Geology and Ground Water of the Molalla-Salem Slope Area, Northern Willamette Valley, Oregon

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1997

Prepared in cooperation with the Oregon State Engineer

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By E. R. HAMPTON

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Report describes geologic features and their relation to the occurrence, quality, and quantity of ground water in the Molalla-Salem Slope area on the east side of the Willamette Valley between Salem and Canby

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GEOLOGY AND GROUND WATER OF THE MOLALLA-SALEM SLOPE AREA, NORTHERN WILLAMETTE VALLEY, OREGON

By E. R. Hampton

ABSTRACT

The Molalla-Salem Slope area of the Northern Willamette Valley includes the lower foothills of the Cascade Range and a narrow strip of valley plain of the Willamette Valley. Annual precipitation on the area ranges from about 40 inches at the westernmost side of the valley plain to about 80 inches in the foothills at the eastern side of the area, providing ample recharge to the aquifers that underlie the area. Volcanic and sedimentary rock units exposed in the foothills range in age from Oligocene to Holocene. Most of these units have been penetrated by wells in the valley-plain area, where the older units are overlain by the Willamette Silt and alluvial deposits. The older units of a given rock type generally are less permeable than the younger.

In general, water levels in wells in the area fluctuate seasonally in response to recharge to, and discharge from, the ground-water reservoirs, and thus are highest following periods of greatest precipitation and lowest following periods of least precipitation. Moderate year-to-year declines of water levels in a few wells that tap aquifers in the basalt of the Columbia River Group indicate that water is being removed from those aquifers at a faster rate than it is being replenished by natural recharge.

The principal water-yielding units in the foothills area, in descending order of average specific capacity of existing wells, are the Columbia River Group, Little Butte Volcanic Series, marine rocks, Troutdale Formation, and Sardine Formation. Ground water occurs under perched, confined, and unconfined conditions, and at most places supplies of water adequate for domestic and stock use can be obtained from wells less than 400 feet deep.

The principal water-yielding units in the five subareas of the transition zone are the Troutdale Formation, alluvium, Boring Lava, Columbia River Group, Little Butte Volcanic Series, and marine rocks. In the northern part of the transition zone, many wells draw water from perched aquifers capable of yielding small to moderate quantities of water. In the central part of the transition zone, most wells draw water from water-table and confined aquifers capable of yielding small to large quantities of water. In the southern part, alluvial aquifers yield large quantities of water to wells, whereas bedrock aquifers yield small quantities of water from perched-water zones. Subareas of the transition zone that are underlain by sedimentary and alluvial materials having large storage capacities can safely accommodate considerable additional withdrawals of water.

The principal water-yielding unit beneath the valley plain is the Troutdale Formation; the Columbia River Group is of secondary importance. In the valley-plain area, the average depth of wells that tap the Troutdale is about 150 feet, and the average yield of irrigation and public-supply wells is about 300 gallons per minute. The average depth of wells drilled into the Columbia River Group is about 330 feet, and the average yield is about 200 gallons per minute. Annual pumpage from the Troutdale aquifers could be increased several fold without causing overdraft in the area.

Chemical quality of all water, except the connate water derived from the marine sedimentary rocks, is generally excellent and within desirable ranges of hardness and salinity for public supply, industrial, and irrigation uses. Connate water from the marine rocks, which at places has migrated into permeable zones in the Little Butte Volcanic Series and Columbia River Group, is too saline for many uses and toxic to many crops.

The volume of water pumped for all uses in 1966, mostly from the aquifers beneath the valley plains, totaled about 12,000 acre-feet. Of this total, about 73 percent, or 8,600 acre-feet, was pumped for irrigation; about 23 percent, or 2,600 acre-feet, was for domestic use; and about 4 percent, or 500 acre-feet, was for municipal use.

The volume of manageable stored water in the 0- to 200-foot depth zone of the 186-square-mile valley area is about 2,900,000 acre-feet, and additional water is stored in the Troutdale Formation below the 200-foot depth horizon beneath much of the area.

The minimum recharge to the ground-water body beneath the valley plain from precipitation, infiltration from irrigation, and fluid-waste disposal directly on the valley plain is estimated to be 180,000 acre-feet, which is equal to 1.5 feet of water over the 186-square-mile area. Recovery of water levels each year to the level of the previous year indicates that recharge equals discharge, which takes place through seepage to streams, evapotranspiration, and pumpage.

The quantity of ground water available for use on a sustained annual basis from aquifers beneath the valley-plain area far exceeds the 12,000 acre-feet pumped for all uses in 1966 and amounts to about 180,000 acre-feet. If supplemental irrigation water were applied to all 119,000 acres in the valley-plain area at the average rate of application used in 1966 (1 acre-foot per acre), then annual replenishment would exceed the amount pumped by about 60,000 acre-feet.

Well-construction methods commonly used in the area are adequate for production of large quantities of water from clean gravel aquifers but inadequate for the production of similar quantities of water from sand aquifers. Because nearly 90 percent of the valley-plain area is underlain by alluvial materials that contain less than 20 percent gravel in the 0- to 200-foot depth zone, future development of ground water in much of the valley plain will be accomplished by utilizing gravel-envelope and screened wells.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

In recent years, the demand for ground water for domestic, irrigation, industrial, and public supplies has increased greatly in the Molalla-Salem Slope area. This report was prepared to answer, in part, the questions:

What parts of the Molalla–Salem Slope are underlain by water-bearing materials?

How much water can be obtained from the water-bearing materials at various places in the area?

Are the supplies of ground water adequate to meet present-day and foreseeable future needs?

The study was begun in 1960 as a part of the continuing cooperative program of water-resources investigations with the Oregon State Engineer. Numerous interruptions delayed the completion of data collection and geologic mapping until October 1964. The report was prepared under the direct supervision of B. L. Foxworthy, district geologist for Oregon, and E. A. Moulder, Pacific Coast Area branch chief for ground water.

This report provides qualitative information on the entire Molalla-Salem Slope area by relating the water-bearing character of the rock units to the geographic distribution of those units. Quantitative information is presented for the valley-plain and adjacent areas that are underlain by the most permeable materials.

LOCATION AND EXTENT OF THE AREA

The Molalla-Salem Slope area occupies about 620 square miles in the northeastern part of the Willamette Valley in Oregon. It is roughly bounded by the Little Pudding and Pudding Rivers on the west, Milk Creek on the north, the Cascade Range on the east, and Mill Creek on the south. The area lies within long 123° W. and 122°20′ W. and lat 45°15′ N. and 44°45′ N., as shown in figure 1.

PREVIOUS INVESTIGATIONS

Investigations of ground-water resources of the Molalla-Salem Slope area include a report by Piper (1942) describing in a general way the ground-water resources of the entire Willamette Valley and a compilation by Hampton (1963) of well records and data on chemical quality of ground water. Geologic studies in or adjacent to the area have been made by Harper (1941), Price (1967), Thayer (1939), Schlicker (1954), Peck, Griggs, Schlicker, Wells, and Dole (1964), Trimble (1963), and Hart and Newcomb (1965).

ACKNOWLEDGMENTS

The friendly cooperation of well drillers, pump company representatives, electrical utility representatives, and well owners and users, who provided information on wells, water use, and other facts pertinent to the water resources of the area is gratefully acknowledged. Mr. Frank G. Mackaness of Portland General Electric Co. and the officials

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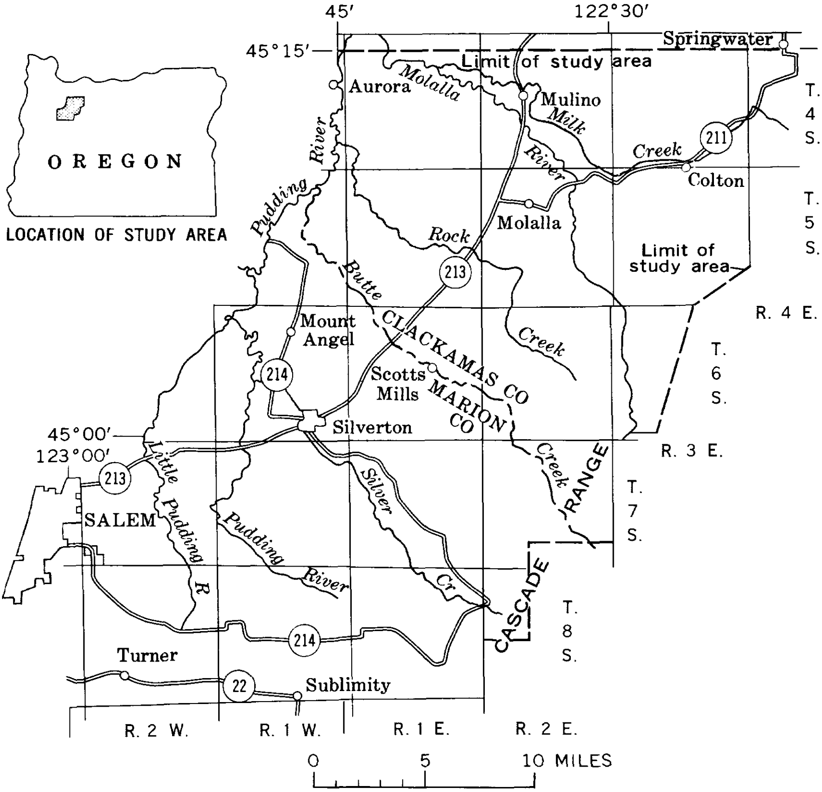

FIGURE 1.—The Molalla-Salem Slope area.

of the Stayton office of Pacific Power & Light Co. were particularly helpful in supplying power-use data to compute the volume of water pumped for irrigation.

WELL- AND SPRING-NUMBERING SYSTEM

In this report, wells and springs are designated by symbols that indicate their location according to the rectangular system of land division. In the symbol 5/1–15H1, for example, the part preceding the hyphen indicates, respectively, the township and range (T. 5 S., R. 1 E.) south and east of the Willamette baseline and meridian. Because most of the State lies south of the Willamette base line and east of the Willamette meridian, the letters indicating the directions south and east are omitted, but the letters "N" and "W" are included for wells lying north of the base line and west of the meridian. The first number after the hyphen indicates the section (sec. 15), and the letter indicates a 40-acre subdivision of the section as shown in figure 2. The final digit is the serial number of the well within that 40-acre tract. Thus, well 15H1 is in the SE¼NE¼ sec. 15, T. 5 S., R. 1 E., and is the first well in the tract to be listed. Springs are numbered in the same manner as the wells, except that the letter "s" is added following the final digit.

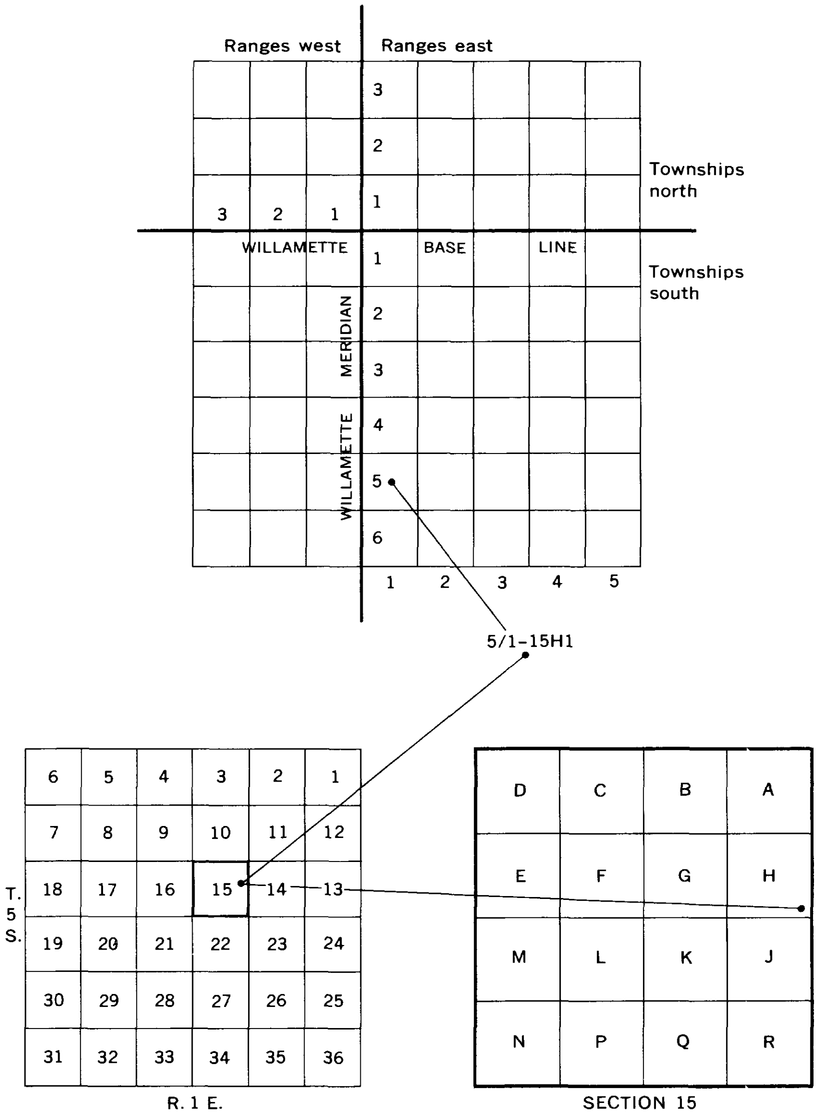

FIGURE 2.—Well- and spring-numbering system.

GEOGRAPHY

CLIMATE

The Molalla-Salem Slope area has a temperate climate, with wet winters and generally dry summers. Mean monthly temperatures of the area as recorded at Salem (alt 195 ft) by the U.S. Weather Bureau range from 38.5°F in January to 66.1°F in July and August, and recorded extremes of temperature range from –10°F to 107°F. Mean monthly temperatures at Silver Creek Falls (alt 1,340 ft) range from 38.5°F in January to 64.5°F in July, and temperature extremes range from about −4°F to about 100°F, but temperatures below 10°F or above 100°F are rare.

Average annual precipitation in the area, based on the total period of record at each of the reporting stations, ranges from 39.30 inches at Salem to 79.73 inches at Silver Creek Falls. The average annual precipitation for the period 1952–65 for six weather stations, along with the altitudes of the various stations, is given in table 1. The average

TABLE 1.—*Average annual precipitation in the Molalla-Salem Slope area for the period 1952–65*

Station	Altitude (feet)	Average annual precipitation (inches)
Canby	153	40. 75
Salem	195	40. 15
Molalla	365	46. 37
Silverton	408	47. 97
Stayton	625	52. 38
Silver Creek Falls	1, 340	79. 82

monthly precipitation for five of those stations is shown in figure 3. As is shown in figure 3, most of the precipitation occurs in the winter, whereas little rain falls during the last half of the growing season in July, August, and September. Consequently, supplemental irrigation is necessary to the success of many crops.

The long-term precipitation and cumulative departure from average for the period 1893–1963 at Salem are shown in figure 4.

LANDFORMS

The physiographic subareas of the Molalla-Salem Slope are the valley plain, the transitional slope between the valley plain and the foothills of the Cascade Range, and the foothills of the Cascade Range. The boundaries of the subareas are shown in figure 5.

The valley plain is an irregular, north-south band about 5 miles wide

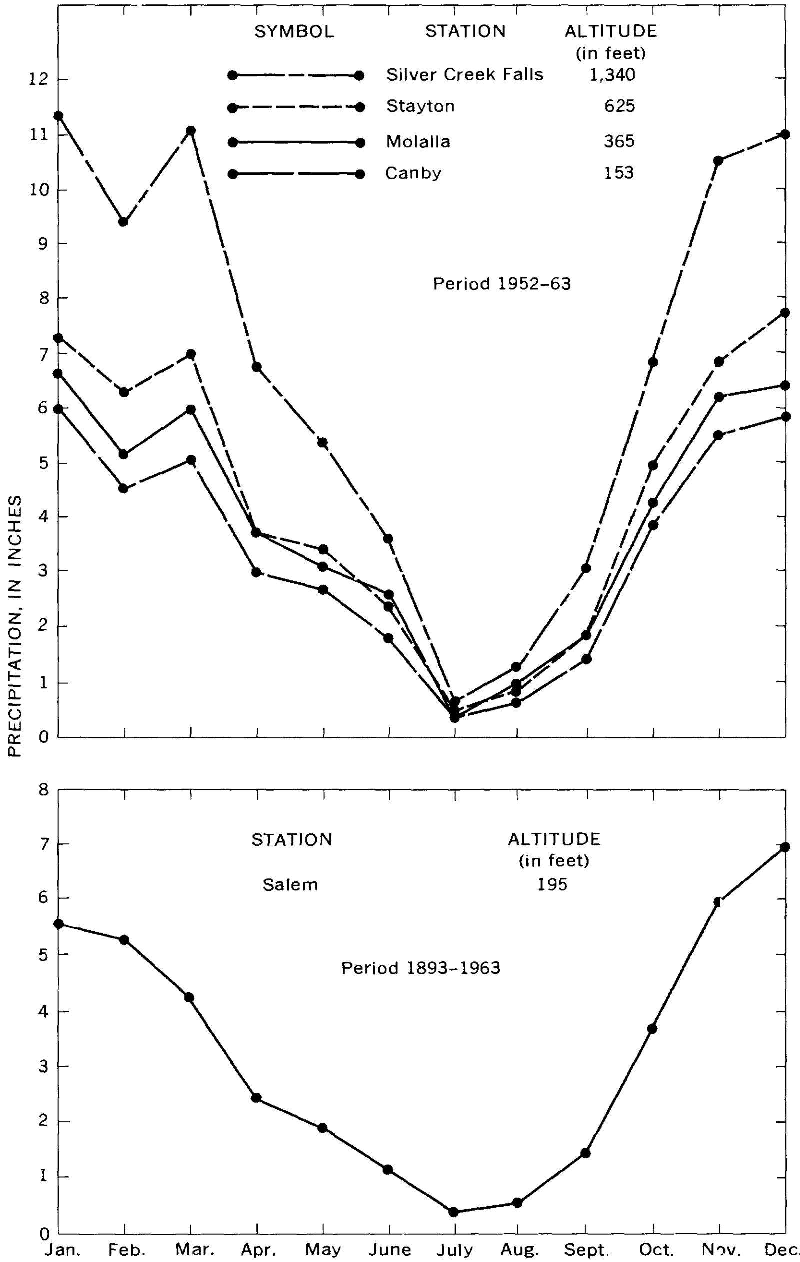

FIGURE 3.—Average monthly precipitation at five weather stations.

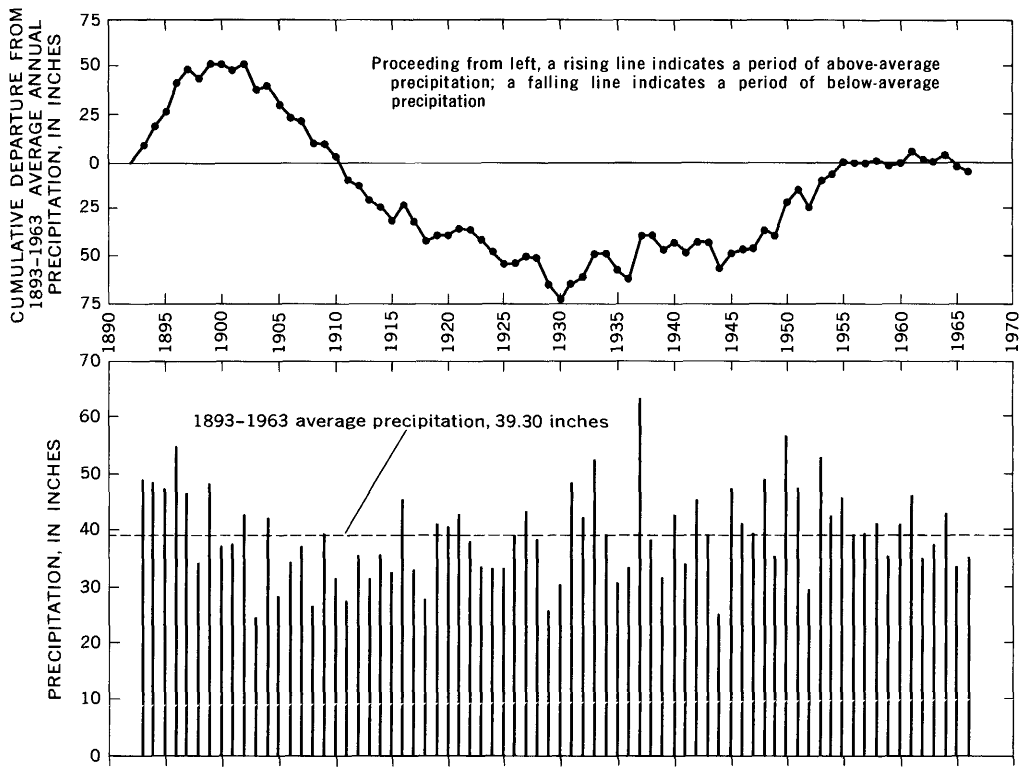

FIGURE 4.—Annual precipitation and cumulative departure from 1893–1963 average annual precipitation at Salem, Oreg.

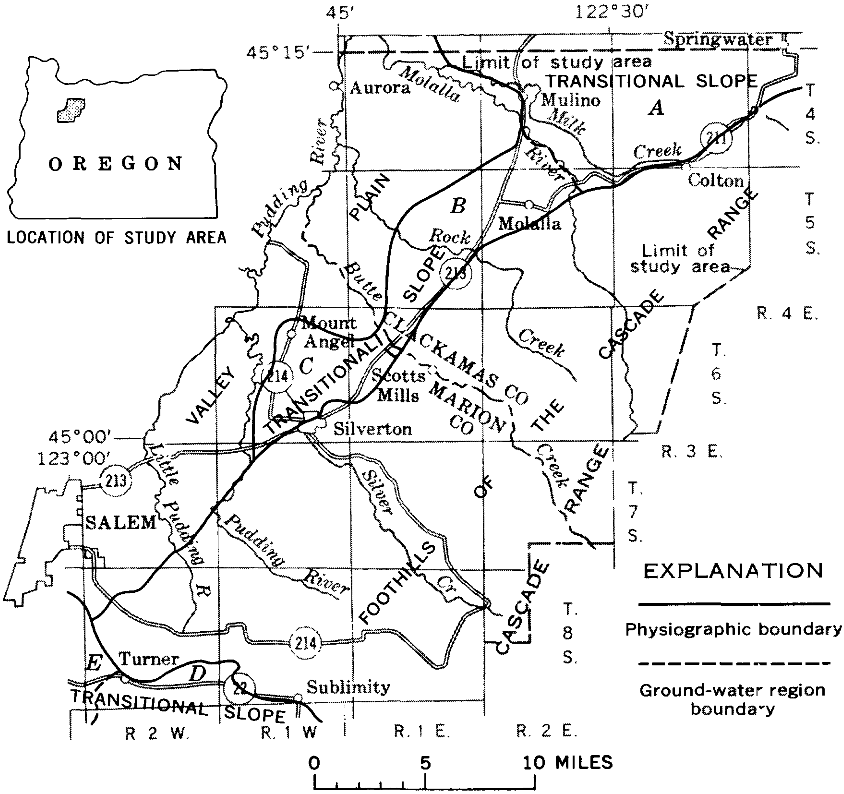

FIGURE 5.—Physiographic and ground-water subareas of the Molalla-Salem Slope. Letters indicate ground-water regions of the transitional slope.

and 28 miles long. It is bounded on the south by the Waldo and Salem Hills, on the west by the Pudding River, on the north by the Molalla River, and on the east by the transitional slope of the foothills of the Cascade Range. The valley plain is characterized by gently rolling topography traversed by steep-walled, flat-floored stream valleys. The broadest stream valleys are those of the Pudding and Molalla Rivers.

The transitional slope is an irregularly shaped area that extends along the foothills of the Cascade Range and occupies about 160 square miles. The slope is characterized by coalesced alluvial fans of tributary streams in the southern part, by outlying hogback ridges of the foothills in the central part, and by a rolling upland in the northern part. The upland in the northernmost part of the transitional slope is characterized by a moderately dissected southwestward-sloping surface that is deeply incised by stream valleys at its edges. The Salem Hills and old alluvial fan of the Santiam River are included in the transitional slope.

