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GROUND-WATER RESOURCES IN HARNEY VALLEY, HARNEY COUNTY, OREGON

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U.S. GEOLOGICAL SURVEY

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GROUND-WATER RESOURCES IN HARNEY VALLEY, HARNEY COUNTY, OREGON

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By A. R. Leonard

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ABSTRACT

Harney Valley is the 400-square-mile northern segment of the closed basin of Malheur and Harney Lakes in southeastern Oregon. The valley is a nearly featureless plain that slopes from about 4,150 feet altitude along its northern edge to about 4,090 feet at Malheur Lake 20 miles to the southeast. The area is semiarid, with an annual precipitation of about 10 inches, most of which occurs during winter. The average growing season is about 110 days, but frost has been recorded in the valley every month of the year.

Hills that frame the valley are formed of resistant volcanic and pyroclastic rocks and sediments derived from volcanic rocks. The valley is both structural and erosional in origin, and faulting is widespread in the surrounding uplands. The unconsolidated valley fill has a maximum thickness of about 250 feet and is predominantly clay, but it contains lenticular beds of gravel, particularly along the alluvial fans and valley extensions of stream courses flowing into the valley from the north. The deeper gravel layers and permeable zones in the underlying volcanic and sedimentary rocks constitute a confined aquifer system containing several water-bearing layers separated by non-water-bearing interbeds of clay and tuff. A large number of irrigation wells tap the confined aquifer, particularly in the Silvies fan subarea east of Burns. Wells in the valley fill produce several hundred gallons of water per minute; many of them also tap water-bearing zones in the underlying bedrock. The aquifer system receives recharge from the adjacent uplands where the bedrock is faulted and broken, and from seepage from streams draining adjacent uplands. In the confined aquifer, ground water moves southeastward, southward, and southwestward, toward Malheur Lake. Ground-water discharge is mainly by evapotranspiration in the valley area.

As water moves southward, its chemical character changes from calcium bircarbonate with low mineral content to sodium bicarbonate with moderate to high mineral content. Near the western, northern, and eastern edges of the valley, the water is of generally excellent quality, but farther out in the valley it contains boron, sodium, and

dissolved solids in excessive concentrations for irrigation. Near Malheur Lake, the ground water is unsuitable for most uses.

In an area near Hines, a number of springs and flowing wells yield thermal water having temperatures of 70° to 80°F (21° to 27°C). Flowing hot-water wells and springs having temperatures of 105° to 176°F (41° to 80°C) occur at several other places. Water of normal temperature is yielded by flowing wells along the east edge of the valley and at other places.

Ground-water use is largely for irrigation (10,000 acre-feet per year), industrial (5,000 acre-feet), and municipal purposes (about 1,000 acre-feet). Total use in 1968, a dry year, was about 17,000 acre-feet; total use in 1969, a wet year, was about 13,000 acre-feet. In an area of concentrated pumping near Hines, the potentiometric head has declined a few feet since 1930, so that some wells and springs no longer flow. Elsewhere, water levels fluctuate seasonally, being lowest in fall and winter and recovering to highest levels in late spring. There is some evidence of mutual interference between wells in the Silvies fan subarea, and possibly declining water levels near the southeastern corner of the valley.

Areas having most potential for additional ground-water development are the Silvies fan subarea and Sage Hen Valley. The north-side and north-central subareas have some potential for development, but past drilling experience suggests that exploration by test drilling may be desirable to locate well sites. The southern part of the valley has little potential for additional development and is characterized by poor ground-water quality.

In general, however, the ground-water reservoir can sustain considerable additional development. The main deterrents to developing ground water are the unpredictability, at many places, of depth and character of aquifers, yield of wells, and water-quality deficiencies for irrigation and domestic use.

INTRODUCTION

Location and Extent of the Area

Harney Valley lies in the north-central part of Harney County in southeastern Oregon (fig. 1). The project area includes the nearly flat valley extending about 20 miles north from Malheur Lake and from near Burns on the west to the Crow Camp Hills on the east. Also included are the valley of Sage Hen Creek southwest of Burns and small areas of the uplands bordering the valley on the west, north, and east.

The area studied is roughly rectangular and extends over an area about 20 miles from north to south and about 30 miles east to west. The nearly flat, featureless lowland known as Harney Valley occupies about 400 square miles of this area, Sunset Valley south of Wrights Point covers about 40 square miles, and Sage Hen Valley about 10 square miles (pl. 1).

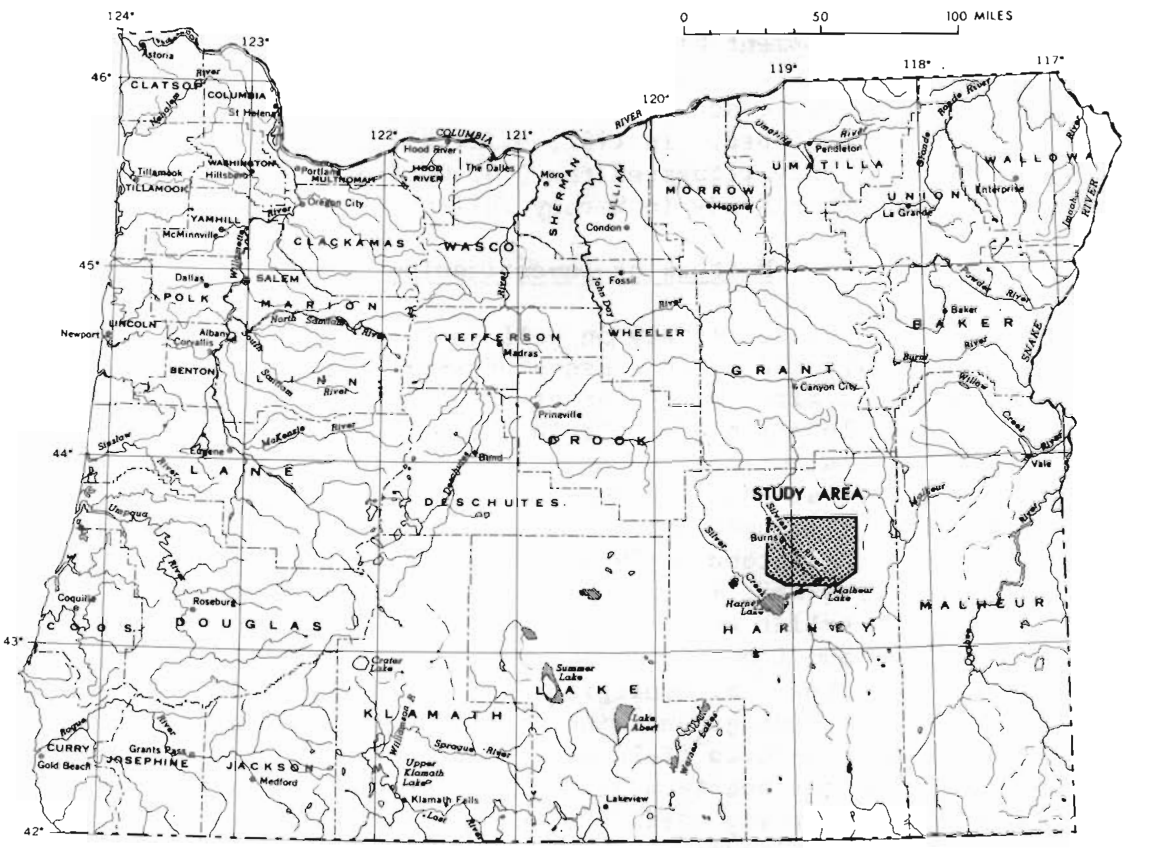

Figure 1.--Map of Oregon showing area covered by this investigation.

Most of the population in the area is concentrated in or within a few miles of the cities of Burns and Hines. However, ranches are scattered throughout the area, particularly along the north side of the valley, near the highways radiating from Burns, and in areas served by water-distribution canals from the Silvies River and Poison Creek. Total population of the area is estimated to be about 5,200, of which 3,206[1/] people live in Burns, 1,396[1/] in Hines, and the remainder in rural areas and the small communities of Lawen and Crane.

Purpose and Scope

The semiarid region of Harney Valley receives little precipitation during summer, and the flows of streams have been fully appropriated for irrigation since before 1900. The ground-water potential for irrigation was recognized many years ago, and by 1893 attempts were being made to develop irrigation from naturally flowing artesian wells (Russell, 1903; Waring, 1909, p. 62). By 1930, more than 600 acre-feet of water was being pumped annually for irrigation from wells in the valley near Burns. Following World War II, interest in obtaining irrigation supplies from wells increased dramatically, so that by 1967 about 100 wells had been drilled for irrigation and about 80 were in use.

1/ Preliminary figures from 1970 U.S. Census of Population.

Regulatory officials and landowners were understandably concerned about the effect this development might have on the supply. Also, they were interested in an estimate of the potential for additional development of the ground-water resource and in identifying areas where additional supplies might be developed. In 1967, officials of the State Engineer's office and Harney County requested the U.S. Geological Survey to make an up-to-date ground-water study in Harney Valley.

Methods of Investigation

This report is based largely on well data and hydrologic information collected during the field seasons of 1967, 1968, and 1969, and on drillers' logs filed with the office of the Oregon State Engineer. Fieldwork included location of wells in the project area, mass measurements of water levels, collection of water samples for analysis, and pumping tests in wells. All irrigation wells and a selected group of other wells were field located, and mass measurements were made in this group of wells in the autumn of 1968 and spring of 1969. In the autumn of 1969 pumping tests were made in three wells. Available geologic data include that from earlier work by Waring (1909), Piper and Park (Piper and others, 1939), and from recent unpublished mapping by G. W. Walker and R. C. Greene of the U.S. Geological Survey and R. E. Corcoran of the Oregon Department of Geology and Mineral Industries. Topographic maps, scale 1:62,500, were used to field locate wells and to obtain well altitudes except in the northeastern part of the area, where a U.S. Forest Service planimetric map was used to determine locations and an aneroid altimeter to obtain altitudes. Data were compiled on a 1:125,000-scale base map obtained by enlarging a segment of the 1:250,000 Burns Army Map Service quadrangle map.

During the summer of 1967 and the early part of 1968, several discharge measurements were made of small streams flowing into the valley area from the north. These measurements, together with miscellaneous measurements made over many years and data from the U.S. Geological Survey gaging station on the Silvies River near Burns, serve as the basis for the streamflow analysis. (See section on "Water resources.")

Water-quality data include (1) detailed analyses of water samples collected from 26 wells and springs during the course of this study; (2) data from the earlier study by Piper, Robinson, and Park (1939); and (3) specific conductance of water from streams and irrigation wells. Some of the specific conductance data were obtained during fieldwork and some were furnished by the county agricultural agent.

This report was prepared in the Oregon District Office of the U.S. Geological Survey, Water Resources Division, under the general supervision of Stanley F. Kapustka, district chief. Several of the author's colleagues in the district office assisted in the collection and interpretation of data and preparation of the report.

Acknowledgments

The cooperation and assistance of local officials, well drillers, ranchers, and well owners greatly facilitated this study. Part of the cooperative funds came from the Harney County Court, and the County Judge, Newton Hotchkiss, helpfully supplied well information and other data. Officials of the cities of Burns and Hines, and the Edward E. Hines Lumber Co. furnished information on water use by their organizations. John and Kenneth Rossberg, Dorland Ray, and the Squaw Butte Experiment Station (Dr. Charles Rumberg, director) kindly allowed use of their irrigation wells for pumping tests. Well drillers John Rossberg, Ed Koeneman, and Jack McAllister furnished information on well locations, subsurface geology, and drilling conditions. Power-consumption records furnished through the courtesy of C. L. Calder, manager of California-Pacific Utilities, and Robert Cole and Ron Brown of Harney Electric Cooperative, Inc., were helpful in estimating the volume of water pumped for irrigation. Merle Clark, former Harney County Watermaster, was also helpful in supplying information on wells, water levels, and other data. Ranchers Ed McConville and Howard Miller, and Dr. Rumberg provided information on irrigation practices and water use.

Well-Numbering System

The well- and spring-numbering system used in Oregon is based on the rectangular system for subdivision of public land, and each number indicates the location of the well with respect to township, range, and section. Well number 23S/31E-16bcc indicates a well in T. 23 S., R. 31 E., sec. 16. The letters show the location within the section, as shown in figure 2. The first letter (b) represents the quarter section; the second (c), the quarter-quarter section; and the third (c), the 10-acre tract. If more than one well is located within a 10-acre tract, a

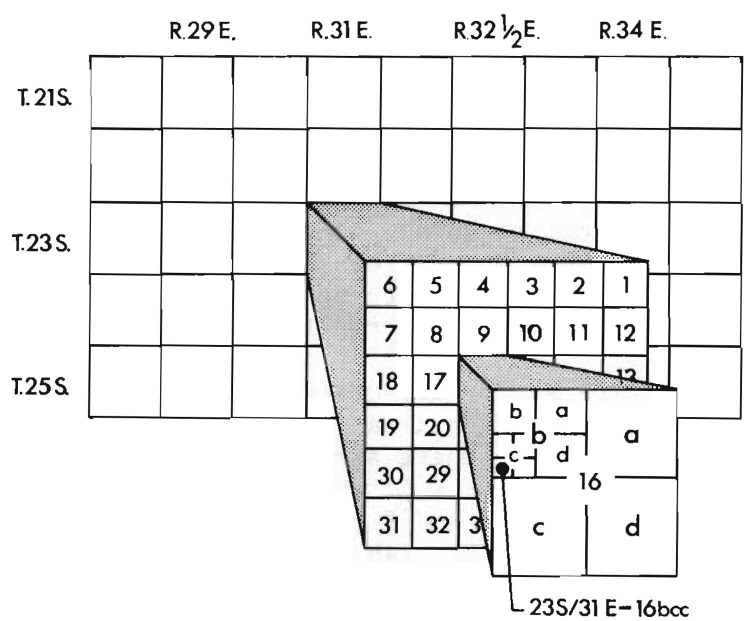

Figure 2.--Well-numbering system.

number is added following the third letter to distinguish them. A spring is identified by the addition of an "s" after the final letter.

GEOHYDROLOGIC SETTING

Geographic Features

Landforms and Streams

Harney Valley is a 400-square-mile plain in the "High Desert" region of southeastern Oregon. The valley is a nearly flat lowland bounded on the south by Malheur Lake and on the east, north, and west by ridges and hills formed of volcanic and sedimentary rocks. Although these rocks extend beneath the valley plain, the edges of the plain are everywhere marked by an abrupt change of slope reflecting the structural and erosional origin of the valley. On the west side of the valley near Hines, hills rise 250 feet (to 4,400 feet above mean sea level) within half a mile of the valley and more than 1,000 feet (to 5,200 feet above mean sea level) within 4 miles. Along the north side, the hills also rise abruptly to about 4,400 feet and continue to rise northward for many miles. The Crow Camp Hills on the east side of the valley have general altitudes of more than 5,000 feet within 2½ miles of the valley, and in places are more than 5,800 feet above mean sea level. Smaller topographic features are prominent landmarks. Wrights Point, about half a mile wide, rises 250 feet above the valley and projects 5 miles into the valley about 10 miles south of Burns. Just north of Malheur Lake, in the southeastern part of the area, Saddle and Warm Springs Buttes rise about 230 and 260 feet, respectively, above valley level.

Basically, the valley and its tributary uplands to the east, north, and northwest constitute part of a closed basin draining into the playa of Malheur Lake. This basin is the northernmost of the closed basins of the Basin and Range physiographic region. Because the bedrock beneath the valley and the uplands that frame it are of volcanic origin, the area also is generally considered to be a part of the Columbia lava plateaus.

The Silvies River, which heads in the Aldrich and Strawberry Mountains 30 miles north of Harney Valley, is the only perennial stream that flows across the valley. The Silvies River splits into an east fork and a west fork just southeast of Burns. Each fork follows a meandering course to Malheur Lake, but water flows through these forks only in unusually wet years. During most years nearly all the water in the stream is diverted to irrigate meadow and crop land.

Several small streams--Poison, Prater, Soldier, Rattlesnake, and Cow Creeks--are generally perennial a few miles north of the valley. During spring runoff periods, these streams discharge a considerable volume of water into the valley. At the north edge of the main valley, streams are diverted by canals and flow from one diked field to another through checkgates. In years of high runoff, sizable areas are irrigated by these diverted high flows, a practice referred to as "wild flooding" (Piper and others, 1939, p. 19). These streams, except for Poison Creek, are diverted for irrigation in the canyons and at the north end of the valley, so their flows seldom extend much south of

Highway 20. Poison Creek extends into the valley by way of Poison Creek Slough as far as sec. 27, T. 23 S., R. 32 E., and supplies irrigation water to a number of ranches near Burns Airport.

Curtis and Crow Creeks and other small streams drain the Crow Camp Hills on the east side of the valley but are generally dry, except in early spring.

Sage Hen Creek drains a sizable area northwest of Burns and flows through Sage Hen Valley, where it receives contributions from several springs. Sage Hen Creek flows only during the spring runoff period, possibly because low flows are lost into the fractured and faulted volcanic rocks. All the water from Sage Hen Creek and its tributary springs is appropriated for irrigation.

In addition to the two Silvies River branches, Malheur Lake also receives drainage from the south, particularly from the Donner und Blitzen River whose headwaters extend more than 50 miles south of Malheur Lake and drain the western flank of Steens Mountain. Malheur Lake overflows through Mud Lake into Harney Lake, southwest of the study area. Malheur Lake is only a few feet deep at its highest stage, but its area varies greatly with stage. In the summer of 1967 the lake covered about 75 square miles, but in October 1968 it was so nearly dry that it could be driven across by truck along Cole Island levee, and cattle were being pastured on the eastern part of the lakebed. Piper, Robinson, and Park (1939) and Phillips and Van Denburgh (in press) have described features and historical fluctuations of these lakes.

The surface of the valley slopes gently from about 4,150 feet altitude near Burns and about 4,135 feet near the northeast corner to about 4,095 feet at the edge of Malheur Lake. Although the average valley gradient is 2 to 3 feet per mile, slopes are slightly greater near the edges of the valley--particularly along the east and west margins. Some areas in the north-central and northeastern parts of the valley are nearly flat and contain many small "playa lakes"--shallow, undrained depressions that are covered with water during wet periods.

Faintly developed alluvial fans extend into the north end of the valley where south-flowing streams debouch from canyons. There, numerous sloughs, canals, and dikes built to convey irrigation water modify the natural topography. An area several miles wide bordering the Silvies River and extending from the canyon mouth of Silvies River and Poison Creek to about Wrights Point is laced with irrigation canals and diked fields.

None of the flows of the smaller streams that drain uplands on the north and east sides of the valley reaches Malheur Lake, even in the wettest years, because the entire flow is diverted for irrigation. In spring, the old stream courses in the eastern half of the valley are marked by shallow lakes, sloughs, and marshes. In most years, these water bodies dry up by early summer.

Hummocky areas of loose "blow sand" cover broad areas in the eastern half of the valley. The surface is reasonably well stabilized by sagebrush and other native vegetation, but the faintly rolling dunelike topography is unmistakable. Other dune areas south and southwest of Saddle Butte and in the southern part of Sunset Valley have been identified (Piper and others, 1939, p. 14) as remnants of an old beach ridge. The dune-sand areas contrast markedly with nearby areas of alkali soil which characteristically are flat, vegetated by greasewood and rabbit brush, and have whitish alkali encrustation.

Climate

Harney Valley has a semiarid winter-rainfall type of climate with cold winters and mild summers. About half the 10 inches of annual precipitation falls during the wettest months of November to February, but only about 10 percent falls during the driest period, July through September (fig. 3). Most of the winter precipitation is in the form of snow, which averages 48.6 inches annually (Sternes, 1967, p. 16). In summer, much of the precipitation occurs during thundershowers, which may be accompanied by hail or strong winds.

North and northwest of the valley, precipitation increases with altitude in the mountains, where Silvies River and Sage Hen, Poison,

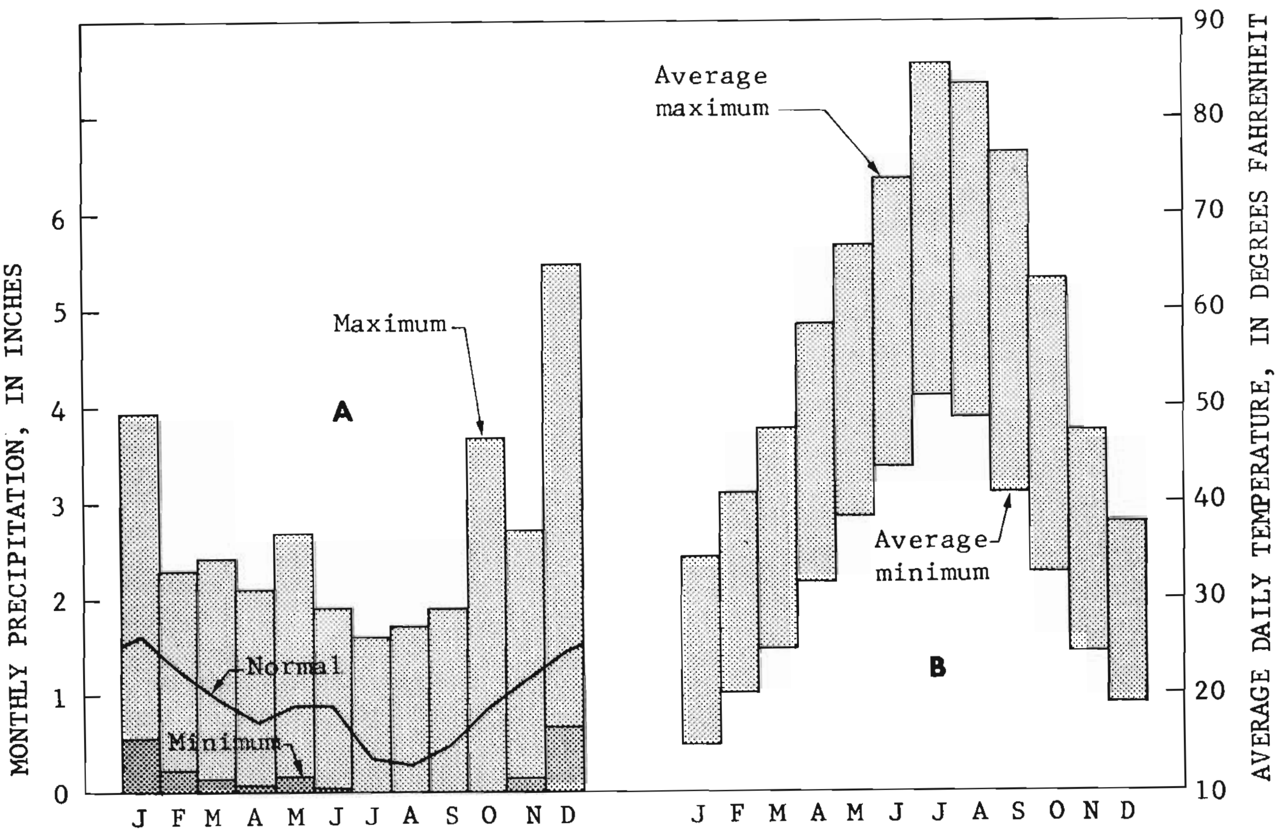

Figure 3.--(A) Normal and extreme monthly precipitation and (B) average maximum and minimum monthly temperature at Burns.

and other creeks head. It has been estimated that annual precipitation in the Silvies River basin above the gaging station averages 19 inches (D. J. Lystrom, oral commun., 1970)--about twice that in the valley. As most of the precipitation in that area is in the form of snow, snowmelt runoff is the principal source of spring streamflow from north-side streams and also the source of ground-water recharge in the uplands.

Climatic data have been collected at Burns for about 48 years between 1891 and 1921 and from 1938 to date. Records were collected at the old Harney Branch Experiment Station (now the Dorland Ray farm) from 1913 to 1953. Data are available for shorter periods for Camp Harney and Malheur Wildlife Refuge south of Malheur Lake. On the basis of these records, annual precipitation averages about 11 inches at Burns but is about 15 percent less 6 miles east and about 20 percent less near Malheur Lake. Thus, the annual total for the valley probably averages less than 10 inches. At Burns, the minimum annual recorded precipitation was 5.32 inches in 1949, and the maximum was 18.12 in 1906. Annual precipitation from 1938 through 1970 is shown in figure 4.

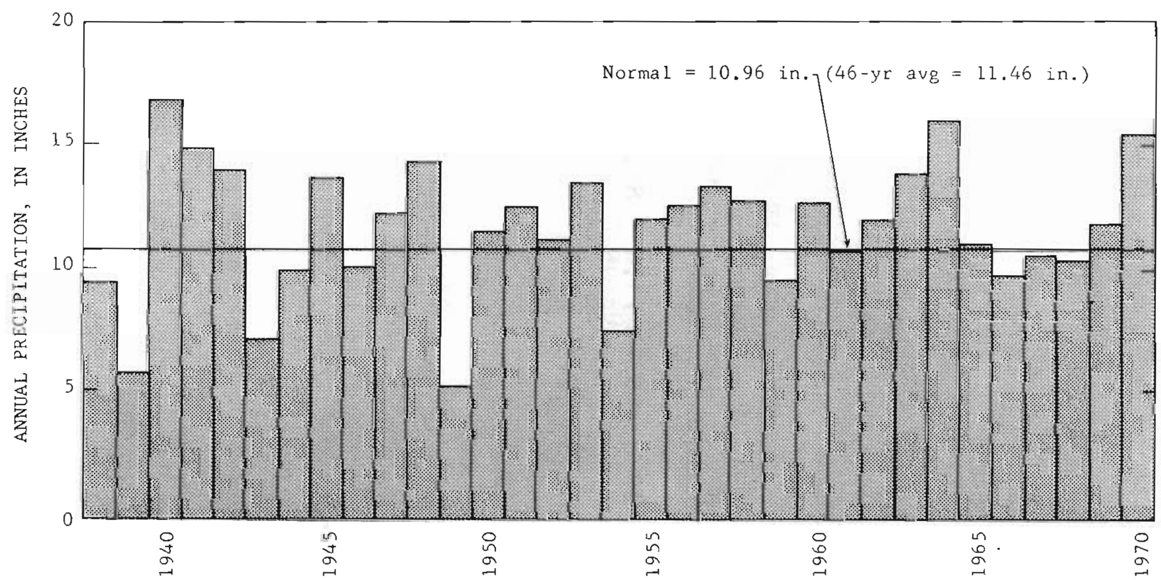

Figure 4.--Annual precipitation at Burns, 1938-70.

As in other high-altitude valleys in eastern Oregon, temperatures in Harney Valley generally are mild in summer and cold in winter. Daily minimum temperatures generally are about 20°F less than daily maximums during winter, but the spread is about 35°F in July and August (table 1). The highest temperature recorded at Burns was 103°F in August 1961 and the lowest -26°F in January 1962. According to National Weather Service records, the average date for the last killing frost in spring is May 29 and for the first in autumn is September 17--an average frost-free growing season of 111 days. However, below-freezing temperatures have been recorded each month at the Harney Branch Experiment Station and at Malheur Refuge, and each month except July at Burns. Therefore, frost can be expected any month of the year--for instance, an unseasonal frost did considerable damage to the potato crop in early August 1969.

Table 1.--Monthly temperatures at Burns

/National Weather Service records/

	Temperature, in degrees Fahrenheit												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average maximum	34.6	40.9	47.5	58.6	66.7	73.6	85.7	83.5	76.3	63.3	47.5	38.1	59.7
Average minimum	14.5	20.1	24.8	31.5	38.5	43.7	51.1	48.9	40.9	32.5	24.3	18.9	32.5
Mean	24.8	29.7	37.4	46.0	53.4	59.8	69.5	67.2	58.8	48.4	36.1	29.1	46.7
Highest	58	64	74	86	93	95	101	103	100	86	70	61	103
Lowest	-26	-18	-3	14	19	28	34	31	24	13	-17	-8	-26

Geologic Features

Local Structure

Harney Valley is both a structural and an erosional valley. The eastern edge, along most of its margin, is marked by a north-trending fault that uplifted the Crow Camp Hills (pl. 1). Faulting also is responsible for "offsetting" the east wall of the valley about 3 miles south of Buchanan. The area just northwest of the valley, between Sage Hen Creek and the Silvies River, consists of a series of fault blocks formed by numerous parallel northwest-trending faults. Concealed faults may mark the valley margin near Burns and Hines.

The upland just north of the valley has few faults but consists of a broad monocline dipping gently southward. Park (Piper and others, 1939, pl. 2) noted dips of 2^{o} to 3^{o} in this area, and comparable dips can be observed in rocks along the Poison Creek and Prater Creek canyons and near the Silvies River north of the valley. Resistant beds of welded tuff along the walls of Devine and Prater Creek canyons can be traced southward and seen to dip beneath the valley. However, erosion has accentuated the valley margin to produce a pronounced topographic break of 200-250 feet.

Erosion also is responsible for the pronounced topographic break between the valley floor and Wrights Point, Dog Mountain, and the adjoining upland area. Wrights Point is a rather striking example of inverted topography--a lava-filled valley left behind as a linear ridge when unprotected softer rocks were stripped away from each side of the former valley.

The alluvial and lacustrine deposits that make up the near-surface part of the valley fill appear to dip a few feet per mile toward Malheur Lake. Tertiary sediments and late volcanic cinders and extrusive rocks that are exposed in cinder pits on the north side of Warm Springs Butte dip steeply northward. These beds have only local structural significance and probably reflect the volcanic origin of the buttes.

Tertiary Rocks

Piper, Robinson, and Park (1939) classified the consolidated volcanic rocks and volcanic-derived sedimentary rocks that form the hills around the valley and extend beneath it as Tertiary and subdivided them into older extrusive rocks, Steens Basalt, Danforth Formation, and Harney Formation. In recent field mapping, more intensive than that of 1939, George Walker and Robert Greene, of the U.S. Geological Survey, and R. E. Corcoran of the Oregon Department of Geology & Mineral Industries, have designated the principal mass of the Crow Camp Hills as Miocene rhyodacite, andesite, and basalt instead of older extrusive rocks and Steens Basalt. They also have recognized about 12 volcanic and sedimentary units of Pliocene and Pleistocene age that supersede the Danforth and Harney Formations north and west of the valley. On plate 1, the recent unpublished mapping is used for the contacts and structural features, but the large number of mapping units comprising the bedrock have been lumped for simplification and because drillers' logs are not sufficiently detailed to distinguish individual units in the subsurface.

Basalt, andesite, and rhyodacite of Crow Camp Hills.--The oldest rocks exposed in the Harney Valley area are the sequence of rhyodacite, andesite, and basalt flows that form the western part of the Crow Camp Hills. The total thickness of these extrusives is not known but must be at least several hundred and probably more than 1,000 feet. These rocks were not studied in detail, but those that cap the western hills and dip slopes appear to be laterally extensive. In places, reddish-brown glassy rhyodacite is interbedded with lenses of lapilli whose granules range from fine sand to pea size, and with altered claylike tuff. Dark-green, dense siliceous rock of undetermined composition occurs in this unit near the Crane-Buchanan road where it crosses the hill in the NE¼ sec. 11, T. 23 S., R. 33 E. In that same area, small lenticular masses of quartz and banded chalcedony, some forming crystal-lined geodes, appear to weather from light-colored clay.

Rocks of this unit are believed to extend beneath the valley fill for at least a mile or two west of the edge of the valley. This is suggested by the lava, cinders, and "gravel" (lapilli?) reported in well 23S/34E-7cac. The owner of a deep abandoned well a few miles southeast of well -7cac reports extremely hard lava(?) at about 500 feet.

The basalt, andesite, and rhyodacite of the Crow Camp Hills constitute an erratic, unpredictable aquifer. The aquifer has been tapped by a number of wells, including several flowing wells, drilled along or near the foot of the Crow Camp Hills. Most of the flowing wells, however, are east of the fault marking the western edge of the hills, and their hydrostatic pressure is due in part to the damming effect of the fault. The most productive well tapping these rocks is the Vickers irrigation well (23S/34E-7cac). When completed in 1969, this well was tested at 400 gpm and was reported to have sufficient hydrostatic pressure to raise water 15 feet above land surface. The driller's log of that well shows several "lava" beds, tuff, and lapilli for a total section of nearly 400 feet of volcanic rock penetrated. (See table 11.) Water evidently occurs in fractures, joints, and cindery zones in the lava flows.

Wells 23S/34E-32aca (328 feet deep) and 24S/34E-31acb (503 feet deep) each yielded 225 gpm and probably are typical of wells penetrating a few hundred feet of the east-side volcanic rocks. Two or three wells, drilled several years ago in sec. 19, T. 23 S., R. 34 E., were reported to be "inadequate for irrigation" by Jim Voss who now owns the property. It is concluded that at favorable sites these rocks might supply as much as a few hundred gallons per minute to wells drilled several hundred feet into them. Expectable yields are marginal for an irrigation supply.

Volcanic, pyroclastic, and sedimentary rocks.--Rocks of this unit form the bedrock hills north, northwest, and west of Harney Valley and extend beneath the unconsolidated valley fill. Included are three distinct welded-tuff units (recognized by Greene, in press) interbedded with pyroclastic and volcanic-derived sedimentary rocks. Also included are (1) the rhyodacite and associated sedimentary rocks that form Burns Butte and (2) small areas of Pliocene and Pleistocene strata that overlie the uppermost welded tuff between Soldier and Coffeepot Creeks and between Soldier and Poison Creeks. Those rocks were previously mapped by Park (Piper and others, 1939) as the "fanglomerate near Coffeepot Creek." North of Harney Valley the welded tuffs and associated sedimentary rocks compose essentially the section of rocks mapped as the Danforth Formation by Park. In the upland west and southwest of Wrights Point, sedimentary rocks formerly mapped by Park as the lower part of the Harney Formation are included in the unit, but the younger basalt capping the upland and the palagonite tuff forming Dog Mountain are mapped separately.

The lowermost of the three welded-tuff units crops out along Devine Canyon and the Silvies River a few miles north of Harney Valley and dips southward beneath overlying sedimentary rocks. The two younger welded tuffs cap canyon walls and uplands along the north side of the valley. According to R. C. Greene, U.S. Geological Survey (written commun., 1971), the welded tuffs are gray to reddish brown, locally dense, and may contain lithophysae. The lowermost tuff is about 80 feet thick, the middle one 20-40 feet, and the uppermost at least 50 feet.

Besides the prominent, laterally extensive welded tuffs, the unit contains a heterogeneous assemblage of siliceous volcanic rocks--basalt and andesite, pumice, unconsolidated lapilli and ash tuff--and loosely to well-consolidated silt, sandstone, and conglomerate. Where they are exposed, the strata are poorly consolidated and range from tuffaceous clays through fine sand to pebbles. The tuffaceous strata commonly contain stringers of sand and waterworn fragments of rhyodacite, basalt, and obsidian. Beds of pumice and ash are common, one of the most prominent being the 25-foot-thick bed exposed in the north wall of the valley between Rattlesnake and Cow Creek Valleys.

North of Sage Hen Valley, Burns Butte and the adjacent uplands are formed primarily by gray to reddish-brown rhyodacite, which contains considerable black obsidian. Locally, the rhyodacite is vesicular or porphyritic and closely jointed. On the south side of the butte, light-colored pumiceous sediments, associated with the rhyodacite flow, generally are only slightly consolidated and poorly exposed.

