GEOLOGICAL SURVEY CIRCULAR 356

GROUND WATER IN THE YELM AREA THURSTON AND PIERCE COUNTIES WASHINGTON

Prepared in cooperation with the State of Washington
Department of Conservation and Development
Water Resources Division

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By M. J. Mundorff, James M. Weigle, and Glen D. Holmberg

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GROUND WATER IN THE YELM AREA, THURSTON AND PIERCE COUNTIES WASHINGTON

By M. J. Mundorff, James M. Weigle, and Glen D. Holmberg

ABSTRACT

This report presents the results of an investigation of the ground-water resources of the Yelm area, Pierce and Thurston Counties, Wash. It was made at the request of the Division of Water Resources, Washington State Department of Conservation and Development, for the purpose of determining the availability of ground water for irrigation to replace surface water that is no longer available as a result of the abandonment of the Yelm Irrigation Ditch.

The Yelm area includes the agricultural land surrounding the town of Yelm in Thurston County and a small adjacent area in Pierce County. The mapped area includes about 218 square miles, but the investigation was concentrated on the Yelm Prairie, which is an area of 11 square miles lying adjacent to and south of the Nisqually River and extending southeast and northwest of Yelm.

Late Pleistocene glacial drift and Recent alluvium are exposed in most of the Yelm area, but some Eocene sedimentary volcanic rocks crop out in the foothills to the south. Older Pleistocene deposits underlie most of the area but are exposed only along the Nisqually River valley and in a small area in the extreme southeastern part of the mapped area. Deposits of outwash sand and gravel and till laid down during Vashon glaciation (the latest glaciation) overlie these older Pleistocene deposits.

The Yelm Prairie was formed as a glacial outwash channel paralleling the present course of the Nisqually River. Recessional outwash sand and gravel are exposed over most of the prairie. Varying thicknesses of till and advance outwash underlie the recessional outwash and rest on the less permeable pre-Vashon deposits.

Permeable gravel makes up much of the advance and recessional outwash and constitute the most productive aquifers utilized in the Yelm Prairie. The pre-Vashon materials are generally less permeable, but some zones serve as aquifers and are utilized by some of the deeper irrigation wells. The till yields little or no ground water.

Ground water in the Yelm Prairie occurs chiefly under water-table conditions. The water table slopes toward the north-northwest with a gradient ranging from 10 to 15 feet per mile in the central part of the prairie to 55 feet per mile in the extreme northwestern part. The average depth to the water table is about 30 feet, and the seasonal fluctuation ranges from less than 1 foot in the south-central part of the prairie to nearly 20 feet in the northwest. The average seasonal range is about 7 feet.

The Yelm Prairie receives about 37 inches of precipitation annually. About 74 percent of the precipitation occurs between October and March. Eighty-five to 90 percent of the annual recharge occurs during the winter because of the higher precipitation and the low rate of evaporation and transpiration during this period. Recharge of the aquifers beneath the Yelm Prairie is derived from precipitation on the immediate area, although some ground water moves into the prairie from the surrounding till and morainal uplands during both winter and summer months.

The outwash gravel readily accepts available recharge during most of the year, but by late winter the water table is raised sufficiently high to cause the rejection of some water during this period. The water table drops in the summer months owing to decreased precipitation and higher rates of evaporation and transpiration. In all likelihood, some of the water that the Yelm Ditch formerly diverted from the Nisqually River onto the Yelm Prairie helped to maintain a relatively higher summer water table by contributing some recharge. As a result of the abandonment of the Yelm Irrigation Ditch the water table probably will drop several feet lower than normal during future low periods. However, it is believed that normal amounts of winter and spring precipitation will be sufficient to raise the water table to its usual high position for that period, because some of the precipitation formerly rejected in later winter and spring will now become ground-water recharge.

The annual recharge to the Yelm Prairie proper (11 square miles) is estimated to be about 25,000 acre-feet. Probably it would not be practical to withdraw more than 7,000 to 8,000 acre-feet annually from wells; however, it is estimated that irrigation of the entire area would require less than 7,000 acre-feet of water annually.

Most wells in the Yelm area have been dug or drilled for domestic, stock, irrigation, and public supply use, in order of decreasing numbers. Many well casings are perforated, but the Yelm municipal well is the only one that is screened. This is the largest-producing well on

the prairie, yielding 550 gallons per minute (gpm) with a drawdown of 0.16 foot. The present use of ground water on the prairie amounts to about 1,000 acre-feet per year, and increased irrigation use probably will increase this figure severalfold within the next 5 years.

The quality of ground water throughout the Yelm Prairie is generally good, however some water contains an objectionable amount of iron.

INTRODUCTION

This report, one of a series on the ground-water resources of the State of Washington, gives the results of an investigation in the vicinity of Yelm, Wash. The investigations upon which these reports are based are conducted cooperatively by the Washington State Department of Conservation and Development, Division of Water Resources, and by the United States Geological Survey.

Location of Area and Scope of Investigation

The Yelm area, about 20 miles south of Tacoma and 15 miles southeast of Olympia, lies in the lowlands of the Puget Sound basin and includes the agricultural lands surrounding the city of Yelm, in Thurston County, and a small area in Pierce County north of Yelm. The area covered by the investigation contains about

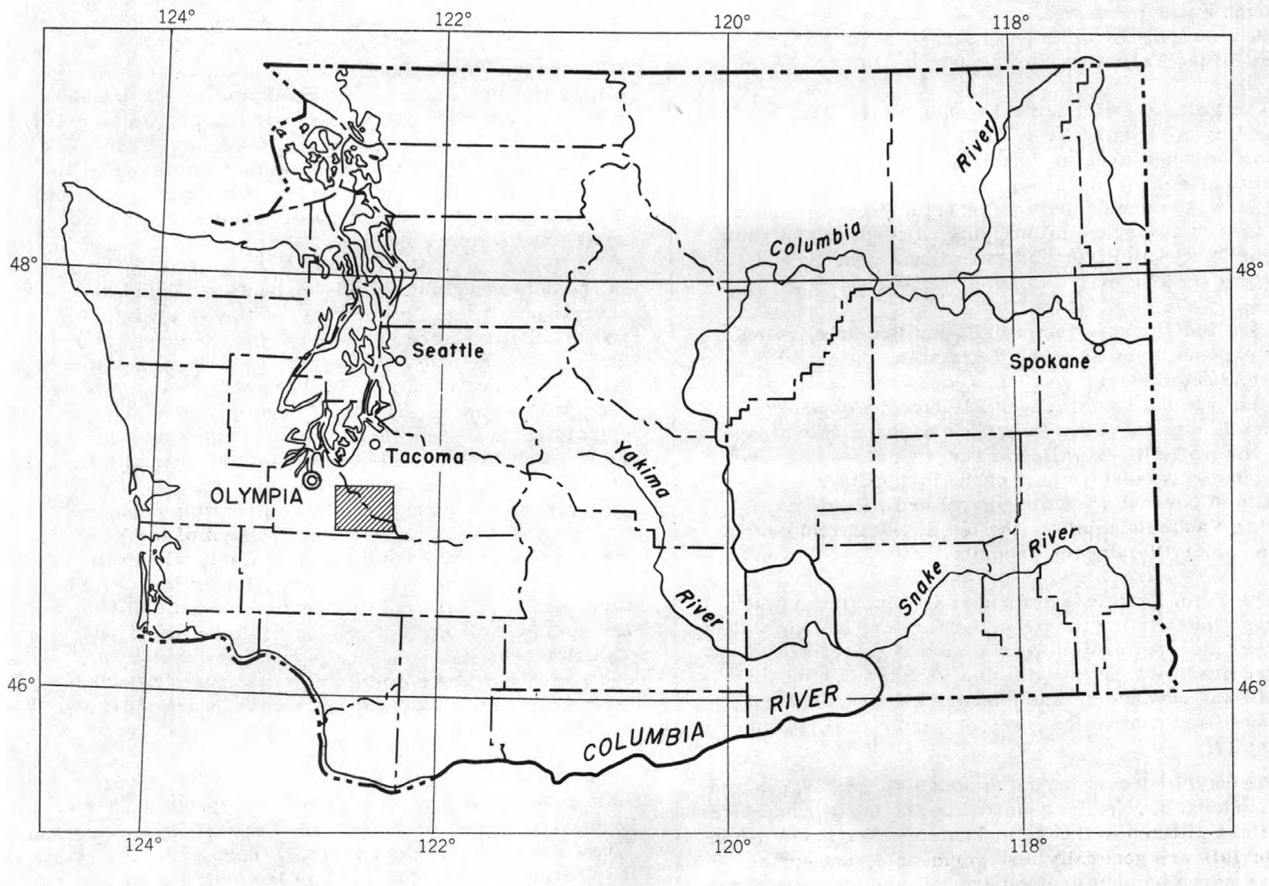


Figure 1.—Map of the State of Washington showing area covered by this investigation.

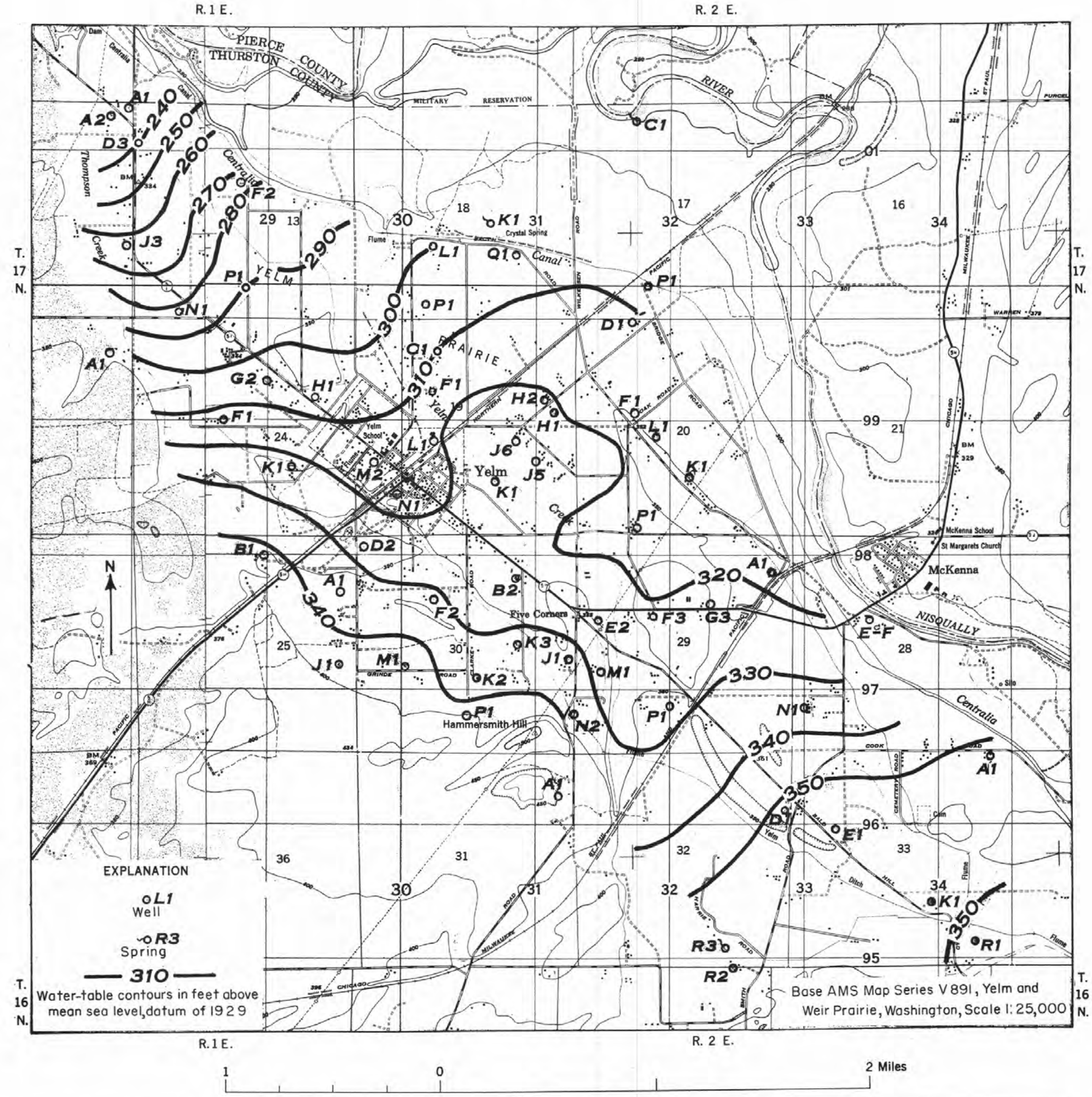


Figure 2.—Map of Yelm Prairie showing well locations and contours on the water table, November 1951.

218 square miles, mostly within the Yelm quadrangle, but it also includes a narrow strip along the western margin of the Ohop Valley quadrangle, which adjoins the Yelm area to the east. The location of the area is shown on the index map, figure 1. The investigation was concentrated on the Yelm Prairie, an area of about 11 square miles (see fig. 2).

Interest in the possibility of utilizing ground water developed when the Yelm Irrigation District voted to discontinue operations at the end of the 1950 irrigation season. The district included a total of 6,532 acres, of which about 4,500 acres was irrigable. The water was obtained from the Nisqually River about 12 miles southeast of Yelm by means of the Yelm ditch. The ditch was in gravel and was unlined over much of its length; therefore, water losses were considerable. The topography of the district is sufficiently irregular to necessitate numerous and lengthy sections of wooden flume on both the main ditch and the laterals. This flume was expensive and difficult to maintain, and the district never had enough water to satisfy all users. Frequently, crops that had a good start would deteriorate later in the season because of a water shortage. It was because of the excessive maintenance expense and the insufficient delivery that the district voted to discontinue operation at the end of the 1950 irrigation season.

The investigation of ground-water resources in the area has included obtaining data on wells, measuring water levels in wells, measuring or estimating discharge of springs, analyzing streamflow and precipitation records, mapping the geology of the area, and analyzing and interpreting all of the data in terms of ground-water occurrence and availability.

Well-Numbering System

The numbers assigned to water wells in the State of Washington by the Geological Survey are based on the locations of the wells according to the rectangular system for subdivision of public lands, indicating township, range, section, and 40-acre tract within the section. For example, in the well number 17/2–18B1, the part preceding the hyphen indicates successively the township and range (T. 17 N., R. 2 E.) north and east of the Willamette base line and meridian. The first number following the hyphen indicates the section (section 18), and the letter (B) gives the 40-acre subdivision of the section as shown in the diagram. The last number (1) is the serial number of the well in that particular 40-acre tract.

D	C	B (B1)	A
E	F	G	H
M	L	K	J
N	P	Q	R

Because all townships in Washington are north of the Willamette base line, the letter "N" is always omitted. Because most of the State is east of the Willamette meridian the letter "E" is omitted for those ranges east of the Willamette meridian, but "W" is included when the range lies west of the Willamette meridian. Thus, the first well recorded in the NW1/4NE1/4, sec. 18, T. 17 N., R. 2 E. would have the number 17/2-18B1. The second well in the same 40-acre tract would be numbered 17/2-18B2. A well located west of the Willamette meridian would have a number such as 16/1W-12A1.

Acknowledgments

The well records were obtained from well owners and users, well drillers, and pump companies. The friendly cooperation of these people and all other residents in the area is gratefully acknowledged. The cooperation of personnel of the State Division of Water Resources is also acknowledged.

GEOGRAPHY

The Yelm area lies within the Puget Trough, a topographic and structural lowland extending from north of the Canadian border southward into Oregon. The western margin of this lowland is formed by the Olympic and Coast Ranges and the eastern margin is formed by the Cascade Range. Except for scattered "islands" of older and harder consolidated rocks, the entire basin has been partly filled with unconsolidated fluvial and glacial materials of Pleistocene age.

Surface Features

The Yelm area is at the southeastern margin of Puget Sound. The southern margin of the area is formed by maturely dissected hills of Tertiary rock against which the Pleistocene ice mass terminated; elsewhere, the boundaries cannot be identified by a particular physiographic feature. The surface of the area has a moderately low relief and consists of several upland segments, including plains and terraces which at many places are separated by prominent scarps. All of the surfaces are related to Pleistocene glaciation, and three different types, corresponding to different modes of origin, can be distinguished. These are outwash terraces or plains, till plains, and recessional moraines.

Bordering the Nisqually River, and extending northwestward across the area, are outwash terraces on which the Yelm Irrigation Project is located. Other outwash terraces and plains extend along the Deschutes River, and an outwash plain, several square miles in extent, lies immediately northwest of Rainier. A large part of the area between the Nisqually and Deschutes drainage systems is occupied by a rather flat poorly drained expanse of till plain, which is partially interrupted by re-entrants of outwash channels leading to the main outwash terraces paralleling the two rivers. Elsewhere, the till plain is interrupted by several large patches of hummocky moraine.

The surface features are largely a product of glaciation by an ice sheet moving from the north during Pleistocene time. The surface has had a rather complex development, which will be described in more detail in the section on glacial geology.

Climate

The climate of the Yelm area is typical of the Puget Sound basin; it is wet and cool in the winter months and warm and dry during the summer (fig. 3).

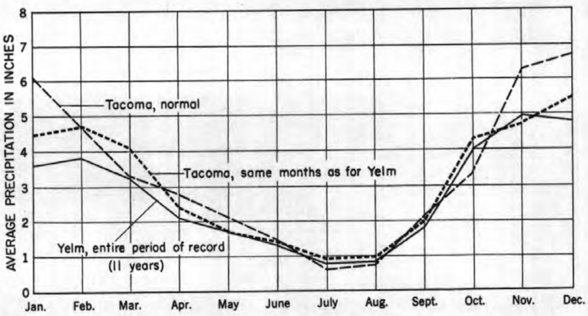


Figure 3. —Comparison of average monthly precipitation at Yelm and Tacoma.

The only weather station in the Yelm area is located about 1 mile southeast of the center of Yelm. The available record, beginning in 1940, is incomplete, but monthly summaries are available for at least 8 years. Precipitation data for the period of record are given in the table on page 5.

The distribution of precipitation at Yelm is similar to that at Tacoma, except for a somewhat smaller maximum in the winter months. Comparison of the two records for the same period of record is instructive and enlightening. The average annual precipitation at Yelm for the period of record is 33.28 inches, but records of the Tacoma station for the same months as those tabulated for Yelm give an average annual precipitation of only 36.95 inches as compared to 40.40 inches at Tacoma (72 years). The average annual precipitation of 33.28 inches at Yelm is just 90 percent of the average annual precipitation at Tacoma for the same period. On this basis, the normal precipitation at Yelm for the period of record corresponding to Tacoma's record would have been 36.36 inches. Such a long range correlation probably is somewhat inaccurate; nevertheless, Monthly precipitation, in inches, at Yelm for period of record

[Data from U. S. Weather Bureau]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940......	....	....	....	....	....	....	....	....	....	4.02	3.06	2.56	....
1941......	3.26	1.19	....	....	3.06	0.83	0.00	2.03	2.81	2.10	4.61	6.58	....
1942......	2.47	1.69	1.48	1.01	....	....	1.41	.27	.15	....	....	....	....
1943......	....	....	3.36	2.61	1.57	....	....	.87	.24	3.66	1.78	2.22	....
1944......	3.53	2.16	1.31	....	....	.79	.00	.56	1.42	....	3.11	1.51	....
1945......	3.33	5.48	3.18	3.22	2.36	.21	.28	.70	2.95	2.38	5.15	5.41	34.65
1946......	4.63	5.13	3.90	1.68	.97	3.70	.91	.55	3.50	4.09	5.99	6.04	41.09
1947......	....	....	2.80	2.41	.00	1.61	1.61	.41	1.22	7.88	2.84	4.68	....
1948......	4.54	6.07	4.12	3.35	4.03	1.61	1.71	1.84	*3.16	2.76	6.19	*7.33	*46.72
1949......	.43	6.36	2.67	.94	2.13	.78	.32	.31	1.10	2.98	7.68	5.96	31.66
1950......	6.68	6.26	6.25	2.53	.72	.62	.75	.91	1.70	6.40	9.10	6.17	48.08

Average for 10-year period

	3.61	3.82	3.23	2.22	1.85	1.27	.78	.85	1.82	4.03	4.95	4.85	33.28

Tacoma, average precipitation for identical months as tabulated for Yelm

	4.47	4.65	4.07	2.40	1.84	1.38	.86	.90	1.95	4.27	4.82	5.34	36.95

Yelm average precipitation, percent of average at Tacoma for identical months

	81	82	79	92	100	92	91	94	93	94	102	91	90

Normal monthly precipitation at Tacoma

	6.14	4.69	3.48	2.78	2.12	1.46	.60	.74	2.09	3.33	6.26	6.71	40.40

*Estimated from nearly complete data.

it is probable that the precipitation at Yelm is roughly 90 percent of that at Tacoma. The data suggest also that the average precipitation during the past 10 years has been considerably less than the average for the past 72 years. Figure 3 shows a graphical summary of the data in the preceding table.

The largest part of the precipitation on the Puget Trough is derived from air moving from the southwest in connection with low-pressure systems moving in from the Pacific. It is likely that the ranges of small mountains and hills to the south, southwest, and west of the Yelm area produce a minor orographic effect and remove part of the moisture from the air moving from that quadrant. The Tacoma area is blocked less effectively, because a low pass extends south-southwestward from Tacoma to the Pacific. This difference in topography may account for the greater amount of precipitation at Tacoma.

No temperature data are available for Yelm. However, temperature records for the weather stations at Tacoma, Olympia, and Centralia, respectively north, northwest, and southwest of Yelm, correspond so closely that temperature records of any one of the three stations could be used with only slight error. It is probable that the temperatures at Olympia correspond most closely to those at Yelm. The coldest month at Olympia is January, with a mean temperature of 38.4° F. The hottest month is July, with a mean temperature of 63.6° F. The mean annual temperature is 50.8° F.

The average number of days between killing frosts at Olympia, based on 71 years of record, is 194. Freezing temperatures are not rare but normally do not persist more than a few days. The soil occasionally may freeze to a depth of a few inches for several days, but this is exceptional even in the coldest month. These freezing conditions rarely prevent downward seepage of the precipitation because the freezing temperatures occur when the area is occupied by drier, colder air of inland origin. Southwest winds carrying most of the precipitation reflect the higher temperature of the Pacific Ocean.

The amounts of snowfall vary, but average about 12 inches per year on the prairie, which is equal to about 1 inch of water, or less than 3 percent of the total precipitation. The proportion is somewhat higher on the hills to the south of the area. The snow cover has little effect on the ground water other than to insulate the surface against subfreezing temperatures; its water content is usually added to the general water supply rather abruptly by rain. The snow rarely persists more than a week.

Drainage

All the drainage in the area is into two major through-flowing streams, the Nisqually and Deschutes Rivers. The Nisqually River, fed by glaciers on the south flank of Mount Rainier, flows in a northwesterly direction into Puget Sound at a point about 10 miles northeast of Olympia. The now-defunct Yelm Irrigation Project is located on the outwash terrace of the Nisqually River about 10 miles above the mouth. The Deschutes River, rising in hills of Tertiary rock southeast of Yelm, follows a course roughly parallel to, and 5 to 10 miles south of, the Nisqually and empties into Puget Sound at Olympia. The divide area between the two drainages is a nearly continuous upland consisting of flat till plains and hummocky moraine. The tributary drainage consists of springs and short, narrow creeks that are fed chiefly by ground water.

The present drainage pattern is largely a product of the Pleistocene glaciation and therefore is discussed more fully in the section on geology.

GEOLOGY AND WATER-BEARING CHARACTERISTICS OF THE MATERIALS

The rocks of the area can be separated into two groups which are quite dissimilar both as to age and to lithology. The geology of the area is shown on plate 1.

Consolidated Rocks of Tertiary Age

The older rocks, which are of Tertiary age, are consolidated "hard" rocks chiefly of volcanic origin, but at a few places they include sedimentary shale and siltstone. Tertiary rocks south and west of the Yelm area have been mapped and described recently by Snavely (Snavely and others, 1951). The Yelm area, as described in the present report (pl. 1), includes narrow strips along the south end of the eastern margin and along the west end of the southern margin of the area shown on the map by Snavely. According to Snavely, all the Tertiary rocks in those small areas belong to the Northcraft formation, which is of late Eocene age. The Tertiary rocks in the remainder of the Yelm area have not been differentiated in detail; however, they have been observed at numerous places, and apparently most of them should be included in the Northcraft formation.

The Tertiary rocks in the Yelm area are chiefly of volcanic origin, including andesitic lava flows, breccia, and other pyroclastics. Coarse basaltic conglomerate was observed at several places south and east of Vail.

Along State Highway 5H, about 3½ miles southwest of Rainier, are exposures of tuffaceous siltstone and shale of the McIntosh formation, ranging in age from middle to late Eocene (Snavely and others). 1/ Only a few small exposures occur in the Yelm area, within the Yelm quadrangle. Except for the small areas of the McIntosh formation, all the Tertiary rocks in the Yelm area are believed to belong to the Northcraft formation. On the geologic map no attempt was made to distinguish the McIntosh from the Northcraft formation.

The Tertiary rocks are moderately hard and compact and generally have a low permeability. At places they have been weathered deeply, and dug wells yield sufficient water from the weathered material for domestic use. In the unweathered rock, water occurs chiefly along fractures and bedding planes, and wells drilled in the Northcraft formation probably will yield only small supplies. Larger supplies might be obtained from sand or sandstone in the McIntosh formation. However, because the Tertiary rocks occur only in the sparsely populated hilly or mountainous areas, they are relatively unimportant as aquifers.

1/ Snavely, Park D. Jr., and others, in preparation, 1955.

Pleistocene Formations

Logan Hill Formation

In the extreme southeastern corner of the Yelm area cemented rusty gravels form a dissected ramp between the high hills of Tertiary rock to the south and the valley of the Deschutes River. These deposits crop out over several square miles east and south of the area included on the geologic map, chiefly along Johnson and Thurston Creeks at altitudes of 700 to 1,000 feet. They consist of porphyritic and even-textured pebbles of volcanic rock, chiefly andesitic (some may be basaltic), in a sandy and clayey matrix. The pebbles are of marble to golf-ball size, with a few larger cobbles, and generally are greatly decayed and stained a rust-red color. The deposits are rather compact and hard, apparently owing chiefly to cementation by iron oxide and to breakdown of grit and sand grains to form a clayey binder. Generally they are rudely stratified, and lenses of yellow and rusty sand are common. The general appearance, which is that of a semiconsolidated rusty-red gravel, is quite striking and distinctive because the area has virtually been stripped during recent logging operations, thus leaving the gravel well exposed.

The gravel deposits have been traced eastward to LaGrande and Alder, about 6 and 8 miles respectively east of the area shown on the map. At the bend of the Nisqually River, about ½ mile north of LaGrande, nearly 200 feet of the gravel is exposed in the bluff, On the upland bench, north of Alder, the gravel appears to be interbedded with glacial till. The gravel has not been traced downstream along the Nisqually into the Yelm area; however, along the left bank, at the northern boundary of section 13, T. 16 N., R. 2 E., weathered, tightly cemented gravel is exposed from the level of the river to the level of the Yelm ditch, nearly 40 feet above the river. The gravel appears to be more tightly cemented and indurated than the overlying pre-Vashon gravel deposits and may be part of the same unit that is exposed along Johnson and Thurston Creeks.

Gravel, similar both lithologically and physiographically, has been described recently by Snavely (Snavely and others, in preparation) southeast of Chehalis (Lewis County) under the name "Logan Hill" formation and tentatively correlated with the Satsop formation of Pleistocene age. The gravel in the Yelm area is similar in occurrence and origin to the Logan Hill formation and undoubtedly should be considered a part of that unit.

The Logan Hill formation occupies less than 1 square mile within the area included on the geologic map, plate 1, and no wells are known to obtain water from this unit within the area. However, in other areas moderate supplies of water have been obtained from permeable sand and gravel in the formation.

Pre-Vashon Glacial Deposits

Indurated and compact sand, gravel, and till, with occasional lenses of clay, crop out almost continuously along the valley of the Nisqually River. A greater degree of induration, more intensive weathering, and a different lithology distinguish these strata from the overlying Vashon drift.