Foothills of the Cascade Range occupy about 340 square miles of the area and extend southward from the vicinity of Elwood near the northern boundary to Turner near the southern boundary of the area. The foothills area is characterized by a gently rolling westward-sloping surface dissected by deeply incised canyons of westward-flowing streams. The southern part of the area—the Waldo Hills—has broad, rounded hills separated by steep-walled, deep canyons. The middle part has narrow, flat-topped ridges separated by broader, steep-walled valleys. The northern part of the foothills is a mountainous upland of steep topography.

DRAINAGE

The principal streams, in north to south order, are: Clear Creek, Milk Creek, Molalla River, Rock Creek, Butte Creek, Abiqua Creek, Silver Creek, Pudding River, Little Pudding River, Beaver Creek, and Mill Creek.

Eight of the 11 principal streams traversing the Molalla-Salem Slope drain the western foothills of the Cascade Range and flow westward to join the Pudding River at the west side of the area. Of the remaining streams, Clear Creek heads near the northeast corner of the area and drains north to the Clackamas River, and Beaver Creek drains most of the southernmost part and is tributary to Mill Creek. Mill Creek, a distributary of the Santiam River, flows through Turner Gap and joins the Willamette River west of Salem. Average and low flows for several streams are given in table 2.

TABLE 2.—*Average flows and selected low flows for selected streams in the Molalla-Salem Slope area*

Stream and station	Drainage area above gaging station (sq mi)	Flow [1]				
		Mean annual (cfs)	Q2		Q10	
			Cfs	Cfsm	Cfs	Cfsm
Molalla River above Pine Creek, near Wilhoit (14-1985)	97.0	539	30.0	0.309	22.0	0.221
Molalla River near Canby (14-2000)	323.0	1,134	60.0	.186	44.0	.136
Butte Creek at Monitor (14-2015)	58.7	216	7.5	.128	4.2	.073
Abiqua Creek near Silverton (14-2005)	49.4	200	10.0	.202	7.4	.150
Silver Creek at Silverton (14-2003)	47.9	185	6.6	.138	4.6	.096
Pudding River near Mount Angel (14-2010)	204.0	676	16.0	.078	8.7	.043

[1] Q2 is lowest mean discharge for 7 consecutive days for 2-yr recurrence interval; Q10 is lowest mean discharge for 7 consecutive days for 10-yr recurrence interval; cfsm is ratio of discharge to drainage area for each recurrence interval in cubic feet per second per square mile; and cf is cubic feet per second.

Most of the streamflow occurs during the winter coincident with periods of greatest precipitation (fig. 3) and during the early spring snowmelt period. The Molalla River and Abiqua Creek, which have the highest ratios of dry-season flow (base flow) to drainage area, drain areas underlain by moderately permeable lava flows and pyroclastic debris of the Sardine Formation. Butte and Silver Creeks and Pudding River, which have lower ratios of base flow to drainage area, drain areas underlain by less permeable lava flows of the Columbia River Group, lava and pyroclastic debris of the Little Butte Volcanic Series, and marine sandstone and siltstone.

CULTURE AND INDUSTRY

The Molalla-Salem Slope area occupies the northeastern part of the agriculturally rich Willamette Valley. Raising a variety of crops and food processing are the principal occupations in the area, whereas lumbering and manufacturing wood products are subordinate occupations. In 1964 there were about 12 operating sawmills in the area.

The principal centers of population are Mount Angel, Silverton, Molalla, Mulino, Turner, Sublimity, and Aumsville. Nearby towns that serve the area are Canby, Woodburn, Hubbard, Gervais, Brooks, Salem, Mehama, and Stayton. In 1964, agricultural income of the area was about $26 million, estimated [1] from the figures for Clackamas and Marion Counties.

GEOLOGY

Water available for use flows in, between, or upon the various rock units composing the earth's crust. Therefore, an understanding of the areal distribution, physical and chemical character, and interrelationship of these rock units is prerequisite to understanding the hydrology of an area and to evaluating its water resources.

SUMMARY OF GEOLOGIC HISTORY

This summary of geologic history of the Molalla-Salem Slope area begins in Oligocene time when lava and pyroclastic debris of the Little Butte Volcanic Series were erupted in the foothills of the Cascade Range. Fragments were carried westward and deposited in a marine embayment. Marine rocks of Oligocene to early Miocene age intertongue in part with Little Butte Volcanic Series; the upper part of the marine rocks was derived largely from erosion of Little Butte Volcanic Series.

[1] Oral communication, November 1966, from Hollis Ottoway, Marion County extension agent, and Clive Cook, Clackamas County extension agent.

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The area was uplifted and folded, probably in early Miocene time. Marine rocks were strongly eroded, producing a terrain of steep-walled westward-trending canyons in the Cascade foothills. In middle Miocene time, basalt of the Columbia River Group was extruded from vents outside the study area, and flows of lava inundated the topography developed earlier on the older geologic units. Most valleys in the foothills of the Cascade Range were filled, and only a few highlands composed of marine rock and Little Butte Volcanic Series remained exposed.

Again, the area was gently warped, probably in late Miocene time. The major north-south synclinal (downwarp) axis is west of the report area—about on a line between Salem and Wilsonville. Warping continued into Pliocene time and was accompanied by accelerated erosion of Cascade Range area and deposition of sediments of the Troutdale Formation near the center and on the eastern flank of the trough.

The late Miocene and early Pliocene warping also was accompanied by eruption of intermediate volcanic materials of the Sardine Formation, so that the Troutdale and Sardine Formations interfinger at places. By middle and late Pliocene time, eruptions of Sardine Formation volcanic rocks had ceased; but warping continued, gently deforming the oldest rocks of the Troutdale Formation.

In late Pliocene and through Pleistocene time, the Boring Lava was erupted intermittently from numerous volcanoes north of the area and from at least one volcano in the northern part.

During Pleistocene glacial epochs, mountain glaciers carved and modified existing canyons. Alluvium was continually deposited in fans at the mouths of mountain canyons and as gravel trains in the southern part of the report area. Volcanic debris and fluvial materials of the Springwater Formation were deposited on upland slopes during Pleistocene time. Sediment-laden glacial melt water from the Columbia River system inundated the Willamette Valley. During late Pleistocene time, older coarse alluvial deposits were covered by the Willamette Silt.

In Holocene time, drainage patterns were reestablished on the valley plain by erosion of the Willamette Silt, and stream channels in the foothills were entrenched below Pleistocene terrace levels. At present, alluvium is being deposited along stream valleys and across the surfaces of alluvial fans of major streams. Many landslides have occurred and continue to occur as erosion removes lateral support from incompetent materials.

GENERAL DESCRIPTION, RELATIONSHIP, AND WATER-BEARING PROPERTIES OF ROCK UNITS

Geologic units are customarily discussed in order of age, from oldest to youngest. When considering the water-bearing and water-yielding properties of rock units, one often notices a general characteristic of increasing permeability with decreasing age. This trend is particularly noticeable when one compares rock units of the same type. For example, the oldest rocks in the area, the basalt flows of the Little Butte Volcanic Series, have a lower permeability as a unit than do the younger basalts of the Columbia River Group, which, in turn, have a lower permeability than do the youngest basaltic lava flows. In the following discussion and description of the rock units of the Molalla-Salem Slope area, the older, and generally least permeable, rock units will be discussed briefly before the more permeable and younger rock units are considered in some detail. The areal distribution of the rock units is shown on the geologic map of the area (pl. 1).

LITTLE BUTTE VOLCANIC SERIES

The oldest rocks exposed in the Molalla-Salem Slope area are the volcanic flows, pyroclastic rocks, and associated water-laid tuffs of the Little Butte Volcanic Series. The Little Butte was named by Wells (1956). In a detailed description by Peck, Griggs, Schlicker, Wells, and Dole (1964), the Little Butte includes all, or parts of, the Mehama Volcanics and Breitenbush Series of Thayer (1939), the Molalla Formation and pre-Butte Creek lavas of Harper (1946), and the Eagle Creek Formation and Bull Creek beds of Barnes and Butler (1930). Rocks assigned to the Little Butte Volcanic Series occupy about 20 square miles between Butte Creek and the northeast border of the area.

The Little Butte Volcanic Series ranges from about 5,000 to about 10,000 feet in thickness over most of the Western Cascade Range (Peck and others, 1964, p. 11). An oil-test well drilled in sec. 11, T. 7 S., R. 1 E., penetrated about 7,000 feet of material logged as "volcanics" (believed by the author to be largely the Little Butte).

Materials that compose the Little Butte Volcanic Series were erupted from several vents in the Western Cascade Range. The lava flows and pyroclastic debris deposited on land are included in the Little Butte, whereas the pyroclastic debris that was carried into a marine embayment adjacent to the erupting volcanoes is included in the marine rocks.

The Little Butte Volcanic Series has been dated on the basis of leaves enclosed in the tuff unit (Molalla Formation of Harper, 1946), and according to Peck, Griggs, Schlicker, Wells, and Dole (1964, p. 8), is Oligocene and early Miocene in age.

The base of the Little Butte Volcanic Series is not exposed in the area. The unit in part interfingers with, so at places is overlain by, marine tuff and sandstone, much of which was derived from the erosion and deposition of materials that compose the Little Butte. Both the Little Butte Volcanic Series and marine tuff and sandstone were folded and eroded, and they are unconformably overlain by rocks of the Columbia River Group, the Sardine Formation, and younger rocks.

BASALT, ANDESITE, AND BRECCIA

Olivine basalt, basaltic andesite, and volcanic breccia underlie about 11 square miles of the area, mostly within Tps. 5 and 6 S., Rs. 1 and 2 E. Olivine basalt is dark-gray green on fresh surfaces and has some specks of red where the olivine has been altered. The andesite is gray to dark green, porphyritic, and dense. Both kinds of lava, as well as their related breccia, display green and red streaks caused by secondary mineralization. All the rocks of this unit have been sheared to some degree, so that one or more sets of joints traverse them. At places, both andesite and basalt have been sheared and silicified, so that they have a shalelike appearance. The olivine basalt, basaltic andesite, and volcanic breccia are light gray to reddish brown on weathered surfaces and decompose to form a reddish-brown rock-strewn clay soil.

Individual flows of basalt range from a few tens to about 100 feet thick, whereas isolated masses of andesite that probably represent only one lava flow may be several hundred feet thick. Where volcanic-breccia layers have been penetrated by wells or exposed by excavations, they are a few tens of feet thick.

PORPHYRITIC ANDESITE

Two masses of porphyritic andesite underlie about a quarter of a square mile in T. 6 S., Rs. 2 and 3 E. One mass is associated with the tuffaceous rocks of the Little Butte, and the other is surrounded by younger volcanic materials. The andesite is medium gray, contains abundant phenocrysts of feldspar 2–4 mm in diameter, and is massive. It weathers into angular blocks and forms a rocky clay soil.

TUFF AND VOLCANIC AGGLOMERATE

Tuff, conglomerate, and agglomerate underlie about 7 square miles in Tps. 5 and 6 S., Rs. 2 and 3 E., where these rocks crop out along the Molalla River, and about half a square mile in secs. 7 and 14, T. 6 S., R. 2 E., where they cap Missouri Ridge. The tuff ranges in color from light gray to buff, depending on whether a particular exposure is composed of predominantly fine-grained layered gray tuff or of buff pumice lapilli. Agglomerate beds are composed of boulder- to sand-sized fragments of red, pink, green, lavender, gray, and black rock. The pastel shades are predominant, and most exposures appear to be lavender, green, or pink. The tuff appears to be uniformly bedded, and the beds range in thickness from ½ to 2 feet. At places, jointing in the tuff has resulted in pencil-sized columns normal to the bedding plane. These columns commonly originate at a layer of fossil-plant material and terminate about 3–5 inches lower in the tuff bed, where the jointed rock merges with the remainder of the bed.

Particles in the volcanic conglomerate and agglomerate range from sand to boulder size, but individual beds may be predominantly of one size. Thus, the volcanic conglomerate and agglomerate appears as distinct beds of sandstone, conglomerate, or boulder conglomerate. Most volcanic conglomerate beds are crossbedded, some show scour and fill structures, and those whose pebble- and cobble-sized particles appear to be stream rounded are presumed to have been water deposited.

At places where the tuff and agglomerate unit has been exposed by excavation, all particles from silt to boulder size have weathered to clay, although the outlines of larger individual particles remain sharp. Some of the clay beds formed by the decomposition of tuff and agglomerate of the Little Butte have been investigated by the U.S. Bureau of Mines (1943), who evaluated them as a source for ceramic clay.

The 1,000-foot-high exposure of the tuff and agglomerate unit along the Molalla River probably represents one of the thickest sections of this subunit in the Molalla-Salem Slope area.

WATER SUPPLY

At most places the basalt and volcanic breccia flows of the unit contain aquifers (water-bearing and water-yielding zones) that have yielded usable quantities of water to wells. Wells 5/1–28R1 and 6/1–31G1 (tables 10, 11) yield quantities of water adequate for irrigation. Several wells drilled into the basalt and volcanic breccia flows have yielded salt water, and one yielded nitrogen gas, but no water. The tuff and agglomerate generally yield small quantities of water, generally adequate for domestic and stock uses.

MARINE ROCKS

Tuff, sandstone, and coquina that intertongue with the Little Butte Volcanic Series include the Butte Creek Beds of Harper (1946) and Illahe Formation of Thayer (1939), which are similar to rocks assigned to the Eugene Formation by Allison and Felts (1956) and Vokes, Snavely, and Myers (1951). In this report, marine sedimentary rocks are informally called marine rocks.

The marine rocks are exposed in the foothills of the Cascade Range from about the latitude of Mount Angel to the southern border of that area. They occupy about 25 square miles in Tps. 6 and 7 S., Rs. 1 and 2 E.; 3 square miles in T. 7 S., R. 1 W.; 3 square miles in T. 8 S., R. 2 W., 6 square miles in T. 8 S., R. 1 W.; and 1 square mile in T. 8 S., R. 1 E.

The commonest rock types in this unit are tuff (shale), tuffaceous sandstone, and sandstone. Coquina beds a few feet thick occur at places—for example, the Marquam lime quarry—as do beds of grit and fine gravel. In most exposures the weathered rock is medium gray to tan, and the fresh rock (beyond the weathered zone) is light blue green. Most of the rock in natural exposures is deeply weathered, so that fresh exposures are buff to light brown or cream colored. A few layers contain a high percentage of shells and shell fragments. These, as well as the enclosing layers, are chocolate brown on fresh surfaces and likely to be logged as "brown shale" by well drillers.

Most of the sandstone layers of the unit are cemented and well indurated and are therefore resistant to erosion. The tuff and shale beds are well indurated, but the volcanic glass in many of the beds has devitrified and altered to clay minerals. Some of the clay minerals swell when they are wetted, so that many of the tuff and shale beds are subject to mechanical failures evidenced by slumping and sliding. Large areas underlain at depth by the finer grained marine rocks are mantled by landslide debris.

Sandstone in the unit is composed mostly of volcanic rock fragments, feldspar crystals, and a few grains of quartz cemented by clays derived from devitrified volcanic glass. Consequently, most sandstone is poorly permeable. At places, however, sandstone is composed largely of rounded particles of feldspar, quartz, cryptocrystalline silica, and rock fragments and is cemented by either silica or calcite. These few sandstone beds are moderately permeable.

About 600 feet of the marine rocks is exposed in the Molalla–Salem Slope area, and an additional 700 feet was penetrated during the drilling of an oil-test well, so that 1,300 feet of the unit remains in part of the area. The unit probably thickens somewhat to the west of the Cascade Range foothills, but it thins to the east where the marine rocks intertongue with, and at places grade into, the Little Butte Volcanic Series.

The base of the unit is not exposed in the area, although contact relationships between parts of the Little Butte and the marine rocks in T. 6 S., R. 1 E., give an impression of an erosional unconformity, at least locally, between the lava flows of the Little Butte and the overlying marine rocks. The marine rocks are separated from overlying units, such as the Columbia River Group and the Sardine Formation, by angular and erosional unconformity.

The marine rocks were deposited in a marine embayment that was adjacent to an area of active volcanism. Consequently, in the marine tuff and sandstone, most of the particles, many of which are poorly resistant to chemical weathering and alteration, were derived from volcanic materials. Near the edge of the basin, the sedimentary materials were occasionally overrun by lava flows and volcanic debris; at other times, due to relative subsidence of the basin, they were deposited upon those volcanic materials.

The marine rocks contain fossils that range in age from Oligocene to early Miocene. A summary of the formations correlative with the marine tuff and sandstone and of the significant fossils in those formations is given by Peck, Griggs, Schlicker, Wells, and Dole (1964, p. 26).

Because the marine rocks yield small to moderate quantities of water to wells, they are an important source of stock and domestic supply over a large area of the foothills of the Cascade Range. In most of the foothills area, wells drilled into the unit yield a few to about 15 gpm (gallons per minute) of good-quality water. However, beneath the valley plain, where there is less opportunity for the removal of entrapped salt water by percolation and dilution with recharge from precipitation, some wells drilled into the unit have yielded salt water (well 5/1–30C1). A few wells at the base of the foothills have been drilled into fairly permeable sandstone layers and have yielded as much as 100 gpm (well 6/1–9M1, tables 10, 11). These wells are the exceptions, as most yield only a few gallons per minute. Several wells that penetrate the marine tuff and sandstone beneath the valley plain have been drilled deeper than 400 feet, and all have produced salty water below that depth.

COLUMBIA RIVER GROUP

Flows of columnar-jointed dark-gray fine-grained basalt that unconformably overlie the Little Butte Volcanic Series and the marine rocks in the Molalla-Salem Slope area are assigned to the Columbia River Group. The rocks mapped as basalt of the Columbia River

Group in this report include basalt flows designated as Columbia River Basalt by previous authors (Peck and others, 1964, p. 27–30), but they do not include the platy andesite mapped by Thayer (1939) as part of the Stayton Lavas.

Rocks of the Columbia River Group underlie about 120 square miles in the southeastern part of the area. There, the lava flows cap long ridges that slope westward from the Cascade Range and underlie large areas of the Waldo and Salem Hills. Near the center of the area about 8 square miles is underlain by the northwestward-dipping basalt flows. In addition, there are small irregular exposures near and along a reach of the Molalla River, mostly in T. 6 S., R. 3 E.

Basalt flows and infrequent sedimentary interbeds compose the Columbia River Group in the area. Three varieties of basalt occur in the Columbia River Group in the area. They are (1) glassy to very fine-grained dark-gray lava; (2) fine-grained medium-gray open-textured porous lava; and (3) porphyritic very fine grained dark-gray lava. The first type is predominant throughout the area and is characteristic of the basalt of the Columbia River Group. Individual basalt flows range in thickness from about 10 to 100 feet, although at places a basalt flow that filled depressions in the prebasalt surface may be as much as 300 feet thick. Most of the flows exhibit columnar jointing. The basal few inches (as much as 3 in.) of a flow is generally slightly rubbly, the central part massive, and the top may be vesicular, rubbly, and brecciated. The zones, including the uppermost part of one flow and the basal part of the overlying flow, are commonly called interflow zones, and are the main aquifers in Columbia River basalts. The thicker and more rubbly the interflow zone, the more water it will transmit and yield. Where a sequence of several lava flows is penetrated by a well, several interflow zones may be found.

The basalt commonly weathers to rust brown or light gray. At most outcrops the exterior of the columns is rust brown, whereas the less weathered zone beneath the exposed surface is light gray brown. The rock is progressively darker toward the unweathered zone and may exhibit one or more narrow bands of dark decomposed minerals between the exterior and unweathered zones. The basalt weathers to a reddish-brown clay soil rarely more than a few tens of feet thick.

Bedded sedimentary material between some of the basalt flows is mostly of volcanic origin. The beds are dark-tan to cream-colored tuff in exposures and are reported as light brown, dark brown, or black by well drillers. One of the light-brown beds is exposed beneath Winter Falls in Silver Creek State Park; cream tuff underlies the uppermost basalt flows southeast of Scotts Mill and is exposed along the road adjacent to the east end of Mount Angel. Tuffaceous beds weather to a fat clay that is subject to slumping and landsliding.

Within the area, the Columbia River Group ranges in thickness from a few to as much as 600 feet. The thickest sections represent accumulations of lava in topographic depressions, such as relict stream valleys. Because the lava inundated a surface of rather steep topography, the thickness of the lava varies greatly within short distances.

Rocks of the Columbia River Group unconformably overlie the Little Butte Volcanic Series and marine rocks. They are, in turn, overlain by various members of the Sardine Formation and by the Troutdale Formation. The overlying formations appear conformable with the Columbia River Group, but close inspection of the attitudes of the units reveals an angular discordance of 2°–4° between them, at places.

Because no dikes or vents relatable to the Columbia River Group have been identified within the area, it is presumed that the lava flows erupted outside of, and then flowed into, the Molalla–Salem Slope area.

The Columbia River Group has been dated at several places in the Pacific Northwest on the basis of the ages of enclosing formations. The age of the group in the report area, according to Peck, Griggs, Schlicker, Wells, and Dole (1964, p. 30), is middle Miocene.

At places in the Molalla–Salem Slope area, lava flows of the Columbia River Group are important aquifers. Quantities of water adequate for irrigation and municipal supplies have been obtained from the rubbly tops of one or more basalt flows in a few places in the area, although most wells that tap the aquifers in the basalt yield quantities of water adequate only for stock and domestic uses. There are about 25 irrigation and public-supply wells that obtain large quantities of water from the basalt. They include wells 8/2W–11P2 (yields 1,000 gpm with 44 ft of drawdown), 8/1W–35C1 (yields 350 gpm with 110 ft of drawdown), 8/1W–34C1 (yields 400 gpm with 30 ft of drawdown), 6/1W–10C1 (yields 650 gpm with 204 ft of drawdown), and 5/1–25G1 (yields 350 gpm with 6 ft of drawdown). At several places, supplies of water adequate for stock and domestic uses have been obtained from the rubbly contact zone between the base of the basalt and the underlying rocks.

Because the interconnected pore spaces in the water-bearing rubbly zones between lava flows constitute a small part of the unit as a whole (perhaps 1–2 percent), the basalt has relatively little space in which to store water. As a consequence, basalt aquifers can easily be overdeveloped, resulting in a year-to-year decline of water levels in wells that tap the aquifers.

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With rare exceptions, the water from the basalt flows of the Columbia River Group is of good chemical quality and suitable for most domestic, irrigation, and industrial uses. The exceptions occur where connate saline water, trapped in the underlying marine sedimentary rocks, has migrated into the permeable lava and mixed with the fresh water in the lava aquifers, such as has occurred at well 7/1W–6R1.

SARDINE FORMATION

In the report area, the Sardine Formation consists predominantly of lava flows, breccia, and hypersthene-andesite tuff, all of which are younger than, and occur stratigraphically above, the Columbia River Group. The Sardine is comformable to the post-Columbia River Group structures because it was erupted upon, and flowed down, the slopes of the structures. It is not, however, comformable to the constructional surface on the lavas of the Columbia River Group, which is presumed to have been horizontal or nearly horizontal. The warping of the surface of the Columbia River Group probably marked the beginning of Sardine volcanic activity.

The rocks of the Sardine are divided into five subunits on plate 1. Two of the subunits have been mapped as formations by workers prior to Peck, Griggs, Schlicker, Wells, and Dole (1964). The volcanic mudflow breccia and water-laid tuff subunit was called the Rhododendron Formation by Hodge (1933), and the massive pumice tuff, basaltic andesite flows, and agglomerate-conglomerate beds were called Fern Ridge tuffs by Thayer (1939). The remaining subunits of the Sardine include pyroxene andesite flows, intrusive dike rocks, and the Sardine Formation undivided.

