumped dry in summer of 1930.
18	SW. ¼ sec. 29	−90	When drilled	None						None		Casing loose in hole; reported that static level did not change after 240-foot water-bearing bed was penetrated.
20	NE. ¼ SW. ¼ sec. 30	([e])		do						do		Reported to have flowed about 15 gallons a minute when 40 feet deep; ceased flowing when drilled through lower confining bed; static level of deep ground water unknown.

[a] Driller's log of well on p. 184.
[c] Chemical analysis of water on p. 162.
[d] Little.
[e] See remarks.

Records of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 2 N., R. 13 E.—Con.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
21	NW. ¼ SE. ¼ sec. 30	Hugh Thornton		Valley	250	Drilled	150?	6				Dalles formation	
22	do	do		do	260	do		4				do	
23	SW. ¼ sec. 30	W. V. Lutz		do	320	do	600±	5				do	
24	NE. ¼ SE. ¼ sec. 32	G. W. Ott	1927	Terrace	175	do	195	6	([f])		Crevices (?)	Yakima basalt (?)	
25	do	E. C. Fitzgerald	1929?	Hillside	215	do	256	4	([f])			do	
26	NW. ¼ SW. ¼ sec. 33	G. Segui	1929	Terrace	150	do	189	6	187	2+	Crevices	Yakima basalt	20
27	SW. ¼ SW. ¼ sec. 33	Wasco County industrial farm.		do	155	Dug	19	[b] 5			Sand and gravel	Intermediate alluvium.	
[a] [c] 29	Lot 1, sec. 33	Spokane, Portland, & Seattle Ry.	1920	do	127	Drilled	149	6	140	5	Porous rock	Yakima basalt	8
	T. 2 N., R. 14 E.												
[a] 32	NW. ¼ sec. 14	do	1923	Valley	165	do	57	6	43	14+	Gravel	Younger alluvium	44
33	Lot 3, sec. 20	U. S. Engineer Office		Terrace	125	do	200	6	200		Intercalated sand	Yakima basalt	
34	W. ½ sec. 31	Seufert Bros		do	125	do	150		([f])			do	
36	NE. ¼ sec. 31	do	1930	Hillside	570±	do	79	4		None.			

[a] Driller's log of well on p. 184.
[b] Feet.
[c] Chemical analysis of water on p. 162.
[f] Near bottom.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 2 N., R. 13 E.—Con.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
21	NW. ¼ SE. ¼ sec. 30.	+0.1	Sept. 19, 1930	Centrifugal pump.	50	50–75		5±		Irrigation	60	Flows 5 gallons a minute by artesian pressure; drawdown reported for pumping daily throughout summer.
22	do	−10±		Deep well pump.							63½	
23	SW. ¼ sec. 30	−30.0	July 30, 1930	None						None	None.	Prospect boring for coal; struck hard rock (Yakima basalt?) at 150± feet.
24	NE. ¼ SE. ¼ sec. 32.	−95	When drilled	Deep well pump.	50	50				Irrigation		2 wells of same depth and 8 feet apart; reported yield is for both wells pumped simultaneously.
25	do			None		9				None		Water running into well from perched water body 57 feet below surface Sept. 5, 1930.
26	NW. ¼ SW. ¼ sec. 33.	−14	When drilled	Deep well pump.	25	20		20	8	Domestic, irrigation.		Pumped as much as 18 hours a day in summer; drawdown reported
27	SW. ¼ SW. ¼ sec. 33.	−4.35	Sept. 5, 1930	Centrifugal pump.	100±	10±				Irrigation		Pump to elevated tank, distributed to spray nozzles by gravity; bedrock at depth of 22 feet.
[a] [c] 29	Lot 1, sec. 33	−47	When drilled	Deep well pump.	10±	45	When drilled	([e])	3	Drinking	60	Well at Grand Dalles station; drawdown reported.
	T. 2 N., R. 14 E.											
[a] 32	NW. ¼ sec. 14	−20	do		30	30	do	1±	½	do		Well at Avery station.
33	Lot 3, sec. 20											Well at camp 2.
34	W. ½ sec. 31			Centrifugal pump.						Cannery		
36	NE. ¼ sec. 31	79+	July, 1930	None								Well ends on top of Yakima basalt.