The only identified outcrops of these strata within the Yelm area are along the valley of the Nisqually River. Elsewhere, the presence of these deposits beneath much of the area is inferred from well logs. Along the Nisqually, from the intake of the Centralia Power Canal about 4 miles southeast of McKenna to beyond the northern boundary of the Yelm quadrangle, the river has cut down sharply below the general prairie level. Vertical or nearly vertical bluffs, 50 to more than 150 feet high, border the river at numerous places, and along a number of these bluffs the exposed strata were examined in detail. Although talus slopes covered the strata at the bases of many of the bluffs, at several places the river is actively eroding at the bases of the bluffs with the result that the strata are exposed down to the river's edge. The basal strata at all these locations belong to the glacial deposits of pre-Vashon age, except at a few upstream locations where the basal deposits may belong to the underlying Logan Hill formation.

The deposits are chiefly cemented gravel, but sand, silt, clay, and till also are present.

The gravel consists chiefly of volcanic materials, including porphyritic andesite, fine-grained andesite and basalt, rhyolite, vesicular andesite and basalt, breccia, and scoria. Also included are minor amounts of granitic and dioritic intrusive igneous rocks and some pebbles of sedimentary rocks such as sandstone and shale. The materials range in size from fine sand to enormous boulders, but the general appearance is that of a coarse gravel with a fine-grained, gritty matrix. Sorting is very poor, and stratification generally is not apparent although some beds that contain very large (as great as 10 or 12 feet in maximum dimension) angular boulders, chiefly of volcanic origin, seem to persist for considerable distances along the river. The gravel generally is dark brown to rusty drab.

Interbedded in the gravel are beds of sand and, rarely, silt or clay. The sand is generally fine to medium grained, yellowish to rusty, and consists chiefly of dark rock and mineral grains with minor amounts of quartz and light-colored rock grains. Some of the sand shows crossbedding and foreset bedding. Like the gravel, the sand is moderately indurated. The clay and silt are generally dark and massively bedded. The beds of both the sand and clay are lenticular and generally do not persist for more than a few hundred yards. At several places glacial till was found interbedded in the gravels. The till could not be traced for more than a few hundred feet and was only a few feet thick. The till was found at various altitudes and appeared to occur in different horizons. It is believed that more than one advance of glacial ice is represented, although this thesis was not proved.

The materials in the gravel have been considerably decayed by weathering and alteration. Many of the pebbles are completely decomposed. The smaller grains generally have been altered so extensively that they form a clayey matrix which, together with cement formed by iron encrustation, serves as the most important binding material. The degree of induration and cementation is sufficient that vertical and even overhanging bluffs are common. Generally, however, the pebbles or cobbles pull out rather than break across, except for those that are particularly friable or considerably decayed.

The maximum thickness of the pre-Vashon glacial deposits in the area is not known, because their base is not exposed in the area, and few if any wells have been drilled completely through them. The maximum measured section at any one place was 106 feet, but the total thickness along the Nisqually River, judging from altitudes at which these deposits have been found, may be several hundred feet.

The types of rocks in these deposits are characteristic of the Cascade Mountains to the east. The very large boulders of relatively soft material, such as scoria, breccia, and sandstone, could not have traveled very far. What appeared to be the same boulder zone was observed at several places along the Nisqually River at about the same height above the stream, so at least some of these strata have about the same westward slope as the present stream. The presence of till proves glacial origin for at least the till beds, and, together with the coarseness and poor sorting of the remainder, strongly suggests a glaciofluvial origin for the gravel. The evidence appears quite conclusive that these materials were deposited as glacial and glaciofluvial debris of a valley glacier originating in the Cascade Mountains to the east.

The base of the pre-Vashon deposits and their contact with the underlying strata is not exposed in the area, but there are many excellent exposures of the contact with the overlying drift. On the north bank of the Nisqually River, in the SW1/4NE1/4 sec. 12, T. 17 N., R. 1 E., about $2\frac{1}{2}$ miles due north of Yelm, in a cliff about 150 feet high, the top of the pre-Vashon deposits is marked by a soil horizon which developed on an old erosion surface. The soil zone is about 6 inches to 2 feet thick and developed at various places on gravel, on sand lenses, and, in one place at least, on a lens of tough brown till. Elsewhere, the contact with the overlying Vashon deposits is marked by an erosional unconformity.

The age of these glacial deposits is certainly pre-Vashon and, on the basis of physiographic relations and comparable degrees of weathering and cementation, is thought to be post-Logan Hill. Further mapping upstream on the Nisqually east of the Yelm area may show definitely that these older glacial deposits overlie the Logan Hill formation.

Although the pre-Vashon deposits crop out only in the bluffs along the Nisqually River, they underlie the Yelm Prairie and other outwash prairies as well as most of the till plains. Where examined along the bluffs of the Nisqually River the pre-Vashon strata are predominantly gravel with lenses and interbeds of sand that generally are only a few feet thick but aggregate possibly 20 to 25 percent of the total. Till was seen at a number of places, and it is thought that at least two different pre-Vashon tills are represented. Clay was found at only a few places. Clay is mentioned a number of times in the well logs, but usually in connection with sand and gravel, which is to be expected, because clay and sand form the matrix for much of the gravel. Many of the well logs indicate "hardpan" in some wells at three different levels. Probably some of these "hardpan" strata actually are till, but it is doubtful that all are till. It would be extremely difficult, in drilling a well, to distinguish a compact gravel having a sand and clay matrix from a till. Alteration and weathering in the uppermost strata have considerably reduced the porosity and permeability. The upper part of this unit therefore not only yields little water, but also it impedes downward percolation of ground water to such an extent that the water table is everywhere above the top of the pre-Vashon glacial deposits.

At depth in these deposits, generally 25 to 50 feet below the top, alteration and cementation have been less, so that moderate to large supplies of ground water can be developed from them. However, at many places the shallower aquifers above the pre-Vashon deposits yield sufficient water; therefore, relatively few wells have had to be drilled into the pre-Vashon deposits. Inasmuch as most wells that have been drilled into them also obtain part of their water from shallower aquifers, it is difficult to evaluate the water-yielding capacity of the pre-Vashon deposits.

Yields of wells that obtain part or all of their water from the pre-Vashon glacial deposits are listed below. In most of these wells the casings were perforated at several depths, and the well logs indicate that water is being obtained from both Vashon drift and the pre-Vashon deposits.

In the sections examined along the Nisqually River bluffs, the entire exposed column of pre-Vashon deposits generally appeared to have a very low permeability. However, the well records indicate that the deposits are moderately permeable at many places. This discrepancy may be due to an effect noted by the writer and other observers at a number of places—that is, apparent concentration of cementing materials and, possibly, increased alteration of the face (and probably extending several feet back from the face) of a bluff or cliff which has been exposed to the weather for a considerable length of time. This results in what might be termed "case-hardening" of the exposure and leads to misconception as to the true porosity and transmissibility.

Well no.	Yield (gpm)	Drawdown (feet)	Remarks
16/1-6J1	19	0	Reported data
16/2-2K2	38	20	Do.
16/2-4A2	45	0	Bailer test
16/2-7Q1	248	62 or less	Pumping test reported
17/1-13D2	50	....	Reported data
17/1-23B1	165	6	Pumping test reported
17/1-24L1	360	5.26	Pumping test
17/2-32Q2	600	55	Do.
17/2-33K2	90	80±	Pumping test reported
17/2-33R1	90	140	Do.

Few of the wells are more than 150 feet deep. It is possible that there are more permeable strata at greater depths. In the absence of more specific data, about all that can be said is that supplies of 50 to 100 gpm probably can be obtained from the pre-Vashon deposits at most places where 50 feet or more of these sediments is penetrated.

Vashon Drift

Nearly all the surface deposits in the Yelm area consist of sand, gravel, and till of the latest glaciation. The materials are relatively fresh and unaltered. In addition to the fresh appearance, an outstanding and distinctive feature is the presence of considerable quantities of pebbles, cobbles, and boulders of granite, gneiss, quartzite, and other igneous and metamorphic rock types that are either uncommon or entirely foreign to the surrounding area. These deposits were named the Vashon drift by Willis (1897 [1898]) and are shown on the geologic map of the Tacoma quadrangle published by Willis and Smith (1899). They were shown by Bretz (1913) to mantle the Puget Sound lowland more or less completely from the Canadian border to Centralia. The extent of the Vashon drift in the Yelm area is shown on the map, plate 1. About 84 percent of the area on this map is occupied by the four mappable units into which the Vashon drift was subdivided.

The Vashon drift was deposited both by the ice and as outwash from a great tongue of ice extending southward from Canada. In large part, the ice accumulated in ice fields in Canada and northern Washington, but it may have been fed also by glaciers to both the east and the west of Puget Sound.

<u>Advance outwash.</u>—As the ice moved southward large quantities of sand and gravel were deposited by meltwaters at the front and sides of the ice mass. In the Yelm area, advance outwash is exposed chiefly in the bluffs along the Nisqually River. A few patches occur also as small inliers in the areas mapped as recessional moraine. At most places the advance outwash is represented by strata not more than a few tens of feet thick, but at the mouth of Thompson Creek the advance outwash is about 90 feet thick.

The deposits consist typically of poorly to moderately well-sorted, well-rounded gravel in a sandy matrix, interbedded with lenses of sand. Crossbedding is common, and foreset bedding was observed at many places. The materials have a fresh, unweathered appearance and appear to be moderately to very permeable. The pebbles and cobbles are predominantly of volcanic rocks of many types, apparently derived from parent rock in the Cascade mountains or foothills at no great distance, but an appreciable percentage consist of granitic and metamorphic rock of types known to crop out a hundred miles or more to the north.

Advance outwash was observed directly overlying the pre-Vashon deposits at a number of places. Wherever a sharp contact was seen it was marked by an erosional unconformity. The advance outwash is overlain at most places by either till or recessional outwash; in both cases the contact is erosional.

Because the advance outwash consists predominantly of permeable sand and gravel, it is one of the most important aquifers in the area. The average thickness of these strata, as shown by 15 well logs, is about 22

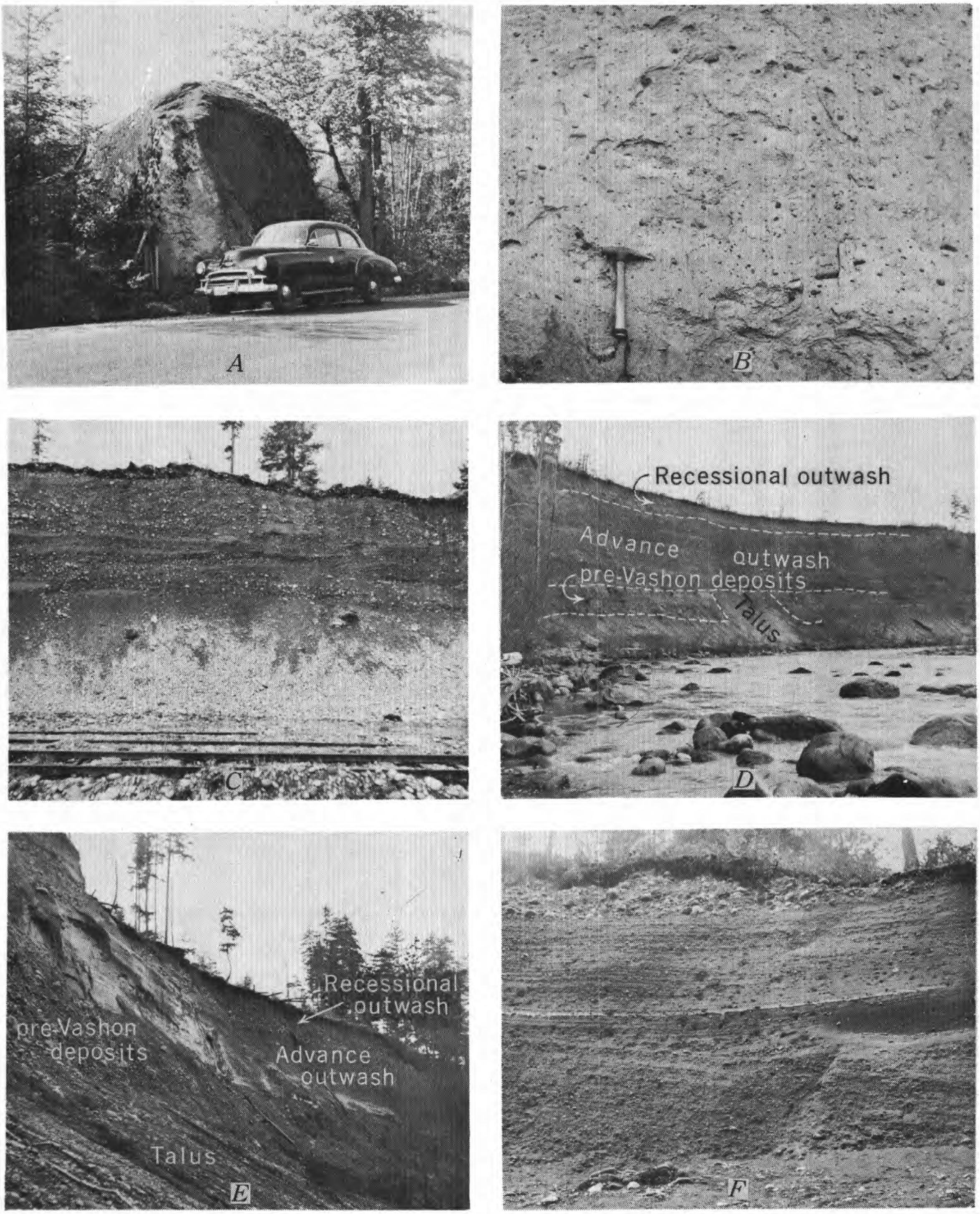


Figure 4.—A, Granite erratic on till plain near Lake Lawrence (16/2-20B). B, Face of cliff showing typical dense, compact, impervious character of till. C, Recessional outwash gravel exposed in gravel pit (16/1-7M) at end of outwash plain $2\frac{1}{2}$ miles east of Rainier, showing poor sorting and lenticular character of beds. D, Typical exposure along Nisqually River. Recessional outwash overlies advance outwash, which overlies pre-Vashon deposits. Boulders have not been transported by the present river but merely reworked from the boulder horizon extending 20 to 30 feet above river level. E, Poorly sorted recessional outwash overlying advance outwash, which in turn overlies pre-Vashon cemented gravel. Along south bank of Nisqually River about 2 miles northeast of Yelm. F, Closer view of recessional outwash overlying advance outwash at locality shown at left (E).

feet. A few wells failed to encounter advance outwash, either because it was never deposited at those places, or because it was removed by erosion prior to deposition of succeeding strata.

At most places, it is probable that one-half to three-fourths of the total thickness of advance outwash is permeable enough to serve as an aquifer. The two best wells on the Yelm Prairie, well 17/2-19N1 belonging to the town of Yelm, and well 17/2-29L4 belonging to Gilbert Roehr, obtain all their water from the advance outwash. The total thickness of permeable sand and gravel of the advance outwash was 27 feet in the Yelm municipal well and 14 feet in Gilbert Roehr's well.

Several wells on the till plain south of the Yelm Prairie obtain water from advance outwash, and it is probable that supplies sufficient for irrigation could be obtained from the advance outwash at many places.

Till.—Till deposited directly by the ice from the north covers more area in the Puget Sound lowland than does any other unit. At most places, the till is readily recognizable because of its characteristic appearance, particularly when fresh, as shown on figure 4B.

Unweathered, it is a gray to light-bluish-gray concretelike mixture of clay, silt, sand, pebbles, cobbles, and boulders. Typically, silt predominates, and the pebbles and coarser sizes are spaced in a fashion similar to raisins in raisin bread. The whole aspect is one of toughness and compactness. The till breaks with a unique "spalling" fracture (fig. 4B). The pebbles and cobbles contained in the till are also diagnostic; most of them are quite fresh and unaltered. They vary greatly in shape but are often faceted, and subangular to subrounded. Volcanic materials of all types predominate, but pebbles of granite, quartzite, and metamorphic rock also are found in considerable quantities at most places.

The till is subglacial and was deposited as a sheet at the base of the ice, and when deposited it formed a mantle covering the pre-ice topography. One of the main features of this pre-ice topography in the Yelm area was the Nisqually River valley. The pre-ice valley apparently was not so deep as the present valley. The pre-ice valley apparently was not so deep as the present valley, because till of Vashon age crops out in the present valley wall at a number of places, but at no place was it found to crop out as low as stream level. Till of Vashon age is found beneath recessional outwash gravel at several places along the scarp separating the Yelm Prairie from the Nisqually Valley, and well logs indicate that till of Vashon age generally is found underlying the outwash gravels that form the prairie, although at places the till was entirely removed by erosion before the recessional gravel was deposited. South of the Yelm Prairie, till mantles a large part of the surface, and in general this area was eroded very little after recession of the ice. The surface is typical of till plains—rolling and poorly drained, with numerous swamps and characteristically dense vegetation. One of the most striking features is the number of large, angular boulders of granite and gneiss (glacial erratics). The largest granite boulder found is located about 0.5 mile north of Lake Lawrence (see fig. 4A).

At its maximum southward extent the ice rode up on the northern flanks of the hills south of the Deschutes River. Till of Vashon age was found mantling many isolated low hills north of the main ridge and also on Jonas Hill, 2 miles southeast of Vail. On Jonas Hill, till caps the summit, and several large granite boulders were found at the top at an elevation of about 1,160 feet.

West of Vail, till caps benches on both sides of Johnson Creek at elevations as high as about 850 feet. The till is very thin on these benches and it is probable that the ice also was quite thin. The approximate maximum extent of the ice sheet and the marginal drainage at the time of, or shortly after, the maximum extent are shown on figure 5.

At most places the till is not very thick, probably averaging 15 to 20 feet. The greatest known thickness is 52 feet, as shown in the log of well 17/1-13D2. Because the till is generally very compact and nearly impervious, it is a very poor aquifer. However, weathering of the top few feet produces a moderately permeable soil and subsoil that may yield enough perched water for domestic purposes. At some places, thin lenses of more permeable materials within the till also may yield small supplies of water. Generally these supplies are quite variable and are not dependable during dry periods.

Recessional moraine.—Several upland areas south of the Nisqually River have been mapped as recessional moraine. The largest area occupies approximately 15 square miles west of Yelm. A second area includes 5 square miles south of Yelm and east of Rainier. The third area includes slightly more than 4 square miles (within the area of the map) southeast of Yelm and west of the Bald Hills. In all three areas the surface is characterized by the irregular "kettle and kame" topography, which is typical of end and recessional moraines. It is apparent that as the ice began to melt back from its maximum extent these particular areas were covered by ice after the surrounding terrain was ice free.

Many of the kettles appear to be floored with till and contain swamps or lakes. Others are dry because the till is far enough below the surface to permit the water to drain out laterally through more permeable overlying deposits. Probably the larger part of the surface is occupied by outwash, but till occupies innumerable irregularly shaped areas. Unlike the till plains, where the ice apparently melted down rather uniformly (thus allowing the debris contained to be carried off the plains by the meltwater and deposited in outwash channels and as outwash plains), in the morainal areas the ice became stagnant and separated into numerous blocks, around each of which outwash debris accumulated. As the ice blocks wasted away, conical hills of outwash (kames) were left between the hollows (kettles) that remained after the ice had completely melted.

Some of the sand and gravel in the morainal areas is moderately well sorted and very permeable. Wells drilled into these deposits will yield moderate to large supplies of ground water. Because the outwash in the kames is generally quite permeable, the water table beneath the kames may be little higher than in the surrounding lower areas.

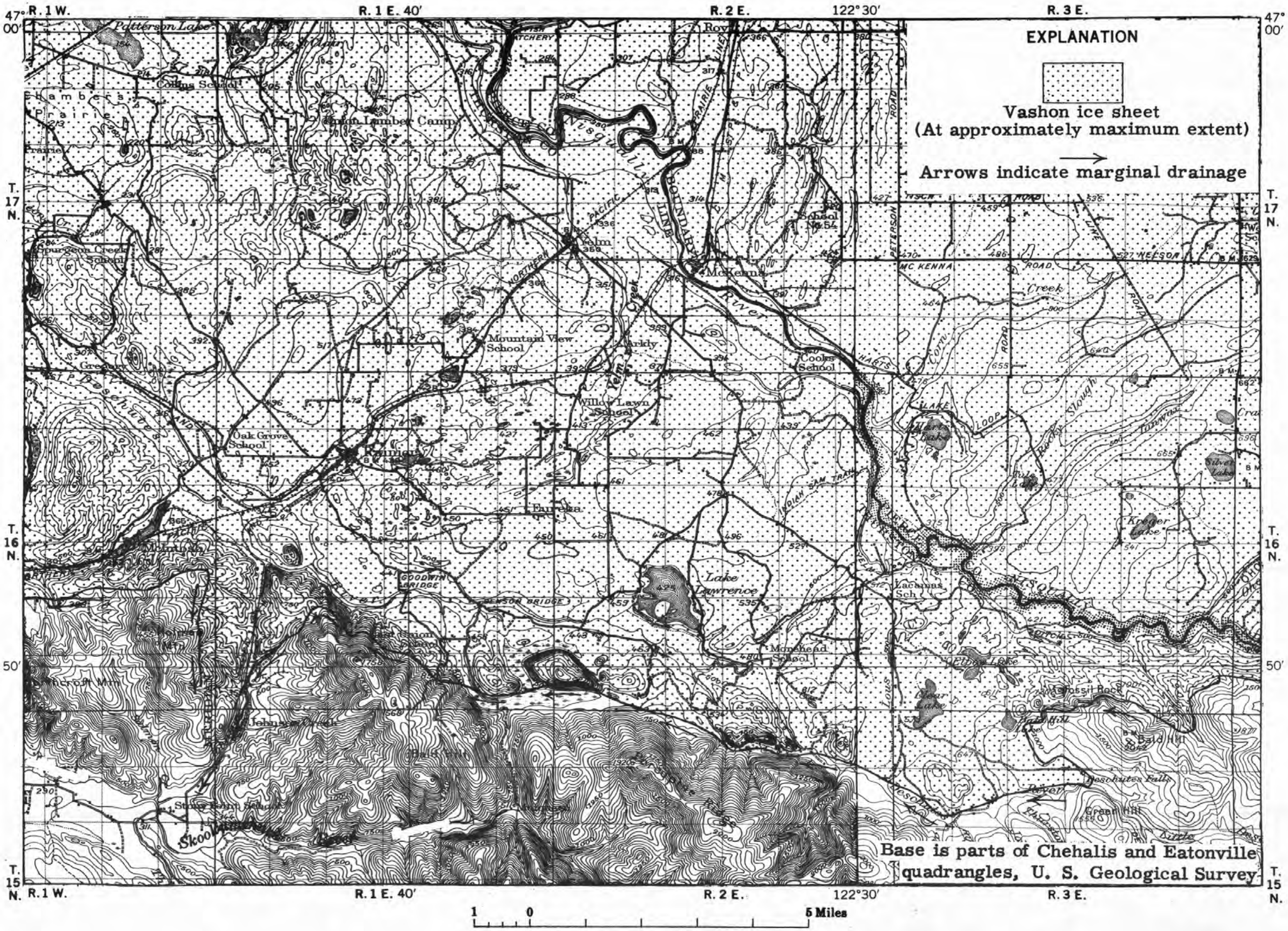


Figure 5.—Map of Yelm area showing approximate maximum extent of Vashon ice sheet.

Largely because of the irregular topography, the land is unsuited for agriculture; hence, most of the area of recessional moraine is uninhabited. Ground water is utilized for a few domestic supplies, chiefly around the margins of these areas.

Recessional outwash.—Prior to the advance of the Vashon ice sheet, drainage in the Puget Sound area had been northward into the Straits of Juan de Fuca. The advancing ice blocked this outlet with the result that during Vashon time the drainage was toward the south and southwest, reaching the Pacific Ocean by way of the lower Chehalis River valley (Bretz, 1913).

At the time of maximum extent of the ice in the Yelm area, the lowland was entirely covered by ice abutting against the hills to the south, blocking the former northward drainage. Drainage then became marginal between the southward-sloping ice and the northward-sloping hills. Apparently the only outlet southward within the Yelm area was south of Rainier through the Johnson Creek channel (Stony Creek channel of Bretz [1913]) into the Skookumchuck. Although one other pass was low enough to have carried glacial drainage southward, this is not considered to be a likely possibility. This passage is the low gap leading southward to the Skookumchuck through Mulqueen Junction from the valley on the south side of Jonas Hill. Bretz (1913) noted that no outwash of Vashon age could be found either in this passage or westward down the Skookumchuck, and he inferred that this gap did not serve as a drainage outlet. However, although he offered no further explanation he evidently believed that because the present pass in the Johnson Creek channel is only a little over 350 feet above sea level and because the Mulqueen Junction gap is between 600 and 650 feet above sea level, the drainage was entirely through the Johnson Creek channel because it was lower. However, detailed mapping during the present investigation, aided very greatly by the more accurate topographic maps now available and by complete coverage with vertical aerial photographs, shows that the altitude of the gap was not the controlling factor. The ice reached an altitude of more than 1,165 feet on Jonas Hill. West of Jonas Hill and on the flat hills on either side of Johnson Creek the ice reached an altitude of more than 850 feet. However, no till has been found on the north flank of Porcupine Ridge south of Jonas Hill. Bretz states that till and erratics are found on a bouldery ridge about 50 feet high which is separated from the base of the Porcupine Ridge by a swamp-floored marginal drainage channel, but that these deposits do not extend more than 50 feet above the floor—that is, above to an altitude of about 525 feet. This ridge has a core of Tertiary volcanic rocks and it is true that it is mantled with glacial debris, but the writers could find no till. Bretz found no till on the northern flanks of Porcupine Ridge, nor was any found during this investigation, although there are many nearly flat surfaces where till would have been preserved had it ever been deposited. The absence of till can be attributed only to the absence of ice. Obviously, the ice would have flowed around Jonas Hill and crowded up on the flank of Porcupine Ridge if the valley trending westward from Reichel Lake to Vail had been in existence at that time. The ice did not move in this manner, and the conclusion is reached that the terrain to the south was higher than Jonas Hill, and that instead of Jonas Hill being an isolated peak, it was part of the main mountain mass. Thus, the present valley separating Jonas Hill from the hills to the south was not in existence before the advent of the ice; instead, it was cut by an ice-marginal stream at the maximum extent of the glacier. Marginal drainage between the ice and the hills at the maximum extent of the ice was at an elevation of 900 to 1,000 feet, and the direction of this drainage was westerly to a point about 2½ miles west of Vail where it crossed a spur of these hills into the Johnson Creek channel at an elevation of more than 800 feet.