On the basis of fossil plants and stratigraphic position, the Sardine Formation has been dated (Peck and others, 1964, p. 34) as middle and late Miocene. The fossil plants were collected from the basal parts of both the volcanic mudflow breccia and massive pumice tuff subunits, so they do not indicate the age of the youngest lava flows (pyroxene andesite). The position of the pyroxene andesite atop sandstone and siltstone mapped by Peck, Griggs, Schlicker, Wells, and Dole (1964) and by the author as Troutdale Formation (and confirmed by drillers' logs of wells) indicates that the youngest pyroxene andesite flows extend at least into the early Pliocene. Consequently, in this report, the Sardine Formation is considered to be of middle Miocene to early Pliocene age.

The volcanic mudflow breccia and water-laid tuff subunit of the Sardine Formation occupies about 12 square miles in the northeastern part of the area and 1 square mile in T. 5 S., R. 2 E. It consists primarily of massive agglomerate and mudflow breccia, but contains scattered beds of tuff. The agglomerate and mudflow breccia is composed of gray porphyritic andesite boulders, some all gray and some glassy dark gray with light-gray to white phenocrysts as much as 5 mm in diameter, in a matrix of devitrified volcanic glass. The matrix generally comprises more than 50 percent of the rock and gives the weathered outcrop a characteristic brick-red to dark-gray-brown color. Where the matrix is fresh, it is gray to tan. In the area along Milk and Clear Creeks, and along the Molalla River where it is best exposed, this subunit ranges from less than 50 feet to more than 400 feet thick. In the Clear Creek exposure, agglomerates are interbedded with siltstone and sandstone mapped as Troutdale Formation, but they are largely overlain by the Troutdale. At the exposure along the Molalla River, similar agglomerate unconformably overlies weathered tuff and agglomerate of the Little Butte Volcanic Series. In the Milk Creek area, Sardine agglomerates are overlain by Boring Lava and pyroxene andesite flows of the Sardine Formation.

The volcanic mudflow breccia and water-laid tuff subunit of the Sardine Formation represents an accumulation of volcanic mudflow debris that must have been erupted near the northeastern corner of the area, where the largest clasts (as much as 5 ft. in diameter) occur in the agglomerate.

The massive pumice tuff, basaltic andesite flows, and agglomerate-conglomerate beds of the Sardine Formation include material mapped as Fern Ridge Tuffs by Thayer (1939) as well as glassy platy andesite included with the Stayton Lavas by Thayer (1939) and with the Columbia River Group by Peck, Griggs, Schlicker, Wells, and Dole (1964). Rocks of this subunit underlie about 36 square miles in the southeastern part of the area. There, they overlie the Columbia River Group and marine rocks and form long, fingerlike ridges that extend westward down the foothill slopes of the Cascade Range.

Lapilli tuff and pumice tuff are the most conspicuous rocks, although they probably do not constitute more than half this subunit. The tuffs are tan at weathered exposures and cream to light tan on fresh exposures. Most easily recognized are the massive bedded, cemented, or welded pumice tuffs, which have been quarried for building stone. The pumice fragments in this rock are commonly as much as 1 inch in diameter and are held together by a matrix of partly welded volcanic glass. Volcanic mudflow and agglomerate, welded tuff, and platy andesite compose the remainder of this subunit. The boulders in the mudflow deposits are salt-and-pepper porphyritic andesite, gray fine-grained andesite, and glassy dark-gray porphyritic andesite. The particles in the tuff and agglomerate are coarsest and unsorted at the eastern border of the area and become finer and better sorted toward the west—much like the agglomerate and tuff of the volcanic mudflow breccia and water-laid tuff subunit. The platy porphyritic andesite flow rock, well exposed north of, and within Stayton, is part of the massive pumice tuff, basaltic andesite flows, and agglomerate-conglomerate beds subunit. Platy porphyritic andesite is underlain by tan tuff near the contact with the underlying basalt of the Columbia River Group, as exposed in a roadcut in the NE¼SW¼ sec. 12, T. 9 S., R. 1 W., and in a natural outcrop in N½ sec. 9, T. 9 S., R. 2 E. Both localities are just south of the area boundary. Drillers' logs of several wells in the area, notably those of wells 8/1W–28G1, 8/1W–30J1, and 8/1W–33E1, record a dark-gray andesite layer within the subunit. The massive pumice tuff subunit thickens to the east and ranges from a few feet thick at the westernmost localities to more than 500 feet thick at the southeastern border.

At most places, this subunit of the Sardine Formation appears to overlie conformably the Columbia River Group. At several places, however, the Sardine lies topographically below nearby exposures of the Columbia River Group, apparently in erosion-carved depressions.

The massive pumice tuff subunit is a stratigraphic equivalent of the volcanic mudflow breccia subunit and at places is overlain by pyroxene andesite flows of the Sardine Formation. Rocks of the massive pumice tuff subunit were erupted from vents east of the southeastern part of the area. The volcanic debris flowed part way down the foothill slopes of the Cascade Range and came to rest upon the moderately dissected and eroded surface developed here on the Columbia River Group.

Pyroxene andesite flows of the Sardine Formation underlie about 31 square miles in Tps. 4 and 5 S., Rs. 3 and 4 E., 4 square miles in T. 6 S., R. 3 E., and 6 square miles in Tps. 6 and 7 S., R. 2 E. Most of the flows in this unit are jointed into curved plates that range from about ½ to 4 inches thick. Individual flows range from about 10 to more than 100 feet thick. Permeable rubble and scoriaceous zones, such as are common between some of the basalt flows in the Columbia River Group, were not observed. The pyroxene andesite flows are light yellow brown to tan on weathered surfaces, whereas the fresh rock, generally observable only in excavations, is medium to dark gray. The pyroxene andesite is porphyritic and contains tabular phenocrysts of plagioclase and less abundant dark-green to black pyroxene prisms. At most places the rock is decomposed by weathering to a rocky soil to a depth of at least 5 feet, and in many places the rock is weathered to depths of 30 feet or more.

In the area, the unit ranges in thickness from about 10 feet to about 1,000 feet. The pyroxene andesite flows mostly overlie rocks of the volcanic mudflow breccia and massive pumice tuff subunits. In T. 5 S., R. 2 E., the pyroxene andesite also overlies sandstone, shale, and siltstone of the Troutdale Formation.

The pyroxene andesite flows were erupted from vents in and east of the area. Two probable vents, in the northeastern part of the area, are Big Hill, in sec. 15, T. 5 S., R. 3 E., and Green Mountain, which occupies most of T. 5 S., R. 4 E. Associated with a probable vent in sec. 29, T. 6 S., R. 2 E., is a sill in sec. 32, T. 6 S., R. 2 E., which was intruded between sandstone beds of the marine rocks.

The Sardine Formation is a potentially important water-yielding unit in the area, although only a few domestic- and stock-water supplies are obtained from wells drilled into the unit. Most wells deriving water from saturated zones in the volcanic mudflow breccia and the pyroxene andesite flows yield quantities adequate only for small domestic and stock supplies, whereas the pumice beds of the massive pumice tuff yield quantities adequate for small-scale irrigation. At many places the permeable rocks of the massive pumice tuff do not extend beneath the water table, but they do absorb large volumes of precipitation. The absorbed water percolates through the unit to emerge eventually as springs at contacts with the underlying rocks.

TROUTDALE FORMATION

Nonmarine sedimentary rocks that unconformably overlie the basalt of the Columbia River Group were named the Troutdale Formation by Hodge (1933). The Troutdale Formation was considered in detail by Trimble (1957), who described it as more than 1,000 feet thick and consisting of a thick lower member predominantly siltstone and mudstone, and an upper member predominantly sandstone and conglomerate. Trimble (1963) formally divided what had been called the Troutdale Formation into the Sandy River Mudstone (lower mudstone unit) and the overlying Troutdale Formation (upper sandstone and conglomerate unit). Because the exposed nonmarine sedimentary rocks that overlie the Columbia River Group in the Molalla-Salem Slope area are predominantly sandstone and conglomerate, they are mapped as Troutdale Formation in this report. In addition, the finer grained facies of the unit (which is not exposed, but is reported in drillers' logs beneath the northwestern part of the area) is included in the Troutdale Formation rather than the Sandy River Mudstone.

On the basis of fossil flora examined by R. W. Brown, of the U.S. Geological Survey, and reported by Trimble (1963, p. 28, 35), the Troutdale Formation is considered to be of early Pliocene age.

The Troutdale Formation is exposed in the north-central part of the area, where it underlies about 28 square miles. In addition, rocks believed by the author to be equivalent in age and lithology to the exposed rock, and included with the Troutdale, underlie most of the valley plain beneath younger sedimentary material. These buried Troutdale rocks are indicated in appropriate well logs and on the geologic cross section on plate 1.

At most of the exposures examined, the Troutdale Formation consists of medium- to fine-grained bedded and crossbedded tuffaceous sandstone and siltstone. At places, the formation contains 1- to 2-foot-thick lenticular beds of grit and pebble conglomerate, some of which attenuate within a few tens of feet. Most of the beds are moderately to strongly indurated and, at places, will stand unsupported in high cliffs. The weathered exposures are tan, cream, or light creamy green. Drillers' logs of wells indicate that the unweathered rock is tan, green, blue, and black. The blue rock is called shale or clay by most well drillers. The Troutdale Formation at depth beneath the valley plain in the northern part of the area is predominantly siltstone, mudstone, and sandstone, with rare beds of pebble conglomerate, and becomes progressively coarser grained upvalley to the south. Near Salem, the Troutdale Formation is predominantly compacted and cemented gravel (conglomerate).

The particles that compose the Troutdale Formation were derived largely from the volcanic rocks of the Cascade Range adjacent to the basin of deposition. In the northernmost part of the area, however, scattered pebbles of quartzite and metamorphic rocks occur in conglomerate beds, and flakes of white mica occur in the siltstone beds. There is a gradual transition from the lithology of the Troutdale Formation at the type locality on the lower Sandy River, where the conglomerate beds contain more than 25 percent quartzite pebbles (derived from the Upper Columbia River drainage system), to the lithology beneath the Salem area, where conglomerate beds contain rocks derived only from the nearby Cascade Range.

The Troutdale Formation ranges from a few feet thick, where it wedges out against the westward-dipping basalt flows of the Columbia River Group in the foothills of the Cascades, to a maximum of about 570 feet west of Aurora, near the center of the Willamette Valley syncline and west of the area. The Troutdale thickens northward from about 180 feet near Salem to about 450 feet in the vicinity of Mount Angel. The approximate thickness of the Troutdale beneath the valley plain area is shown on plate 2.

Rocks mapped as Troutdale Formation in this report unconformably overlie the Columbia River Group and older rocks in the area.

They are unconformably overlain by the Boring Lava in the northeastern part of the area, by the Willamette Silt on the valley plain, and, at places, by younger alluvial deposits. In addition, the pyroxene andesite flows and volcanic agglomerate of the Sardine Formation locally overlie the sandstone and siltstone of the Troutdale Formation.

The basal part of the Troutdale, which was deposited in the lowest part of the Puget-Willamette synclinal basin, is mostly fine-grained mudstone and siltstone. As the basin became filled and volcanism became more active in the Cascade Range area, the coarser Troutdale materials that were first deposited on the east side of the basin near the source volcanoes were carried farther westward and northward across the basin, so that the youngest Troutdale materials in the center of the basin are coarser grained than the oldest. A generalized representation of the distribution of grain sizes in the Troutdale is shown in figures 12–14.

Rocks included in the Troutdale Formation compose the principal aquifers in the area. Hundreds of wells tap the formation and provide water for stock, domestic, industrial, municipal, public, and irrigation uses. The principal aquifers are in the southern part of the valley-plain area, where the Troutdale is predominantly conglomerate and sandstone. There, the more productive irrigation wells, most less than 200 feet deep, yield 300–800 gpm, with as much as 100 feet of drawdown. (See records of wells 7/2W–9P1, 17K1, 29L1 in tables 10 and 11.) Important, but less productive, aquifers of sand and fine gravel underlie the northern part of the valley-plain area, where yields of the more productive wells range from about 100 to more than 300 gpm. (See records of wells 4/1W–36R1, 4/1–16H1 and 20C1, and 5/1–11C1 in tables 10 and 11.) The volumes of water presently used and potentially available from the Troutdale Formation aquifers are discussed in sections on ground-water subareas and water use (p. 43–53).

BORING LAVA

Overlying the Troutdale Formation in the northern and northeastern part of the area are young basaltic lava flows, called the Boring Lava by Treasher (1942) and Trimble (1957, 1963).

The Boring Lava underlies about 34 square miles in the northeastern part of the area, mostly in T. 4 S., Rs. 3 and 4 E. The lava flows are basalt and basaltic andesite and range in color from light-blue gray to dark-blue gray. Many flows are open textured and porous, although some are glassy and dense. The Boring is typically reddish brown on weathered surfaces and decomposes to a moderate- to dark-reddish-brown soil. In most places the Boring is composed of one or two flows. Each flow generally has a rubbly zone at the base and a thick scoria zone at the top. The upper scoria zone commonly is decomposed to red clay. The Boring Lava ranges in thickness from a few feet at the western and southernmost exposures in the area to more than 350 feet near Highland Butte, a center of eruption of lava. Over most of the area the Boring Lava ranges in thickness from about 100 to 250 feet. The Boring Lava overlies, with slight unconformity, the Troutdale Formation and older rocks in the area. The distribution, thickness, and attitude of the lava suggest that the Boring was erupted upon a moderately eroded surface carved into the slightly folded Troutdale Formation. In the northeast corner of the area, the Boring Lava is overlain by the Springwater Formation.

The Boring Lava was erupted from centralized vents, such as Highland Butte, and then flowed radially across the land. Lavas from several vents compose this unit, so that the unit may span a considerable period of time. It is considered to range in age from late Pliocene to late(?) Pleistocene (Trimble, 1963, p. 42).

Several wells in the area tap perched aquifers within the Boring Lava, whereas many others penetrate the lava and obtain water from the underlying Troutdale Formation. The Boring Lava has relatively good vertical permeability and allows much of the infalling precipitation to percolate downward to zones of saturation. Yields of wells (such as 4/3–7J1 and 20D1) that obtain water from the Boring Lava range from about 5 to 20 gpm—adequate for domestic and stock use.

SPRINGWATER FORMATION

Volcanic mudflow deposits that overlie the Boring Lava in the northeast corner of the area were named the Springwater Formation by Trimble (1963). The Springwater Formation underlies about 3 square miles in T. 4 S., R. 4 E. It is composed of volcanic agglomerate and mudflow breccia, most of which has decomposed to a deep-red clay soil strewn with infrequent boulders and cobbles that are more resistant to weathering than is the matrix material. At the margins of the area of exposure, where maximum erosion has occurred, the Springwater Formation is about 30–50 feet thick, whereas near the center of the area of exposure, drillers' logs record a thickness of about 100 feet.

The Springwater Formation appears to lie conformably upon the Boring Lava. Springwater materials were erupted from a vent or vents east of the area and flowed westward down the gentle slopes, probably in the Pleistocene. Springwater materials appear to be only moderately permeable and are not known to yield water to wells. However, the Springwater does allow infiltration of sufficient precipitation so that the underlying Boring Lava contains zones of saturation high above the level of nearby stream channels.

ALLUVIAL DEPOSITS UNDIVIDED

Alluvial deposits that underlie about 5 square miles, mostly in T. 5 S., R. 1 E., contain conglomerate, gravel, sandstone, sand, siltstone, and silt. This unit includes materials of the Troutdale Formation, Willamette Silt, and terrace and alluvial deposits. The undivided alluvial deposits overlie Little Butte Volcanic Series, marine rocks, and the Columbia River Group and provide a thin cover over the older rocks. The coarser materials in this unit yield small quantities of water to wells.

TERRACE ALLUVIUM

Silt, sand, and gravel deposits that underlie terraces adjacent to some of the streams tributary to the Pudding River, as well as the remnants of alluvial fans near the mouths of the canyons of Silver, Abiqua, and Butte Creeks, compose the terrace alluvium unit. Terrace alluvium occurs as isolated patches and stringers and occupies a total of about 6 square miles, mostly in T. 6 S., Rs. 1 W. and 1 E., and about 1 square mile in T. 5 S., R. 2 E. Terrace alluvium consists of bedded and crossbedded clay, silt, sand, and gravel. Some of the beds contain well-sorted materials; others contain poorly sorted materials that range in size from gravel to clay. Deposits that underlie the terraces along the Molalla River and Butte and Abiqua Creeks range in thickness from a few to about 20 feet. Between Butte and Silver Creeks, the thickest remnants of the alluvial fan range from 60 to 100 feet.

Materials of the terrace alluvium overlie older geologic units where stream-cut terrace surfaces have been re-covered by a veneer of the alluvium. There are at least two terrace levels, standing about 50 and 100 feet above the present-day flood plain of the Molalla River and Butte Creek. The terrace alluvium is believed by the author to be largely of Pleistocene age. At places, the base of the terrace alluvium may contain a thin saturated zone perched upon poorly permeable underlying rocks and may yield small quantities of water to wells. The alluvial-fan remnants between Silver and Butte Creeks probably will yield moderate quantities of water to wells.

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WILLAMETTE SILT

The thick sequence of fine-grained sand and silt beds that overlie Troutdale Formation and older geologic units in the Willamette Valley was named the Willamette Silt by Allison (1953, p. 12). Allison applied this name to silts that occur in the Albany quadrangle south of the Molalla-Salem Slope area. The name has been applied by Price (1967, p. 27) to similar deposits in the French Prairie area, which is west of, and adjacent to, the Molalla-Salem Slope area.

The Willamette Silt underlies about 128 square miles, mostly in the western part of the report area below the 325-foot contour level. It is exposed in erosional scarps along reaches of the Molalla and Pudding Rivers north of the latitude of Mount Angel and along Bear, Rock, and Butte Creeks.

The Willamette Silt is composed mostly of alternating 8- to 12-inch-thick layers of sand and silt. At places, thin clay layers occur in the unit. In outcrop, the silt and sand units range from yellowish gray to pale yellowish brown. Newly exposed clay layers are grayish blue to dusky blue. Drillers often report Willamette Silt materials as yellow clay, yellow silt, yellow sandy clay, blue clay, and blue silty clay; some log the entire thickness of the Willamette Silt as silty or sandy clay, yellow and blue. A comprehensive discussion and description of the mode of occurrence and textural composition and variations of the Willamette Silt is given by Glenn (1965). Data presented by Glenn (1965, p. 87–126) show that individual beds within the Willamette Silt range from clay to coarse sand in texture; that some beds are normally graded, reverse graded, and double graded; and that the coarser grained beds are more evenly or better graded than are the finer grained beds.

The Willamette Silt ranges in thickness from a few feet at the eastern and southern borders of the area to as much as 100 feet in a few areas near the western border of the area. Plate 2 shows the approximate thickness of the Willamette Silt in the study area. The silt is separated from older underlying units by an old soil zone, or rests on a cleanly scoured surface, and is overlain by Holocene stream-valley alluvium at a few places where streams are entrenched into, but not through, the Willamette Silt.

When water was ponded in the Willamette Valley, the Willamette Silt was deposited over all rocks in the valley up to an altitude of at least 350 feet. The ponding was probably caused by blockage or damming of the Willamette River near its mouth because of aggradation of the Columbia River in the Portland area, much as described in part by Glenn (1965) and as suggested, but discounted, by Treasher (1942).

According to Glenn (1965), the Willamette Silt is younger than about 34,000 years B.P. (before present) and older than about 19,000 years B.P., on the basis of carbon-14 dating of carbonaceous materials that occur stratigraphically below and above the silt.

Although the Willamette Silt, largely because of its small grain size and rather poor sorting, is poorly permeable in comparison to the coarser and better sorted alluvial units, it is important to the ground-water resources of the Willamette Valley plain because of its capacity to transmit infalling precipitation to the underlying aquifers. The Willamette Silt has relatively high porosity. According to data presented by Price (1967), the porosity of five samples of the Willamette Silt ranged from about 41 to 45 percent, although the specific yield, or the ratio of the volume of water that will drain from a rock material to the volume of the rock, averaged about 27 percent for these samples. The lack of well-developed drainage systems on the valley plain, such as at Howell Prairie in the southern part of the area and at Marks Prairie in the northern part, indicates that much of the 40-inch average annual precipitation that is not evaporated or transpired by vegetation must infiltrate the Willamette Silt.

Many of the earliest wells dug in the valley-plain area were completed in the Willamette Silt and provided quantities of water adequate for stock and domestic uses. Some of those wells, such as 6/1-7M1, are still in use, but most modern wells are completed in the underlying Troutdale Formation, which affords the greater yields required by most modern-day water users.

LANDSLIDE DEPOSITS

Several large and small tracts within the Molalla-Salem Slope area are underlain by large blocks or chaotic piles of various kinds of rock that compose the landslide deposits. These materials underlie about 8 square miles, 6 of which are in T. 7 S., Rs. 1 and 2 E. The landslides have developed in areas that are underlain by marine rocks or the Troutdale Formation and where streams have eroded deep canyons, removed support, and thus provided a space for the less competent beds to slide or slump toward.

Landslide debris resulting from failure of the Troutdale Formation is composed mostly of displaced large blocks of tuffaceous sandstone, which at places is mantled by disjointed blocks of the Boring Lava. Debris resulting from failure of the marine rocks is composed mostly of chaotic piles and hummocks of tuffaceous sandstone and siltstone, generally partly mantled by, and intercalated with, disjointed blocks or large segments of basaltic lava from the Columbia River Group.

Although landslide deposits rarely yield usable quantities of water to wells, they trap and release a considerable quantity of water to perennial springs. Many of the larger landslide areas are characterized by numerous small lakes, swamps, and springs issuing from the bases of various slump blocks.

VALLEY ALLUVIUM

Alluvial materials that underlie flood plains of the streams compose the valley alluvium. At one place or another, the alluvium overlies all the older units in the area. Materials of this unit underlie about 50 square miles. The two largest areas are 7 square miles along the Molalla River valley in the northern part of the area and 28 square miles of the Santiam alluvial fan in the southern part. Coarser gravel beds within the Santiam alluvial fan constitute a major aquifer in the area. The driller's log of well 8/2W–33K1 in table 11 shows the kinds of materials that typically compose this body of alluvial materials. The remaining 15 square miles are made up of flood-plain deposits of Pudding River and Silver, Abiqua, Butte, and Rock Creeks.

Particles in alluvial deposits along Mill, Silver, Abiqua, and Butte Creeks and the Molalla River commonly range from sand to cobble size, whereas the deposits along most of the valley-plain reaches of the Pudding River, Rock Creek, and smaller streams range from sand to clay size.

The deposits are thinnest in the valleys of the smaller streams, such as the headwater tributaries of the Pudding River, and thicker (as much as 30 ft) in the valleys of the larger streams, such as the Molalla River and Silver and Abiqua Creeks. The alluvium beneath the Santiam alluvial fan is a hundred feet or more thick.

Where the coarser materials that compose the valley alluvium are saturated, they yield moderate quantities of water to wells.

GROUND WATER

SOURCE AND MOVEMENT OF GROUND WATER

All water that occurs in a saturated zone below land surface is called ground water. The source of ground water in the study area is precipitation. Part of the precipitation runs off in streams, part is stored for a time in lakes and reservoirs, part is evaporated back to the atmosphere, and part is absorbed by the soil and rock materials. Of the latter part, some water is held in the soil zone where it satisfies soil-moisture requirements and is used by growing plants, and some percolates to a saturated zone. The water in a saturated zone moves by the force of gravity downgradient to points of discharge, such as at springs, seeps along stream channels, or wells. Saturated permeable rock materials that yield usable quantities of water to wells are called aquifers.

RECHARGE

The aquifers of the Molalla-Salem Slope area are recharged seasonally by precipitation. Winter and spring, when most precipitation occurs, are seasons of greatest potential and actual recharge (fig. 3). Most aquifers beneath the valley plain receive recharge from precipitation directly on the plain. Deeper aquifers (especially those of the Troutdale Formation in the northern part of the area and those of the Columbia River Group) probably receive some of their recharge at outcrop areas in the transition zone or the foothills of the Cascade Range. In addition, alluvial aquifers receive some recharge from streams during periods when the water table is low in the flood-plain areas of the Molalla River and Mill Creek. However, the generalized water-table map of the area (pl. 1) indicates that adjacent to most stream courses, the water table is at a higher altitude than the stream surface. Consequently, most streams gain water from, rather than lose water to, the aquifers.

