UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY AND GROUND-WATER RESOURCES OF THE SWAN LAKE-YONNA VALLEYS AREA, KLAMATH COUNTY, OREGON

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Abstract

The Swan Lake-Yonna Valleys area consists of two intermountain valleys with their subordinate side valleys, adjoining slopes, and mountainous boundary ridges. In all, the area covered is about 256 square miles, but the essential agricultural sections are restricted to the floors of Swan Lake and Yonna valleys with their respective subsidiary extensions of Pine Flats and Alkali Lake flats, a valley-floor area totaling about 90 square miles.

The floors of Swan Lake Valley and Yonna Valley lie at an altitude of about 4,200 feet, but the mountainous boundary ridges rise generally to 6,000 feet. Yonna Valley is largely drained to Lost River by Buck Creek, but also in part to Alkali Lake. Swan Lake Valley and Pine Flats have only internal drainage. The Swan Lake Valley floor is the top of a deep alluvial fill, while Yonna Valley floor is mainly an erosional surface sloping to lines of through drainage.

Precipitation is about 14 inches annually on the valley floors, but must be much more, possibly 18 to 24 inches, on the higher parts of the drainage basins. The growing season is short and killing frosts do occur in late spring and early fall.

The rock units forming the bedrock structure of the area are consolidated or semiconsolidated rocks of Tertiary age and are largely of volcanic-flow and volcanic-sedimentary origin. They consist of three main elements: a lower lava-rock unit, a sedimentary and volcanic-sedimentary unit, and an upper lava-rock unit. The unconsolidated deposits are the older alluvium of Quaternary (and in part of late-Tertiary) age and the younger alluvium of Quaternary age. The bedrock is faulted and deformed, particularly so along a northwest-southeast set of fault lines that have given a remarkable linearity to the topography.

Ground water occurs below a regional water table that slopes southward to the level of the Lost River. The upper lava rocks and the lower lava rocks contain the principal permeable zones that occur beneath the area. Breccia and other porous zones in those rocks in places yield water to wells at a rate as large as 3,000 gallons per minute with but 1 or 2 feet of drawdown. The economical construction of irrigation wells requires the determination of the best possible location at which those rocks may be tapped at shallow depth below the level of the water table.

The ground water in general is relatively low in dissolved mineral matter and is but slightly to moderately hard and would be considered chemically satisfactory for most uses.

Irrigation is the principal use of the ground water in the area north of the Horsefly Irrigation District. There 35 wells supplied about 6,000 acre-feet of water to about 3,800 acres of land in 1950. Water-level records obtained since 1948 and approximations of the probable annual recharge from precipitation indicate that the present withdrawals are considerably less than the annual increment of the ground-water recharge. Rough estimates indicate that an increase in withdrawals of as much as 100 percent or more can take place before ground-water levels, by a persistent lowering, will begin to indicate that the annual replenishment is being exceeded.

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INTRODUCTION

Location and extent of area

The Swan Lake-Yonna Valleys area of Klamath County, Oregon, is located in the south-central part of the state where it adjoins Klamath Lake Valley east of the city of Klamath Falls (see pls. 1 and 3). The two valleys are subparallel and roughly rectangular in shape with a high north-south ridge separating Swan Lake Valley from Yonna Valley on the east. Within, or adjacent to these larger valleys are the smaller Meadow Lake Valley, Pine Flat, Alkali Lake Flat and Poe Valley (pl. 1). The first three of these small valleys are treated herein, but Poe Valley lies south of the area covered in this study. Though Pine Flat is separated by a low topographic divide, it is treated herein as part of Yonna Valley. As the adjacent mountain ridges and slopes play a vital part on the over-all water resources situation, this report also describes the geologic fabric and hydrologic characteristic of those features.

The total drainage area of the two basins is approximately 256 square miles and lies within Townships 36 to 38 South, Ranges 8 to 11 East of the Willamette Base and Meridian. Lost River, which flows from east to west across the region is the principal stream, and is the southern boundary of the area studied.

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The valleys are easily accessible via the Klamath Falls-Lakeview Highway state route No. 66, and the Oregon, California, and Eastern Railway (see pl. 1). Olene, Dairy, and Bonanza are the principal communities within the area. Bonanza, with a population of 141, was the largest incorporated town in 1940. Klamath Falls, with a population of 16,093, lies just outside the west boundary of the area. It is the chief commercial center of the district and also the county seat of Klamath County. The Yonna store, formerly a postoffice, is shown as Yonna on plate 1 to locate the weather station. The valley lands of the region are used as pasture lands or are dry farmed except where irrigation water is available. The Horsefly Irrigation District supplies river water to about 7,500 acres of land in lower Yonna Valley, the Pine Flat extension of Swan Lake Valley, and Poe Valley near the Lost River (see pl. 1).