Although the more resistant beds of welded tuff can be traced for several miles along canyon walls, the less resistant tuffaceous and sedimentary beds are highly lenticular, vary greatly in thickness locally, and grade into sediments of different type in short distances. Drillers' logs of wells suggest that this characteristic continues after the unit dips beneath the valley floor.

The conglomerate, sandstone, and sand layers are clearly stratified and are probably the "gravel" and "sand" beds reported in drillers' logs of the deeper wells in the northern part of the valley. As shown in the Cow Creek section of the Danforth Formation measured by Park (Piper and others, 1929, p. 44), pumice and dark claylike tuff are common. Beds of similar lithology also are widely reported in drillers' logs of wells drilled in Harney Valley. Other terms used in drillers' logs, such as "cinders" and "broken rock" (commonly associated with "lava" or "hard rock"), may represent the scoriaceous parts of basalt or andesite layers. Permeable volcanic rocks and coarse sediments seem most common in and adjacent to the northwestern part of the valley, whereas fine-grained sediments predominate in the northeastern part of the valley and the adjacent upland. Because its sedimentary members are lenticular, the unit varies greatly in thickness and, at the maximum, doubtless is greater than the 700-foot thickness cited for the Danforth (Piper and others, 1939, p. 48). On the basis of logs of some of the deeper wells (such as 22S/31E-34aaa) that penetrate this volcanic and sedimentary lithology, the thickness at some places probably is more than 1,000 feet.

Along Devine Canyon, Prater Creek, and the Silvies River, the welded tuffs can be seen to dip southward so that rocks exposed there must lie beneath Harney Valley, at least in the northern part. Although some of the pumice layers, welded tuff, and lava beds can be traced for considerable distances at the surface, it was impossible to identify these beds in available drillers' logs. Some of the "lava" or "rock" beds reported in drillers' logs probably are the welded-tuff layers, but their thickness and altitude are too inconsistent to attempt correlation with exposed beds. Because the welded-tuff beds dip at about 200 feet per mile, most wells a few miles from the north edge of the valley are not drilled deep enough to reach them. However, many wells near Burns and along the north edge of the valley clearly obtain water from these rocks and from sand and gravel interbedded with them. Such wells include the Burns municipal wells, several irrigation wells of the Pon Ranch, Werner Arntz, George Purdy, and others.

Overall, the Pliocene volcanic and sedimentary rocks have the capacity to transmit large volumes of water. Yields of wells tapping these rocks are as much as 1,000 gpm. As discussed later, much of the recharge for the main aquifers beneath the valley originates in the hills to the north and moves through those rocks.

In contrast to the overall permeability and water-yielding capacity of the unit, its individual tuffaceous and clayey sedimentary members are poor aquifers. Several wells drilled hundreds of feet into such members yielded so little water that they were never put to use.

One of the more productive wells tapping Pliocene volcanic rocks is the Burns municipal well, 23S/30E-12ddd, which was tested at 1,280 gpm and had a specific capacity of 15.8 gpm per foot of drawdown. Another is the George Purdy irrigation well, 22S/31E-34aaa, which also obtains some water from alluvial gravel between 40 and 60 feet depth. The Purdy well was tested at 800 gpm and had a specific capacity of 6.5 gpm per foot. Logs of these wells are given in table 11.

Several wells near Rattlesnake Creek, a few miles east of the Purdy well, have much smaller yields and specific capacities. Two test wells (22S/32½E-5bb and -18aad) drilled for Charles Danuser to 545- and 445-foot depths, respectively, produced so little water that they were abandoned. Also not in use is the Huggard irrigation well (22S/32E-36bbb), which is 611 feet deep but yielded only 110 gpm with a specific capacity of 2 gpm per foot. (See table 11.)

The lithology of material penetrated by the Danuser well is generally similar to that in the section tapped by the Burns and Purdy wells. However, the volcanic rocks evidently are considerably more dense and less broken along Rattlesnake Creek than near Burns, perhaps reflecting differences in local structural activity.

Material penetrated by the Huggard well is predominantly fine grained and resembles the tuffaceous sedimentary section in the upper part of the Danforth Formation (Piper and others, 1939). Several hundred feet of similar material was penetrated in the Davis hot-water well, 22S/32E-35bbb, 1 mile west of the Huggard well. However, well 22S/32E-35bbb reached a 100-foot section (780- to 880-foot depth) composed mostly of sand, sandstone, and gravel. This well, along with other wells producing thermal water, is discussed in more detail in the section on "Water resources."

On the southwest side of the valley, beds exposed on the lower slope of Wrights Point consist mostly of fine, light-colored sandstone; crossbedded sand and fine gravel; siltstone; clay; and cemented gravel. Like those along the north edge of the valley, these sediments are generally lenticular and grade and interfinger into one another. The layers exposed on the lower slopes of Wrights Point and those on the east face of Dog Mountain described by Piper, Robinson, and Park (1939) seem to be poorly permeable and unlikely to be highly productive aquifers, as suggested by logs of wells 25S/31E-4cba and 25S/31E-30ddb, given in table 11.

Tertiary and Quaternary Rocks

Basalt and palagonized tuff.--Wrights Point and the adjacent upland south of Sage Hen Valley are capped by resistant dark-gray, vesicular basalt formerly mapped by Park as the upper part of the Harney Formation (Piper and others, 1939). On plate 1, the basalt is not separated from the palagonized basaltic tuff, breccia, and interbedded sedimentary rocks, which are approximately the same age as the basalt. These extrusive, pyroclastic, and sedimentary rocks form the main part of Dog Mountain, where approximately 500 feet of rocks were measured by Park (Piper and others, 1939, p. 38-39).

The basalt that caps the upland is clearly above the regional and local water tables. Being fine-grained, the tuffs and sediments beneath the upland are considered to be poor aquifers; no wells are known to be drilled into them. Wells on slopes west of Sunset Valley tap Tertiary sediments that stratigraphically underlie the basalt and tuff.

Cinder cones and associated volcanic ejecta.--The youngest volcanic rocks in the Harney Valley area are the basaltic rocks and cinders that cover several square miles west of Hines and form the cores of Saddle and Warm Springs Buttes. Near Hines, massive and scoriaceous reddish basalt, scoria, and volcanic cinders make up several lava domes and cinder cones (Piper and others, 1939, p. 36). Saddle and Warm Springs Buttes consist in part of small cinder cones whose slopes are mantled by pyroclastic rocks. The main mass of each butte, however, consists of basalt capping a somewhat broader area of Tertiary sediments. The basalt and cinder cones are not areally extensive and probably extend only a short distance beneath the adjacent valley plain.

The scoriaceous and cinder zones are permeable and should take in and transmit water readily. However, because of their small areal extent and topographic position, these rocks are only locally productive aquifers. Several warm-water springs formerly issued from the scoriaceous zones near Hines, but most have ceased flowing. These volcanic rocks yield slightly warm water to the Hines municipal wells, the Edward E. Hines Lumber Co. wells, and several nearby flowing wells. When they were drilled, most of these wells had natural flows of several hundred gallons per minute, and several still flow. Many of these wells are highly productive; for instance, well 23S/30E-35aad was reported to have yielded 1,750 gpm with 1½ feet of drawdown when drilled in 1965. It is inferred that the scoria and cinders serve as conduits to discharge water that infiltrates into and is stored in the Pliocene pyroclastic and volcanic rocks to the north and northwest. The relation of the scoria and cinders to the warm water in the Hines area and at Crane Hot Springs is discussed later in this report.

Quaternary Deposits

Alluvium and valley fill.--The material comprising the upper part of the fill beneath the Harney Valley plain is partly lacustrine and partly fluvial in origin. The predominantly clayey soils, the predominance of clay reported in logs of wells drilled in the valley, and the nearly undissected plain all indicate a lacustrine origin. Fans of alluvial sand and gravel intertongue with the silt and clay, which is the main mass of the valley fill. The most prominent fan is the Silvies River-Poison Creek fan which extends at least 12 miles into the valley and is 8 to 10 miles wide. Plate 1 shows a longitudinal section through the eastern part of this fan. In general, the proportion of clay to gravel in the upper 150 feet of fill increases gradually toward the southeast, from about 1 to 1 at the valley margin to about 3 to 1 within a distance of 10 miles.

Small gravel tongues extend valleyward from the mouths of Prater, Soldier, Mill, Coffeepot, Rattlesnake, Cow, and Rock Creeks. Another narrow band of gravel parallels the east edge of the valley at the foot of the Crow Camp Hills.

Drillers' logs indicate that the layers forming the valley fill are lenticular and grade laterally into beds of different lithology. Individual beds of stream-deposited sediments probably extend considerable distances in a north-south or northwest-southeast direction--down the gradient of the streams that deposited them. However, at right angles to these old stream courses the beds may change abruptly. The coarsest material was dropped as stream gradients became flatter in the main valley downstream from canyon mouths. Thus, sand and gravel make up a higher proportion of the valley-fill material near the north edge of the valley, and that proportion becomes progressively smaller with distance from the hills. The decrease in gravel is summarized in table 2 and is demonstrated by the logs of wells 23S/31E-5cbb and 23S/32E-28acd in table 11.

Except for alluvial-fan areas, most of the near-surface part of the valley fill is clay. Thus, clay or silt lies immediately beneath the surface over most of the area between the two branches of the Silvies River south of Burns. In drillers' logs, clay is reported to depths of more than 300 feet in the Lawen area, near Malheur Lake, and in the east-central part of the valley. Inasmuch as the valley fill generally is less than 300 feet thick, the entire valley-fill section in those areas may be clay.

Piper, Robinson, and Park (1939, p. 30) reported that peat had been penetrated in wells near Malheur Lake. Several drillers reported to the author that they had penetrated plant material in that area--probably the peat reported earlier.

The clay reported in most drillers' logs is described as gray, blue, or green. Some of the darker clays may be of Tertiary age, but cannot be distinguished from the Quaternary valley fill by color nor texture. Clays brought up during drilling and examined by the author were generally light gray or dark gray, noncalcareous, and free of sand or coarser material. Volcanic ash (pumice) was noted by Piper, Robinson, and Park (1939, p. 30) in the upper part of the valley fill near the Silvies River and at the old Harney Branch Experiment Station in sec. 7, T. 23 S., R. 32 E. At the latter place, the pumice evidently serves as a perching layer a few feet beneath the surface and impedes the downward seepage of water. As pumice, "chalk," and "white clay" are reported in many drillers' logs, there may be several relatively extensive ash layers in the valley fill. The author noted pumice shards in clay from wells drilled near the north side of the valley and about 10 miles south of the north valley margin.

Gravel layers within the valley fill probably are interconnected, allowing water to move from one layer to another. The gravel layers that form a large part of the fill near the canyon mouths and in the canyons just upstream are derived largely from the volcanic and pyroclastic rocks in the hills. Thus, the gravel consists of waterworn fragments of basalt, welded tuff, obsidian, and other volcanic rocks. Fine black sand, containing magnetite, also occurs in the fan areas, and many wells pump sizable quantities of this abrasive sand.

In logs of wells in the central part of the valley, layers of waterworn gravel commonly are reported at distances of 10 miles or more from the valley margin. These gravel beds may connect with those of the alluvial fans, or they may lie along ancient stream courses cut in the underlying Tertiary rocks.

Table 2.--Relative percentages of gravel and clay in valley fill of the Silvies fan subarea

	Secs. 5 and 6, T. 23 S., R. 31 E.	Sec. 11 T. 23 S., R. 31 E.	Secs. 20, 28, and 29, T. 23 S., R. 32 E.
30- to 60-foot-depth interval			
Gravel------------------------	54	48	24
Clay--------------------------	33	50	71
60- to 80-foot-depth interval			
Gravel------------------------	38	48	24
Clay--------------------------	38	43	71
80- to 100-foot-depth interval			
Gravel------------------------	25	32	16
Clay--------------------------	35	48	75
100- to 140-foot-depth interval			
Gravel------------------------	16	17	25
Clay--------------------------	43	50	69

The thickness of the valley fill is reported by Piper, Robinson, and Park (1939, p. 32) to range from less than 50 feet to more than 250 feet. The difficulty in estimating the thickness, now as then, is in differentiating between unconsolidated deposits in the fill and similar material in the underlying Tertiary sedimentary rocks. The thickness of the fill also is related to the buried topography of the underlying surface--a surface that may have been dissected to considerable relief before the valley was filled. The irregularity of that surface and the varying thickness of the valley fill are indicated in the cross section, plate 1. Piper, Robinson, and Park (1939, p. 31) suggest that the valley was relatively deep before it was dammed by lava at Malheur Gap during the latter part of the Pleistocene. The concept of a lake filling a major part of the valley also is accepted in later investigations (Phillips and Van Denburgh, in press). Generally, the level of Malheur Gap (4,114 feet) is taken as the postulated level of the Pleistocene lake, but the character of the valley floor and the occurrence of lacustrine clays near the northern part of the valley at altitudes of 4,130 to 4,140 feet suggest that at times the lake surface may have risen to somewhat higher levels. As suggested by Piper, Robinson, and Park (1939, p. 31), the coarser deposits near the valley margin may have accumulated as a near-shore deltaic deposit in such a lake. Deposition in a relatively extensive lake is the most logical explanation for the thin pumice at shallow depth that extends over a broad area east of Burns and perhaps elsewhere.

At several places, thin layers of wind-drifted sand form the surface of the valley fill. The most conspicuous sandy areas are northwest of Malheur Lake, south of Warm Springs Butte, and in the east-central part of the area from near Highway 78 northward about 10 miles. The two sandy areas near Malheur Lake have been explained (Piper and others, 1939, p. 14) as representing an ancient beach ridge associated with a high stage of the lake. The sand in the east-central area may have drifted northward from this same beach source, inasmuch as sand is not a prominent constituent of the alluvium along present-day streams.

At most places, the sand is no more than a few feet thick and constitutes a thin veneer overlying typical clayey valley fill. It forms productive well-drained soils but has no hydrologic significance so far as ground water is concerned.

Water-bearing properties.--In the northwestern part of Harney Valley, most wells obtain water from sand and gravel layers in the valley fill. Commonly, drillers' logs report several water-bearing beds of sand and sandstone or sand and gravel separated by clay interbeds. Wells more than 200 or 300 feet deep probably penetrate through the entire thickness of the valley fill and into underlying Tertiary rocks. Because they had the same sources as the valley fill, the tuff, clay, sand, and gravel layers of the Tertiary deposits cannot be identified clearly in the subsurface. However, "rock," "lava," "basalt" (probably partly welded tuff), and cinders are reported in many drillers' logs, indicating that the wells penetrate rocks below the valley fill.

Near the edges of the valley there probably is good interconnection between individual water-bearing beds in the valley fill and also with those in the adjacent and underlying Tertiary rocks. A few miles into the valley, clay and tuff layers separating water-bearing sand and gravel beds may be so continuous and extensive as to serve as local confining beds. Thus, during a pumping test on well 23S/32E-7dcb1, reported to be 160 feet deep, water levels remained unchanged in two nearby shallower wells although more than 1 foot of drawdown was noted in a well (23S/32E-18bbb) 2,100 feet to the southwest.

The effects of separating layers between water-bearing beds is largely offset by the common practice of setting 50 to 100 feet of surface casing and leaving the rest of the well open to all lower water-bearing beds. As a result, water levels, yields, drawdowns, and specific capacities of most wells in the valley represent a composite of several water-bearing beds, generally including some in both the valley fill and the underlying Tertiary rocks. (See section on "Availability of ground water by subareas.")

Short pumping tests were made on wells 23S/32E-7dcb1 and 24S/31E-5acc, both of which probably are open to only a part of the valley-fill aquifer system. Transmissivity[2/] values, calculated from those tests, were about 2,000 ft^2 per day (15,000 gal per day per ft) at well 23S/32E-7dcb1 and 4,000 ft^2 per day (30,000 gal per day per ft) at well 24S/31E-5acc. Considering the specific capacities reported for many wells in that part of the valley and the volume of water pumped from wells in secs. 21, 22, 28, and 29, T. 23 S., R. 32 E., these transmissivity values seem unreasonably low. Probably they represent the transmissivity for only a part of the valley-fill aquifer.

WATER RESOURCES

The source of both surface and ground water in Harney Valley is the precipitation that falls within the topographic basin framing the valley. Annual precipitation in the northernmost part of the Silvies River basin averages more than 30 inches and is 19 inches in the area above the gaging station in sec. 30, T. 21 S., R. 30 E. However, the rate diminishes with altitude to about 11 inches at Burns and to 10 inches or less over much of the valley. Because a large part of the winter precipitation is snow, most of the runoff in streams flowing into the valley comes from snowmelt during early spring. Essentially all the streamflow is diverted for irrigation and is discharged by evapotranspiration in the valley. During high-runoff years, such as the 1965 water year, some of the runoff in the Silvies or in streams draining the valley floor flows to Malheur Lake. However, water in Malheur Lake is discharged by evapotranspiration or overflows into

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2/ Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. In an aquifer having a transmissivity of 1,000 $feet^2$ per day, water would move laterally through a 1-mile-wide section of the aquifer at the rate of 1,000 cubic feet per day for each 1 foot per mile of hydraulic gradient.

Harney Lake where it is evaporated. In addition, summer precipitation is wholly dissipated by evapotranspiration; ordinarily it is so little that it serves only to replenish soil moisture and rarely produces runoff, except locally.

Streams flowing into the valley all lose some flow by percolation into the ground--part of this is used to subirrigate riparian vegetation, including hayfields, and part infiltrates into deeper aquifers.

In the uplands around the valley, fractured and porous volcanic and sedimentary rocks absorb sizable volumes of the precipitation and runoff. This subsurface water also moves toward the valley and eventually is discharged in the southern part of Harney Valley. Areas where hydrostatic head increases with depth of penetration into aquifers generally are considered to be discharge areas; many such areas are marked by alkali crust on the soil, caused by mineral salts that are being carried to the surface, where the water is evaporated.

In general, Harney Valley and the adjacent parts of its enclosing topographic basin can be considered a "closed system" into which water arrives in the form of precipitation and leaves through evapotranspiration.

Streamflow

Streamflow records for the Silvies River in the vicinity of the present gaging site, about 11 miles northwest of Burns, have been collected intermittently since 1903 and continuously since 1922. Figure 5

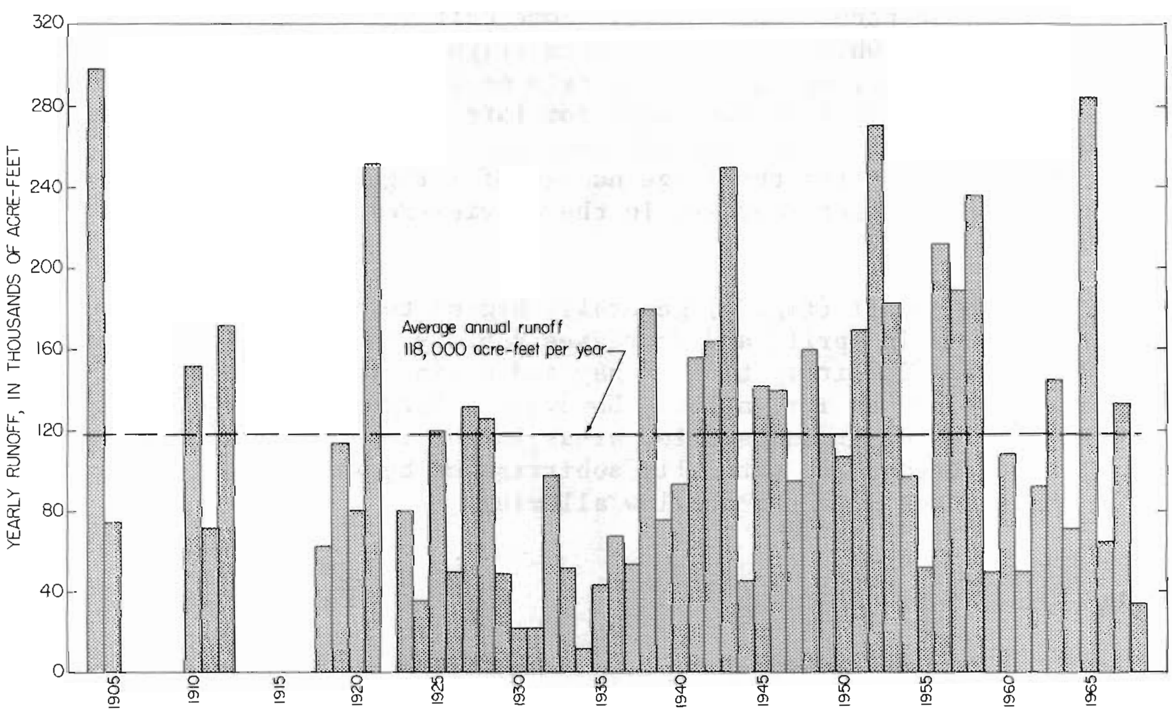

Figure 5.--Yearly runoff of the Silvies River for period of record.

shows the variation of annual runoff for the period of record. During the 55 complete years of record, runoff has averaged 116,600 acre-feet per year (161 cfs). Maximum discharge was 4,960 cfs on April 6, 1952; there was no flow July 19 to September 22, 1934. Arrays of monthly runoff for the period of record are shown in figure 6. On the average, 76 percent of the total runoff occurs during the 3 spring months March through May and 89 percent during February through June. In comparison, only 2½ percent of the total runoff occurs during July through September. Figure 7 shows the daily and seasonal variations for a year of above-average flow (1965), a year of below-average flow (1968), and a typical water year (1969).

During the spring of 1968, a series of discharge measurements were made of north-side and east-side tributaries. These measurements were correlated to the concurrent daily discharge of Silvies River near Burns, and estimates of the mean annual runoff were made. These estimates were corroborated by correlation to Silver Creek near Riley, which is gaged at a site about 30 miles west of Burns. Thus, the north-side streams from Poison Creek to Buchanan are estimated to yield 23,000 acre-feet per year. The east-side tributaries from Buchanan to Crane are estimated to yield 1,700 acre-feet per year. These streams display the same seasonal variation in flow as does the Silvies River. Their waters seep into the valley fill a relatively short distance from the foothills.

The flow of all streams draining into Harney Valley from the north is fully appropriated for irrigation and in most years is wholly utilized for this purpose. The most common irrigation practice is "wild flooding," whereby water is diverted into a diked meadow or grainfield, where it may be ponded for a time. Some cultivated fields are irrigated by siphons which draw water from slightly elevated ditches at the ends of the fields, but nearly all rely on gravity for distribution. In most years, runoff is too small for late-priority water-right holders to receive any water, and many others receive only a partial supply. This is one reason for the large number of irrigation wells, developed as supplemental water sources, in the Silvies-Poison Creek area east of Burns.

Because runoff (fig. 7) generally begins to increase in March, reaches a peak in April, and decreases rapidly in June, streamflow generally is used for irrigation of hay and grain crops which do not require late-summer irrigation. However, a large area between the forks of the Silvies River and smaller areas in the lower canyons of other north-side streams are naturally subirrigated by water that percolates from the streams into the shallow alluvium.

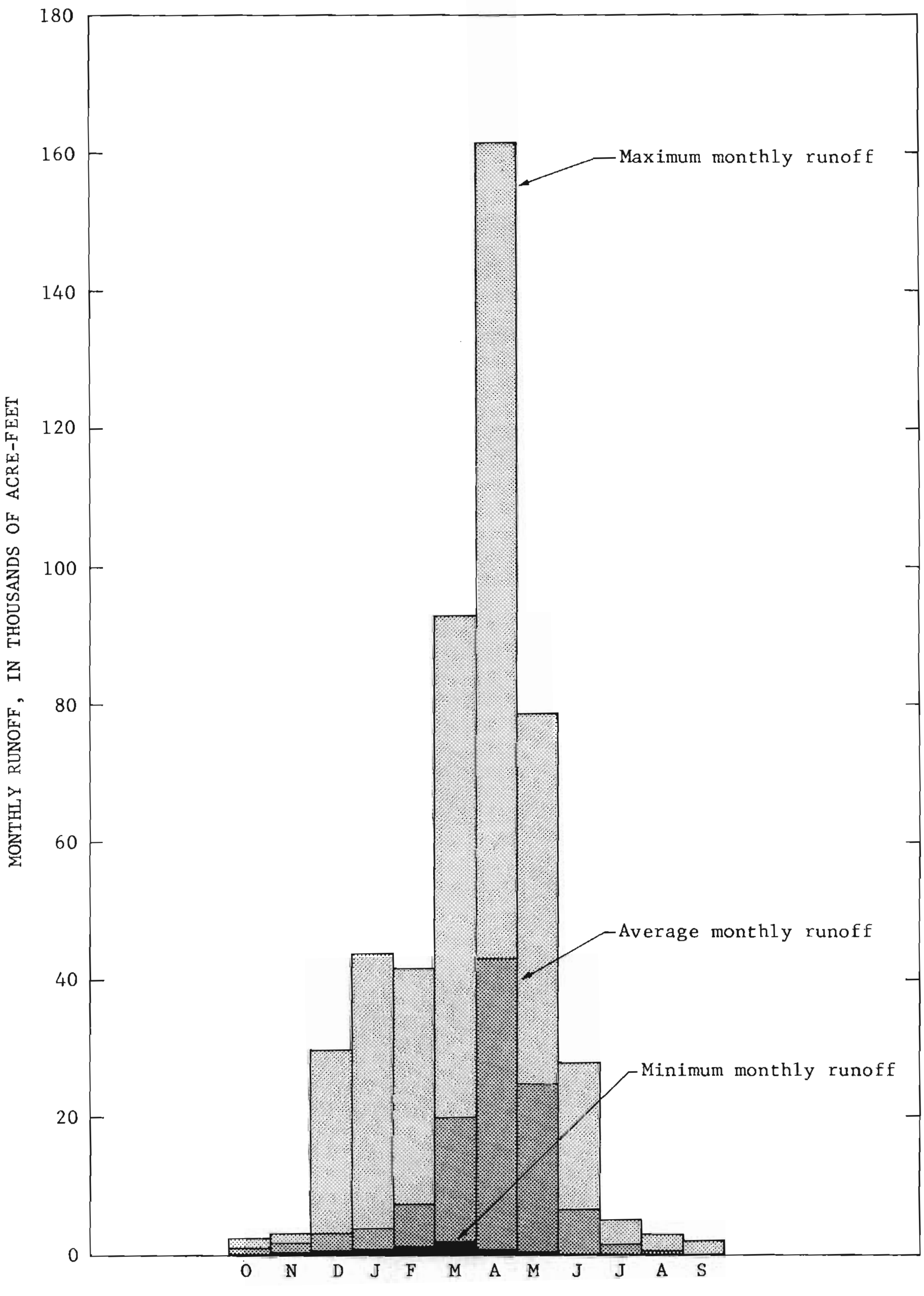

Figure 6.--Monthly runoff of Silvies River near Burns for period of record.

Figure 7.--Hydrographs of daily flow of the Silvies River for water years 1965, 1968, and 1969.

Ground Water

Occurrence

Ground water is that which occurs beneath the land surface, under hydrostatic pressure, and that completely fills all the openings within the rock in which it occurs. Ground water may be either unconfined or confined. Unconfined ground water occurs in an aquifer, or water-bearing bed, which is only partly filled so that the surface of the water, called the water table, is at atmospheric pressure. Confined water is that in an aquifer which is enclosed above by a bed of very small permeability so that the water is under pressure greater or less than the atmosphere. In the Harney Valley area, shallow aquifers in the valley fill are unconfined, but the deeper alluvial aquifers and those in the underlying Tertiary volcanic and sedimentary rocks generally are confined. A special type of confined aquifer is one where water is confined under sufficient pressure to flow at land surface when tapped by a well. Wells in such aquifers are locally termed "artesian" wells, but in this report are referred to as "flowing" wells.

Source, Recharge, and Discharge

Harney Valley and surrounding water-contributing uplands may be considered a closed hydrologic system. Inflow to the system is from precipitation; outflow, or discharge, is by evapotranspiration. Because the uplands around the valley are dotted by undrained depressions and commonly are underlain by highly permeable volcanic rocks, the outer margins of the ground-water part of the system are not sharply defined. However, the drainage basins of the Silvies River, Sage Hen Creek, and other streams draining into Harney Valley from the north, west, and east may be logically included in the Harney Valley hydrologic system.

In this closed hydrologic system of Harney Valley (1) the deeper confined aquifers remain filled at a volume that is essentially constant; (2) the shallower unconfined aquifers, over a term of years, remain filled to an average water-table stage which is locally related to the stage of the Silvies River; and (3) over the same term of years, recharge must equal discharge. For such a system, water moves through the shallow, unconfined zone to recharge deeper, confined aquifers in recharge areas. In discharge areas, the confined aquifers lose water upward through the unconfined aquifers.

The basic principle governing recharge is that water moves from a zone of high potentiometric head toward one of lower head. Thus, the uplands tend to be areas of recharge and lowlands areas of discharge.

The ultimate source of ground water in the area is precipitation on the surface of the catchment area. Recharge to the ground-water body results from infiltration of precipitation on the land surface and from percolation from streams. In the uplands several miles from the valley, most streams have little alluvium and lose water readily where they cross fractured, jointed, or porous rock. Much of the recharge to aquifers in Harney Valley comes from the infiltration of precipitation and streamflow in the mountains north, west, and east of the valley, and from stream losses near the edge of the valley. For instance, in

July 1967 Rattlesnake Creek was flowing nearly 1 cfs a few miles north of the valley, but at the edge of the valley all its flow was lost into the alluvium.

In the Silvies fan area near Burns, some recharge to the principal confined aquifer comes from downward percolation of water from the unconfined, near-surface water-table aquifer. Thus, in May 1969, water levels in several wells near the Silvies River and Foley Slough east of Burns were 5 to 10 feet below the water levels in the nearby channels. Water in the channels undoubtedly represented the local water table, and water in the near-surface deposits probably moved down by somewhat indirect routes to the underlying confined aquifers. A similar condition occurs at wells 23S/31E-11dcc1 and -11dcc2. The water level in well 23S/31E-11dcc1, which is 120 feet deep, is consistently about 7 or 8 feet higher than the water level in well -11dcc2, which is 561 feet deep (fig. 8).

In the Harney Valley area, the rate of recharge to aquifers may be estimated indirectly from the discharge. Piper, Robinson, and Park (1939, p. 74-82) equated recharge to discharge for the valley-fill aquifers in about a 210-square-mile area near the Silvies River and in the western part of the valley, and estimated the annual rate to be about 40,000 acre-feet. That estimate is primarily for an area where the water-table aquifer is in direct connection with the Silvies River but includes water that percolates from the shallower to the deeper alluvial aquifers. It includes the water that circulates to the valley in aquifers in the volcanic and sedimentary rocks beneath the valley fill--water that is discharged by evapotranspiration in the southern part of the area.

A crude estimate of recharge for the Tertiary volcanic and sedimentary aquifers is the rate at which water moves into Harney Valley in those aquifers. To compute that rate, the western, northern, and eastern margins of the valley were divided into several segments based on performance of wells. For each segment, the transmissivity of the aquifer was estimated using specific-capacity data from irrigation wells in the method suggested by Meyer (1963, p. 338-341). Inflow to the valley through those rocks was computed by multiplying the transmissivity estimates by the potentiometric gradient and length along which the water was moving, both derived from plate 2. Using Meyer's method, inflow to the valley through the Tertiary rocks is estimated to be about 22,000 acre-feet per year. Because of the known local variations in aquifer characteristics and the wide variation in yield and specific capacity from one well to another, that estimate is undoubtedly very rough.

Precipitation in the Silvies River drainage area averages about 19 inches per year upstream from the gaging station northwest of Burns, but runoff is only about 2½ inches. Most of the remaining 16½ inches probably is dissipated by evapotranspiration, but a small part infiltrates to ground water because much of the snow melts during months when evapotranspiration loss is small. Recharge of one-fourth to 1 inch has been estimated for rocks such as those cropping out in the upland part of the basin (Columbia-North Pacific Technical Staff, 1969, app. V, p.

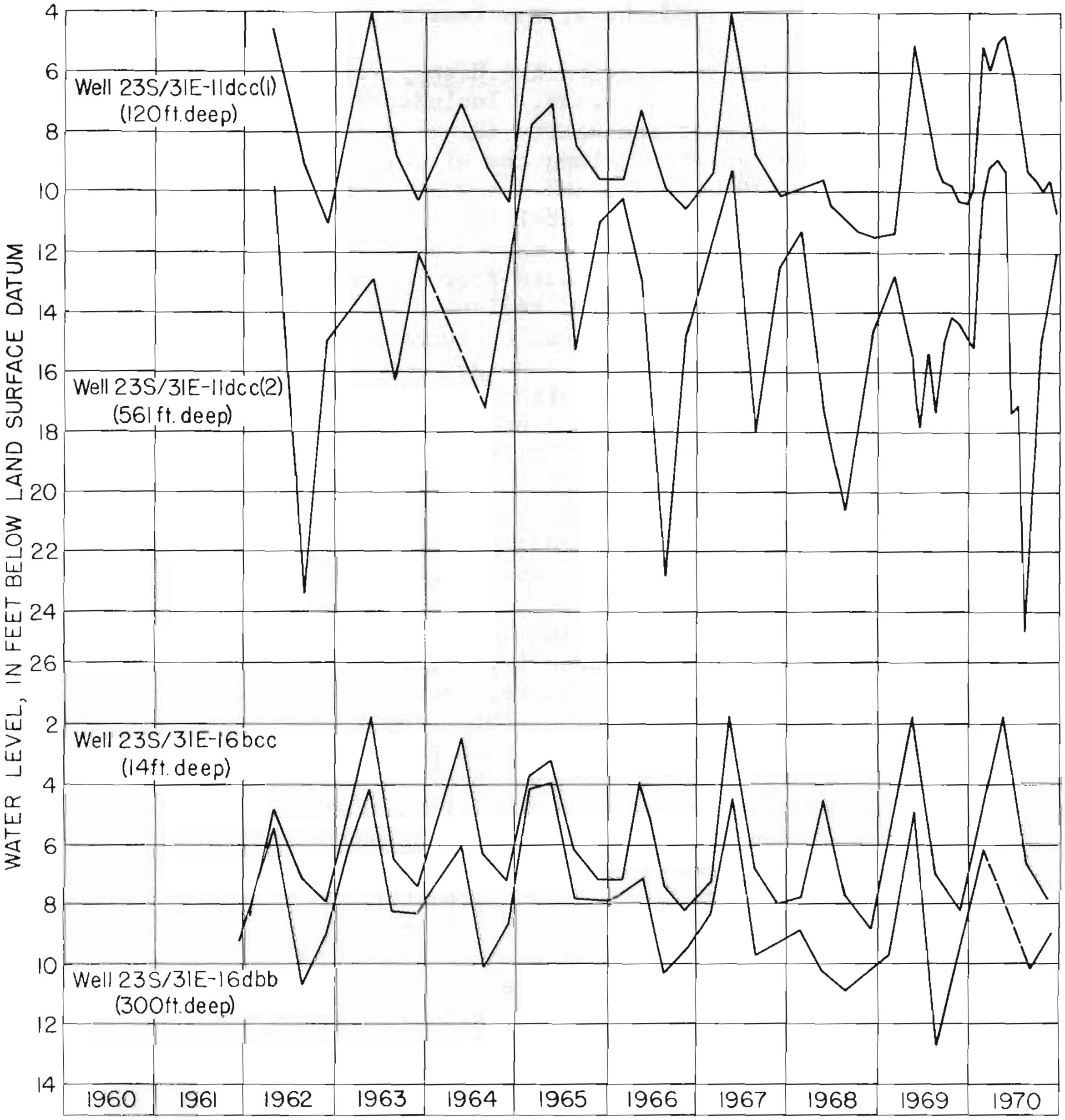

Figure 8.--Hydrographs of water levels in wells 23S/31E-11dcc1, -11dcc2, -16bcc, and -16dbb.