Shallow aquifers beneath the transition zone are recharged by precipitation which is absorbed by the soil and percolates to saturated zones. The deeper aquifers, especially those of the Columbia River Group, are recharged by precipitation in outcrop areas in the foothills of the Cascade Range.

DISCHARGE

Ground water is discharged from aquifers in the Molalla-Salem Slope area at springs and seeps, by evapotranspiration, and through wells. In the valley-plain area, ground water is discharged mainly by springs and seeps adjacent to or in stream channels, by evapotranspiration in areas where the water table is near the surface, and by pumping from wells. Ground water discharged through springs and seeps supports the base flows of the streams that head in the valley plain and strengthens the flow of streams that head in adjacent areas.

In the transition zone, most of the discharge is by evapotranspiration or seepage from springs and seeps in shallow perched-water bodies and by pumping from wells.

Evapotranspiration and flow from seeps and springs that issue from perched ground-water bodies are the principal modes of discharge in the foothills of the Cascade Range. The springs and seeps supply base flow to the streams that drain this area.

MODE OF OCCURRENCE OF GROUND WATER

UNCONFINED

The upper surface of a body of unconfined ground water is free to fluctuate in response to additions made to (recharge) and withdrawals made from (discharge) the ground-water body or reservoir. When recharge is added to an unconfined ground-water body in excess of concurrent discharge, the upper surface of the body, called the water table, will rise (as noted by a rise in the water level in a well that taps the ground-water body). Conversely, the water table will fall when discharge from the ground-water body exceeds recharge. Unconfined ground water occurs commonly in shallow alluvial aquifers beneath the flood plains of the Molalla River and Mill Creek, beneath the Santiam alluvial fan, and at many places in the shallowest aquifers beneath the valley plain, as well as at shallow depths in some of the more permeable rocks that underlie the transition zone and foothills area.

CONFINED

Confined ground water occurs where an aquifer is overlain by materials less permeable than the aquifer, so that the water is under pressure and will rise above the level at which it is first found when a well penetrates the aquifer. When recharge is added to a confined aquifer, the pressure increases throughout the aquifer. Conversely, when water is discharged from a confined aquifer, the pressure decreases throughout the aquifer. The fluctuations of water level within a well that taps a confined aquifer reflect pressure changes within the aquifer. Confined ground water occurs throughout the area in the deeper alluvial, sedimentary, and volcanic aquifers.

PERCHED

Where ground water occupies an aquifer above the regional water table,[2] the water is referred to as "perched." In many places in the foothills of the Cascade Range, one or several successively perched-water bodies, which may be either confined or unconfined, have been penetrated by wells. The perched-water bodies generally occupy aquifers that have both limited volumes of water in storage and limited recharge and yield small to moderate quantities of water to wells. In many places where the regional water table may be as much as 500–

[2] The regional water table defines a surface below which all permeable earth materials are saturated.

1,000 feet below land surface, perched-water bodies afford moderate supplies of water to relatively shallow wells.

WATER-LEVEL FLUCTUATIONS

Water-table fluctuations are determined by periodically measuring water levels in wells that extend into a ground-water reservoir. Water levels fluctuate seasonally and from year to year in response to natural as well as man-induced variations in recharge and discharge. In most wells in the Molalla-Salem Slope area, water levels are highest following periods of greatest precipitation and greatest recharge and are lowest following periods of least precipitation and recharge. Seasonal water-level fluctuations follow much the same pattern as shown by the graph of average monthly precipitation in figure 3.

SEASONAL FLUCTUATIONS

During this study, water levels were measured monthly in 34 wells in the period from the summer of 1962 to the fall of 1964, so that 2 full years of record were obtained at most wells. In that period, high-water levels occurred in wells during the months of January to June, and low levels occurred during the months of July to October. The following table gives the monthly distribution of highest and lowest water levels for the 2-year period.

TABLE 3.—*Monthly distribution of highest and lowest water levels in observation wells for the 1963–64 period*

1963		1964	
Month	Number of wells	Month	Number of wells
High-water levels		**High-water levels**	
March	1	January	5
April	20	February	12
May	11	March	7
June	2	April	4
		May	1
Low-water levels		**Low-water levels**	
July	1	August	18
August	12	September	0
September	11	October	10
October	7		

Data in the table show that the highest levels in all 34 wells were reached 1–2 months sooner in 1964 than in 1963. The early rise in 1964 was due largely to greater-than-average precipitation on the area in December 1963 and January 1964. Low-water levels occurred about the same times in both years.

Annual water-level fluctuations ranged in amplitude from 3 to 28 feet, and average amplitude of annual fluctuations in all wells was 12.3 feet. Amplitude of annual fluctuations in 17 wells finished in the Troutdale Formation ranged from 3 to 28 feet and averaged 13.4 feet; six wells finished in the basalt of the Columbia River Group ranged from 4 to 25 feet and averaged 11 feet (four of the six wells averaged 5 ft); and three wells in the alluvium of the Santiam alluvial fan ranged from 3 to 6 feet and averaged 4 feet.

Figures 6–10 are representative hydrographs of wells measured during the study. The hydrographs show that water levels in most wells recovered to equivalent, or nearly equivalent, levels in 1964 following the 1963 summer pumping season.

LONG-TERM FLUCTUATIONS

In many areas, seasonal fluctuations of water levels in wells are in effect "superimposed" upon long-term water-level trends that generally parallel, and perhaps lag a few or several years behind, a trend defined by a cumulative departure from long-term average annual precipitation (fig. 4). Although there may be some correlation between the 1928–67 hydrograph for well 6/1–7M1—which taps a semiperched shallow Willamette Silt aquifer (fig. 11)—and the cumulative-departure curve in figure 4, it is not apparent. Comparison of long-term water-level fluctuations and long-term weather records suggests that even in, or following, years of below-normal precipitation, sufficient recharge is absorbed to refill nearly, if not completely, ground-water reservoirs in the valley plain.

Another cause of long-term trends of water-level fluctuations is removal of water from storage by pumping more water than is naturally recharged. Bedrock aquifers, such as Columbia River basalts, may yield water to a well or wells at faster rates than those at which they can accept natural recharge. This condition may be reflected in the gradual, but steady, declines of water levels in irrigation wells 8/2W–11P2 and 8/1W–35C1 throughout the period 1962–66. (See fig. 7.) However, the below-average precipitation for the 1962–66 period (Weather Bureau data, not in this report) may be a contributing factor.

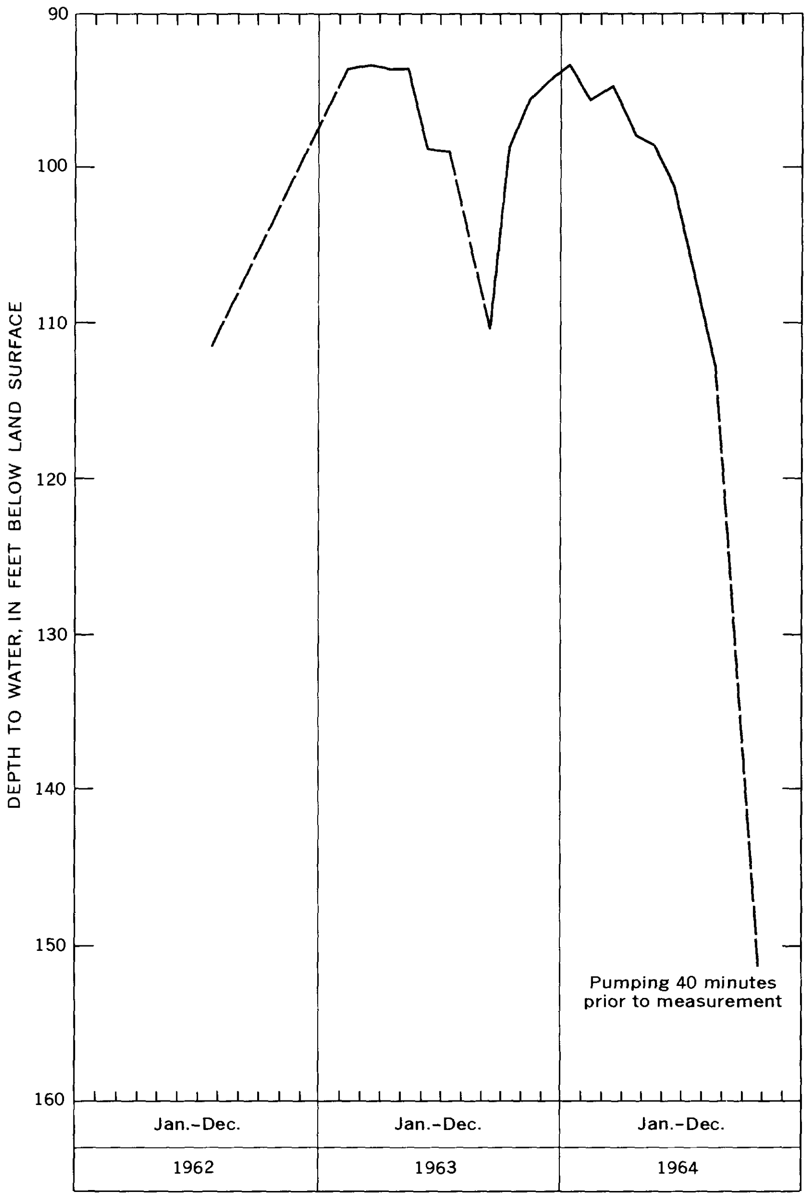

FIGURE 6.—Hydrograph of well 7/1W-25B1, in marine sandstone. Range of annual fluctuation is about 19 feet.

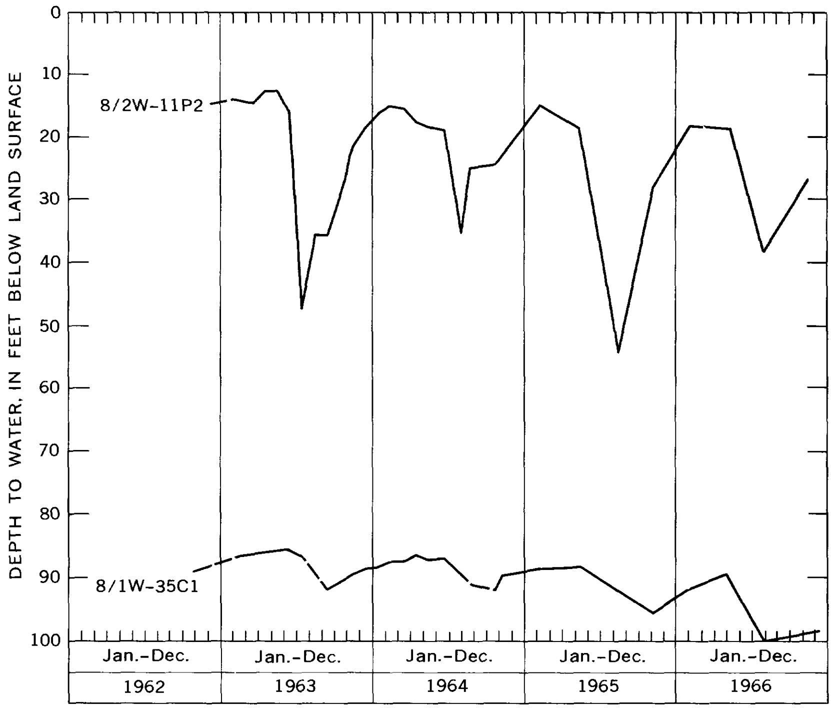

FIGURE 7.—Hydrographs of two irrigation wells in basalt of the Columbia River Group. Range of annual fluctuation is about 30 feet in well 8/2W-11P2 and about 6 feet in well 8/1W-35C1. Note the gradual year-to-year decline in water levels in both wells.

OCCURRENCE IN THE FOOTHILLS AREA

Ground water occurs under perched, confined, and unconfined conditions in the foothills of the Cascade Range. Many wells in that area draw water from aquifers perched above the regional water table, whereas only a few wells tap water-table and confined aquifers. At most places in the foothills, supplies of water adequate for stock and domestic uses can be obtained from wells less than 400 feet deep. At a few places, such as near the edges of the high westward-trending interfluvial ridges, the rocks have been drained to near the level of the stream in the adjacent valley, so that the water table probably

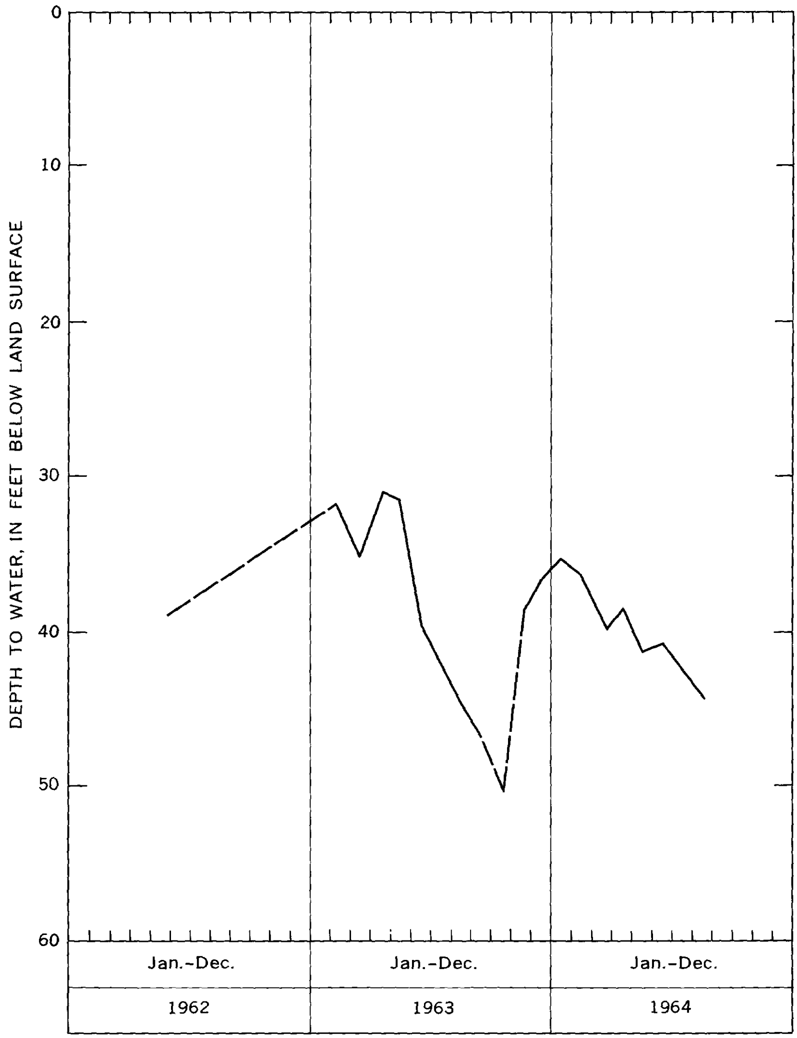

FIGURE 8.—Hydrograph of well 5/3-19Q1, in the Sardine Formation.

is as much as 800–1,000 feet deep. At other places, the geologic units at depth are poorly permeable and yield little water to wells. In the southern part of the foothills, several wells yield volumes of water adequate for irrigation and public uses.

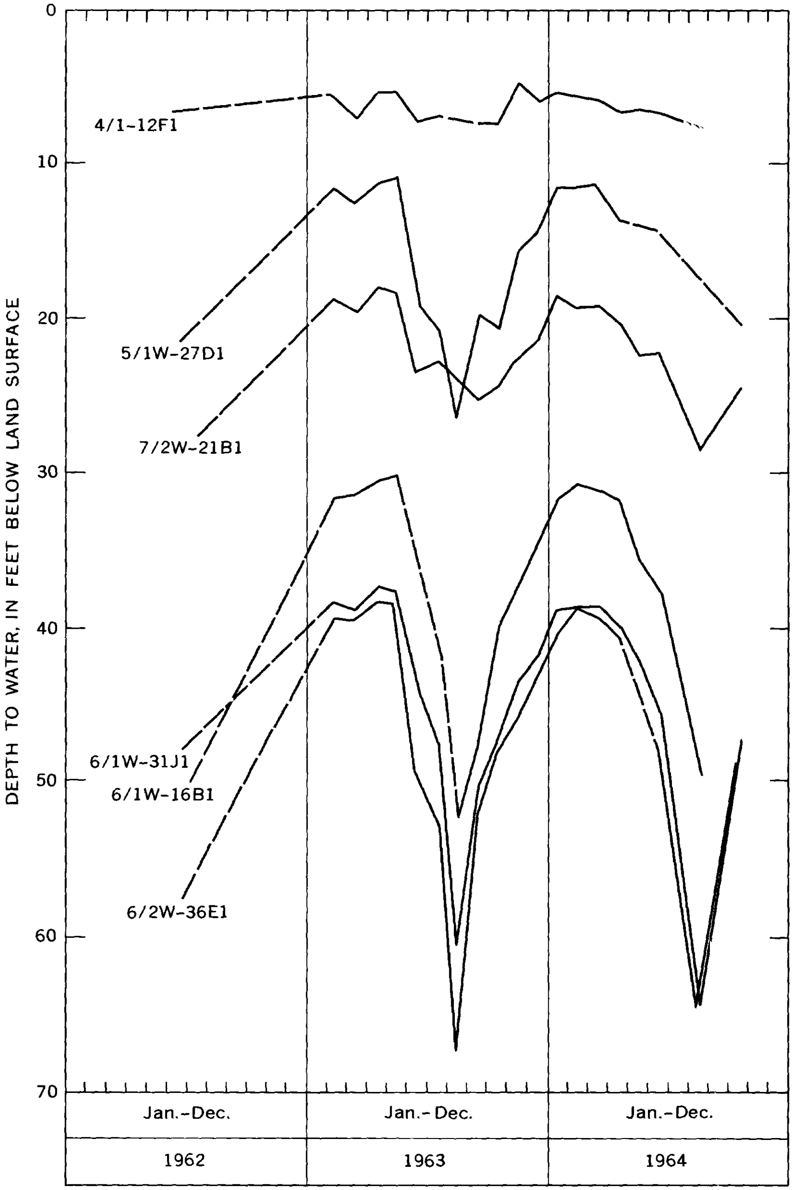

FIGURE 9.—Hydrographs of six wells in the Troutdale Formation. Annual fluctuations range from about 3 feet in well 4/1-12F1 to about 28 feet in well 6/2W-36E1.

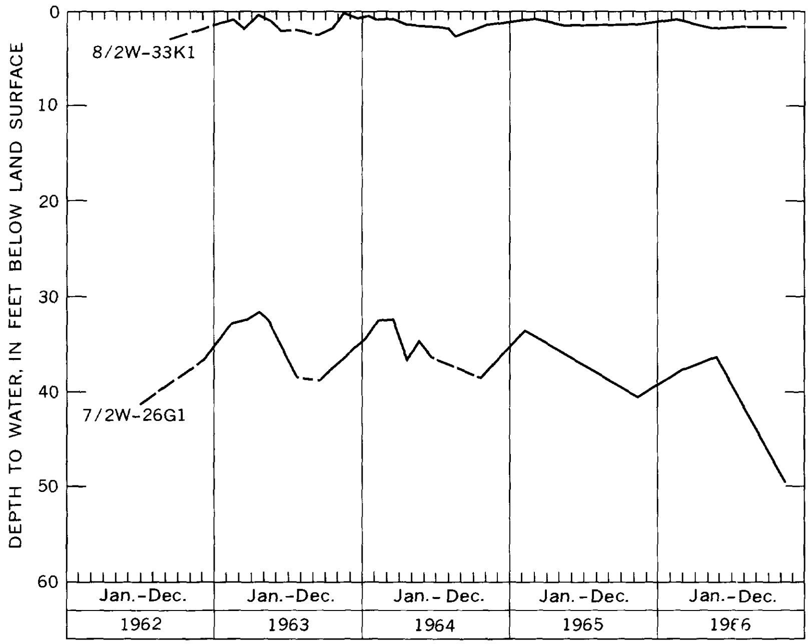

FIGURE 10.—Hydrographs of well 7/2W-26G1, finished in both the Troutdale Formation and basalt of the Columbia River Group, and well 8/2W-33K1 in the alluvium of the Santiam alluvial fan.

All major geologic units in the foothills have been tapped by wells. Of the 122 wells in the foothills for which information was compiled for this report, 60 were completed in basalt of the Columbia River Group, 29 in the marine rocks, 18 in the Sardine Formation, nine in the Little Butte Volcanic Series, and six in the Troutdale Formation. Records of some of these, as well as other wells in the Molalla-Salem Slope area, are given in table 10, and drillers' logs are given in table 11. Records of a much larger number of wells in the area are given in the basic-data report by Hampton (1963).

The water-yielding capacities of the various geologic units in terms of range of yields to wells, average yields of wells, range of specific capacities (ratio of yield of well in gallons per minute to drawdown while pumping at stated yield), and average specific capacities of wells, are presented in table 4.

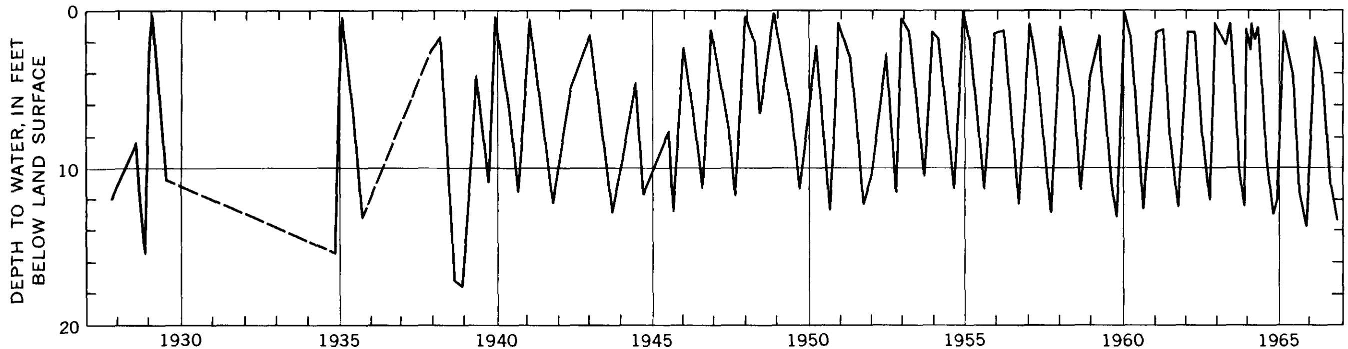

Figure 11.—Hydrograph of well 6/1–7M1, in the Willamette Silt, for the period 1928–67.

TABLE 4.—*Yields and specific capacities of wells in the foothills area*

Geologic unit	Number of wells	Yield (gpm)		Specific capacity (gpm per ft)	
		Range	Average	Range	Average
Columbia River Group	60	2–1, 000	84	0. 01–22	3. 8
Marine rocks	29	[1] 2–50	18	. 01–6	. 84
Sardine Formation:					
Undivided and pyroxene andesite flows	9	2–22	12	. 02–2. 2	. 51
Volcanic mudflow breccia	3	2–40	21	. 03–1. 3	. 52
Pumice tuff	6	12–30	19	. 12–2. 1	. 66
Troutdale Formation	6	10–22	19	. 02–2. 5	. 75
Little Butte Volcanic Series:					
Basalt and breccia	6	15–100	50	. 18–4	1. 4
Tuff and volcanic breccia	3	13–45	23	. 11–1. 3	. 54

[1] 1 well in breccia reported to yield 580 gpm with 147 ft of drawdown.

Data in table 4 indicate that in the foothills the Columbia River basalts contain the most permeable aquifers, followed by basalt and breccia of the Little Butte Volcanic Series, and the marine rocks. Water occurs mainly in permeable rubbly zones in the Columbia River basalt and Little Butte Volcanic Series, so that these rocks are capable of yielding large quantities of water to wells that tap such zones. However, the total quantity of recoverable water stored in the rock unit below a water table may be as little as 1–2 percent of the volume of the saturated rock. Water occurs in many moderately to poorly permeable zones in the marine rocks (sandstone and shale) and Troutdale Formation, so that, in general, these rocks are capable of yielding only small to moderate quantities of water to wells. However, the quantity of recoverable water that these rocks store below a water table may be as much as 10 percent of the volume of the saturated rock. In the area around, and adjacent to, Sublimity, in the southern foothills, several large-yield irrigation and public-supply wells draw water from aquifers in the Columbia River basalt. Hydrographs of water levels in some of these wells (fig. 7) show gradual declines in water levels for the period 1963–66. Careful monitoring of water levels in wells will be necessary to determine if present withdrawal rates exceed natural recharge. Because aquifers in the Sardine and Troutdale Formations and in the marine rocks beneath the foothills area yield water slowly to wells, there is little possibility of their being dewatered by overpumping either regionally or locally. Aquifers in those formations could supply small quantities of water to many additional wells in the foothills.