[a] Driller's log of well on p. 184.
[c] Chemical analysis of water on p. 162.
[e] Less than 1.

Records of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 2 N., R. 15 E.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
[a] 37	Lot 4, sec. 17	Oregon Trunk Ry	1918	Terrace	172	Drilled	301	13½	172	4	Intercalated sand.	Yakima basalt	107
[a] 38	do	do	1926	do	171	do	399	15½	367	32	Porous basalt	do	220
[a] 39	do	do	1930	do	169	do	472	15	467	5	do	do	242
[a] 40	SW. ¼ sec. 26	do		do	290	do	151	6	116½	½	Gravel	Older (?) alluvium	117
	T. 1 N., R. 12 E.												
41	SW. ¼ SE. ¼ sec. 25	T. A. Sammis, jr.		Upland	2,010	do	1,345	8	1,215			Dalles formation	
42	NE. ¼ SE. ¼ sec. 28	The Dalles City Water Commission.	1928	Valley	885	do	875	6	([f])			Yakima basalt (?)	16

[a] Drillers' logs of wells on pp. 184–185.
[f] Near bottom.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 2 N., R. 15 E.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
[a] 37	Lot 4, sec. 17	−33.95	May 25. 1930	None		200		20		None		Well 14 feet south and 3 feet west from southeast corner of power house at Wishram; abandoned in 1927 because of contamination of water through defective casing. Measuring point is top of 12-inch casing in bottom of pump pit 4 feet deep.
[a] 38	do	−36		Turbine	900	835	May, 1930	19		Railway		Well 280 feet east of No. 37; maximum use 500,000 gallons a day; static level approximately same level as Columbia River.
[a] 39	do	−49.5	May, 1930	None		750	do	18	4	do		Well about 100 feet east of No. 38; pump not yet installed in May, 1930; tested at 1,500 gallons a minute for periods of several minutes each.
[a] 40	SW. ¼ sec. 26	−115	When drilled			10	When drilled			Drinking		Well at Moody station; reported yield is bailing test.
	T. 1 N., R. 12 E.											
41	SW. ¼ SE. ¼ sec. 25	−1,200	do	Formerly deep-well pump.	5							Well on summit of Mount Hood Flat.
42	NE. ¼ SE. ¼ sec. 28	−132.77 −133.07	June 7, 1930 Sept. 11, 1930	None						None		Well at Wicks Reservoir; top of Yakima basalt at depth of 350 to 400 feet; basalt intercalated with clay; well will absorb water at rate of 50 gallons a minute with casing filled to the top.

[a] Drillers' logs of wells on pp. 184–185.

Records of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 1 N., R. 13 E.												
					Feet		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
43	NE. ¼ sec. 2	Ralph Murray	1930	Valley	95	Drilled	125±	8	115	10	Basalt	Yakima basalt(?)	13
44	S. ½ sec. 2	Oregon-Washington R. R. & Navigation Co.	1916	do	105	do	135	12			do	do	60+
45	NW. ¼ sec. 2	do	1905±	do	75±	do	1,003?					do	
46	SW. ¼ NE. ¼ sec. 3	Libby, McNeill & Libby.	1915	Terrace	105	do	120	4	115±	1–2	Porous basalt	do	
47	do	Stadelman Ice Co.		do	105	do	129	6	(f)		do	do	
a c 48	NW. ¼ sec. 3	The Dalles City Water Commission.		do	99	do	200½	14	180	20½+	do	do	62

a Driller's log of well on p. 186.
c Chemical analysis of water on p. 162.
f Near bottom.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 1 N., R. 13 E.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
43	NE. ¼ sec. 2	−20.1	Sept. 15, 1930	None								Drilled for irrigation well; no pump installed September, 1930.
44	S. ½ sec. 2			Suction pump.	300	500				Shops		Well at southwest corner of machine shop near west end of roundhouse at The Dalles; has been pumped 500 gallons a minute for 96 hours for emergency municipal supply.
45	NW. ¼ sec. 2	[h] +30	When drilled	None						None		Drilled as coal prospect; Yakima basalt, 0–836 feet; clay shale, 836–878 feet; Yakima basalt 878–1,003 feet. Well submerged by floods of Columbia River; originally flowed by artesian pressure; yield unknown.
46	SW. ¼ NE. ¼ sec. 3	[h] −28		Suction pump.	300	300				do		Pump set in pit 16 feet deep; drawdown to bottom of 26-foot suction pipe in about 10 minutes; pumping 300 gallons a minute. At northwest corner of machine shop; cannery at 802 East First Street, The Dalles.
47	do	[h] −18		Suction and centrifugal pumps.	68, 125	125		8±		do		In basement at First and Laughlin Streets, The Dalles; has been pumped 68 gallons a minute steadily for 4 months.
[a] [c] 48	NW. ¼ sec. 3	−22.4	May 26, 1930	Centrifugal pumps.	2, 500	2, 500	June, 1925	5.5±	[i] 2–3	Municipal	63½	At northwest corner city hall, Third and Court Streets, The Dalles; water level referred to ground.