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PLATE 3

Map of The State of Oregon showing area covered by this investigation

PLATE 3

Purpose and scope of the investigation

The investigation upon which this report is based was made for the purpose of collecting the pertinent data on the nature and occurrence of ground water within and adjacent to Swan Lake and Yonna Valleys. With the beginning of development of irrigation wells in Yonna Valley, a study of the area became necessary in order to lay the basis for ultimate determination of the maximum safe yield and for the economical development of the ground-water supply.

The study was started in cooperation with the office of the State Engineer in the spring of 1948. The well canvass was begun and the geologic structure was partially mapped by F. D. Trauger during that year. The differentiation of the rock units, the mapping of their boundaries, further delineation of the structure, and completion of the well canvass were accomplished by the senior author during October and November 1949, and preparation of the report was started during the early part of 1950. After the senior author left the Geological Survey, the sections on structure, occurrence of the ground water, and chemical quality of the water were written and the report was completed by the junior author.

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Although the drainage area of the two basins totals approximately 256 square miles, about 310 square miles was included on the maps (pls. 1 and 2) in order better to show the rock relations that govern the position and the nature of the aquifers. In general, the geologic mapping was of a reconnaissance nature, particularly in the high timber levels in the north part of the area. In the valley floors, and wherever else good rock exposures were found, more detailed study was made. Almost all of the irrigation wells, completed or in process of being drilled at the time of the investigation, were visited and their water levels measured. Logs were obtained for most of the irrigation wells and water samples taken wherever possible. A number of representative domestic wells and springs were also included within the well canvass. Comprehensive chemical analyses were run on water samples from 4 typical wells and from one of the Bonanza springs. Partial chemical analyses by field methods were made on water samples from other wells and springs to determine the hardness and chloride content of the ground water. The data from this well canvass are given in the tables and in plate 1. The geologic map of the area is shown as plate 2.

Well-numbering System

In this report each well is designated by a symbol which indicates its location according to the official rectangular survey of public lands. For example, the symbol 37/11½-2H1 refers to a well in sec. 2, T. 37 S., R. 11½ E. The letter after the section number refers to a 40-acre subdivision of the section according to the following diagram, and the number 1 to the first well visited in that particular 40-acre tract.

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

The townships are all south from the Willamette base line and the ranges are all east of the Willamette principal meridian.

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GEOGRAPHIC SETTING

Climate

The region in which the Swan Lake-Yonna Valley area lies is semiarid. The area has warm, dry summers and cool, more humid winters. At the Yonna weather observation station, located on the floor of Yonna Valley, July has the highest monthly average temperature (65.7° F.), January has the lowest monthly average temperature (27.3° F.), and the mean annual temperature is recorded as 46.0° F. for the period of record, 1924-48. During that period the highest recorded temperature was 103° F., the lowest, -21° F. By comparison at the Chiloquin weather station, located on the Sprague River about 15 miles northwest of Swan Lake at an altitude of 4,200 feet, temperature readings for the same period show a monthly average of 61.1° F. in July and 26.2° F. in January. The average annual temperature at the Chiloquin station for that period was 43.0° F.

The average growing season, or frost-free period, at Yonna is 102 days, from June 3 to September 13. During the 25-year period 1924-48, the frost-free period has ranged from 175 days in 1940 to less than 30 days in 1946 when frosts occurred in every month of the year. Killing frosts are rare in July and only 6 frosts are reported to have occurred in the month of August during that 25-year period. In contrast, the Chiloquin station during the same period has reported frosts occurring in every month of the year for 15 out of the 25 years.

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Examination of the Weather Bureau records for four stations in and near the Yonna and Swan Lake Valleys shows that the major factor in the distribution of rainfall in the area is the periodic movement of cyclonic storms. These storms move from west to east across the area, causing a maximum precipitation during the winter months and a minimum precipitation during the summer. Altitude is also a controlling factor; precipitation increases progressively with altitude (see pl. 5). The average of the annual precipitation for the years during which records were kept in relatively unbroken continuation at the four stations in or near the Swan Lake-Yonna Valleys area are as follows: Klamath Falls, 1905-08, 12.92 inches; Yonna, 1908-48, 13.35 inches; Chiloquin, 1912-48, 16.51 inches; and Gerber Dam, 1930-48, 17.71 inches (see pl. 5).

No precipitation records are known to have been kept on the upland areas surrounding the valley basins. However, both the recorded increase of precipitation with greater altitude and distribution of natural vegetation (which includes fir forests on the upper slopes at 5,000 feet altitude and above, and predominantly pine forests on the lower slopes) indicate that there is at least 16 inches of precipitation annually at the lower parts of the uplands and probably more than that in the higher altitudes above 5,000 feet. Thus, the climatic conditions recorded at Chiloquin and Gerber Dam are probably more representative of the conditions in the upland part of the Swan Lake and Yonna Valleys drainage basins than are those recorded at the Yonna station.

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In general, the wet season begins in November and continues through March with a gradual decline in precipitation during April and May to a minimum in July and August.