OCCURRENCE IN THE TRANSITION ZONE

Ground water occurs under perched, confined, and water-table conditions in the transition zone. In region A, north of Milk Creek (fig. 5), many wells tap perched aquifers capable of yielding small to moderate quantities of water, whereas a few wells tap unconfined or confined aquifers capable of yielding moderate quantities of water. Most wells in regions B and C tap water-table aquifers capable of yielding small to large quantities of water. In region D, most wells tap water-table aquifers capable of yielding large quantities of water, whereas in region E, most wells tap perched-water bodies capable of yielding only small quantities of water.

The Boring Lava and Troutdale Formation are the principal water-bearing units in region A. In region B, the Troutdale Formation is the principal water-bearing unit, although basalts of the Columbia River Group and the Little Butte Volcanic Series supply moderate quantities of water to a few wells, and the marine rocks supply small to moderate quantities of water to a few wells. In region C, the Troutdale Formation is the principal water-bearing unit and supplies small to large quantities of water to wells, as do the Columbia River basalts, which are of secondary importance. Aquifers in the older alluvial deposits of the Santiam alluvial fan supply moderate to large quantities of water to wells in region D, whereas the Columbia River basalts and the marine rocks supply small to moderate quantities of water to wells in region E.

Data on depth of wells, depth to the top of the water-bearing unit, depth to the first aquifer in that unit, yield, and specific capacity of wells in the ground-water regions of the transition zone are presented in table 5.

Most of the wells represented by data in table 5 were constructed so as to provide domestic water supplies; therefore, the average yield given is not indicative of the quantity of water available from a well constructed to obtain maximum yield. The higher values of yield for wells in regions B–D are indicative of the possible yields of rock units in those areas. Beneath those areas the rock units that are capable of yielding large quantities of water to wells are alluvium of the Santiam fan, the Troutdale Formation, and Columbia River basalts.

Because regions B–D are for the most part underlain by water-bearing units having moderate to large storage capacities, considerable additional development of ground water can be accommodated. In general, the materials that underlie regions A and E are less permeable and have smaller storage capacity than do materials underlying other regions. However, no indications of overdevelopment, such as declining water levels, have been noted in regions A and E.

TABLE 5.—*Summary of data on wells in the transition zone*

Unit [1]	Number of wells	Depth (feet)		Yield (gpm)		Specific capacity (gpm per ft)		Depth to top water-bearing unit (feet)		Depth to aquifer (feet)	
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Region A											
QTb	14	68–195	113	6– 40	22	0.08– 7.0	1.17	0– 67	10	30–176	71
Tt	29	70–437	164	7– 60	23	.10– 9.0	.97	0–235	34	36–239	137
Region B											
Tt	21	40–520	298	8–450	56.0	0.31–10.0	3.33	0– 78	11	41–245	85
Tcr	3	175–218	201	15– 50	31.6	.10– .5	.36	67–234	143	67–262	152
Tm	9	77–299	166	6– 50	23.0	.05– 2.3	.82	20–115	28	15–179	101
Tlb	6	90–428	239	9–110	58.0	.06– 2.5	.83	30–226	109	30–357	170
Region C											
Tt	25	62–225	138	14–350	101	0.19–4.50	1.73	2– 52	30	1[illegible]–149	70
Tcr	8	72–631	298	7–650	187	.10–3.18	1.66	19–450	186	74–600	256
Region D											
Alluv	6	21–100	56	16–500	102	0.83–7.81	3.37	0– 4	1	8– 49	28
Region E											
Tcr	1	110	--------	20	--------	4.00	--------	0	--------	80	-------
Tm	2	117–123	120	10– 11	10	.15	--------	0– 5	2.5	5[illegible]–112	81

[1] Alluv, alluvium of Santiam fan; QTb, Boring Lava; Tt, Troutdale Formation; Tcr, basalt of Columbia River Group; Tm, marine rocks; Tlb, Little Butte Volcanic Series.

OCCURRENCE IN THE VALLEY-PLAIN AREA

The valley-plain area is underlain, in general, from the surface down, by Willamette Silt, Troutdale Formation, basalt flows of the Columbia River Group, and marine rocks. Ground water occurs in the Willamette Silt under semiperched conditions, at places in the Troutdale variously under unconfined or confined conditions, and generally under confined conditions in the Columbia River basalts and the marine rocks.

The principal water-bearing unit beneath the valley plain is the Troutdale Formation. The main water-yielding zones in the Troutdale Formation are layers of permeable coarse sand, sand and gravel, or gravel that occur throughout the unit. Thus, the capacity of the Troutdale to yield water to wells can be approximated by the proportion of permeable gravel to less permeable finer materials at any given place.

Figure 12 shows the percentage of saturated gravel in the zone from land surface to a depth of 50 feet beneath the valley-plain and

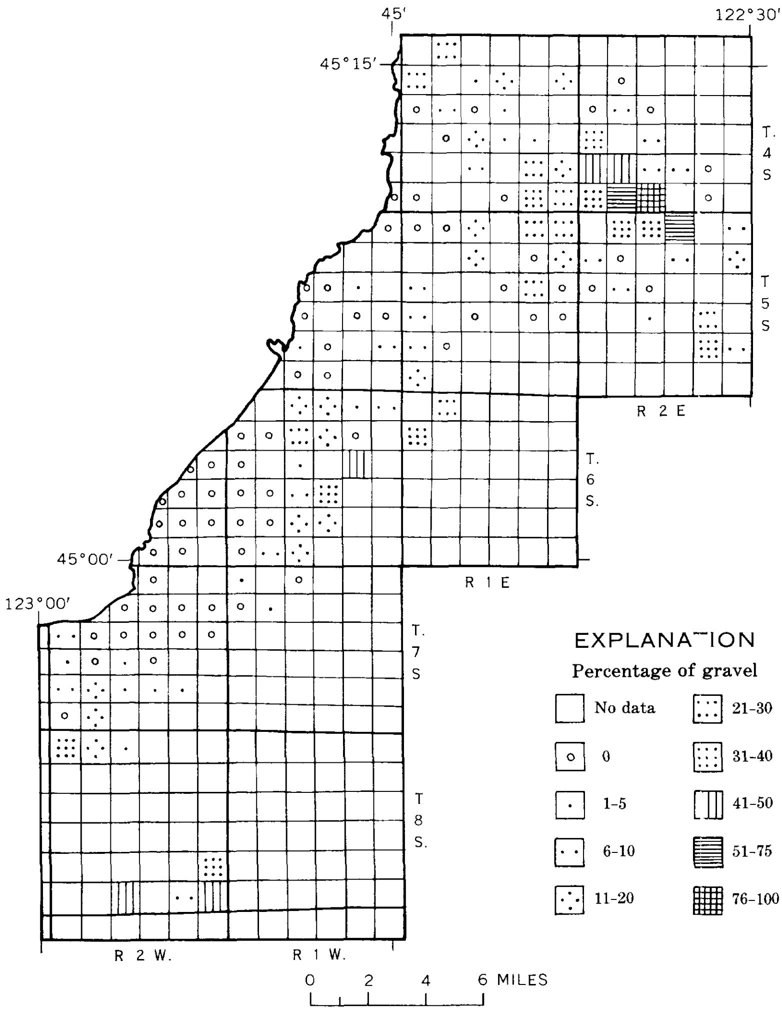

FIGURE 12.—Percentage of gravel below water table, 0–50 feet below land surface. (Data based on footage reported in available drillers' logs and averaged by sections.)

transition zones. Because in most of the valley plain the Willamette Silt is more than 50 feet thick, there are few areas where gravel occurs in the 0- to 50-foot zone. Figure 13 shows the percentage of saturated gravel in the zone 50–100 feet below land surface, and figure 14 shows the percentage of saturated gravel in the zone 0–200 feet below land surface beneath the valley-plain and transition zones. Wl ere the

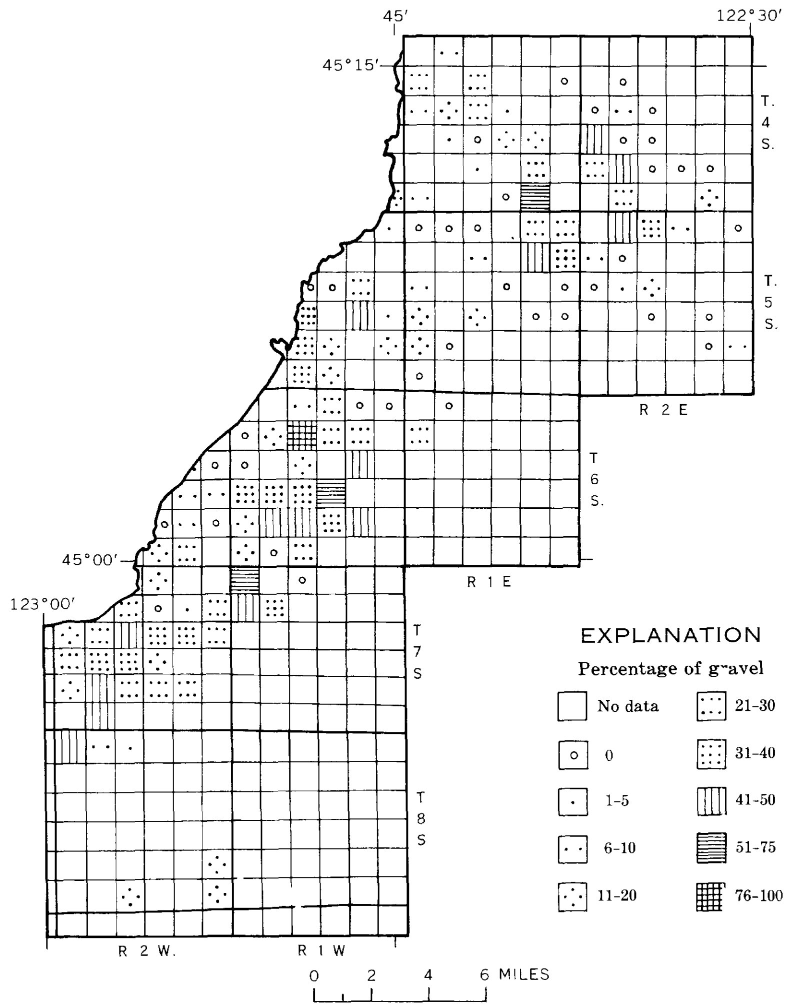

FIGURE 13.—Percentage of gravel below water table, 50–100 feet below land surface. (Data based on footage reported in available drillers' logs and averaged by sections.)

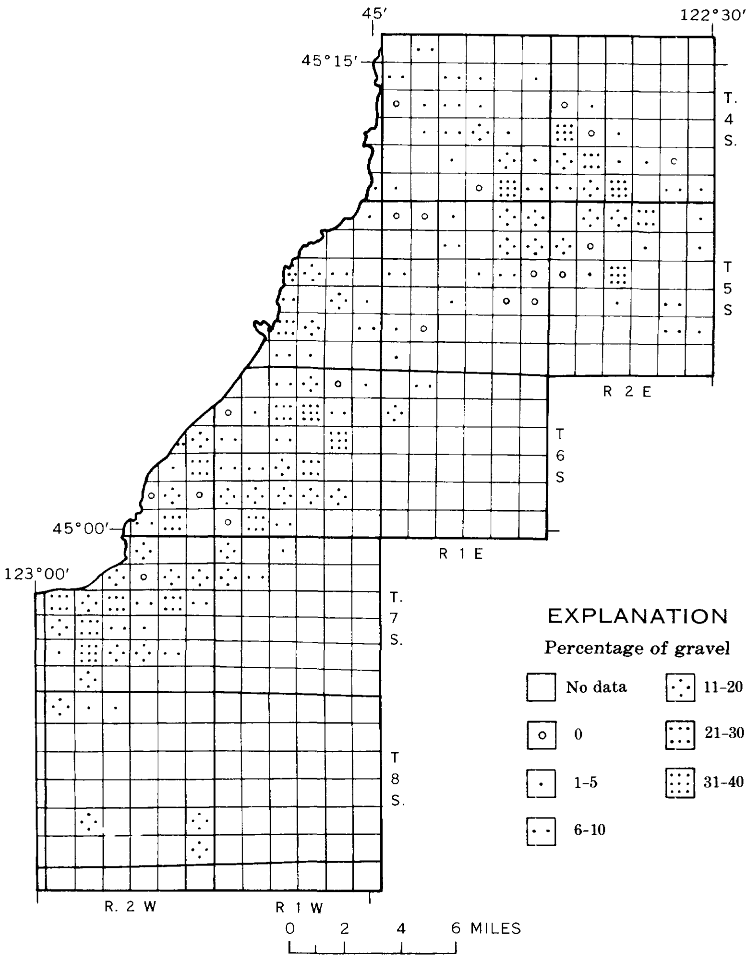

FIGURE 14.—Percentage of gravel below water table, 0–200 feet below land surface. (Data based on footage reported in available drillers' logs and averaged by sections.)

Troutdale aquifers contain the highest percentages of sand and gravel, they are capable of yielding the largest volumes of water to wells.

The depth to the top of the Troutdale beneath the valley plain and parts of the transition zone is shown on plate 2, a map showing the thickness of both the Willamette Silt and the Troutdale Formation.

The depth, yield, and specific capacity of irrigation and public-supply wells in parts of nine townships in the valley-plain area are presented in table 6.

Data in table 6 show that the highest average yields and specific capacities are from wells in Tps. 6 and 7 S., Rs. 1 and 2 W., areas that are underlain by the highest percentages of gravel in the 50- to 100- and the 0- to 200-foot zones. The depths of wells completed in the Troutdale Formation in the above four townships average about 150 feet.

Hydrographs of wells in the area that tap the Troutdale show that even in heavily pumped areas, water levels recover fully following the pumping season each year—one indication that additional water could be pumped from Troutdale aquifers each year without causing overdraft. Data in this report on present use of water and quantities available in the valley-plain area also indicate that annual pumpage from the Troutdale aquifers could be increased severalfold without causing overdraft.

TABLE 6.—*Yields and specific capacities of irrigation and public-supply wells in the valley-plain area*

Location	Number of wells	Depth (feet)		Yield (gpm)		Specific capacity (gpm per ft)	
		Range	Average	Range	Average	Range	Average
Wells in Troutdale Formation							
T. 4 S., R. 1 E	12	65–235	117	105–320	181	1.61–32	3.27
T. 4 S., R. 2 E	1		180		120		1.84
T. 5 S., R. 1 E	7	130–435	220	96–350	207	1–5.17	2.56
T. 5 S., R. 1 W	18	85–177	129	40–500	205	.80–12.28	3.80
T. 6 S., R. 1 W	6	100–161	130	55–750	430	1.10–18.29	9.21
T. 6 S., R. 2 W	9	123–204	168	400–700	561	6.33–16.66	10.44
T. 7 S., R. 1 W	2	119–140	129	275–400	337	7.84–11.00	9.42
T. 7 S., R. 2 W	33	68–220	149	30–800	328	.79–25	6.37
T. 8 S., R. 2 W	2	80–166	123	55–100	77	1–6.87	3.93
Total or average	90		149		297		5.71
Wells in basalt of the Columbia River Group							
Tps. 5–6 S., R. 1 W	6	243–500	327	90–300	193	0.66–3.60	2.65

CHEMICAL QUALITY OF GROUND WATER

Except for saline connate water derived from the marine rocks at places, the quality of the ground water in the Molalla-Salem Slope area is generally excellent. Most water sampled was potable and within the desirable ranges of hardness and salinity for public and most industrial uses. Samples of water from 18 wells and one spring were analyzed by the U.S. Geological Survey. A chemical analysis of water from one well was obtained from another source. These 20 analyses are given in table 7.

HARDNESS

Certain constituents in water, especially calcium and magnesium, cause hardness, which affects the use of detergents and dyestuffs, causes the deposition of scale when the water is heated, and consumes soap in laundry operations. Water has been classified by the Geological Survey according to the following scale of hardness:

Hardness as $CaCO_3$ (milligrams per liter)	*Class*
0–60	Soft
61–120	Moderately hard
121–200	Hard
More than 200	Very hard

The hardness of potable water sampled in the area ranged from a low of 22 mg/l (milligrams per liter) to a high of 124 mg/l. The average hardness of water from six wells in the Troutdale Formation was 82 mg/l, and that from four wells in the Columbia River basalts and marine rocks was 62 mg/l. The hardness of the brackish to saline water ranged from 292 to 5,760 mg/l. Although this water is pumped from wells that tap aquifers in Columbia River basalts, marine rocks, and Little Butte Volcanic Series, it is derived from connate water in the marine rocks.

CHLORIDE, SULFATE, AND NITRATE

The chloride content of potable water sampled ranged from 1.0 to 172 mg/l. Water from the Troutdale Formation, Columbia River basalts, and the marine rocks had average chloride contents of 3.30, 30, and 45 mg/l, respectively. Chloride content of saline water ranged from 585 to 6,190 mg/l.

Sulfate content of all water sampled ranged from 0.0 to 24 mg/l and averaged 6.1 mg/l. Samples of water from the Troutdale Formation, Columbia River basalts, and marine rocks averaged 0.7, 5.6, and 12.7 mg/l, respectively.

Nitrate concentrations in all water sampled ranged from 0 to 25 mg/l and averaged about 2.0 mg/l. The highest nitrate concentrations were in water from marine rocks.

MINOR CONSTITUENTS

PHOSPHATE

Phosphate, generally occurring in small concentrations, is a natural constituent in most water. The presence of more than 0.1 mg/l in areas not known to be underlain by phosphate rocks is sometimes construed to indicate the presence of detergents or other man-generated waste materials in the water. In the Molalla-Salem Slope area, depth of aquifers and type of well construction minimize the possibility that phosphate in the water is derived from surface contamination. (See table 7.)

Phosphate concentrations in 17 samples ranged from 0.01 to 1.5 mg/l and averaged 0.33 mg/l. Water from the Troutdale Formation contained the highest average concentration of phosphate, 0.65 mg/l. Water from the Columbia River basalts averaged 0.24 mg/l, and that from the marine rocks averaged 0.12 mg/l.

BORON

A small amount of boron is required for plant growth; however, a slightly larger amount is harmful to many plants. According to Wilcox (1948), a concentration of less than 0.33 mg/l is excellent for sensitive plants, whereas a concentration exceeding 3.75 mg/l is unsuitable for even the most boron-tolerant plants.

In the 18 samples analyzed for boron, concentrations ranged from 0.00 to 0.89 mg/l. Thus, most water analyzed was suitable for even the most boron-sensitive plants.

FLUORIDE

A concentration of about 1.0 mg/l of fluoride in drinking water is considered beneficial to children's teeth. Because concentrations of more than about 1.5 mg/l may cause mottling of tooth enamel, the U.S. Public Health Service (1962, p. 8) has recommended 1.3 mg/l as the maximum limit of fluoride in drinking water for climates similar to those of this area.

Fluoride concentrations in all water analyzed ranged from 0.0 to 0.7 mg/l and averaged about 0.1 mg/l.

IRON AND MANGANESE

A concentration limit of 0.3 mg/l of iron is suggested for water for domestic use. Water containing greater concentrations of iron or manganese may stain plumbing fixtures and laundry, thus making such water undesirable unless these constituents are removed. The combined iron and manganese concentrations in potable water analyzed ranged from 0.01 to 4.2 mg/l. Water from the Troutdale Formation ranged from 0.19 to 2.2 mg/l and averaged 0.86 mg/l. That from the Columbia River basalt ranged from 0.03 to 1.1 mg/l and averaged 0.72 mg/l, and that from the marine rocks ranged from 0.06 to 4.2 mg/l and averaged 1.12 mg/l. Of the 19 water samples, 10 had more than the recommended amount, suggesting that excessive iron is a problem in many well supplies.

TABLE 7.—*Chemical analyses of ground*

[Analyses by U.S. Geological

Geologic unit [1]	No. of well or spring	Depth of water-bearing zone(s) (feet)	Date of collection	Temperature		Milligrams per liter						
				°C	°F	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
Tt	4/1W-36R1	126–129	6- 6-62	13	55	42	2.2	31	10	7.6	2.5	164
Tt	4/1-12F1	285–293	6-11-62	14	57	48	.50	20	9.0	25	2.4	166
Tt	4/2-5Q1	115–122	6-11-62	13	55	25	1.2	4.0	3.0	5.1	.4	40
QTb	4/3-7J1	113	6- 6-62	12	54	29	.01	7.0	3.5	4.0	.4	47
Tcr	5/1-25G1	325–340	7-26-62	16	60	43	1.1	30	7.5	33	4.0	130
Tlb	5/1-33A2	436–438	2-14-57	----	----	12	.01	2,310	.0	1,410	3.2	13
Tt	5/2-7J1	105–138	6- 6-62	11	52	43	.30	11	6.4	8.1	.8	83
Tcr	6/1W-10C1	600–631	5- 7-62	17	62	65	.03	28	1.9	20	3.5	106
Tlb	6/1-2M1	54–77	6- 6-62	13	56	22	.04	15	.8	32	.6	125
Tm	6/1-5B1	179–184	6- 6-62	14	58	21	.06	41	.2	103	1.0	72
Tm	6/2-16G1 [2]	----	2- 9-62	----	----	28	26	404	124	1,200	24	----
Tm?	7/1W-5M1s [3]	----	7-20-62	14	57	----	----	----	----	----	----	112
Tcr	7/1W-6R1	120–225	7-20-62	13	56	54	.64	99	11	282	14	110
Tcr, Tm	7/1W-27N1	159–178	6- 7-62	14	58	26	.66	6.5	2.0	4.0	1.4	28
Tm	7/1W-34L1	135–150	6- 7-62	11	51	10	.17	6.5	2.6	3.2	.6	13
Tt	7/2W-7B1	80–220	6- 7-62	13	56	43	.19	31	11	8.1	2.2	164
Tt	7/2W-29L1	65–147	6- 5-62	13	56	40	.79	19	9.5	7.0	1.8	123
Tm	7/1-11K1	46–90	6- 7-62	8	47	28	[4]4.2	21	7.2	30	3.2	171
Tcr	8/1W-34L1	182–317	6- 5-62	13	56	41	1.1	10	4.4	14	1.6	80
Tm	8/2W-28A1	160–205	6- 8-62	14	57	44	.07	12	1.5	44	.6	126

[1] QTb, Boring Lava; Tt, Troutdale Formation; Tcr, basalt of the Columbia River Group; Tm, marine rocks; Tlb, Little Butte Volcanic Series.
[2] Analyzed by Pittsburgh Testing Laboratory.
[3] Small s indicates spring.
[4] Includes 1.1 mg/l of manganese.

SUITABILITY OF THE WATER FOR IRRIGATION

The characteristics most important in determining the quality of irrigation water have been described by the U.S. Department of Agriculture (U.S. Salinity Lab. Staff, 1954). They are (1) the concentration of soluble salts, (2) the proportion of sodium to the other principal cations, and (3) the concentration of boron (discussed previously) or other possible toxic elements. Concentrations of soluble salts can be determined approximately by measuring the electrical conductivity of the water. Conductivity, usually expressed in micromhos, is therefore a partial measure of the suitability of water for irrigation.

The sodium (alkali) hazard of an irrigation water is determined by the proportion of sodium to other major cations, magnesium and calcium. If the proportion of sodium is high, the hazard is high; if calcium and magnesium predominate, the hazard is low.