[a] Driller's log of well on p. 186.
[c] Chemical analysis of water on p. 162.
[h] Reported.
[i] Months.

Records of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 1 N., R. 13 E.—Con.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
50	SW. ¼ SE. ¼ sec. 4	Libby, McNeill & Libby.	1900±	Hillside	408	Drilled	503	4½	459			Yakima basalt (?)	
51	NE. ¼ SW. ¼ sec. 9	Mrs. E. M. Williams	1926?	Valley	510	do	290	6				Dalles formation	
52	NE. ¼ SE. ¼ sec. 9	G. C. Blakely	[i] 1915	Hillside	680	do	300±	6				do	
53	do	Mrs. E. M. Williams		do	685±	do	400±	6	400±		Joint clay	do	
54	SE. ¼ SE. ¼ sec. 10	James Taylor		do	630	do	190	8	190±		Sandstone	do	180
[e] 55	NE. ¼ NE. ¼ sec. 12	Fred Cyphers	1930	Valley	345	do	70	8	54		Limestone	do	44
57	NW. ¼ NW. ¼ sec. 14	L. J. Harvey		Hillside	677	do	300±	12				do	
58	do	T. A. Sammis, jr		Rolling	635	do	326					do	
59	do	do	[k] 1930	do	662	do	333	12	110, 125	Thin.	Sandstone	do	

[e] Chemical analysis of water on p. 162.
[i] Before.
[k] Drilling.

No on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 1 N., R. 13 E.—Con.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
50	SW. ¼ SE. ¼ sec. 4			None						None		South of upper reservoir, near Sixteenth and Lincoln Streets, The Dalles; water-bearing beds struck at depths of 105, 164, 374, and 459 feet; static level reported about —100 feet for upper 3 water-bearing beds but more than —300 feet for the 459-foot water-bearing bed.
51	NE. ¼ SW. ¼ sec. 9	—105+	Sept. 6, 1930	None		15	When drilled	25±		None		Test well for irrigation; top of Yakima basalt reported 280 feet below the surface.
52	NE. ¼ SE. ¼ sec. 9	—225	Sept. 5, 1930	do								
53	do	—300		do		20	When drilled	85±		Formerly irrigation.		Located about 80 feet south of No. 52; test well for irrigation; abandoned.
54	SE. ¼ SE. ¼ sec. 10	[b]—90	When drilled	Deep-well pump.	10	25±	do					
[c]55	NE. ¼ NE. ¼ sec. 12.	Above surface.	June, 1930	Natural flow.		60	June, 1930			Irrigation	62	Well pumped 80 gallons a minute with pumping level 12 feet below surface, for 4 hours; two wells about 20 feet apart; top of Yakima basalt at depth 67 feet.
57	NW. ¼ NW. ¼ sec. 14.	—190±	Sept. 6, 1930	Deep-well pump.								
58	do	—120±	When drilled	do		6		100±		Domestic		Well at residence; top of Yakima basalt at depth 320 feet.
59	do	—119.1 —119.3 —119.5	May 12, 1930 June 10, 1930 Sept. 6, 1930	None		10±	1930					Well in orchard, intended for irrigation; yield of 110-foot and 125-foot beds estimated 10 gallons a minute by bailer test; measuring pointis top of temporary 12-inch casing at ground level.

[c] Chemical analysis of water on p. 162.
[b] Reported.