1011). For the approximately 1,300-square-mile area of the upper Silvies River and Sage Hen Creek drainage basins, where most recharge probably occurs, a conservative estimate of half an inch would amount to about 30,000 acre-feet of recharge per year. Of course, some of the water that infiltrates to the ground-water body seeps back to streams before reaching the valley, but at least 20,000 to 25,000 acre-feet, or the 22,000 acre-feet derived above, may remain in the bedrock aquifers.

Total ground-water recharge to the Harney Valley is the sum of recharge to various aquifers and areas. Included is about 40,000 acre-feet in the Silvies area of the valley (Piper and others, 1939, p. 74-82), about 17,000 acre-feet along the alluvial fans of small streams (Piper and others, 1939, p. 91), and a few thousand acre-feet along the eastern side of the valley. The total for these recharge sources suggests that ground-water recharge may be about 60,000 acre-feet per year, which includes about 22,000 acre-feet moving into the valley through Tertiary volcanic rocks and sediments, principally from the north and northwest. Because the valley functions as a closed system, an equal volume of water must be discharged annually. Natural discharge is largely by evapotranspiration, although in wet years some ground water may seep into East and West Forks of the Silvies River and then flow into Malheur Lake. However, the water that reaches Malheur Lake evaporates from the water surface or is used by aquatic vegetation in and around the lake. When the lake is at a high stage, it may lose some water by lateral seepage through underlying peat deposits to the local shallow ground-water body (Phillips and Van Denburgh, 1971, p. 40).

In and adjacent to Harney Valley an average of about 15,000 acre-feet of ground water is pumped annually. Records of water levels, covering a period of more than 30 years, indicate only minor changes in water levels within the valley. Therefore, any reduction in the volume of ground water in storage, as a result of pumping, must be in upland recharge areas remote from the valley. A slight lowering of water levels there would provide space for additional recharge previously rejected from the overflowing aquifer. At the same time, even a slight lowering of water levels would reduce evapotranspiration losses near recharge areas. More likely, the reduction in ground-water storage is quite small, and the accommodation of the system to pumping has been through a combination of increased recharge and a slight decrease in natural discharge in the main discharge area of the valley. The net overall effect is that a new regimen is established in which total discharge is equal to total recharge, on a long-term basis.

Movement

The regional movement of ground water is generally toward the valley from uplands on the northwest, north and east, and within the valley toward Malheur Lake (pl. 2). This pattern of movement is consistent with interpretations of the geology of the valley area and with the interpretation that the uplands are areas of recharge and the playa area near Malheur Lake is an area of discharge.

Plate 2 shows the configuration of the composite water-level surface in the confined-water zone in October 1968 and May 1969. There probably are differences in head between distinct aquifers; however, most wells are finished open hole except for short lengths of surface casing--seldom more than 100 feet. This method of construction allows water to circulate from higher head to lower head zones in the well, so that the water level in these wells represents a mean of the potentiometric heads of the several aquifers. For this reason and because differences in head between aquifers probably are small, water-level patterns shown on this map are believed to be reasonably representative of the main confined zone.

The confined-water-level contours on plate 2 depict a pattern similar to the water-table configuration for 1931-32 (Piper and others, 1939, pl. 2), although the two maps portray different features. For the northern part of the valley the two maps agree closely, but they differ for the southern part of the valley. For the southern part, plate 2 shows a much flatter gradient in the confined zone and water levels 10 to 15 feet higher than the unconfined levels shown on the older map. The contours on plate 2 do not indicate a closed depression in the water-level surface north of Malheur Lake such as was depicted on the water-table map of 1931-32. In large measure, these differences between the two water-level maps occur because the potentiometric head is higher in the deeper confined zones than in the unconfined water-table zone (Piper and others, 1939, p. 65, pl. 13).

The configuration of the confined-water-level surface in October 1968 is roughly similar to that in May 1969, the main difference being the existence of a "pumping depression" near the southeastern end of the Silvies fan in October 1968. By spring, that depression had disappeared and water-level contours crossed the area in a smooth pattern.

Ground Water in Storage

Well-log records and other subsurface geologic data at hand suffice for reasonably dependable estimates of ground-water storage in the Silvies fan area, but not elsewhere. In that fan area, the volume of ground water in storage in a 100-foot-thick zone (from about 40 to 140 feet in depth) of the confined alluvial aquifer averages about 11 percent of the gross volume. On this basis, the 56-square-mile northern half of the fan, potentially one of the most productive ground-water areas in the valley, contains about 400,000 acre-feet of water in the 100-foot zone. The volume of water in storage elsewhere in the northern part of the valley probably is less than half this amount per unit area, and probably is still less in the southern part of the valley.

Data are inadequate to make any valid estimates of the volume of water stored in the Tertiary volcanic and sedimentary rocks. The sedimentary beds are highly lenticular and grade in short distance from pervious sand and gravel to tuff and clay. The volcanic rocks are probably more extensive and consistent than are the sediments; however, the cindery and scoriaceous zones and fractures that can store water are highly erratic in occurrence. Over a broad area, the specific yield of the bedrock probably ranges between 1 and 5 percent, but it may be much greater locally, especially in the northwestern part of the study area.

Fluctuations of Water Levels

As in most areas of Oregon, water levels in wells in the Harney Valley fluctuate seasonally, being highest in early spring and lowest in late summer and autumn. During wet seasons, water levels rise largely in response to additions of water to storage, and water levels decline owing to the movement and withdrawal of water by natural discharge and by pumping during summer.

A number of shallow wells tapping unconfined water in the uppermost part of the alluvium have been measured periodically for many years (figs. 9, 10). Hydrographs of these wells all show the same patterns--generally a rise to within 3 or 4 feet below land surface in spring and a decline to 8 to 10 feet below land surface in autumn. During extremely wet years, some water levels rise to within a foot of land surface; conversely, in driest years they may fall to more than 10 feet. The deeper, confined-water wells in Harney Valley show fluctuation patterns similar to those of the shallow wells, but commonly the fluctuations are greater (figs. 9, 10). Table 3 shows the range of water-level fluctuations for observation wells in the area; both confined and unconfined levels are represented.

In most areas, water levels recover in spring to or near those of the previous spring, indicating little or no decline of water levels in any single year. In contrast, water levels in wells 24S/34E-31bac (91 feet deep) and -31cbd (110 feet deep) declined progressively from 1965 to 1968--a total decline of about 6 and 4 feet, respectively (fig. 11). This decline suggests some potential overdraft of the aquifer, but in both wells water levels rose in the spring of 1969--in well -31bac to near its 1962-64 levels, and in well -31cbd to about 0.5 foot above its 1968 level. Should water levels in this area, north of Crane, decline progressively in the future, overdraft would be suggested, especially because of the inferred small dimensions of the local alluvial aquifer.

Flowing Thermal Water

Waters having a temperature warmer than about 15°F (8°C) above the mean annual air temperature at the site are generally considered to be thermal (Waring, 1965, p. 4). According to National Weather Service records, the mean annual temperature at Burns is about 48°F (9°C), but the temperature of shallow, unconfined ground water sampled in the Harney Valley generally ranged from about 50° to 55°F (10° to 13°C) (table 5). Therefore, in this report, any water warmer than 65°F (18°C) is considered to be thermal.

In the Harney Valley area, thermal water potentially flows--that is, it discharges from flowing wells and from thermal springs. Necessary features are an intake area at higher altitude than the area of artesian wells and an impervious layer overlying and confining the artesian aquifer.

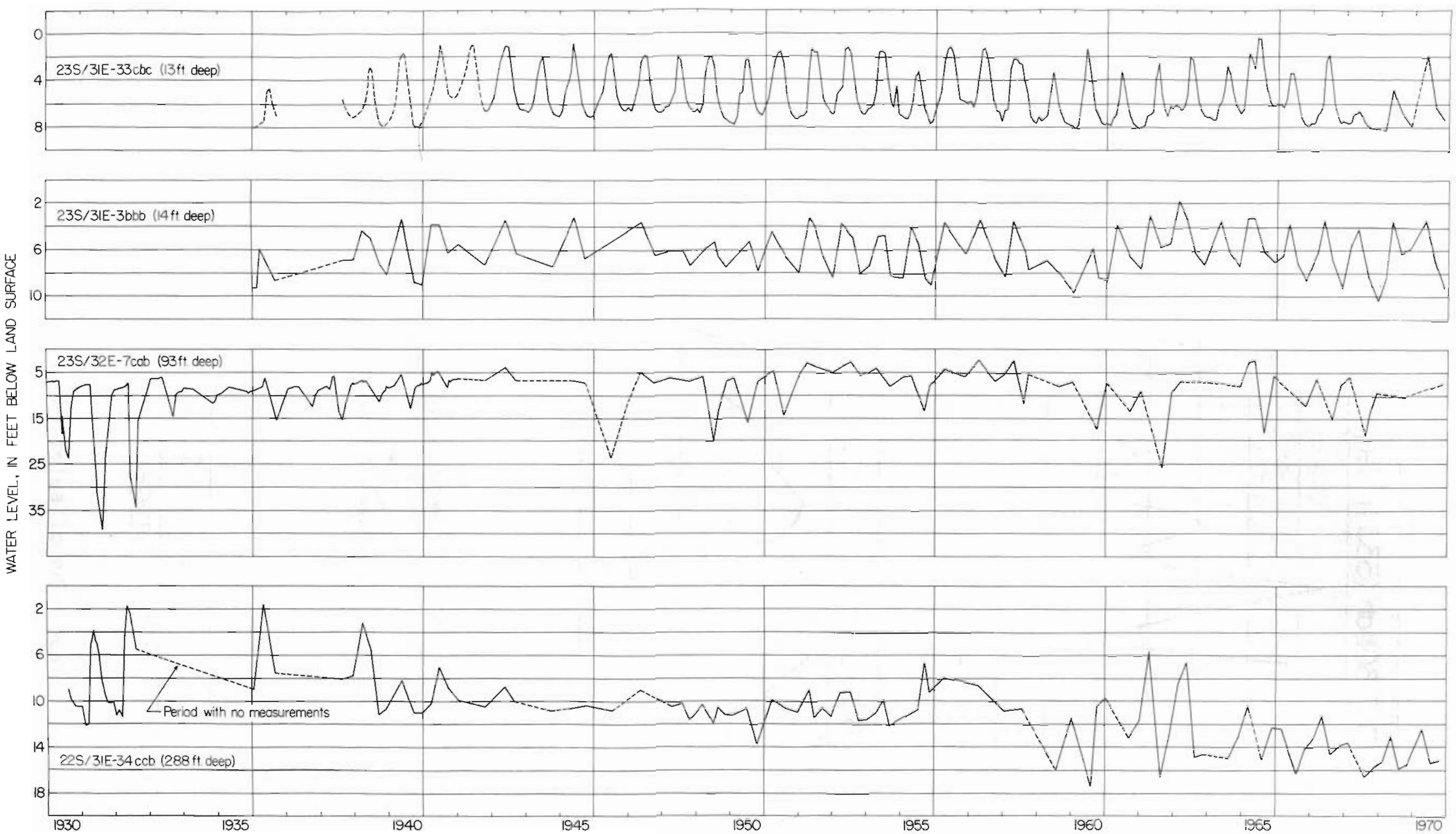

Figure 9.--Hydrographs of selected observation wells.

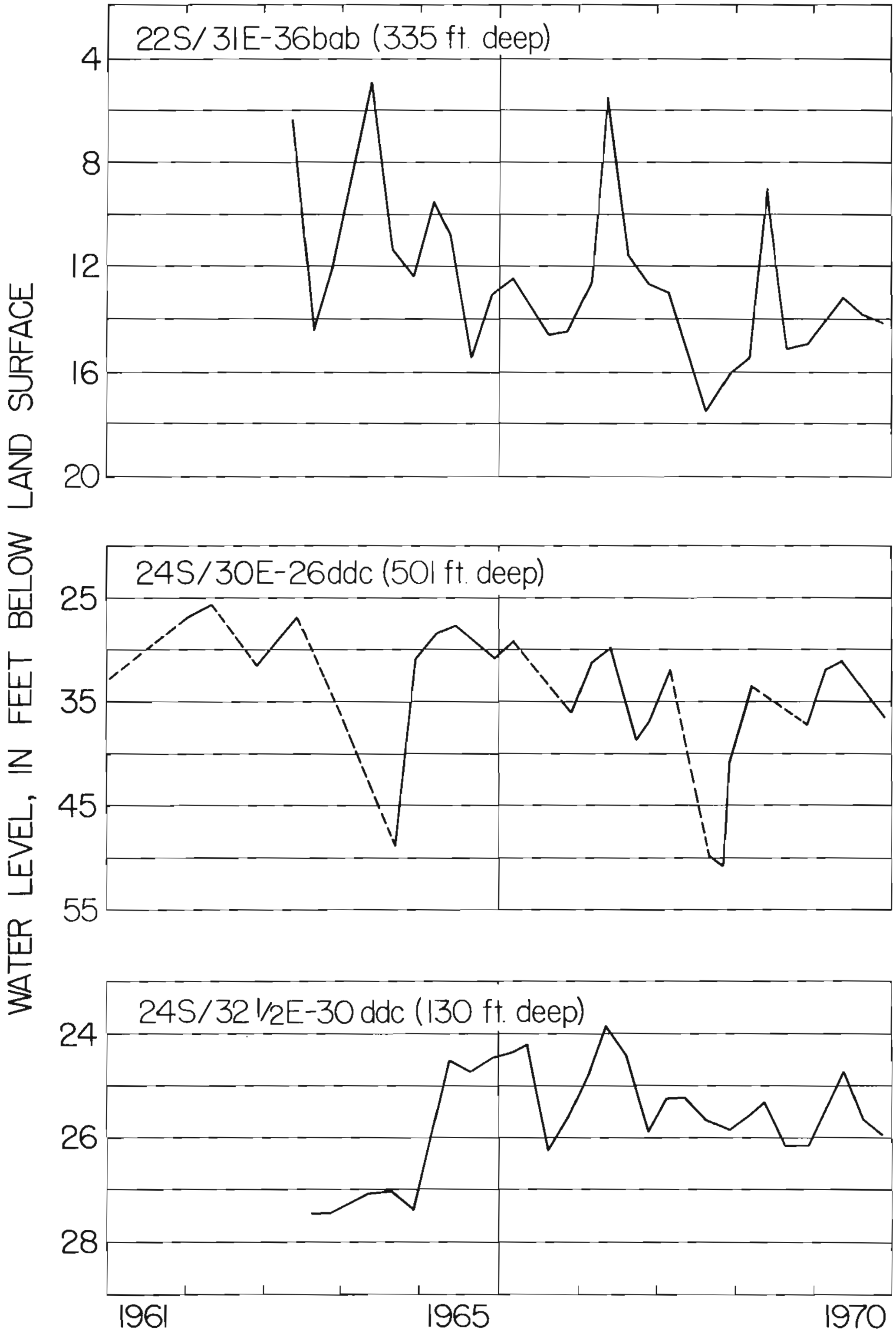

Figure 10.--Hydrographs of selected observation wells.

Table 3.--Range of water-level fluctuations in observation wells in Harney Valley

Well number	Depth (feet)	Aquifer[1/]	Date observations started	Depth to water, below land surface	
				Highest	Lowest
22S/30E-27ddc	127	Tvs	1966	46	52
22S/31E-28ddb	490	Qal, Tvs	1966	18	27
22S/31E-34ccb	288	do	1930	6	17
22S/31E-36bab	335	do	1963	5	15
22S/32½E-30cdb	647	do	1966	4	10
22S/33E-27adc	833	Tvs	1966	12	24
23S/31E-3bbb	14	Qal	1936	2	10
23S/31E-5aac	400	Qal, Tvs	1962	11	28
23S/31E-11dcc1	120	Qal	1959	4	11
23S/31E-11dcc2	561	Tvs	1959	7	23
23S/31E-14aab	17	Qal	1936	2	13
23S/31E-16bcc	14	do	1936	1	9
23S/31E-16dbb	300	Qal, Tvs	1930	4	13
23S/31E-33cbc	13	Qal	1936	0	9
23S/32E-3aad	220	do	1965	8	11
23S/32E-7cab	93	do	1928	2	38(?)
23S/32E-28aba	140	do	1966	18	43
23S/32E-29adb	240	do	1967	17	34
23S/32E-30ddd	19	do	1936	6	Dry
23S/32½E-1bbb	350	Qal, Tvs	1965	6	14
24S/30E-7cdd	347	Qal, Tvs	1966	8	20
24S/30E-26ddc	501	Tvs	1960	26	51
24S/31E-28bcc	19	Qal	1936	3	13
24S/32½E-30ddc	130	do	1963	24	27
24S/34E-31bac	91	Tb	1959	24	33
24S/34E-31cbd	110	Qal	1963	20	27
25S/31E-4cba	170	Tvs	1962	36	36
25S/31E-29ccb	209	do	1964	71	72

1/ See plate 1 for explanation of aquifer symbols.

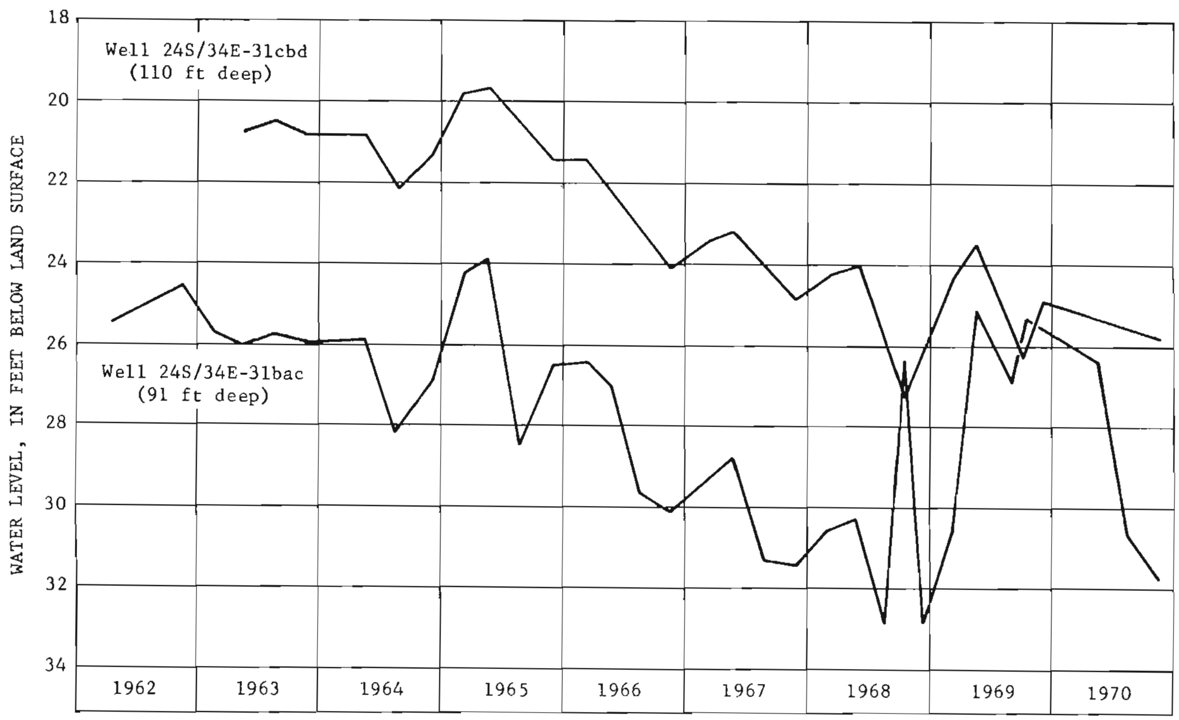

Figure 11.--Hydrographs of observation wells 24S/34E-31bac and -31cbd.

The recharge areas in the mountains north, west, and east of Harney Valley provide one of the essential features for an artesian system. The many beds of clay, tuff, and fine sediments sandwiched between water-bearing beds in the bedrock and valley fill serve as confining layers. If most of the hydraulic head in the confined aquifers were not dissipated as the water moves through the beds, artesian wells would occur throughout most of the valley. The two extensive areas of flowing water are near Hines and along the eastern edge of the valley; elsewhere in the valley, flowing wells are scattered widely.

The Hines warm-water subarea

Several springs and flowing wells near Hines yield water at temperatures ranging from about 70° to 80°F (21° to 27°C). The locations and temperatures of these springs and wells are shown in figure 12.

Confined thermal water extends at least 4 miles south from sec. 26, T. 23 S., R. 30 E. Springs and flowing wells occur principally along the valley margin, but several wells are about a mile out into the valley. Several springs issue from scoriaceous zones in the younger volcanic rocks at the edge of the hills, and a number of wells tap the thermal zone in these same rocks. Although the wells range from less than 100 feet to as much as 566 feet deep, similarities in hydrostatic head and water quality suggest that they tap a common aquifer. This aquifer evidently has an elevated recharge and storage area to the northwest and is confined by pumice and tuff layers in the volcanic rocks. Water levels in the flowing wells correspond closely with those in the Burns municipal wells 2 miles north, and with those at the Agricultural Experiment Station 2 miles east. This coincidence of water

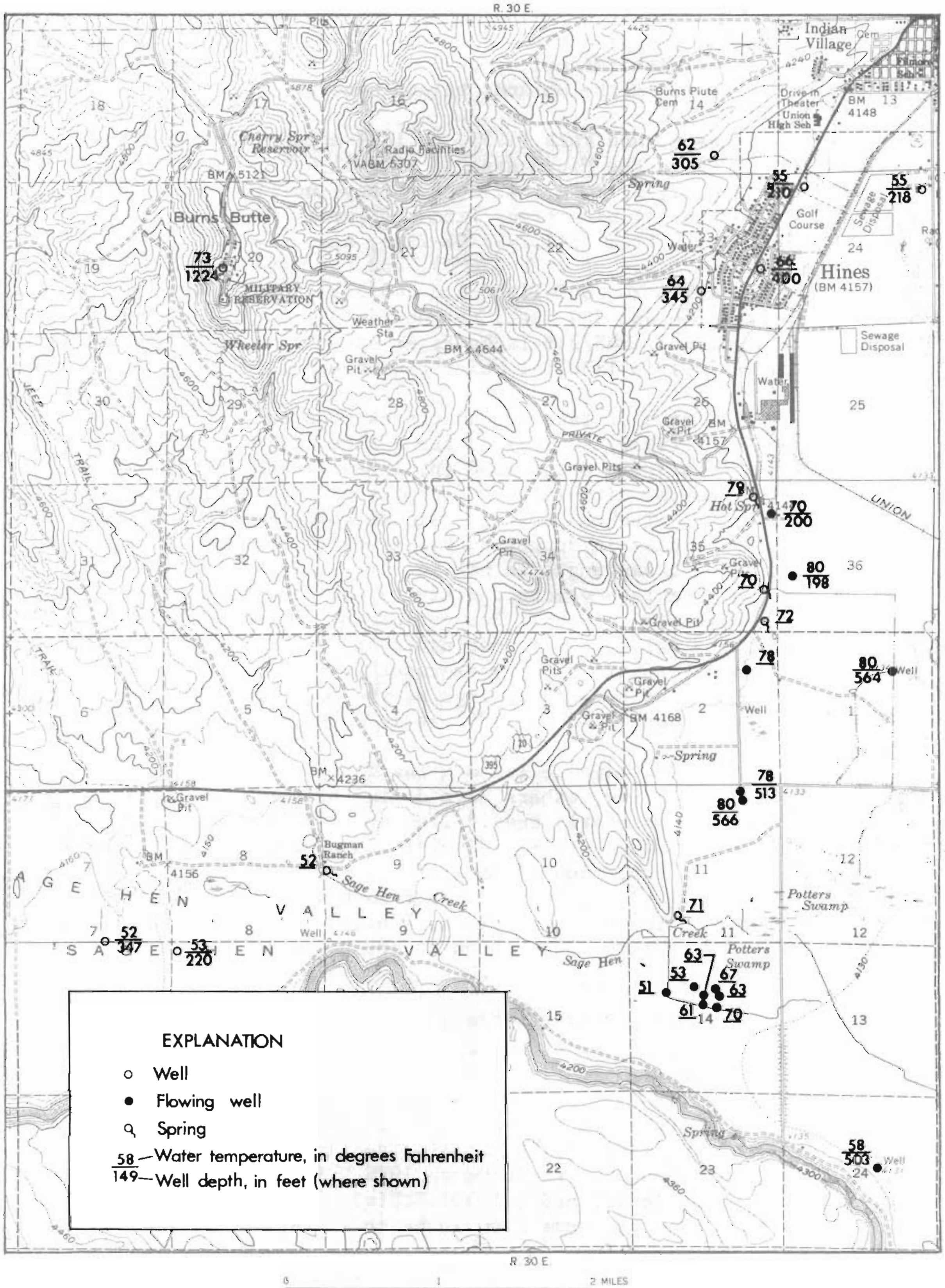

Figure 12.--Temperatures of water from wells and springs near Hines.

levels suggests that the confined thermal water near Hines is hydraulically continuous with the main ground-water body which, to the east and north, extends from the uplands to and beneath Harney Valley.

Piper, Robinson, and Park (1939, p. 103) noted that the warmest water (82°F, 28°C) in the Hines area in 1930-31 was from an 80-foot well in the NW¼NE¼ sec. 2, T. 24 S., R. 30 E. They indicated that temperatures diminished in all directions from that well. During the present investigation, water from well 24S/30E-2aac, near the well cited by Piper, had a temperature of 78°F (26°C), and the warmest waters (80°F, 27°C) were from wells 24S/30E-11abd and 24S/31E-1adb. These wells also are the deepest, 566 and 564 feet, respectively, in the Hines area. In one of these two, well 24S/31E-1adb, Piper noted a constant temperature of about 80°F (27°C) in 1930, at which time the well was 478 feet deep.

The adjacent area of late volcanic rocks was suggested by Piper, Robinson, and Park (1939, p. 103) as the source of heat for this thermal area. They alternatively postulated (p. 106-107) that the ground water might gain its heat by circulating to depths of several hundred feet along a fault zone. The concept of residual volcanic heat associated with the volcanic rocks is supported by Greene's mapping of cinder cones in the area. Recent mapping does not identify a fault along the valley margin, although the late volcanic activity may have been localized by a fault zone no longer evident. Because of the steep geothermal gradient in Harney Valley, it is not necessary to postulate circulation to great depths to explain the temperatures found in waters near Hines. The water issuing from several springs at the edge of the valley may be heated to temperatures of 70°F (21°C) as it moves toward the Hines area.

Heads in the area have declined a few feet since 1930-31 so that some wells no longer flow, others have diminished in flow, and several springs have ceased or nearly ceased flowing. Wells 23S/30E-26add and -36bbc, which flowed when drilled several years ago, no longer flow. According to the owners, flow of most of the other wells has diminished since they were drilled, and well 24S/30E-1adb was deepened from 478 to 564 feet in 1964 to increase its yield. Neither accurate flow measurements nor precise data on fluctuation of potentiometric head are available for the wells.

The flow of spring 23S/30E-35dd(s), estimated to be about 300 gpm in May 1931, declined to about 100 gpm in March 1968 and to about 25 gpm in June 1968 (table 4). The flow of spring 23S/30E-35da(s) declined from about 300 gpm in 1930 to about 80 gpm on March 5, 1968, and to about 5 gpm on June 6, 1968; there was no flow at the spring site in May 1969. The flow of spring 23S/30E-35aa(s) declined from an estimated 500 gpm in 1930-31 to about 10 gpm in March 1968. In contrast, measurements of springs 24S/30E-11cd(s) and 24S/30E-9cb(s), 2 or 3 miles to the south, indicate about the same flow in March and April of 1968 as in 1930-31.

The area of declining head seems to be localized within a mile or two of the northeast corner of sec. 35, T. 23 S., R. 30 E. Piper, Robinson, and Park (1939, p. 103) indicated that the static water level

Table 4.--Discharge and temperature data for springs in the Hines warm-water subarea

Location number	Date	Discharge (gpm)	Temperature (°F)	Temperature (°C)
23S/30E-35aa(s)	Sept. 4, 1930	1/ 500	73-80	23-27
	May 29, 1931	1/ 500		
	Mar. 5, 1968	10	79	26
	Apr. 4, 1968	10	76	24
23S/30E-35da(s)	Sept. 3, 1930	1/ 300	78	26
	May 29, 1931	1/ 300		
	Mar. 5, 1968	80	64	18
	Apr. 4, 1968	18	70	21
	May 6, 1968	9		
	June 6, 1968	5		
23S/30E-35dd(s)	Sept. 3, 1930	1/ 300		
	May 29, 1931	1/ 300		
	Mar. 5, 1968	100	63	17
	May 6, 1968	70		
	June 6, 1968	27		
24S/30E-9cb(s)	Sept. 3, 1930	330	54	12
	May 29, 1931	250		
	Mar. 5, 1968	430	52	11
	Apr. 1, 1968	350	52	11
24S/30E-11cd(s)	Sept. 3, 1930	495	72	22
	May 29, 1931	370		
	May 6, 1968	360		
	June 3, 1968	290	71	22

1/ Estimated.

in flowing wells in this area was only a few feet above land surface and that pumping from spring 23S/30E-35aa(s) at 500 gpm was sufficient to lower the head below land surface. Thus, the decline of head in the Hines area is believed to be small, probably 5 to 10 feet. Undoubtedly, this decline resulted from the large local withdrawals from several irrigation wells, the industrial wells of the Edward E. Hines Lumber Co., and the Hines municipal wells.

Hot-water wells and springs

Hot water issues from four flowing wells (22S/32E-34aaal, -35bbb; 24S/32E-8dab; 25S/32E-7bab) and one spring (24S/33E-34cca(s)). The chemical quality of water from these sources is discussed in detail in the water-quality section. Wells -34aaal and -35bbb are about 900-1,000 feet deep and tap deep confined sand and gravel aquifers in the Tertiary sedimentary deposits. Because the wells are near the north edge of the valley in an area where no faults or young volcanic rocks have been mapped, the geologic structure and the source of heat are not readily apparent. Undoubtedly, their head is related to the south monoclinal dip of the strata from the recharge areas in the hills to the north. The high temperature (172°F, 72°C) of water from these wells may result from deep circulation along a concealed fault zone. The unusually high concentrations of boron and arsenic in the water from well -34aaal (table 6) also supports the idea that the water may be circulating deep enough to mix with water of volcanic origin.

The area of above-normal water temperatures associated with these two wells may extend at least 2 miles to the south. About a mile south, well 23S/32E-3aaa yields water at a temperature of 72°F (22°C), and about 2 miles south, well 23S/32E-13bbb yields water at 64°F (18°C). These wells are only 90 and 232 feet deep, respectively, and probably tap aquifers in valley fill. Presumably, some water from the deep hot-water aquifers is seeping upward, mixing with the shallower water and increasing its temperature.

Well 24S/32E-8dab is an oil-test well 2,812 feet deep. Water at a temperature of 115°F (46°C) flows from this well, reportedly from a confined zone at about the 2,000-foot depth. Like the other hot-water wells discussed above, water from this well may owe its high temperature to deep circulation.

An unusual flowing well, 25S/32E-7bab, about 1 mile south of the east end of Wrights Point in the northeastern part of Sunset Valley, is reported to be 1,345 feet deep and to have penetrated clay for most of that depth before reaching the sand aquifer yielding the water. About 5 gpm flows from a 1-inch discharge pipe into a series of stock tanks. The hydrostatic head may result from the low topographic site of the well, but the high temperature is less easily explained. The water has a temperature of 105°F (41°C), contains hydrogen sulfide gas, and is chemically unlike any other water analyzed in the basin. (See chemical-quality section.) If the high temperature is due to deep circulation, the water must have circulated to considerably greater depth than the zone tapped by the well. Even with the abnormally steep geothermal gradients noted on Dog Mountain (Piper and others, 1939, p. 94-96), circulation to a depth of 2,500 feet would be required for the water to reach a temperature of 41°C.

Crane Hot Springs (24S/33E-34caa(s)) issues from a large circular orifice, discharges about 100 gpm through a narrow outlet, and flows into the sagebrush where it sinks into the ground. Temperature of the spring was 176°F (80°C) in September 1968; other measurements of its temperature and flow are given in table 5. At one time, water from the spring was utilized for a small natatorium; ruins of the swimming pool and other buildings are nearby. This hot spring is just north of a cinder cone that forms the main mass of Saddle Butte. The unusually hot water of the spring may result from its proximity to the young cinder cone.

Table 5.--Discharge and temperature data for Crane Hot Springs

Date	Discharge (gpm)	Temperature (°F)	Temperature (°C)
1903	110		
Aug. 13, 1907	180		
Oct. 10, 1930	1/180	126	52
Apr. 2, 1968	100	2/115	46
May 8, 1968	110	2/118	48
June 6, 1968	110	2/117	47

1/ Estimated.

2/ Measured at outlet from spring pool.

Other flowing wells

Flowing wells yielding water of normal temperature are found along the west edge of the Crow Camp Hills and at scattered places in the valley. The most extensive area is along the east edge of the valley, from sec. 7, T. 23 S., R. 34 E., to sec. 32, T. 24 S., R. 34 E. Flowing wells in this area include wells 23S/34E-7cac, -7dbb, -32aca; 24S/34E-31ada; and several small-diameter wells in the southern part of sec. 32, T. 24 S., R. 34 E., that were not scheduled during the present investigation. In all these wells, the head is small (reported to be about 15 feet above land surface for well 23S/34E-7cac), and most are equipped with pumps for water supply. Flow results from the combination of a relatively high recharge area in the Crow Camp Hills, confining layers in the volcanic rocks forming the hills, and the damming effect of the fault at the west edge of the hills.

Two flowing wells (24S/32½E-13acb and 24S/33E-18bca) near Ninemile Slough are in a topographically low area. Water from both wells is of about normal temperature (55°F, 13°C), is somewhat mineralized, and contains hydrogen sulfide gas. (See water-quality section.) Well -13acb is 242 feet deep and taps a bed of coarse, flat, subangular gravel. The well barely flows at land surface and is equipped with a pump to deliver water for irrigation. The driller's log shows that the aquifer is overlain by a thick sequence of blue and gray clay which serves as a confining layer. According to reports, other flowing wells, some producing water too mineralized for use, have been drilled and abandoned along Ninemile Slough a few miles west of this well.

Another well, 24S/30E-24acd, about 3 miles south of the Hines warm-water area, probably flows because of hydrostatic pressure from recharge in the adjacent uplands to the southwest. According to the driller's log, this 503-foot-deep well penetrated a 364-foot section of sand, gravel, clay, and "chalk" before reaching the volcanic-rock aquifer. The water has a temperature of 58°F (14°C)--normal for water from that depth. Reportedly, the well flowed 250 gpm when drilled, but heavy pumping lowers the hydrostatic head during the irrigation season and several months are required for recovery.