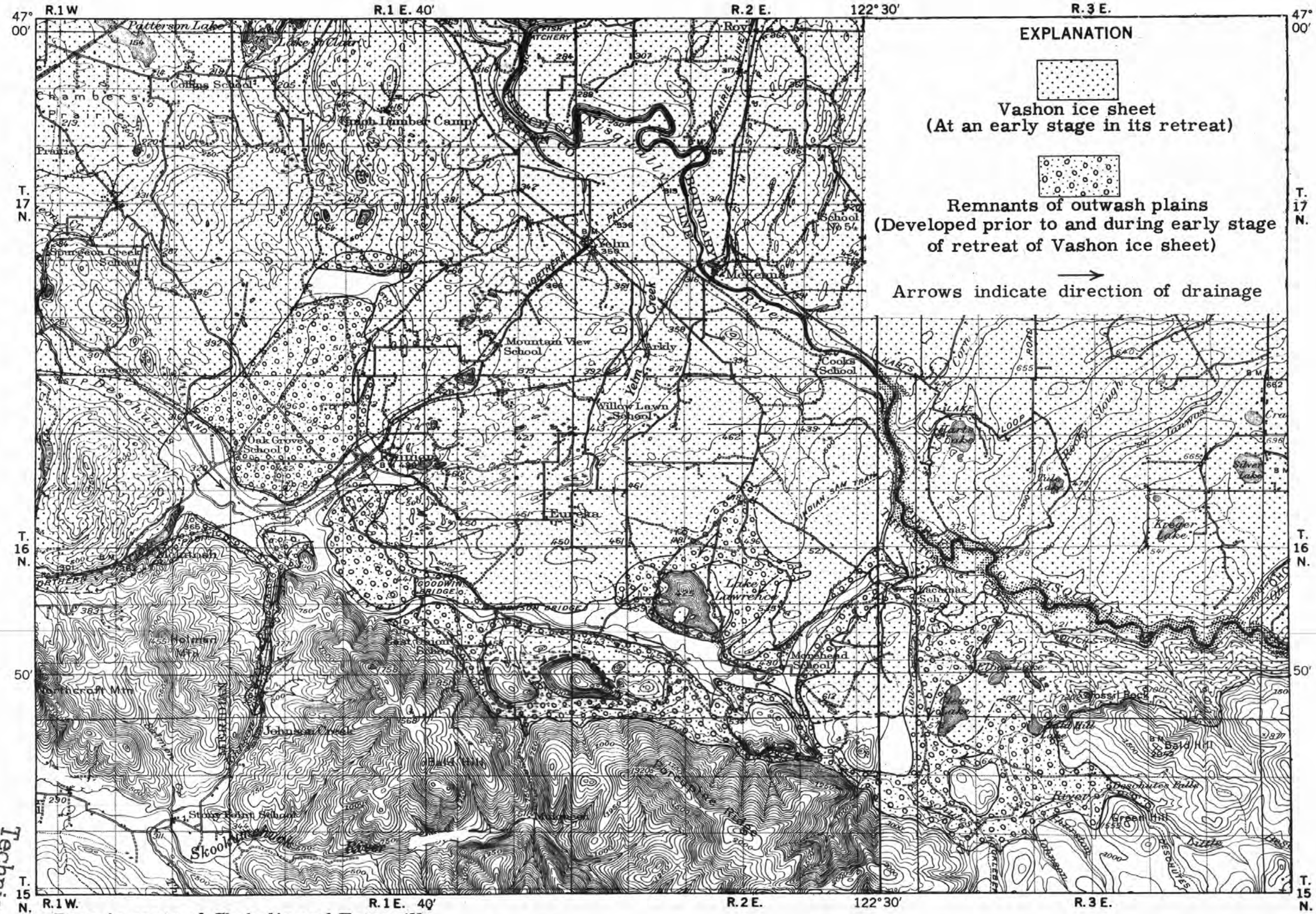
Prior to the advance of the Vashon ice sheet the Skookumchuck River flowed northward through the Mulqueen Gap, either flowing northward and parallel to the Deschutes River or discharging into the Deschutes River. At any rate, water from the Skookumchuck emptied into Puget Sound. The floor of the valley through the gap could not have been at an altitude of more than 500 feet, although later landslides have filled the center part of the gap to an altitude of slightly more than 600 feet. The mouth of the Skookumchuck Valley was blocked by the advancing Vashon ice sheet, and eventually a new outlet was cut, almost due west by south of Mulqueen Gap, so that the drainage now is westward into the Chehalis River and thence to the Pacific Ocean. There is considerable evidence that Mulqueen Gap and the present course of the Skookumchuck below the gap were occupied by a tongue of ice. The evidence includes (1) the U-shaped cross-section of the valley, (2) blocks plucked from the sill forming Miller Hill at the site of the quarry in sec. 11, T. 15 N., R. 1 E., (3) remnants of glacial till, (4) hanging tributaries and truncated ridge spurs, and (5) coarse moraine, consisting chiefly of boulders of the sill rock from Miller Hill, 3 to 4 miles downstream from the quarry.

The fact that only local rock materials are found in the till and moraine through Mulqueen Gap and downstream along the Skookumchuck suggests the possibility that the ice tongue may have been of local origin, forming at higher elevations in the drainage of the upper reaches of the Skookumchuck. According to this hypothesis, the local ice tongue would have been blocked near Jonas Hill by the advancing Vashon ice sheet, so that the melt water eventually spilled westward over a low divide south of Mulqueen Junction to cut a new lower course for the drainage of the Skookumchuck.

There is some evidence that the upper part of the Skookumchuck also was glaciated: flat-bottomed, bedrock-floored valley; hanging tributaries; truncated ridge spurs; and till-like deposits. However, although there are a few small cirques in the headwaters of the Skookumchuck, the lack of positive evidence of a large collecting area for local ice is a serious objection to the hypothesis of a local ice tongue in the Skookumchuck.

A complete account of the glacial history of the Skookumchuck Valley is outside the scope of this report, but it should be noted that the Skookumchuck River failed to return to its former northward drainage channel after the ice melted, because landslides in the oversteepened valley had blocked the valley at Mulqueen Junction.

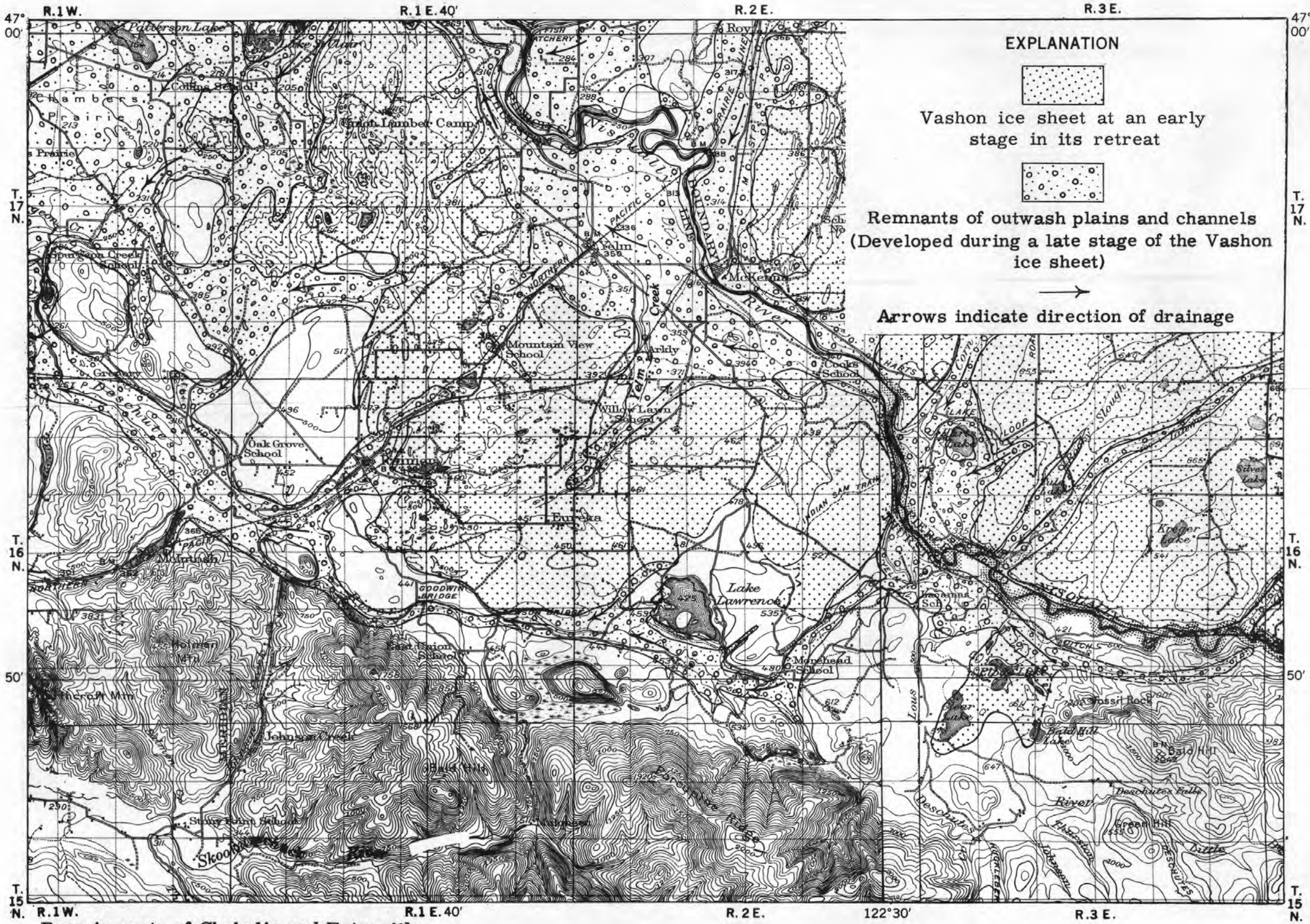
It is also beyond the scope of this report to describe in detail the intricate glacial drainage that developed and changed continually as the various outlets were



Base is parts of Chehalis and Eatonville quadrangles, U. S. Geological Survey.

1 0 5 Miles

Figure 6.—Map of Yelm area showing an early stage in the retreat of the Vashon ice sheet.



Base is parts of Chehalis and Eatonville quadrangles. U. S. Geological Survey

1 0 5 Miles

Figure 7.—Map of Yelm area showing a later stage in the retreat of the Vashon ice sheet.

lowered by erosion and as new outlets were opened after further retreat of the ice. In general, however, the earliest recessional outwash deposits accumulated in the southern part of the area and, as the ice melted back to the north, deposits of outwash accumulated farther north. In addition to accumulating in areas successively farther north, these deposits also formed at successively lower levels during retreat of the ice, as outlets opened at lower altitudes.

The highest and southernmost—and therefore the earliest—of the outwash deposits lie south of the Deschutes River, east of Reichel Lake, and occur intermittently to the southeast, approximately as far as the falls of the Deschutes, just beyond the eastern boundary of the map. The maximum altitude of the outwash that accumulated in the marginal drainage is about 700 to 750 feet.

Prominent terrace remnants having surface altitudes ranging from 600 to 700 feet are found at the foot of Porcupine Ridge east of Reichel Lake. At a later stage, when the ice had melted 1 to 4 miles back from its maximum advance, another outwash plain or group of coalescing plains was formed. The drainage at that time continued to be through the Johnson Creek channel, and the deposits all slope toward that channel. Weir Prairie west of Rainier, Ruth Prairie south of Rainier, and Smith Prairie north and east of Lake Lawrence are remnants of this outwash plain. The position of the ice and terrace remnants of this stage are shown on figure 6.

At a later stage, as the ice retreated still farther north, large masses of ice remained in an irregular belt extending from Lake St. Clair to Bald Hill, while at the same time the Yelm Prairie was free of ice. It is probable, however, that the bottom of the pre-Vashon Nisqually Valley itself remained ice-filled. As a matter of fact, many of the apparently anomalous features of the outwash are due to its having been deposited across, and on top of, the ice in ice-filled depressions and valleys, thus resulting in discordant levels of the outwash deposits after the ice melted. At a number of places steep scarps in the outwash are impossible to explain as erosion scarps; they could have been formed only as ice-contact faces. The outwash deposits formed during the stage when this area was covered by ice are shown on figure 7.

The recessional outwash deposits at most places consist of sand and gravel of many rock types, including volcanic, granitic, metamorphic, and sedimentary types. At a few places, where water was ponded by irregularities of the topography or by blocking of the drainage with ice, sand and silt were deposited. The recessional outwash deposits in the Yelm area are typical of such deposits, which were laid down rapidly by swift, overloaded streams.

The degree of sorting ranges from poor to moderately good (fig. 4C) and stratification is rude to fair, with great lateral variation. Beds commonly pinch out in short distances; foreset bedding is common. Sorting and stratification of the materials forming the outwash plains, of which Weir and Ruth Prairies are typical remnants, was considerably better than in the narrower outwash channels. Typical of the latter is the southwestward-trending channel in which the town of Rainier is located. Outwash materials in this channel range in size from sand to boulders several feet in diameter.

Even though poorly sorted, the outwash is quite porous and moderately permeable. A few dozen wells yield moderately large supplies of water from the recessional outwash deposits where they fill depressions in less permeable materials and, in their lower part, are saturated. However, because the outwash is relatively thin and everywhere fairly permeable, water drains out freely into the perennial streams that have cut through these deposits, and in many places they are unsaturated.

Measured Sections

Several geologic sections were measured in the area, most of them in the bluffs along the Nisqually River. As most of these measured sections include several of the geologic units described (see fig. 4D, 4E, and 4F) it did not appear feasible to try to break up the sections for description with the various geologic units. The measured sections have been numbered according to the same system used for numbering the wells, so that the number gives the locations by township and range, section and 40-acre tract in the section. The measured sections are given below in upstream order.

18/1-35N. About 4.5 miles northwest of Yelm. Left bank of river, along road leading to river on Nisqually Indian Reservation. Altitude at top about 278 feet.

Materials	Thickness (feet)
Vashon drift:	
Recessional and advance outwash:	
Gravel and sand poorly sorted, rudely stratified, fresh-appearing and loose. At base gravels are pea-size	89
Pre-Vashon deposits:	
Clay, brown, tough, compact, silty	1-1½
Till, cobbly, brown to rusty colored	2-4
Gravels, cemented, mostly volcanic materials, some decayed granitic pebbles, lenses of yellow to rusty colored grit and sand	103

17/1-12H. About 2.5 miles north of Yelm. Right bank of river, at bend along section line between sections 7 and 12. Altitude at top about 280 feet.

Materials	Thickness (feet)
Vashon drift:	
Recessional outwash:	
Gravel, sand, some cobbles, poorly sorted, rudely stratified, loose; much granitic material, mostly fresh and unweathered	12-15
Advance outwash:	
Gravel, stratified, crossbedded, clean fresh appearance, interbedded with sand lenses. Sand increases downward, and at base of interval sand predominates	18-20
Pre-Vashon deposits:	
Soil (?), brick-red, gravelly, greatly decayed zone persists along entire length of scarp; unconformable on beds beneath. At places along cliff soil horizon has formed on pods or lenses of tough brown till	$\frac{1}{2}$-2
Gravel, fine to medium, some cobbles, rudely to moderately well stratified, frequently crossbedded. Interval contains lenses of compact gritty sands, generally not more than 50-100 ft long, 3-4 ft thick. (At places top of interval is 2 ft-3 ft of tough brown till	45
Boulders, commonly 6 to 15 ft diameter, all of volcanic material, several of red scoria in a sand and gravel matrix (this horizon is quite persistent)	6-15
Gravel, coarse, cobbles to 8-in. diameter, unsorted, non-stratified, compact but not cemented, with sand and grit matrix. Mostly volcanic material but some light-colored, coarse-grained granitic material	8
(Talus-covered slope to river)	20

17/2-8Ma. About 2.4 miles northeast of Yelm, left bank of Nisqually River. Altitude at top about 300 feet.

Vashon drift:	
Recessional outwash:	
Gravel, coarse; and cobbles, sand matrix; some layers of sand; rudely stratified; much granitic material	10-15
Advance outwash:	
Gravel, fine; and sand, stratified; lenticular, grades laterally into fine sand and silt; at places entire interval is finely laminated blue silty clay	20-25
Pre-Vashon deposits:	
Gravel, cobbles, and boulders in sand and clay matrix. Compact, hard, impermeable. Predominantly volcanic, some granitic material. Large boulders are volcanic material	15-20
(Talus slope to river)	40

17/2-8B, C. About 2.5 miles southwest of Roy, right bank of Nisqually River. Altitude at top about 280 feet.

Vashon drift:	
Recessional outwash;	
Gravel and sand, rudely stratified, some cobbles	8
Advance outwash:	
Gravel and sand, interbedded, lenticular, crossbedded gravels generally not very coarse but contain some cobbles; considerable granitic material	30
Pre-Vashon deposits:	
Gravel and sand, compact, cemented; predominantly volcanic material	15
Boulders and gravel in sandy matrix; compact, impervious 'No granite, materials generally considerably decayed	10-15
(Talus slope to rivers edge)	20-25

17/2-8Mb. About 2.3 miles northeast of Yelm. Left bank of Nisqually River, 0.25 mile south of section 17/2-8Ma. Altitude at top about 300 feet.

Materials	Thickness (feet)
Vashon drift:	
Recessional outwash:	
Sand, some gravel lenses	8-15
Gravel and sand, rudely stratified, fairly clean and quite fresh, considerable granite	15-22
Sand, fine, light-brownish-gray, well sorted; and siltstone, finely laminated	18
Till:	
Gravelly and sandy till, tough, compact, brown to gray	2-3
Advance outwash(?):	
Gravel, rudely stratified, some lenses of sand	3-4
Pre-Vashon deposits:	
Gravel and boulders, compact, cemented in a grit and clay matrix. Some of pebbles and cobbles greatly decayed, others quite fresh. Matrix greatly weathered. Almost entirely volcanic materials in gravels and matrix. Boulder horizon near top of interval, one boulder 12 ft to 15 ft in diameter	29

17/2-28R. About 1 mile southeast of McKenna at bend in road, opposite power pole, 100 ft west of car turnout. Altitude at top about 375 ft.

Vashon drift:	
Recessional outwash:	
Gravel, coarse, and sand, poorly sorted, rudely stratified	18
Till:	
Till, hard, compact, blue-gray, clay till; fresh appearing angular to subangular pebbles include metamorphic and granitic rocks. Near base, till becomes somewhat more sandy	23
Pre-Vashon deposits:	
Gravel, cemented, interbedded with lenses of hard and compact crossbedded sand. Materials, chiefly volcanic, some granitic, all greatly decayed, some completely rotten, generally yellow to rusty colored	27

16/2E-1F. Above Yelm Ditch, ½ mile west of Centralia Power Canal intake, left bank of river. Altitude at top about 480 ft.

Vashon drift:	
Till:	
Till, gray, very compact clay till with pebbles, becoming sandier toward base	15
Advance outwash:	
(a) Sand, dark-gray, compact, angular to subrounded grains of volcanic rock with considerable quartz grains. Some pebbles scattered throughout. Indistinctly laminated	9
(b) Gravel and sand; moderately coarse, mostly volcanic, contains some chert, quartzite, and granite. Fresh appearance, rudely stratified. Boulder layer about 2 ft below top, some boulders at base of interval	10
(c) Sand, dark gray, compact, similar to interval (a)	
(d) Gravel and sand similar to interval (b); occasional lenses of sand along strike of beds	21
Pre-Vashon deposits:	
Gravel, cemented hard and compact, mostly volcanic materials, very little granite. Mostly greatly decayed, stained yellow, orange, brown. Unstratified (Base of section at Yelm Ditch)	37

16/2-13P. About 0.6 mile north of Bald Hill road, 0.5 mile southwest of Nisqually River. Altitude at top about 450 feet.

Materials	Thickness (feet)
Vashon drift:	
Recessional outwash:	
Gravel, sandy, stratified, chiefly as large as baseball size but some larger, much granite	6-7
Sand, stratified, crossbedded, gray; fresh appearance; small amount of pea- to filbert-size gravel along some bedding planes	15-18
Gravel, pea- to egg-size, also a few cobbles	$1\frac{1}{2}$
Sand, compact, yellowish-gray	12±
Till:	
Till, hard, gray, clayey, mostly volcanic pebbles, but contains some granite, quartzite and metamorphic rocks	4-5

Geologic Sections

The geologic sections shown in figures 8, 9, 10, 11, and 12 are based on the measured sections, on other outcrop information, and on well logs.

Geologic History

During the Tertiary period, beginning some 60 million years ago, a great thickness of strata accumulated, including marine and continental sedimentary deposits, volcanic flows, and pyroclastics (McIntosh and Northcraft formations in the Yelm area). This was not a period of continuous deposition; instead, the deposition was interrupted by intervals of erosion and, at times, by deformation. The Tertiary period ended with folding and warping of the strata into broad anticlinal arches of the present Coast and Cascade Ranges with the synclinal Puget Sound lowland between. During and after this period of deformation, streams cutting downward into the uplifting mountains deposited coarse gravels (Logan Hill formation in the Yelm area) as a broad piedmont alluvial fan leading from the mountains to the lowlands. The fact that glaciers were present in the mountains during at least the latter part of this period is indicated by the glacial till interbedded with the gravel. It is also probable that folding continued during this period and that the earliest gravel beds were uplifted later and partially dissected at the same time that deposition continued in the center of the basin. The folding and deposition of these alluvial gravels may have begun during the Pliocene epoch, but the deposition continued well into the Pleistocene epoch. Sometime during the Pleistocene epoch the entire area was uplifted and valleys of considerable depth were cut into the earlier deposits. Changed conditions, possibly due to subsidence of the entire area or to renewed downwarping of the basin, caused the streams, which had been downcutting, to aggrade their courses and build

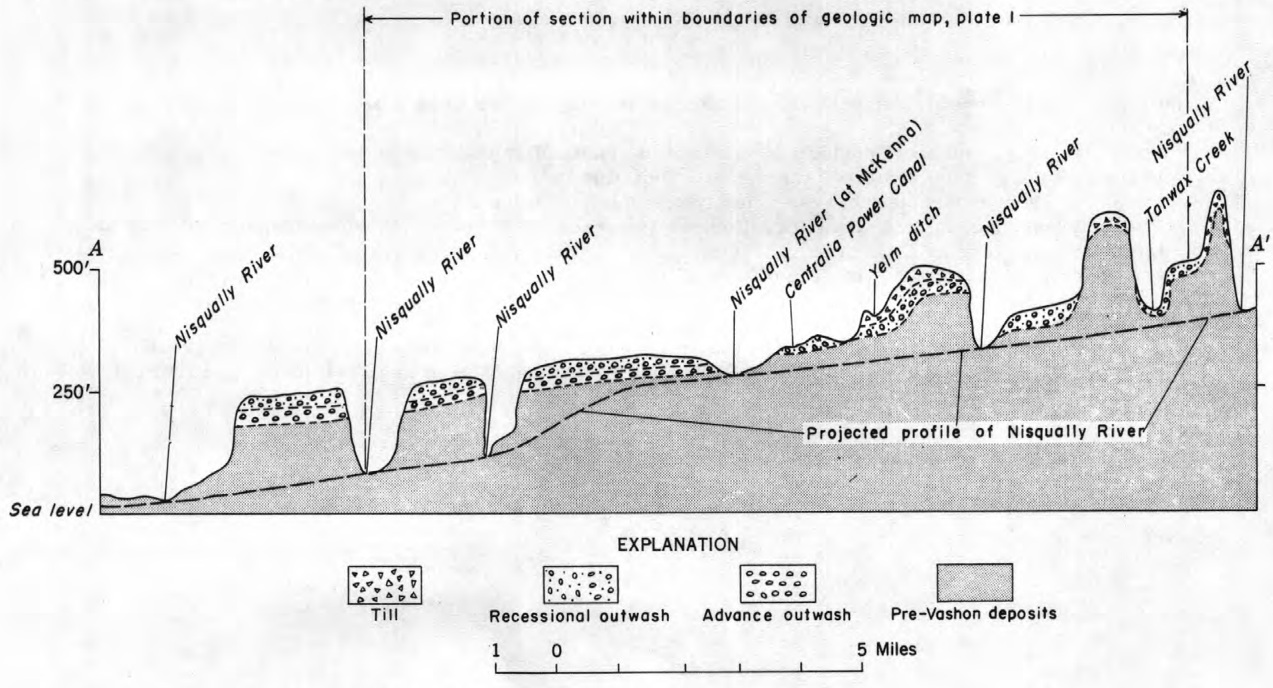


Figure 8.—Postulated geologic section A–A'.

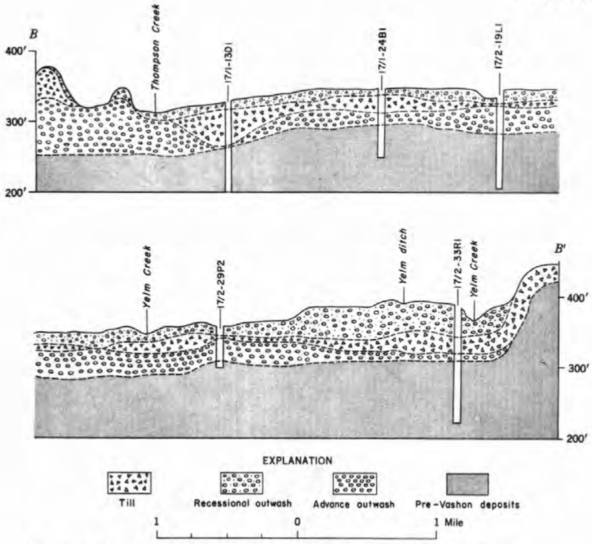


Figure 9.—Postulated geologic section B–B'.

extensive sand and gravel deposits. The climate had become colder and the ice fields and glaciers became progressively larger and extended to lower altitudes; much of the material deposited at this time therefore was glacial outwash. At times, the mountain glaciers extended down the valleys and out into the Puget lowland. In the Yelm area, glacial tills and glaciofluvial sand and gravel that were deposited during this interval are exposed only along the Nisqually River where they have been mapped as pre-Vashon deposits.

It is probable that these valley glaciers advanced and retreated several times prior to the last, and most widespread, glacial advance. At any rate, immediately preceding the last advance (in Vashon time) the valley glaciers had retreated from the Yelm area, and the Nisqually River and other streams had cut down into the earlier glacial deposits. At this time, then, a great continental ice mass began forming to the north. West of the Cascades this ice mass accumulated in Canada and in the northern part of Washington and began pushing southward. It is probable that glaciers from the bordering mountains to the south also contributed considerably to this vast southward moving ice tongue, which inundated the entire Puget Sound Basin except for a few isolated peaks that remained as nunataks above the ice. In the northern part of the basin the ice must have been several thousand feet thick, and even as far south as Vail, which is near the southern limit of the ice sheet in western Washington, the ice was at least 700 feet thick. After the ice reached its maximum extent a few miles south of the Yelm area, the climate became warmer, and the ice mass stagnated and began to wane. In the Yelm area the ice apparently lingered longest in a strip extending from the southeast in the vicinity of Clear Lake to the northwest in the vicinity of Lake St. Clair.

The drainage of the area had been northward into Puget Sound prior to the advance of the ice sheet from the north. With the advent of the ice this drainage was blocked and the drainage of the area, from both precipitation and melting of the ice, was southwestward into the Pacific by way of the Chehalis River valley. Extensive deposits of sand and gravel were formed as outwash plains and channel fillings of the streams from the melting ice. As the ice continued to melt, new outlets for the glacial meltwaters were established at progressively lower altitudes with the streams cutting down into the earlier deposits, leaving terraces, and building outwash channel deposits at lower levels. Glacial drainage changes and the sequence of depositional features related to melting of the Vashon ice sheet are very complex. They are described in more detail in the previous section describing the outwash of the Vashon.

GROUND WATER

Source

Most ground water is derived from precipitation. A small additional amount may be connate water (water trapped with the sedimentary materials at the time they were deposited) and juvenile water (water originating within the earth)—neither of which is of significance in the Yelm area. The streams of the Yelm area are fed mainly by ground water, and most of the ground-water recharge stems from precipitation on the interstream areas. Between 35 and 40 inches of precipitation falls annually on the Yelm area, and about two-thirds of this amount reaches the water table. The remainder leaves the area as direct surface runoff or is lost by evaporation and transpiration without reaching the water table.

Occurrence

Of the water entering the soil, part is held by molecular attraction as a film around the grains, part is held in openings of capillary size, and the remainder percolates downward to the water table.

A large quantity of water occurs below the water table in the openings or interstices of the rocks. The interstices range in size from the minute pores in clays to large tunnels and caverns in lavas and limestone. The interstices are of two main types—the original interstices formed when the rocks came into existence, including the interstices between grains of any granular rock such as sand, gravel, and clay; and the secondary interstices, including fractures and solution channels, which formed later. In the saturated zone, these interstices comprise the storage space for ground water, and from this storage space the water may be drawn through wells.

The porosity of a material is the proportion of the total volume that is occupied by the interstices. When all the interstices are filled with water, the rock is saturated. Natural rock materials differ greatly in porosity. The porosity of consolidated rocks such as some lava flows, tightly cemented sandstone, and granite, may be only a few percent or even a fraction of 1 percent whereas the porosity of some clays may exceed 50 percent. The porosity of clean sand and gravel may be 30 or 40 percent; a small amount of silt or clay mixed in the coarser materials reduces the porosity to a small extent, and large boulders mixed with sand or gravel will reduce the porosity of the material to a large degree.