Record of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T.1 N., R. 13 E.—Con.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
[a] 60	SW. ¼ NE. ¼ sec. 15	R. F. Kelley	1927	Rolling	713	Drilled	494	12½	387	2	Sandstone	Intercalated in Yakima basalt(?)	386
61	SW. ¼ SE. ¼ sec. 15	Carl Williams		Hillside	635	do	280					Dalles formation	
62	SW. ¼ NE. ¼ sec. 17	J. S. Bailey		do	700	do	405	6	([f])		Sandstone	do	
63	SE. ¼ NE. ¼ sec. 17	Ed. Ball		Upland	1,010	do	180	6	([f])			do	
64	NW. ¼ NE. ¼ sec. 22	W. W. Rawson & Son	1930	Hillside	585	do	158	6	158	Thin.		Bottom of Dalles formation	
[a] [c] 65	NW. ¼ NW. ¼ sec. 23	Cherry Hill District Improvement Co.	[l] 1926	Hillside gulch.	623	do	301	12	281	7	Porous basalt (?)	Yakima basalt (?)	193

[a] Drillers' logs of wells on pp. 186–187.
[c] Chemical analysis of water on p. 162.
[f] Near bottom.
[l] March.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 1 N., R. 13 E.—Con.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
[a] 60	SW. ¼ NE. ¼ sec. 15.	−247.5 −243.3	Jan. 9, 1930 Apr. 28, 1930	Turbine	175–215	229	May 10, 1930	107	4±	Irrigation		Secondary water-bearing bed at depth 185 feet, static level also −185 feet±; top of Yakima basalt at depth 330 feet (?).
61	SW. ¼ SE. ¼ sec. 15	−90±	When drilled	Deep-well pump.		3½						Top of Yakima basalt at depth 230 feet.
62	SW. ¼ NE. ¼ sec. 17.	−365	do	do		10±	When drilled			Domestic, stock		Well first drilled 60 feet deep and developed little water; deepened to about 300 feet and developed small additional supply; deepened to 405 feet for permanent supply.
63	SE. ¼ NE. ¼ sec. 17	−80	do	do						Stock		
64	NW. ¼ NE. ¼ sec. 22.	−112 −141.3	February, 1930 May 10, 1930	do						do		First water-bearing bed at depth 55 feet, static level −35 feet; static level dropped to −60 feet when well was 100 feet deep; static level of February, 1930, is reported; static level of May 10 measured while well No. 65 was being pumped and is presumably within circle of influence of that well; well bottoms on top of Yakima basalt.
[a] [c] 65	NW. ¼ NW. ¼ sec. 23.	−147 −157.5 −158	When drilled Jan. 9, 1930 Mar. 28, 1930	Turbine	400	300–400	March to August, 1930	[m] 66	[n] 7	Irrigation	62	First water-bearing bed at depth 188 feet, static level −90 feet; second water-bearing bed at depth 223–239 feet, static level −128 feet; static levels of Jan. 9 and Mar. 28, 1930, are reported; top of Yakima basalt at depth 188 feet (?).

[a] Drillers' logs of wells on pp. 186–187.
[c] Chemical analysis of water on p. 162.
[m] Maximum.
[n] Weeks.

Records of wells in the Dalles region, Oregon and Washington—Continued

No. on pl. 11	Location	Owner or name	Date completed	Topographic situation	Altitude above sea level	Type of well	Depth of well	Diameter of well	Principal water-bearing bed: Depth to top of bed	Principal water-bearing bed: Thickness	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Depth to which well is cased
	T. 1 N., R. 13 E.—Con.				*Feet*		*Feet*	*Inches*	*Feet*	*Feet*			*Feet*
66	NE. ¼ NW. ¼ sec. 23	H. G. Miller		Hillside	800	Drilled	300	6	271		Sandstone	Dalles formation	
67	NE. ¼ sec. 24	Tipton & Manchester	1915±	Hilltop	1,020	do	550	6	None.				
[a] 68	NW. ¼ NW. ¼ sec. 25	J. F. Austin		Hillside	1,030	do	447	6	([f])		Sandstone	Dalles formation	350
69	NW. ¼ NE. ¼ sec. 33	E. B. Elton		do	1,040	do	214	6	170	20	Porous basalt	Yakima basalt	
70	SE. ¼ SW. ¼ sec. 36	Frank Dick		Valley	925	do	80	6	80		Sandstone	Dalles formation	20
	T. 1 N., R. 14 E.												
71	NW. ¼ sec. 19	Henry Darnielle		do	685	do	305	6	([f])		Joint clay	Yakima basalt	
	T. 1 S., R. 13 E.												
72	NW. ¼ SE. ¼ sec. 24	Mountain View Orchard Co.		Ridge top	1,500	Dug	357?	[b] 4x6	([f])			do	

[a] Driller's log of well on p. 187.
[b] Feet.
[f] Near bottom.