The earliest settlers in the Harney Valley recognized that geologic and topographic conditions were favorable to the development of flowing wells. I. C. Russell made a reconnaissance of the area in the summer of 1901 and described two deep wells drilled in search of flowing water (Russell, 1903, p. 40-41). One, 507 feet deep, was drilled in 1896 in sec. 2, T. 23 S., R. 32½ E., and water from a zone between depths of 200 to 300 feet flowed at the surface. The other well, 848 feet deep, was drilled in 1893 in sec. 13, T. 23 S., R. 31 E., and water at about 350 feet depth flowed at the surface. The head in both wells was apparently small, because both wells ceased flowing after a short time and efforts to restore their flow were unsuccessful (Russell, 1903, p. 40; Piper and others, 1939, p. 109).

Confined ground water occurs in all but the shallowest aquifers beneath Harney Valley. However, drilling experience to date suggests that hydrostatic head is generally not great enough at most places to produce flowing wells. With the exception of the few wells in the Hines area, already described, the flow of most wells has been small. It may be possible to construct small flowing wells in topographically low areas, such as along Ninemile Slough, but despite the favorable geologic structure, wells with large flows are unlikely in Harney Valley.

Quality of the Water

Quality (chemical character) of water in Harney Valley ranges from excellent to poor. Stream water generally is of excellent quality, as is ground water around the margins of the valley. The quality of ground water deteriorates toward Malheur Lake; near the lake the water is so mineralized that it is unsuitable for drinking, and at some places unsuitable for watering livestock.

Dissolved constituents listed in table 6 are reported in milligrams per liter, 1 mg/l (milligram per liter) being a weight of 1 milligram of the particular constituent dissolved in 1 liter of water. In the range generally found dissolved in waters, mineral concentrations in milligrams per liter are numerically equivalent to values in parts per million, which formerly was used in reporting chemical-quality data (Piper and others, 1939, appendix).

Chemical analyses also may be expressed in milliequivalents per liter, based on the concentrations of the dissolved materials in chemical equivalents or combining weights. In water, one equivalent of a positively charged constituent (cation) potentially may combine with one equivalent of a negatively charged ion (anion); therefore, in a given water the total equivalents of cations equal the total of anions. For Harney Valley, milliequivalents are not reported in table 6 but were used to classify the water by chemical types and to prepare plate 3 and figure 14.

Water is classified by chemical types according to the predominant cations and anions dissolved in it. Thus, a calcium bicarbonate water is one in which at least 50 percent of the cations are calcium and at least 50 percent of the anions are bicarbonate. If no constituent is predominant, two cations or anions are used in designating the type of water. For example, the water from well 23S/31E-5aac is a calcium magnesium bicarbonate water.

Surface Water

Water in the streams is of generally excellent quality because it is largely snowmelt that picks up only a small quantity of dissolved minerals en route to the valley. Perhaps a small amount of dissolved minerals is added by ground-water seepage that returns to the Silvies River, the only stream receiving influent seepage within the valley. A check of the Silvies River downstream from Burns in July 1969 showed only a small increase in specific conductance[3/], from 240 at the bridge on Highway 20 northeast of Burns to 300 in West Fork at the east side of sec. 31, T. 24 S., R. 32 E., and 300 in East Fork at the south side of sec. 16, T. 24 S., R. 32 E.

In parts of the valley, soils are covered with an alkali crust in large areas. Water draining over such areas will dissolve and carry off part of the alkali. In May 1969 water flowing into the road ditch from an alkali-encrusted field in the NE¼ sec. 11, T. 24 S., R. 30 E., had a brown color and a specific conductance of 900 micromhos. In contrast, water in the West Fork Silvies 1½ miles east had a specific conductance of only 245 micromhos. Most of the alkali being carried in the water probably moves only short distances, because most of the drainage water

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3/ Specific conductance, a measurement of the ability of water to conduct an electrical current, is related to the dissolved solids in the water and increases roughly in proportion to the increase in those solids.

evaporates in ditches or nearby fields. There is no evidence to suggest that alkali from such fields reaches the Silvies River.

Ground Water

Ground water in the principal confined zone ranges from a calcium bicarbonate type of low mineral content to sodium chloride and sodium bicarbonate types of moderately large mineral content. Analyses of 26 samples of ground water from deeper wells and springs in the area are given in table 6, and the areal variations in water quality are shown on plate 3.

Suitability for use

Domestic water.--Several constituents commonly dissolved in water may affect its usefulness for domestic purposes. In excessive amounts, sodium, chloride, sulfate, and bicarbonate each may impart a disagreeable taste to the water. Dissolved iron in concentrations of more than 0.3 mg/l also may affect the taste, and even less iron may stain plumbing fixtures, utensils, and clothing laundered in the water. Hardness, caused largely by calcium and magnesium, affects the amount of soap used for laundry and causes the formation of scale in hot-water pipes or in utensils in which water is heated. Most of the water sampled in the Harney Valley area is soft (hardness less than 60 mg/l) but that from several wells is very hard (more than 180 mg/l). Most of the hard waters also contain one or more other constituents in amounts that are undesirable for domestic use.

The U.S. Public Health Service (1962) has recommended maximum concentrations of dissolved constituents in drinking water used by interstate carriers, as follows:

Constituent	Maximum concentration (mg/l)
Iron (Fe)	0.3
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1/ 1.2
Arsenic (As)	.05
Nitrate (NO_3)	44
Dissolved solids	500 (1,000 acceptable)

1/ Based on annual average maximum daily air temperature at Burns.

Table 6.--Chemical analyses of water from representative wells and springs in the Harney Valley area

Sample no.	Location number	Depth of well (feet)	Date of col-lection	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Arsenic (As)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Calculated	Hardness as $CaCO_3$: Calcium magnesium	Noncarbonate	Specific conductance (micromhos per cm at 25°C)	pH	Temperature (°F)	(°C)	Percent sodium	Sodium-adsorption-ratio (SAR)
1	22S/30E-27ddc	127	7-23-68	55	0.01	10	4.8	13	4.5	82	0	5.2	2.5	0.2	2.5	--	0.05	139	138	44	0	161	7.5	57	14	44	0.9
2	22S/31E-34aaa	725	do	60	.04	23	4.8	22	5	124	0	16	8.5	.4	3.3	--	.11	193	204	77	0	261	7.7	58	14	41	1.1
3	22S/32E-34aaa1	1,000	9-13-68	89	.03	1	.2	157	1.8	49	92	89	38	2.8	0	0.06	3.99	515	499	4	0	716	9.5	172	72	99	36
4	22S/32½E-30cdb	647	7-26-68	61	.06	16	4.4	39	3.7	154	0	12	5.5	.6	1.9	--	.11	211	220	58	0	279	8	--	--	61	2
5	-36aab	182	7-25-68	63	.04	24	8.1	40	8	190	0	23	7.5	.4	.4	--	.11	257	268	94	0	367	7.5	58	14	51	1.8
6	23S/30E-23cda	345	7-24-68	60	.05	15	5.7	35	6.9	128	0	18	13	.5	3.8	--	.53	212	221	61	0	289	7.8	64	17	58	1.2
7	-35aad	200	do	55	.02	11	2	33	4	105	0	14	7	.5	1.5	--	.38	179	180	36	0	222	7.8	76	25	69	2.4
8	-35ddd(s)	Spring	9-13-68	46	.02	8.2	1.4	35	3.2	92	0	16	7	.6	2.1	--	.23	167	165	26	0	210	7.5	72	22	74	.81
9	23S/31E-5aac	400	7-23-68	58	.30	25	10	13	4.1	143	0	14	3	.4	1.4	--	.09	190	199	104	0	270	7.4	52	11	24	.56
10	-24aac	114	7-24-68	40	.28	21	6.2	32	4.3	164	0	15	5	.3	.2	--	.16	204	205	78	0	295	7.7	51	11	49	1.4
11	23S/32E-7cab	93	6-12-69	51	--	21	4.5	22	3.6	137	2	3.6	3.5	.4	.2	.01	--	182	179	71	0	226	8.3	51	11	43	1.25
12	-28acd	250	7-23-68	52	.34	5.4	3.9	172	5.6	472	0	.4	16	.8	1.9	--	1	511	491	30	0	771	7.6	60	16	93	14
13	24S/30E-1abd	564	9-11-68	46	0	8.8	1.4	31	2.9	93	0	12	5	.5	1.1	--	.06	158	155	28	0	194	8.1	80	27	72	2.6
14	24S/32E-5aad	270	7-23-68	44	3.2	5.9	4.2	160	5.8	450	0	3.2	7	1.1	2.1	.04	1.5	458	456	32	0	684	8	55	13	92	12
15	-8dab	2,812	9-12-68	72	.20	.8	.2	135	1.6	94	84	29	11	12	.2	--	4.11	427	396	3	0	602	9.6	115	46	99	39
16	24S/32½-13acb	242	7-24-68	53	.21	5.4	4.6	255	14	504	0	2.6	117	6	14	.04	8.9	726	729	32	0	1,170	7.5	58	14	95	19
17	-22bcc	--	6-11-69	53	--	65	44	113	18	552	0	105	35	.4	5.1	--	--	762	711	343	0	1,040	7.9	54	12	44	2.9
18	-30add1/	185	do	60	2.3	12	40	724	33	1,430	0	0	478	1.2	58	.00	6.7	1,990	2,120	194	0	3,200	7.8	58	14	89	23
19	24S/33E-24aac	340	7-25-68	60	.89	97	32	706	28	348	0	269	975	.5	1.4	--	4.8	2,360	2,350	374	88	4,000	7.8	--	--	81	16
20	-34cca(s)	Spring	9-12-68	80	.02	3.8	.2	170	3.6	199	6	81	78	9.3	0	--	6.2	545	536	10	0	814	8.3	176	80	97	23
21	24S/34E-31bac	91	6-12-69	53	--	65	19	37	4.5	249	0	55	41	.2	5.1	.00	--	410	403	240	36	611	7.9	53	12	27	1.12
22	-31dda	305	do	53	--	32	8.1	20	3.5	170	0	11	4.5	.3	2.9	.00	--	205	219	114	0	296	8	53	12	30	.9
23	25S/32E-7bab	1,345	do	54	--	.5	.2	386	4.4	674	144	8	9	19	.1	.00	--	938	957	2	0	1,450	9.3	105	41	100	120
24	-24bdb	60	do	40	--	95	177	662	31	635	0	1,550	195	.6	25	.00	--	3,110	3,090	965	444	3,960	7.4	51	11	61	9.5
25	-35bdb	400±	do	72	--	6.4	36	835	28	2,000	0	0	236	1.4	65	.00	--	2,240	2,260	164	0	3,300	7.6	--	--	92	35
26	25S/32½E-25aab	--	do	52	--	11	22	681	19	888	0	5.2	630	1.4	19	.00	--	1,900	1,880	118	0	3,030	7.6	53	12	93	29

1/ Also contained 6.1 mg/l of aluminum, 0.18 mg/l of manganese, 0.04 mg/l of copper, and 0.07 mg/l of zinc.

Waters from five wells have dissolved-solids concentrations greater than the acceptable limit of 1,000 mg/l and four others greater than the recommended limit of 500 mg/l. Waters from three of these wells contain excessive chloride, two contain excessive nitrate, and two contain excessive sulfate. Waters from three wells that are otherwise suitable have excessive iron. In five wells, concentration of fluoride was much above the permissible limit; in two others, it was slightly above the limit.

Suitability for irrigation.--According to the U.S. Department of Agriculture (U.S. Salinity Laboratory Staff, 1954), the most important characteristics in determining suitability of water for irrigation are (1) total concentration of soluble salts, (2) the relative proportion of sodium to other principal cations, and (3) the concentration of boron. Specific conductance of water gives a general indication of the concentration of soluble salts. The sodium (alkali) hazard may be shown by the sodium-adsorption-ratio (SAR), determined by the formula

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

where the sodium (Na^{+}), calcium (Ca^{++}), and magnesium (Mg^{++}) values are in milliequivalents per liter.

In table 6, SAR values are given for waters from Harney Valley, and in figure 13 these waters are classified for irrigation use by degrees of hazard. Most of the 26 samples of water analyzed are of good quality for irrigation, but several are in the high or very high sodium-hazard class and 10 also have high or very high salinity hazard.

In small concentrations, boron is essential for plant growth; however, a slightly larger concentration may be harmful to many plants. Boron-sensitive plants may be affected by water containing more than 0.33 mg/l of boron, and water containing boron concentrations exceeding 3.75 mg/l may be unsuitable for even the most tolerant plants. Sensitive plants include most fruit and nut trees, and some garden plants. Tomatoes, potatoes, most cereal grains, and many garden vegetables are in the semitolerant class. Tolerant plants include alfalfa, sugar beets, and garden vegetables such as onions, cabbage, lettuce, and turnips.

In the 18 samples of water analyzed for that constituent, boron ranged from 0.05 to 8.9 mg/l. Six samples contained more than the maximum concentration that can be tolerated by alfalfa and other tolerant crops, and 10 samples contained more than 0.33 mg/l.

Areal variations in chemical quality

The general areal variations in quality of ground water in the principal aquifer, with particular reference to suitability for irrigation, are shown on plate 3. Around the north and east sides of the valley, most of the ground water is of the calcium bicarbonate type, is relatively low in dissolved solids and hardness content, and is suitable for most uses.

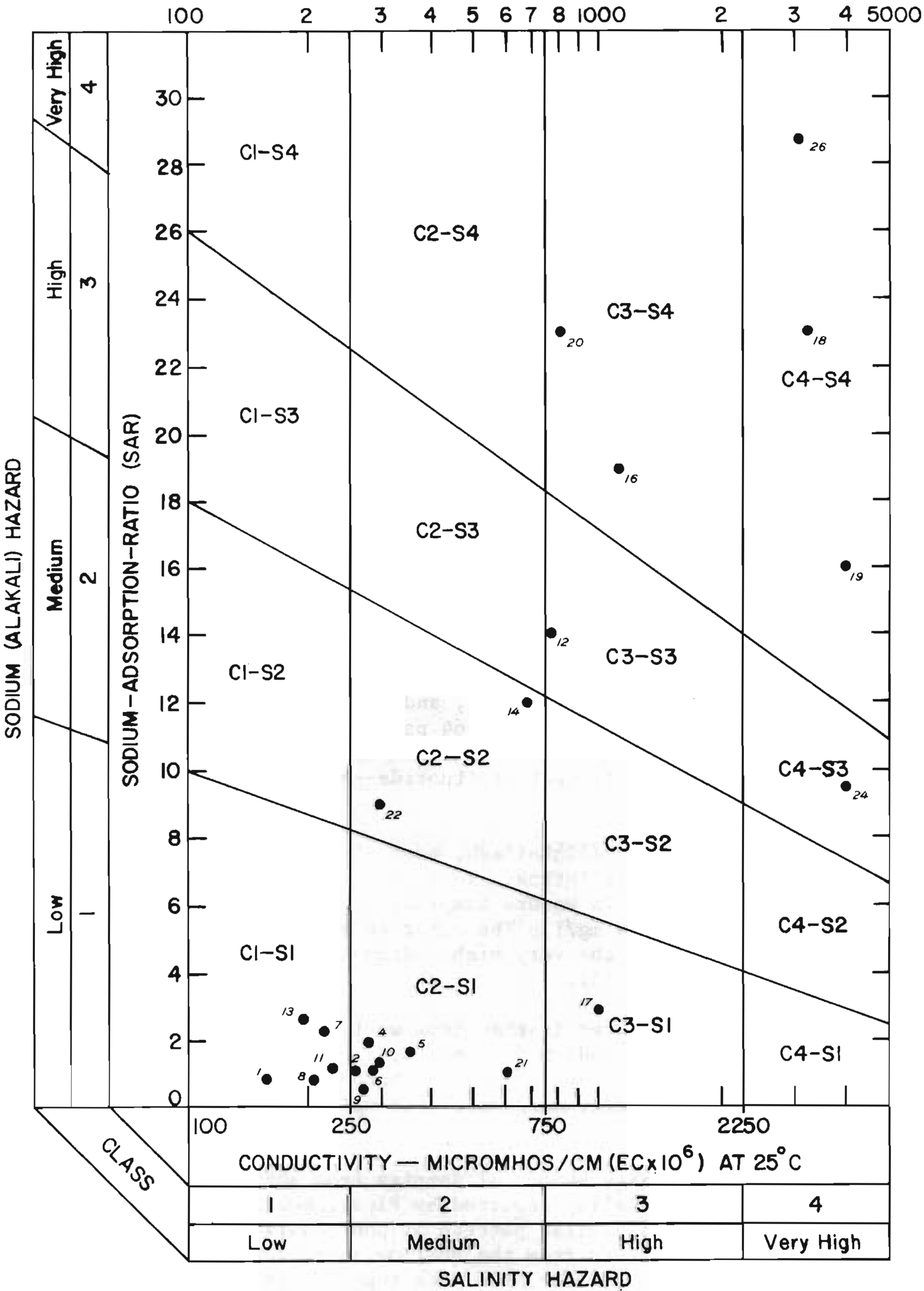


Figure 13.--Classification of irrigation waters (after U.S. Salinity Laboratory Staff, 1954, p. 80). Numbers of plotted circles correspond to sample numbers in table 6.

Water from the flowing warm-water area near Hines, including the Hines municipal well 23S/30E-23cda, is of the sodium bicarbonate type, is relatively low in dissolved solids content, and is suitable for domestic and irrigation use.

Toward the southeast end of the Silvies fan, water from wells 23S/32E-28acd and 24S/32E-5aad is of the sodium bicarbonate type, very soft, and moderately mineralized. The concentration of sodium is higher than is desirable for irrigation, particularly on clay soils that are high in potassium content, such as those in Harney Valley.

Toward the south, in the Lawen area and north of Malheur Lake, most waters are more highly mineralized than is desirable for a domestic supply. They are of several types--sodium bicarbonate, sodium bicarbonate chloride, sodium chloride, sodium sulfate, and calcium sodium bicarbonate. Sodium-adsorption-ratio values are high, most waters are excessively hard, and some have excessive iron content. Waters of unusual types that occur in this area include the only sulfate-type water found, that from well 25S/32E-24bdb, which contains 1,550 mg/l of sulfate, 195 mg/l of chloride, and a hardness of 965 mg/l. Water containing uncommonly large concentrations of chloride issues from wells 24S/32½E-30add (478 mg/l), 25S/32E-35bdb (236 mg/l), and 25S/32E-25acb (630 mg/l).

One of the more unusual waters is from a flowing well (25S/32E-7bab) just south of the east end of Wrights Point. In that water, sodium is more than 99 percent of the cations, and the calcium and magnesium content is negligible. Anions are 64 percent bicarbonate and 28 percent carbonate, with small amounts of sulfate and chloride. The pH is 9.3, and the water contains 19 mg/l of fluoride--by far the highest of any water sampled.

Water from well 24S/32½E-13acb, east of the Lawen area, also has several unusual characteristics. That water has the highest concentration of boron found in waters sampled, 8.9 mg/l, and also a high amount of arsenic, 0.04 mg/l. The water is being used for irrigation, although it is in both the very high sodium-hazard and the high-salinity classes (fig. 13).

Another unusual water is that from well 24S/32½E-30add, which had high concentrations of sodium (724 mg/l), bicarbonate (1,430 mg/l), chloride (478 mg/l), nitrate (58 mg/l), boron (6.7 mg/l), and several metals (aluminum 6.1 mg/l, manganese 0.18 mg/l, copper 0.04 mg/l, and zinc 0.07 mg/l).

Analyses of a large number of samples from shallow wells in the southern part of the valley reported by Piper, Robinson, and Park (1939, appendix) indicated a similar pattern of poor-quality water in the shallow aquifers. Waters from the shallow zones were of similar chemical quality to those from the same area reported in table 6--that is, the water generally contains sodium chloride, sulfate, and other constituents in amounts excessive for domestic use.

On the basis of field measurements of specific conductance and a few laboratory analyses, water along the east side of the valley seems to be generally of good quality for most uses, of low mineral content, and of the calcium bicarbonate type. An exception is water from well 24S/33E-24aac, which is 340 feet deep and apparently taps a section of volcanic rocks and volcanic-derived sediments. Water from that well is of the sodium chloride type and contains 706 mg/l of sodium, 975 mg/l of chloride, 2,350 mg/l of dissolved solids, and 4.8 mg/l of boron. The water is unsuitable for irrigation because of excessive boron content and very high salinity- and sodium-hazard classifications.

Thermal water

Waters from two wells (22S/32E-34aaa1 and 24S/32E-8dab) and one spring (24S/33E-34cca(s)) had extremely high temperatures. These waters have many similarities, including the highest concentrations of dissolved silica in the area, high percent sodium, fluoride, boron, and pH (table 7). However, they are only moderately mineralized and differ in that the water from the two wells is of the sodium carbonate type and that from the spring is sodium bicarbonate sulfate type. The high silica concentration, together with the corrosive effects of high pH, would limit the suitability of the water for industrial use. The high boron content and percent sodium make the water poor for irrigation, and the high fluoride content makes the water generally unsatisfactory for drinking.

Quality changes as evidence of water movement

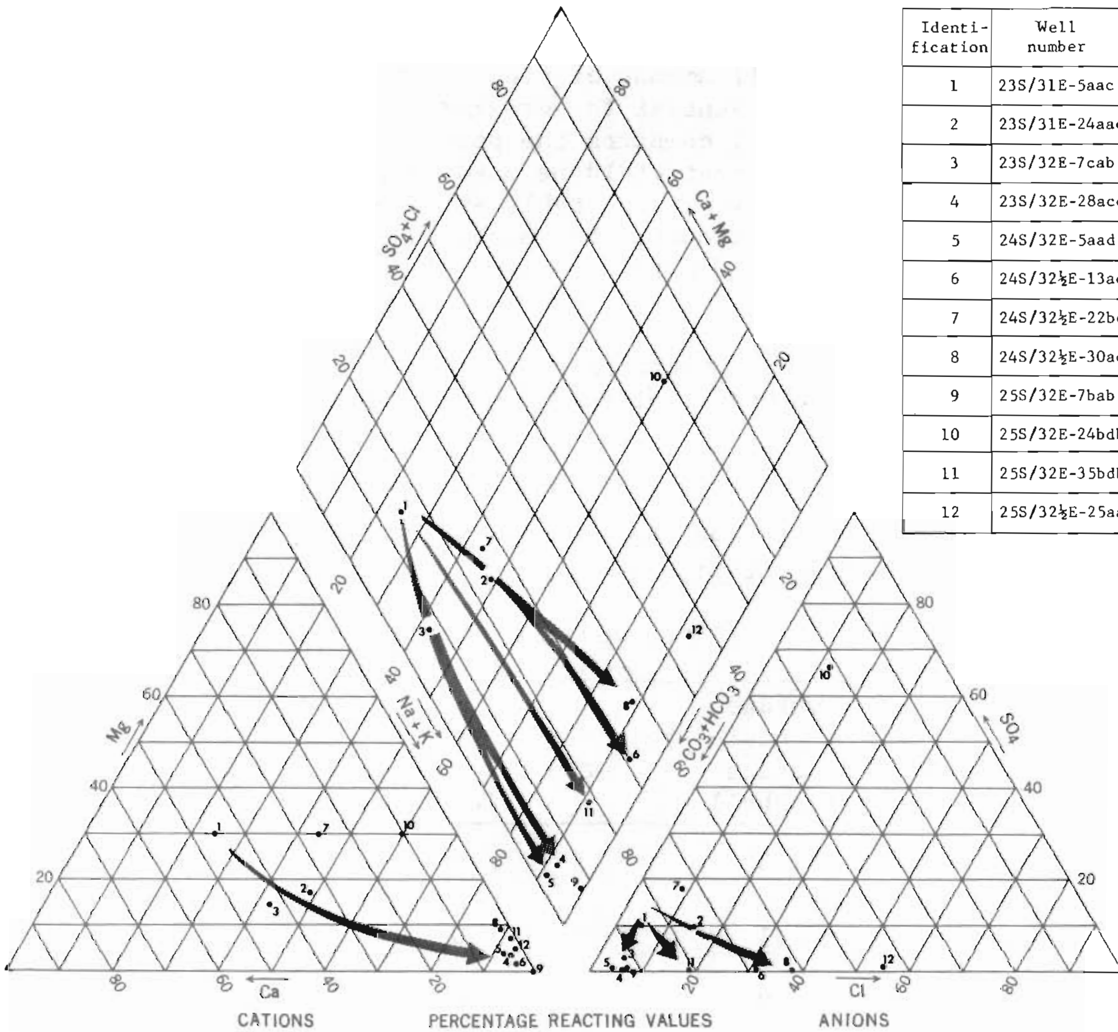
Water quality changes progressively from north of Burns toward the southeast. In general, as indicated in figure 14, water evidently changes from calcium bicarbonate type to calcium sodium bicarbonate to sodium bicarbonate as it moves southeastward. Water from well 25S/32E-7bab, a sodium bicarbonate type, seems to represent an end point of this trend. Waters from wells 24S/32½E-22bcc, 25S/32E-24bdb, and 25S/32½E-25aab do not fit the trend, and all are highly mineralized. Water from well 25S/32½E-25aab deviates from the general trend in having an anomalously large content of chloride. Waters from wells 24S/32½E-22bcc and -24bdb deviate in their large contents of magnesium and sulfate. Reasons for these anomalous characteristics are not clear.

Use of Ground Water

In the Harney Valley area, ground water is used mainly for irrigation but also for industrial, domestic, stock, and public supplies. Table 8 shows the volume of water pumped for various uses in the project area during 1968 and 1969. As the table shows, the volume needed for irrigation and public supplies varies considerably between dry years, such as 1968, and wet years, such as 1969.

Table 7.--Selected quality data for water from a hot spring and thermal wells

Number	Depth (feet)	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Milligrams per liter: Sodium (Na)	Milligrams per liter: Fluoride (F)	Milligrams per liter: Boron (B)	pH	Specific conductance (micromhos per cm at 25°C)	Percent sodium
22S/32E-34aaa	1,000±	72	89	157	2.8	3.99	9.5	716	99
24S/32E-8dab	2,812	46	72	135	12.0	4.11	9.6	606	99
24S/33E-34caa(s)	Spring	80	80	170	9.3	6.2	8.3	814	97



Identi-fication	Well number
1	23S/31E-5aac
2	23S/31E-24aac
3	23S/32E-7cab
4	23S/32E-28acd
5	24S/32E-5aad
6	24S/32½E-13acb
7	24S/32½E-22bcc
8	24S/32½E-30add
9	25S/32E-7bab
10	25S/32E-24bdb
11	25S/32E-35bdb
12	25S/32½E-25aab

Figure 14.--Chemical characteristics of water from selected wells. (Arrows show postulated direction of progressive alteration of chemical quality indicating direction of water movement beneath valley.)

Table 8.--Estimated use of ground water in Harney Valley, 1968 and 1969

Use	Pumpage, in acre-feet 1968 (dry)	1969 (wet)
Irrigation	10,700	7,900
Municipal	1,100	930
Industrial	5,000	4,000
Rural (domestic and stock)	100	100
Total (rounded)	17,000	13,000

Irrigation Use

Because of the small amount of precipitation during the growing season, irrigation is essential for growing all but the most drought-resistant crops. Table 9 compares the potential evapotranspiration (the maximum amount of water that could be used by plants and evaporated from the soil) and precipitation. The table shows a water deficit of nearly 19 inches for April to October, the months that span the growing season. Theoretically, this is the maximum volume of irrigation water needed during an average year. However, somewhat more probably is applied where irrigation is by flooding of fields and somewhat less where water is applied by sprinkler. Crops that mature early also require less water than do pasture and alfalfa, which need irrigation throughout the growing season.

Table 9.--Precipitation and evapotranspiration data at Harney Branch Experimentation site, sec. 7, T. 23 S., R. 32 E.

[After Johnsgard, 1963]

Month	Average precipitation (inches)	Average potential evapotranspiration (inches)	Water deficit (inches)
January	1.3	0.0	--
February	1.1	.0	--
March	.9	.6	--
April	.7	1.7	1.0
May	.8	2.7	1.9
June	.8	4.3	3.5
July	.2	5.1	4.9
August	.2	4.3	4.1
September	.4	2.8	2.4
October	.8	1.7	.9
November	1.1	.0	--
December	1.3	.0	--
Annual	9.6	23.2	18.7

In the Silvies fan-Foley Slough area and along the north side of the valley, ground water is both a primary source and a supplement to stream-water diversions; elsewhere, it is largely the primary source of water. In the valley, there are primary ground-water rights for about 5,000 acres and supplemental rights for about 7,000 acres.

In 1968, ground water was pumped from about 85 wells to irrigate about 9,200 acres, including a few hundred acres for which no water right was on file at that time. Because of the small streamflow in 1968, about as much water was pumped to irrigate lands with supplemental rights as those with primary rights. Water applied to the land averaged about 14 inches in 1968.

A slightly larger area was irrigated with ground water in 1969, but because stream runoff was large and continued into late spring, much less water was needed for the lands with supplemental rights. Many of the lands with primary rights also used less water, perhaps because of the accumulation of soil moisture from snow that did not melt until later than usual.

The principal crops irrigated are grain, alfalfa, hay, and pasture, and recently, small acreages of potatoes. Application by sprinkler is common, but a number of supplemental irrigators distribute ground water by ditch. Irrigation usually starts in April, although a small amount of water may be pumped earlier. Figure 15 shows the approximate distribution of irrigation pumpage during the year. The slight decline in use from May to June results from temporary curtailment of pumping when hay and alfalfa are being cut.

Other Uses

Next to irrigation, the largest use of water is by industry, the Edward E. Hines Lumber Co. being the largest industrial user. No accurate measure of industrial use is available, but the lumber mill at Hines has three large-capacity wells, two of which pump nearly continuously to supply water for plant operation and to sprinkle the large log deck. Outflow from the mill operation is used to irrigate an adjacent hayfield and meadow.

Both the Burns and Hines public supplies are obtained from wells several hundred feet deep in the hills near the edge of the valley. Pumpage by Burns is metered but there are no records of pumpage by Hines. About 80 percent of the municipal water use shown in table 7 is at Burns; the remainder is at Hines.

Ground water is used widely for domestic supplies at the many ranches throughout the area. A number of suburban homes a short distance from Burns have individual wells for domestic supply. Much of the stock water used in the area also comes from wells, particularly in the areas east and south of the "island" between the two Silvies River branches. Even near the river, some stock water may be supplied by wells, especially during summer and autumn.

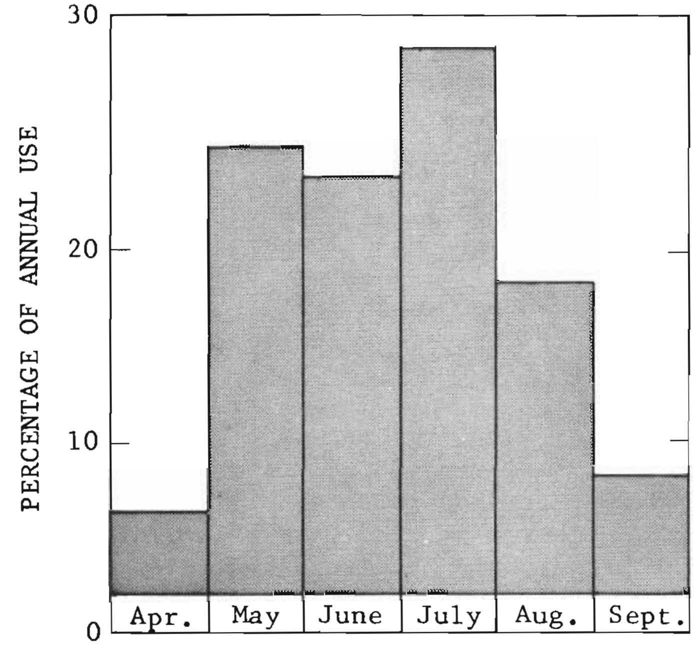


Figure 15.--Monthly distribution of ground-water pumpage for irrigation.

Water from well 22S/32E-34aaa1, a hot-water flowing well, has an unusual use--to heat a large greenhouse where winter vegetables are grown. The well also supplies some of the water used to irrigate the vegetables, although the boron content of the water (3.99 mg/l) is higher than is desirable for irrigation water. (See section on quality of water.)

Availability of Ground Water for Future Development

Limitations

Parts of Harney Valley have large quantities of available ground water, but a number of limitations may restrict its development. Few wells in the valley produce as much as 1,000 gpm, and many of the higher capacity ones pump sand. The sand pumped from several of the wells contains considerable magnetite, which is quite hard and abrasive and causes rapid wear of pumps. Sand pumping might be reduced or eliminated by use of well screens and gravel packs, but probably at the expense of reduced yields and greater pumping lifts. The individual water user would have to weigh the advantages or disadvantages of correcting this problem.

Another limitation is mutual interference between wells--that is, the water level falling in one well when a nearby one is pumped. This is an expected effect of pumping wells closely spaced in a confined aquifer. Interference has been recognized for many years southeast of Burns airport and also is apparent currently in the area of secs. 28 and 29, T. 23 S., R. 32 E. In the latter area, the concentration of a large number of irrigation wells results in a general decline of the water level during the pumping season (pl. 2). Records of observation wells in the area show that the seasonal "pumping depression" is dissipated during winter. Water users in both areas seem to have recognized and adjusted to the interference, but if additional wells were drilled in the affected areas, the difficulty would be aggravated.

Overdraft results when ground water in any area is pumped at a rate perennially greater than it is replenished. One of the most common effects of overdraft is the progressive decline of water levels over a term of years. The only part of the area where overdraft was positively identified is the Hines warm-water subarea, which is discussed in the section on thermal water. Overdraft may be incipient north of Crane near the Rossberg Ranch, where observation-well records indicate that the water levels in two irrigation wells have fallen in recent years (fig. 11). Some seasonal declines have been noted in other irrigated areas in the valley, but there water levels have recovered rapidly during the nonpumping season.

The quality of available ground water is a limitation that has not received the attention it deserves. Highly mineralized water, generally unsuitable for drinking, occurs near Lawen and westward on the north side of Malheur Lake. According to landowners and well drillers, quality of the water does not improve with depth. There may be exceptions to this generalization in certain areas, as south of Wrights Point. In that area, Island Ranch well 25S/32E-7bab, a flowing well 1,345 feet deep, produces water of the sodium bicarbonate type containing 957 mg/l of total solids. About 2 miles southwest, Island Ranch "salt well" (25S/31E-13cda) was reported by the former owner to have produced water, suitable for stock use, from a depth of 360 feet for a number of years until water in a highly mineralized overlying zone "broke through" into the well. Water pumped from it is now so highly mineralized that cattle will not drink it. It was noted in the quality-of-water section that a number of wells produce water containing sodium or boron in amounts excessive for irrigation. One well, 24S/33E-24aac, produces water with a concentration of sodium chloride so high that it damaged the alfalfa irrigated with it.

In general, water along the north side of the valley, including the northern part of the Silvies fan subarea, is of good quality for irrigation. In the southern part of the Silvies fan subarea percent sodium is a potential limitation, as it may be elsewhere (fig. 13). Water from the hot-water wells and several others, such as well 24S/32½E-13acb, contains boron in excessive quantities for an irrigation supply. Because of the possibility of water-quality difficulties, it is suggested that a chemical analysis be made of water from prospective irrigation wells that are more than 2 miles from the edge of the valley.