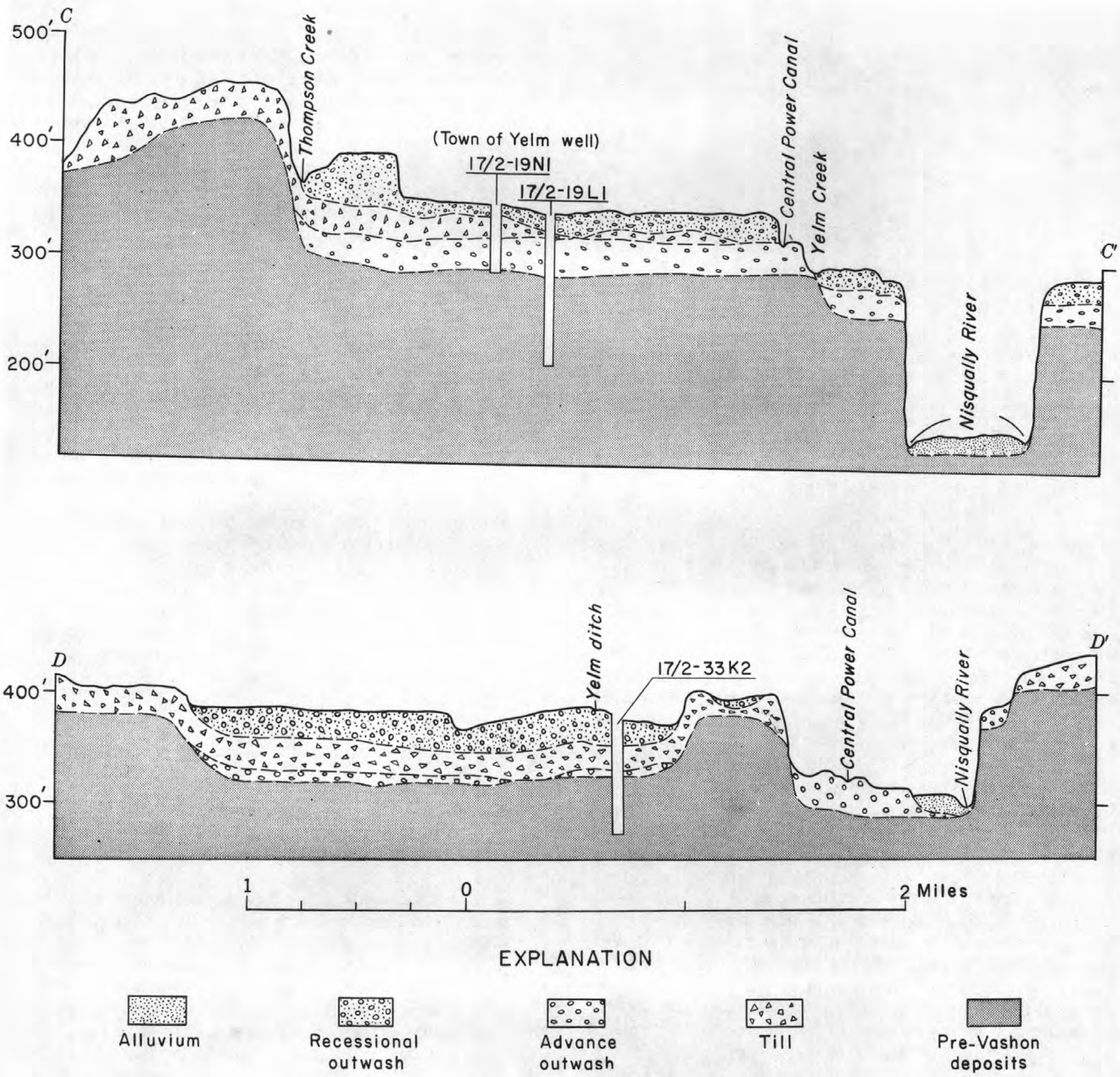


Figure 10.—Postulated geologic sections C-C' and D-D'.

Soil and rock materials may have a large porosity and yet yield little water even though allowed to drain for a long time. For example, a clay having a porosity of 50 percent or more might not yield any water because of the smallness of the grains and interstices, the water being retained by molecular attraction. Some water also may be retained in a material because the pores are isolated. The ratio of the volume of water a saturated rock will yield, by gravity, to the total volume of rock is the specific yield and may be stated as a percentage.

Although porosity and specific yield are important attributes of an aquifer, probably the most important aspect is its ability to transmit water. This characteristic has little relation to the porosity. For example, a clay may have a high porosity and yet it may not yield an appreciable amount of water, whereas a sand or gravel having a porosity of only 20 to 25 percent may yield large quantities in a short time. The ability of a rock to transmit water is called its permeability. Clays are relatively impermeable because the pores are so small that the water is held by molecular attraction. In silt and fine sand the pores are larger; therefore, although the relative effect of molecular attraction is less it still may be great enough that water can be transmitted only very slowly. An admixture of silt or fine sand in coarser sand or gravel greatly decreases both the porosity and the permeability of the material.

Ground water moves principally in response to the force of gravity; therefore, the discharge area must be at a lower elevation than the intake or recharge area. The velocity of ground water varies directly as the hydraulic gradient; that is, all other factors remaining the same, doubling the hydraulic gradient doubles the velocity.

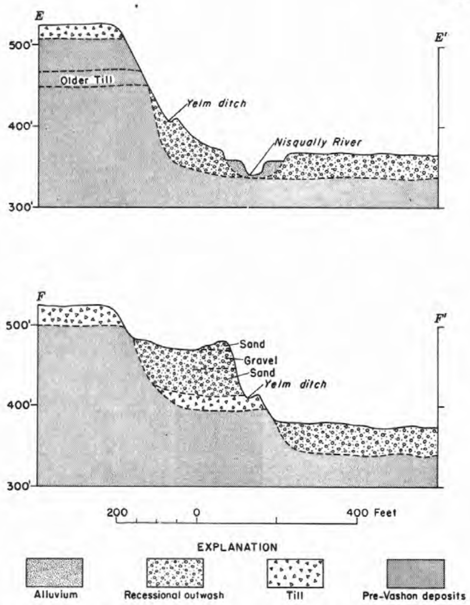


Figure 11.—Postulated geologic sections E-E' and F-F'.

The Water Table

Water falling on the earth percolates downward through the soil and subsoil to the zone of saturation, in which all the interstices are filled with water. The surface of the zone of saturation is the water table, and the water in a well will stand at that level. The water table is an undulating surface reflecting in a general, but modified, way the irregularities of the topography. The correlation of water table with topography would be closer if the material were entirely homogeneous, but because the material is not

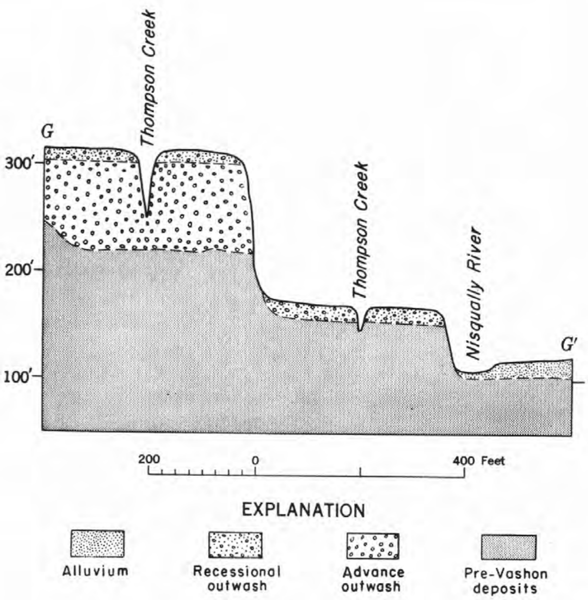


Figure 12.—Postulated geologic section G–G'.

homogeneous the configuration of the water table is in part dependent upon differences in porosity and permeability. The water table is highest in the areas where recharge occurs and slopes toward the areas of discharge in stream valleys, lakes, and swamps. Within the zone of saturation, ground water moves in the direction of slope of the water table to the point of discharge.

At some places, permeable zones are confined between impermeable layers. As the water percolates down the slope or dip of the aquifer, the slope of the overlying impermeable layer may be greater than the slope of the water table; then the water becomes confined in the aquifer and is prevented by the overlying layer from escaping freely upward. If a well is drilled through the impermeable stratum, the water will rise above the saturated aquifer; such a well is called an artesian well. The surface determined by the heights to which the water will rise in a number of wells penetrating the aquifer is called the piezometric surface. Where the piezometric surface is above the land surface, wells will flow.

Fluctuation of the Water Table

The water table is not a fixed surface; instead, it is continually fluctuating. Discharge of ground water is continuous although not at a constant rate, but recharge is intermittent. Therefore, ground-water levels recede except during and immediately after a period of rainfall, when ground-water supplies are replenished. The downward movement of meteoric water is most rapid through materials containing large interconnected openings; thus, precipitation affects the water table promptly where the materials are permeable and where the water table is near the surface.

Temperature, humidity, and wind velocity combine to determine the rate of evaporation. Direct evaporation is effective to a depth of only a few inches below the surface, but transpiration processes draw from a greater depth; some plant roots extend several tens of feet below the surface. Evaporation and transpiration are most active in the summer, which is also the season of least precipitation in the Yelm area. During long, dry, warm seasons the water table declines and the surface layer is desiccated. The first rains marking the end of the dry season often are utilized almost entirely in replenishing the soil moisture, so that the decline of the water table may continue after the first rain in the fall of the year.

Recharge in the Yelm Area

Contrary to a rather popular belief, the ground water of the Yelm area is not derived from precipitation on Mount Rainier; instead, it results from local precipitation. In areas where glacial outwash is at the surface, conditions are extremely favorable for recharge. In these areas, and in the areas occupied by end and recessional moraines, there appears to be little, if any, direct surface runoff. In areas where glacial till is at the surface, downward percolation is greatly hindered. However, the generally poor drainage, especially on the flat upland areas south of the Yelm Prairie, traps much of the precipitation in perched marshes and swamps where at least part of it percolates slowly downward to the water table.

Precipitation at Yelm, discussed in some detail in the section on climate, probably averages about 37 inches per year. The percentage that actually reaches the water table varies greatly, depending largely upon the type of material at the land surface and in the subsoil. This percentage probably ranges from 10 or 15 percent where till forms a continuous sheet below the surface, to as much as 75 percent or more where outwash gravels are at the surface. The seasonal distribution of the precipitation is favorable for recharge because very little precipitation occurs during summer months when evaporation and transpiration rates are high. Precipitation during the 4 months of June, July, August, and September averages only about 14 percent of the annual total. During the 6-month period from October to March, inclusive, 74 percent of the precipitation occurs. During this 6-month period evaporation and transpiration rates are relatively low, therefore a larger proportion of precipitation is available for recharge. In the Yelm area probably 90 percent of the recharge occurs during this 6-month period.

Ground Water in the Till Plains

Although most of the surface in the till plains is underlain by till, which in itself is almost completely impermeable, a considerable percentage of the precipitation does percolate downward to the water table. The till generally is not more than 20 to 30 feet thick, and at many places it is much thinner or entirely absent. At many places a few feet of recessional outwash mantles the till and, where till is exposed at the surface, weathering of the till has produced a layer of soil and subsoil that is 2 to 3 feet thick. The thin covering of outwash and soil is capable of absorbing considerable amounts of water, some of which percolates downward to the water table at places where the till is absent or where roots of trees and other plants have penetrated it.

Because of the generally poor drainage, direct surface runoff is small. Much of the water not intercepted by vegetation, and not percolating directly into the ground, collects in marshes, swamps, and kettles, where a considerable part is dissipated by transpiration or evaporation. Considerable quantities, however, percolate downward to the water table. A reasonable estimate of the quantity of water actually reaching the water table in the till plains probably would be 30 to 40 percent of the precipitation, which would be a recharge of roughly 1 acre-foot per acre each year. Although practically all domestic and farm water supplies are obtained from the ground, the amount thus used is quantitatively insignificant. Much of the ground water is used by vegetation in areas where the water table is near the surface. The remainder of the area is uninhabited or only sparsely covered by farms that withdraw water only for domestic use; therefore, artificial withdrawal of water in these areas is small. This area is higher, and the water table is higher, than the gravel plains along the Nisqually to the northeast and along the Deschutes to the southwest. Therefore, ground water percolates laterally outward from the area, in part appearing as springs and seeps along the scarps separating the upland till plains from the outwash channels and plains, and in part percolating directly into the outwash gravel.

Shallow bodies of ground water are perched in the recessional outwash upon the till and in the upper weathered part of the till at numerous places. Some of these bodies are seasonal; hence, not all wells depending on them are reliable. Advance outwash deposits of the Vashon glaciation occur beneath the till at some places, and sand and gravel of the pre-Vashon deposits underlie the till almost everywhere. A considerable number of wells have been dug or drilled into the deposits underlying the till, from which adequate supplies of water generally are obtained. Dug wells range in depth from about 15 to 55 feet. Drilled wells range in depth from about 30 to 220 feet, averaging 98 feet. Of 36 drilled wells tabulated, only 5 were more than 150 feet deep.

Ground Water in the Morainal Areas

The morainal areas are typical of recessional-moraine (kame and kettle) topography. Most of the surface area is formed by recessional-outwash sand and gravel deposited around ice blocks as the continental ice sheet wasted away. Underlying the entire area is a till sheet which serves to perch the ground water. The hills and ridges consist of very permeable sand and gravel, but in some of the kettles the till is at or near the surface, thus forming numerous lakes and swamps. Many of the kettles, however, are completely dry even immediately after rainfall, indicating that a sufficient thickness of outwash collected in the depressions to permit the water table to maintain a position below the surface.

Direct surface runoff from the morainal areas is negligible. The porosity of the materials and the topography are so favorable for recharge that most of the precipitation that is not intercepted by vegetation seeps immediately into the ground. Some moisture evaporates from the soil or is transpired by vegetation, but probably 75 to 80 percent of the precipitation on the area actually reaches the water table.

After reaching the water table, part of the water flows into and evaporates from lakes and swamps, or is used by phreatophytes. The land surface and water tables are higher than in most of the surrounding areas; therefore ground water percolates laterally into those areas. It is probable that more than 60 percent of the precipitation percolates out of the area as ground water.

In the morainal area west of Yelm, part of this underflow percolates eastward into the outwash gravel plain and thence to the bluffs of the Nisqually River, where it is discharged by springs. Part of the underflow from this morainal area percolates into the outwash plains surrounding Lake St. Clair. In the morainal area east of Rainier, ground water moves westward and southward into the gravel plains surrounding Rainier and eventually reaches the Deschutes River.

In the morainal area west of Bald Hill, most of the underflow eventually reaches the Nisqually River, although some of it may discharge into the Deschutes River to the south.

The outwash sand and gravel of the recessional moraine is generally very porous and permeable. Wells drilled in these deposits, where a thickness of at least 15 to 20 feet is saturated, should yield moderate to large supplies of water. Where till is at or near the surface, ground water supplies can be obtained from the underlying advance outwash or pre-Vashon deposits. Water levels in the materials overlying the till probably are only a few to a few tens of feet above the top of the till, and the water levels in wells drilled on hills or ridges of outwash might be 100 to 200 feet below the surface. No information is available on water levels in the deposits underlying the till, but in general they may be somewhat lower than the water level in the overlying deposits.

The area between Yelm and Lake St. Clair is virtually uninhabited—most of it is included in the Fort Lewis Military Reservation. The other two morainal areas have very few inhabitants; consequently, utilization of water in these areas is quantitatively unimportant.

Ground Water in the Outwash Plains

Areas of outwash occur chiefly in two broad, irregularly shaped belts paralleling the Deschutes and Nisqually Rivers, where they form terraces and benches at several levels. The surfaces on these benches and terraces in general are quite flat, but in detail they show minor irregularities originating at the time the outwash was deposited. Practically the only modification of these surfaces since the glacial epoch has been produced by the downcutting of the two major streams, the Deschutes and Nisqually Rivers.

Weathering of the surface has produced 2 or 3 feet of porous gravelly loam soil through which water percolates readily. Thus, the opportunity for recharge in these areas is exceedingly good. Not only does a large proportion of the precipitation on the area enter the soil and subsoil, but also a considerable quantity of water falling on the surrounding areas, which are generally higher and underlain by less permeable materials, discharges into them as surface or underground flow.

Ground Water in the Yelm Prairie

The Yelm Prairie is the terrace surface, formerly a glacial-outwash channel, extending along the southwest side of the Nisqually valley from approximately 5 miles southeast to $4\frac{1}{2}$ miles northwest of Yelm. The surface of the prairie has an average slope to the northwest of about 10 feet per mile. Between the Yelm Prairie and the Nisqually River, and parallel to both, are terraces at lower levels which are remnants of outwash channels formed as the outlet for the drainage declined to progressively lower altitudes.

The Yelm Prairie proper has an area of about 11 square miles; lower terrace remnants between the prairie and the river cover about 4 square miles. South of the prairie, and separated from it at most places by a prominent scarp, is the belt of morainal and till-plain uplands previously described. Several tributary outwash channels lead from this upland onto, and merge with, the Yelm Prairie.

The surface soils are porous gravelly loam and offer little obstruction to the downward percolation of precipitation. There has been practically no erosion on the prairie since Vashon time. Yelm Creek probably has cut down slightly, but it chiefly follows a channel cut in the outwash by glacial melt water. The absence of erosional features is evidence that surface runoff from the area has been small since the Vashon glaciation. Even during moderately heavy rainstorms in the summer and fall months little water runs off in either Thompson or Yelm Creek. For example, on October 25, 1951, Thompson Creek was completely dry at its junction with the Centralia Power Canal wasteway in section 11, T. 17 N., R. 1 E., although 3.6 inches of rain had fallen in the preceding 13 days. Later in the season, after the water table has risen to the level of these streams, water flows in considerable quantity.

Miscellaneous streamflow measurements made in the Yelm area, which are listed below, are enlightening. On January 19, 1948, the discharge of Yelm Creek near its mouth was 28.6 cubic feet per second (cfs), whereas the flow 1 mile southeast of Yelm was 10.4 cfs. The difference, 18.2 cfs, compares with a total discharge of 14 to 15 cfs during the summer, when the stream is fed entirely by springs and seepage along its lower course and has practically no flow above Yelm. These figures indicate that the ground-water discharge along the bluffs of the Nisqually River does not vary greatly from summer to winter. Actually, the flow of 10.4 cfs (see table) probably was due mostly to ground-water discharge from seepage where the stream channel lies slightly below the water table.

Eaton Creek, west of the Yelm Prairie near Lake St. Clair, has a uniform flow of about 7 cfs during the summer, all of which is derived from ground-water discharge. Toboton Creek, which is east of the Yelm Prairie, also showed a uniform discharge derived from ground water in the till plains to the west and the morainal area to the east. Thompson Creek, on Yelm Prairie as in the case of Yelm Creek at and above Yelm, was virtually dry during the summer because its bed is above the summer position of the water table.

Recharge of ground water.—During July and August, when the average precipitation recorded at Yelm is less than 1 3/4 inches, very little water reaches the water table. During the rest of the year, and particularly from October to April, a large proportion, possibly 80 to 90 percent of the precipitation, reaches the water table. Average annual recharge to the water table on Yelm Prairie therefore is estimated to be about 75 percent of the precipitation, which would be about 2 1/4 acre-feet per acre over 11 square miles, a total of about 16,000 acre-feet annually.

Although, at first glance, an average annual recharge of about 75 percent of the precipitation may appear to be very large, it is believed that such a figure actually is conservative. The soil of the area, consisting of loose, granular black organic material mixed with sand and gravel, usually is from 6 to 12 inches thick. Farmers report that fields can be cultivated within an hour after the heaviest rains. Direct surface runoff is nonexistent. Natural vegetation is sparse and consists of weeds, grasses, and a few scrubby trees and bushes. The weeds and grasses usually are very short lived—lasting only until the end of the rainy season, generally in June. Thus, the soil-moisture content is relatively low, and transpiration and evaporation losses also are low, so that the bulk of the precipitation percolates rapidly downward to the water table.

Streamflow Measurements in the Yelm Area

[Discharge in cubic feet per second]

Date	Yelm Creek 200 ft above mouth (SE1/4SW1/4 sec 12, T. 17 N., R. 1 E.)	Yelm Creek 1/4 mile upstream (SW1/4 SE1/4 sec 12, T. 17 N., R. 1 E.)	Yelm Creek 1/2 mile north of Yelm (SW1/4NW1/4 sec 19, T. 17 N., R. 2 E.)	Yelm Creek 1 mile southeast of Yelm (SW1/4NW1/4 sec 29, T. 17 N., R. 2 E.)
1-19-48	28.6	27.0	...	10.4
7- 5-49	...	...	0.52	...
7-20-49	...	...	1.20	...
8- 2-49	...	...	1.37	...
8-16-49	15.9	...	.58	...
9- 7-49	15.7	...	.40	...
9-12-50	13.7	...	.32	...
9-13-50	...	...	...	.39

Date	Eaton Creek near Lake St. Clair (NW1/4SW1/4 sec 6, T. 17 N., R. 1 E.)	Thompson Creek at Yelm-Olympia Highway crossing (SW1/4SE1/4 sec 11, T. 17 N., R. 1 E.)	Toboton Creek Hobson Road crossing (SE1/4NW1/4 sec 19, T. 16 N., R. 3 E.)
7- 8-49	...	...	13.3
7-20-49	...	...	12.9
8- 3-49	...	...	12.0
8-15-49	6.94	...	...
8-16-49	...	0.42	12.9
9- 6-49	7.41	.19	...
9- 8-49	...	...	10.6
10- 3-49	...	...	8.32

The till plains and morainal areas along the southwestern side of Yelm Prairie average nearly 100 feet higher in elevation than the Yelm Prairie and are separated from the prairie nearly everywhere by a scarp. Also, the water level in these areas is higher than in the prairie, and ground water moves laterally from them into the prairie. Many springs and seeps were seen along the scarp, but it is probable that most of the ground water moving into the prairie from the uplands does not appear at the surface. Approximately 25 square miles of the upland is believed to contribute recharge to the Yelm Prairie. Recharge in the upland till plains was estimated to be 30 to 40 percent of the precipitation, and in the upland morainal areas it was estimated to be 75 to 80 percent. Very little of this water is withdrawn in the upland areas, but a considerable amount is evaporated from marshes and ground-water ponds and used by vegetation. The amount percolating out of the areas probably is only about half of the total recharge, or possibly 20 percent of the annual precipitation, which would be more than 9,000 acre-feet annually.

Irrigation on the prairie was a source of recharge when surface water was being brought into the area by the Yelm Irrigation Ditch. The average area irrigated was about 2,000 acres and it is probable that, including canal and lateral losses in the area, 4,000 to 5,000 acre-feet of water was recharged from this source each year. However, now that wells on the prairie constitute the sole source of irrigation supply, percolation from irrigation merely returns a part of the water withdrawn from the aquifers.

At the present time, therefore, recharge consists of precipitation on the area and lateral percolation from the upland till plains and morainal areas. The average annual recharge from those two sources probably is approximately 25,000 acre-feet.

Precipitation on the lower terraces between the Yelm Prairie and the Nisqually River recharges the ground water in that area. Recharge at a rate of 75 percent of average annual precipitation on 4 square miles would give an annual average recharge of 5,700 acre-feet. Thus, the total recharge to the prairie and bordering terraces averages nearly 31,000 acre-feet annually.

Discharge of ground water from the Prairie.—Discharge of ground water consists principally of three components. In order of importance these are:
1. Discharge from springs and seeps.
2. Discharge by evaporation and transpiration where the water table is at or near the surface.
3. Pumpage from wells.

Discharge from springs and seeps:—Numerous springs and seeps occur along the scarp separating the Yelm Prairie from the next lower terrace paralleling it on the northeast. The largest of these is Crystal Spring in sec. 18, T. 17 N., R. 2 E. Other important springs occur along scarps separating this terrace from still lower terraces, but many of the springs and seeps appear in the face of the bluffs overlooking the Nisqually River. In September 1950 the flow of a number of the larger springs was measured. These springs appear in a 5-mile stretch of the Nisqually Valley, between the Centralia Power Plant and McKenna. The measurements are given in the following table.

It will be noted that Yelm Creek was almost dry above the town of Yelm. The flow below that point came

Spring Discharge Measurements, Yelm Area

Spring no.	Name and location	Approximate altitude	Flow (gpm)	Flow (cfs)	Date
17/1-12M1	1/4 mile southeast of Centralia Power Plant.	125	260	0.58	9-12-50
-12Q1	Spring branch of Yelm Creek..........	250	830	1.84	9-12-50
-12P	Yelm Creek, near mouth*.............	175	6,150	13.7	9-12-50
17/2- 7N1	Near Devils Slide.........................	150	550	1.22	9-14-50
- 7N2	.........do.................................	150	590	1.31	9-14-50
-17C1	....	225	320	.71	9-15-50
-17D1	....	225	40	.09	9-15-50
-17J1	....	250	27	.06	9-21-50
-28D1-F1	McKenna Springs.........................	300	3,360	7.48	9-26-50
-18K1	Crystal Springs...........................	320	2,970	6.61	9- 7-49
-19L	Yelm Creek, at Yelm....................	340	145	.32	9-12-50
-29M	Yelm Creek, 1 mile southeast of Yelm.	350	175	.39	9-13-50

*Flow of Yelm Creek consists almost entirely of spring discharge; including 17/1-12Q1 and Crystal Springs.

entirely from springs and seeps. Subtracting the flow of Yelm Creek at Yelm from the flow at the mouth, and considering the difference to the ground-water discharge, gives a total measured spring discharge of 11,327 gpm. A number of large springs and many small ones were not measured. It is estimated that the total discharge in this 5-mile stretch could not have been less than 18,000 gpm in September 1950. The Yelm Prairie, as used in this report, extends for a total distance of about 9 miles southeast and northwest of Yelm. Using the same rate of underflow for the entire 9 miles (as in the 5-mile reach) would give a total discharge of about 33,000 gpm. Not all of this discharge is derived from underflow of Yelm Prairie; seepage loss from the Centralia Power Canal must be deducted. The Centralia Power Canal, owned by the city of Centralia, diverts water from the Nisqually River near the center of section 1, T. 16 N., R. 2 E., and delivers it to the power plant some 9 miles downstream. Seepage loss was determined for the city of Centralia by Cary and Kramer, consulting engineers of Seattle, by making two discharge measurements on the canal, one near the power plant, the other near the intake; the difference between these two discharge measurements, 16 cfs, or roughly 7,000 gpm, was assumed to be seepage loss. However, this amount is only a small percentage of the total flow, therefore it is subject to considerable error. Furthermore, the seepage loss may vary from time to time. An assumption of an average seepage loss of 8,000 gpm would leave 25,000 gpm for underflow from the Yelm Prairie and associated terraces during 1950. This rate is equivalent to an annual discharge of 40,000 acre-feet.

One other factor must be considered—the irrigation from the Yelm Irrigation Ditch in 1950, with water obtained from the Nisqually River. It is estimated that not more than 5,000 acre-feet were added to the ground water from this source in 1950. Subtracting this amount from the discharge leaves 35,000 acre-feet of water that is thought to be derived from precipitation.

Shape of the water table and movement of ground water.—Records of many wells were obtained in the Yelm area during the spring of 1950. Water levels were measured in many of the wells, and a map of the Yelm area showing the approximate position of the water table during that period is shown in plate 2.

The water table in Yelm Prairie is shown on a larger scale map in figure 13. Almost all the water-level measurements were made just prior to turning water into the irrigation system for the 1950 season, and therefore the position of the water table is approximately in its natural position without benefit of recent recharge from imported water.

The spring of 1951 was exceptionally dry, and water levels were unusually low. Water levels of many wells were remeasured in May and the first part of June 1951, and it was found that the water table was considerably lower than at the same period in the previous year. It is obvious that the low water level was due entirely to the exceptionally dry spring months, during which the aquifers failed to receive their normal recharge. It could not have resulted from cessation of irrigation from the Yelm Ditch, because irrigation for the 1951 season would not have commenced until the end of June, and the water levels were already considerably below normal at that time. It probably is true, however, that the water table generally dropped a little lower during the late summer and fall of 1951 because of cessation of irrigation from Yelm Ditch.

Beginning in May 1951, biweekly measurements were made on 18 to 20 observation wells on the Yelm Prairie, and a water-level recorder was installed on well 17/2-19M2, the abandoned city well. In November, it was apparent that the water table had reached its lowest level for the season, and water levels were measured in as many wells as possible. The water-table map based on these measurements is shown in figure 2. Measurements were continued in the observation wells during the winter, and, when it appeared that the water table had reached, in general, its highest level for the season, all available wells were again remeasured and the water table map for March 1952 (see fig. 14) was drawn. The water table in March 1952 was only a little higher than in May-June 1950, and it is apparent that the subnormal rainfall of the winter of 1952 had not filled the aquifers quite to the level reached in 1950.