No. on pl. 11	Location	Water level: Above or below surface	Water level: Date of measurement	Method of lift	Capacity of pump	Yield: Rate	Yield: Date of measurement	Drawdown: Amount	Drawdown: Duration of test	Use of water	Temperature (° F.)	Remarks
	T. 1 S., R. 13 E.—Con.	*Feet*			*Gallons a minute*	*Gallons a minute*		*Feet*	*Hours*			
66	NE. ¼ NW. ¼ sec. 23.	−166	When drilled	Deep-well pump.		3				Domestic		Drilled 520 feet deep, 271-foot water-bearing bed drained when well was 503 feet deep; plug set at depth 300 feet to recover water from 271-foot water-bearing bed; some water from bed 166 feet below surface.
67	NE. ¼ sec. 24											Dry hole, abandoned.
[a] 68	NW. ¼ NW. ¼ sec. 25.	−407	When drilled	Deep-well pump.	5	10	When drilled			Domestic		Capacity reported from bailer test.
69	NW. ¼ NE. ¼ sec. 33.	−130	do	do	7	30	do			do		Water level reported by driller; capacity from bailer test.
70	SE. ¼ SW. ¼ sec. 36	−30	do	do		25	do			do		
	T. 1 N., R. 14 E.											
71	NW. ¼ sec. 19	−265	do	do						do		
	T. 1 S., R. 13 E.											
72	NW. ¼ SE. ¼ sec. 24.			None								Very little water encountered.

[a] Driller's log of well on p. 187.

Drillers' logs

[Formations inserted by A. M. Piper]

Well of Spokane, Portland & Seattle Railway at Lyle water station, NE. ¼ sec. 3, T. 2 N., R. 12 E.

[No. 1, pl. 11. Drilled by A. A. Durand in 1928; diameter 15 inches to 130 feet, 10 inches 130 to 340 feet; cased to 20 feet and from 210 to 270 feet; reported yield, 700 gallons a minute with drawdown about 5.6 feet]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Yakima basalt:		
Basalt	230	230
Clay, blue	22	252
Clay or shale, brown	18	270
Basalt, dense	55	325
Basalt, porous, water bearing; static level—50 feet	15	340

Well of Spokane, Portland & Seattle Railway at Grand Dalles station, lot 1, sec. 33, T. 2 N., R. 13 E.

[No. 29, pl. 11. Drilled by G. E. Scott in 1920; diameter 6 inches; cased to 8 feet; reported yield, 45 gallons a minute with inappreciable drawdown in 2-hour test]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Rock fill	3	3
Yakima basalt:		
Basalt, black, hard; seepage of water at 25 and 30 feet	62	65
Basalt, gray, hard	10	75
Basalt, black	28	103
Shale, blue, dense	27	130
Shale, brown	8	138
Basalt, black, water bearing; static level—47 feet	11	149

Well of Spokane, Portland & Seattle Railway at Avery station, NW. ¼ sec. 14, T. 2 N., R. 14 E.

[No. 32, pl. 11. Drilled by G. E. Scott in 1923; diameter 6 inches; cased to 44 feet; reported yield, 30 gallons a minute with drawdown 1 foot in 30-minute test]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Sand	7	7
Gravel and sand	6	13
Sand	5	18
Gravel, fine, water bearing; static level—20 feet	12	30
Sand, black	10½	40½
Gravel and clay	3	43½
Stone, loose	13½	57

Well 1 of Oregon Trunk Railway at Wishram, lot 4, sec. 17, T. 2 N., R. 15 E.