Silvies Fan Subarea

For many years, the most intensive irrigation development has been in a fan-shaped area formed by the valleyward extension of the Silvies River and Poison Creek drainage systems (fig. 16). This fan extends about 12 miles into the valley toward the south and southeast and nearly halfway across the east-west length of the valley. In 1969, more than

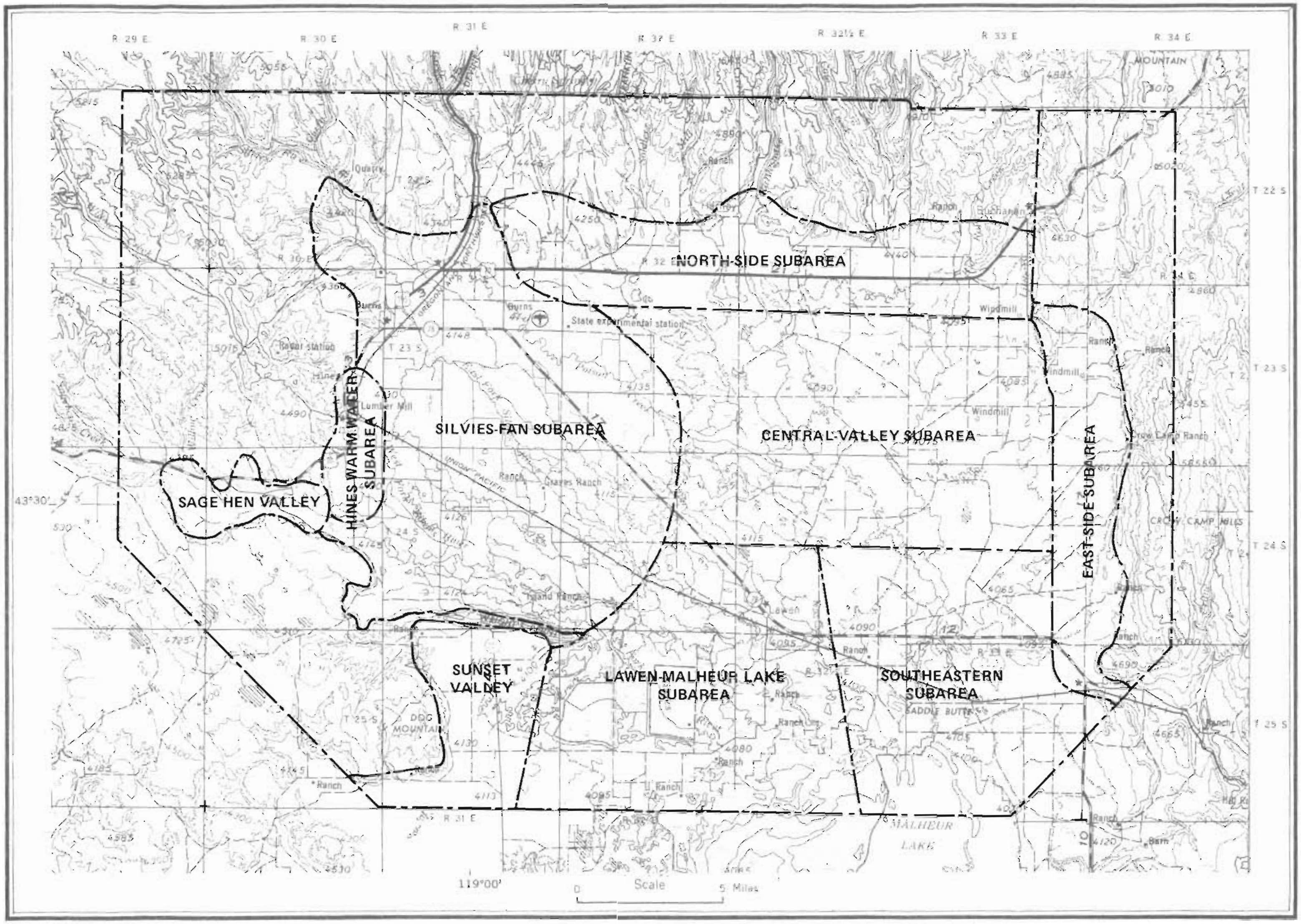


Figure 16.--Ground-water subareas of the Harney Valley.

40 irrigation wells were in use, and several unused irrigation wells were in the area. Because many irrigated tracts in the subarea have surface-water rights, about half the wells are used only for supplemental water supply. Consequently, the volume of ground water pumped for irrigation varies widely from year to year--pumpage was about 4,600 acre-feet in 1968 but only 2,700 acre-feet in 1969.

Wells in the subarea range from 60 to 725 feet in depth, but only three are less than 100 feet, two-thirds are between 100 and 300 feet, and only one is deeper than 500 feet. Many of these wells yield more than 500 gpm, and several yield more than 1,000 gpm. Specific capacities range from about 3 to nearly 50 gpm per foot of drawdown.

At the north end of the subarea, a few wells (22S/30E-27ddc, 22S/31E-28ddb, and -33baa) that tap only the Tertiary rocks have high yields and large specific capacities. Elsewhere, several productive wells (23S/31E-3ada, -4abc, and -19daa) tap aquifers only in the valley fill. The most productive well is 23S/31E-19daa, which is 113 feet deep and is reported to yield 1,450 gpm and to have a specific capacity of 36 gpm per foot of drawdown. This well is only about a quarter of a mile from West Fork Silvies River and may tap aquifers that receive direct recharge from the river.

Most wells in the subarea produce water both from alluvial gravel associated with the Silvies River fan and from beds of cinders, lava, or gravel in the underlying Tertiary rocks. The common drilling practice is to set well casing to exclude the near-surface alluvial material and to finish the well "open hole" through deeper beds in the valley fill and underlying rocks so that several confined aquifers are tapped by each well. For the 100- to 300-foot-depth interval, several wells yield more than 1,000 gpm; the average yield is about 700 gpm and average specific capacity is about 14 gpm per foot.

The rapid recovery of water levels after pumping, demonstrated by hydrographs of wells in the subarea, indicates that ground water is not overdeveloped and that the subarea undoubtedly could sustain additional ground-water development. As previously noted, many wells in the area pump sand, and it might be desirable to eliminate this problem in new wells by use of well screens. The northern part of the subarea has the most promise because there the percentage of gravel in the alluvium is greatest and volcanic-rock aquifers seem most permeable. Also, the chemical quality of the water is best in the northern part, where the water is of the calcium bicarbonate type and low in concentration of dissolved solids. However, additional ground-water development is expected to be small there because of the number of irrigation wells already in use and the availability of surface water for some tracts. The transition of irrigated land to suburban-housing developments also may reduce slightly the demand for irrigation water.

In the southern part of the fan, irrigation pumpage is most concentrated in secs. 21, 22, 27-29, T. 23 S., R. 32 E. A cone of depression in this part of the subarea in the fall of 1968 resulted from the intensive pumping (pl. 2). Ground water there has a moderate concentration of dissolved solids but is of the sodium bicarbonate type so that successful irrigation requires use of good drainage practices.

It may be possible to obtain small-yielding irrigation wells (200-300 gpm) for a few miles south of the present area of development. Well 24S/32E-5aad produces about 350 gpm--enough to operate a quarter-mile line of sprinklers, with a drawdown of less than 15 feet. However, the percentage of gravel in the alluvium and the quality of ground water both can be expected to deteriorate toward the south and southeast. To extend this irrigation area, test holes may be desirable to explore for potential aquifers and to check water quality. Logs of test wells 23S/32E-31bbc (240 feet deep) and 24S/32E-4bbb (500 feet deep) report a thin alluvial section, containing no good water-bearing beds, which overlies a section of Tertiary strata composed largely of clay with a few thin sands. Well 23S/32E-31bbc was tested at only 50 gpm and had a specific capacity of about 1 gpm per foot; the yield of the other well was not tested. The prevalence of pumice and clay in these wells suggests that the Tertiary rocks have little potential there, at least in the upper part.

North-Side Subarea

About 20 irrigation wells scattered along the north edge of the valley (fig. 16) supply about 2,000 acre-feet of ground water annually for irrigation. The ground-water potential of that area seems very erratic--wells range in depth from about 100 to more than 800 feet, and yields range from 100 to 560 gpm. The average well yield is about 360 gpm, and average specific capacity is about 4 gpm per foot. Wells near the mouths of Prater and Cow Creeks obtain water from both shallow alluvial deposits and the upper part of the underlying rock. Near the mouth of Rattlesnake Creek the prospects are poor because the alluvium seems to contain no productive gravel layers and overlies rocks that consist largely of pumice, tuff, and similar fine-grained rocks. In that area, however, several productive wells that tap the alluvium have been drilled south of Highway 20, although other wells drilled there found only clay to depths of more than 300 feet. The only irrigation well in the Buchanan area is well 22S/33E-27adc, which is about 830 feet deep, apparently taps the Tertiary consolidated rocks, and yields 150 gpm.

Attempts to develop ground water for irrigation north of Highway 20 in Rs. 32, 32½, and 33 E. have met with little success, except on the Richard Temple ranch in sec. 36, T. 22 S., R. 32½ E. Even there, two unproductive wells have been drilled. The best possibility of obtaining large yields seems to be from wells several hundred feet deep that would reach the lower volcanic-rock section. Well 22S/32½E-36ddb, however, failed to reach satisfactory water-yielding zones to a depth of 840 feet, and the Danuser test wells (see discussion of geology) that were drilled into the volcanic rocks in the canyon of Rattlesnake Creek also yielded little water.

East-Side Subarea

About a dozen irrigation wells have been drilled along the east edge of the valley within about a mile of the Crane-Buchanan road. Several of them are less than 100 feet deep and tap sand and gravel in a buried channel that parallels the western margin of the Crow Camp Hills. Yields of these wells range from about 380 to 750 gpm, and aquifer transmissivity, determined from a short pumping test on well 24S/34E-31bac, is about 7,500 feet^2 per day (about 56,000 gal per day per ft gradient). According to rancher Howard Miller, the higher yielding wells are some distance out from the foot of the hills, probably near the center of the old channel. Two flowing wells, 23S/34E-7cac and 23S/34E-32aca, and wells 24S/33E-1cda and -24aac, west of the highway, tap lava, cinders, and other volcanic rocks.

Because a large part of the cultivated area east of the highway is already being irrigated, it seems unlikely that many additional wells will be drilled into the shallow gravel aquifer. In 1968, more than 1,300 acre-feet was pumped from wells tapping that aquifer, although it is relatively narrow and consequently limited in capacity to store and transmit water. As figure 11 shows, water levels in two wells open to the shallow aquifer have declined a few feet since 1965. Therefore, that aquifer should be watched for signs of overdevelopment.

Attempts to develop water from the Tertiary rocks in this area have been only partially successful, although several irrigation wells tap cinders and volcanic rocks. Yields of these wells range from 225 to 1,000 gpm and specific capacities range from 2.8 to 10 gpm per foot. Highly mineralized water is produced by well 24S/33E-24aac, which is 340 feet deep and taps lava, pumice, and black "sandstone." Well 24S/33E-1cda, only 2½ miles to the north, is 357 feet deep and produces good-quality water from rocks of similar lithology. There is no logical explanation for the mineralized water in well 24S/33E-24aac, although the water may be moving upward, in the vicinity of the well, along a buried fault plane in the bedrock beneath the valley fill. Whether the mineralized water is limited to the immediate area of the well or extends over a larger area also is unknown. Water from any new wells drilled in this general area probably should be checked for chemical quality before being used.

Central-Valley Subarea

East of the Silvies fan, in the eastern part of T. 23 S., R. 32 E., and the western part of T. 23 S., R. 32½ E., is a marshy area containing several playa lakes and much alkali soil. Farther east, in the eastern part of T. 23 S., R. 32½ E., and in T. 23 S., R. 33 E., the soil generally is sandier, and large tracts of land seem to be suitable for irrigation. In that area, there are a number of scattered irrigation wells, most of which are less than 200 feet deep, that tap alluvial sand and gravel and yield from a few hundred to 1,000 gpm. Logs of a number of wells in the area report 200 to 300 feet of clay, suggesting that the gravels occur in lenses that may mark buried stream courses. Probably the only practical way to locate these aquifers is by test drilling.

Despite the poor success of obtaining water from the Tertiary rocks north of Highway 20, the Tertiary rocks south of the highway may be potentially productive. A large number of stock wells were drilled in the area a few years ago, mostly to depths of 200 to 500 feet. Many of these wells tapped confined water with a hydrostatic head only a few feet below land surface. No logs or test data are available for these wells, but the former landowner who had them drilled believes that some should yield several hundred gallons per minute.

An unusual well in this general area is the flowing well 24S/32½E-13acb, now owned by C. W. Tripp. That well was drilled through a section of blue and yellow clay to a depth of 240 feet. At 240 feet a bed of loose sand and gravel, containing many flat, semiangular pebbles, contains water under sufficient hydrostatic head to flow at land surface. This well, tested at 1,125 gpm with 40 feet of drawdown, probably taps the same general confined zone reported in the stock wells; it is believed to flow mainly because of the low elevation along Ninemile Slough, where it is located.

Sage Hen Valley

Five irrigation wells are in use on the Kisle Ranch in Sage Hen Valley. These wells range in depth from 220 to 347 feet, and four of them yield more than 1,000 gpm. Drillers' logs indicate considerable gravel in the alluvium to a depth of about 100 or 120 feet. Most of these wells tap the lower part of the gravel section as well as basalt and cinder beds in the underlying volcanic rock. Some general decline of water levels during the pumping season has been reported, but recovery evidently is quite rapid because water levels were about the same in September 1968 as they had been in the previous June, even though three wells had been shut off only a few days and one was still pumping. The water has a specific conductance of about 150 micromhos per centimeter and seems to be of excellent quality.

Although one low-yielding well has been drilled in Sage Hen Valley, data from the five high-capacity irrigation wells indicate that the area has excellent potential for additional development. The valley is just south of an upland area of highly faulted volcanic rocks where ground-water recharge probably is greater than average. A number of small reservoirs on small streams in the area reportedly failed to hold water because it moves readily into the fractured bedrock (D. A. Webster, U.S. Geol. Survey, written commun., 1969).

Other Areas in the Valley

Other areas in the valley offer little potential for high-capacity wells, but should be adequate for domestic and stock wells. In the southeastern subarea, along Highway 78, most wells were drilled through a predominantly clay section and have low yields. Wells more than a few hundred feet deep in this area are likely to produce mineralized water.

In the area near Lawen, and to the south and southwest (Lawen-Malheur Lake subarea, fig. 16), the valley fill consists largely of clay, and the water is of poor quality. Much of it is unfit for domestic use, and some is unsuitable for stock water. (See water-quality section.)

In the western part of Sunset Valley, south of Wrights Point, several exploratory irrigation wells have been drilled and tested at 100 to 300 gpm. Well 25S/31E-4cba, 170 feet deep, obtains water from yellow sandstone and cemented gravel in the Tertiary bedrock and was tested at 100 gpm with 86 feet of drawdown. Well 25S/31E-27daa, 179 feet deep, obtains water from sand and cinders and was tested at 288 gpm with 63 feet of drawdown. Well 25S/31E-32aaa, 111 feet deep, obtains water from sand, cinders, and gravel and was tested at 314 gpm with 40 feet of drawdown. Records of these three wells suggest that it might be possible to develop small-yield irrigation wells in the area. Because of the limited recharge potential of the sedimentary deposits composing the upper part of the Tertiary rocks where they crop out to the west, Sunset Valley probably could not sustain large withdrawals of ground water. The quality of water from these wells is not known and should be checked, particularly in view of the prevalence of mineralized water a few miles away at the Island Ranch well and southeast near Malheur Lake.

In summary, parts of Harney Valley have excellent potential for additional ground-water supplies suitable for irrigation, but other parts offer little potential. It seems likely that good-yielding wells that produce water of suitable quality can be obtained in most places in Sage Hen Valley and the northern part of the Silvies fan. Prospects are fair in the southern part of the Silvies fan and the central-valley subarea. In both these areas some exploration may be needed to find the most productive aquifers, and water quality may be unsatisfactory. Availability of water is unpredictable along the north edge of the valley east of Prater Creek. The east-side area has had considerable development from the alluvial aquifer, considering its inferred extent, but there may be some additional potential from deep wells drilled into the volcanic rocks. The southern and southwestern parts of the valley have little potential because of the thick section of clay in the valley fill, the prevalence of fine-grained sediments in the bedrock, and the poor quality of water in all depth zones. An exception is the western part of Sunset Valley, where a few hundred gallons of water per minute may be obtained from wells a few hundred feet deep.

SUMMARY

Precipitation infiltrates to the ground-water body in the volcanic and sedimentary rocks of the uplands north, east, and west of Harney Valley. Ground water moves to the valley in these rocks and in stream-valley alluvial deposits which are recharged by seepage from the streams and from the adjacent volcanic rocks. Lenticular beds of gravel extend into the valley, principally in the Silvies fan subarea near Burns, but also along other present streams and perhaps along the buried courses of former streams. Along the northern and eastern margins of the valley, highly productive wells tap these alluvial gravels or aquifers in the underlying volcanic sediments, or both.

The most intensively developed ground-water area is the Silvies fan, which extends from the edge of the valley north of Burns to about 10 miles southeast of the city. Most of the irrigation wells in that area tap gravel aquifers in the valley fill and also underlying gravel layers or volcanic rocks. Near the south end of the fan area, mutual interference between wells limits the rate of withdrawal, but water levels recover in the winter following the cessation of irrigation pumping, and there is no evidence of perennial overdraft. Water quality changes from a calcium bicarbonate type containing about 200 mg/l of dissolved solids at the north end of the area to a sodium bicarbonate type containing about 450 mg/l at the south end.

Except for the Silvies fan subarea and smaller areas extending out from other streams, the valley fill is predominantly clay and other fine-grained sediments. Beneath most of the valley, the fill is underlain by Tertiary sedimentary rocks, lavas, or pyroclastic rocks. Because of lithologic similarities of alluvial material to underlying unconsolidated sediments, the two cannot be distinguished readily in most drillers' logs. Wells of large yield tap volcanic rocks near the northwest corner of the valley, younger volcanics near Hines, and the Miocene volcanic rocks along the east side of the valley. The tuffaceous and sedimentary phase of the bedrock generally yields only moderate to small quantities of water to wells. In the central and southern parts of the valley, the valley fill consists of a thick section of clay and peat overlying fine-grained sediments. In that area, wells generally yield only small quantities of water, at places too highly mineralized for most uses.

Thermal artesian water at temperatures of 70° to $80^{\circ}F$ (21° to $27^{\circ}C$) underlies an area of several square miles near Hines. Water at temperatures of 105° to $176^{\circ}F$ (41° to $80^{\circ}C$) flows from four wells and the Crane Hot Springs. Flowing water at normal temperature occurs along the east side of the valley and in a few other places. Head is low in all areas, and most flowing wells are equipped with pumps for water supply. Geologic structure favors flowing wells over most of the valley, but prospects of large yield by natural flow probably are poor.

About 10,000 acre-feet of ground water is pumped yearly for irrigation, the principal use. Other uses are public supply, about 1,000 acre-feet per year; industrial use, about 5,000 acre-feet; and domestic and stock water, about 100 acre-feet. Except for a small area on the east side of the valley, the ground water could sustain considerable additional development. However, the water varies considerably in chemical quality, and at some places contains excessive concentrations of boron, sodium, or dissolved solids, making it unsuitable for irrigation. As part of the exploration, water should be checked for its suitability for the intended use. Because of high concentrations of boron or salts, water from several wells intended for irrigation is unsuitable for that purpose.

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Table 10.--Records of selected wells in the Harney Valley area

Well number: See p. 5 for description of well-numbering system.
Type of well: B, bored; Dg, dug; Dr, drilled.
Finish: F, gravel packed and perforated; G, gravel packed and screened; Ø, open end; P, perforated; S, screened; X, open hole.
Altitude: Altitude of land surface at well, in feet above mean sea level.
Water level: Depth to water given in feet and decimal fractions were measured, those given in whole feet were reported by well driller or owner. F, flowing well whose static water level is not known.
Specific conductance: Field measurements by U.S. Geological Survey personnel or county agent.

Type of pump: C, centrifugal; N, none; P, piston; S, submersible; T, turbine.
Well performance: Yield, in gallons per minute, and drawdown, in feet, generally reported by driller, owner, or pump company for period indicated under "Remarks."
Use: H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; T, institutional; U, unused.
Remarks: C, chemical analysis reported in table 6; L, driller's log available in Survey files; P, pumped; B, bailed for indicated time to determine yield under "Well performance"; Obs, observation well whose water level is measured periodically.

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level		Specific conduct-ance of water	Type of pump and hp	Well performance		Use	Remarks
										Feet below datum	Date			Yield (gpm)	Draw-down (feet)		
T. 22 S., R. 30 E.																	
27ddc	W. W. Arntz	Dr	1961	127	12	40	X	Gravel, cinders	4,230	52.42	10-14-68	140	T, 50	700	--	I	L, Obs, C.
35bbb	do	Dr	1966	97.5	12	20	X	Sandstone, pumice	4,190	37.26	10-16-68	--	N	100	--	N	B 2 hr, L.
T. 22 S., R. 31 E.																	
25aba	Les Tyler	Dr	1931	490	16	--	--	Tuff, "shale"	4,180	24.15	5-12-32	--	T, 40	--	--	I	
28dda	Harry Pon	Dr	1961	490	12	22	X	Lava, gravel	4,170	26.16	12-12-68	--	T, --	1,000	42	I	P 4 hr, L, Obs.
32bbb	do	Dr	--	200	14	100	--	--	4,190	14.48	10-11-68	--	T, 30	240	95	I	
32bcc	do	Dr	1961	260	14	36	P, X	--	4,180	8	2-14-61	--	T, --	540	122	I	P 8 hr, L.
33baa	do	Dr	1962	425	12	21	X	Sand and gravel, "rock"	4,190	44.70	10-11-68	--	T, 30	1,100	86	I	Do.
33ccd	do	Dr	1961	390	12	80	X	Gravel, pumice, cinders	4,155	16.15	10-16-68	250	T, 30	900	44	I	P 4 hr, L.
34aaa	George Purdy	Dr	1966	725	12	40	P, X	Gravel, cinders	4,162	19.26	9-10-68	240	T, 40	800	122	I	P 24 hr, L, C.
34ccb	L. F. Lazarus	Dr	1930	288	18	68	X	Gravel, sand, rock	4,153	15.73	12-12-68	--	--	400	50	S,I	Obs.
36aba	R. F. Smith	--	--	240+	12	--	--	--	4,158	14.8	10-23-69	--	T, 20	--	--	I	
36bab	do	Dr	1961	335	12	18	P, X	Gravel, sand, lava	4,156	16.04	12-12-68	--	T, 25	500	98	I	P 4 hr, L, Obs.
36cad	do	--	--	360	40	12	X	--	4,150	4.56	5-24-69	--	T, 10	300	150	I	
T. 22 S., R. 32 E.																	
34aaa1	Desert Growers, Inc.	Dr	--	1,000	6	120	X	--	4,148	F	9-13-68	670	C, 2	20-30	--	I	C; used to heat greenhouse for winter vegetables.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com- pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti- tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct- ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw- down (feet)	Use	Remarks
T. 22 S., R. 32 E.--Continued																	
34aaa2	Desert Growers, Inc.	Dr	1965	215	6	60	X	Gravel	4,148	--	--	245	S	35	7	H,I	
35bbb	R. W. Davis	Dr	1957	880	24	90	X	Gravel, sand	4,150	4.68	9-13-68	600	T, 50	--	--	I	L; 160°F water, cooled in reservoir to use for irri- gation.
36bbb	William Huggard	Dr	1967	611	12	60	X	Sand, clay, sand- stone, rock, pumice	4,142	11.54	10-11-68	--	N	110	51	I	P 4 hr, L.
T. 22 S., R. 32½ E.																	
5bb	Charles Danuser	Dr	1966	545	6	30	X	Basalt, gravel	4,395	2	11- 6-66	--	N	2	100	N	P ½ hr, L.
18aad	do	Dr	1967	445	6	20	X	Basalt, sand	4,300	26.09	10-10-68	--	N	110	80	I	P 4 hr, L.
30cdb	Jack McGee	Dr	1964	647	12	--	X	Sand, rock, gravel	4,146	11.23	do	290	S	450	166	I	P 1 hr, L, C.
36aab	Richard Temple	Dr	1968	182	12	20	X	Clay, rock	4,135	13.63	do	360	T, 15	495	94	I	P 6 hr, L, C.
36aac	J. C. Temple & Sons	Dr	1964	132	12	52	X	Lava, pumice	4,133	11.90	do	360	T, 40	560	91	I	P 6 hr, L.
36dab	do	Dr	1966	345	12	71	X	Shale, gravel	4,132	9.89	10-14-68	--	T, 15	341	51	I	Do.
36ddb	do	Dr	1966	840	12	80	X	Shale, pumice	4,132	7.56	do	--	N	100	95	I	P 5 hr, L.
T. 22 S., R. 33 E.																	
27adc	John Temple	--	--	833	--	--	--	--	4,170	29.25	10-14-68	270	T, 10	--	--	I	Obs.
27cbd	do	Dr	--	100+	6	--	Ø, F	--	4,165	35.25	do	--	P,wind	5-10	--	S	
31aaa	Donald Corcoran	Dr	1961	225	6	143	X	"Blue granite"	4,138	13	10-18-61	--	P,wind	25	20	S	B 2 hr, L.
34bbb	do	Dr	1961	167	6	160	Ø, X	Broken "granite"	4,153	21.40	10-14-68	--	P,wind	20	18	S	Do.
T. 23 S., R. 30 E.																	
12dab1	City of Burns	Dr	1925	253	12	150	X	Welded tuff, breccia	4,229	85	12-10-58	--	T, 50	800	27	P	P 4 hr.
12dab2	do	Dr	1926	251	12	150	X, S	do	4,229	85	do	--	T, 50	800	27	P	Do.
12ddd	do	Dr	1950	304	16	144	X	Welded tuff, lava	4,160	14	12-10-59	--	T, 100	1,280	81	P	P 2 hr, L.
14dcc	F. H. Garland	Dr	1967	305	14	140	X	Volcanic rock, cinders	4,250	105.15	10-16-68	160	T, 30	1,000	105	I	P 7 hr, L.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct-ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw-down (feet)	Use	Remarks
								T. 23 S., R. 30 E.--Continued									
20cac	U.S. Air Force	Dr	1959	1,224	10	1,122	X, P	Lava, cinders	5,233	1,090	1-17-59	--	S, 30	68	23	T	P 12 hr, L.
23bdd	City of Hines	Dr	1930	325	10	275	X	--	4,315	--	--	--	T	800	--	P	
23cda	do	Dr	1967	345	14	260	X, P	Volcanic rock, cinders	4,200	65	4-28-67	295	T, 200	675	150	P	P 8 hr, L.
23dad	do	Dr	1949	400	12	100	X	--	4,157	--	--	220	T, 100	800	--	P	
24aad	Harney County Fair Assoc.	Dr	1963	218	10	195	X	Sandstone, sand	4,143	6.39	10-11-68	140	T, 15	130	70	I,H	P 6 hr, L.
24bba	J. E. Enneberg	Dr	1967	210	6	60	X, P	--	4,163	24.20	5-27-69	--	S, 3	40	20	I	B 2 hr, L.
26add	Hines Lumber Co.	Dr	--	190	--	--	--	--	4,139	--	--	--	C, 75	--	--	--	Flowed, when drilled.
26dac	do	Dr	1965	218	12	20	X, P	Cinders, volcanic rock, sand and gravel	4,147	10	4- 7-65	220	T, 100	1,500	23	N	P 8 hr, L.
35aad	do	Dr	1965	200	12	56	X, P	Cinders, volcanic rock	4,140	5	3-27-65	220	T, 125	1,750	1.5	N	P 8 hr, L, C.
36bbc	Walter Baker	--	--	--	12	--	--	--	4,137	4.82	10- 3-69	--	--	1,100	--	I	Flowed, when drilled.
36cbb	Hazel M. Gouldin	Dr	1965	198	10	104	X	Red and black lava	4,138	.25	5-27-69	190	J, 2	--	--	I	L; originally flowed 400 gpm.
								T. 23 S., R. 31 E.									
3bbb	Harney County	Dg	1935	14	18	14	P	"Quicksand"	4,153	--	10- -68	--	N	--	--	N	Obs; 1½-inch pipe inside wooden crib.
3ada	Tommy Swisher	--	--	150	--	--	--	--	4,145	9.30	10- 8-68	320	T, 10	700	30	I	
4abc	Lester Tyler	Dr	1929	98	18	38	X, P	Sand, rock	4,153	13.12	9-10-68	400	T, 30	700	--	I	L.
4bca	do	Dr	1961	200	12	85	X, P	Cinders, rock, gravel	4,156	15.6	do	--	T, 30	1,100	61	I	
5aac	Harry Pon	Dr	1961	400	12	18	X, P	Gravel, volcanic rock	4,157	20.35	do	240	T, 40	1,000	22	I	P 4 hr, L, Obs, C.
5aad	do	Dr	1961	438	14	60	X, P	Gravel, rock	4,155	15.20	do	--	T, 40	1,000	44	I	P 4 hr, L.
5bca	Eban Ray	Dr	1962	214	12	120	X, P	Gravel, sand	4,162	--	10- -68	250	T	950	60	I	L, Obs.
5cba	Harry Pon	Dr	1961	205	14	14	X, P	do	4,155	10.10	9-10-68	320	T, 20	700	59	I	P 41 hr, L.
5cbb	Eban Ray	Dr	1961	200	12	15	X, P	do	4,160	13.93	10- 9-68	--	T, 20	700	55	I	P 28 hr, L.
6add	Lloyd Hill	Dr	1965	185	8	76	X, P	Gravel	4,160	14.10	do	--	S, 7½	100	20	I	B 1 hr, L.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct-ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw-down (feet)	Use	Remarks
T. 23 S., R. 31 E.--Continued																	
6bcb	Kenneth Rether-ford	Dr	1969	170	6	161	X	Sand and gravel	4,161	19.55	5-20-69	255	T, ?	350	10	I	P 15 hr, L; drilled to 150 feet in 1968.
6bcc	Hobart Tiller	Dr	1966	120	12	55	P	Gravel	4,160	14.77	10- 9-68	250	T, 15	200	33	I	P 3 hr, L.
6ccd	Pluribus Tiller	Dr	1968	140	8	110	P	Gravel and sand	4,160	17	4-26-68	--	--	200	55	I	P 4 hr, L.
9dbb	Hilton Whiting	Dr	1961	364	12	55	X, P	Gravel, sand, cinders	4,146	8.74	9-10-68	280	T, 50	1,100	65	I	P 22 hr, L.
11bbb	Cliff Gunderson	Dr	1966	170	6	107	X	Coarse sandstone	4,143	15	10- 1-66	180	S, ?	150	5	H	B 2 hr, L.
11dcc1	Riley & Sewell	Dr	--	120	12	15	Ø, P	Gravel	4,145	11.34	10- 8-68	--	N	--	--	N	L, Obs.
11dcc2	do	Dr	1959	561	12	220	X	Pumice, boulders	4,145	18.13	do	--	T, 30	--	--	I	Do.
12ccd	Burns Airport	--	--	76	5	--	--	--	4,140	16.20	10- 9-68	--	S, ?	--	--	H	
13bcc	Clarence Gardner	B	1935	330	12	83	--	Sand, gravel, clay	4,143	15.22	do	490	T, 30	--	--	I	L.
14aab	Harney County	Dg	1936	17	18	17	P	Sand	4,143	10.32	12-11-68	--	N	--	--	N	Obs.
15abb	Henry Ausmus	Dr	1930	60	12	43	F	Gravel	4,145	9.55	9-10-68	--	T, 15	600	50	I	P 2 hr, L.
16bcc	Harney County	Dg	1936	13	18	14	P	Sand	4,146	8.78	12-11-68	--	N	--	--	N	Obs.
16dbb	T. A. Jones	Dr	1930	300	12	37	P	Sand and gravel	4,146	10.28	11-21-68	--	T, ?	750	26	I	Obs, L.
19daa	Dorman Otley	Dr	1955	113	12	18	X, F	Gravel	4,142	8.09	10-11-68	200	T, 30	1,450	40	I	P 7 hr, L.
20abd	Culp Cattle Ranch	Dr	1963	43	6	33	P	do	4,140	8.50	10- 9-68	--	S, ?	50	10	S	P 24 hr, L.
24aac	Al and Ron Brown	Dr	1962?	114	12	20	F	--	4,137	18.55	10- 8-68	280	T, 20	660	79	I	P 24 hr, C.
28bbb	Culp Cattle Ranch	Dr	1930	45	8	--	--	Sand and gravel	4,138	9.4	10- 9-68	--	N	--	--	N	
33cbc	Harney County	Dg	1935	12.6	18	13	P	Coarse sand	4,134	7.95	10-22-68	--	N	--	--	N	Obs.
T. 23 S., R. 32 E.																	
2bca	Dennis Dooley	Dr	1969	225	16	--	G	Gravel	4,135	12.73	5-24-69	--	--	500	170	I	
3aaa	do	Dr	--	90	--	--	--	--	4,135	11	?	295	T, 20	330	18	I	P 16 hr.
3aad	do	Dr	1963	220	12	220	--	--	4,135	11.13	10- 9-68	--	T, 20	240	--	I	Obs.
7bdc	Dorland Ray	--	--	210	12	157	X	Gravel?	4,136	16.13	do	--	T, 10	--	--	I	
7cab	do	--	1926	93	18	36	Ø, G	Gravel, sand	4,135	13.43	do	245	T, 20	540	55	I	P 20 days, L, Obs, C.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct-ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw-down (feet)	Use	Remarks
								T. 23 S., R. 32 E.--Continued									
7dcb1	Dorland Ray	Dr	1916?	160	8	--	--	--	4,136	18.80	10-10-69	260	S	320	110	I	Pump test, October 1969.
7dcb2	do	Dr	1966	235	12	200	X	Pumice	4,136	19.22	10-11-69	--	N	--	--	N	L.
9cbd	Peter Clemens	Dr	--	36	6	--	--	--	4,132	13.90	10- 9-68	--	P,wind	--	--	S	
11bbc	J. H. Raine	Dr	1964	90	12	47	F	Sand, gravel	4,128	11.84	do	--	T, 15	580	29	I	P 30 hr, L.
12daa	Unknown	Dr	--	--	6	--	--	--	4,125	10.24	do	--	N	--	--	N	
13bbb	Pat Hays	Dr	1963	232	14	72	F	Gravel	4,125	9.95	do	380	T, 50	1,100	--	I	L.
18bbb	Bar Negative Ranch	Dr	1963	170?	16	160	X	--	4,140	28.21	10- 8-68	260	T, 75	1,800	60	I	P 36 hr, L; sulfur odor; originally drilled to 1,316 feet.
18ccb	do	Dr	1961	200	12	--	--	--	4,139	19.82	do	300	N	--	--	N	Cased to 96 feet now.
20cca	Henry Cowing	Dr	1968	155	6	153	X	Sand, gravel, black	4,134	19.04	10-10-68	--	S, ?	20	20	S	B 3 hr, L.
21bba	Bar Negative Ranch	Dr	1955	130	12	--	--	--	4,133	23.00	10- 8-68	--	T, 20	250	--	I	"Tiller well."
21cbc	do	Dr	--	--	12	--	--	--	4,133	26.46	do	--	T, ?	--	--	I	Pump removed in 1968.
22ccd	Wallace Shepard	Dr	1955	250	8	50	X, P	Sand, "shale"	4,128	29.78	10-10-68	--	T, 15	600	50	I	P 20 hr, L.
27bbb	Wayne Howes	B	1956	100	12	60	X	Sand and gravel	4,130	20.79	5-25-69	--	--	500	25	H,S	P 1 hr, L.
27bdb	do	Dr	1955	465	18	60	X	do	4,128	28.04	10-10-68	800	T, 30	500	25	I	P, L.
27cbd	do	--	1965?	330	8	100	X	do	4,128	--	--	--	T, ?	1,000	--	I	Not in use, 1968.
28aba	Bar Negative Ranch	Dr	1955	140	10	50	P, X	Gravel	4,131	32.98	10- 8-68	--	T, 25	--	--	I	L, Obs.
28acd	do	Dr	1959	250	14	50	P	do	4,129	31.72	do	725	T, 30	900	--	I	L, C.
28bbd	Roy Duhaime	Dr	1955	220	8	115	X, P	Sand and gravel	4,133	--	--	--	T, 7½	150	50	I	P 100 hr, L.
28bcc	do	Dr	1955	191	8	50	X, P	--	4,132	30.25	9-12-68	--	T, 25	590	50	I	Do.
29adb	do	Dr	1955	240	12	50	X, P	Sand and gravel	4,132	25.92	10- 8-68	--	N	1,150	57	N	P 17 hr, L, Obs.
29bbd	Wallace Shepard	Dr	1962	200	8	65	F	Sand, shale	4,132	20.70	8-15-67	580	T, 30	730	70	I	P 10 hr, L.
29daa	Roy Duhaime	--	--	--	--	--			4,130	--	--	550	P, 1½	--	--	S	
30ddd	Harney County	Dg	1936	19.3	1¼	19	P	Sand	4,131	6.88	5-22-69	--	N	--	--	N	Obs, L.
31bbc	Sitz & Sitz	Dr	1962	240	12	90	X	Sandstone	4,130	13.37	10-13-68	--	N	50	40	N	B 1 hr, L.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Specific conductance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Drawdown (feet)	Use	Remarks
T. 23 S., R. 32 E.--Continued																	
32aaa	Roy Duhaime	Dr	1963	224	12	90	P	Gravel	4,128	24.43	10- 8-68	--	T, 50	1,000	100	N	P 10 hr, L.
T. 23 S., R. 32½ E.																	
1bbb	E. A. McConville	Dr	--	350	24	--	F	--	4,130	11.57	10-10-68	300	T, 15	450	63	I	Obs.
1bdc	do	Dr	1968	115	12	20	F	Clay and gravel	4,133	10.20	do	--	T, 15	350	15	I	L.
1cdc	Meadowland Ranches	Dr	--	110?	6	--	--	--	4,130	10.50	10-14-68	--	N	--	--	N	
9ccc	do	Dr	--	180?	6	--	--	--	4,125	10.48	10-10-68	--	S, ?	--	--	S	Not in use.
10cdc	Mrs. Wesley Claunch	Dr	1966	205	12	40	X	Sand, rock	4,125	7.59	do	--	N	1,118	33	N	P 3 hr, L.
14adb	Unknown	Dr	--	104?	6	--	--	--	4,125	9.37	do	--	S	--	--	S	Not in use.
19baa	do	Dr	--	180	6	--	--	--	4,125	12.10	10- 9-68	--	S	--	--	S	Do.
23dab	do	Dr	--	64?	6	--	--	--	4,123	9.57	10-10-68	--	S	--	--	S	Do.
26cbb	Harry Withers	Dr	1964	253	6	161	X	Black sandstone, gravel	4,116	2.82	do	--	S	60	1	S	B 2 hr, L.
32dbc	Unknown	Dr	--	314	6	--	--	--	4,120	8.68	do	--	S	--	--	S	
T. 23 S., R. 33 E.																	
5bca	A. J. Lawson	Dr	1964	99	12	48	F	Clay and gravel	4,133	8.64	10-10-68	--	C	100	5	I	B 2 hr, L.
8aac	Jesse Hankins	Dr	1969	365	12	30	F, X	Gravel and sand	4,133	--	--	--	--	--	--	--	L; not yet in use.
10abb	Lyle Vickers	--	--	--	2	--	--	--	4,137	3.48	5-22-69	--	P, 3	--	--	S	
12adb	do	Dr	1966	160	6	18	X	Pumice, gravel, basalt	--	22.00	7-26-66	--	S, 1	40	1	H	P 2 hr, L.
12dab	do	Dr	--	80	6	--	--	--	4,149	14.95	10-14-68	--	S	--	--	S	
15ccc	do	Dr	1965	101	6	101	Ø	Gravel	4,126	8.24	10-12-68	--	S, ?	15	4	S	B 3 hr, L.
18caa	Melvin Davenport	Dr	1967	100	8	60	P	"Clay"	4,128	6.73	5-21-69	--	S, 15	215	39	I	L.
20adb	Roy Ralston	Dr	1965	187	12	147	F	Sand	4,127	11.13	10-12-68	--	T, 50	1,270	--	I	L.
20ddc	Unknown	Dr	--	121	6	--	--	--	4,126	9.30	do	--	N	--	--	N	
29cdd	do	Dr	--	300?	6	--	--	--	4,126	10.14	do	--	S, ?	--	--	S	
31aba	do	Dr	--	300?	6	--	--	--	4,122	10.12	do	--	S, ?	--	--	S	