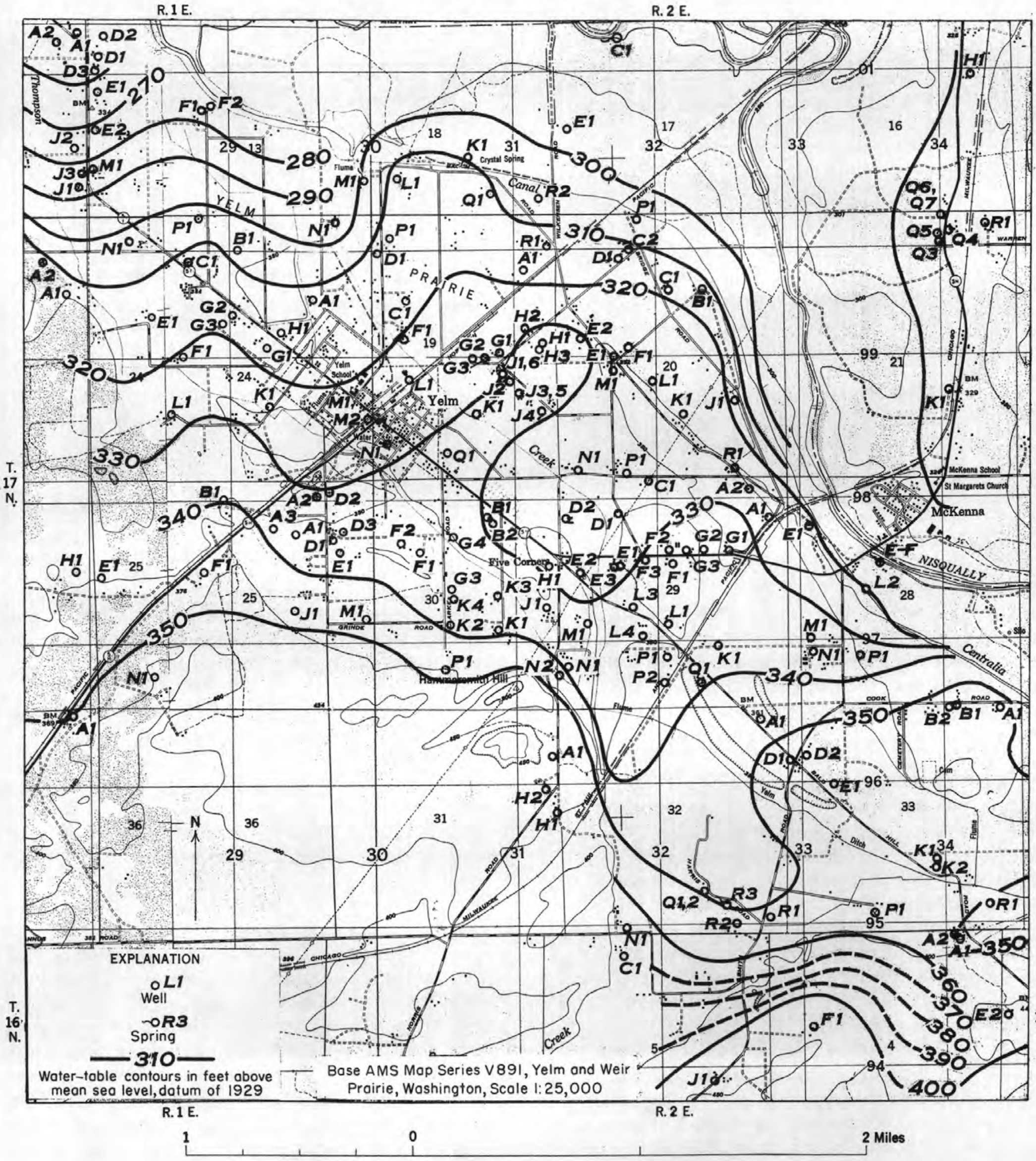


Figure 13.—Map of Yelm Prairie showing well locations and contours on the water table. May–June 1950.

The typical seasonal range in water level is illustrated in the generalized section across Yelm Prairie, figure 15.

Of all the wells measured for the March 1952 map, 48 were the wells that had been measured in November 1951. The average difference in water level between the March (high) and November (low) level was 7. 3 ft. The greatest difference in any well was 17. 7 feet in well 17/1-13N1, and the least was 0. 5 foot in well 17/2-30K3. Of the 48 wells, only 3 had a range of 10 feet or more and only 4 had a range of 1. 0 foot or less. The greatest seasonal fluctuation occurred in the extreme northwestern corner of the prairie, where the fluctuation probably was nearly 20 feet. The smallest seasonal fluctuation occurred in the south-central part of the prairie, south of Yelm, where most wells had a seasonal range of about 5 feet to less than 1 foot. Hydrographs of 15 wells, and of the average of the 15 wells (composite well), are shown in figures 16 and 17.

The water table beneath the Yelm Prairie slopes generally toward the Nisqually River. The only noticeable discontinuity is where ground water emerges along the face of the bluffs above the level of the Nisqually River.

The slope of the water table is steepest, about 55 feet per mile, in the northwestern part of the prairie, and it is flattest, 10 to 15 feet per mile, in the central part. The general water-table gradient is toward the north-northwest, but in a strip adjacent to the south side of the Nisqually River in the eastern half of the prairie the slope is toward the north-northeast.

In the fall and early winter the slope is steepened somewhat, especially in the northern and northwestern parts of the area. However, the general shape of the water table shows little change seasonally.

The water-table contours show that the gross ground-water flow under the Yelm Prairie is toward the north-northwest. In any given area, of course, the general direction of flow is at right angles to the water-table contours, in the direction of decreasing elevation. For example, in the mile-wide belt along the south side of the Nisqually River, in the eastern half of the prairie, the flow is generally toward the north-northeast. Many smaller exceptions to the general direction of flow can be inferred from the water-table map.

During former years, direct recharge of ground water in the Yelm Prairie from the Yelm Irrigation Ditch was equivalent to about 15 to 20 percent of the aggregate recharge from precipitation on the prairie and underflow from the upland till plains and morainal areas. Because the irrigating was done in the dry summer months, none of the water was rejected, and the water table undoubtedly was higher at the end of the irrigation season than it would have been had there been no irrigation. Normally, however, some water is rejected as runoff in the winter months when the water table has been raised above the level of the streams, and it is anticipated that in most years this surplus of water will be sufficient to raise the water table to its normal position in the winter and spring. Therefore, the abandonment of the ditch probably has merely increased the annual range of water-table elevation by lowering the water table several feet in the summer and fall, but it has not decreased the height to which water levels will rise in the spring.

Storage of ground water.—The following discussion applies to storage of ground water in the Yelm Prairie proper, exclusive of the terraces, and therefore it involves an area of about 11 square miles.

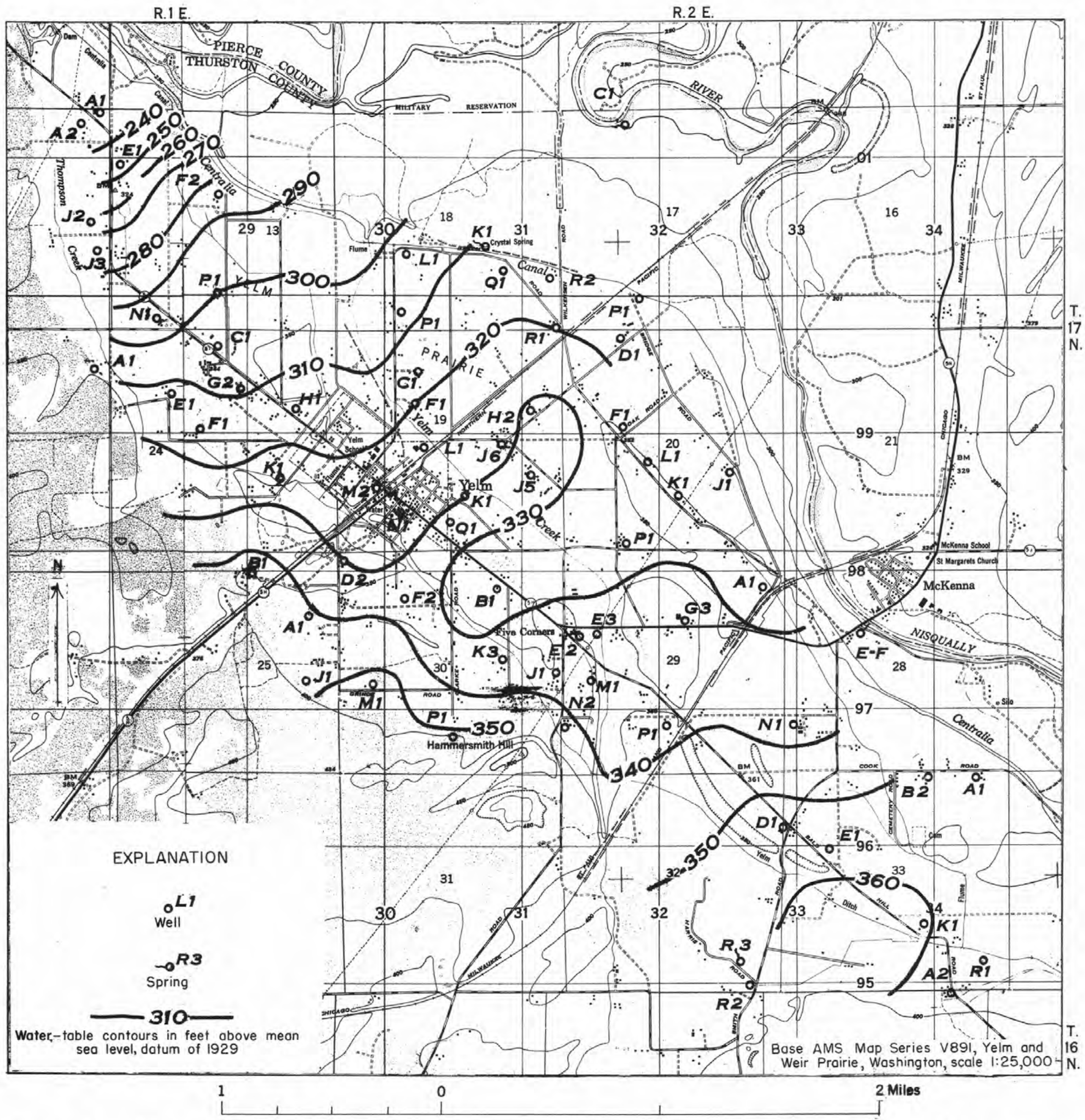


Figure 14.—Map of Yelm Prairie showing well locations and contours on the water table, March 1952.

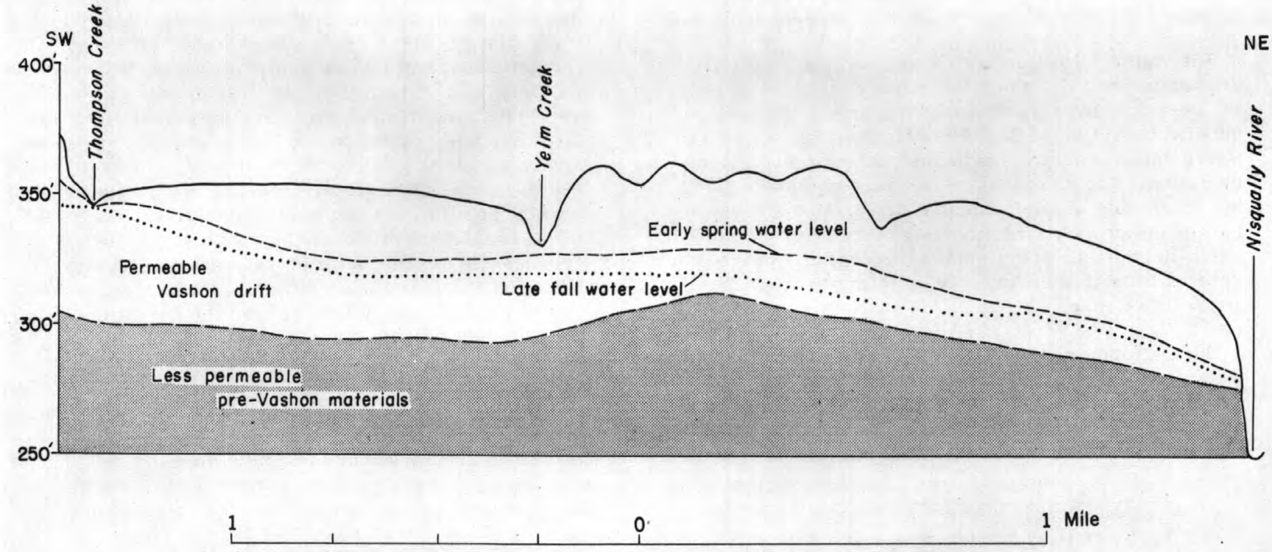


Figure 15.—Generalized section across the Yelm Prairie showing seasonal range of water level.

The upper zone of the pre-Vashon deposits, as described above, is relatively impervious, and is usually referred to by drillers and inhabitants of the Yelm Prairie as "hardpan." It varies in character and thickness, but is persistent enough to serve as a reference datum. Ground water is available both above and below the hardpan. Most of the older wells have obtained water from the Vashon drift, but a considerable number of the newer wells extend into the underlying pre-Vashon deposits.

The pre-Vashon surface under the prairie has a considerable range in elevation; however, it averages 292 feet above sea level. The average altitude of the land surface is 347 feet, thus the average thickness of Vashon drift throughout the Yelm Prairie is 55 feet and

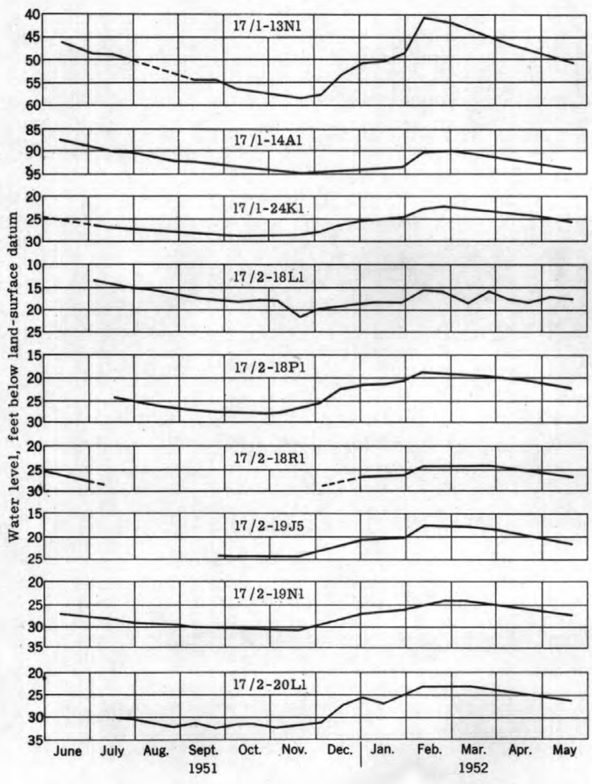


Figure 16.—Hydrographs of wells on Yelm Prairie.

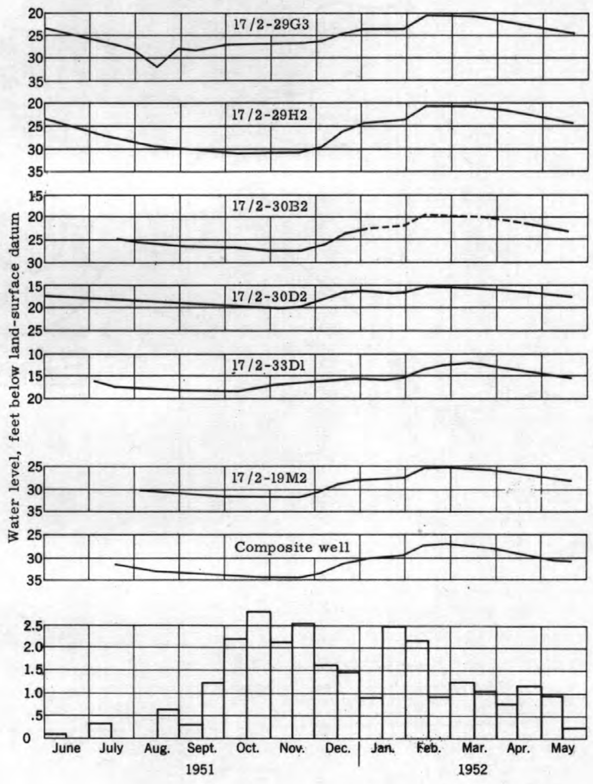


Figure 17.—Hydrographs of wells on Yelm Prairie, and precipitation at Yelm.

the average thickness of the saturated part is nearly 30 feet when the water table is high and about 23 feet when it is low. The materials of Vashon age are composed mainly of till, clay, sand, and gravel. The clay and till below the water table contain a negligible amount of water available directly to wells.

Approximately 50 percent of the material of Vashon age below the water table is composed of gravel and sand; till and clay constitute the remaining part. The average specific yield of the sand and gravel probably is in excess of 25 percent. The specific yield of the clay and till is generally only a few percent, so that the average specific yield for all saturated materials of Vashon age would be about 15 percent. Available storage in those saturated materials underlying the Yelm Prairie, during the March 1952 high water levels, would have been equal to 11 square miles, or 7,040 acres times 30 feet times 15 percent (7,040 times 4.5), or about 31,500 acre-feet. At the lowest stage in November 1951, several months after the end of the irrigation season, the water in storage in the Vashon drift would have been equal to a layer of water 3.45 feet deep over the entire prairie, or about 25,000 acre-feet.

Sixteen wells that penetrate the pre-Vashon deposits beneath the Yelm Prairie show that these deposits differ considerably in their water-yielding characteristics; on the average, however, strata of sand and gravel constitute about 25 percent of the total thickness.

If 25 percent is taken as the specific yield of the sand and gravel, and if 5 percent is used as the specific yield of the till, clay, and cemented gravel, then an over-all average specific yield of about 10 percent is obtained for the pre-Vashon deposits penetrated.

Assuming 10 percent as the average specific yield of the pre-Vashon material, a saturated layer of this material 1 foot thick would contain, on the average, 0.1 acre-foot of water per acre. On the same basis, the available storage in the upper 45 feet of pre-Vashon deposits then would amount to 4.5 acre-feet per acre for the entire prairie. This result is less reliable than the corresponding figures for the material of Vashon age, because it is based on less field data. However, adding the 4.5 acre-feet to the 3.6 acre-feet in the Vashon drift, the total amount of available water remaining in the upper 100 feet of the deposits underlying the Yelm Prairie at low water levels averages approximately 57,000 acre-feet, equivalent to a layer of water more than 8 feet deep over the entire prairie.

During the summer of 1951 very little rain fell on the Yelm area. Recharge in the Yelm Prairie during that period was chiefly by underflow of ground water into the prairie from adjoining till and morainal uplands; the rate of recharge by underflow has been estimated as averaging about 9,000 acre-feet per year.

The average annual underflow from the Yelm Prairie (excluding the bordering terraces) is believed to be not less than 25,000 acre-feet. Disregarding small losses by evaporation, transpiration, and pumping, the annual discharge less recharge from the uplands is roughly 15,000 acre-feet, or 41 acre-feet per day. From March 25 to September 25, 1951, the water table dropped an average of 6.5 feet—an unwatering for the prairie of 0.0353 foot per day, which is equivalent to nearly 250 acre-feet of material unwatered. Discharge of 41 acre-feet of water from 250 acre-feet of material would give a specific yield of 16 percent.

Quantity of ground water available in Yelm Prairie.— In a previous section of the report (p. 23) the average annual recharge to the Yelm Prairie and bordering terraces was estimated to be about 31,000 acre-feet. This figure is reasonably close to the calculated discharge of 35,000 acre-feet (p. 24) after seepage from the Centralia Power Canal was deducted. Both these figures include recharge added to the lower terraces which are not considered to be part of the Yelm Prairie proper. Deducting 5,700 acre-feet estimated to be added on these lower terraces leaves about 25,000 acre-feet for annual recharge and outflow based on recharge calculations, or about 29,000 acre-feet based on discharge calculations.

Not all this outflow could be recovered, even under extreme pumping conditions. Heavy pumping during the summer would lower the water table so that discharge from springs and seeps would be reduced; however, such natural discharge could not be entirely eliminated even during the irrigation period, and during the winter and spring, as the aquifers were replenished, more and more natural discharge would occur. Thus, although 25,000 to 30,000 acre-feet annually is the quantity theoretically available, it probably would not be feasible to recover more than one-quarter to one-third of that amount—perhaps 7,000 or 8,000 acre-feet annually.

These estimates of recharge to, and discharge from, the Yelm prairie include only the water occurring under water-table conditions and moving in the shallower aquifers. Water in the deeper aquifers occurs under artesian pressure, and these aquifers probably receive much of their recharge in areas of outwash and moraine to the south and east of the Yelm Prairie. Present data are insufficient to permit any close estimation of the quantity of ground water that might be available. However, it is probable that several thousand acre-feet per year would be available from these deeper aquifers in addition to the amount estimated above.

Consumptive use on 2,000 acres, the maximum acreage that has been irrigated on the Yelm Prairie, probably would not be more than 3,000 acre-feet. If the entire irrigable acreage of 4,500 acres were irrigated (which is very unlikely), consumptive use probably would be less than 7,000 acre-feet annually. It seems evident, therefore, that ample ground water is available for irrigation of Yelm Prairie.

Although the question of total quantity of water available in the prairie is of primary importance in over-all planning, the individual farmer probably is more concerned with the quantity of water that can be obtained from an individual well, the depth required, and the pumping lift. The following table summarizes data on irrigation, municipal, and industrial wells in the Yelm Prairie (more complete data are listed in table 1, p. 32).

Summary of municipal, irrigation, and industrial wells in Yelm Prairie

Well no.	Depth (feet)	Diameter (inches)	Yield (gpm)	Drawdown (feet)	Finish: Perforated (Pf), screen, or open-end casing
16/2-4A2	158	8	45	(small)	Pf 44-60, 69-92, 99-105, 113-118, 142-149 ft.
-5C1	81	12	60	75	Pf 64-80 ft.
-5R1	181	12	150	66	Pf 40-56, 67-78, 88-98,112-134, 144-177 ft.
17/1-13D2	158	8	50	1.5	Pf 60-66, 76-88, 92-94 ft.
-24B1	97	12	165	6	Pf 35-42, 85-93 ft.
-24L1	275	12	360	5.26	Pf 22-26, 64-68, 95-101, 201-211, 253-257 ft.
-25J1	8.1	72	83	.8	Dug well, open bottom.
17/2-19F1	21.3	10	....	....	Dug well, open bottom.
-19G2	13	48	52	(small)	Dug sump and well.
-19H3	63	8	45	5	Pf 21-31 ft.
-19J5	87	10	....	....	Pf 30-68 ft.
-19J6	105.2	8	80	....	Open-end casing only.
-19L1	135	10	265	1.5	Pf 19-24, 50-62 ft.
-19M1	34	42	75	(small)	Dug well, open bottom.
-19M2	97	8	240	8	Open-end casing.
-19N1	63	12	550	.16	Screen, 52-62 ft.
-20D1	27	30	....	....	Dug well, open bottom.
-20E2	61	12-10	100	10	Pf
-29E3	119	10	150	34	Pf 22-36, 42-58, 78-117 ft.
-29F3	78	6	20	(small)	Pf 32-37 ft.
-29L4	52	10	500	3	Pf 30-42 ft.
-29N1	50	8	50	....	Pf 16-50 ft.
-29N2	81	12	25	....	
-29P2	57	12	120	(small)	Pf 25-27, 38-53 ft.
-29Q1	55.5	8	42	....	Pf 24-44 ft.
-32Q2	254	12-8	600	55	Pf 13-18, 38-74, 80-98, 145-152, 238-251 ft.
-33K2	105	10	100	....	Pf 24-28, 44-56, 72-78, 92-102 ft.
-33P1	105	8	200	(small)	Pf 30-97 ft.
-33R1	150	12	90	100	Pf 42-146 ft.

The following discussion applies to these wells and does not include the domestic wells on the Prairie. The shallowest drilled well (other than domestic wells) on the prairie is 50 feet deep and the deepest one is 275 feet deep. However, only 5 wells are more than 150 feet deep, and the average depth is only 96 feet.

Only one well, 17/2-19N1 in the town of Yelm, is screened; most of the other wells are perforated. It seems significant that the only screened well on the prairie, with a yield of 550 gpm and a drawdown of only 0.16 feet, is by far the most prolific producer.

The specific capacity of the perforated wells ranges from less than 1 to 176 gpm per foot of drawdown. Of the 16 wells for which yield and drawdown data are available, 9 have specific capacities of more than 25 gpm per foot of drawdown.

It is possible that the perforations have been adequate in some of the other wells, but it is certain that many others are inadequately perforated. Even though the total opening included in perforations may be fairly large, a large percentage of the perforations may be opposite materials that are not very permeable. Some of the wells may be yielding very much less water than the aquifer is capable of supplying.

Quality of Ground Water

One partial and two complete chemical analyses were made of ground-water samples from wells in the Yelm area. These analyses are given in table 4. The water samples from wells 17/2-29L4 and 17/2-19N1 were from outwash deposits of the Vashon drift and that from well 17/2-19J5 was from pre-Vashon deposits. In addition to these analyses, hardness and chloride were determined by field methods in a number of water samples, and results of these tests are given in the column of remarks in the table of well records (table 1). The hardness was determined by titration with versenate, using a modification of the Schwarzenbach method, and chloride was determined by titration with silver nitrate, using potassium chromate as an indicator.

The most important uses of ground water in the Yelm area are domestic, irrigation, and municipal. In most respects the water is suitable for all three purposes. The water is soft, the hardness of all samples tested averaging about 50 parts per million (ppm). Dissolved solids, determined for the three samples shown in table 4, ranged from 66 to 102 ppm. With few exceptions, the water is odorless and has no objectionable tastes. However, the iron content of some samples was objectionably high; that of the three samples shown in table

4 ranged from 0.3 to 2.0 ppm. Although many well owners reported iron-free water, many others, possibly one-third, reported objectionable amounts of iron. In some water supplies the excess iron may have been caused by corrosion of pipes and plumbing, but in others the iron undoubtedly is already present in the water when it is pumped from the ground. The hydrogen-ion concentration (pH) of the samples ranged from 6.8 to 7.3.

Ground water in the Yelm area appears to be entirely suitable for agricultural use. The two important chemical factors affecting use of water for irrigation, boron concentration and percentage of sodium, were insignificant in the two samples analyzed. The boron content of both samples was only 0.02 ppm, far less than 0.33 ppm which is the maximum for water classed as "excellent" for use on sensitive crops by the Department of Agriculture (Wilcox, 1948). The percentage of sodium in the two samples was 22 and 20, respectively, and the quantity of dissolved solids was sufficiently low for both samples to be classed as "excellent" for irrigation.

The measured temperatures of ground water in the Yelm area ranged from 47° to 51° F.

UTILIZATION OF GROUND WATER

Most wells in the Yelm area are used solely for domestic purposes. Of the wells canvassed in the entire area, approximately 85 percent are utilized for domestic supply, 23 percent for stock watering, 8 percent for irrigation, and only 1 percent for public supply. There are a considerable number of multipurpose wells, which explains why the above percentages total more than 100.

Not all the domestic wells were canvassed, but probably all the public-supply wells and nearly all the irrigation wells are described in this report. Hence, the latter two types actually constitute smaller percentages than those given above.

A considerable number of wells of all types have been deepened as a result of the lowering of water levels in the dry spring and summer of 1951. Barring an unexpected increase of population, however, no great increase in the number of domestic wells is anticipated after the drillers have drilled or deepened wells for the residents who were affected by the dry spring and summer of 1951.

After the Yelm Irrigation Ditch ceased operations, and, in part, as a result of the dry spring and summer of 1951, a number of irrigation wells were drilled or deepened during 1951 and 1952, and more wells are being drilled at the present time. At the close of the summer of 1951, 300 to 500 acres was being irrigated on the Yelm Prairie. It was the consensus of opinion among residents of the Yelm Prairie that, by the end of the summer of 1952, nearly 1,000 acres would be under irrigation. Applications for 30 to 40 irrigation wells on the prairie have been filed with the Washington State Division of Water Resources, and these probably will constitute the majority of new irrigation wells for the next several years. The new irrigation wells drilled thus far have been somewhat deeper, on the average, than the older irrigation wells, and usually they have penetrated the pre-Vashon deposits, although much of the water is obtained from the overlying Vashon drift.

Present usage of ground water on the prairie is estimated at about 1,000 acre-feet annually. The quantity used probably will be several times as great within the next 5 years.

WELL CONSTRUCTION AND DEVELOPMENT

Of the entire number of wells tabulated in this report, about half were dug and about half were drilled; perhaps 1 percent were driven. It is probable that a large number of wells will be dug in the future, but the trend is toward drilled wells—particularly for irrigation wells.

The dug wells listed range in depth from a few feet to more than 130 feet (averaging 32 feet). Many of them are dug under difficult conditions—through hard till or loose sand and gravel. The dug wells are superior to drilled wells in storage capacity per foot of depth, because the diameter must be at least large enough to permit a digger to work. Many wells are dug by the owners. However, a disadvantage of dug wells is the difficulty of preventing contamination by surface water. Moreover, the wooden casing that is commonly used will rot, necessitating dangerous repair work. Furthermore, it is difficult to dig much below the water table for obvious reasons, although some wells are dug considerably below the water table before an aquifer is encountered, especially where the digger passes from till or clay to sand or gravel. It was chiefly the dug wells that went dry in 1951.