[No. 37, pl. 11. 14 feet south and 3 feet west from southeast corner of power house near Wishram roundhouse; drilled by N. C. Jannsen in 1918; diameter 12½ inches to 79 feet, 12 inches 79 to 107 feet, 10 inches 107 to 301 feet; cased to 107 feet. Well abandoned in 1927 because water was contaminated by oil from near-by waste pit; contamination suggests defective casing]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Alluvium: Sand and gravel	92	92
Yakima basalt (?):		
Rock	80	172
Sand, water bearing; static level—38 feet	4	176
Shale, sandy	19	195
Basalt, creviced	106	301

Drillers' logs—Continued

Well 2 of Oregon Trunk Railway at Wishram, lot 4, sec. 17, T. 2 N., R. 15 E.

[No. 38, pl. 11. About 285 feet east of power house near Wishram roundhouse; drilled by G. E. Scott in 1926; diameter 15½ inches at top, 10 inches at bottom; cased to 75 feet, 122 to 154 feet, and 170 to 220 feet; reported yield, 900 gallons a minute with drawdown of 19 feet]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Alluvium: Sand	75	75
Yakima basalt:		
Basalt, black, hard	57	132
Clay, blue	22	154
Basalt, black, water bearing	26	180
Sandy shale and clay	35	215
Basalt, black, soft	110	325
Basalt, gray, hard	42	367
Basalt, black, porous, water bearing; static level −36 feet	32	399

Well 3 of Oregon Trunk Railway at Wishram, lot 4, sec. 17, T. 2 N., R. 15 E.

[No. 39, pl. 11. About 400 feet east of power house near Wishram roundhouse; drilled by A. A. Durand in 1930; diameter 15 inches to 84 feet, 13 inches 84 to 94 feet, 12½ inches 94 to 242 feet, 8 inches 242 to 475 feet; 12-inch casing to 38.6 feet, 8-inch casing 185 to 242 feet; reported yield, 750 gallons a minute with drawdown 18 feet in 4-hour test]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Alluvium: Sand and gravel	28	28
Yakima basalt:		
Basalt, black, dense at 50 to 61 feet	66	94
Basalt, gray, dense	19	113
Basalt, black	76	189
Clay, blue	30	219
Basalt	2	221
Sandstone, blue	9	230
Basalt, black, very dense at 240 to 245 feet	15	245
Basalt, gray, dense	112	357
Basalt, black, very dense	87	444
Basalt, gray, dense	13	457
Basalt, black, soft	10	467
Basalt, black, porous, water bearing; static level −49.5 feet	5	472
Basalt, black, dense	3	475

Well of Oregon Trunk Railway at Moody, SW. ¼ sec. 26, T. 2 N., R. 15 E.

[No. 40, pl. 11. Drilled by G. E. Scott; diameter, 6 inches; cased to 117 feet; reported capacity, 10 gallons a minute by bailer test when drilled]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Alluvium:		
Sand	87	87
Gravel and sand	28	115
Gravel and clay	1½	116½
Gravel, water-bearing; static level −115 feet	½	117
Yakima basalt:		
Stone, fractured	14	131
Stone, gray, hard	20	151

Drillers' logs—Continued

Well of The Dalles City Water Commission, Third and Court Streets, The Dalles

[No. 48, pl. 11. Drilled by G. E. Scott in December, 1923; diameter, 12 inches; cased to 62 feet; specific capacity about 450 gallons a minute for each foot of drawdown. Depths measured from normal ground level, which is about 4.5 feet above top of 12-inch casing in pump pit]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Clay	12	12
Yakima basalt:		
Rock, platy	7	19
Basalt, black	11	30
Clay, blue	31	61
Basalt, black	1	62
Basalt, gray, dense	4	66
Basalt, black, dense	26	92
Basalt, gray, very dense	43	135
Basalt, soft, water bearing	13	148
Basalt, black, dense	32	180
Basalt, black, soft, water bearing; static level −23 feet	20½	200½

Well of R. F. Kelley, SW. ¼ NE. ¼ sec. 15, T. 1 N., R. 13 E.