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct-ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw-down (feet)	Use	Remarks
T. 23 S., R. 33 E.--Continued																	
33bcc	Unknown	B	1968?	49	6	--	X	--	4,123	8.27	10-12-68	--	N	--	--	H	Not completed.
33cdd	do	Dr	--	--	4	--	--	--	4,121	10.50	do	--	N	--	--	N	
36dda	A. A. McCrea	Dr	1965	150	6	125	X	Sandstone, gravel	4,134	9.20	8-16-67	--	S, 3/4	30	24	H	B 2 hr, L.
T. 23 S., R. 34 E.																	
7cac	Lyle Vickers	Dr	1969	615	12	140	X, P	Gravel, basalt	4,146	F	9-30-69	198	T, 25	350	100	I	P 5 hr, L.
7dbb	C. P. Topliff	Dr	1968	170	8	147	X	Lava, pumice	--	F	7-26-68	--	--	50	50	H	B 2 hr, L.
18aaa	J. W. Cassy	Dr	1964	130	6	70	Ø	Cemented gravel, pumice	4,156	15.70	10-14-68	--	P, ¼	15	40	H	B 1 hr, L.
18acd	Dick Arnold	Dr	1963	77	12	19	F	Clay and gravel	4,148	17.55	do	--	T, 20	380	50	I	P 8 hr, L.
31add	Miller Bros.	Dr	1949	207	14	88	F	Sand and gravel	4,155	23.30	do	230	T, 10	350	120	I	L.
32aca	do	Dr	1961	328	12	77	X	Lava, cinders, sandstone	--	F	3-31-61	--	T, 7½	225	80	I	P 24 hr, L.
T. 24 S., R. 29 E.																	
2cab	Hal McUne	Dr	1966	150	12	110	P	Cinders, sand, gravel	4,198	47.58	10-10-68	--	N	100	45	I	B 1 hr, L.
T. 24 S., R. 30 E.																	
1abd	O. D. Hotchkiss	Dr	1930	564	10	117	X	Sandstone, vol-canic rock	4,134	F	9- 8-64	160	N	600	--	I	L; deepened in 1964 from 472 feet; C.
2aac	Unknown	Dr	--	--	8	--	--	--	4,140	F	8-23-67	--	N	10	--	I	
7cdd	A. J. Kisle	Dr	1962	347	14	100	P	Cinders, lava	4,155	19.15	9-11-68	160	T, 40	1,800	84	I	P 3 hr, L.
8bdd	do	Dr	1966	300	12	110	X	Pumice, lava	4,148	14.39	do	--	T, 40	500	88	I	Do.
11aba	L. E. Tyler	Dr	1962	513	6	181	X	Pumice, cinders, sand	4,134	F	10-11-68	--	N	450	--	I	L.
11abd	do	Dr	1962	566	12	183	X	"Rock," cinders	4,133	F	do	160	N	2,000	--	I	L.
17bab1	A. J. Kisle	Dr	1967	300	12	70	X	Sand, gravel, cinders	4,148	10.0	9-11-68	--	N	100	7	I	B ½ hr, L.
17bab2	do	Dr	1967	324	12	100	P, X	Clay and gravel, sand and gravel	4,148	9.83	do	--	T, 60	1,050	61	I	P 4 hr, L.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Altitude (feet)	Water level		Specific conductance of water	Type of pump and hp	Well performance		Use	Remarks
										Feet below datum	Date			Yield (gpm)	Drawdown (feet)		
T. 24 S., R. 30 E.--Continued																	
17bbb	Adolf Kisle	Dr	1966	220	12	60	X	Clay and gravel, pumice, lava	4,150	14.58	9-10-68	150	T, 50	1,200	60	I	P 3 hr, L.
18acb	do	Dr	1966	240	12	40	X	Pumice, cinders, lava	4,153	16.42	9-11-68	--	T, 60	117	46	I	Do.
24acd	John Campbell & Son	Dr	1959	503	16	65	P, X	Sand, gravel, cinders	4,131	4.43	10-11-68	170	T, 30	3,200	85	I	P 4 hr, L.
26ddc	do	Dr	1959	501	16	90	P, X	Pumice, sand, gravel	4,130	49.68	do	380	T, 50	2,500	16	I	P 4 hr, L, Obs.
T. 24 S., R. 31 E.																	
1abc	Dan Oney	Dr	--	--	6	--	--	--	4,129	23.11	10-13-68	--	--	--	--	S	
5acb	State of Oregon	Dr	1967	245	12	25	F, S	Sand and gravel	4,130	6.49	10-11-68	200	T, 40	500	61	I	P 13 hr, L.
5dbb	do	Dr	1958	146	10	52	P	Gravel	4,129	5.02	do	160	N	475	45	N	P 4 hr, L.
28bcc	Harney County	Dg	1936	19	1½	15	--	do	4,126	9.63	10- 9-68	--	N	--	--	N	Obs.
T. 24 S., R. 32 E.																	
1ada	H. C. Vogler, Jr.	Dr	--	631	6	--	--	--	4,125	17.06	10- 9-68	--	N	--	--	N	
4bbb	T. F. Drumm	Dr	1966	500	12	175	X	Clay	4,125	16.04	9-12-68	--	N	--	--	N	L.
5aad	John Wood	Dr	1965	270	12	213	X	Clay and sand	4,125	21.00	do	684	T, 15	--	--	I	L, C.
8dab	Harney Valley Devel. Co.	Dr	1937	2,812	8	--	--	--	4,120	F	do	580	--	35	--	N	Oil-test well, C.
12cbb	Mervin Johnson	Dr	1965	82	6	60	X	Sandstone	4,119	22.49	10- 9-68	--	J	10	--	H	B 1 hr, L.
T. 24 S., R. 32½ E.																	
13acb	C. W. Tripp	Dr	1967	242	12	230	X	Gravel	4,112	F	6-29-68	1,170	T	1,125	40	I	P 4 hr, L, C.
18bdc	Calvin Pelroy	Dr	1959	180	6	--	--	--	4,119	18.36	10- 9-68	--	S, 3/4	20	--	H	
20aac	Unknown	Dr	--	--	6	--	--	--	4,116	39.0	6-11-69	1,300	S	--	--	S	
22bcc	James Seeley	Dr	--	--	6	--	--	--	4,117	45.58	5-27-69	1,040	S	--	--	S	C; pumping measurement reported.
30add	Sam Gunterson	Dr	1967	185	6	99	X	Clay	4,106	15.95	10-13-68	3,200	S	45	54	S	B 2 hr, L, C.
30ddc	Ansel Marshall	Dr	--	130+	18	80	--	Sand, gravel	4,106	25.67	8-22-68	--	N	--	--	N	Obs, L.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Specific conduct-ance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Draw-down (feet)	Use	Remarks
								T. 24 S., R. 33 E.									
1cda	Diversified Ranches, Inc.	Dr	1964	357	14	100	F	Cinders, gravel	4,128	9.12	10-12-68	--	T, 50	1,000	100	I	P 10 hr, L.
1ddd	do	Dr	1963	185	6	171	X	Cemented cinders	4,132	12.32	10-18-68	--	N	30	9	N	B 3 hr, L.
2bdc	Joe Ingly	Dr	1967	250	6	229	X	Pumice	4,125	6	8-20-67	1,000	S	30	2	H	P 7 hr, L.
4abd	Diversified Ranches, Inc.	Dr	1964	380	14	100	F	Cinders, rock, gravel	4,122	8.10	10-12-68	--	N	760	100	N	P 10 hr, L.
6daa	George Mefford	Dr	1959	1,513	10	--	--	--	4,120	1.95	do	--	P	--	--	N	Oil test, started in 1939.
9acc	Dewey Kiem	Dr	1965	262	12	18	F	Clay and sand	4,118	5.05	do	--	N	600	55	N	P 6 hr, L.
9dad	H. C. Vogler, Jr.	Dr	--	400±	6	--	--	--	4,118	2.89	do	--	N	--	--	U	Unused stock well.
11ccc	do	Dr	--	180±	6	--	--	--	4,124	12.57	do	--	N	--	--	U	Do.
18bca	J. W. Coldiron	Dr	--	--	6	--	--	--	4,110	F	7- 2-68	1,200	S, 2½	20	--	H,S	Sulfur odor; tastes bad.
20aaa	David Long	Dr	1968	104	6	36	X	Clay and sand	4,110	6.59	10-12-68	--	N	40	--	U	B 1 hr, L.
24aac	R. H. Straw	Dr	1966	340	12	100	X	Lava, pumice, sandstone	4,128	11.97	10-15-68	4,000	T, 60	500	95	I	P 6 hr, L, C.
33ccb	Pacific Northwest Bell Telephone Co.	Dr	1966	200	6	126	X	Clay	4,110	26	7- 6-66	--	S	10	50	--	B 1 hr, L.
								T. 24 S., R. 34 E.									
6aac	Miller Bros.	Dr	1963	70	12	20	F	Gravel, sand, clay	4,145	25.00	10-14-68	--	T, 30	764	35	I	P 20 hr, L.
6abc	do	Dr	1968	85	12	20	F	Sand and clay	4,138	19.40	do	--	T, 30	650	56	I	P 12 hr, L.
19cdc	Jim Voss	Dr	--	800±	24	--	--	--	4,140	25.60	9-12-68	--	N	--	--	U	
31acb	J. W. Rossberg	Dr	1959	503	14	16	X	Pumice, basalt, cinders	4,142	32.32	10-15-68	--	T	225	58	I	P 60 hr, L.
31ada	do	Dr	1892	92	4	20	X	--	4,240	F	8-17-67	--	N	15	--	I	
31bac	do	Dr	1962	91	14	50	F	Gravel	4,137	26.39	10-15-68	600	T, 40	600	26	I	P 8 hr, C, Obs.
31cbd	do	Dr	1962	110	12	50	F	Gravel and sand	4,136	27.32	do	--	T, 30	600	80	I	P 5 hr, L.
31dcb	do	Dr	1960	305	14	9	X	Lava, cinders	4,145	35.72	8-24-67	--	N	200	100	U	P 2 hr, L.
31dda	do	--	1968	305	32	68	X	Gravel, cinders, lava	4,172	19.40	8-17-67	315	T	650	60	I	P 24 hr, L; originally 128 feet in 1956; C.

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Specific conductance of water	Type of pump and hp	Well performance: Yield (gpm)	Well performance: Drawdown (feet)	Use	Remarks
T. 25 S., R. 31 E.																	
4cba	James Stahl	Dr	1962	170	12	90	X	Sandstone, conglomerate	4,140	36.17	9-11-68	--	N	100	86	U	P 3½ hr, L, Obs.
9cdb	Unknown	Dr	--	105	6	--	--	--	4,109	12.25	10-13-68	--	P	--	--	S	
13cda	Island Ranch	Dr	--	360±	6	--	--	--	4,103	13.64	do	--	S	--	--	S	Water very salty.
27daa	Harney Land Devel. Co.	Dr	1962	179	6	129	P	Clay, cinders	4,110	16.25	9-11-68	--	N	288	63	U	P 3 hr, L.
29ccb	E. L. Koeneman	Dr	1963	209	8	70	P, X	Gravel	4,170	71.07	10-13-68	--	N	100	70	U	P 4 hr, L, Obs.
30ddb	do	Dr	1963	660	12	290	X	Clay	4,150	51.90	do	--	N	52	250	U	B 2 hr, L.
32aaa	Harney Land Devel. Co.	Dr	1962	111	6	70	F	Cinders and gravel	4,113	20.55	do	--	N	314	40	U	P 2 hr, L.
T. 25 S., R. 32 E.																	
7bab	Island Ranch	Dr	1952±	1,345	6	--	--	Clay, sand	4,106	F	5-27-69	1,450	N	3	--	S	C, temp 105°F.
12bab	do	Dr	--	50±	6	--	--	--	4,100	8.60	10-13-68	--	S	--	--	S	
16bcb	do	Dr	--	60	8	--	--	--	4,100	16.88	do	--	S	--	--	S	Pumping.
24bdb	do	Dr	--	60±	6	--	--	--	4,098	10.09	do	3,960	S	--	--	S	C.
35bdb	Clayton King	--	1964?	400±	--	--	--	"Blue mud"	4,097	--	--	3,300	--	--	--	H	Water has bicarbonate taste; C.
T. 25 S., R. 32½ E.																	
3bbb	M. H. Glenn	Dr	1967	91	6	40	X	Sand	4,110	34.20	10-13-68	--	N	20	10	U	B 3 hr, L.
4cdd	Unknown	Dr	--	--	6	--	--	--	4,099	13.15	do	--	S	--	--	S	
14aab	do	--	--	--	6	--	--	--	4,096	10.17	10-15-68	--	P	--	--	S	
25aab	U.S. Fish & Wildlife Service	--	--	--	--	--	--	--	4,095	11.35	do	3,030	S	--	--	S	C.
26aab	do	--	--	--	6	--	--	--	4,095	13.97	do	--	S	--	--	S	

Table 10.--Records of selected wells in the Harney Valley area--Continued

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level		Specific conduct-ance of water	Type of pump and hp	Well performance		Use	Remarks
										Feet below datum	Date			Yield (gpm)	Draw-down (feet)		
T. 25 S., R. 33 E.																	
1cdb	M. F. O'Donell	Dr	1967	205	12	190	X	Cinders, gravel	4,125	16.92	10-15-68	--	--	1,100	64	I	P 8 hr, L.
12abc	Tom Gillespie	Dr	1960	152	12	46	X	Volcanic ash, gravel, sand	4,130	23.17	do	--	T, 15	650	--	I	P, L.
14dcc	Unknown	Dr	--	--	6	--	--	--	4,110	14.30	do	--	J	--	--	S	
T. 25 S., R. 34 E.																	
7bbc	George Hoffman	Dr	1966	402	8	125	X	Sandstone, lava	4,130	29.14	10-15-68	--	T	160	--	I	L.
30dcc	Forrest Skinner	Dr	1957	41	14	20	X	Cinders	4,128	40.3	do	580	T, 25	1,000	2	I	P 12 hr, L, Obs.

Table 11.--Drillers' logs of representative wells

22S/30E-27ddc. W. W. Arntz. Altitude 4,230 ft. Drilled by Crane Drilling Co., 1961. Casing: 12-in. diam to 40 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Clay and rock, mixed	9	12
Rock, lava, red	22	34
Boulders, large	5	39
Rock, gray, solid	24	63
Clay, crumbly, and gravel	4	67
Pumice	2	69
Sand and gravel, with crumbly clay	19	88
Clay, yellow	30	118
Cinders, red	9	127

22S/30E-35bbb. W. W. Arntz. Altitude 4,190 ft. Drilled by Skinner & Sons, 1966. Casing: 12-in. diam to 20 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	3	3
Clay, brown, sandy	14	17
Clay, brown, with boulders	43	60
Pumice and sandstone, brown, water-bearing	35	95
Pumice, white, water-bearing	1	96
Pumice, gray, and soft rock, water-bearing	1½	97½

22S/31E-28dda. Harry Pon. Altitude 4,170 ft. Drilled by Holloway Drilling Co., 1961. Casing: 12-in. diam to 22 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	16	16
Sand, water-bearing	4	20
Clay	2	22
Rock, lava	73	95
Clay, hard	137	232
Sand and pea-sized gravel	3	235
Clay, yellow, sticky	133	368
Cinders, black	2	370
Clay, yellow, sticky	90	460
Gravel, pea-sized	2	462
Soapstone	2	464
Clay, yellow	26	490

22S/31E-32bcc. Harry Pon. Altitude 4,180 ft. Drilled by Holloway Drilling Co., 1961. Casing: 14-in. diam to 226 ft; perforated 36-226 ft

Materials	Thickness (feet)	Depth (feet)
Soil	18	18
Clay and gravel	56	74
Shale, blue	10	84
Sand and gravel	28	112
Shale, blue	29	141
Sandstone	12	153
Sand and gravel	20	173
Clay, gray, and gravel	32	205
Clay, red	3	208
Cinders, red	4	212
Rock, red, porous	14	226
Rock, red, hard	11	237
Rock, black, hard	11	248
Rock, soft	2	250
Rock, hard	10	260

22S/31E-33baa. Harry Pon. Altitude 4,190 ft. Drilled by Holloway Drilling Co., 1962. Casing: 12-in. diam to 21 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Loam, sandy	6	6
Clay	13	19
Rock, black, hard	25	44
Clay	10	54
Gravel and sand, some water	4	58
Clay, brown	302	360
Rock, black, hard	28	388
Rock, red, porous	5	393
Rock, black, hard	27	420
Rock, loose, crevice	5	425

22S/31E-33ccd. Harry Pon. Altitude 4,155 ft. Drilled by Holloway Drilling Co., 1961. Casing: 12-in. diam to 80 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	18	18
Sand, water-bearing	20	38
Clay	22	60
Sand, coarse, water-bearing	18	78
Rock, hard	22	100
Clay, brown	133	233
Shale, blue	21	254
Gravel	2	256
Shale, blue	29	285
Clay, yellow	60	345
Gravel	2	347
Clay, white	27	374
Pumice, white	2	376
Clay, brown	4	380
Sandstone, gray	8	388
Cinders, red	2	390

22S/31E-34aaa. George Purdy. Altitude 4,162 ft. Drilled by Western Drilling Co., 1966. Casing: 12-in. diam to 60 ft; perforated 40-60 ft

Materials	Thickness (feet)	Depth (feet)
Soil	5	5
Sand and gravel	11	16
Clay, brown	11	27
Clay and gravel	30	57
Rock, red	53	110
Pumice	36	146
Sandstone	54	200
Clay, brown, and gravel	10	210
Clay, blue, and gravel	290	500
Clay, white, and gravel	144	644
Rock, multicolored, hard	48	692
Cinders, red	13	705
Cinders, dark-colored	15	720
Clay, brown	5	725

22S/31E-36bab. R. F. Smith. Altitude 4,156 ft. Drilled by Holloway Drilling Co., 1961. Casing: 12-in. diam to 33 ft; perforated 18-33 ft

Materials	Thickness (feet)	Depth (feet)
Soil	20	20
Gravel, fine, water-bearing	11	31
Clay	11	42
Sandstone, brown	31	73
Sandstone, red	7	80
Sandstone, brown, soft	14	94
Rock, lava, black, hard	44	138
Slate	10	148
Clay	28	176
Claystone, blue	34	210
Sandstone, black	8	218
Clay, black	22	240
Clay, black, sandy	15	255
Slate	15	270
Clay, green	4	274
Shale, blue	34	308
Sand, black, fine	3	311
Shale, blue	14	325
Sand, black, coarse	6	331
Shale, blue	4	335

Table 11.--Drillers' logs of representative wells--Continued

22E/32S-35bbb. R. W. Davis. Altitude 4,150 ft. Drilled by Paul Chrisley, 1957. Casing: 24-in. diam to 90 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Gravel, large, and yellow clay	50	50
Clay, blue	15	65
Clay, yellow	10	75
Clay, blue	15	90
Clay, yellow, and pumice	45	135
Sand, hard	5	140
Clay, yellow, and pumice	25	165
Sandstone, hard, and pumice	30	195
Pumice	30	225
Clay, yellow	15	240
Sand, blue and gray	15	255
Sand and shale, blue	40	295
Shale, blue and green; hard sand in lower 5 ft	20	315
Shale and sand, blue	25	340
Shale, green	10	350
Shale, blue, and pumice	5	355
Shale, blue	15	370
Shale, blue and gray, and pumice	20	390
Shale, gray and blue, and yellow clay	15	405
Sand, gray	15	420
Sand, blue and gray, and green shale	10	430
Shale, gray, and sand layers	15	445
Sand, gray, and yellow clay	5	450
Pumice and yellow clay	25	475
Pumice and green clay	20	495
Pumice and gray sand	15	510
Shale, blue, and volcanic ash	25	535
Clay, brown	10	545
Shale, gray	10	555
Volcanic ash	5	560
Clay, yellow	15	575
Shale, gray	30	605
Sand, gray, and shale	5	610
Shale, green	5	615
Clay, yellow	5	620
Sand, gray, hard	15	635
Pumice	15	650
Pumice and gravel	15	665
Shale, blue	5	670
Gravel, loose, water-bearing	5	675
Sandstone, blue	10	685
Sand, blue-gray, fine	5	690
Sand, blue-gray, coarse	25	715
Sand, gray, coarse	35	750
Shale, gray and blue	30	780
Sand, fine to coarse, blue	10	790
Sand and pea-sized gravel, blue, water-bearing	5	795
Sand, blue, fine to coarse	5	800
Sand, blue, fine, and brown rock	5	805
Sandstone, gray, water-bearing	5	810
Gravel, pea-sized, gray and black, water-bearing	5	815
Sand, gray and brown, coarse	5	820
Rock, hard, and coarse sand, gray	15	835
Sand, light-gray, coarse, and pea-sized gravel	10	845
Rock, brown, and gray sandstone	10	855
Sand, gray, coarse	5	860
Sandstone, gray, hard	20	880

22E/32S-36bbb. William Huggard. Altitude 4,142 ft. Drilled by Skinner & Sons, 1967. Casing: 12-in. diam to 60 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	4	4
Clay, brown	3	7
Gravel and clay, brown	11	18
Gravel, with trace of clay, water-bearing	15	33
Clay, brown	3	36
Sand, brown, fine	18	54
Claystone, brown, with trace of white pumice	88	142
Clay	29	171
Clay, green, sandy, with trace of water	11	182
Clay, brown, with white pumice	15	197
Clay, green, with trace of fine gravel and white pumice	26	223
Claystone, yellow, and white pumice	33	256
Pumice, white, and green claystone	25	281
Clay, green, sticky	47	328
Clay, gray, sandy	7	335
Clay, green	94	429
Rock, hard	2	431

22E/32S-36bbb.--Continued

Materials	Thickness (feet)	Depth (feet)
Clay, green, and black sandstone, water-bearing	56	487
Claystone, brown	54	541
Sandstone, brown, with traces of white pumice and green claystone, water-bearing	38	579
Pumice, white, with traces of black sandstone	32	611

22S/32½E-5bb. Charles Danuser. Altitude 4,395 ft. Drilled by John W. Rossberg, 1966. Casing: 6-in. diam to 30 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	18	18
Sandstone	22	40
Pumice	70	110
Basalt, gray	50	160
Shale, cindery	25	185
Clay, brown	5	190
Basalt, black	65	255
Rock, red, cindery	5	260
Clay and gravel, mixed	40	300
Clay, red, and gravel, mixed	101	401
Lava, honeycombed	19	420
Basalt, black	50	470
Rock, red, soft	5	475
Basalt, fractured	70	545

22S/32½E-18aad. Charles Danuser. Altitude 4,300 ft. Drilled by John W. Rossberg, 1967. Casing: 6-in. diam to 20 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Clay and gravel	40	40
Rock, lava, black	20	60
Basalt, black, hard	15	75
Shale, blue	50	125
Sandstone, gray	100	225
Clay, blue	51	276
Sand, medium, and shale	109	385
Sand, black, fine, water-bearing (118 gpm)	2	387
Basalt, black	58	445

22S/32½E-30cdb. Jack McGee. Altitude 4,146 ft. Drilled by Skinner & Sons, 1963; deepened in 1964. Casing: 12-in. diam to unknown depth; unperforated

Materials	Thickness (feet)	Depth (feet)
Old well	202	202
Clay, brown	8	210
Pumice, gray, and coarse sand, water-bearing	10	220
Clay, green	20	240
Clay, green, and medium sand	33	273
Claystone, green and white	21	294
Clay, blue, and medium sand	22	316
Claystone, green	37	353
Clay, blue, trace of fine sand	7	360
Clay, blue, trace of gray pumice	24	384
Clay, green	14	398
Clay, green, sandy	12	410
Clay, blue, with fine sand and trace of white pumice	16	426
Rock, black	5	431
Clay, blue	23	454
Clay, green, trace of gravel	19	473
Clay, black, and gravel	4	477
Clay, green	32	509
Clay, black	3	512
Claystone, green	115	627
Gravel, coarse, water-bearing	12	639
Pumice, green and black	8	647
Rock, lava	--	--

22S/32½E-36aab. Richard Temple. Altitude 4,135 ft. Drilled by John W. Rossberg, 1968. Casing: 12-in. diam to 70 ft; perforated 20-180 ft

Materials	Thickness (feet)	Depth (feet)
Soil, "hardpan"	11	11
Gravel, cemented	7	18
Clay, blue	62	80
Shale and clay, mixed	90	170
Shale "rock," blue	12	182

Table 11.--Drillers' logs of representative wells--Continued

22S/32½E-36aac. J. C. Temple & Sons. Altitude 4,133 ft. Drilled by John W. Rossberg, 1964. Casing: 12-in. diam to 52 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	6	6
Clay, brown, and sand, mixed	9	15
Sand, brown, medium	11	26
Sand, black, medium	4	30
Clay, blue	2	32
Sand, fine, and gravel, mixed	13	45
Diatomite, gray	2	47
Rock, lava, brown	18	65
Shale "rock," red	25	90
Pumice	42	132

22S/32½E-36dab. J. C. Temple & Sons. Altitude 4,132 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 71 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
"Hardpan" and yellow clay	17	20
Sand, fine	10	30
Gravel and clay, mixed	10	40
Clay, yellow	10	50
Clay, green	55	105
Shale, black	28	133
Shale, brown	62	195
Clay and fine gravel	35	230
Pumice	15	245
Clay, green	65	310
Pumice, hard, and gravel	10	320
Clay, blue, and shale	25	345

22S/32½E-36ddb. J. C. Temple & Sons. Altitude 4,132 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 80 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	?	?
Clay	?	?
Sand, coarse	?	?
Gravel, fine	?	70
Clay, green, and gravel	80	150
Pumice and blue clay, mixed	10	160
Clay, green	50	210
Shale, brown, hard	160	370
Clay, blue	320	690
Shale(?), black, soft	15	705
Shale, blue	40	745
Shale(?), black, soft	5	750
Clay, brown, and shale	50	800
Pumice and clay	15	815
Clay, green	25	840

22S/33E-31aaa. Donald Corcoran. Altitude 4,138 ft. Drilled by E. L. Koeneman Drilling Co., 1961. Casing: 6-in. diam to 143 ft

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, yellow	14	17
Sand, black, silty; a little water	25	42
Clay, blue	54	96
Clay, white	5	101
"Granite rock," broken, water-bearing (3 gpm)	4	105
Shale, green	114	219
"Granite rock," blue, porous, water-bearing	6	225

22S/33E-34bbb. Donald Corcoran. Altitude 4,153 ft. Drilled by E. L. Koeneman, 1961. Casing: 6-in. diam to 160 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, yellow	22	24
Clay, blue	43	67
Clay, green	54	121
Shale, green, hard	41	162
"Granite rock," blue, broken, water-bearing	5	167

23S/30E-12ddd. City of Burns. Altitude 4,160 ft. Drilled by R. J. Strasser Drilling Co., 1950. Casing: 16-in. diam to 144 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	9	9
Sand	9	18
Rock, soft	6	24
Rock, gray, hard	22	46
Rock, decomposed	30	76
Rock, gray, hard	8	84
Rock, decomposed	15	99
Rock, gray, hard	4	103
Pumice	37	140
Rock, porous	24	164
Rock, red	17	181
Rock, gray, hard	18	199
Rock, gray, hard, rough	22	221
Rock, gray, hard	28	249
Rock, gray, hard, rough	18	267
Rock, black, broken	5	272
Pumice, white	8	280
Rock, soft, mixed	13	293
Rock, gray, hard	11	304

23S/30E-14dcc. F. H. Garland. Altitude 4,250 ft. Drilled by Western Drilling Co., 1967. Casing: 14-in. diam to 140 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Clay and gravel	35	38
Clay and boulders	47	85
Pumice	15	100
Rock, volcanic, red, hard	9	109
Cinders, mixed colors	33	142
Rock, volcanic, red, hard	23	165
Cinders, red	25	190
Pumice	25	215
Rock, black, very hard	53	268
Cinders, red	20	288
Rock, black, very hard	17	305

23S/30E-20cac. U.S. Air Force. Altitude 5,233 ft. Drilled by R. J. Strasser Drilling Co., 1959. Casing: 10-in. diam to 1,224 ft; perforated 1,122-1,128 ft, 1,156-1,162 ft, and 1,218-1,223 ft

Materials	Thickness (feet)	Depth (feet)
Lava, red, black, and brown	14	14
Lava, brown, rough	140	154
Rock, brown with white streaks, rough, broken	334	488
Rock, gray with red and brown streaks	21	509
Rock, gray with red and brown streaks, very rough	100	609
Lava, brown	36	645
Lava, brown and gray	33	678
Lava, with conglomerate streaks	28	706
Lava, gray, brown, and white	20	726
Lava, mixed colors, with conglomerate	17	743
Lava, gray, brown, and white	38	781
Rock, broken, loose	6	787
Lava, red and white	3	790
Lava, with decomposed layers	2	792
Lava, gray and white streaks	17	809
Lava, gray, broken	29	838
Lava, brown and gray, very rough	13	851
Lava, brown and white, rough	187	1,038
Lava, brown with black streaks	31	1,069
Lava, black, red, brown, and white	87	1,156
Rock, mixed colors, broken, some water	6	1,162
Lava, mixed colors	7	1,169
Cinders, red	49	1,218
Rock, gray, broken, water-bearing	6	1,224

Table 11.--Drillers' logs of representative wells--Continued

23S/30E-23cda. City of Hines. Altitude 4,200 ft. Drilled by Western Drilling Co., 1967. Casing: 14-in. diam to 280 ft; perforated 260-280 ft

Materials	Thickness (feet)	Depth (feet)
Soil	4	4
Clay, brown, hard	12	16
Clay, brown, and gravel	64	80
Gravel, coarse, cemented	20	100
Rock, red, hard	20	120
Clay, brown	10	130
Pumice	35	165
Rock, red, hard	55	220
Rock, volcanic, dark-red, hard	25	245
Rock, red, hard	10	255
Pumice	14	269
Cinders, red	16	285
Cinders, red, and rock, mixed	15	300
Cinders, multicolored	27	327
Cinders, red, and hard red rock	18	345