The drilled wells range from 24 to 362 feet and average about 90 feet in depth. Nearly all have been drilled by the cable-tool (percussion) method and are cased as drilling progresses. The casings of most of the drilled wells are 6 inches in diameter, unperforated, with open ends, and normally extend the full depth of the well.

On the Yelm Prairie, most of the older drilled wells have 6-inch, open-end, and usually unperforated casings, but many of the newer wells have 8-inch, 10-inch, or even 12-inch casings (most of them perforated, but well 17/2-19N1 is the only one that is screened).

Casings are necessary in all wells whose walls may collapse if devoid of support. As far as is known all wells drilled in the Yelm area are cased. Some of the dug wells are uncased, particularly if the walls are composed of till. Some of these wells have caved in, especially in times of heavy rain.

The yield varies with the diameter of the casing, but doubling the diameter of the casing generally increases the yield only 10 to 20 percent, depending on the size of casing and on the permeability of the aquifer.

All water entering the open-end, unperforated casing must pass through the material into which the casing opens. This limits the rate at which water from upper aquifers can enter the well and excludes it almost entirely if the upper aquifer is separated from the open end of the casing by an impermeable layer, such as till or clay.

Perforating or screening a well at the proper levels may increase its yield several fold. Assuming a theoretical well with a 12-inch casing, for example, the open end itself would present an entry area of 113 square inches. Perforating with 10 holes or slots per foot, each hole 1/4 inch by 2 inches, in sandy or gravelly beds would add open space equal to 50 square inches for 10 feet of perforated casing; screening with 20 percent of openings would add about 900 square inches of opening for 10 feet of 12-inch screen.

Screens commonly used in other localities range from 10 to 40 percent in open area. They are expensive, but they may be very effective for increasing yields and for excluding sand from wells. Perforating is less expensive than using screen, but it is less effective; however, it may be of considerable help in tapping aquifers through which the casing passes.

The above observations may serve to indicate the importance of perforating and screening, not only in increasing the intake area, but in opening up intake areas in permeable zones above the bottom of the well.

Finer material often is removed from the material immediately surrounding the perforated casing or screen, by "cleaning" or "surging" with compressed air or a surge block, or by alternately starting and stopping the pump. The finer materials are removed from the well, and the coarser material is concentrated adjacent to the perforated or screened portion of the casing, thus permitting more rapid inflow of water.

In the area covered by this report, the two wells having the highest specific capacity are the well of the town of Yelm (17/2E-19N1) and Gilbert Roehr's well (17/2E-29L4). The well of the town of Yelm was drilled to 63 feet—1 foot below the base of a 27-foot aquifer of coarse gravel and sand. Twelve-inch unperforated casing was set to 53 feet, and a 12-inch wire-wound screen was installed from 53 to 63 feet. The screen is rated at $37\frac{1}{2}$ percent of opening, which presents 1,700 square inches, or 11 3/4 square feet of open space, along the 10-foot length. During the pumping test the well yielded 550 gpm with a drawdown of only 0.16 foot.

Gilbert Roehr's well was drilled to 66 feet and was refilled to 53 feet when heaving fine sand was encountered. Ten-inch casing was set to 66 feet and was perforated from 30 to 42 feet with 10 holes per foot, 1/4 inch by 2 inches, giving a total open area of 60 square inches due to perforation in addition to 78 square inches at the open end. A pumping test at 550 gpm for $1\frac{1}{2}$ hours resulted in a drawdown of $2\frac{1}{2}$ feet. The recovery was reported to be very rapid (too fast to be measured, according to the owner).

CONCLUSIONS

The unconsolidated deposits of Pleistocene age that underlie the Yelm area contain aquifers of sand and gravel at many horizons, ranging from a few feet to several hundred feet below the surface. Some of these aquifers are very permeable and are capable of yielding large amounts of water. The water occurs chiefly under water-table conditions. The depth to water generally ranges from 20 to 70 feet.

Many irrigation wells are less than 100 feet deep, but a few have been drilled to depths of more than 200 feet. It is possible that the deeper drilling has been necessitated, in part, by failure to effectively utilize the shallower aquifers. Most of the irrigation wells are perforated, but some of the wells yield only a small part of the water available in the aquifers because of the limited intake area of the perforations. In some wells the total area perforated would be sufficient to let in all of the water that the aquifer is capable of yielding, if the perforations were all cut opposite productive horizons. However, in some of these wells, possibly 75 percent of the perforations are useless because they are cut opposite impermeable strata.

Ground water in the Yelm area is derived principally from precipitation on the area; the supply is replenished annually, chiefly during the winter and spring. Ground water under the Yelm Prairie moves generally northward and northwestward, discharging into the Nisqually River. The total annual underflow and discharge from the 11 square miles included in the Yelm Prairie is estimated to be roughly 25,000 acre-feet. Probably 7,000 to 8,000 acre-feet annually could be recovered by wells for irrigation on the prairie.

The effect of cessation of irrigation with water imported to the area by way of the Yelm Irrigation Ditch will be to reduce summer recharge of ground water on the Yelm Prairie. However, winter and spring precipitation usually will be sufficient to fill the aquifers to normal levels.

The quality of ground water is generally good throughout the Yelm area for all uses, although some water has a high iron content.

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RECORDS OF WELLS

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.

[Locations of wells are shown on pl. 2 and fig. 13]

Topography and approximate altitude: Fp, flood plain; Oc, outwash channel; Op, outwash plain; U, upland surface. Altitude of land-surface datum at well from barometric traverses or interpolated from topographic maps.
Type of well: Dg, dug; Dr, drilled; Dn, driven.
Depths and water levels: Measurements expressed in feet and decimal parts of feet were made by the Geological Survey; those in whole feet were reported by owner, tenant, or driller.
Type of pump: B, bucket; C, centrifugal (larger than that used for domestic supply); J, jet; P, piston (deepwell type); S, suction (any of several types of suction pumps used for domestic supply); T, turbine; HP hand-operated piston; HS, hand-operated suction.
Use of water: D, domestic; Ind, industrial; Irr, irrigation; PS, public supply; S, stock; NU, not in use.
Remarks: dd, drawdown; ft, foot or feet; gpm, gallons per minute; field tests for hardness (as calcium carbonate) and chloride in parts per million, ppm; hr, hours (s); L, log in table; min, minute; temp, temperature in degrees Fahrenheit.

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s)			Water level		Type of pump and yield (gpm)	Use of water	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material	Feet below land-surface datum	Date			
							T. 16 N., R. 1 E.							
1D1	Paul Fry	U, 380	Dr	72	6				Gravel, pea.	20	Reported	J	D	Drilled through "hardpan." Bailer test 17 gpm.
1Q1	T. T. Dalan	U, 415	Dg	27.4					Till	16.53	6-15-50	S	D	Drilled through "hardpan."
2G1	J. Zeller	U, 400	Dr	104	6							J	D, S	Report hard water.
2H1	E. Neeley	U, 400	Dr	118-127	6					60	Reported	P	D, S	Report soft water.
2M1	—Lukons	U, 435	Dr	155	6							P	D, S	Do.
2Q1	Harry Livingston.	U, 410	Dr	110±	6							J	D	Do.
2R1	H. Neeley	U, 410	Dr	108	6							J	D	Drilled through "hardpan" and boulders.
3F1	M. Fagan	U, 430	Dg	35	36							HP	D	"Hardpan" near surface.
4E1	(Vacant house)	U, 487	Dg	11.34	48					6.28	6-21-50	HS	S	Well at edge of perched swampy area.
4J1	R. W. Gehrke	U, 450	Dr	195	6					115	Reported	P	D, S	Drilled through "hardpan" and blue clay.
4L1	J. D. Clark	U, 465	Dg	11.74	50					2.39	6-20-50	S	D	Well in perched swampy area.
5D1	E. Gifford	Op, 505		90	4							P	D	
5K1	A. Swenson	Op, 510	Dg	130	48 by 72					127	Reported	P	D, S	Report soft water.
5L1	G. Heupel	Op, 505	Dg	125	48							J	D	Do.
5Q1	L. Kristoferson.	Op, 490	Dr	110	6				Sand	100(?)	Reported	J	D	Report water at 87 ft in sand. Hardness 84, chloride 10 ppm.
5Q2	do.	Op, 490	Dr	212	4				Gravel, pea.	200	Reported	P	D	Bailer test 2 1/4 gpm. Gravel at bottom.
6J1	Leon Barnhouse.	Op, 500	Dr	216	6	216				202	Reported	P	D	Pumped 19 gpm, no dd. L.

6P1	—McGiven	Op, 455	Dr	180	6							J	D	Well is 100 yards from edge of 40 ft scarp.
7E1	C. B. Frost	Op, 425	Dg	66.36	24-10	152			Sand	58.99	6-21-50	J	D	Drilled to 152 ft. L.
7G1	W. W. Reid	Op, 440	Dr	125	6	80			Sand and gravel.			J	D	Perforated at 57 ft.
7G2	R. Owens	Op, 450	Dr	69	6				Gravel			J	D	Report soft water.
7P1	—Tanner	Op, 430	Dr	105	6	105						J	D, S	Pump jet at 35 ft.
7R1	F. Stansky	Op, 435	Dr	167	6							J	D	Bailer test 13 gpm.
8C1	J. Longnecker	Op, 480	Dg	86	10				Sand and gravel.	69	Reported	P	D, Irr	Report soft water.
8D1	N. Bullpitt	Op, 485	Dr	180	6							J	D, S	Do.
8D2	J. Christiansen.	Op, 485	Dg	81.5	48					68.61	6-21-50	P	D	Do.
8R1	Arnald Englund.	Op, 405	Dg	22	36				Sand	17	Reported	S	D	Well in depression 100 ft southwest of house.
9A1	J. M. Kearns	Oc, 425	Dr	120	6				Gravel	95	Reported	P	D	Report soft water.
9F1	Town of Rainier (Well no. 1).	Oc, 428	Dr	120	6	120				120	Reported	J, 29	PS	
9F2	Town of Rainier (Well no. 2).	Oc, 428	Dg-Dr	120	6	120				115	12-13-51	50	PS	Pumped 48 hr at 50 gpm, 1 2/3-ft dd. Peerless Hi-Lift Pump.
9M1	Dr. B. L. Phillips.	Op, 425	Dr	117	6				Gravel	107	Reported	J, 10-15	D	
11B1	O. Englund	U, 408	Dg	105.7	22-(?)	105.7	103.3		do.	58.51	6-15-50	P	D	L.
12B1	W. Price	U, 415	Dg	42.2	30					10.42	6-15-50	J	D	Report soft water.
12F1	—Clausen	U, 440	Dr	100+	6									
12K1	J. D. Metrakes.	U, 435	Dg	55.7	60					30.45	6-16-50	J	D, S	Report soft water.
12P1	—Peoples	U, 425	Dr	127	6							P	D, S	Do.
13A1	W. C. Gifford.	U, 445	Dr	35	6				Gravel	29	Reported	J	D, S	"Hardpan" nearly to bottom.
13E1	Charles Pettit.	U, 450	Dr	93	6				do.	30	Reported	P	D	"Hardpan" to bottom.
13G1	—Vandervier.	U, 470	Dr	100+	6								D	
13G2	Earl Nelson	U, 443	Dr	54	12	54	45	9	Gravel					Pumped 65 (?) gpm. L.
13H1	D. Martin	U, 445	Dr	103	6							P	D, S	Report hard water.
13J1	A. B. Smith	U, 455	Dr	85	8							J	D	Report soft water.
13K1	—Vandervier.	U, 465	Dr	80	6							J	D, S	Do.
13R1	J. Hodge	U, 455	Dg	46.81	36					38.30	6-14-50	B	S	"Hardpan", 6 ft; gravel and boulders at bottom.
14E1	Al Wall	U, 455	Dr	102	6				Gravel	81	Reported	HP	D	Goes dry in winter. Roaring sounds when dry.
14F1	W. J. Lazelle	U, 460	Dr	110	7				do.	71.01	6-16-50	P	D, S	Report soft water.
14M1	C. Colman	U, 450	Dr	123.5	6	123.5	102		Sand and pea gravel.	82.5	8-21-50		D	Bailer test 16 gpm, dd 12 ft. L.
16L1	R. Reichel	Oc, 480	Dr	149	6							P	D	Report hard water.
16L2	R. C. Stewart	Oc, 480	Dr	159	6				Gravel			P	D	Do.
17K1	R. Pettit	Oc, 350	Dr	27	6							S	D	Report soft water.
21J1	T. Bullpitt	Oc, 445	Dr	130	6				Gravel			P	D, S	Sand and gravel upper 106 ft. Report soft water.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Water level: Feet below land-surface datum.	Water level: Date	Type of pump and yield (gpm)	Use of water	Remarks
							T. 16 N., R. 1 E—Continued							
21J2	H. Middleton.	Oc, 445	Dr	98	6	....	....	....	Gravel.....	92	Reported	J	D, S	Report soft water.
22F1	M. W. Martin	Oc, 452	Dr	98.28	6	....	....	....	....	82.73	6-23-50	P	D, S	Bailer test 25 gpm.
22P1	W. Goodwin...	Oc, 431	Dg	80.28	30	....	....	....	....	75.20	6-23-50	P	D, S	Report hard water.
23C1	W. Seeley.....	U, 465	Dr	120	6	....	....	....	Gravel, pea.	90	Reported	J	D, S	Bailer test 36 gpm.
23D1	F. Porter.....	U, 470	Dg	31	24	....	....	....	....	....	....	S	D	Report soft water.
23E1	R. A. Walls..	U, 465	Dg	35.10	....	35.10	....	....	Till.........	32.28	6-26-50	J	D	Goes dry in late summer.
23M1	T. L. Jenson.	Oc, 430	Dr	105	6	....	....	....	.....do.....	....	....	P	D	Report soft water.
26M1	E. Horsfall...	Oc, 450	Dr	150	6	150	....	....	Gravel.....	10	Reported	J	S, Irr	Perforated at 50 ft. Report hard water, high iron content.
27H1	Weyerhauser Timber Co.	Oc, 420	....	190	12-8	....	178	8+	Gravel and sand.	....	....	100	....	Some water in gravel and sand between 70 and 80 ft.
							T. 16 N., R. 2 E							
1K1	Centralia Power Co.	Fp, 340	Dn	16+	1½	....	....	....	....	....	....	HS	D	Well on bank of canal.
2K1	A. D. Blackler.	U, 450	Dg	17.6	36 by 60	....	....	....	....	8.40	6- 9-50	S	D	Considerable perched water in the area.
2K2	......do.........	U, 450	Dr	225	8	195	....	....	Gravel.....	87	Reported	T	D, S	Pumped 38 gpm, 20-ft dd. Submersible pump.
2M1	G. Longmire..	U, 446	Dg	22.6	48	....	....	....	.....do.....	11.60	6- 9-50	J	D	Dug through "hardpan." Report hard water.
3E1	B. E. Rieke...	U, 455	Dn	60	4-2	60	....	....	....	....	....	P	D, S	Casing, 4-in.; to 30 ft.
4A1	C. H. Johnston.	Oc, 380	Dg	42.1	28	42	....	....	....	32.80	5-25-50	J	D	Creek 80 ft south, 5 ft below level of well cap.
4A2	.......do.........	Oc, 380	Dr	158	8	158	....	....	....	40	Reported	T	Irr	Bailed ½ hr at 45 gpm, no dd. L.
4F1	Else Bonnie...	U, 450	Dg	33.74	48	....	....	....	Till.........	23.82	6-16-50	J	D	Goes dry in early fall.
5C1	J. & A. Mc-Monigle.	Oc, 380	Dr	79.5	12	81	64	80	Gravel.....	4.28	2-26-52	....	Irr	Pumped 3 hr at 60 gpm, 75-ft dd. L.
5J1	H. Rochester.	U, 440	Dg	28	36	....	....	....	....	14	Reported	J	D	"Hardpan" to bottom.
5R1	S. Dunagan....	U, 450	Dg-Dr	181	12	181	....	....	Sand and gravel.	30.66	2-26-52	J	D, Irr	Pumped 4 hr at 150 gpm, dd 66 ft. L.
6A1	Minnie Lane...	U, 420	Dg	37.7	48	....	....	....	....	22.89	5-26-50	P	D	Goes dry in fall after a dry summer.
6B1	A. J. Barrett	U, 405	Dg	40.6	48	....	....	....	Gravel and sand.	10.50	5-29-50	J	D	Chloride 9 ppm.
6D1	C. Cullens.....	U, 400	Dr	48	6	....	....	....	....	14.8	Reported	P	D, S	Report soft water.
6F1	N. Windsor....	U, 405	Dg	55	60	....	....	....	Till.........	8	Reported	P	D, S	Report all "hardpan" except sand from 37 to 47 ft.

7A1	E. W. Edwards.	Oc,	409	Dr	63.41	6	63.41	62	......	Gravel......	14.59	6- 9-50	J	D	Bailer test 16 gpm.
7Q1	R. W. Shattuck.	U,	450	Dr	287	10	287	......	......	Gravel and sand.	42	Reported	......	......	Pumped 4 hr at 248 gpm, 62 ft dd (or less). L.
7R1	R. Judd........	U,	452	Dg	15	36	......	......	......	......	12.50	6- 9-50	......	NU	Dry 9-28-50.
8C1	W. A. Needles.	U,	440	Dr	56.9	6	56.9	......	......	......	28.10	6- 9-50	J	D	Water occasionally flows from casing in late winter. Hardness 48, chloride 7 ppm.
8E1	R. Judd........	U,	440	Dr	46+	6	......	......	......	......	16.3	6- 9-50	P	D	Report soft water.
8N1	—Capen.........	U,	465	Dr	80	6	......	......	......	Gravel, sandy	40	Reported	J	D	Report hard water.
9G1	R. H. Smith..	U,	465	Dg	16.7	48	......	......	......	Till.........	7.20	6- 9-50	S	D	Easily pumped dry.
9K1	J. A. Green..	U,	455	Dg	20.8	48	......	......	......	......	4.4	6- 9-50	S	D	
9L1	Gana Hayes...	U,	458	Dg	20	36	......	......	......	Till..........	9.80	6- 9-50	S	D	Report hard water. Temp 48.
9L2	J. Bonney......	U,	460	Dg	17.8	48	......	......	......	Gravel......	10.10	6- 9-50	S	D	"Hardpan" to bottom. Report soft water. Temp 47.
9L3	R. McLucas...	U,	455	Dg	14.2	30	......	......	......	Sand.........	4.90	6 -9-50	HS	D	Report soft water. Temp 47.
10C1	Harvey Thompson.	U,	468	Dg	29.95	48	......	......	......	......	5.55	6 -9-50	J	D	Hardness 72, chloride 11 ppm.
10E1	—Dotson.......	U,	465	Dr	30	6	......	......	......	......	6	Reported	J	D, S	Report iron in water.
14M1	F. Kelley......	U,	490	Dg	40	48	......	......	......	......	......	......	......	D, S	Report well dry in 1948.
15J1	J. F. Peterson	U,	480	Dg	21.07	36	......	......	......	......	6.42	6-12-50	HS	D	Drilled through cemented gravel.
16G1	L. L. Lawton	Oc,	486	Dg	38.76	48	......	......	......	Till..........	22.70	6-14-50	P	D	Report soft water.
17D1	Roy C. Hansen	U,	465	Dg	55	48	......	......	......	......	......	......	J	D	Do.
17F1	.... do.........	U		Dg-Dr	49.5	......	......	......	......	......	......	......	100	Irr	Used 30 gpm continuously during 1947 irrigation season.
17L1	E. Dame.......	U,	460	Dg	45	48	......	......	......	Gravel, pea and sand	26	Reported	P	D, Ind	Test pumped at 50 gpm. L.
17M1	G. Summers..	U,	462	Dr	39.01	6	39.01	......	......	......	17.64	6-14-50	J	D	Well dry in fall of 1949.
18A1	D. Edmunds...	U,	450	Dg	33.99	36	......	......	......	......	3.45	6-15-50	J	D	Report soft water.
18C1	—Shultz........	U,	435	Dg	57	36	......	......	......	Till..........	15	Reported	J	D	Top 6 ft soil, remainder "hardpan."
18H1	—Boudreau....	U,	445	Dg	31.26	60	31.26	......	......	......do......	8.61	6-14-50	P	D	Water has flowed from casing late in winter. L.
18M1	R. Stewart.....	U,	455	Dg	43.49	36	43.49	......	......	......	31.43	6-14-50	P	D	"Hardpan" predominates.
18N1	R. D. Summers	U,	455	Dr	51.25	6	......	......	......	......	37.29	6-14-50	P	D	Report soft water.
20G1	—Edwards.....	Oc,	450	Dg	20	......	......		......	Sand.........	14	Reported	......	D	Well is 50 yards from lake.
20M1	M. Stewart....	Oc,	470	Dg	39.50	48	......	......	......	......	36.98	6-14-50	J	D	Report soft water.
22D1	Reta Watson...	Oc,	495	Dg	42.92	12	......	......	......	......	25.14	6-13-50	P	Irr	Goes dry in October. Report foul taste and odor.
22Q1	G. W. Lee.....	U,	537	Dr	47.98	6	......	......	......	......	25.47	6-13-50	J	D	Report soft water.
25C1	M. McVittie...	U,	500	Dg	19.74	48	19.74	......	......	......	17.09	6-12-50	HS	D	Springs and perched water approximately 100 yards from well.
25L1	J. McLaughlin	U,	570	Dr	76	6	......	......	......	......	......	......	J	D, S	Pump can be run only 15 min at a time.
26J1	G. D. Ruttledge	U,	515	Dg	12.33	36	......	......	......	......	6.56	6-12-50	S	D	Drawdown 3 to 4 ft but refills rapidly.
26L1	L. Johnson.....	Oc,	500	Dg	9	30	......	......	......	......	4.30	6-12-50	B	D	Report iron in water.
27A1	C. Warner.....	U,	540	Dg	54.21	48	......	......	......	Till..........	45.64	6-13-50	J	D	Well was pumped dry in $5\frac{1}{2}$ hr, 6-12-50.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s)			Water level		Type of pump and yield (gpm)	Use of water	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material	Feet below land-surface datum	Date			
							T. 16 N., R. 2 E.—Continued							
27B1	G. L. Warner	U, 537	Dr	100	6	...	...	...	...	80	Reported	J	D, S	Report soft water.
27Q1	D. A. Jensen	Oc, 490	Dg	16	...	...	...	...	...	...	...	S	D	Iron stain on clothes. Hardness 44, chloride 11 ppm.
29H1	I. T. Beck....	Oc, 450	Dr	312	8	...	...	...	...	15	Reported	T	D	Perforated at 50 ft.
30A1	N. J. Smith..	Oc, 460	Dg	12	36	...	...	...	Sand.......	8	Reported	S	D	Report soft water.
34D1	Cougar Mt. Camp.	Oc, 470	Dr	362	6	...	...	...	...	...	...	...	...	Report hard water, foul to taste.
36A1	George Bergman.	U, 515	Dg	15	...	...	...	...	Gravel....	10	Reported	S	D	Report soft water.
							T. 16 N., R. 3 E.							
19H1	W. Van Den Elzen.	Oc, 380	Dg	27	36	...	...	...	...	22	Reported	HP	D, S	Report soft water.
							T. 17 N., R. 1 E.							
13D1	E. Livernash.	Oc, 335	Dr	100	4	...	...	...	...	...	...	P	D	Unable to measure depth. Report soft water.
13D2	Edward Percival.	Oc, 330	Dr	158	8	158	...	...	Gravel, sandy, clayey	78	Reported	T	Irr	Tested 50 gpm before perforating. Bailed 1/4 hr, 1½-ft dd.
13D3	A. H. Weeks	Oc, 335	Dr	118.0	6	118	...	...	...	89.18	11-19-51	...	...	
13E1	Milo Schneider	Oc, 334	Dr	93	6	93	...	...	...	63.5	6-2-50	J	D	Chloride 9 ppm.
13E2	H. M. Erickson.	Oc, 335	Dr	80	6	...	...	...	...	...	...	J	D	Report soft water.
13F1	C. S. Massey.	Oc, 345	Dr	100	6-5	52.5	...	...	...	70	Reported	J	D	Do.
13F2	A. Tafoya.....	Oc, 340	Dg	61.0	29 by 34	...	...	...	...	59.95	11-19-51	...	NU	
13M1	L. Parker and E. A. Dinwiddie.	Oc, 338	Dg-Dr	98	6	98	...	...	...	43	Reported	J	D	Bailed ½ hr at 13 gpm; 20-ft dd. Supplies five families and store.
13N1	A. Clarambeau.	Oc, 337	Dg-Dr	101	6	101	...	...	...	54.55	9-11-51	J, 5	D, S	Chloride 8 ppm. (Sample taken when well 52.5 ft deep.) Bailed 10 gpm.
13P1	W. C. Ettinger	Oc, 345	Dr	92	4	92	...	...	...	54.68	11-26-51	J	D, S	
14A1	W. R. Simcox	Oc, 320	Dr	110+	4	...	...	...	...	87	6- 2-50	J	D	Chloride 9 ppm.
14A2	R. W. Shattuck.	Oc, 317	Dr	95.0	6	95	...	...	...	29.5	6- 2-50	P	D, S	Report soft water.
14J1	Irrigation District.	Oc, 325	Dr	94.5	6	94.5	...	...	...	41.5	6- 2-50	...	NU	Never used.