[No. 60, pl. 11. Drilled by G. E. Scott in 1927; diameter, 12½ inches at top, 10 inches at bottom; 13-inch casing to 335 feet, 10-inch casing 310 to 386 feet; filled up to 385 feet after use; yield, about 229 gallons a minute with drawdown of 55 feet; specific capacity, 3.5 to 4 gallons a minute for each foot of drawdown]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Soil	24	24
Boulder	2	26
Dalles formation:		
Clay	14	40
Sandstone, brown	34	74
Clay, white, soft	2	76
Sandstone, brown	52	128
Sandy clay, brown, soft	3	131
Sandstone, gray	8	139
Sandstone, dark brown	40	179
Sandstone, gray, with some "basalt" (agglomerate?), yields small amount of water	6	185
Sandstone	20	205
"Basalt" (agglomerate?)	15	220
Sandstone	38	258
Shale, gray	11	269
Sand	3	272
Shale, brown	22	294
Clay, sandy	4	298
Shale, brown	8	306
Shale, white	2	308
Sandstone	12	320
Shale, gray and white	10	330
Yakima basalt (?):		
Basalt and green clay	5	335
Basalt, dense	30	365
Shale, cream	22	387
Sand, yellow, principal water-bearing stratum; static level −247 feet	2	389
Basalt	21	410
Clay, blue	4	414
Basalt, disintegrated	3	417
Shale, white	11	428
Basalt, black	11	439
Shale, blue, sandy	3	442
Basalt, black	18	460
Shale, blue	34	494

Drillers' logs—Continued

Well of Cherry Hill District Improvement Co., NW. 1/4 NW. 1/4 se. 23, T. 1 N., R. 13 E.

[No. 65, pl. 11. Drilled by G. E. Scott in March, 1926; diameter, 12 inches at top, 10 inches at bottom; 10-inch casing to 193 feet; yield 300 to 380 gallons a minute as much as 5 weeks steadily; maximum drawdown 66 feet; specific capacity diminished during irrigation season of 1930 from 14½ to 5 gallons a minute for each foot of drawdown]

	Thickness	Depth to bottom of stratum
	Feet	*Feet*
Soil	3	3
Dalles formation:		
Sandstone, yellow	115	118
Clay, cream	21	139
Sandstone, buff	17	156
"Basalt" (agglomerate?), moderately dense	20	176
Clay, yellow; static level −90 feet when well was 188 feet deep	12	188
Yakima basalt (?):		
Basalt, porous	33	221
Basalt, dense	2	223
Basalt, porous, water bearing; static level −128 feet	16	239
Basalt, principal water-bearing bed at 281 to 288 feet; static level −147 feet	49	288
Clay, dark, sticky	13	301

Well of J. F. Austin, NW 1/4 NW. 1/4 sec. 25, T. 1 N., R. 13 E.

[No. 68, pl. 11]

	Approximate thickness	Approximate depth to bottom of stratum
	Feet	*Feet*
Soil	5	5
Dalles formation:		
"Lava, soft" (volcanic agglomerate?) water bearing at base; yields 1 gallon a minute	45	50
Clay	15	65
Sand, clay, and conglomerate in thin beds	55	120
"Lava" (agglomerate?), gray, moderately dense	30	150
Conglomerate, boulder deposits, and clay in thin beds; water bearing; yield, 5 to 7 gallons a minute	200	350
Sandstone with thin beds of clay, water bearing at bottom; static level −407 feet	97	447

96268°—32——13

Records of springs in the Dalles region, Oregon and Washington

No. on pl. 11	Location	Owner	Topographic situation	Altitude above sea level	Type of spring [a]	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon
	T. 2 N., R. 13 E.			*Feet*			
4	NW. ¼ SE. ¼ sec. 15	M. A. Leonardo	Hillside	605	Fracture (?)	Tuffaceous sandstone	Base of Dalles formation.
5	SE. ¼ NW. ¼ sec. 15	do	do	685	do	do	Do
6	SE. ¼ NE. ¼ sec. 16	do	Terrace	530	Contact (pocket)		Alluvium.
7	SE. ¼ SW. ¼ sec. 16	S. Van Vactor	do	290	do		Do
10	NE. ¼ SE. ¼ sec. 19	Clayton and Clifford Sanderson	Hillside	365	Fracture	Jointed basalt	Yakima basalt.
11	SE. ¼ SE. ¼ sec. 20	Charles Bunn	Valley	205	Valley or fracture		Intermediate alluvium.
13	SE. ¼ NW. ¼ sec. 21	M. A. Leonardo	Terrace	115	Contact (pocket)	Sand and gravel	Alluvium.
14	W. ½ sec. 24	J. T. Rorick	do	310	Fracture	Jointed basalt	Yakima basalt.
15	SE. ¼ SE. ¼ sec. 27	W. E. Lowell	do	195	Contact (pocket)	Sand and gravel	Alluvium.
19	NE. ¼ NE. ¼ sec. 30	Pat Foley	Hillside	335	do	Talus and hill wash	Older (?) alluvium.
28	Lot 5, sec. 33	L. W. Curtis	Terrace	185	do	Sand and gravel	Do
30	NW. ¼ NW. ¼ sec. 36	State of Washington	do	130	do	do	Intermediate (?) alluvium.
	T. 2 N., R. 14 E.						
31	NW. ¼ NW. ¼ sec. 8	J. C. Crawford	Hillside	1,275	do	Hill wash	
35	NE. ¼ sec. 31	Seufert Bros	do	475	Contact (gravity)		Base of Dalles information.
	T. 1 N., R. 13 E.						
49	NE. ¼ SE. ¼ sec. 4	The Dalles High School	do	255	do	Agglomerate	Do
56	NE. ¼ NE. ¼ sec. 14	E. V. Moore	do	510±	Fracture (?)	Jointed sandstone	Do