A useful index for designation of the sodium hazard is the sodium-adsorption-ratio (SAR), which is related to the adsorption of sodium

water from the Molalla-Salem Slope area
Survey unless otherwise noted]

Milligrams per liter—Continued															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Percent Na	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
0	1.2	2.8	0.1	0.2	1.5	0.00	180	--------	120	0	16	0.3	260	7.5
0	.0	6.5	.0	.2	1.2	.02	195	193	87	0	46	1.2	273	7.3
0	.0	2.0	.0	.1	.01	.03	61	62	22	0	42	.5	72	6.5
0	.8	1.0	.0	.9	.05	.00	70	--------	32	0	28	.3	84	6.6
0	5.2	50	.3	.0	.11	.11	238	--------	106	0	47	1.4	376	7.8
0	18	6,190	.0	------	------	------	9,950	--------	5,760	5,750	38	8.1	16,700	7.1
0	1.6	2.2	.3	.1	.24	.00	115	--------	54	0	33	.5	139	7.3
0	3.0	24	.4	.0	.22	.02	198	--------	78	0	40	1	257	7.4
0	1.8	4.2	.2	.0	.06	.08	139	--------	41	0	67	2.2	206	7.8
0	24	172	.2	.2	.03	.46	398	--------	104	44	72	4.4	743	7.5
------	7.6	2,750	------	.1	------	------	6,280	--------	1,170	------	74	13	--------	6.1
0	------	------	------	------	------	.94	------	--------	292	200	------	------	2,100	7.3
0	15	585	.7	1.6	.03	.89	1,120	--------	292	202	72	7.2	2,030	7.4
0	1.0	2.5	.0	9.0	.40	.00	67	--------	24	1	32	.3	74	6.8
0	.8	5.2	.0	25	.01	.06	61	--------	27	16	26	.3	87	5.9
0	.8	3.5	.2	.2	1.3	.01	182	--------	124	0	16	.3	262	7.5
0	.8	2.8	.4	.0	.61	.00	144	--------	86	0	20	.3	196	7.6
0	8.2	2.0	.2	.0	.35	.13	189	--------	82	0	51	1.4	280	7.1
0	4.2	3.5	.4	.0	.45	.04	120	--------	43	0	49	.9	143	7.8
0	23	3.8	.1	.0	.10	.00	191	--------	36	0	76	3.2	253	7.5

by the soil. This ratio may be determined by the following formula, in which all principal cations are expressed in milliequivalents per liter:

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

A diagram used for the classification of irrigation water, based on the SAR and the electrical conductivity, is shown in figure 15. In this diagram, 16 types of irrigation water are classified, ranging from low sodium (S1) and low salinity (C1) to very high sodium (S4) and very high salinity (C4). Water classed as C1–S1 can be used to irrigate any type of crop on nearly all soils with little danger of harmful effects to either crops or soil. Water classified as C4–S4 is not suitable for irrigation of any crops in any soil, except under special conditions.

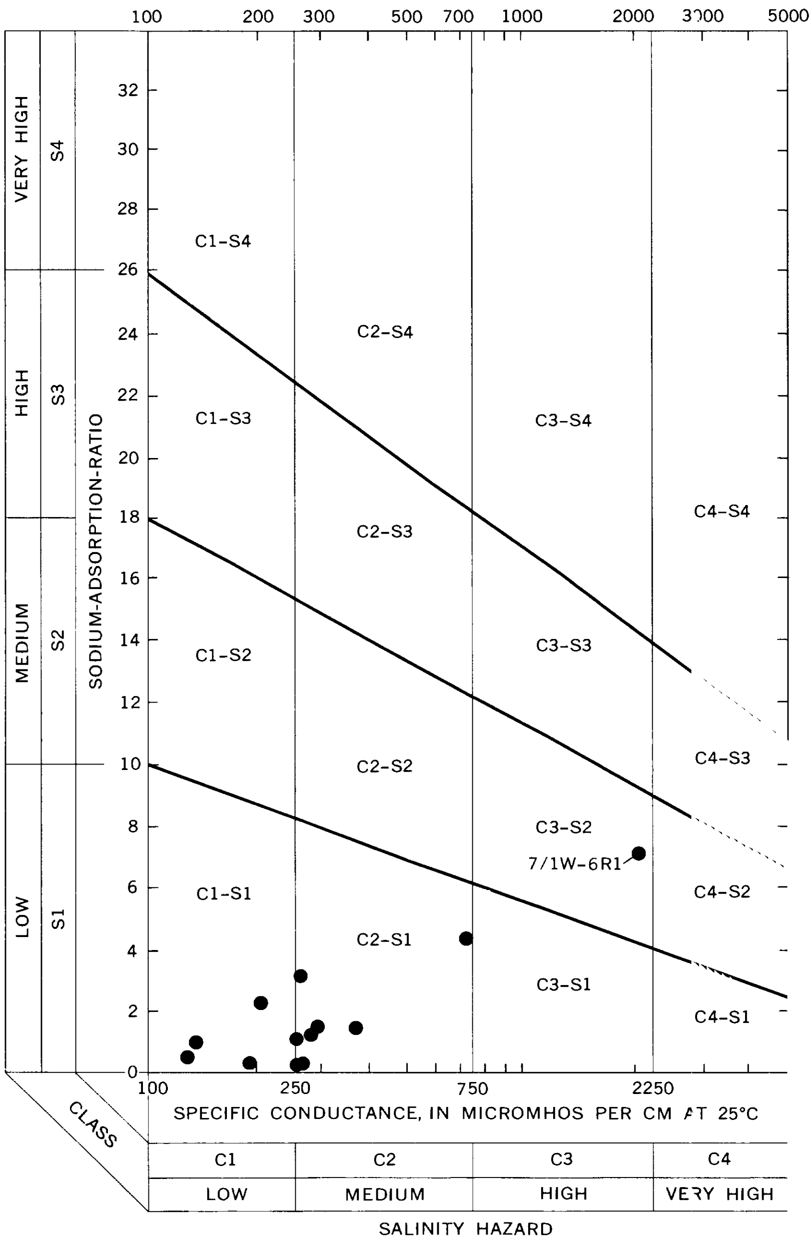

FIGURE 15.—Classification of irrigation waters. After U.S. Salinity Laboratory Staff (1954, p. 80).

Of the 19 samples for which adequate data are available for computing the SAR, 16 fall in either the C1–S1 or the C2–S1 class (including four that plot too far to the left to be shown in fig. 15). Such waters are generally suitable for irrigation of most crops on most soils, especially in areas that receive about 40 inches of precipitation per year. Water from well 7/1W–6R1 fell in the C3—S2 class and can be used only with special management practices on well-drained permeable soils and on plants that have good salt tolerance. SAR conductance-value plots for water from wells 5/1–33A2 and 6/2–16G1 fall off the graph to the right, indicating that the waters are too saline for irrigation and many other uses.

USE OF GROUND WATER

The principal uses of ground water in the Molalla-Salem Slope area are for irrigation, domestic, and municipal supply. The volume of water pumped for all uses in 1966 totaled about 12,000 acre-feet. Of this total, about 73 percent, or 8,600 acre-feet, was pumped for irrigation; about 23 percent, or 2,600 acre-feet, was for domestic use; and about 4 percent, or 500 acre-feet, was for municipal use.

IRRIGATION USE, 1966

The volume of ground water pumped for irrigation was estimated from electrical power-use data using the equation:

$$\text{Acre-feet pumped} = \frac{0.977 \times \text{kwhr} \times \text{efficiency}}{\text{Head}}.$$

In using the above equation to determine the pumpage from privately owned wells, the following assumptions were made:

1. Average pumping lift in the area was 100 feet, average operation pressure at well head was 90 pounds per square inch; therefore, total pumping head was about 300 feet.
2. Average overall efficiency was 50 percent.

In using the equation to determine the pumpage from State-owned wells and sumps, the following assumptions were made:

1. Total pumping head was 200 feet.
2. Average overall efficiency was 65 percent.

Using the above equation and assumptions, pumpage from about 320 privately owned wells in 1966 was about 5,600 acre-feet, and pumpage from State-owned sumps and wells was about 3,000 acre-feet; thus, total ground-water pumpage for irrigation was about 8,600 acre-feet.

MUNICIPAL USE, 1966

Three incorporated towns in the Molalla-Salem Slope area obtain their water supply from wells. Using the power-use formula and applying modification for different pumping heads, it is estimated that Mount Angel pumped 380 acre-feet, or 180 gpd (gallons per day) per person; Sublimity pumped 64 acre-feet, or 135 gpd per person; and Aumsville pumped 60 acre-feet, or 160 gpd per person. Thus, total municipal use of ground water in 1966 was about 500 acre-feet.

DOMESTIC USE, 1966

Nearly all rural-domestic and group-domestic water supplies in the area are obtained from wells. In this report, well water used for all household purposes, lawn and garden watering, and stock supplies is included in this category.

The 1966 rural population of the Molalla-Salem Slope area was estimated using 1960 census district figures and applying a percentage increase (determined by comparing 1960 and 1966 population totals by counties) to the parts of the two counties within the area. In this manner the rural population of the area was estimated to be 31,500 in 1966. Assuming that the average water use is 75 gpd per person, then rural domestic water use was about 2.4 mgd, or about 2,600 acre-feet for the year.

ESTIMATED VOLUMES OF GROUND WATER AVAILABLE

The greatest present use of ground water is in the valley plain and adjacent regions B–D of the transition zone. Because these areas are underlain by the more productive aquifers, future use is expected to be greater there than in other areas of the Molalla-Salem Slope.

The volume of ground water perennially available for use in any area is dependent on the average annual recharge. If more water is withdrawn from aquifers on a year-to-year basis than is recharged, water levels will decline and aquifers will eventually be dewatered. In the Molalla-Salem Slope area, alluvial aquifers beneath the valley plain and parts of the transition zone retain a large volume of water in storage throughout the year, accept large volumes of recharge, and discharge a like amount to seeps, springs, evapotranspiration, and wells. A knowledge of the volume of water in storage and of the volumes of water that are discharged and recharged annually is required if the ground-water resources of the area are to be managed properly.

POTENTIALLY AVAILABLE WATER IN STORAGE

Not all the water stored in the pores of the saturated materials beneath the area is available for use; only that part of the water that will drain from the materials by gravity flow can be considered to be a manageable part of the ground-water resource. The ratio of the volume of water that drains from a given volume of saturated materials is called the specific yield of that material. Coarse-grained materials with many connected pore spaces (such as a clean gravel) have higher specific-yield values than do finer grained materials with few connected pore spaces (such as clayey sandstone). The values of specific yield assigned to various saturated rock types beneath the Molalla-Salem Slope area were adopted from Price (1967), who computed manageable stored water for the adjacent French Prairie area as follows (table 8):

TABLE 8.—*Categories of alluvial materials, and assigned specific-yield values, in percent*

Category	Driller description	Assigned specific yield (percent)
G	Gravel, cobbles, and boulders	25
S	Sand, sand and gravel	25
Cs	Sandy clay, silt and sand, clay with sand lenses, and sand with clay lenses	20
Cg	Clay and gravel; gravel with clay binder; conglomerate; gravel, cemented; clay with gravel lenses	15
C	Clay, silt, silt and clay, shale, hard clay, sticky clay	5

Materials reported in drillers' logs (like those in table 11) were assigned to one of the five categories and tabulated by areas for two depth zones—water table to 100 feet below land surface and from 100–200 feet below land surface. The areas given in table 9 are parts of one or more townships, as indicated by the headnotes.

On the basis of table 9, the volume of manageable stored water in the 0- to 200-foot depth zone of the 186-square-mile valley plain and adjacent transition zone is about 2,900,000 acre-feet. The Troutdale Formation below the 200-foot depth horizon beneath much of the area (see pl. 2) contains an additional large, but presently undetermined, volume of stored water.

TABLE 9.—*Volumes of manageable ground water stored beneath the valley plain and adjacent areas*

Depth zone (feet)	Saturated sedimentary deposits					Total	Area (acres)	Total volume (acre-feet)	Storage volume [1] (acre-feet)
	G	S	Cs	Cg	C				
T. 4 S., Rs. 1 E. and 1 W. (Average depth to water table, 30 ft)									
Water table to 100:									
Feet	78	183	324	329	521	1, 435			
Percent	5	13	23	23	36	100			
Average specific yield	1. 25	3. 25	4. 60	3. 45	1. 80	14	20, 500	1, 400, 000	200, 000
100–200:									
Feet	4	144	254	42	350	794			
Percent	1	18	32	5	44	100			
Average specific yield	. 25	4. 50	6. 40	. 75	2. 20	14	20, 500	2, 050, 000	290, 000
Total									490, 000
T. 4 S., R. 2 E. (Average depth to water table, 20 ft)									
Water table to 100:									
Feet	111	87	113	349	509	1, 169			
Percent	9	7	10	30	44	100			
Average specific yield	2. 25	1. 75	2. 00	4. 50	2. 20	13	6, 400	510, 000	66, 000
100–200:									
Feet	7	33	116	62	493	711			
Percent	1	5	16	9	69	100			
Average specific yield	. 25	1. 25	3. 20	1. 35	3. 45	10	6, 400	640, 000	64, 000
Total									130, 000
T. 5 S., R. 1 W. (Average depth to water table, 30 ft)									
Water table to 100:									
Feet	83	142	371	99	348	1, 043			
Percent	8	14	36	9	33	100			
Average specific yield	2. 00	3. 50	7. 20	1. 35	1. 65	16	11, 500	800, 000	130, 000
100–200:									
Feet	59	85	97	73	141	455			
Percent	13	19	21	16	31	100			
Average specific yield	3. 25	4. 75	4. 20	2. 40	1. 55	16	11, 500	1, 150, 000	180, 000
Total									310, 000
T. 5 S., R. 1 E. (Average depth to water table, 30 ft)									
Water table to 100:									
Feet	28	115	240	312	546	1, 241			
Percent	2	9	20	25	44	100			
Average specific yield	. 50	2. 25	4. 00	3. 75	2. 20	13	17, 000	1, 200, 000	160, 000
100–200:									
Feet	0	41	198	62	437	738			
Percent	0	6	27	8	59	100			
Average specific yield	0	1. 50	5. 40	1. 20	2. 95	11	17, 000	1, 700, 000	190, 000
Total									350, 000

See footnote at end of table.

TABLE 9.—*Volumes of manageable ground water stored beneath the valley plain and adjacent areas*—Continued

Depth zone (feet)	Saturated sedimentary deposits					Total	Area (acres)	Total volume (acre-feet)	Storage volume [1] (acre-feet)
	G	S	Cs	Cg	C				
T. 5 S., R. 2 E. (Average depth to water table, 20 ft)									
Water table to 100:									
Feet	80	27	55	298	497	957			
Percent	8	3	6	31	52	100			
Average specific yield	2.00	.75	1.20	4.65	2.60	11	8,300	660,000	73,000
100-200:									
Feet	10	28	5	5	372	420			
Percent	2	7	1	1	89	100			
Average specific yield	.50	1.75	.20	.15	4.45	7	8,300	830,000	58,000
Total									130,000
T. 6 S., R. 2 W. (Average depth to water table, 40 ft)									
Water table to 100:									
Feet	27	124	245	27	105	528			
Percent	5	23	47	5	20	100			
Average specific yield	1.25	5.75	9.40	.75	1.00	18	5,100	310,000	56,000
100-200:									
Feet	47	173	7	262	12	501			
Percent	9	35	1	53	2	100			
Average specific yield	2.25	8.75	.20	7.95	.10	19	5,100	510,000	96,000
Total									150,000
T. 6 S., Rs. 1 W. and 1 E. (Average depth to water table, 30 ft)									
Water table to 100:									
Feet	169	249	442	715	588	2,163			
Percent	8	12	20	33	27	100			
Average specific yield	2.00	3.00	4.00	4.95	1.35	15	23,000	1,600,000	240,000
100-200:									
Feet	53	216	192	367	523	1,351			
Percent	4	16	14	27	39	100			
Average specific yield	1.00	4.00	2.80	4.05	1.95	14	23,000	2,300,000	320,000
Total									560,000
T. 7 S., Rs. 1 and 2 W. (Average depth to water table, 30 ft)									
Water table to 100:									
Feet	84	285	416	736	655	2,176			
Percent	4	13	19	34	30	100			
Average specific yield	1.00	3.25	3.80	5.10	1.50	15	20,000	1,400,000	210,000
100-200:									
Feet	41	164	132	773	193	1,303			
Percent	3	13	10	59	15	100			
Average specific yield	.80	3.25	2.00	8.90	.75	16	20,000	2,000,000	320,000
Total									530,000

See footnote at end of table.

TABLE 9.—*Volumes of manageable ground water stored beneath the valley plain and adjacent areas*—Continued

Depth zone (feet)	Saturated sedimentary deposits G	S	Cs	Cg	C	Total	Area (acres)	Total volume (acre-feet)	Storage volume [1] (acre-feet)
T. 8 S., R. 2 W. (Average depth to water table, 10 ft)									
Water table to 100:									
Feet	33	99	28	233	64	457			
Percent	7	22	6	51	14	100			
Average specific yield	1.75	5.50	1.20	7.65	.70	17	7,000	630,000	110,000
100–200:									
Feet				15					
Percent				100					
Average specific yield [2]						15	7,000	700,000	100,000
Total									210,000

[1] All values rounded.
[2] Estimated.

RECHARGE

Because the valley-plain area is underlain by permeable soils that readily absorb infalling precipitation, little rainwater runs off the land directly to the few streams that drain the area. Most of the precipitation is absorbed by the soil and percolates to a saturated zone beneath the land surface. Average annual precipitation on the valley plain ranges from about 40 inches at Salem and Canby (at lowest altitudes on the west edge) to about 46 inches at Molalla and 48 inches at Silverton (at higher altitudes on the east edge) and averages about 43 inches for the plain as a whole. The volume of precipitation on the 186 square miles of valley plain and adjacent area is about 428,500 acre-feet annually, but because of some direct runoff and considerable evapotranspiration from the soil zone, recharge is less. In the adjacent French Prairie area, Price (1967, p. 47) found that infiltration from 28 inches of rainfall in the winter and spring of 1960–61 was sufficient to refill the part of the ground-water reservoir that had been emptied by natural drainage and pumpage the previous summer. He therefore tentatively concluded that 28 inches of precipitation (70 percent of the average annual precipitation) was the minimum amount required to replenish the ground-water supply each year under present conditions of water use.

Part of the water that infiltrates during winter and spring is not available for use during the dry summer because of evapotranspiration losses and continual discharge of water from aquifers to seeps and springs. Price (1967, p. 55) presented criteria and data that permit an approximation of evapotranspiration losses from the ground-water body during the winter and spring recharge period. Price's assumptions were:

1. Potential evaporation (open-water surface) for October to March period is about 5 inches.
2. Evapotranspiration losses in French Prairie area may be 70 percent of potential evaporation.

If October to March evapotranspiration losses from the aquifer are in fact equal to 70 percent of the potential evaporation for the same period, then losses equal about 4 inches. Price (1967, p. 54) also tentatively concluded that in 1960 the average annual yield of ground water to seeps and springs in the French Prairie area was about 540 acre-feet per square mile, or about 10 inches (Price, 1967, p. 46), over the area. A rough idea of the monthly distribution of this discharge can be obtained by comparing data shown by Price (1967, figs. 13–15; p. 48, 52, 53). For the purposes of this discussion, the October to March discharge of ground water to streams through seeps and springs was estimated, using Price's figure 14, to be equivalent to about 6 inches of water over the French Prairie area. Therefore, if we consider that of the 28 inches of rainfall required to refill the ground-water reservoir in the French Prairie area, 4 inches is lost to evapotranspiration and 6 inches is discharged to seeps and springs (some of which feed streams), then at the end of the period in which the 28 inches of rainfall occurred, only 18 inches will remain in storage in the aquifer.

The similarities of the valley plain of the Molalla-Salem Slope area to the French Prairie area lead to the conclusion that 18 inches (180,000 acre-ft) is a reasonable value for the recharge that would remain in storage in the aquifer at the end of the winter-spring rainy season, and also a conservative estimate of annual recharge.

Other sources of recharge to the valley-plain area are underflow from upland areas to the east, underflow from the south through alluvium of Mill Creek, and infiltration from irrigation and fluid-waste disposal. If we assume that 20 percent of the applied irrigation water pumped from wells is absorbed by the soil and percolates to the water table (disregarding applied surface water), then 1,700 acre-feet is recharged each year. Similarly, disposal of domestic liquid wastes through septic tanks may account for about 75 percent of the water pumped for domestic use and would thus add an additional 2,000 acre-feet to the volume recharged annually.

The minimum recharge to the ground-water body beneath the valley plain from precipitation and infiltration from irrigation and fluid-waste disposal directly on the valley plain is estimated to be more than 180,000 acre-feet, or equal to 1.5 feet of water over the 186-square-mile area. An additional undetermined volume of underflow also recharges the valley-plain aquifers.

DISCHARGE

Ground water is discharged from valley-plain aquifers through seeps and springs, by evapotranspiration, and by pumping from wells. Price (1967) estimated the annual seepage and spring inflow to the Pudding River between Mount Angel and Aurora to be about 540 acre-feet per square mile of drainage area. If this figure is applied to the valley plain of the Molalla-Salem Slope, then about 100,000 acre-feet of ground water drains from valley-plain aquifers each year and leaves the area through the Pudding and Molalla Rivers. Price (1967) also estimated evapotranspiration losses of the French Prairie area to be about 22 inches per year. At that rate, about 210,000 acre-feet of water, some of it ground water, would be lost from the Molalla-Salem Slope valley-plain area through evapotranspiration. As already stated, the pumpage from the valley plain and adjacent areas was about 12,000 acre-feet in 1966.

Hydrographs of wells in the area (figs. 9–11) show that the ground-water reservoir is refilled to capacity each year, indicating that recharge balances discharge. If we assume that the estimates for seepage loss and pumpage are reasonable, then an additional discharge of 70,000 acre-feet is necessary to balance the estimated 180,000 acre-feet of annual recharge. If we assume that the additional 70,000 acre-feet of discharge (0.6 ft. over the area) takes place through evapotranspiration from the water table, then our estimates of recharge and discharge balance. Because perched-water zones occur over much of the valley plain at least part of the year, the above assumptions seem warranted even though the water table is 30 feet or more below the land surface throughout much of the area.

ADDITIONAL SUPPLIES AVAILABLE

The quantity of ground water available for use on a sustained annual basis from aquifers beneath the valley-plain area far exceeds the quantity pumped in 1966. If we assume that the estimated minimum recharge of 180,000 acre-feet to the area from infiltrated precipitation represents the "perennial yield"[3] of the area, then the 1966 pumpage for all uses (12,000 acre-ft) was only 6.7 percent of the perennial yield, leaving about 170,000 acre-feet available for additional withdrawal. The average application rate of supplemental irrigation water in the valley-plain area was about 1 acre-foot per acre in 1966. If supplemental irrigation water were applied at the 1966 average rate to all 119,000 acres in the valley-plain area, the annual

[3] "Perennial yield" is here defined as that volume of pumpage equal to the estimated minimum natural annual recharge to the aquifers of the area.

replenishment would exceed the volume pumped by about 60,000 acre-feet.

Ground-water resources are more than adequate to supply man's needs in the foreseeable future because (1) the estimated minimum recharge is probably exceeded in most years, (2) the area receives an undetermined amount of underflow from adjacent areas, and (3) 2,900,000 acre-feet of manageable water is stored in the zone 0–200 feet below land surface beneath the area.

WELL CONSTRUCTION

Although an abundance of ground water is stored in aquifers beneath the valley plain and adjacent areas of the Molalla-Salem Slope, the physical nature of some of the aquifers imposes rather strict requirements on well-construction techniques necessary to obtain efficiently maximum quantities of water. The commonest well-completion methods used in the area, in order of least to greatest well efficiency, are open-bottom casing, torch-perforated casing, and casing perforated opposite zones that the driller judges to be most likely to yield water.

In alluvial aquifers, cased wells with open bottoms are the least efficient because only the area of the aquifer beneath the casing directly contributes water to the well. In an attempt to increase the efficiency of this type of well, some drillers extend the hole a few feet into the aquifer, with the hope that the area of aquifer open to the well will be increased. In most cases, however, the uncased part of the hole soon sloughs in.