14J2	Dept. of Agriculture.	Oc, 322	Dr	62.3	6					48.3	6- 6-50		NU	
14J3	L. Raab	Oc, 335	Dr	106	6	106				72.77	11-20-51	J	D	Bailed 8 gpm. Much fine sand came in bottom.
14N1	L. A. Crimmins.	U, 375	Dr	133	6				Sand and gravel.	115	Reported			Bailer test 16 gpm, report no dd. L.
23A1	Bruno Burnetti.	Oc, 340	Dr	51	6				do.	22	do.	J	D	Bailer test 16 gpm, dd 22 ft.
23A2	H. Willuweit	Oc, 345	Dr	54.8	6	54.8				28.1	6- 1-50	P	D	Chloride 15 ppm. Well deepened to 81 ft in 1951; bailed 10 gpm.
24A1	R. W. Dyckeman.	Oc, 349	Dg	33.3	48					24.4	6- 2-50	B	D	Dug through gravel, "hardpan" and cemented gravel. Report soft water.
24B1	C. R. Lewis	Oc, 347	Dr	97	12	97			Gravel			T	Irr	Pumped 2 hr at 165 gpm, 6-ft dd. L.
24C1	R. C. Shear	Oc, 345	Dg	39.9	36	39.9				34.3	6- 2-50	J	D	Report soft water.
24E1	C. Hansen	Oc, 340	Dg	27	60	27				27	Reported	S	D	Report hard water.
24F1	F. L. Beggs.	Oc, 343	Dg	32	6					26.2	6- 1-50	S	D	Report soft water.
24G1	F. W. Nobel	Oc, 343	Dg	37.8	6	37.8				27.3	6- 1-50	J	D	Do.
24G2	Carl Iverson	Oc, 345	Dg-Dr	97	6	97				41.17	11-26-51	J	D	Report water soft before deepening well from 39.8 to 97 ft.
24G3	Robert Hutches.	Oc, 335	Dr	43.3	6					32.26	11-18-51	HP	NU	
24H1	—MacAuley	Oc, 341	Dg	29.8	8					23.3	6- 2-50	S	D	Report soft water.
24K1	W. J. Brougger.	Oc, 350	Dg	29.6	6	29.6				23	6- 1-50	S	D	Do.
24L1	Warren Simmons.	Oc, 345	Dr	275	12	263			Sand and gravel.	13.58	2-26-53			Pumped 4 hr at 360 gpm, 5.26-ft dd. L.
25A1	L. M. Detton.	Oc, 356	Dg	22	30					13.2	5-31-50	S	D	Iron in water.
25A2	T. Windsor	Oc, 345	Dn	28	3	28			Gravel, pea.	16.0	6- 1-50	S	D	Well dug to 24 ft. Casing driven to 28 ft.
25A3	S. C. Maybee	Oc, 356	Dg	29	6					18.8	6- 1-50	S	D	
25B1	—Philby	Oc, 350	Dg	9.8	48					7.2	6- 1-50	S	D	Well 20 yards east of large perched swamp.
25E1	—Nordburg	Oc, 355	Dr	29.5	6					21	Reported	J	D	Report soft water.
25J1	Ray Sias	Oc, 350	Dg	8.1	72	9			Gravel	3	5-31-50	C	Irr	Drawdown 0.8 ft at 83 gpm.
25F1	J. J. McKay.	U, 380	Dr	76	6	73								Report soft water. Bottom 5 ft of well excellent source of water. No noticeable dd when bailed.
25N1	—Lenholm	U, 415	Dr	125	6							J	D, S	Report soft water.
26H1	G. E. McKenzie.	Oc, 350	Dg	36	36				Gravel	14	Reported	J	D	Considerable perched water in area.
33G1	J. W. Fillman	U, 485	Dr	220	4				Gravel, pea and sand.	208	Reported	P	D	Report soft water.
34F1	C. Roetter	U, 450	Dr	180	6				Gravel, pea.			P	D, S	Hardness 70, chloride 8 ppm.
34L1	E. B. Bauldwin.	U, 441	Dg	29.46	60				Sand	21.95	6-20-50	B	D	Report soft water.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Water level: Feet below land-surface datum.	Water level: Date	Type of pump and yield (gpm)	Use of water	Remarks
T. 17 N., R. 1 E.—Continued														
34R1	P. S. Dutton.	U, 425	Dg	21.75	48	....	....	....	Till.........	14.77	6-20-50	S	D	"Hardpan" to bottom.
35A1	—Bowen......	Oc, 355	Dg	18.25	30	....	....	....	....	3.63	6-19-50	S	D	Report soft water.
35F1	H. J. Muller.	U, 413	Dr	81.01	6	....	....	....	Gravel.....	52.35	6-20-50	J	D, S	Hardness 90, chloride 15 ppm. Bailer test 25 gpm.
35F2	...... do........	U, 412	Dr	69.70	6	....	....	....	....	45.15	6-20-50	J	D, S	Well goes dry in late fall.
35K1	E. Broughton	Oc, 400	Dg	30.56	24	....	....	....	....	17.00	6-19-50	J	D	Report soft water.
35L1	F. C. Koeppen	U, 405	Dg	24.39	48	....	....	....	....	10.7	6-19-50	S	D	Do.
35L2	...... do........	U, 405	Dr	95	4	....	....	....	....	87	Reported	....	....	Supply not large enough.
35P1	—Koeppen....	U, 410	Dr	140	6	....	....	....	....	....	....	P	D, S	Iron in water.
T. 17 N., R. 2 E.														
1E1	U. W. Waite.	U, 400	Dg	55	48	....	....	....	....	31	Reported	P	D	Report soft water.
1M1	Nels Peterson	U, 390	Dg-Dr	27	6	25	14	13	Gravel.....	14	Reported	S	D	Report plentiful supply of water.
1N1	L. W. Wood..	U, 410	Dg	8	....	....	....	....	..... do.....	6	Reported	S	D; S	Report soft water.
2N1	—Lawranz...	U, 360	Dg	7.16	72	....	....	....	....	4.86	6-28-50	S	D	Well 10 ft from creek.
2Q1	S. Goltao.....	U, 433	Dg	44.96	48	....	....	....	....	30.87	6-29-50	J	D; S	Hardness 62, chloride 16 ppm.
3C1	E. Halsey....	U, 355	Dg	30	36	....	....	....	Gravel.....	23	Reported	S	D, S	Report soft water.
3D1	J. J. Scott...	Oc, 330	Dr	37.5	6	....	....	....	Sand........	25.5	Reported	J	D	Do.
3D2	M. H. Booth..	Oc, 330	Dr	40	6	40	....	....	Gravel.....	20	Reported	J	D, S	Pumped 20 min at 45 gpm, no dd. L.
6H1	H. C. Golman	U, 307	Dg	62.3	36	....	....	....	....	56.96	11-8-37	....	D, S	Adequate supply of water, 3 ft "hardpan" at bottom.
10M1	O. Soklik......	Oc, 340	Dr	39	6	....	....	....	....	....	....	J	D, S	Report soft water.
11F1	H. Anderson.	U, 370	Dg	14.86	36	....	....	....	Sand........	3.48	6-28-50	S	D	Well is 60 ft from creek.
11N1	G. R. Nixon.	U, 382	Dg	13.33	48	....	....	....	...... do.....	8.00	6-28-50	S	D	Report soft water.
14G1	E. J. Locke..	U, 400	Dg	15	48	....	....	....	Gravel.....	5.46	6-28-50	S	D, S	Hardness 30, chloride 10 ppm.
14R1	H. L. Willhoite.	U, 410	Dg	38	48	....	....	....	Gravel, cemented	32	Reported	J	D	Went dry during fall of 1949.
15A1	E. W. Brock	U, 380	Dg	35	....	....	....	....	....	15	Reported	S	D	Report hard water.
15D1	—Golding.....	Oc, 350	Dr	97	6	....	....	....	....	....	....	J	D, S	Report soft water.
15G1	—Crowser....	U, 392	Dg	13.43	30	....	....	....	Gravel.....	8.74	6-28-50	S	D, S	Well at edge of large perched swampy area.
15J1	Milo Jenson..	U, 395	Dg	24	....	....	....	....	....	....	....	S	D, S	Hardness 86, chloride 14 ppm.
15N1	—Knott........	U, 390	Dr	47	6	....	....	....	....	....	....	J	D	Report soft water.
16H1	—Golding.....	Oc, 330	Dr	105	6	....	....	....	....	....	....	J	D	Hardness 44, chloride 9 ppm. Little dd at 60 gpm.
16Q3	Roy Gonia....	Oc, 320	Dg	39.0	48	....	30	10	Sand and gravel.	37.15	10- 4-43	J	NU	Little change in water level with pump turned off 5 min.

16Q4	James Gonia..	Oc,	330	Dr	115	6	...	...	...	Sand.......	7.05	10- 4-43	J	D	Boulders to 20 feet, "hard-pan" to 78 feet. Recovered in 20 min.
16Q5	Roy Gonia......	Oc,	320	Dr	96	6	96	...	...	...	32.83	8-20-45	J	D, S	Pump off 10 min before water level measured.
16Q6	J. T. Harrison.	Oc,	330	Dr	100	6	...	...	...	Sand.......	1	Reported	J	Irr	Drilled inside 16Q7. Use both wells.
16Q7	..... do..........	Oc,	330	Dg	47	36	...	...	...	Till.........	27	Reported	J	D	Report soft water.
16R1	F. Poletowski	Oc,	325	Dg	20	...	...	...	...	Gravel....	16	Reported	S	D	Easily pumped dry in dry weather. Report soft water.
17E1	C. Hutches....	Oc,	330	Dg	35	8	...	...	...	...	32	Reported	J	D, S	Report soft water.
17P1	R. V. Booth..	Oc,	340	Dr	72.7	6	72.7	...	...	...	32.35	6- 7-50	J	D	Perforated at 3 levels.
18L1	P. H. Gorman	Oc,	325	Dr	24.5	6	...	...	...	...	9.3	6- 6-50	S	D	Hardness 36, Chloride 6 ppm.
18N1	F. A. Scharman.	Oc,	325	Dr	71	6	71	70	1	Gravel....	30.4	Reported	...	D	Bailing test: dd 15 ft after 24 gpm for 3 min. L.
18P1	E. T. Combes	Oc,	330	Dg	25	12	...	...	...	...	19.3	6- 6-50	S	D, Irr	Report soft water.
18Q1	John Domick..	Oc,	332	Dr	36.6	6	...	...	...	...	27.74	11-20-51	HP	NU	
18R1	F. W. Peterson.	Oc,	343	Dg	28.5	22	28.5	...	...	...	24.92	5-15-51	HP	NU	About 25 ft from Yelm ditch flume.
18R2	....	Oc,	330	Dr	31.2	6	...	...	...	...	16.77	3-27-52	HP	NU	About 10 ft above Centralia Power Canal.
19A1	—Rochester...	Oc,	332	Dg	20.4	30	...	...	...	...	15.5	6- 6-50	HP	D	Goes dry in late summer.
19C1	Bessie McBride.	Oc,	335	Dg	25.4	6	...	...	...	...	18.9	6- 6-50	C	D	Report soft water.
19D1	C. H. Massey	Oc,	335	Dg	22.1	48	22.1	...	...	...	17.55	6- 6-50	C	D	Hardness 44, chloride 6 ppm.
19F1	F. Cummings	Oc,	338	Dg	21.3	10	...	...	...	...	17.13	11-24-51	J	D, Irr	Well 100 ft southeast of house.
19G1	E. Dunham....	Oc,	340	Dg	26.3	6	26.3	...	...	...	18.9	6- 7-50	S	D	Pumped 7 gpm all day, no change in water level.
19G2	—Cochran.....	Oc,	339	Dg	13	...	...	...	...	Gravel....	12	6- 8-50	C, 40	Irr	Sump dug by a bulldozer. Use six to eight sprinklers.
19G3	.... do.......	Oc,	345	Dg	28.55	8	28.55	...	...	...	20.05	6- 8-50	S	D	Hardness 26, chloride 5 ppm.
19H1	A. Hewitson..	Oc,	350	Dr	42	6	...	...	...	Gravel, pea	18.5	Reported	J	D, S	L.
19H2	G. Bruns......	Oc,	353	Dr	35	6	35	...	...	Sand, black	20.4	6- 7-50	S	D	Hardness 52, chloride 9 ppm.
19H3	A. Hewitson..	Oc,	350	Dr	63	8	63	...	...	Gravel and sand.	21		T	Irr, S	Pumped 45 gpm, 5-ft dd. Report to recover in 45 seconds. L.
19J1	G. Paradis....	Oc,	348	Dg	29.2	10	29.2	...	...	...	18.7	6- 7-50	S	D	Reported plenty of water. Hardness 28, chloride 8 ppm.
19J2	D. A. Dey.....	Oc,	348	Dg	29.5	6	...	...	...	Sand, black	20.1	6- 7-50	S	D	Report soft water.
19J3	J. M. Hales..	Oc,	350	Dg	33.8	48 by 72	...	...	...	...	18.3	6- 8-50	J	D	Water reported soft. L.
19J4	Florine M. Bradley.	Oc,	340	Dr	51.0	6	51	...	...	...	15.3	6- 8-50	J	D, S	Report soft water. No "hard-pan."
19J5	J. M. Hales...	Oc,	350	Dr	87	10	87	...	...	...	24.30	9-25-51	T	D, Irr	L.
19J6	George Paradis.	Oc,	348	Dr	105.2	8	105.2	...	...	...	29.93	10-23-51	T, 80	D, Irr	Open-end casing, nor perforated.
19K1	D. A. Dey.....	Oc,	335	Dg-Dr	13.5	60	None	...	...	...	9.34	10- 5-51	...	NU	Originally 97-ft well, casing pulled.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gpm)	Use of water	Remarks
							T. 17 N., R. 2 E.—Continued							
19L1	Enumclaw Creamery Co.	Oc, 340	Dr	135	10	112	53.5	2.5	Gravel and sand.	7.24	3-27-52	T, 265	Ind	Report 1.5 ft dd at 265 gpm. L.
19M1	Town of Yelm	Oc, 350	Dg	34	42	34	29	5	Sand and gravel.	29	Reported	C, 75	PS	Report no dd at 75 gpm.
19M2	......do......	Oc, 350	Dr	97	8	97	......	......	......	26	Reported	......	NU	Report 240 gpm with 8 ft dd.
19N1	......do......	Oc, 350	Dr	63	12	63	35	27	Gravel and sand.	25.5 27.2	9-14-50 10-18-50	T, 270	PS	Test at 550 gpm with dd of 2 in. (0.16 ft). L. Analysis in table 3.
19Q1	Guy Johnston.	Oc, 350	Dr	32.8	6	......	......	......	Gravel.....	24.01	10-12-51	S	D	Report plenty of water.
20B1	J. A. Childers	Oc, 356	Dr	47.5	6	......	......	......	......	30.7	7- 7-50	......	NU	
20C1	E. R. Shranklen.	Oc, 348	Dr	36	6	......		......	Gravel, fine and sand	......	......	J	D	Report pumped several hours without noticeable change in water level. L.
20C2	F. Klingenberg.	Oc, 330	Dg-Dr	90	6	90	......	......	......	10	Reported	J	D	Tested 10 gpm.
20D1	Dewey Hutton	Oc, 341	Dg	27	30	......	......	......	......	24.3	6- 7-50	C	D, Irr	Report soft water.
20E1	Eva Hovis.....	Oc, 353	Dg	33.8	18	......	......	......	......	25.9	6- 7-50	J	D	Do.
20E2	C. Hewitson..	Oc, 345	Dr	61	12-10	61	......	......	Gravel.....	23	Reported	T	D, Irr	Tested at 100 gpm with dd of 10 ft.
20F1	G. Echtle.....	Oc, 355	Dg	32	6	......	......	......	......	28.3	6- 7-50	J	D, S	Deepened to 80 ft July 1951; bailed 10 gpm. Hardness 28, chloride 19 ppm.
20J1	......	Oc, 353	Dg	35.4	42	......	......	......	......	30.17	3-27-52	......	NU	
20K1	A. Landon.....	Oc, 360	Dr	52.6	6	......	......	......	......	32.0	6- 8-50	J	D, Irr	Hardness 24, chloride 9 ppm.
20L1	C. R. Keep...	Oc, 351	Dr	36.7	6	......	......	......	......	22.65	6- 8-50	J	D	Report soft water.
20M1	C. F. Russell	Oc, 355	Dr	43	6-4	......	......	......	Gravel, pea	27	Reported	J	D	"Hardpan" 31 to 43 ft, underlain by pea gravel.
20N1	L. Robison...	Oc, 350	Dr	60	10	......	......	......	......	......	......	J	D, S	Perforated at approximately 20 ft.
20P1	G. Van Wey...	Oc, 340	Dg	17.5	16	17.5	......	......	......	12.0	6- 8-50	S	D	Report soft water. Temp 49.5.
20R1	J. Lenard.....	Oc, 360	Dg	43.5	12	43.5	......	......	......	34	6- 8-50	J	D	Well sometimes goes dry.
21K1	L. Lommire.	Oc, 324	Dr	55	6	......	......	......	......	......	......	J	D	Tested 8 gpm.
22A1	Mark Towers	Oc, 408	Dr	103	6	......	......	......	......	......	......	J	D, S	Jet 75 ft down.
22B1	W. Goodwin...	Oc, 395	Dg-Dr	86	6	86	......	......	Gravel.....	50	Reported	J, 8	D	Report reached water at 40 ft (May 1951). Intercalated "hardpan" and gravel. Bailed 10 gpm.
22Q1	J. E. Ockfen..	Oc, 402	Dg	46.92	72	......	......	......	Gravel and sand	16.72	6-27-50	J	D, S	Report soft water.

22R1	A. Kirsten....	Oc, 410	Dr	33	6	....	....	....	Sand........	6	Reported	J	D, S	Report soft water.
22R2	.......do........	Oc, 410	Dg	22.57	60	....	....	....	Till........	10.55	6-27-50	S	D, S	"Hardpan" to bottom.
23J1	J. Goldman...	Oc, 447	Dr	87	6	....	....	....	....	....	....	J	D, S	Report soft water.
23M1	J. Kuffel.......	U, 422	Dg	20.96	36	....	....	....	....	7.08	6-27-50	S	D, S	Do.
23N1	E. Kirsten....	U, 403	Dg	28.62	36	....	....	....	....	17.51	6-27-50	S	D	Well 30 ft from large swamp.
23R1	A. Johnson....	U, 455	Dr	90+	6	....	....	....	....	....	....	J	D, S	Report hard water.
25D1	D. Reichlein..	U, 428	Dr	82	6	....	....	....	Sand........	....	....	J	D	Report water at 32 ft when drilling.
26D1	F. Kirsten....	U, 438	Dr	90	6	....	....	....	.......do....	30	Reported	J	D, S	D1 about 200 ft north of D2.
26D2	.......do........	U, 436	Dr	96	6	....	....	....	.......do....	30	Reported	J	D, S	D1 and D2 seem to be in same water strata.
26H1	Robert Hansen	U, 450	Dr	42	6	....	....	....	Sand, black	14	Reported	S	D	Report soft water.
26K1	J. Grinde......	U, 460	Dg	37.34	36	37.34	....	....	....	33.94	6-26-50	J	D, S	Went dry during fall of 1949. Report soft water.
28E1	H. S. Moyer..	Oc, 350	Dg	37	24	....	....	....	Gravel, sandy	25	Reported	J	D	Report no water until "hard-pan" dug through; water then raised to 8 ft below surface.
28L2	W. N. Goodwin	Oc, 325	Dg	10.5	36	....	....	....	....	3.86	5-24-50	S	D	Well on bank of power canal.
28M1	C. Bruhn......	Oc, 360	Dr	33.8	6	30	....	....	....	21.3	5-24-50	S	D	
28N1	G. P. Tice....	Oc, 370	Dr	81	6	81	....	....	....	32.2	5-24-50	J	D, S	
28P1	R. G. Allison, Sr.	Oc, 365	Dg	35	36	35	36	35	....	30.59	5-24-50	J	D	Report soft water.
29A1	R. M. Crutch-field.	Oc, 358	Dr	81.2	6	....	....	....	....	29.55	6- 8-50	J	D	Hardness 36. Chloride 7 ppm.
29A2	J. G. Story....	Oc, 355	Dr	52.7	6	....	....	....	....	37.1	6- 8-50	J	D	Bailer test 25 gpm.
29C1	F. R. King....	Oc, 329	Dr	69.6	6	69.6	....	....	....	12.35	6- 8-50	J	D	Report soft water.
29D1	Lester Wilson	Oc, 340	Dg	26.7	6	27	....	....	....	19.2	6- 8-50	S	D	Do.
29D2	J. Glaser......	Oc, 337	Dg	20.2	30	....	....	....	....	15.45	6- 8-50	S	D	Iron in water.
29E1	A. Justman....	Oc, 348	Dg	24.5	4-2	26	....	....	....	15.55	5-24-50	J	D, S	Plenty of water. Back-filled around casing.
29E2	Bob Jolley.....	Oc, 355	Dg	27.5	27	27.5	....	....	....	21.75	5-24-50	S	D	
29E3	A. Justman...	Oc, 346	Dr	119	10	119	....	....	"Rocks", coarse	14.35	3-27-52	....	S, Irr	Pumped $5\frac{1}{2}$ hr at 150 gpm; dd 34 ft. "Recovered" in 2 min. L.
29F1	C. F. Norman	Oc, 355	Dg	29	30	30	....	....	....	21.34	3-27-52	....	....	
29F2	M. K. Thomas	Oc, 355	Dg	55.4	8	55.4	....	....	....	29.83	11-12-51	HP	D, S	Bailed 30 gpm with 6 ft dd.
29F3	J. T. Sparks..	Oc, 358	Dr	34.3	6	34.3	32	....	Gravel.....	22.55	5-24-50	S	D	Report soft water. Deepened to 78 ft; bailed 20 gpm little dd. L.
29G1	Harry Bell.....	Oc, 352	Dg	20.15	25	....	....	....	....	17.59	5-24-50	S	D	
29G2	W. A. Wright, Jr.	Oc, 350	Dg	26	8	26	....	....	....	16.64	5-24-50	J	D	
29G3	O. J. Horse-field.	Oc, 355	Dr	50	6	50	....	....	Sand, gray	21.49	5-24-50	J	D, S	Test 25 gpm.
29K1	C. C. Thomp-son.	Oc, 350	Dg	18.7	10	....	....	....	Gravel.....	13.75	5-24-50	HS	D	
29L1	Neal H. Sher-man.	Oc, 355	Dg-Dr	57	6	57	....	....	....	16.31	5-24-50	S, J	D	Bailer test. Little dd.
29L3	W. G. Mosman	Oc, 345	Dg	26.5	48 by 60	26.5	....	....	....	17.62	5-25-50	S	D	Chloride 8 ppm. Caved in October 1951.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gpm)	Use of water	Remarks
							T. 17 N., R. 2 E.—Continued							
29L4	Gilbert Roehr	Oc, 350	Dr	52	10	66	28	14	Gravel.....	21.5	Reported	T	Irr	Tested at 500 gpm with 3 ft dd. Well drilled 66 ft deep, filled back to 52 ft. L. Analysis in table 3.
29M1	John Wright (Smith).	Oc, 354	Dr	43.5	6	....	....	....	....	24.53	5-24-50	J	D	Report iron stain.
29N1	Frank Vogt...	Oc, 355	Dr	50	8	50	....	....	Gravel.....	19	Reported	T	Irr	Tested at 50 gpm. L.
29N2	.......do.......	Oc, 358	Dr	81	12	81	....	....	....	13.70	5- 8-51	T, 25	Irr	
29P1	J. A. Peugh..	Oc, 355	Dg-Dr	87	6	87	....	....	....	27.49	11-26-51	T	D	Report water harder than when well only 28 ft deep.
29P2	.......do.......	Oc, 355	Dr	57	12	57	38	16	Gravel.....	14	....	....	....	Estimated 120 gpm continuous pumping without perceptible dd. L.
29Q1	W. B. Benefield.	Oc, 350	Dg-Dr	55	8	55	....	....	....	14.21	5-20-51	T, 100	Irr	Pumped 42 gpm (sprinkling). Water level for 22½-ft well. L.
30B1	C. W. Hughes	Oc, 350	Dg	25	30	....	....	....	....	21.75	6- 8-50	J	Irr	Reported pumped 13 gpm 4 hr.
30B2	.......do.......	Oc, 350	Dg	40	30	....	....	....	....	19.8	6- 8-50	J	D	Report soft water.
30D1	J. Raab........	Oc, 360	Dg	36	30	....	....	....	....	30	Reported	J	D	At one time well supplied six houses.
30D2	A. Fry.........	Oc, 345	Dr	45	6	....	....	....	....	14	5-31-50	J	D	Report soft water.
30D3	Edward Smith	Oc, 350	Dg	20	8	20	....	....	....	15	5-31-50	S	D	Do.
30E1	J. A. Kelley..	Oc, 369	Dg	37.6	27	....	....	....	....	32.6	5-31-50	J	D	Chloride 9 ppm.
30F1	A. C. Flick...	Oc, 353	Dg	21.4	48	21.4	....	....	....	19.0	5-31-50	S	D	Report soft water.
30F2	E. O. Wooten	Oc, 353	Dr	72	6	72	....	....	Gravel, pea and sand	18.6	5-31-50	J, 10	D	Chloride 7 ppm. Casing perforated 68-72 ft.
30G3	W. W. Kirkendall.	Oc, 355	Dg	21.3	8	21.3	....	....	....	18.1	5-29-50	S	D	Report soft water.
30G4	A. Meredith...	Oc, 350	Dg	29.2	30	....	....	....	....	14.64	5-31-50	S	D	Do.
30H1	Mrs. Dona Hobart.	Oc, 355	Dr	40	6	40	....	....	....	29	Reported	S	....	Report plenty of water at 40 ft.
30J1	Bill McNett...	Oc, 355	Dr	27	6	27	....	....	Gravel......	18.57	5-24-50	S	D	
30K1	R. Harrington	Oc, 360	Dg	23.8	30	23.8	....	....	....	22.2	5-29-50	S	D	Report soft water.
30K2	K. R. Butler..	Oc, 365	Dr	39.8	6	39.8	....	....	....	27.64	5-29-50	HP	D	Do.
30K3	H. S. Jones...	Oc, 352	Dg	21.75	24	....	....	....	....	20.0	5-29-50	S	D	Do.
30K4	Frank Yenne..	Oc, 380	Dr	44	6	....	....	....	Gravel.....	....	....	....	D	Water under "hardpan" in fine and medium gravel.
30M1	J. A. Conner.	Oc, 382	Dr	29.5	6	....	....	....	....	19.7	5-31-50	J	D	Report soft water.

30P1	Elmer Johnson.	Oc, 365	Dg	16.3	24	16.3	...	...	...	8.2	5-29-50	HS	D, S	Report soft water, Report 6 ft blue "hardpan" at bottom.
31A1	R. Games.....	U, 418	Dr	89.8	6	...	...	...	...	28.62	5-29-50	J	D	Report soft water.
31H1	Eva Pullman (Stancel).	U, 415	Dr	83	6	83	...	...	...	32.6	5-26-50	J	D	
31H2	R. F. Galent..	U, 400	Dg	60	60	...	...	...	...	30	Reported	J	D	Report soft water.
32A1	Dinah Arnold.	Oc, 360	Dg	21	48	21	...	...	...	20.64	5-25-50	HP	D	No water in late summer.
32N1	W. T. Mc-Monagle.	Oc, 380	Dr	47	6	47	...	...	Gravel, pea	16.3	5-26-50	J	D, S	Report soft water.
32Q1	T. M. Sheldon	Oc, 365	Dg-Dn	26	18-2	26	...	...	...	17.2	Reported	J	D	Dug 22 ft, sand point driven 4 ft.
32Q2	.... do........	Oc, 365	Dr	254	12-8	254	...	...	Gravel and Sand.	8	Reported	...	...	Pumped 600 gpm; 55-ft dd. L.
32R1	C. A. Prince.	Oc, 375	Dg	24.5	48	...	...	...	Gravel......	19.16	5-26-50	J	D, S	Chloride 7 ppm.
32R2	—Mosman.....	Oc, 380	Dg	27.7	36	24.5	...	...	...	20.46	5-26-50	S	D	Report soft water.
33A1	E. Games.....	Oc, 370	Dg	19	48	19	...	...	Gravel.....	14.18	5-24-50	S	D	Encountered slightly cemented gravel
33B1	M. McKim....	Oc, 370	Dg	21	36	21	...	...	...	17.19	5-24-50	S	D	
33B2	A. C. Gilman	Oc, 370	Dr	72	6	72	...	...	Sand.........	16.83	3-25-52	P, 6	D	Report unable to bail down.
33D1	E. R. Lowery	Oc, 370	Dg	19	30	19	...	...	...	12.67	5-25-50	S	S	Report soft water.
33D2	R. J. Vroman	Oc, 370	Dr	82	6	...	...	...	...	14.18	5-25-50	J	D	Water contains sediment.
33E1	G. Reeves.....	Oc, 373	Dg-Dn	24	24-2	24	...	...	...	17.89	5-24-50	C	D	Occasional oil film. Well deepened with sand point. Chloride 8 ppm.
33K1	D. C. Jewell..	Oc, 380	Dg	18.7	16	18.7	...	...	...	20.5	5-26-50	S	D	Report hard water.
33K2	.... do........	Oc, 380	Dr	105	10	105	...	...	...	19.81	2-28-51	T, 60	D, Irr	Perforated 30 ft, 50 ft, 75 ft, and between 92 and 100 ft. Tested at 90 gpm. L.
33P1	Louis Peterson.	Oc, 360	Dr	105	8	105	56	6	Gravel, coarse	15.00	2-26-52	...	Irr	Pumped 4 hr at 200 gpm; dd not noticeable. L.
33R1	D. C. Jewell..	Oc, 390	Dr	150	12	150	...	...	...	40.35	5- 8-51	T	Irr	Tested 90 gpm with dd to 140 ft. L.
34B1	R. Mantik.....	Oc, 325	Dr	43.6	6	...	...	...	...	13.6	5-25-50	S	D	Report soft water.
34F1	Roland Weder	Oc, 345	Dg	42	24	42	...	...	...	33.75	5-25-50	J	D	
34G1	K. E. Brodan	Oc, 349	Dg	45	30	...	45	...	Gravel, pea	38.26	5-25-50	P	D	No dd after 5 hr pumping at 10 gpm.
34H1	E. A. Long....	Oc, 325	Dg	22	48	22	...	...	Gravel......	12.5	5-26-50	P	D	Report soft water.
34K1	Dan Cook......	Oc, 340	Dr	39	6	...	...	...	...	23.36	5-25-50	J	D	Lime deposits in tea kettle.
34K2	O. McGlather	Oc, 353	Dg	48.4	12	48.4	...	...	Gravel and sand.	42.0	5-26-50	J	D	Report soft water.
34M1	Noah Graybill	Oc, 370	Dg	24.1	24	...	...	...	...	18.58	5-26-50	S	D	Goes dry in early fall.
34M2	.... do........	Oc, 370	Dg	23.2	48	23.2	...	...	...	16.6	5-26-50	HP	S	Do.
35L1	Jack Richardson.	Oc, 338	Dr	78	6	78	...	...	Sand.........	9.78	5-25-50	J	D	Tested 25 gpm. Casing perforated bottom 10 ft.
35L2	L. W. Peter-	Oc, 330	Dr	76.5	6	76.5	...	...	...	1.43	5-25-50	J	D	Well flows part of year.
							T.	17 N., R.	3 E.					
5E1	John Gruenfelder.	Op, 415	Dr	70	6	70	65	5	Gravel	48	Reported	29	...	Pumped 29 gpm (4 hr?) with 10-ft dd. L.