No. on pl. 11	Location	Character of opening	Yield: Gallons a minute	Yield: Date of measurement	Fluctuation	Use of water	Temperature	Remarks
	T. 2 N., R. 13 E.						° *F.*	
4	NW. ¼ SE. ¼ sec. 15	Boggy area 25 yards in diameter.	15±	June 27, 1930	Perennial	Irrigation	57	On flank of Dalles syncline near fault: water may be derived in part from fractured rocks of fault zone.
5	SE. ¼ NW. ¼ sec. 15	Seepage from hill wash	25±	do	do	Domestic, stock	53	Do.

6	SE. ¼ NE. ¼ sec. 16	Boggy area 50 by 150 yards	25	do	do	Stock	53	On former Curtis property; water probably derived from fractured rocks of near-by fault zone.
7	SE. ¼ SW. ¼ sec. 16	Seepage at points 200 yards apart.	15–20	do	Seasonal, large	Domestic	53	Supplied by rainfall on alluvium.
10	NE. ¼ SE. ¼ sec. 19	Seepage from talus above rock.	10±	June 19, 1930	Minimum flow about 5 gallons a minute.	Irrigation	58	Supplies spray nozzles for irrigating truck patch.
11	SE. ¼ SE. ¼ sec. 20	Pool 20 by 100 feet excavated.			Perennial	do	56	Pumped about 70 gallons a minute June 19, 1930; water may be derived partly from fractured rocks of fault zone.
13	SE. ¼ NW. ¼ sec. 21	Orifice at bottom of buried channel.	45	June 27, 1930	do	Stock	57	Chemical analysis of water on p. 162.
14	W. ½ sec. 24	Joint crevice	8	do	do	Domestic, stock	54	
15	SE. ¼ SE. ¼ sec. 27	Pool 10 feet in diameter excavated.	None.	do	Intermittent	Stock	61	
19	NE. ¼ NE. ¼ sec. 30	Three openings excavated, curbed, and roofed.	50±	June 18, 1930	Perennial	Stock, irrigation	50	Seepage along base of hill-wash fan about 200 yards wide; water may be derived in part from fractured rocks of fault zone.
28	Lot 5, sec. 33	Orifice excavated 3 feet in diameter.	15	Reported	do	Domestic, stock	59	Supplied by rainfall on alluvial terrace.
30	NW. ¼ NW. ¼ sec. 36	Boggy area 50 by 100 feet	1	June 27, 1930	do	None	57	Do.
	T. 2 N., R. 14 E.							
31	NW. ¼ NW. ¼ sec. 8	Seepage over area 50 feet in diameter.	40	do	do	Domestic, stock	53	Supplied by underflow at top of bedrock.
35	NE. ¼ sec. 31	Cut-off trench	([b])	June, 1930		Domestic		
	T. 1 N., R. 13 E.							
49	NE. ¼ SE. ¼ sec. 4	Pool 20 feet in diameter excavated, curbed, and roofed.			Perennial	Sprinkling		
56	NE. ¼ NE. ¼ sec. 14	Cut-off trench	([b])	May, 1930		Domestic	52	Supplied by weathered jointed sandstone underlain by clayey tuff.

[a] Bryan, Kirk, Classification of springs: Jour. Geology, vol. 27, pp. 522–561, 1919.
[b] Less than 1.