23S/30E-24aad. Harney County Fair Assoc. Altitude 4,143 ft. Drilled by E. L. Koeneman, 1963. Casing: 10-in. diam to 195 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, yellow	10	12
Rock, broken, and clay	33	45
Rock, broken, and sand	5	50
Rock, broken, and yellow clay	34	84
Clay, blue	21	105
Sand, brown, dry	19	124
Clay, blue	42	166
Rock, lava, broken, and clay	21	187
Pumice	3	190
Rock, lava	3	193
Sandstone, water-bearing	22	215
Sand, black	3	218

23S/30E-24bba. J. E. Enneberg. Altitude 4,163 ft. Drilled by Western Drilling Co., 1967. Casing: 6-in. diam to 80 ft; perforated 60-80 ft

Materials	Thickness (feet)	Depth (feet)
Soil	9	9
Clay, brown, hard	5	14
Clay, brown, and medium gravel	11	25
Clay, brown	11	36
Gravel, medium	24	60
Clay, brown, and gravel	50	110
Rock, brown, hard	6	116
Clay, dark-colored, and gravel	74	190
Rock, hard, with some obsidian	18	208
Clay, yellow	2	210

23S/30E-26dac. Hines Lumber Co. Altitude 4,147 ft. Drilled by Western Drilling Co., 1965. Casing: 12-in. diam to 41 ft; perforated 20-41 ft

Materials	Thickness (feet)	Depth (feet)
Fill	4	4
Clay	3	7
Sand, medium, water-bearing	7	14
Clay, hard	21	35
Sand and gravel	5	40
Rock, volcanic, very hard	11	51
Cinders, red	69	120
Rock, volcanic, dark-colored, very hard	25	145
Cinders, red	20	165
Rock, hard	28	193
Cinders, red	24	217
Rock, hard	1	218

23S/30E-35aad. Hines Lumber Co. Altitude 4,140 ft. Drilled by Western Drilling Co., 1965. Casing: 12-in. diam to 113 ft; perforated 56-113 ft

Materials	Thickness (feet)	Depth (feet)
Fill	6	6
Clay, blue, and medium gravel	45	51
Cinders, red	9	60
Clay, sandy	12	72
Rock, red, and cinders	11	83
Cinders, red	55	138
Rock, volcanic, very hard	62	200

23S/30E-36cbb. Hazel M. Gouldin. Altitude 4,138 ft. Drilled by Skinner & Sons, 1965. Casing: 10-in. diam to 104 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	2	2
Clay, gray	6	8
"Hardpan," brown	2	10
Pumice, white, and sandy clay	8	18
Sand, black, fine, water-bearing	7	25
Sand, gray, with trace of brown clay	12	37
Sand, gray, fine	40	77
Sand, gray, fine, with trace of red cinders	25	102
Rock, lava, red and black	41	143
Rock, lava, red, artesian water	37	180
Rock, lava, black, water-bearing	18	198

23S/31E-4abc. Lester Tyler. Altitude 4,153 ft. Drilled by P. S. Weitenhiller(?), 1929. Casing: 18-in. diam to 38 ft; perforated at unknown depth

Materials	Thickness (feet)	Depth (feet)
Loam	40	40
Sand, fine	12	52
Clay, dark-gray, sticky	49	101
Rock, hard; would not penetrate	--	--

23S/31E-5aac. Harry Pon. Altitude 4,157 ft. Drilled by Holloway Drilling Co., 1961. Casing: 12-in. diam to 95 ft; perforated 18-34 ft, 52-56 ft, 69-74 ft, and 93-95 ft

Materials	Thickness (feet)	Depth (feet)
Soil	18	18
Gravel and sand, water-bearing	16	34
Clay	18	52
Gravel	4	56
Clay	13	69
Gravel	5	74
Clay and yellow sandstone	6	80
Clay	13	93
Gravel	2	95
Clay	8	103
Rock, brown	27	130
Rock, black, hard	9	139
Sandstone, gray	21	160
Clay, gray, and sand	18	178
Gravel, pea-sized	2	180
Clay, yellow	75	255
Shale, black	83	338
"Granite rock," gray	10	348
Gravel, pea-sized	7	355
Soapstone, white	35	390
Clay, with pea-sized gravel	4	394
Rock, red and black, broken	6	400

Materials	Thickness (feet)	Depth (feet)
23S/31E-5aad. Harry Pon. Altitude 4,155 ft. Drilled by Holloway Drilling Co., 1961. Casing: 14-in. diam to 127 ft; perforated 60-80 ft and 110-125 ft		
Soil	12	12
Gravel and sand, water-bearing	8	20
Clay	40	60
Gravel, water-bearing	20	80
Clay	30	110
Gravel	15	125
Clay	2	127
Rock, very hard	55	182
Cinders and coarse sand	15	197
Clay, brown	109	306
Clay, yellow	46	352
Sand	3	355
Clay	65	420
Gravel	4	424
Clay	11	435
Rock, red, broken	3	438
23S/31E-5bca. Eban Ray. Altitude 4,162 ft. Drilled by Paul G. Chrisley, 1962. Casing: 12-in. diameter to 120 ft; unperforated		
Soil	6	6
Clay, gray	11	17
Gravel and yellow clay conglomerate	92	109
Clay, yellow, hard (caliche)	16	125
Clay, blue	70	195
Sand, black, heavy water flow	19	214
23S/31E-5cba. Harry Pon. Altitude 4,155 ft. Drilled by Holloway Drilling Co., 1961. Casing: 14-in. diam to 125 ft; perforated 14-120 ft		
Soil	8	8
Clay	6	14
Sand and gravel, water-bearing	14	28
Clay	12	40
Gravel	12	52
Clay and gravel, mixed	28	80
Gravel	12	92
Clay	8	100
Gravel	14	114
Shale, blue	46	160
Sand, blue	4	164
Shale, blue	16	180
Sand, black	4	184
Shale, blue, sandy	19	203
Gravel, pea-sized	2	205
23S/31E-5cbb. Eban Ray. Altitude 4,160 ft. Drilled by Holloway Drilling Co., 1961. Casing: 12-in. diam to 124 ft; perforated 15-124 ft		
Soil	10	10
Clay, sandy	3	13
Sand and gravel, water-bearing	39	52
Clay	8	60
Gravel, pea-sized	30	90
Clay	5	95
Gravel	25	120
Shale, blue	40	160
Shale, sandy	10	170
Shale, blue	25	195
Sand, blue and green	5	200
23S/31E-6add. Lloyd Hill. Altitude 4,160 ft. Drilled by Western Drilling Co., 1965. Casing: 8-in. diam to 116 ft; perforated 76-116 ft		
Soil	6	6
Clay	14	20
Gravel, medium	6	26
Clay and gravel	64	90
Clay, blue	16	106
Gravel, medium	9	115
Clay, blue	30	145
Clay, brown, and some sand	40	185
23S/31E-6bcb. Kenneth Retherford. Altitude 4,161 ft. Drilled by John W. Rossberg, 1968; deepened from 150 to 170 ft, 1969. Casing: 6-in. diam to 161 ft; unperforated		
Soil	18	18
Clay, yellow, and sand, mixed	107	125
Clay, blue	15	140
Sand, black, and gravel	10	150
Clay, blue	12	162
Sand, fine, and gravel	8	170
23S/31E-6bcc. Hobart Tiller. Altitude 4,160 ft. Drilled by Skinner & Sons, 1966. Casing: 12-in. diam to 120 ft; perforated 55-75 ft		
Soil, brown	6	6
Clay, brown	2	8
Clay, brown, and gravel, water-bearing	72	80
Gravel, fine	20	100
Gravel, coarse	9	109
Gravel, coarse, with green clay	11	120
23S/31E-6ccd. Pluribus Tiller. Altitude 4,160 ft. Drilled by E. L. Koeneman, 1968. Casing: 8-in. diam to 140 ft; perforated 110-138 ft		
Soil	3	3
Clay, blue, and sand	15	18
Gravel, cemented, and small boulders	18	36
Sand, yellow	72	108
Sand, yellow, with small gravel	19	127
Gravel, 1-in. diam and larger, and coarse yellow sand	13	140
23S/31E-9dbb. Hilton Whiting. Altitude 4,146 ft. Drilled by Paul G. Chrisley, 1961. Casing: 12-in. diam to 154 ft; perforated 55-68 ft and 129-149 ft		
Soil	20	20
Gravel, coarse, and sand	20	40
Clay, yellow	4	44
Gravel, coarse	24	68
Clay, yellow	52	120
Clay, blue	8	128
Sand, coarse, and gravel and cinders	16	144
Shale, green	86	230
Pumice, cinders, and clay	50	280
Clay, blue	65	345
Sand, blue, coarse, and cinders	17	362
Shale, green	2	364
23S/31E-11bbb. Cliff Gunderson. Altitude 4,143 ft. Drilled by Skinner & Sons, 1966. Casing: 6-in. diam to 107 ft; unperforated		
Soil, brown	2	2
Clay, brown	18	20
Clay, brown, and fine gravel	20	40
Gravel and fine sand, with trace of clay	30	70
Sand, black, fine, water-bearing	11	81
Sand, yellow, fine, water-bearing	24	105
Sandstone, coarse, water-bearing	65	170
23S/31E-11dcc1. Riley & Sewell. Altitude 4,145 ft. Drilled by Russell Stooksberry (date drilled unknown). Casing: 12-in. diam to 120 ft; perforated 15-30 ft, 50-67 ft, 100-120 ft		
Soil and brown clay	12	12
Sand, brown	3	15
Gravel, brown, 3/8-in. diam	15	30
Clay, blue and brown	20	50
Gravel, blue and brown, 1/2- to 5/8-in. diam	17	67
Clay, blue	43	110
Gravel, blue, 3/8-in. diam	3	113
Clay, blue	7	120

Materials	Thickness (feet)	Depth (feet)
23S/31E-11dcc2. Riley & Sewell. Altitude 4,145 ft. Drilled by John W. Rossberg, 1959. Casing: 12-in. diam to 220 ft; unperforated		
Soil and "hardpan"	29	29
Sand, gray	5	34
Clay, blue	17	51
Gravel, fine to coarse	8	59
Clay, brown, and sand	39	98
Gravel, coarse	1	99
Boulders and black sand	11	110
Clay, blue, and sand, mixed	200	310
Clay, green, and shale	30	340
Pumice, gray	33	373
Boulders, "granite," gray, decomposed	37	410
Clay, blue, and shale	30	440
Sand, gray, and boulders	20	460
Rock, hard	4	464
Clay, green	49	513
Clay, yellow, and boulders	14	527
Clay, blue	34	561
23S/31E-13bcc. Clarence Gardner. Altitude 4,143 ft. Drilled by O. L. Gasch, 1931; deepened 1934-35. Casing: 18-in. diam 0-83 ft, 12-in. diam to 200 ft; perforated 67-200 ft		
Soil	12	12
Gravel	11	23
Clay	26	49
Gravel	12	61
Clay	8	69
Sand	4	73
Clay	22	95
Sand	55	150
Sand and clay, mixed	25	175
Clay	110	285
Rock	8	293
Clay, yellow	7	300
Gravel	3	303
Clay, black	7	310
Clay, yellow	20	330
23S/31E-15abb. Henry Ausmus. Altitude 4,145 ft. Drilled by P. S. Weitenhiller, 1930. Casing: 12-in. diam to 60 ft; perforated 43-58 ft		
Loam, black	6	6
Gravel, fine to coarse, contains a little sand	15	21
Clay, blue	17	38
"Hardpan"	1	39
Gravel; contains a little red sand	13	52
Clay, blue	35	87
23S/31E-16dbb. T. A. Jones. Altitude 4,146 ft. Drilled by P. S. Weitenhiller and A. A. Durand, 1930. Casing: 12-in. diam to 117 ft, 8-in. diam 155-300 ft; perforated 37-117 ft and 160-240 ft		
Soil	9½	9½
Gravel, loose; cemented layers 1 ft thick at 50 and 75 ft	74½	84
Clay	6	90
Gravel, black, coarse, loose; coarser toward bottom	27	117
Clay, blue	38	155
Gravel, fine, or sand, coarse	105	260
Clay	8	268
Sand, grains as large as 1/8-in. diam, black; some pebbles as large as 2-in. diam; considerable fine silt	32	300
23S/31E-19daa. Dorman Otley. Altitude 4,142 ft. Drilled by Paul G. Chrisley, 1955. Casing: 12-in. diam to 94 ft; perforated 18-30 ft and 55-73 ft		
Soil	18	18
Gravel	7	25
Clay, brown	15	40
Gravel	15	55
Gravel and brown clay	15	70
Clay, yellow, and gravel	15	85
Clay, yellow	15	100
Gravel	13	113
23S/31E-20abd. Culp Cattle Ranch. Altitude 4,140 ft. Drilled by McGuire Drilling Co., 1963. Casing: 6-in. diam to 43 ft; perforated 33-43 ft		
Soil	8	8
Sand and fine gravel	22	30
Gravel, coarse	13	43
23S/32E-7cab. Dorland Ray. Altitude 4,135 ft. Drilled by P. S. Weitenhiller, 1926. Casing: 18-in. diam to unknown depth, 12-in. diam to 93 ft; perforated 36-86 ft		
Silt loam, sandy	1½	1½
Adobe, black, angular	3½	5
Clay, yellow	4½	9½
Sand, blue, fine	1	10½
Gravel, fine; water table at 11 ft	1½	12
Gravel, fine, grading to coarse sand	2	14
Clay, blue, and fine sand	1½	15½
Clay, blue, and fine sand, grading to fine sand at base	6½	22
Clay, blue	17	39
Clay, blue, and gravel "hardpan"	3½	42½
Gravel and coarse sand; fine sand and gray clay at bottom; "second flow" at 42½ ft	12½	55
Sand, red, fine	1	56
Clay, yellow and gray	5	61
Sand, gravel, and clay	2	63
Sand, blue, fine	1	64
Clay, blue, and blue sand seams	11	75
Sand, bluish-gray, fine, coarser with some gravel at bottom; "third flow" at 74 ft	11	86
Clay, blue	½	86½
23S/32E-7dcb2. Dorland Ray. Altitude 4,136 ft. Drilled by Skinner & Sons, 1966. Casing: 12-in. diam to 200 ft; unperforated		
Soil, brown	2	2
Clay, brown	13	15
Sand, coarse, water-bearing	3	18
Sand, black	7	25
Clay, blue	15	40
Gravel, coarse, water-bearing	15	55
Clay, brown, with sand	3	58
Clay, blue	17	75
Sand, black, fine	34	109
Clay, blue	16	125
Sand, fine	48	173
Claystone, green, with gravel	7	180
Pumice, gray, and claystone	40	220
Pumice, gray, water-bearing	15	235
23S/32E-11bbc. J. H. Raine. Altitude 4,128 ft. Drilled by John W. Rossberg, 1964. Casing: 24-in. diam to 30 ft, 12-in. diam 0-106 ft; perforated 47½-90 ft		
Soil	3	3
Sand, fine	15	18
Clay, blue	32	50
Sand, fine	10	60
Clay, blue	25	85
Sand, fine	4	89
Gravel, coarse	1	90
Clay, blue	16	106

Materials	Thickness (feet)	Depth (feet)
23S/32E-13bbb. Pat Hays. Altitude 4,125 ft. Drilled by McGuire Drilling Co., 1963. Casing: 14-in. diam to 232 ft; perforated 72-232 ft		
Soil	8	8
Clay, brown	38	46
Clay, blue	20	66
Gravel, coarse	6	72
Clay, blue	31	103
Gravel, coarse	8	111
Clay, blue	47	158
Gravel, medium	5	163
Clay, blue	25	188
Gravel, medium	7	195
Clay, blue	8	203
Gravel, coarse	27	230
Rock, hard	2	232
23S/32E-18bbb. Bar Negative Ranch. Altitude 4,140 ft. Originally drilled in 1961 by John A. VanMeter to depth of 1,316 ft; reconditioned in 1963 by Holloway Drilling Co. to depth of 170 ft. Casing: 16-in. diam to 160 ft; unperforated		
Soil	3	3
Clay	2	5
Clay and sand	10	15
Quicksand	15	30
Mud, gray, and fine sand	11	41
Sandstone, hard	15	56
Clay, gray and yellow	3	59
Clay, gray	23	82
Clay, gray, and fine sand	93	175
Clay, gray	15	190
Gravel, "shattered lava," and gray clay	33	223
Clay, gray	10	233
Clay, green	10	243
Clay, gray, and pumice gravel	72	315
Shale, gray, and pumice and sand	24	339
Clay, green, and some pumice	17	356
Pumice, gravel, sand, and clay	4	360
Clay, green, with streaks of sand	227	587
Sand and gravel	3	590
Clay, brown, with streaks of sand	115	705
Pumice, sand, and gravel, with streaks of white clay	79	784
Rock, brown, sedimentary	7	791
Rock, gray, sedimentary	16	807
Pumice, sand and gravel, and blue clay	63	870
Clay, yellow	20	890
Clay, brown, and sand	7	897
Pumice, sand, and black gravel	15	912
Clay, gray	82	994
Pumice and black gravel	9	1,003
Clay, gray	17	1,020
Pumice and black gravel	8	1,028
Clay, gray, and sand	12	1,040
Pumice and black gravel	22	1,062
Clay, gray	14	1,076
Pumice and black gravel	12	1,088
Clay, gray	24	1,112
Pumice and black gravel	6	1,118
Pumice and clay, hard-packed	11	1,129
Clay, varicolored, and sand	19	1,148
Shale, gray, hard, and layers of sticky clay	24	1,172
Clay, yellow, and shale	21	1,193
Pumice sandstone, hard	85	1,278
Shale, black, soft	6	1,284
Shale, gray, hard	32	1,316
23S/32E-20cca. Henry Cowing. Altitude 4,134 ft. Drilled by John W. Rossberg, 1968. Casing: 6-in. diam to 153 ft; unperforated		
Soil	20	20
Sand and gravel	20	40
Clay, blue	40	80
Clay and gravel, mixed	50	130
Sandstone, with gravel streaks	23	153
Sand, black	2	155
23S/32E-22ccd. Wallace Shepard. Altitude 4,128 ft. Drilled by Paul G. Chrisley, 1955. Casing: 8-in. diam to 72 ft, 6-in. diam to unknown depth; perforated 50-70 ft, 120-130 ft, and 150-180 ft		
Soil	16	16
Quicksand, brown	24	40
Shale, blue	25	65
Gravel	5	70
Shale, blue	15	85
Sand and shale	20	105
Sand, blue	20	125
Shale, blue, sticky	5	130
Sand and shale	15	145
Shale, blue, sticky	15	160
Sand, gravelly	5	165
Shale, blue	45	210
Sand and shale	10	220
Shale, black	20	240
Shale, blue	10	250
23S/32E-28aba. Bar Negative Ranch. Altitude 4,131 ft. Drilled by Stooksberry, 1955. Casing: 10-in. diam to 93 ft; perforated 50-78 ft		
Soil	8	8
Quicksand, brown	24	32
Clay, blue	17	49
Gravel, fine to coarse, water-bearing	23	72
Clay, blue	35	107
Gravel, water-bearing	4	111
Clay, blue	29	140
23S/32E-28acd. Bar Negative Ranch. Altitude 4,129 ft. Drilled by Paul G. Chrisley, 1959. Casing: 14-in. diam to 146 ft; perforated 50-140 ft		
Soil	5	5
Quicksand, brown	27	32
Clay, blue	18	50
Gravel, water-bearing	19	69
Clay, blue	41	110
Gravel, water-bearing	6	116
Clay, blue	44	160
Gravel, water-bearing	2	162
Clay, blue	55	217
Clay, white and gray	11	228
Gravel, water-bearing	10	238
Clay, blue	12	250
23S/32E-28bbd. Roy Duhaime. Altitude 4,133 ft. Drilled by Paul G. Chrisley, 1955. Casing: 8-in. diam to 65 ft, 6-in. diam 65-175 ft; perforated 115-160 ft		
Old well	155	155
Sand, blue, and gravel	5	160
Sand, blue	5	165
Shale, blue	30	195
Shale, sandy	10	205
Sand and gravel	5	210
23S/32E-28bcc. Roy Duhaime. Altitude 4,132 ft. Drilled by Paul G. Chrisley, 1955. Casing: 8-in. diam to 70 ft, 6-in. diam to unknown depth; perforated 50-65 ft, 115-155 ft		
Soil	30	30
Shale, blue	25	55
Gravel and sand, water-bearing	10	65
Shale, blue	50	115
Gravel, water-bearing	30	145
Clay, blue	35	180
Sand	9	189
Gravel, water-bearing	2	191

23S/32E-29adb. Roy Duhaime. Altitude 4,132 ft. Drilled by Paul G. Chrisley, 1955. Casing: 12-in. diam to 75 ft, 10-in. diam to unknown depth; perforated 50-65 ft and 115-160 ft

Materials	Thickness (feet)	Depth (feet)
Soil	16	16
Quicksand, brown	24	40
Shale, blue	10	50
Gravel	15	65
Shale, blue	35	100
Gravel and sand	25	125
Shale, blue	20	145
Shale, sandy	10	155
Gravel	10	165
Shale, blue	30	195
Gravel and sand	20	215
Shale, sandy	10	225
Gravel and sand	15	240

23S/32E-29bbd. Wallace Shepard. Altitude 4,132 ft. Drilled by McGuire Drilling Co., 1962. Casing: 8-in. diam to 200 ft; perforated 65-190 ft

Materials	Thickness (feet)	Depth (feet)
Soil	8	8
Clay, hard	2	10
Sand, fine	32	42
Sand, coarse, and fine gravel	28	70
Sand, black, fine	26	96
Sand, coarse	34	130
Shale, blue, and fine sand	60	190
Shale, blue	10	200

23S/32E-30ddd. Harney County. Altitude 4,130 ft. Drilled by U.S. Geological Survey, 1936. Casing: 1¼-in. diam to 19 ft; perforated at unknown depth

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	4	4
Soil, sandy	4	8
Sand, brown, coarse	4	12
Sand, coarse, clean	4	16
Not recorded	3	19

23S/32E-31bbc. Sitz & Sitz. Altitude 4,130 ft. Drilled by Edgar L. Koeneman, 1962. Casing: 12-in. diam to 90 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Volcanic ash	2	4
Clay, black, hard	6	10
Clay, black, soft	37	47
Gravel, fine, cemented	10	57
Sand; a little water	3	60
Sand, black	5	65
Pumice	5	70
Sandstone, yellow	10	80
Sandstone, black	58	138
Clay, black	24	162
Clay, gray	4	166
Sandstone, gray	8	174
Shale, green	44	218
Clay, gray, sandy	22	240

23S/32E-32aaa. Roy Duhaime. Altitude 4,128 ft. Drilled by McGuire Drilling Co., 1963. Casing: 12-in. diam to 224 ft; perforated 90-210 ft

Materials	Thickness (feet)	Depth (feet)
Soil	8	8
Sand, fine	14	22
Clay, blue	38	60
Gravel, medium-sized	2	62
Clay, blue	34	96
Gravel, medium-sized	2	98
Clay, blue	102	200
Gravel, medium-sized	10	210
Clay, blue	14	224

23S/32½E-1bdc. E. A. McConville. Altitude 4,133 ft. Drilled by John W. Rossberg, 1968. Casing: 12-in. diam to 115 ft; perforated 20-105 ft

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	15	15
Clay, blue	25	40
Clay, brown, and gravel	25	65
Clay, blue	25	90
Sand, black, fine	20	110
Clay, hard	5	115

23S/32½E-10cdc. Mrs. Wesley Claunch. Altitude 4,125 ft. Drilled by Skinner & Sons, 1966. Casing: 12-in. diam to 40 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	19	19
Clay, blue	1	20
Sand, fine, water-bearing	2	22
Clay, blue, trickles of water	68	90
Sandstone, gray, hard, water-bearing	46	136
Clay, pumice, hard black rock, and water-bearing sandstone	69	205

23S/32½E-26cbb. Harry Withers. Altitude 4,116 ft. Drilled by Skinner & Sons, 1964. Casing: 6-in. diam to 161 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	3	3
Soil, brown, hard	4	7
Sand, gray, fine	13	20
Sand, black, fine, water-bearing	74	94
Clay, blue, sandy	20	114
Clay, green, sandy	6	120
Sand, green, trace of water	6	126
Sand, green and black, fine, water-bearing	27	153
Sandstone, black, coarse, water-bearing, with trace of green clay	96	249
Gravel, coarse, water-bearing	4	253

23S/33E-5bca. A. J. Lawson. Altitude 4,133 ft. Drilled by Western Drilling Co., 1964. Casing: 12-in. diam to 98½ ft; perforated 48-99 ft

Materials	Thickness (feet)	Depth (feet)
Soil	4	4
Clay, yellow	14	18
Sand, water-bearing	5	23
Clay, blue	7	30
Clay, brown, sandy	10	40
Clay and coarse gravel, water-bearing	59	99

23S/33E-8aac. Jesse Hankins. Altitude 4,133 ft. Drilled by owner, 1969. Casing: 12-in. diam to 120 ft; perforated 30-110 ft

Materials	Thickness (feet)	Depth (feet)
Soil	10	10
Clay and sand	10	20
Clay	17	37
Gravel, medium-sized	5	42
Clay, with sand streaks	21	63
Sand with seashells	47	110
Clay, blue	30	140
Sandstone	5	145
Clay, green and blue	220	365

23S/33E-12adb. Lyle Vickers. Drilled by John W. Rossberg, 1966. Casing: 6-in. diam to 18 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, hardpan	8	8
Sandstone	32	40
Pumice	55	95
Pumice and gravel, mixed	55	150
Basalt	10	160

Table 11.--Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
23S/33E-15ccc. Lyle Vickers. Altitude 4,126 ft. Drilled by John W. Rossberg, 1965. Casing: 6-in. diam to 101 ft; unperforated		
Soil	6	6
Sand and clay, mixed	29	35
Clay, blue	25	60
Sandstone and fine sand	10	70
Sand, black, fine	30	100
Gravel, medium-sized	1	101
23S/33E-18caa. Melvin Davenport. Altitude 4,128 ft. Drilled by Western Drilling Co., 1967. Casing: 8-in. diam to 100 ft; perforated 60-100 ft		
Soil	2	2
Clay, hard	5	7
Clay, brown	15	22
Clay, blue, sandy	78	100
23S/33E-20adb. Roy Ralston. Altitude 4,127 ft. Drilled by Western Drilling Co., 1965. Casing: 12-in. diam to 187 ft; perforated 147-187 ft		
Soil	3	3
Hardpan	2	5
Clay, blue	8	13
Sand, fine to medium, water-bearing	5	18
Sand, coarse to medium, and blue clay	169	187
23S/33E-36dda. A. A. McCrea. Altitude 4,134 ft. Drilled by John W. Rossberg, 1965. Casing: 6-in. diam to 125 ft; unperforated		
Soil	2	2
Clay, brown	28	30
Gravel, coarse	1	31
Clay and sand	19	50
Sand, fine	50	100
Sand, black	10	110
Sand, medium, and gravel	15	125
Sandstone, with streaks of gravel	25	150
23S/34E-7cac. Lyle Vickers. Altitude 4,146 ft. Drilled by John W. Rossberg, 1969. Casing: 12-in. diam to 140 ft; unperforated		
Soil and hardpan	10	10
Clay, brown	35	45
Gravel, sand, and clay, mixed	45	90
Clay, blue	5	95
Clay, yellow	45	140
Clay, blue	92	232
Shale, blue, and hard rock	138	370
Clay, blue, and gravel, mixed	35	405
Basalt, red	80	485
Basalt, with crevice	15	500
Clay, blue	45	545
Basalt, gray	55	600
Clay, red, and gravel, mixed	10	610
Basalt, red	5	615
23S/34E-7dbb. C. P. Topliff. Drilled by E. L. Koeneman, 1968. Casing: 8-in. diam to 147 ft; unperforated		
Soil	2	2
Gravel, cemented	5	7
Clay, gray, sandy	17	24
Clay, blue	34	58
Clay, yellow	64	122
Clay, blue-gray	25	147
Rock, lava	8	155
Pumice, water-bearing	15	170
23S/34E-18aaa. J. W. Cassy. Altitude 4,156 ft. Drilled by John W. Rossberg, 1964. Casing: 6-in. diam to 70 ft; unperforated		
Soil and hardpan	8	8
Clay, brown, and gravel, mixed	42	50
Clay, green	30	80
Clay, yellow	25	105
Gravel, cemented	15	120
Gravel, cemented, and pumice	10	130
23S/34E-18acd. Dick Arnold. Altitude 4,148 ft. Drilled by John W. Rossberg, 1963. Casing: 12-in. diam to 76 ft; perforated 19-76 ft		
Soil	15	15
Clay and gravel, mixed	5	20
Clay, yellow	10	30
Clay and gravel, mixed	40	70
Sand, fine, and clay	5	75
23S/34E-31add. Miller Bros. Altitude 4,155 ft. Drilled by F. W. Eaton, 1949. Casing: 14-in. diam to 197 ft; perforated 88-197 ft		
Soil	15	15
Gravel, sandy	35	50
Clay	8	58
Sand and gravel, mixed	37	95
Clay, sandy	15	110
Sand	6	116
Sandstone, shattered	24	140
Sand and gravel, mixed	6	146
Shale, shattered	8	154
Sand and gravel, mixed	14	168
Shale, shattered	20	188
Sand	6	194
Clay, blue	13	207
23S/34E-32aca. Miller Bros. Drilled by John W. Rossberg, 1961. Casing: 12-in. diam to 77 ft; unperforated		
Soil, sandy, and clay	10	10
Gravel, medium	4	14
Boulders	1	15
Gravel, medium	1	16
Boulders and coarse gravel	6	22
Rock, lava	16	38
Clay and fine gravel	22	60
Clay, water-bearing	10	70
Rock, lava	10	80
Clay and gravel	40	120
Clay, blue, coarse	15	135
Rock, lava, black	15	150
Clay, blue	25	175
Clay, brown; started to flow at 185 ft	35	210
Sandstone, fine-grained	15	225
Rock, lava, red	10	235
Rock, lava, gray	5	240
Claystone, yellow	18	258
Cinders, red	5	263
Rock, red, hard	12	275
Claystone, brown	15	290
Rock, black, hard	15	305
Gravel, fine, and clay	5	310
Basalt, gray	18	328
24S/29E-2cab. Hal McUne. Altitude 4,198 ft. Drilled by Western Drilling Co., 1966. Casing: 12-in. diam to 150 ft; perforated 110-150 ft		
Soil	5	5
Gravel, small	1	6
Clay, hard	8	14
Clay, brown	14	28
Basalt, hard	10	38
Clay, brown, sandy	26	64
Sandstone	8	72
Limestone	8	80
Cinders, red	45	125
Sand and gravel, mixed	25	150

Materials	Thickness (feet)	Depth (feet)
24S/30E-1abd. O. D. Hotchkiss. Altitude 4,134 ft. Drilled by Boyer and Koeneman, 1930; deepened from 472 ft to 564 ft by Western Drilling Co., 1964. Casing: 10-in. diam to 117 ft; unperforated		
Soil	60	60
Sand and gravel; first artesian flow	22	82
Clay, blue	15	97
Gravel; second artesian flow	12	109
Clay, blue, soft	98	207
Clay, yellow	10	217
Clay, blue, soft	28	245
Clay, yellow	10	255
Clay, blue, hard	58	313
Shale, green	39	352
Sandstone; third artesian flow	106	458
Rock, red	19	477
Soapstone; fourth artesian flow	1	478
Rock, red, volcanic, hard	86	564
24S/30E-7cdd. A. J. Kisle. Altitude 4,155 ft. Drilled by McGuire Drilling Co., 1962. Casing: 14-in. diam to 347 ft; perforated 100-342 ft		
Soil	12	12
Sand, fine	8	20
Gravel, medium	8	28
Clay, brown	12	40
Gravel, medium	4	44
Clay and gravel	24	68
Clay, brown	26	94
Gravel, coarse	4	98
Shale, brown, and gravel	22	120
Cinders, red, and gravel	11	131
Cinders, black	155	286
Cinders, black and red	59	345
Rock, lava, hard	2	347
24S/30E-8bdd. A. J. Kisle. Altitude 4,148 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 110 ft; unperforated		
Soil and hardpan	4	4
Sand, brown	26	30
Sand and gravel	10	40
Clay and gravel, mixed	70	110
Sandstone	45	155
Rock, lava, red, very hard	75	230
Pumice	67	297
Rock, lava, red, very hard	3	300
24S/30E-11aba. L. E. Tyler. Altitude 4,134 ft. Drilled by Paul G. Chrisley, 1962. Casing: 6-in. diam to 181 ft; unperforated		
Soil	12	12
Quicksand, brown	18	30
Clay, yellow	20	50
Quicksand, blue	30	80
Clay, blue	15	95
Cinders, red, and pumice and sand	45	140
Pumice, cinders, and clay	30	170
Clay, yellow	25	195
"Pumice," hard, and cinders	90	285
"Pumice," hard, and gray sand	70	355
Sandstone, gray, hard	25	380
"Pumice," hard, porous, water-bearing	55	435
Rock, black, hard	10	445
Clay, blue	40	485
Clay, yellow	20	505
Rock, red, cindery, hard, porous, water-bearing	8	513
24S/30E-11abd. L. E. Tyler. Altitude 4,133 ft. Drilled by Paul G. Chrisley, 1962. Casing: 12-in. diam to 183 ft; unperforated		
Soil	15	15
Sand, gray	5	20
Clay, blue	30	50
Clay, yellow	285	335
Clay, gray	10	345
Clay, blue	73	418
Rock, black, hard	10	428
Clay, blue	22	450
Clay, green	5	455
Rock, red, cindery	5	460
Clay, yellow	10	470
Rock, gray, hard	45	515
Rock, porous	51	566
24S/30E-17bab1. A. J. Kisle. Altitude 4,148 ft. Drilled by Western Drilling Co., 1967. Casing: 12-in. diam to 70 ft; unperforated		
Soil	2	2
Clay, brown	8	10
Clay and coarse gravel	6	16
Clay, brown	11	27
Clay, brown, and gravel	25	52
Sandstone	11	63
Clay, brown, and gravel	7	70
Sand, black, and gravel	75	145
Sandstone	6	151
Rock and gravel	47	198
Cinders and gravel	50	248
Clay, red, and cinders	50	298
Rock, hard	2	300
24S/30E-17bab2. A. J. Kisle. Altitude 4,148 ft. Drilled by Western Drilling Co., 1967. Casing: 12-in. diam to 120 ft; perforated 100-120 ft		
Soil	3	3
Clay, brown	7	10
Clay and gravel	6	16
Clay, brown	13	29
Clay, brown, and gravel	25	54
Sandstone	6	60
Clay, brown, and gravel	14	74
Clay, sand, and gravel	61	135
Clay and large gravel	77	212
Clay, light-brown, and medium gravel	83	295
Sandstone, gray	15	310
Sand and medium gravel	14	324
24S/30E-17bbb. A. J. Kisle. Altitude 4,150 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 60 ft; unperforated		
Soil and hardpan	8	8
Gravel, pea-sized	7	15
Gravel, cemented	20	35
Clay and gravel, mixed	85	120
Sandstone	50	170
Pumice	15	185
Sandstone	30	215
Rock, lava, black	5	220
24S/30E-18acb. A. J. Kisle. Altitude 4,153 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 40 ft; unperforated		
Hardpan and soil	18	18
Gravel, medium	17	35
Clay and gravel, mixed	55	90
Pumice	5	95
Pumice and clay, mixed	50	145
Rock, lava	10	155
Sandstone	10	165
Cinders, black	10	175
Basalt	20	195
Pumice	40	235
Basalt	5	240