Table 1.—Records of representative wells in the Yelm area, Thurston and Pierce Counties, Wash.—Continued

Well no.	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s)			Water level		Type of pump and yield (gpm)	Use of water	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material	Feet below land-surface datum	Date			
T. 18 N., R. 1 E.														
32M1	L. K. Pomeroy.	Oc, 152	Dr	112	6	112	....	....	Gravel and sand.	84.88	11- 1-51	J	D	Bailed ½-hr at 15 gpm, no dd. L.
T. 18 N., R. 2 E.														
34G1	C. A. North..	Oc, 335	Dr	23	8	26(?)	2	24	Gravel.....	12.07	5- 8-51	C	Irr	Reported pumped 150 gpm, 2½-ft dd.
34P1	Roy Cemetery	Oc, 332	Dr	50	6	50	....	....	....	20	Reported	J(?)	Irr	Pumped dry in 20 min summer of 1951 (water level reported 20 ft below surface).

Table 2.—Representative springs in the Yelm area, Thurston and Pierce Counties, Wash.

[Locations of springs are shown on pl. 2]

Topography and approximate altitude: M, marsh or swamp; Sc, scarp (base or face). Altitude of land surface from barometric traverse or interpolated from topographic maps. Use: Irr, irrigation; NU, not used; S, stock.

Spring no.	Owner or tenant	Name	Topography and altitude (feet above sea level)	Water-bearing material	Occurrence	Yield		Use	Temperature (° F)	Remarks
						Gallons per minute	Date			
16/2-3E2	B. E. Rieke	....	M, 455	....	Seepage	....	....	S	....	Flows most of year.
17/1-12M1	....	....	Sc, 120	Sand and gravel	Discharges from gravel overlying impermeable pre-Vashon deposits.	260	9-12-50	NU	....	Some of flow by-passed measuring section.
17/1-12Q1	....	....	Sc, 225	do	do	830	do	NU	51	Flows into Yelm Creek.
17/2-7N1	....	....	Sc, 150	do	do	550	9-14-50	NU	....	
17/2-7N2	....	....	Sc, 150	do	do	590	do	NU	51	
17/2-17C1	—Hutches	....	Sc, 200	do	do	320	9-15-50	NU	....	Numerous springs along same scarp, nearby.
17/2-18M1	R. Beckendorf, Jr.	....	M, 300	do	Discharges from outwash overlying till (?).	....	....	NU	....	Total flow, several hundred gpm.
17/2-18K1	R. Beckendorf, Sr.	Crystal Springs	M, 310	do	do	3,660 3,000	8-16-49 9- 7-49	NU	55 53	Principal dry season source for Yelm Creek.
17/2-28E-F	....	McKenna Springs	M, 300	....	Discharges on top of pre-Vashon deposits.	4,050 3,560 3,370	6- 2-50 8-22-50 9-26-50	....	....	Combined flow of a number of springs feeding McKenna Creek.
17/2-32R3	—Mosman	....	M, 380	....	Discharges on top of till of the Vashon.	200	5-26-50	S, Irr	....	

Table 3.—Materials penetrated by representative wells

[Tentative stratigraphic designations by M. J. Mundoroff]

Materials	Thickness (feet)	Depth (feet)
16/1-6J1. Leon Barnhouse. About 1.8 miles northwest of Rainier, on Rainier-Olympia road. Altitude about 500 ft. Drilled by Richardson Well Drilling Co., 1950. Casing, 6-in., set to 216 ft.		
Vashon drift:		
Recessional outwash:		
Old well 96 ft deep caved to 87 ft	96	96
Clay, sandy	29	125
Till:		
"Hardpan"	10	135
Gravel and clay	6	141
Pre-Vashon deposits (?):		
"Hardpan"	74	215
Sand, coarse, and gravel	1	216
16/1-7E1. C. B. Frost. About 2.5 miles west of Rainier. Altitude about 425 ft. Dug by J. P. Davidson. Casing, 10-in., tile, set to 152 ft.		
Vashon drift:		
Recessional outwash:		
Gravel	50	50
Clay	2	52
Sand	15	67
Gravel and sand, water-bearing	18	85
Till:		
"Hardpan"	27	112
Advance outwash:		
Sand and gravel, water-bearing	40	152
Clay, blue	At	152
16/1-11B1. O. Englund. About 3.7 miles southwest of Yelm. Altitude about 408 ft. Dug by H. Livingston.		
Vashon drift:		
Till:		
Soil	6	6
"Hardpan"	20	26
Pre-Vashon deposits:		
Sand, yellow	2/3	26 2/3
Gravel and clay, yellow	50	76 2/3
Gravel, cemented	26 2/3	103 1/3
Gravel, fine to medium	2 1/3	105 2/3
16/1-13G2. Earl Nelson. About 4.8 miles south of Yelm. Altitude about 443 ft. Drilled by A. P. Graf, 1951. Casing, 12 in., set to 54 ft; perforated from 44 to 54 ft.		
Topsoil and peat	4	4
Vashon drift:		
Till:		
Clay, blue and gravel	41	45
Advance outwash:		
Gravel, water-bearing	9	54
16/1-14M1. C. Colman. About 2 miles southeast of Rainier. Altitude about 450 ft. Drilled by E. J. Webber. Casing, 6-in., set to 123½ ft.		
Vashon drift:		
Recessional outwash:		
Boulders, sand, and gravel	8	8
Till:		
Boulders, and "hardpan"	52	60

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
16/1-14M1—Continued		
Vashon drift—Continued		
Outwash:		
Boulders, coarse gravel	25	85
Sand and gravel, water-bearing	15	100
Till (?):		
"Hardpan", no water	2	102
Outwash:		
Sand, fine to coarse, with some gravel, water-bearing	21½	123½

16/1-27H1. Weyerhauser Timber Co. At Vail. Altitude about 420 ft. Drilled by N. C. Jannsen, 1927 (?). Well measured 190 ft deep. Casing, 12-to 8-in., set to 190 ft., perforated from 170 to 190 ft.

Boulders, large	11	11
Gravel, cemented	3	14
Gravel and boulders	21	35
Gravel	10	45
Gravel and sand	5	50
Sand and gravel	10	60
Gravel and sand, with some water	10	70
Boulder and gravel	4	74
Gravel, some clay	6	80
Gravel and boulder with a little clay	5	85
Gravel and sand	10	95
Sand and boulders	7	102
Boulders, large	5	107
"Sand rock" (sand and boulder)?	4	111
Sand and boulders	3	114
Clay and "hardpan"	18	132
Sand and some gravel	21	153
Sand and boulders	2	155
Sand and gravel	18	173
Gravel, water-bearing	5	178
Sand, with a boulder	7	185
Gravel, water-bearing	2	187
Sand, with some gravel, water-bearing	1	188

16/2-4A2. Charles Johnston. About 3.4 miles southeast of Yelm on Bald Hill Road, about 200 ft southwest of road. Altitude about 380 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 8-in., set to 158 ft; perforated from 44 to 60 ft, from 69 to 92 ft, from 99 to 105 ft, from 113 to 118 ft, and from 142 to 149 ft.

Vashon drift:		
Recessional outwash:		
Gravel and black dirt	3	3
Clay, yellow, coarse sand, and gravel	21	24
Till:		
"Hardpan"	7	31
Clay, yellow, and gravel	14	45
"Hardpan"	13	58
Advance outwash:		
Clay, gravel, some sand	4	62
Sand and clay, some gravel	4	66
Sand, coarse, and gravel	10	76
Pre-Vashon deposits:		
"Hardpan"	5	81
Clay, sand and gravel	13	94
Sand, a little gravel	2	96
"Hardpan"	11	107
Sand, some coarse gravel	3	110
"Hardpan"	6	116
Sand	2	118

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
16/2-4A2—Continued		
Pre-Vashon deposits—Continued		
"Hardpan"	2	120
Sand, clay, and gravel	15	135
Clay, gray, and gravel	14	149
Sand, fine to coarse (water rose in hole)	5	154
Clay, gravel, and sand	4	158

16/2-5C1. J. and A. McMonigle. About 2.5 miles southeast of Yelm and 0.8 mile east of Norris Road. Altitude about 380 ft. Drilled by A. P. Graf, 1951. Casing, 12-in., set to 81 ft; perforated from 64 to 80 ft.

Vashon drift:		
Outwash (undifferentiated):		
Topsoil	2	2
Sand, brown	15	17
Sand and gravel	47	64
Gravel, water-bearing	16	80
Pre-Vashon deposits:		
Clay, brown	1	81

16/2-5R1. Stan Dunagan. About 3.5 miles south-southeast of Yelm, and about 0.2 mile southeast of Smith Road. Altitude about 450 ft. Drilled by A. P. Graf, 1951] Casing, 12-in., set to 181 ft; perforated from 40 to 56 ft, 67 to 78 ft, 88 to 98 ft, 112 to 134 ft, and from 144 to 177 ft.

Old well, no log	39	39
Gravel, coarse, some water	7	46
Pre-Vashon deposits:		
Sand, brown	12	58
Boulders and gravel	7	65
Sand, brown, and gravel, some water	9	74
Sand, brown	20	94
Sand, volcanic, some water	4	98
Gravel, hard-packed	14	112
Sand and gravel, some water	32	144
Clay, gravel, and sand, in thin layers	33	177

16/2-7Q1. R. W. Shattuck. About 4.5 miles south of Yelm. Altitude about 450 ft. Drilled by A. P. Graf, 1953. Casing, 10-in., set to 287 ft. Perforated from 48 to 50, 85 to 89, 160 to 162, 176 to 184, 190 to 198, and 277 to 283 ft.

Vashon drift:		
Till:		
Topsoil	2	2
Boulders and gravel	9	11
Advance outwash:		
Sand and gravel	11	22
Gravel, some water	4	26
Pre-Vashon deposits:		
Clay and gravel, some water	65	91
Gravel and sand	10	101
"Hardpan"	64	165
Gravel, loose, and sand	23	189
"Hardpan"	1	190
Gravel, loose, and sand, water-bearing	8	198
Sand, black, some water	2	200
Sand and gravel, hard-packed	78	278
Gravel, some water	9	287

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)

16/2-17L1. E. Dame. About 5 miles south of Yelm. Altitude about 460 ft. Dug well. Wood curbing, 48-in. square.

Vashon drift:		
Till:		
Soil	6	6
Gravel, cemented	18	24
Boulders and white clay	21	45
Advance outwash:		
Gravel, pea size, and black sand	At	45

16/2-18H1. T. J. Boudreau. About 5 miles south of Yelm. Altitude about 445 ft. Dug well.

Vashon drift:		
Till:		
"Hardpan"	4	4
Gravel	4	8
"Hardpan"	23	31

17/1-13D2. Ed Percival. About 2.0 miles northwest of Yelm, about 400 ft northeast of highway to Olympia. Altitude about 330 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 8-in., set to 158 ft; perforated from 60 to 66 ft, from 76 to 88 ft, and from 92 to 94 ft.

Vashon drift:		
Recessional outwash:		
Dirt, black and gravel	3	3
Boulders, clay, and gravel	9	12
Till:		
"Hardpan"	47	59
Sand	2	61
"Hardpan"	3	64
Advance outwash:		
Clay, coarse sand, and gravel	2	66
Pre-Vashon deposits:		
"Hardpan"	8	74
Clay, yellow, sand, and gravel (7 feet of water)	7	81
Gravel and clay (water shut off at 87 feet)	6	87
Clay, brown, and gravel	7	94
"Hardpan"	30	124
Clay, blue and brown	4	128
"Hardpan"	30	158

17/1-14N1. L. A. Crimmins. About 1.3 miles northwest of Yelm. Altitude about 370 ft. Drilled by E. J. Webber, 1950.

Glacial drift, undifferentiated:		
Gravel, cemented (?)	88	88
Sand	4	92
Gravel	41	133
Sand and gravel	2	135

17/1-24B1. Lewis Poultry Farm. About 1.0 mile northwest of Yelm, 0.2 mile north of Olympia Highway. Altitude about 347 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 12-in., set to 99 ft; perforated from 35 to 42 ft, and from 85 to 93 ft.

Vashon drift:		
Recessional outwash:		
Gravel and black dirt	3	3
Boulders and clay	5	8
Till:		
"Hardpan"	27	35

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
17/1-24B1—Continued		
Vashon drift:		
Advance outwash:		
Sand, coarse, and loose gravel	7	42
Clay, sandy, and gravel	4	46
Sand, fine, gravel with clay	4	50
Pre-Vashon deposits:		
Clay, yellowish, and fine sand	19	69
Sand and blue clay	6	75
"Hardpan" (cemented gravel?) and boulders, water shut off	18	93
Sand and gravel, some clay, water-bearing	2	95
"Hardpan" (cemented gravel?) and boulders	4	99

17/1-24L1. Warren Simmons. About 1 mile west of Yelm. Altitude about 345 ft. Drilled by A. P. Graf, 1953. Casing, 12-in., set to 263 ft; perforated from 22 to 26, 64 to 68, 95 to 101, 201 to 211, and 253 to 257 ft.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Boulders and gravel	9	11
Till:		
Sand and gravel, claybound	11	22
Advance outwash:		
Sand and gravel, water-bearing	4	26
Gravel, cemented, with a few boulders	38	64
Sand and gravel, water-bearing	3	67
Pre-Vashon deposits:		
Sand and gravel, claybound	27	94
Sand and gravel, water-bearing	7	101
"Hardpan" with a few boulders (very hard, clayey) Till?	28	129
Gravel, cemented	36	165
Gravel and sand, loose	14	179
Gravel, cemented	5	184
Clay and gravel, some boulders	14	198
Sand, fine, black, about 20 percent gravel	13	211
Sand and gravel	15	226
Clay and sand	14	240
Gravel, cemented	13	253
Gravel and black sand	4	257
Gravel, cemented	18	275

17/2-3D2. M. H. Booth. About 200 ft south of south city line of Roy, on Roy-Yelm highway. Altitude about 330 ft. Drilled by Tacoma Pump Co., 1950. Casing, 6-in., set to 40 ft. ("Memory" log.)

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Outwash, undifferentiated:		
Sand, coarser toward bottom	12	12
Gravel, fine	2	14
Sand, brown, with iron	5	19
Gravel (struck water at 20 feet)	5	24
Gravel and sand	16	40

17/2-18N1. Frank A. Scharmann. About 1 mile north of Yelm. Altitude about 325 ft. Drilled by E. J. Webber. Casing, 6-in., set to 71 ft.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Till:		
Till	15	15
Advance outwash:		
Gravel and water	5	20
Gravel and clay	30	50

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
17/2-18N1—Continued		
Advance outwash—Continued		
Gravel, medium to coarse, and clay	20	70
Pre-Vashon deposits:		
Gravel, hard	1	71

17/2-19H1. A. Hewitson. About 0.5 mile northeast of Yelm. Altitude about 350 ft. Drilled, 1946.

Vashon drift:		
Recessional outwash:		
Gravel and boulders	25	25
Sand, fine, black	5	30
Gravel, coarse	8	38
Till:		
"Hardpan"	3	41
Advance outwash:		
Gravel, "pea", black	1	42

17/2-19H3. A. Hewitson. About 0.5 mile northeast of Yelm. Altitude about 350 feet. Drilled by Richardson Well Drilling Co., 1951. Casing, 8-in., set to 63 ft; perforated from 21 to 31 ft.

Vashon drift:		
Recessional outwash:		
Dirt, black, and gravel	2	2
Gravel, boulders, and clay	5	7
Till:		
"Hardpan"	13	20
Advance outwash:		
Sand, coarse, and loose gravel, showing some clay; 7 ft of water at 30 ft	9	29
Pre-Vashon deposits:		
"Hardpan"	18	47
Clay, yellow, and gravel (water shut off)	15	62
Sand, coarse, and gravel	1	63

17/2-19J3. J. M. Hales. About 0.5 mile northeast of Yelm. Altitude about 350 ft. Dug well.

Vashon drift:		
Recessional outwash:		
Soil	$1\frac{1}{2}$	$1\frac{1}{2}$
Gravel, some sand	$18\frac{1}{2}$	20
Till:		
"Hardpan"	13	33
(Well bottomed on large boulder)		

17/2-19J5. J. M. Hales. About 0.5 mile east of Yelm. Altitude about 350 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 10-in., set to 87 ft; perforated from 30 to 68 ft.

Vashon drift:		
Recessional outwash:		
Gravel and black dirt	3	3
Clay, yellow, and gravel	6	9
Till:		
"Hardpan"	18	27
Pre-Vashon deposits:		
Clay, yellow, and gravel	4	31
"Hardpan" (cemented gravel?)	7	38
Clay, yellow, and gravel	3	41
"Hardpan" (cemented gravel?)	20	61
Sand, gravel, and clay	1	62
"Hardpan" (cemented gravel?)	11	73
(?)	14	87

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
17/2-19L1. Enumclaw Co-op. Creamery Co. at Yelm. Altitude about 340 ft. Drilled by J. L. Bell, 1944.		
Vashon drift:		
Recessional outwash:		
Gravel and clay	15	15
Till:		
"Hardpan"	2	17
Advance outwash:		
Sand and gravel, loose, water-bearing	3	20
Gravel, hard, cemented	33½	53½
Sand and gravel, rock (boulder?) water-bearing	2½	56
Pre-Vashon deposits:		
Gravel, cemented	44	100
"Hardpan", brown	35	135

17/2-19N1. Town of Yelm. Near elevated water tank. Altitude about 350 ft. Drilled by Richardson Well Drilling Co., 1950. Casing, 12-in., set to 52 ft, screen from 52 to 62 ft.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Recessional outwash:		
Soil	3	3
Boulders and clay	8	11
Till:		
"Hardpan", gray	20	31
Advance outwash:		
Gravel and clay, yellow	4	35
Gravel (to 5"-6") and sand	27	62
Pre-Vashon deposits:		
"Hardpan", gravel and clay, yellow	1	63

17/2-29E3. Arthur Justman. On Washington State Highway 5-H, about 0.2 mile east of intersection with Bald Hill Road, which is about 1 mile southeast of Yelm. Altitude about 346 ft. Drilled by A. P. Graf, 1952. Casing, 10-in., set to 119 ft; perforated from 22 to 36 ft, from 42 to 58 ft, and from 78 to 117 ft.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Boulders and gravel	22	24
Gravel, water-bearing (est. yield 30 gpm)	7	31
Till:		
Gravel, cemented	2	33
Clay, brown, and gravel	15	48
Pre-Vashon deposits:		
Clay and gravel	30	82
Gravel, some water, (est. yield 10 gpm)	12	94
Clay, brown, and gravel	18	112
Gravel, water-bearing	5	117
Clay, blue, and small stones	2	119

17/2-29F2. Marion K. Thomas. Washington State Highway 5-H, 1.45 miles east of Yelm center. Altitude about 355 ft. Drilled by Richardson Well Drilling Co., 1950. Casing, 8-in., set to 55 ft.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Till:		
"Hardpan"	48	50
Advance outwash:		
Gravel, water-bearing	5	55

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
17/2-29F3. J. T. Sparks. Between Yelm and McKenna, about 0.4 mile east of intersection of Bald Hill Road and Washington State Highway 5-H. Altitude about 358 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 6-in., set to 78 ft; perforated from 32 to 37 ft.		
Vashon drift:		
Recessional outwash:		
Topsoil, gravelly	3	3
"Hardpan", boulders, gravel, and sand with zone of clean gravel at 9 ft	29	32
Gravel, "pea", water-bearing	4	36
Till:		
Clay, bouldery, hard	21	57
Pre-Vashon deposits:		
"Hardpan", becoming gravelly toward bottom, with a little water	21	78
17/2-29L4. Gilbert Roehr. About 500 ft southwest of Bald Hill Road, about 1.7 miles southeast of Yelm. Altitude about 350 ft. Drilled by Richardson Well Drilling Co., 1950. Casing, 10-in., set to 66 ft; perforated from 30 to 42 ft (10 holes per foot, 1/4-in. by 2 in.).		
Vashon drift:		
Recessional outwash:		
Topsoil and boulders	3	3
Clay and gravel	5	8
Till:		
"Hardpan"	20	28
Advance outwash:		
Gravel, loose, with some sand (7 ft of water at 30 ft)	2	30
Clay and gravel	2	32
Gravel, loose, water-bearing	10	42
Clay and sand, with some pebbles	11	53
Sand, fine, heaving	13	66
(Well plugged from 53 to 66 ft with boulders and clay)		
17/2-29N1. Frank Vogt. About 1.3 miles southeast of Yelm, on Norris Road. Altitude about 355 ft. Drilled by O.E. Erdman, 1950. Casing, 8-in., set to 50 ft; perforated from 16 to 50 ft.		
Vashon drift:		
Recessional outwash:		
Topsoil	10	10
Gravel and boulders	20	30
Till:		
Gravel and sand, hard-packed	15	45
Advance outwash:		
Gravel	5	50
17/2-29P2. J. A. Peugh. About 1.75 miles southeast of Yelm on Bald Hill Road. Altitude about 355 ft. Drilled by Richardson Well Drilling Co., 1950. Casing, 12-in., set to 57 ft; perforated from 25 to 27 ft and from 38 to 53 ft, 18 holes per round.		
Vashon drift:		
Recessional outwash:		
Gravel and black dirt	3	3
Clay and gravel	8	11
Till:		
"Hardpan"	3	14
Vashon drift:		
Advance outwash:		
Sand, coarse, gravel, and clay	15	29
Sand, fine, some coarse sand	5	34
Sand, coarse, and loose gravel	4	38
Sand, coarse, some gravel	4	42
Sand, gravel, and clay	2	44
Sand, coarse, and coarse loose gravel	2	46

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
17/2-29P2.—Continued		
Pre-Vashon deposits:		
"Hardpan" (cemented gravel?)	9	55
Water shut off		
Clay and gravel	2	57

17/2-29Q1. W. B. Benefield. About 400 ft southwest of Bald Hill Road, about 1.9 miles southeast of Yelm. Altitude about 350 ft. Drilled by Richardson Well Drilling Co., 1951. Casing, 8-in., set to 55 ft; perforated from 24 to 44 ft.

Old dug well	23	23
Vashon drift:		
Advance outwash:		
Sand, coarse, clay, and gravel	17+	40
Sand, coarse, and fairly loose gravel	3	43
Pre-Vashon deposits:		
"Hardpan"; water shut off	3	46
Clay and gravel	9	55

17/2-32Q2. T. M. Sheldon. About 2.5 miles southeast of Yelm. Altitude about 365 ft. Drilled by A. P. Graf, 1952. Casing, 12-in., set to 93 ft, 8-in., from 87 to 254 ft; perforated from 13 to 18, 38 to 74, 80 to 90, 145 to 152, and 238 to 251 ft.

Vashon drift:		
Recessional outwash and till:		
Topsoil	2	2
Gravel and clay, some water	36	38
Advance outwash:		
Gravel, sand, and boulders	15	53
Pre-Vashon deposits:		
Gravel and boulders	19	72
Boulders	4	76
Gravel and sand	14	90
Gravel	2	92
Clay, blue, and gravel	53	145
Gravel	5	150
Clay and gravel	82	232
Sand, black, some water	2	234
Gravel, water-bearing	15	249
Clay and gravel	5	254

17/2-33K2. D. C. Jewell. About 3.25 miles southeast of Yelm on Bald Hill Road. Altitude about 380 ft. Drilled by A. P. Graf, 1951. Casing, 10-in., set to 105 ft; perforated from 24 to 28 ft, from 44 to 56 ft, from 72 to 78 ft, and from 92 to 102 ft.

Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Boulders and coarse gravel	19	21
Gravel and sand, some water	3	24
Till:		
Gravel, hard-packed	24	48
Advance outwash:		
Gravel, loose, and sand, some water	4	52
Pre-Vashon deposits:		
Gravel, cemented	20	72
Gravel, loose, some water	6	78
Gravel, cemented	14	92
Gravel, loose, some water	10	102
Gravel, cemented	3	105

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)

17/2-33P1. Louis Peterson. About 3.0 miles southeast of Yelm. About 0.5 mile east and 0.4 mile south of crossing of Yelm Irrigation Ditch and Smith Road. Altitude about 360 ft. Drilled by A. P. Graf, 1952. Casing, 8-in., set to 105 ft; perforated from 30 to 97 ft.

Vashon drift:		
Recessional outwash:		
Soil	2	2
Gravel, sand, and some boulders	28	30
Gravel, fine, water-bearing	4	34
Till:		
Gravel and rock, with brown clay binder	22	56
Advance outwash:		
Gravel, coarse, water-bearing	5	61
Gravel, hard-packed	11	72
Gravel, coarse, water-bearing	2	74
Pre-Vashon deposits:		
Clay, brown, and gravel	17	91
Gravel, some water	4	95
Clay, brown, and gravel	10	105

17/2-33R1. D. C. Jewell. About 3.5 miles southeast of Yelm on Bald Hill Road. Altitude about 390 ft. Drilled by A. P. Graf, 1951. Casing, 12-in., set to 150 ft; perforated from 42 to 146 ft.

Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Boulders and coarse gravel	36	38
Gravel and sand, some water	9	47
Till:		
Gravel and sandy clay	7	54
Gravel, hard-packed	15	69
Advance outwash (?):		
Gravel and sand	9	78
Pre-Vashon deposits:		
Gravel, hard-packed	12	90
Gravel and sand	5	95
Gravel, hard-packed	13	108
Gravel and sand	4	112
Gravel and clay	16	128
Gravel, hard-packed	18	146
Sand and gravel	4	150
Clay, brown, and broken rock (boulders?)	20	170

17/3-5E1. John Gruenfelder. About 4 miles east of Roy, about 0.3 mile south of intersection of Roy Pettit (Roy Muck) Road and Tisch Road, North. Altitude about 415 ft. Drilled by Peterson Bros. Casing, 6-in., set to 70 ft.

Vashon drift:		
Outwash, undifferentiated:		
Soil, sandy	12	12
Gravel, clayey	11	23
Gravel, water-bearing	2	25
Clay and rock	40	65
Gravel, water-bearing	5	70

18/1-32M1. L. K. Pomeroy. Lake St. Clair, at neck of peninsula jutting northward from south shore. Altitude about 152 ft. Drilled by Richardson Well Drilling Co. 1951. Casing, 6-in., set to 112 ft. Memory log.

Vashon drift:		
Recessional outwash:		
Gravel and sand, with some boulders	80	80

Table 3.—Materials penetrated by representative wells—Continued

Materials	Thickness (feet)	Depth (feet)
18/1-32M1—Continued		
Recessional outwash—Continued		
Alternately hard and soft, similar to "hardpan"	5	85
Sand, black	5	90
Gravel and coarser sand	22	112
Till (?):		
Hard at bottom	....	112+

18/2-34G1. C. A. North. About 500 ft north of Yelm-Tacoma highway, about 0.5 mile east-northeast of Roy. Altitude about 335 ft. Drilled by Sides. Casing, 8-in., set to 26 (?) ft; perforated from 14 to 26 ft with 20 percent openings, 3/16 in. by 1½ in.

Materials	Thickness (feet)	Depth (feet)
Vashon drift:		
Recessional outwash:		
Topsoil	2	2
Gravel, up to 2 inches in diameter	24	26

Table 4.—Analyses, in parts per million, of ground water from Yelm Prairie, Thurston County, Wash.

	Well no.		
	[1]17/2-19J5	[2]17/2-19N1	[1]18/2-29L4
Silica (SiO_2)	21	28	33
Iron (Fe)	[3]2.0	.3	[3]1.2
Manganese (Mn)	.0	....	.42
Calcium (Ca)	7.8	....	11
Magnesium (Mg)	3.4	....	5.7
Sodium (Na)	4.7	....	6.1
Potassium (K)	1.6	....	2.0
Bicarbonate (HCO_3)	34	34	64
Sulfate (SO_4)	4.4	.0	3.5
Chloride (Cl)	5.2	1.6	3.5
Fluoride (F)	.5	....	.2
Nitrate (NO_3)	9.4	....	4.7
Boron (B)	.02	....	.02
Hardness ($CaCO_3$)	33	56	51
Percent sodium	22	....	20
Specific conductance (Micromhos at 25° C)	96.8	....	129
pH	7.0	6.8	7.3

[1]Analyses by U. S. Geological Survey, Feb. 12, 1952 (date of collection).
[2]Analysis by Bennetts chemical Laboratory, Tacoma, Wash., Sept. 14, 1950 (date of collection).
[3]Total iron.

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