Some wells are constructed by preperforating the casing with a cutting torch and then driving the casing as the drilling progresses. If, when the well is at the final depth, some of the perforations are adjacent to an aquifer, more of the aquifer is exposed than in an open-end cased well. In some wells where water-bearing materials at depth will stand unsupported by casing, a torch-perforated liner is placed below solid, unperforated casing. For the most efficient wells constructed in this manner, the driller keeps accurate records of the materials as they are penetrated during drilling and predetermines the position of the perforations so that they will be placed adjacent to probable water-yielding zones.

In wells that are perforated after reaching the final depth, the casing is usually moved down as the drilling progresses, so that the well is completely cased when drilling stops. The driller then places a perforating tool in the hole and perforates the casing opposite zones shown by his record of materials penetrated to be most likely to yield water.

Final construction techniques for both torch-perforated and perforated-casing wells consist of development operations using surge blocks, pumping, and bailing. Such development removes drill cuttings, wall cake, and fine-grained aquifer materials from the well and exposed parts of the aquifer and promotes free passage of water from the aquifer to the well bore.

Figure 14 shows that of the sections in the valley plain and adjacent areas for which data are available, only 13 percent contain more than 11–20 percent gravel below the water table in the 0- to 200-foot depth zone below land surface. To obtain maximum yields in the remaining 87 percent of the area, wells must be constructed to obtain water largely from aquifer materials in the sand- and silt-sized ranges. Well operators report that throughout the area where sand and gravel or sand beds form the principal water-producing zones, moderate to troublesome amounts of sand and silt, which cause excessive wear to pumps and irrigation or other equipment, are pumped from the wells.

Several well-construction methods commonly used in other areas, but, as yet, infrequently employed in the Molalla-Salem Slope area, allow the production of large yields of sand-free water from fine-grained aquifer materials.

Gravel-packed, or gravel-envelope, wells are constructed, using cable-tool drilling methods, by first drilling a fully cased hole at least 6 inches larger in diameter than the planned finished well. A preperforated casing or screen the diameter of the finished well is centered in the larger diameter casing and, while pulling up the outside casing, a gravel envelope is placed in the annular space between the two pipes.

In properly designed gravel-envelope wells, the size of the slots in the pipe or screen to be placed opposite the aquifer, as well as the size of the particles of the gravel envelope, is determined by the size of aquifer materials (Johnson, 1966, p. 199–201). Consequently, if the aquifer materials are of fine-sand size, the "gravel" envelope must be of coarse-sand size. Most gravel-envelope wells are equipped with a gravel-feeder pipe through which gravel can be added to the pack during and after well development. This is necessary because gravel packs settle in the aquifer and fill voids caused by the removal of the finer grained materials during development. The principal advantages of properly constructed gravel-envelope wells are: (1) all materials opposite the perforations in the liner or screen are free to yield water; (2) velocity of water entering the well is low—flow is laminar rather than turbulent; and (3) aquifer materials are stabilized after development—no fine-grained particles move from aquifer through gravel envelope and into the well.

Screened, naturally developed wells are generally less costly to construct than gravel-envelope wells, and in suitable aquifer materials they are as efficient or more efficient than gravel-envelope wells. Screened wells are constructed by placing a screen opposite aquifer materials, using one of several placement methods. The screen-slot size is selected on the basis of the size and size distribution of particles in the aquifer. In some wells, two or more slot sizes are used to screen aquifers of different particle sizes. The several advantages offered by a properly designed and constructed screened well include (1) exposure of maximum possible area of aquifer, (2) low water-entrance velocities, and (3) easier removal of fine-grained aquifer materials and drilling mud from the aquifer in the screened zone.

In essence, then, a well screen is simply a permeable wall that allows free passage of water into the well but prevents the entrance of the larger particles of the aquifer immediately adjacent to the screen.

Future development of ground water from fine-grained aquifers in the Molalla-Salem Slope area for irrigation and other uses that require large yields from individual wells will, of necessity, be accomplished by using gravel-envelope and screened wells.

BASIC DATA

Tables 10 and 11 contain supporting information in the form of well data and drillers' logs that are representative of those contained in a basic-data report by Hampton (1963) that presents data on 443 wells. Basic well data in the form of drillers' reports to the Oregon State Engineer are collected on a continuing basis and is available for examination at the office of the Oregon State Engineer in Salem, Oreg., or at the U.S. Geological Survey Water Resources Division office in Portland, Oreg.

TABLE 10.—*Records of representative wells*

Well number: See p. 4 for description of well-numbering system.
Type of well: Dg, dug; Dr, drilled.
Finish: B, open bottom (no perforations); G, gravel packed; P, casing perforated. Depth interval of gravel pack and perforations given in feet below land surface at well.
Altitude: Altitude of land surface at well, in feet above mean sea level, interpolated from topographic maps.
Water level: Depths to water given in feet and decimal fractions are measured; those given in whole feet are reported by well owner or driller. F, flowing well whose static water level is not known.
Type of pump: C, centrifugal; Cy, cylinder; J, jet; N, none; S, submersible turbine; T, turbine.

Well	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s)	
								Depth to top (feet)	Thickness (feet)
				T. 4 S., R. 1 W.					
36R1	Gust Rosenblatt	Dr	1956	132	6	132	P, 126–129	123	4
				T. 4 S., R. 1 E.					
12F1	Leonard Burdett	Dr	1961	300	6	288	P, 38–43, 65–72.	43 285	3 8
16H1	A. J. Krzmarzick	Dr	1960	127	8–6	127	P, 74–84	107	20
20C1	Robert May	Dr	1960	235	10	190	P, 62–75	200	35
				T. 4 S., R. 2 E.					
5Q1	C. T. Foster	Dr	1961	141	6–5	141	P, 75–122	115	7
30Q1	V. H. Steinhauser	Dr	1965	500	10	458	P, 40–122, 129–136, 204–225, 453–456.	30 64 86 120 129 204 453	34 2 11 2 7 21 3
				T. 4 S., R. 3 E.					
7J1	Fred Wiegele	Dr	1958	113	6	30	B	78	35
20D1	Charles Marshal	Dr	1960	81	6	70.5	B	41	40
				T. 5 S., R. 1 W.					
27D1	Gordon Scaly	Dr	1953	134	8	134(?)	P, (?)	52 71	19 9

in the Molalla-Salem Slope area

Well performance: Yield, in gallons per minute (gpm), and drawdown, in feet below nondischarging water level, reported by owner, operator, driller, or pump company. Bailed yields are indicated by "b"; flowing yields are indicated by "f."
Use: D, domestic; Ind, industrial; Irr, irrigation; N, none; O, observation; PS, public supply; S, stock.
Acres irrigated: Approximate number of acres irrigated or planned for irrigation reported by owner; may vary from year to year.
Remarks: Ca, chemical analysis in table 7; H, hydrograph included in this report; L, driller's log of well in table 11; temp, temperature. Remarks on adequacy, dependability, general quality, and materials penetrated are reported by owners, tenants, drillers, or others.

Water-bearing zone(s)—Con. Character of material	Altitude (feet)	Water level Feet below datum	Water level Date	Type of pump and horsepower	Well performance Yield (gpm)	Well performance Drawdown (feet)	Use	Acres irrigated	Remarks
T. 4 S., R. 1 W.—Continued									
Sand and gravel	170	60	10- 6-56	T, 5	160	56	D, Irr	20	Ca, L, temp 12° C (53° F).
T. 4 S., R. 1 E.—Continued									
Gravel, pea-size. Sand, medium-sized.	160	6	4-12-61	S, 3	100	10	D, Irr	15	Drilled to 330 ft; backfilled to 300 ft. Ca, H, temp 12° C (54° F).
Sand	170	29	9-13-60		140	56	D		L, temp 11° C (52° F).
Sand and gravel, thin strips.	170	35 31.16	1-30-60 6-12-62	T, 30	310	114	Irr		L.
T. 4 S., R. 2 E.—Continued									
Sand	570	60	1- 1-61	S, ¾	b, 10	60	D		Ca, temp 13° C (55° F).
Gravel, partly cemented. Sand, black. Gravel, coarse. Sand and gravel. Clay and sand. Sand. Sand and gravel.	260	15	7-20-65		575	65	Irr		L.
T. 4 S., R. 3 E.—Continued									
Basalt, porous	820	52	8-11-58		b, 40	30	D		Ca, L, temp 12° C (54° F).
Lava, decomposed	890	24 23.59	6- 8-60 6-15-62		b, 35	5	D		L, temp 11° C (52° F).
T. 5 S., R. 1 W.—Continued									
Gravel, brown	175	12	1953	T, 20	300		Irr		H.
Sand and gravel		21.36	6-20-62						

TABLE 10.—*Records of representative wells*

Well	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s) Depth to top (feet)	Water-bearing zone(s) Thickness (feet)
				T. 5 S., R. 1 E.					
11C1	Henry Kyllo	Dr	1957	520	8	520	P, 55–60, 80–128, 508–518	80 508	48 8½
25G1	Rudolph Schnack	Dr	1962	350	8	33	B	325	15
28R1	Melvin Satrum	Dr	1961	195	12	148	P, 143–148	190	5
30C1	George Bond	Dr	1961	301	6	301	P, 32–297	40 57 149 240	12 12 1 2
33A2	Melvin Satrum	Dr	1957	376	8	232	P, 83–95		
				T. 5 S., R. 2 E.					
7J1	J. H. Snively	Dr	1960	142	6–5	142	P, 110–136	105 134	12 4
				T. 5 S., R. 3 E.					
19Q1	Hubert Goodwin	Dr	1960	156	6	55½	B	51 119	59 33
				T. 6 S., R. 1 W.					
10C1	City of Mount Angel.	Dr	1962	631	12 10	297 631	P, 601–629	600	31
16B1	John Beyer, Jr	Dr	1961	109	6	109	B	107	2
31J1	J. G. Morgan	Dr	1961	137	6	137	B	132	5
				T. 6 S., R. 2 W.					
26E1	A. J. Haslebacher	Dr	1959	173	10	173	P, 94–172	145 151 167	5 5 6
36E1	Maurice Hynes	Dr	1937	105	6		P, 89–105		
				T. 6 S., R. 1 E.					
2M1	Chester Lichty	Dr	1960	77	6	54	B	68	1
5B1	Verl Jacobson	Dr	1956	185	6	175	B	179	6
7M1	Fred Lucht	Dg	1925(?)	21	36	21	B		
9M1	Ronald Asboe	Dr	1955	292	6	22	B		
31G1	Oscar Loe	Dr	1950	301	12	52	B	275	21

in the Molalla-Salem Slope area—Continued

Water-bearing zone(s)—Con. Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and horsepower	Well performance: Yield (gpm)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 5 S., R. 1 E.—Continued									
Gravel, cemented	260	52	4-20-57	T	450	74	D, Ind		L, temp 12°C (53°F).
Sand, black									
Basalt, honeycomb	330	156	4-19-62	T, 30	350	6	D, Irr		Ca, L, temp 15°C (59°F).
Basalt(?), gray	223	55	7-20-61	S, 5	110	90	D, Irr		L.
Gravel and sand, muddy.	210	34	11-17-61		200	200	Irr	30	L.
Gravel, cemented									
Sand, gray									
do									
	244	40	3- -57		b, 9	192	D		Drilled to 456 ft, cemented to 376 ft to seal out salt water. Ca.
T. 5 S., R. 2 E.—Continued									
Sand and gravel	326	18	9-12-60	S, 3	60	6	D		Ca, temp 11°C (52° F).
Sand, coarse, black									
T. 5 S., R. 3 E.—Continued									
Sandstone	1,050	45	9-20-60	S, ⅓	b, 3	85	D		H, temp 10°C. (50° F).
do		39.70	6-26-62						
T. 6 S., R. 1 W.—Continued									
Basalt	178	8	5- 7-62	T, 60	650	204	PS		Ca, L, temp 17°C (62.5° F).
Gravel	182	50 50.44	9-16-61 7- 5-62	J, ¾	b, 36	20	D, Irr		H.
Sand and gravel	204	50 48.91	7-22-61 6-29-62	S, ¾	b, 30	60	D		H, temp 13°C (55°F).
T. 6 S., R. 2 W.—Continued									
Sand and gravel	193	48	3-16-59	T, 20	675	74	Irr		Temp 14°C (57°F).
do									
do									
	204	43.55	2- 8-60	T, 5			Irr		H.
T. 6 S., R. 1 E.—Continued									
Basalt	300	+5	1-20-60		b, 18	53	D, S		Ca, temp 13°C (55.5°F).
Sandstone	263	45	3-24-56	S, 1	b, 30	60	D		Ca, temp 14°C (57°F).
	260			Cy	5		0		H.
Sandstone	326	60	9-13-55	S, 2	14	150	D		L.
Rock, soft, black	480	113	8- -50	T	580	147	Irr		L.

TABLE 10.—*Records of representative wells*

Well	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s) Depth to top (feet)	Water-bearing zone(s) Thickness (feet)
T. 6 S., R. 2 E.									
16G1	T. G. Mandrones	Dr			6				
T. 7 S., R. 1 W.									
6R1	O. E. Steffen	Dr	1960	225	8	138	P, 75–100, 125–135.	57 214	46 11
25B1	Wayne Goode	Dr	1960	400	8–6	352	P, 200–240, 320–340.		
T. 7 S., R. 1 W.									
27N1	K. G. Johnson	Dr	1960	210	10	29	B	159	19
34L1	O. H. Johnson	Dr	1957	200	8	85	P, 25–35	135	15
T. 7 S., R. 2 W.									
7B1	B. A. Stewart	Dr	1960	220	10	220	P, 90–96, 105–187, 191–217.	80 105 190	16 82 29
9P1	H. C. Toelle	Dr	1959	137	8	137	P, 1–135	70	67
17K1	Alton Roth	Dr	1961	168	10	168	P, 87–113, 130–139, 150–165.	79 120 147	33 19 21
21B1	Albert Gerig	Dr	1960	91	8	91	B	66½ 83	3 8
26G1	Cornelius Bateson	Dr	1955	208	8	84	P, 50–65, 74, 78–84.	60 73 77 84	6 2 7 124
29L1	West Foods Co	Dr	1959	200	12	198	P, (?)	65	82
T. 7 S., R. 1 E.									
11K1	M. G. Tycer	Dr	1960	126	8	47	B	46	44
T. 8 S., R. 1 W.									
28G1	Josephine Gerpacher.	Dr	1960	178	6	122	B	122	56
30J1	Francis Hendricks	Dr	1960	270	8	117	B	116	154
33E1	G. R. Duncan	Dr	1962	213	6	78	B		
34C1	R. M. Stuckart	Dr	1958	210	10	48	B	161	49

in the Molalla-Salem Slope area—Continued

Water-bearing zone(s)—Con. Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and horsepower	Well performance: Yield (gpm)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 6 S., R. 2 E.—Continued									
Sandstone	740			Cy			PS		Known as Wilhoit Springs, Ca
T. 7 S., R. 1 W.—Continued									
Gravel	201			T, 3	105	135	Irr		Ca, temp 13°C (56°F).
Basalt, caving. Sandstone	830	90 111.38	2-11-60 7-23-62		b, 18	260	D		Drilled to 405 ft. H.
T. 7 S., R. 1 W.—Continued									
Basalt, vesicular	610	48	3-10-60	S, 5	55	120	Irr		Ca, temp 14° C (57° F).
Sandstone	650	75	8- 3-57		b, 25	25	D		Ca, temp 11° C (51° F).
T. 7 S., R. 2 W.—Continued									
Gravel, cemented	174	22	9-15-60	T, 20	700	100	PS		Ca, temp 13° C (56° F).
----do ----do									
Gravel and sand	185	10	5- 4-59	T, 2	600	84	D, Irr		L, temp 13° C (56° F).
Gravel	190	19	4-15-61	T, 40	800	36	Irr		L, temp 13° C (55° F).
Gravel and sand Gravel, cemented Gravel, loose	185	26	7-20-60	T, 7½	110	59	Irr		H.
Sand and gravel		27.80	7-26-62						
Gravel, cemented ----do ----do Basalt	220	38	12-29-55	T, 7½	135	112	Irr		H.
Gravel, cemented	215	30	8- 8-59	T	575	100	Ind		Ca, L, temp. 13°C (56° F).
T. 7 S., R. 1 E.—Continued									
Sandstone	700	37	5- 2-60		b, 6	88	D		Ca, temp 8° C (47° F).
T. 8 S., R. 1 W.—Continued									
Basalt	475	112	4- 7-60	S, 5	90	48	D, Irr		L, temp 12° C (54° F).
----do	425	67 70.51	5-18-60 8-14-62	S, 25	220	82	D, Irr		L.
	320	82 85.42	6-19-62 8-14-62		b, 24	68	D		L.
Basalt	525	52	10-24-58	S, 10	400	30	D, Irr		

TABLE 10.—*Records of representative wells*

Well	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s)	
								Depth to top (feet)	Thickness (feet)
T. 8 S., R. 1 W.									
34L1	Town of Sublimity	Dr	1960	317	10	191	B	182	135
35C1	Richard Schumacher.	Dr	1959	285	8	40	B	115	145
T. 8 S., R. 2 W.									
11P2	Rieck Bros	Dr	1962	245	12-10	75	P, 40-50, 60-65	230	10
28A1	D. L. Norlin	Dr	1958	205	6	45	B	160	45
33K1	Anna Etzel	Dr	1957	100	12	101	P, 5-99	8	92

in the Molalla-Salem Slope area—Continued

Water-bearing zone(s)—Con. Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and horsepower	Well performance: Yield (gpm)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 8 S., R. 1 W.—Continued									
Basalt	530	68	10-21-60	S, 20	300	122	PS	--------	Ca, L, temp 13°C (55°F).
Basalt(?)	560	85	5-19-59	T, 30	350	110	Irr	--------	L, H.
T. 8 S., R. 2 W.—Continued									
Basalt, fractured	485	25	7-21-62	----------	1,000	44	Irr	--------	L, H.
Sandstone	400	53	9-20-58	S, 1	b, 10	55	D	--------	Ca, temp 13°C (56°F).
Sand and gravel layers.	302	1½ 2.98	6- 5-57 9-16-62	T, 30	500	64	Irr	--------	L, H.

TABLE 11.—*Drillers' logs of representative wells*

4/1W-36R1

[Gust Rosenblatt. Alt 170 ft. Drilled by John W. Beck, 1956. Casing: 6 in. to 132 ft; perforated 126-129 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	5	5
Willamette Silt:		
Silt, light-brown	50	55
Silt, blue	15	70
Clay and sand, blue	11	81
Troutdale Formation:		
Gravel, cemented	2	83
Silt, dark-brown, and black sand	26	109
Sand, black	14	123
Sand and gravel	4	127
Clay	5	132

4/1-16H1

[A. J. Krzmarzick. Alt 170 ft. Drilled by John T. Miller, 1960. Casing: 8 in. to 97 ft, 6 in. to 127 ft; perforated 74-84 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Willamette Silt:		
Sand	38	41
Boring Lava:		
Rock, black	23	64
Troutdale Formation:		
Gravel, cemented	30	94
Clay, blue	13	107
Sand, "broken," and clay	20	127

4/1-20C1

[Robert May. Alt 170 ft. Drilled by Irving Sears, 1960. Casing: 10 in. to 190 ft; perforated 62-75 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Willamette Silt:		
Clay, yellow	7	10
Clay, sandy, yellow	14	24
Sand, gray	29	53
Shale, soft, blue	7	60
Shale, sticky; some grit; blue	2	62
Troutdale Formation:		
Gravel, cemented	5	67
Shale, blue; thin streaks of sand	8	75
Shale, sandy, blue	60	135
Shale, sandy, black	45	180
Shale, sticky, blue	20	200
Shale, sandy, black, and thin layers of sand and gravel	35	235

4/2-30Q1

[V. H. Steinhauser. Alt 160 ft. Drilled by Miller-Robinson & West Drilling Co., 1965. Casing: 10 in. to 458 ft; perforated 40-122, 129-136, 204-225, 453-456 ft]

Materials	Thickness (feet)	Depth (feet)
Willamette Silt:		
Clay, brown	30	30
Troutdale Formation:		
Gravel, partly cemented	34	64
Sand, black	2	66
Gravel, coarse, and brown clay	17	83
Clay, brown	3	86
Gravel, coarse	11	97
Clay, brown, and gravel	23	120
Sand, black, and gravel	2	122
Clay, brown	7	129
Clay, brown, and sand	7	136
Clay, gray	68	204
Sand, black, water-bearing	21	225
Clay, brown	30	255
Troutdale Formation—Con.		
Clay, gray	13	268
Sand and gravel, with brown clay	9	277
Clay, gray	8	285
Clay, gray, and sand	7	292
Clay, gray	70	362
Clay, gray, and sand and gravel	18	380
Clay, brown	12	392
Clay, gray	46	438
Clay, blue	4	442
Claystone, brown	11	453
Sand, black, and small gravel	3	456
Claystone, brown	44	500

TABLE 11.—*Drillers' logs of representative wells*—Continued

4/3-7J1

[Fred Wiegele. Alt 820 ft. Drilled by C. G. Westerberg, 1958. Casing: 6 in. to 30 ft.]

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Boring Lava:		
Clay, brown	18	20
Boulders and clay	5	25
Boulders and soft rock	22	47
Basalt	23	70
"Clay" hard, red	8	78
Boring Lava—Con.		
Rock, porous, soft	7	85
Sandstone	10	95
Rock, hard	13	108
Rock, porous, soft	2	110
Basalt	3	113

4/3-20D1

[Charles Marshal. Alt 890 ft. Drilled by William J. Stennett, 1960. Casing: 6 in. to 71 ft.]

Materials	Thickness (feet)	Depth (feet)
Soil	6	6
Boring Lava:		
Clay, red	9	15
Boring Lava—Con.		
"Sandstone," black and yellow; contains boulders	26	41
Lava, decomposed	40	81

5/1-11C1

[Henry Kyllo. Alt 260 ft. Drilled by John W. Beck, 1957. Casing: 8 in. to 520 ft; perforated 55—60, 80—128, 508—518 ft]

Materials	Thickness (feet)	Depth (feet)
Willamette Silt:		
Silt and clay mixed	20	20
Troutdale Formation:		
Gravel, cemented	17	37
Clay, light-brown	8	45
Gravel, imbedded in light-brown clay	10	55
Sand and gravel with clay binder	3	58
Gravel imbedded in brown clay	18	76
Clay, brown	4	80
Gravel, cemented	48	128
Clay, brown	8	136
Sand fine, brown	1	137
Gravel, imbedded in clay	3	140
Clay, blue	18	158
Shale, "broken," blue	3	161
Gravel imbedded in blue shale	3	164
Clay, light-blue	10	174
Clay, light-brown	26	200
Troutdale Formation—Con.		
Clay, dark-blue	15	215
Clay, dark-blue; some sand and gravel	5	220
Clay, blue	35	255
Silt, dark-brown	5	260
Sand, fine, black	4	264
Clay, dark-brown	11	275
Clay, blue	30	305
Sand, very fine	1	306
Clay, blue	90	396
Clay, blue; contains pea-sized gravel	7	403
Clay, blue; contains brown streaks	95	498
Sand, fine, black	8	506
Sand and pea-sized gravel imbedded in clay	1	507
Sand, black	7	514
Sand, loose, black	2½	516½
Clay, gray	1½	518
Clay, blue	2	520

5/1-25G1

[Rudolph Schnack. Alt 330 ft. Drilled by William J. Stennett, 1962. Casing; 8 in. to 33 ft]

Materials	Thickness (feet)	Depth (feet)
Columbia River Group:		
Clay and boulders	26	26
Basalt, gray, hard	25	51
Basalt, soft, brown	4	55
Basalt, hard, gray	45	100
Rock, brown	10	110
Columbia River Group—Con.		
Basalt, hard, gray	32	142
Shale, brown	18	160
Basalt, hard, gray	165	325
Lava, honeycomb, water-bearing	15	340
Basalt, hard, gray	10	350

TABLE 11.—*Drillers' logs of representative wells*—Continued

5/1-28R1.