Materials	Thickness (feet)	Depth (feet)
24S/30E-24acd. John Campbell & Son. Altitude 4,131 ft. Drilled by John A. VanMeter, 1959. Casing: 16-in. diam to 210 ft; perforated 65-210 ft		
Soil and hardpan	4	4
Clay and sand	12	16
Quicksand, green	11	27
"Chalk," green	16	43
Sand and gravel	28	71
Clay and sand	36	107
Shale	18	125
"Chalk," green	19	144
Sand, white, and black gravel	14	158
Clay, green, and streaks of sand	206	364
Basalt and sandstone	6	370
Cinders, sand, and gravel	21	391
Sandstone, red and gray	15	406
Shale, black	88	494
Clay, green	9	503
24S/30E-26ddc. John Campbell & Son. Altitude 4,130 ft. Drilled by John A. VanMeter, 1959. Casing: 16-in. diam to 150 ft; perforated 90-95 ft, 110-115 ft, and 130-135 ft		
Hardpan	4	4
Sand, brown, loose	27	31
Boulders and sand	6	37
Sandstone, hard and soft	13	50
Boulders of lava, and sand	8	58
Clay, yellow, and sand	12	70
Clay, green and yellow	54	124
Shale, green	2	126
Clay, green	55	181
Pumiceous sand, and "lava" gravel	3	184
Shale, green, and clay	13	197
Mud, gray	27	224
Shale, green, and clay	19	243
Sandstone, hard and soft, and gravel	9	252
Shale, gray	80	332
Shale, broken	3	335
Shale, black, broken	166	501
24S/31E-5acb. State of Oregon. Altitude 4,130 ft. Drilled by Western Drilling Co., 1967. Casing: 20-in. diam to 20 ft, 18-in. diam to 56 ft, 12-in. diam to 80 ft; perforated 25-80 ft		
Soil	8	8
Sand, fine, and medium gravel	7	15
Clay, blue	10	25
Sand, fine, and medium gravel	35	60
Clay, blue	5	65
Sand, fine, and medium gravel	45	110
Clay, blue	130	240
Sand, blue, and gravel	5	245
24S/31E-5dbb. State of Oregon. Altitude 4,129 ft. Drilled by Rich Knoblock, 1958. Casing: 10-in. diam to 100 ft, 8-in. diam 98-146 ft; perforated 52-60 ft		
Soil, black, heavy	8	8
Soil, light-brown, sandy	7	15
Hardpan, sandy	6	21
Clay, light-blue, sandy	16	37
Clay, blue-black	5	42
Clay, with trace of gravel	1	43
Clay and gravel, cemented	6	49
Gravel, coarse	11	60
Shale, light-blue, sandy	63	123
Sand, with traces of gravel, and light-blue shale	10	133
Shale, sandy, blue-black	13	146
24S/32E-4bbb. T. F. Drumm. Altitude 4,125 ft. Drilled by Skinner & Sons, 1966. Casing: 12-in. diam to 175 ft; unperforated		
Soil, brown	3	3
Clay, brown, with sand	22	25
Clay, blue, with trace of water	23	48
Sand, black	97	145
Sand, black, with trace of pumice	2	147
Sand, black, with trace of green clay	23	170
Clay, green	228	398
Clay, green, with trace of water	102	500
24S/32E-5aad. John Wood. Altitude 4,125 ft. Drilled by John W. Rossberg, 1965. Casing: 12-in. diam to 213 ft; unperforated		
Soil and hardpan	8	8
Sand, coarse, and clay, mixed	32	40
Clay, blue	10	50
Gravel, fine	1	51
Clay, blue, and gravel, mixed	29	80
Sand, black	30	110
Clay, blue	46	156
Clay, blue, and sand, mixed	49	205
Clay, gray	65	270
24S/32E-12cbb. Mervin Johnson. Altitude 4,119 ft. Drilled by Skinner & Sons, 1965. Casing: 6-in. diam to 60 ft; unperforated		
Soil, brown, sandy, and brown hardpan	5	5
Clay, brown, with fine sand, water-bearing	33½	38½
Shale, blue	17½	56
Sandstone, blue, water-bearing	26	82
24S/32½E-13acb. C. W. Tripp. Altitude 4,112 ft. Drilled by John W. Rossberg, 1967. Casing: 12-in. diam to 230 ft; unperforated		
Soil	3	3
Clay, yellow	27	30
Clay, blue	35	65
Sand, black, fine	5	70
Clay, blue, and sand, mixed	40	110
Clay, blue	130	240
Gravel, coarse to medium	2	242
24S/32½E-30add. Sam Gunterson. Altitude 4,106 ft. Drilled by Skinner & Sons, 1967. Casing: 6-in. diam to 99 ft; unperforated		
Soil, brown, sandy	3	3
Clay, brown, sandy	32	35
Clay, blue	12	47
Sand, green, fine, water-bearing	48	95
Clay, blue; trace of water	85	180
Clay, black, water-bearing	5	185
24S/32½E-30ddc. Ansel Marshall. Altitude 4,106 ft. Drilled by P. S. Weitenhiller, date unknown. Casing: 18-in. diam to 80 ft		
Soil, sandy	12	12
Sand, very fine, and gravel, water-bearing	8	20
Clay, blue	32	52
Quicksand, fine, black, water-bearing	18	70
Clay, blue	60	130
Sand and gravel	?	130+

Table 11.--Drillers' logs of representative wells--Continued

24S/33E-1cda. Diversified Ranches, Inc. Altitude 4,128 ft. Casing: 14-in. diam to 357 ft; perforated 100-347 ft

Materials	Thickness (feet)	Depth (feet)
Soil	10	10
Sand, fine	4	14
Clay, brown	12	26
Sand, medium	34	60
Clay, blue	13	73
Sand, coarse	6	79
Clay, blue	141	220
Cinders, black	12	232
Clay, blue	19	251
Cinders, black	2	253
Clay, blue	34	287
Cinders	9	296
Clay, blue	42	338
Cinders and gravel	6	344
Clay, blue	4	348
Cinders	4	352
Clay, blue	5	357

24S/33E-1ddd. Diversified Ranches, Inc. Altitude 4,132 ft. Drilled by John W. Rossberg, 1963. Casing: 6-in. diam to 171 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	20	20
Sand, brown, fine	40	60
Sand, black, fine	10	70
Clay, yellow	5	75
Sand, brown, fine	30	105
Sand, black, fine	60	165
Cinders, cemented	22	187

24S/33E-2bdc. Joe Ingly. Altitude 4,125 ft. Drilled by John W. Rossberg, 1967. Casing: 6-in. diam to 229 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	30	30
Silt, black, and clay	194	224
Pumice	26	250

24S/33E-4abd. Diversified Ranches, Inc. Altitude 4,122 ft. Drilled by McGuire Drilling Co., 1964. Casing: 14-in. diam to 380 ft; perforated 100-370 ft

Materials	Thickness (feet)	Depth (feet)
Sand, fine	3	3
Clay, brown	3	6
Sand, black	9	15
Clay, blue	143	158
Cinders, gray	3	161
Clay, blue	119	280
Cinders	8	288
Rock, black, hard	26	314
Cinders	2	316
Rock, black, hard	24	340
Cinders	4	344
Rock, black	3	347
Cinders	4	351
Rock, black	15	366
Cinders and gravel	8	374
Clay, blue	6	380

24S/33E-9aac. Dewey Kiem. Altitude 4,118 ft. Drilled by John W. Rossberg, 1965. Casing: 12-in. diam to 227½ ft; perforated 18-98 ft

Materials	Thickness (feet)	Depth (feet)
Soil	4	4
Clay	14	18
Clay and sand, mixed	12	30
Clay, blue	30	60
Clay, black, and sand streaks	20	80
Clay, black	60	140
Clay, green	135	275
Clay, yellow	65	340
Sand, black, medium	2	342

24S/33E-20aaa. David Long. Altitude 4,110 ft. Drilled by Skinner & Sons, 1968. Casing: 6-in. diam to 36 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	28	28
Clay, blue	52	80
Clay, blue, with sand, water-bearing	24	104

24S/33E-24aac. R. H. Straw. Altitude 4,128 ft. Drilled by John W. Rossberg, 1966. Casing: 12-in. diam to 100 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	20	20
Clay, blue, with sand	40	60
Sand, black, fine	37	97
Rock, lava, black	10	107
Pumice	23	130
Clay, green	45	175
Pumice	55	230
Clay, green	10	240
Pumice, with streaks of green clay	75	315
Sandstone, black	15	330
Clay, black, and silt	10	340

24S/33E-33ccb. Pacific Northwest Bell Telephone Co. Altitude 4,110 ft. Drilled by Western Drilling Co., 1966. Casing: 6-in. diam to 126 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	7	7
Clay, yellow	18	25
Clay, blue	160	185
Clay, blue, hard	15	200

24S/34E-6aac. Miller Bros. Altitude 4,145 ft. Drilled by John W. Rossberg, 1963. Casing: 12-in. diam to 70 ft; perforated 20-69 ft

Materials	Thickness (feet)	Depth (feet)
Soil	19	19
Sand, fine	3	22
Sand and clay	32	54
Sand, coarse, and gravel	5	59
Clay, yellow	11	70

24S/34E-6abc. Miller Bros. Altitude 4,138 ft. Drilled by John W. Rossberg, 1968. Casing: 12-in. diam to 85 ft; perforated 20-75 ft

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	19	19
Clay, yellow, and sand	51	70
Sand, brown, fine	13	83
Shale	4	87
Clay, yellow	3	90

24S/34E-31acb. J. W. Rossberg. Altitude 4,142 ft. Drilled by owner, 1959. Casing: 14-in. diam to 16 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	28	28
Sandstone, water-bearing	17	45
Clay, blue	66	111
Pumice	43	154
Clay and "rock" layers	94	248
Rock, lava	17	265
Basalt, gray	18	283
Clay, blue and yellow	107	390
Rock, lava, black	86	476
Rock, red, cindery	27	503

24S/34E-31cbd. J. W. Rossberg. Altitude 4,136 ft. Drilled by McGuire Drilling Co., 1962. Casing: 12-in. diam to 110 ft; perforated 50-100 ft

Materials	Thickness (feet)	Depth (feet)
Soil	23	23
Clay and fine sand	38	61
Gravel, coarse	33	94
Clay, brown	16	110

24S/34E-31dcb. J. W. Rossberg. Altitude 4,145 ft. Drilled by owner, 1960. Casing: 14-in. diam to 9 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	24	24
Sandstone, brown	23	47
Pumice	22	69
Clay, blue	73	142
Rock, lava, black	143	285
Rock, red, cindery	15	300
Rock, lava, black	5	305

24S/34E-31dda. J. W. Rossberg. Altitude 4,172 ft. Drilled by Jack McClure, 1956; deepened to 305 ft in 1968. Casing: 32-in. diam to 68 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	6	6
Clay, hard	10	16
Sandstone, water-bearing	9	25
Sandstone	10	35
Sand and gravel	10	45
Gravel, water-bearing	5	50
Pumice and cinders	8	58
Sandstone	32	90
Shale, blue	12	102
Clay and cinders	24	126
Sand and gravel	2	128

25S/31E-4cba. James Stahl. Altitude 4,140 ft. Drilled by Edgar L. Koeneman, 1962. Casing: 12-in. diam to 90 ft

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, yellow, sandy	7	10
Sandstone	7	17
Sand and clay	5	22
Sandstone, yellow, some water at 50 ft	53	75
Gravel and boulders, cemented	40	115
Clay, blue	55	170

25S/31E-27daa. Harney Land Development Co. Altitude 4,110 ft. Drilled by McGuire Drilling Co., 1962. Casing: 6-in. diam to 179 ft; perforated 129-169 ft

Materials	Thickness (feet)	Depth (feet)
Soil	14	14
Sand, fine	14	28
Clay, blue	17	45
Clay, brown	21	66
Cinders	2	68
Clay, blue	29	97
Cinders and fine sand	2	99
Sand, black, fine	22	121
Clay, blue	29	150
Cinders	23	173
Clay, blue	6	179

25S/31E-29ccb. E. L. Koeneman. Altitude 4,170 ft. Drilled by owner, 1963. Casing: 8-in. diam to 104 ft; perforated 70-80 ft

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Gravel, cemented	10	12
Sand, yellow	20	32
Gravel, cemented	38	70
Gravel, some water	11	81
Clay, blue	21	102
Gravel, cemented	45	147
Clay, blue	60	207
Gravel, loose, some water	2	209

25S/31E-30ddb. E. L. Koeneman. Altitude 4,150 ft. Drilled by owner, 1963. Casing: 12-in. diam to 139 ft, 10-in. diam to 290 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Gravel, cemented	9	12
Sand, yellow, fine	76	88
Sand, black, fine	22	110
Clay, blue	146	256
Clay, yellow	121	377
Clay, red	38	415
Clay, black, hard	75	490
Clay, green	83	573
Clay, yellow	45	618
Clay, black, very hard	42	660

25S/31E-32aaa. Harney Land Development Co. Altitude 4,113 ft. Drilled by McGuire Drilling Co., 1962. Casing: 6-in. diam to 111 ft; perforated 70-101 ft

Materials	Thickness (feet)	Depth (feet)
Soil	14	14
Sand, fine	12	26
Shale, blue	45	71
Cinders and gravel	32	103
Clay, brown	8	111

25S/32½E-3bbb. M. H. Glenn. Altitude 4,110 ft. Drilled by Rossberg & Son, 1967. Casing: 6-in. diam to 40 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	6	6
Sand, brown	29	35
Clay, brown	15	50
Clay, blue	40	90
Sand, black	5	95

25S/33E-1cdb. M. F. O'Donell. Altitude 4,125 ft. Drilled by John W. Rossberg, 1967. Casing: 12-in. diam to 190 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil and hardpan	30	30
Clay, blue, and silt	40	70
Clay, blue, and cinders, mixed	90	160
Clay, blue	35	195
Sandstone	5	200
Cinders, dark-colored, loose, and trace of medium gravel	5	205

25S/33E-12abc. Tom Gillespie. Altitude 4,130 ft. Drilled by Crane Drilling Co., 1960. Casing: 12-in. diam to 46 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	30	30
Sand, water-bearing	4	34
Clay, yellow	7	41
Shale, blue	5	46
Volcanic ash, water-bearing	4	50
Rock, gray	55	105
Shale, blue	45	150
Sand, black, water-bearing	2	152

25S/34E-7bbc. George Hoffman. Altitude 4,130 ft. Drilled by Skinner & Sons, 1966. Casing: 8-in. diam to 125 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil, brown	3	3
Clay, brown, sandy	27	30
Sand, gray, fine, water-bearing	61	91
Sand, medium, in brown clay	30	121
Clay, brown, and sandstone	69	190
Sandstone, green	61	251
Sandstone, black	104	355
Rock, lava, black, and blue clay	8	363
Rock, lava, black, hard	39	402

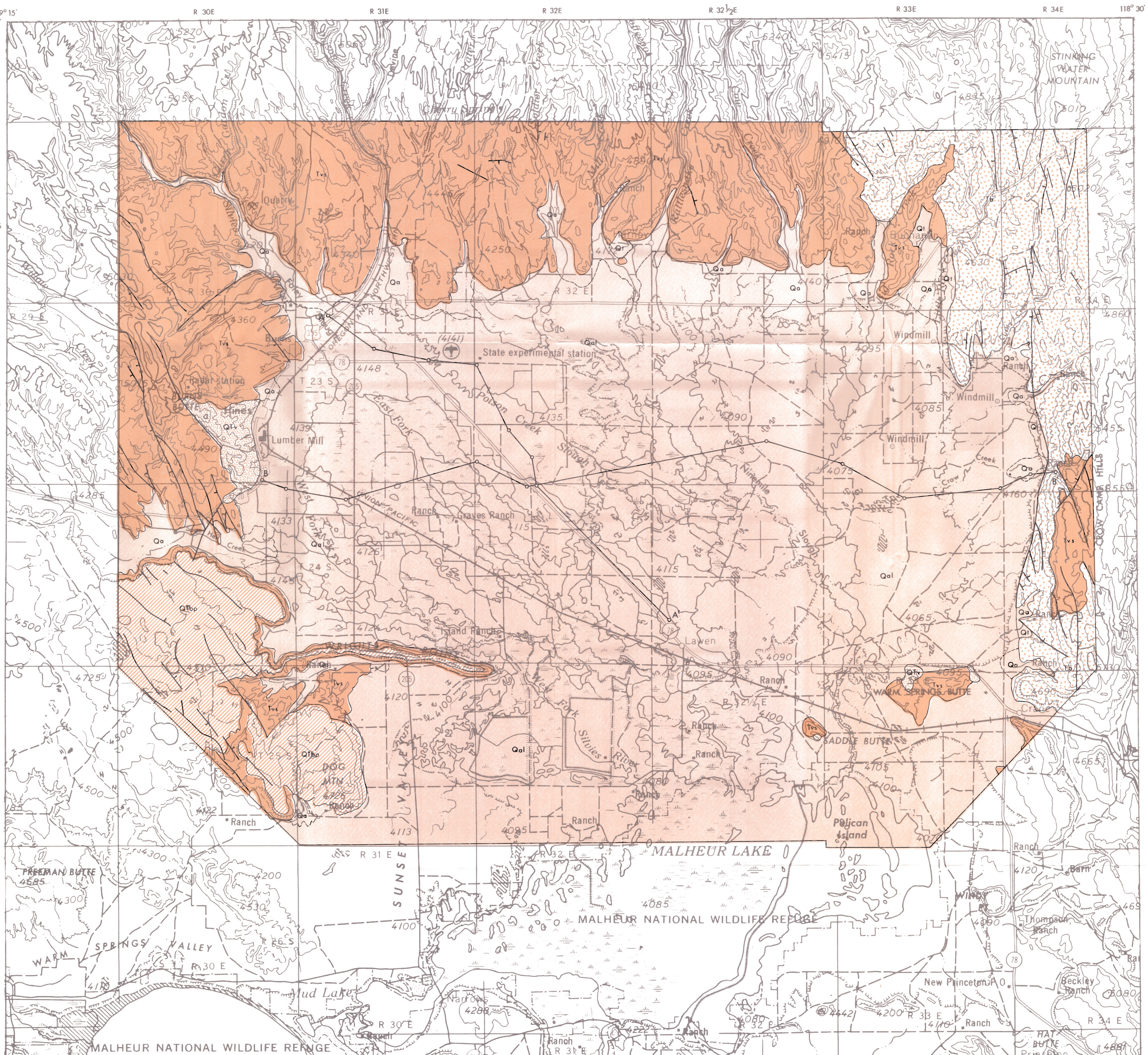
25S/34E-30dcc. Forrest Skinner. Altitude 4,128 ft. Drilled by owner, 1957. Casing: 14-in. diam to 20 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, hard	1	2
Clay, sandy	14	16
Sand	4	20
Rock, black, hard	16	36
Cinders, blue	5	41

OREGON STATE ENGINEER
GROUND-WATER REPORT NO. 16

PREPARED IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

PLATE 1



Base from U.S. Geological Survey, 1969

SCALE 1:125,000

0 5 10 MILES

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
DATUM IS MEAN SEA LEVEL

Geology modified after R.C. Green, G.W. Walker, and R.E. Corcoran (in press)

EXPLANATION

QUATERNARY — Holocene

Qal | Qa | Qt

Alluvium and valley fill

Alluvium along streams (Qa), valley-fill deposits (Qal), and stream terraces (Qt). Consists of clay, silt, sand, and gravel, locally containing pumice and peat; complexly interbedded and lenticular. Includes thin wind-drifted sands locally. Sand and gravel beds yield moderate to large quantities of water to wells, principally around margins of valley and in Silvies fan area. Clay beds yield small quantities of water, generally mineralized in southwestern part of valley area

TERTIARY AND QUATERNARY — Pliocene and Pleistocene

QTv

Cinder cones and associated volcanic ejecta

Scoriaceous basalt, scoria, and volcanic cinders forming lava domes and cinder cones. Near Hines, fragmental zones yield warm flowing water of excellent quality to wells and springs

QTbp

Basalt and palagonized tuff

Vesicular to dense basalt capping Wrights Point and upland to the west, and palagonite tuff, breccia, and associated fine sediments forming Dog Mountain. Locally include unconsolidated siltstone, sandstone, and conglomerate overlying basalt in upland west of valley. Generally a poor aquifer, but zones of sand and gravel may yield small quantities of water

TERTIARY — Pliocene

Tvs

Volcanic, pyroclastic, and sedimentary rocks

Welded ash-flow tuffs, basaltic and andesitic lavas, pyroclastics, and associated tuffaceous lacustrine and fluvial sediments. Locally, rhyodacite northwest of Hines is mapped with the unit, as are scattered deposits of high-level sand and gravel overlying uppermost welded tuff northeast of Burns. Some of the welded tuff and lava beds are extensive over broad areas, but most sediments are lenticular and complexly interbedded. Wells obtain large yields from lower section of volcanic rocks and inter-bedded sand and gravel beds near the northwest corner of the valley; upper section of tuffaceous and fine sediments is a poor aquifer

TERTIARY — Miocene

Tb

Basalt, andesite, and rhyodacite of Crow Camp Hills

Locally contain glassy layers, other siliceous rocks, and lenticular beds of lapilli and claylike tuff. Generally dense and poorly water bearing except for cindery and fractured lava and lapilli beds. Yields water to flowing wells near fault at foot of Crow Camp Hills

Contact

Dashed were inferred or obscured by surficial deposits

Fault

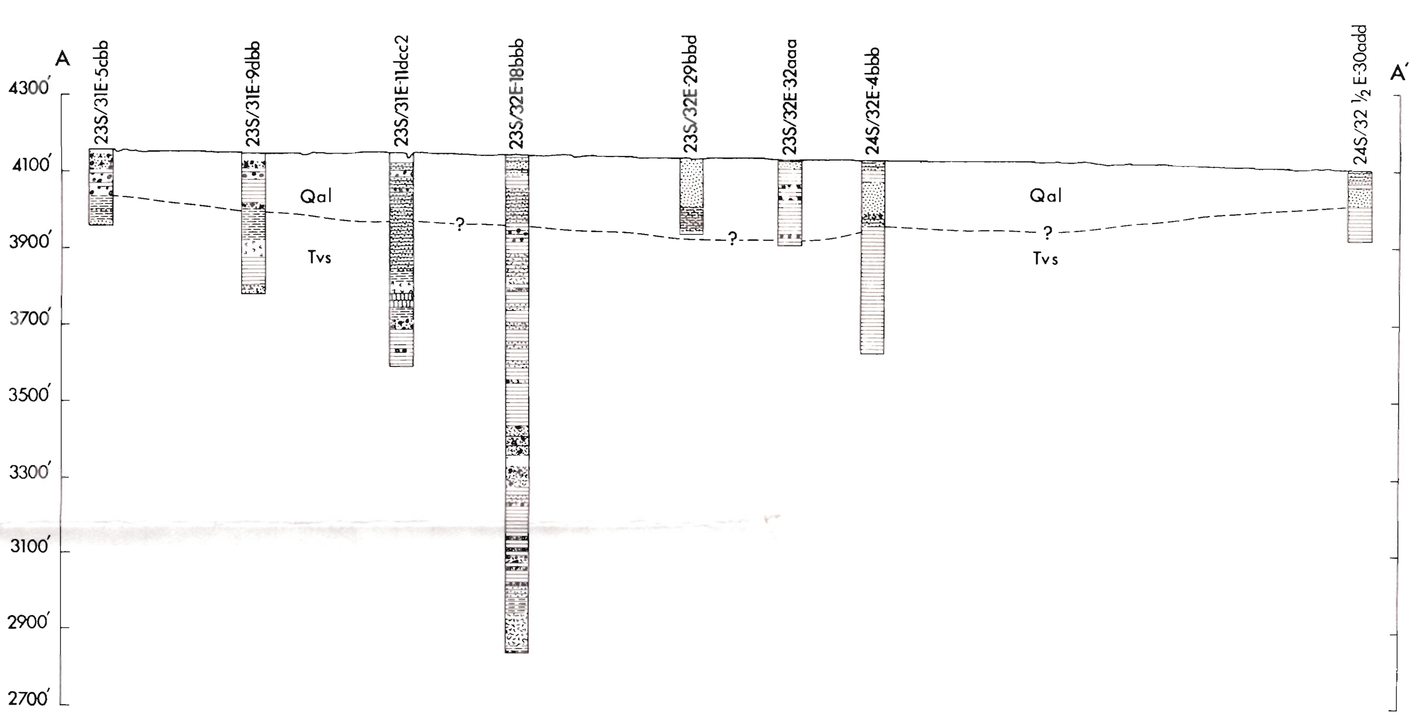
Dashed where inferred or concealed. Tick indicates downthrown side

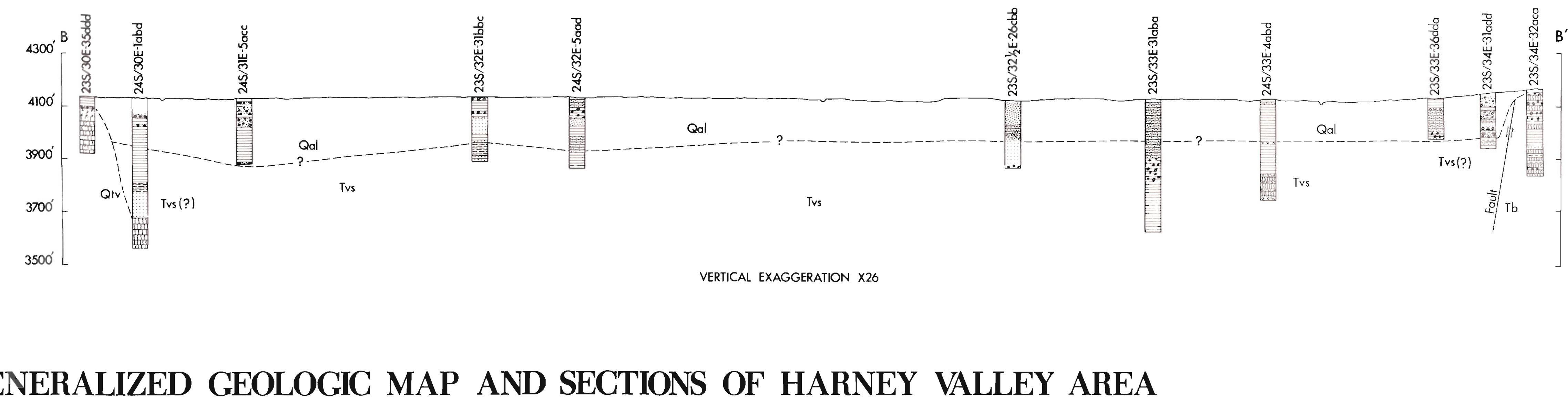
A——A'

Location of section shown above

Soil
Clay
Sand
Gravel
Cinders
Basalt
Pumice
Shale
Sandstone

Log of well or test hole





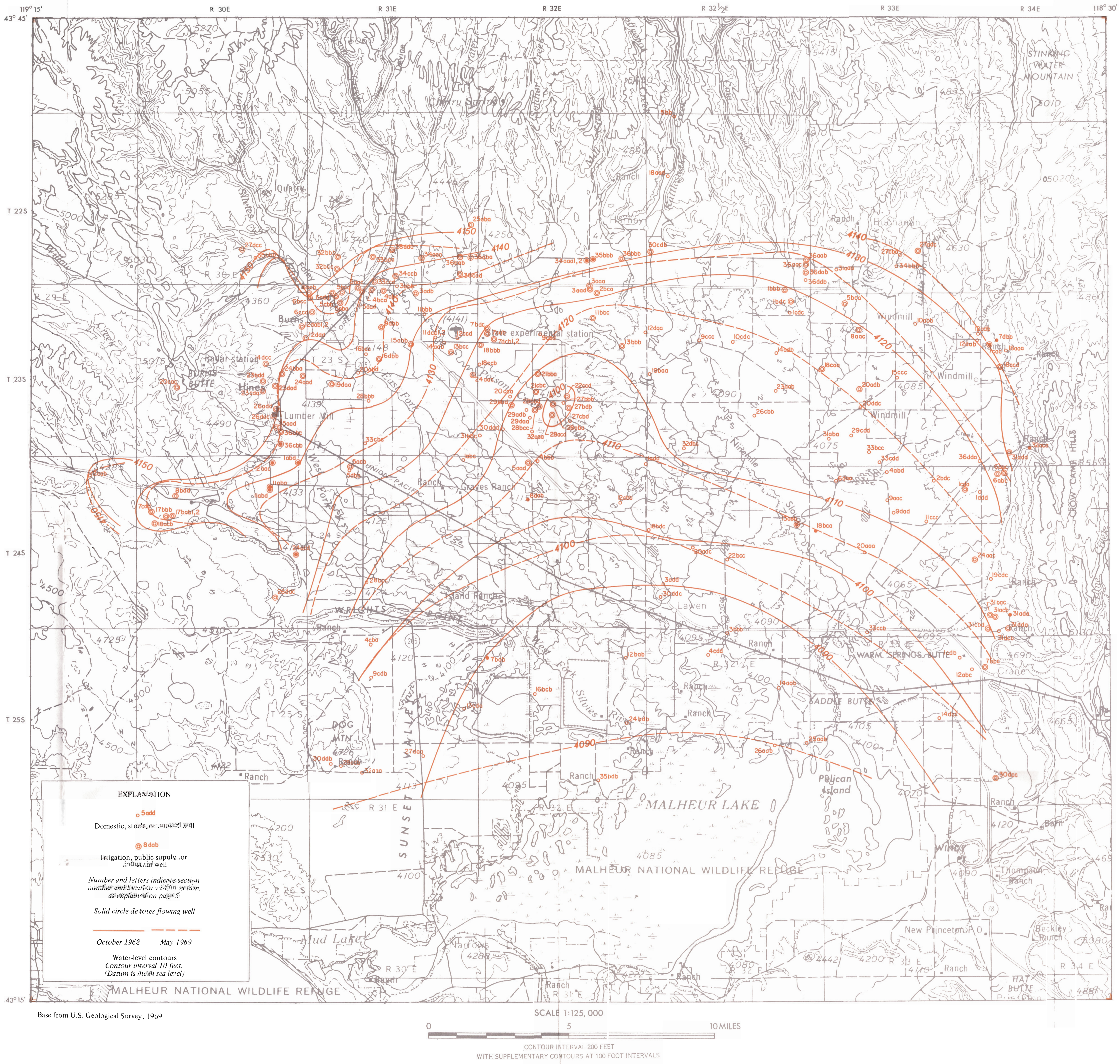
VERTICAL EXAGGERATION X26

GENERALIZED GEOLOGIC MAP AND SECTIONS OF HARNEY VALLEY AREA

OREGON STATE ENGINEER
GROUND-WATER REPORT NO. 16

PREPARED IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

PLATE 2



MAP OF HARNEY VALLEY SHOWING WATER-LEVEL CONTOURS FOR PRINCIPAL AQUIFER, OCTOBER 1968 AND MAY 1969

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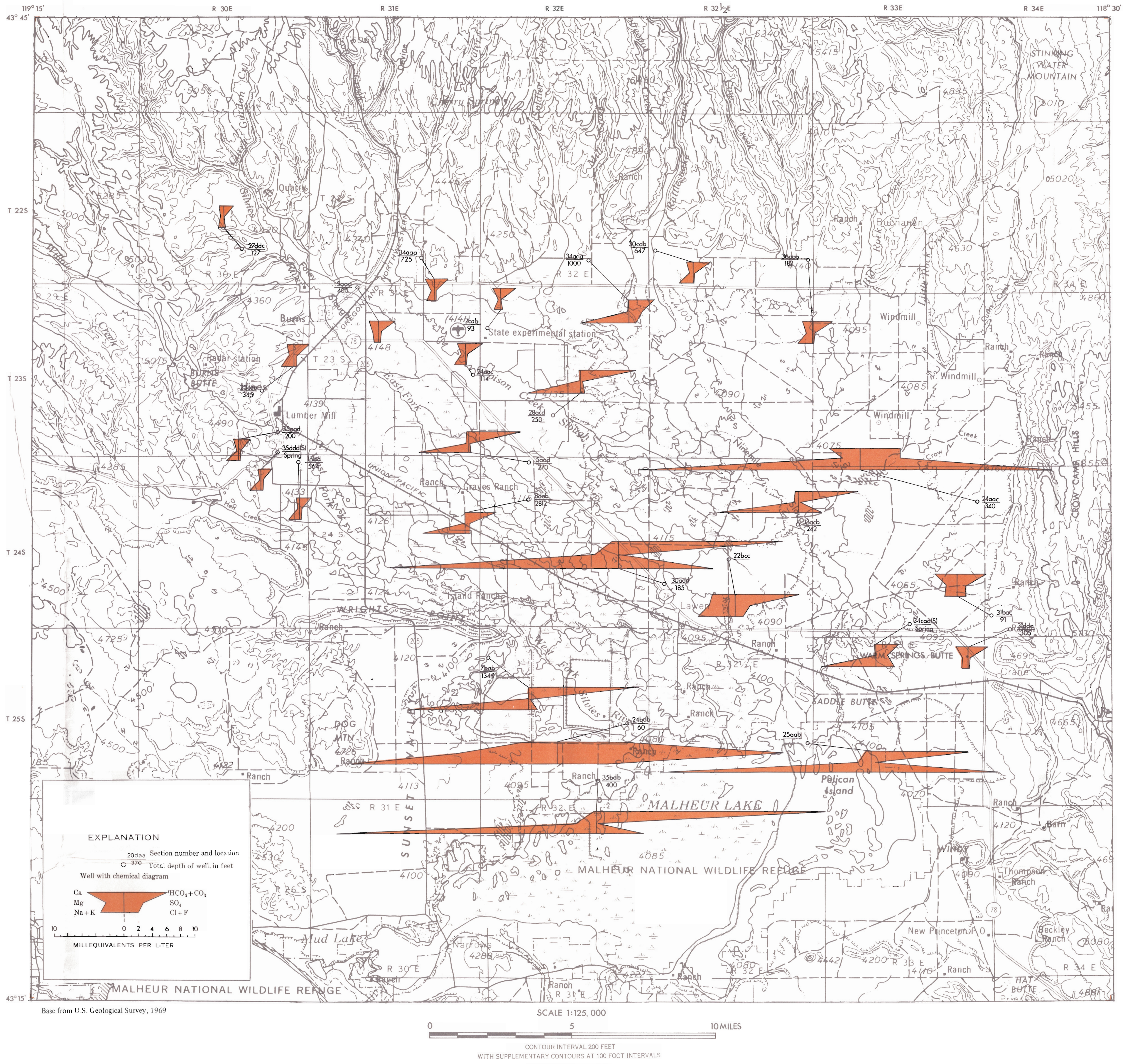
PLATE 3



MAP OF HARNEY VALLEY SHOWING AREAL VARIATIONS IN CHEMICAL QUALITY OF GROUND WATER