[Melvin Satrum. Alt 223 ft. Drilled by J. T. Miller, 1961. Casing: 12 in. to 10 ft, 8 in. to 148 ft; perforated 143–148 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Willamette Silt:		
Clay, sandy, yellow	17	20
Marine rocks:		
Clay, brown	10	30
Clay, white	2	32
Clay, brown	15	47
Clay, white	2	49
Clay and "shell," broken, brown	91	140
Marine rocks—Con.		
Shale, broken, and rock; water bearing	8	148
Little Butte Volcanic Series:		
Rock, red	4	152
Rock, black	6	158
Clay, broken, gray	12	170
Rock, hard, black	1	171
Shale, hard, gray	15	186
Shale, sandy, gray, and boulders; water bearing	9	195

5/1-30C1.

[George Bond. Alt 210 ft. Drilled by R. Stadeli & Sons, 1961. Casing: 6 in. to 301 ft; perforated 32–297 ft]

Materials	Thickness (feet)	Depth (feet)
Soil, brown	2	2
Willamette Silt:		
Clay, brown	13	15
Clay, blue	15	30
Troutdale Formation:		
Clay, brown; some gravel; water bearing	10	40
Gravel and sand, muddy, brown, water-bearing	12	52
Clay, brown, sandy	5	57
Conglomerate, medium-sized pebbles, brown; water bearing	12	69
Clay, brown	14	83
Clay, sticky, blue	7	90
Clay, sandy, grayish-green	35	125
Clay, sandy, grayish-brown	24	149
Sand, gray, water-bearing	1	150
Clay, sandy, gray, water-bearing	27	177
Clay, sandy, crumbly, bluish-gray	53	230
Clay, sandy, grayish-brown	10	240
Sand, packed, gray, water-bearing	2	242
Troutdale Formation—Con.		
Claystone, sandy, crumbly, bluish-gray	23	265
Clay, gray	34	299
Sand, muddy, gray	3	302
Clay, very sticky, gray	75	377
Marine rocks:		
Claystone, firm, dark-gray, water-bearing	3	380
Clay, very sticky, chocolate-brown	22	402
Clay, sticky, grayish-brown	11	413
Clay, sticky, gray	2	415
Clay, sticky, brown	3	418
Clay, sticky, gray	2	420
Clay, gritty, chocolate-brown	3	423
Clay, sandy, gray	36	459
Sand, "soupy," gray, water-bearing (static water level raised to 75 ft)	5	464
Clay, very sticky, gray	16	480
Clay, sandy, crumbly, dark-gray, water-bearing (salt water)	4	484

6/1W-10C1.

[City of Mount Angel. Alt 178 ft. Drilled by R. J. Strasser Drilling Co., 1962. Casing: 12 in. to 296 ft, 10 in. to 290–631 ft; perforated 601–629 ft]

Materials	Thickness (feet)	Depth (feet)
Willamette Silt:		
Clay, brown	3	3
Clay, blue	9	12
Troutdale Formation:		
Clay and gravel, brown	43	55
Clay, brown and blue	214	269
Conglomerate	27	296
Columbia River Group:		
Rock, hard, brown	28	324
"Conglomerate" (weathered basalt?)	7	331
Rock, brown; some "broken"	37	368
Rock, black	17	385
Rock, "broken"; caving	13	398
Columbia River Group—Con.		
Rock, black	16	414
"Conglomerate" (weathered basalt?)	7	421
Rock, medium-hard, gray	28	449
Rock, hard, gray	47	496
Rock, soft, black	27	523
Rock, medium-hard, black	37	560
Rock, soft, brown	26	586
Rock, brown	25	611
Rock, porous, water-bearing	8	619
Rock, "broken," yellow-brown	12	631

TABLE 11.—*Drillers' logs of representative wells*—Continued

6/1-9M1

[Ronald Asboe. Alt 325 ft. Drilled by William J. Stennett, 1955. Casing: 6 in. to 22 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil and gravel	14	14	Marine rocks—Con.		
Marine rocks:			Shale	8	215
Shale, blue and gray	160	174	Sandstone	12	227
Sandstone	17	191	Sandstone, blue	13	240
Shale	11	202	Rock	2	242
Sandstone, green	5	207	Sandstone, blue and green	50	292

6/1-31G1

[Oscar Loe. Alt 480 ft. Drilled by Harty Bros., 1950. Casing: 12 in. to 52 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Marine rocks:			Marine rocks—Con.		
Boulders	52	52	Shale, green, "quartz-bearing"	32	273
Shale, hard, blue	65	117	Shale, brown	2	275
Shale, hard, gray	11	128	Rock, soft, black	21	296
Shale, hard, blue	113	241	Shale, hard, "quartz-bearing"	5	301

7/2W-9P1

[H. C. Toelle. Alt 185 ft. Drilled by J. A. Sneed & Sons, 1961. Casing: 8 in. to 137 ft; perforated 1-135 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	2	2	Troutdale Formation—Con.		
Willamette Silt:			gravel; water bearing	½	80
Clay, yellow	21	23	Gravel, cemented, water-bearing	22	102
Clay, blue	32	55	Sand and 1-in.-diameter gravel; water bearing	1	103
Clay, sticky, yellow	8	63	Gravel, cemented	31	134
Clay, sandy, yellow	6	69	Gravel, 3-in.-diameter; water bearing	1	135
Sand, fine, water-bearing	½	69½	Gravel, cemented	2	137
Troutdale Formation:					
Gravel, cemented	10	79½			
Sand and ¾-in.-diameter					

7/2W-17K1

[Alton Roth. Alt 190 ft. Drilled by J. A. Sneed & Sons, 1961. Casing: 10 in. to 168 ft; perforated 87-113, 130-139, 150-165 ft]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Soil	2	2	Troutdale Formation—Con.		
Willamette Silt:			Conglomerate; pebbles 2-in.-diameter	10	98
Clay, yellow	22	24	Gravel, 1-in.-diameter; water bearing	1	99
Clay, sandy, blue	11	35	Conglomerate; pebbles 3-in.-diameter	13	112
Clay, sticky, blue	25	60	Clay, blue	1	113
Clay, yellow	8	68	Sand and clay	7	120
Clay, blue	7	75	Conglomerate	15½	135½
Vegetation, decomposed, and fine sand	4	79	Clay, yellow	½	136
Troutdale Formation:			Gravel and sand, water-bearing	3	139
Conglomerate; pebbles 1½-in. diameter	8	87	Sand, silty	8	147
Gravel, 1½-in.-diameter; water bearing	1	88	Conglomerate, water-bearing	21	168

TABLE 11.—*Drillers' logs of representative wells*—Continued

7/2W-29L1

[West Foods Co. Alt 215 ft. Drilled by Willamette Drilling Co., 1959. Casing: 12 in. to 198 ft: perforated]

Materials	Thickness (feet)	Depth (feet)
Soil	4	4
Willamette Silt:		
Clay, yellow	18	22
Troutdale Formation:		
Shale, blue	18	40
Gravel and sand	17	57
Shale, soft, yellow	8	65
Troutdale Formation—Con.		
Gravel, cemented	82	147
Shale, brown	35	182
Shale, hard, gritty, brown; contains thin strips of fine gravel	25	207
Columbia River Group:		
Rock, hard	(?)	....

8/1W-28G1

[Josephine Gerpacher. Alt 475 ft. Drilled by Robinson Drilling & Supply, 1960. Casing: 6 in. to 122 ft]

Materials	Thickness (feet)	Depth (feet)
Clay, red, and soil	3	3
Sardine Formation:		
Tuff, decomposed, yellow	22	25
Tuffstone, gray	40	65
Tuff, brown to black; contains wood fragments	10	75
Tuff, light-gray	25	100
Gravel, cemented in a green matrix	10	110
Gravel, cemented; with dark-green matrix	5	115
Sardine Formation—Con.		
Gravel, cemented; with black matrix	7	122
Columbia River Group:		
Basalt	43	165
Clay, red-brown (weathered basalt?)	5	170
Basalt, vesicular; graduating to solid basalt	8	178

8/1W-30J1

[Francis Hendricks. Alt 425 ft. Drilled by Robinson Drilling & Supply, 1960. Casing: 8 in. to 117 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Sardine Formation:		
Clay, yellow	20	22
Gravel	1½	23½
Ash, volcanic, weathered	31½	55
Ash, volcanic, carboniferous	11	66
Andesitic basalt, fresh	12	78
Ash, volcanic, green	25	103
Sardine Formation—Con.		
Ash, volcanic, carboniferous	13	116
Andesitic basalt, fresh	20	136
Columbia River Group:		
Clay, red	1	137
Basalt, vesicular, gray	33	170
Basalt, fresh, gray	74	244
Basalt, vesicular, gray	26	270

8/1W-33E1

[G. R. Duncan. Alt 320 ft. Drilled by Robinson Drilling & Supply, 1962. Casing: 6 in. to 78 ft]

Materials	Thickness (feet)	Depth (feet)
Soil and clay	6	6
Sardine Formation:		
Gravel, with clay	34	40
Clay, red grading to yellow	25	65
Clay, cream-color	10	75
Tuffstone	15	90
Sardine Formation—Con.		
Basalt or andesite, hard	10	100
Tuff, dark-gray	50	150
Tuff, white	35	185
Tuff, blue-black	13	198
Columbia River Group:		
Basalt, fresh	15	213

8/1W-34L1

[Town of Sublimity. Alt 530 ft. Drilled by R. Stadeli & Sons, 1960. Casing: 10 in. to 191 ft]

Materials	Thickness (feet)	Depth (feet)
Soil, brown	3	3
Sardine Formation:		
Clay, brown	27	30
Clay, gray	40	70
Clay, reddish-brown	6	76
Clay, light-gray	4	80
Sardine Formation—Con.		
Shale, sticky, grayish-green	9	89
Rock, medium-hard, grayish-blue	56	145
Rock, medium-hard, gray; mixed with quartz and silica	3	148

TABLE 11.—*Drillers' logs of representative wells*—Continued

8/1W—34L1—Continued

Materials	Thickness (feet)	Depth (feet)
Sardine Formation—Con.		
Rock, medium-hard, gray; with quartz, silica, and decayed wood	21	169
Shale, sandy, soft, sticky, light-gray	3	172
Shale, firm, gray	2	174
Shale, soft, sticky, gray	8	182
Columbia River Group:		
Rock, hard, black	8	190
Rock, very hard, dark-gray	15	205
Columbia River Group—Con.		
Rock, very hard, black	10	215
Rock, medium-hard, black	3	218
Shale, soft, gray	4	222
Rock, medium-hard, black, porous, water-bearing	29	251
Rock, hard, black	14	265
Shale, medium-hard, gray	10	275
Rock, very hard, dark-gray	37	312
Rock, very hard, black	5	317

8/1W-35C1

[Richard Schumacher. Alt 560 ft. Drilled by Robinson Drilling & Supply, 1959. Casing: 8 in. to 40 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Sardine Formation:		
Clay, red and yellow	14	17
Rock, fresh, gray	82½	99½
Ash, volcanic, soft	15	114½
Rock, fresh, shattered and caving, gray	8	122½
Sardine Formation—Con.		
Rock, fresh, gray	115½	238
Columbia River Group:		
Clay, Red	1	239
Rock, vesicular, gray	21	260
Basalt, fresh	25	285

8/2W-11P2

[Rieck Bros. Alt 485 ft. Drilled by Barron & Strayer, 1962. Casing: 12 in. to 75 ft; perforated 40–50 60–65 ft]

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Sardine Formation:		
Clay, yellow	22	25
Clay and gravel	25	50
Clay, yellow	15	65
Columbia River Group:		
"Hardpan" and rock	10	75
Rock, hard, black	20	95
Shale, blue-black	10	105
Columbia River Group—Continued		
Basalt boulders, blue	32	137
Basalt, hard, black	13	150
Basalt, soft, black	14	164
Basalt, hard, black	16	180
Basalt, platy, broken, gray	17	197
Basalt, firm, black	8	205
Basalt, hard, black	40	245

8/2W-33K1

[Anna Etzel. Alt 302 ft. Drilled by R. Stadeli & Sons, 1957. Casing: 12 in. to 101 ft; perforated 5–99 ft]

Materials	Thickness (feet)	Depth (feet)
Valley alluvium (of Santiam fan):		
Soil, black, with gravel	3	3
Soil, sand, and gravel, gray	5	8
Cobblestones and sand, gray, water-bearing	19	27
Sand and gravel, gray	18	45
Gravel, gray, water-bearing	2	47
Gravel, cemented, loose, reddish-brown	8	55
Gravel, gray, water-bearing	2	57
Valley alluvium—Continued		
Sand and gravel, gray	14	71
Gravel, gray, water-bearing	2	73
Sand and gravel, with small amount of clay	9	82
Gravel, gray, water-bearing	3	85
Sand and gravel, gray	10	95
Clay, medium-brown	2	97
Sand and gravel, gray, water-bearing	3	100

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[Italic numbers indicate major references]

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
OREGON STATE ENGINEER

EXPLANATION

QUATERNARY

Holocene

Qal — Valley alluvium
Silt, sand, and gravel; includes all stream-valley alluvium of Holocene age. Yields moderate quantities of water to wells where saturated

Qls — Landslide deposits

Pleistocene

Qw — Willamette Silt
Clay, silt, and fine sand. Thickness ranges from 0 to over 70 feet in places. Sand layers yield small amounts of water to large-diameter dug wells

Qt — Terrace alluvium
Silt, sand, and gravel. Usually not more than 10 to 20 feet thick beneath terrace surfaces, but 60 to 100 feet thick beneath alluvial-fan remnants between Butte and Silver Creeks. Saturated, better sorted, and coarser grained beds yield small to moderate amounts of water to wells

Qs — Springwater Formation
Volcanic mudflow and piedmont deposits. Up to 100 feet thick in the Springwater area. May contain perched water bodies at places, but not known to yield water to wells

QTau — Alluvial deposits undivided
Conglomerate, gravel, sandstone, sand, siltstone, and silt. Include Troutdale Formation, Willamette Silt, terrace deposits, and valley alluvium. Provide a rather thin cover over Tertiary bedrock units

QTb — Boring Lava
Flows of light- to medium-gray, inflated open-textured olivine basalt and basaltic andesite. Ranges in thickness from a few feet to more than 200 feet. Contains many bodies of perched ground water that yield small to moderate quantities of water to wells

TERTIARY

Pliocene

Tt — Troutdale Formation
Claystone, siltstone, sandstone, conglomerate, and massive pumice tuff. Ranges in thickness from a few feet to more than 300 feet. Coarse sandstone and conglomerate beds of this unit are the principal aquifers in the area and yield moderate to large quantities of water to properly constructed wells

Miocene

Tsu, Tsa, Tsi, Tsb, Tst — Sardine Formation
Tsu, *Sardine Formation undivided. Andesite and basaltic andesite flows, volcanic mudflow breccias, and pumice tuff. More permeable breccias, tuffs, and lava flows yield small to moderate amounts of water to wells*
Tsa, *pyroxene andesite flows. Caps other rocks of the Sardine Formation*
Tsb, *volcanic mudflow breccia, water-laid tuff, and tuff (Rhododendron Formation of Hodge, 1933)*
Tst, *massive pumice tuff, basaltic andesite flows, and some agglomerate-conglomerate beds (Fern Ridge Tuffs of Thayer, 1939)*
Tsi, *intrusive rocks. Medium-grained felsic dike rock*

Tcr — Columbia River Group
Flows of gray to dark-gray fine-grained basalt. Thickness ranges from 0 to more than 500 feet. Permeable zones between successive flows yield small to large quantities of water to wells

UNCONFORMITY

Oligocene and Miocene

Tm — Marine rocks
Sandstone, siltstone, and tuff. Intertongues with Little Butte Volcanic Series. Total thickness not known; as much as 1,000 feet exposed in the report area. Permeable sandstone beds yield small to moderate quantities of water to wells. Water from deeper wells in this unit may be saline

Tlt, Tla, Tlb — Little Butte Volcanic Series
Andesitic basalt, basaltic andesite, tuffs, agglomerate, and welded tuff. Lower unit in area is basalt, basaltic andesite, and volcanic breccias. Upper unit is water-laid tuffs and agglomerate. Porphyritic andesite masses occur at places within upper unit. Lower unit appears to underlie marine rocks; upper unit overlies marine rocks
Tlt, *tuffs of Molalla River area, agglomerate and fluvial deposits. More than 700 feet of this unit exposed along the Molalla River. Tuffaceous beds yield only small amounts of water to wells, whereas breccias yield small to moderate amounts*
Tla, *porphyritic andesite*
Tlb, *olivine basalt, basaltic andesite, and volcanic breccias. At least 400 feet thick. Permeable zones between basalt flows or within the breccia yield small to moderate quantities of water to wells. Water from deep wells that tap this unit in the Willamette Valley may be saline*

Contact
Dashed where approximately located

Fault
Dashed where inferred, dotted where concealed. Ball and bar on downthrown side

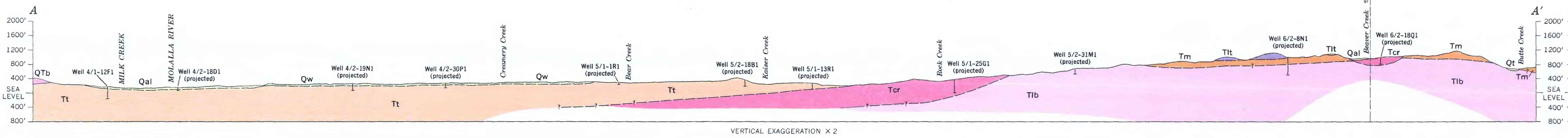
16
Strike and dip of beds or flows

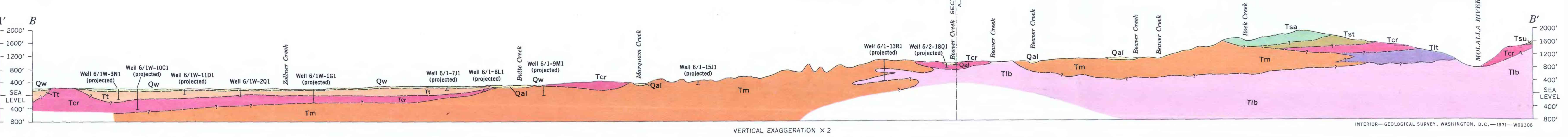
300
Approximate water-table contours
Show altitude of the regional unconfined water table. Contour interval 10 feet

● M1 Well described in this report
○ B1 Well described in Hampton (1963)
Numbering system described in text

Base from U.S. Geological Survey, 1:24,000: Molalla, Scotts Mills, 1954; Yoder, Colton, Wilhoit, 1955; Silverton, Woodburn, 1956; Gervais, 1957; and Colton, 1:62,500, 1955

Geology by E. R. Hampton, 1963–64, in part from Thayer (1939)



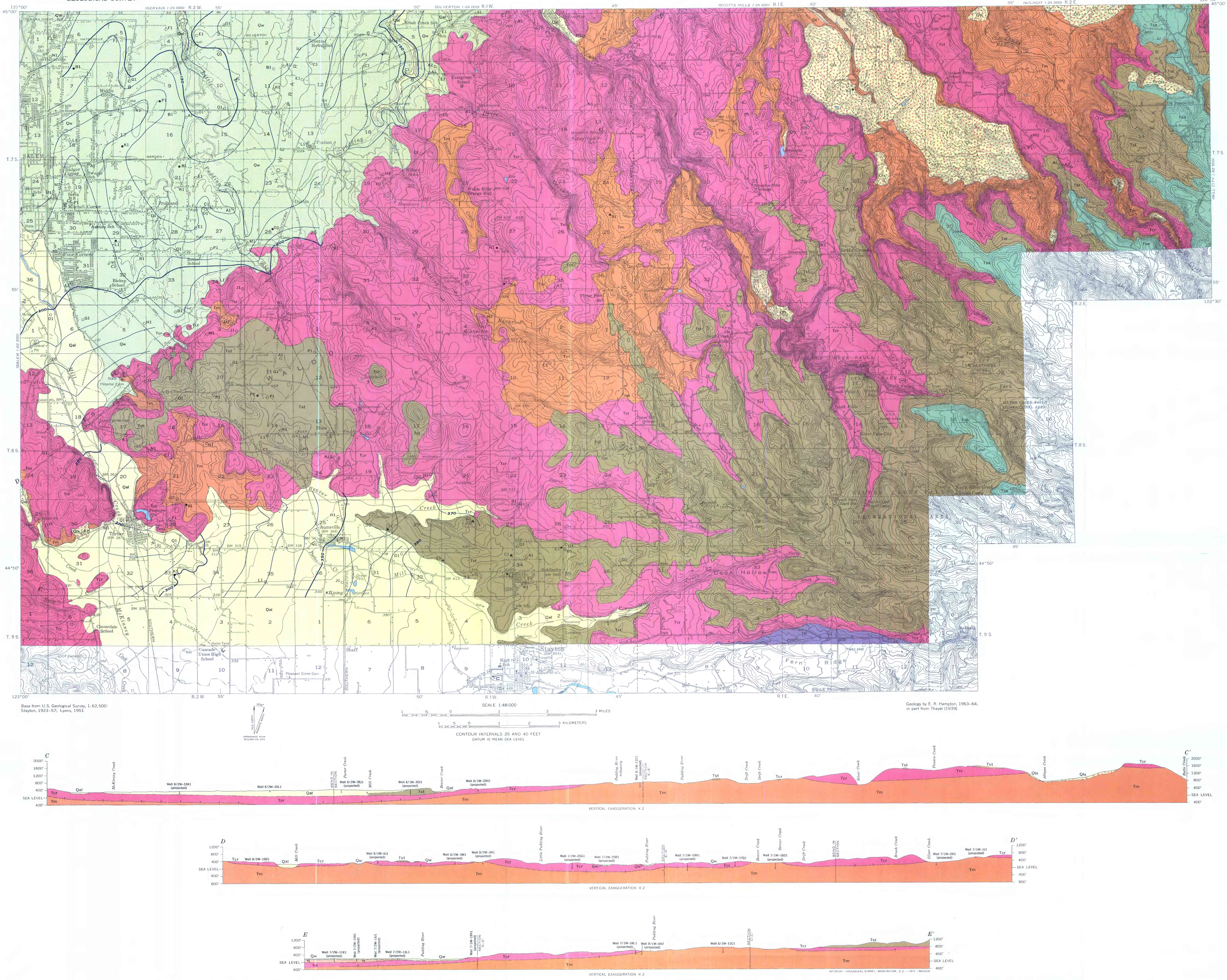


GEOLOGIC MAP AND SECTIONS OF THE MOLALLA-SALEM SLOPE AREA, NORTHERN WILLAMETTE VALLEY, OREGON, SHOWING THE LOCATIONS OF REPRESENTATIVE WELLS AND GENERALIZED WATER-TABLE CONTOURS IN MAY 1963

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
OREGON STATE ENGINEER

WATER-SUPPLY PAPER 1997
PLATE 1 (SOUTH HALF)



GEOLOGIC MAP AND SECTIONS OF THE MOLALLA-SALEM SLOPE AREA, NORTHERN WILLAMETTE VALLEY, OREGON, SHOWING THE LOCATIONS OF REPRESENTATIVE WELLS AND GENERALIZED WATER-TABLE CONTOURS IN MAY 1963

See north half for explanation of map units

PREPARED IN COOPERATION WITH THE
OREGON STATE ENGINEER

EXPLANATION

—60—
Approximate line of equal thickness of the Willamette Silt
Dashed where inferred. Interval 20 feet

—300—
Approximate line of equal thickness of the Troutdale Formation
Dashed where inferred. Interval 50 feet

Inferred fault
Ball and bar on downthrown side

Base from U.S. Geological Survey, 1:24,000: Molalla, Scotts Mills, 1954; Yoder, 1955; Wilhoit, 1955; Silverton, Woodburn, 1956; Gervais, 1957
1:62,500: Stayton, 1923–57; Lyons, 1951

Geology by E. R. Hampton, 1963–64, in part from Thayer (1939)

MAP SHOWING APPROXIMATE THICKNESS OF THE TROUTDALE FORMATION AND WILLAMETTE SILT BENEATH THE VALLEY PLAIN AND ADJACENT AREAS, MOLALLA-SALEM SLOPE AREA, NORTHERN WILLAMETTE VALLEY, OREGON

427-989 O - 72 (In pocket)