The averages of precipitation recorded at the four stations during the wet season of November to March, inclusive, are 8.18 inches at Klamath Falls, 8.16 inches at Yonna, 10.46 inches at Chiloquin, and 10.65 inches at Gerber Dam for the periods of record cited above. For the claendar years 1909-43 the average annual total depth of snowfall at each of the three stations of Klamath Falls, Yonna, Chiloquin was recorded as 39.0 inches, 33.6 inches, and 69.4 inches, respectively. The snow begins to melt in February or March; this fact accounts for the increased runoff and streamflow that occurs during those months.

The period of minimum precipitation begins in June and continues through September. The averages at the four stations for this 4-month "dry" period are: Klamath Falls, 1.93 inches; Yonna, 2.04 inches; Chiloquin, 2.35 inches; and Gerber Dam, 2.70 inches. August is the driest month at Klamath Falls, Yonna, and Chiloquin, with only 0.28 inch or less being recorded at these stations. The Gerber Dam station records show July to be the driest month with an average precipitation of 0.33 inch during that month and 0.46 inch in August.

The short growing season and the danger of frosts during the summer months practically limits field crops to the more hardy grains, quickly maturing row crops and forage plants. In the final development, because of the above-mentioned climatic characteristics, the use of ground water for irrigation may assume the primary function of augmenting the present water supply and stabilizing the livestock industry of the region.

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Surface features and drainage

General

The Swan Lake-Yonna Valleys area lies in the northwest corner of the Great Basin physiographic province approximately 15 miles east of the Cascade Mountains section.1/ It is just east of the middle part of the Klamath graben, the principal physiographic feature of the region. Lost River flows through the area to Tule Lake, a closed basin ordinarily not discharging to the Klamath River. Most other streams of this region discharge into Tule Lake or the Klamath River.

1/ Fenneman, N. M., Physiography of Western United States, New York, McGraw-Hill Book Co., Inc., 1931, map.

East of Upper Klamath Lake youthful blocklike mountains trend roughly parallel to each other in a northwest-southeast direction and divide the area into basins, among which are Swan Lake Valley and Yonna Valley. The altitude of the valleys' floors lies between 4,100 and 4,300 feet and the altitude of the crests of boundary ranges between 5,000 and 7,000 feet.

The principal features which lie within the drainage area of the two valleys, from west to east, are: (1) Modoc Ridge, the escarpment-faced hogback that forms the eastern boundary of the Klamath graben and the western watershed for Swan Lake Valley; (2) Swan Lake Valley, a rectangular inter-mountain plain; (3) Swan Lake Ridge, a cuesta that separates Swan Lake Valley from Yonna Valley; (4) Yonna Valley, a rather narrow undulating, north-south plain; and (5) several ridges in the sloping land east of Yonna Valley.

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The northern boundary of the area follows the summits of the hills and mountains which make up the natural divide between the Lost River and Sprague River Valleys. The hills and mountains of the drainage divide are continuous from the northern part of Modoc Ridge to Swan Lake Ridge. East of Swan Lake Ridge the northern boundary is not so clearly defined, but the approximate location of the drainage divide between Sprague River and Buck Creek has been taken here as the northern limit for Yonna Valley. South of that drainage divide the ridges descend to Lost River, which flows from east to west across the general structure of this area.

Ridges

<u>Fault blocks</u>.- The most prominent features of the area are the elongated northwest trending ridges that are the highest parts of relatively raised fault blocks (horsts). These upraised blocks outline the basins of the area.

In general, the fronts of the ridges are steep, only slightly dissected fault scarps. The back slopes are tilted undulating surfaces mostly formed on moderately eroded lava flow planes. The gentle back slopes of two of the major ridges (Modoc and Swan Lake Ridges) and several of the minor ridges are interrupted by secondary fault scarps.

The principal fault block ridges within the area are Modoc Ridge, Swan Lake Ridge, Horton Rim, the unnamed ridge that outlines the northeast boundary of Yonna Valley, and the series of ridges north of the town of Bonanza.

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Fault scarps.- The front scarps of Modoc Ridge, Swan Lake Ridge, and the unnamed ridge on the northeast edge of Yonna Valley all face to the west, whereas the front scarps of Horton Rim and the ridges just north of the town of Bonanza all face to the east. Inasmuch as all the faults observed within the area are of the normal type, the front scarp of these ridges faces in the direction of relatively depressed or downthrown blocks not in most places buried under valley fill.

All of these scarps are comparatively youthful; dissecting ravines are almost completely absent from their faces. The base line at the toe of the scarps is relatively straight or is only gently curved. Talus slopes extent well up the face of the scarps. Steplike benches and ramps are indications that fault "splinters" and "slices" are common in the major fault zones.

Upland topography.- In contrast to the comparative freshness of the fault scarps, the upland areas of the blocks are considerably more eroded and seem to represent an older pre-faulting topography. Large angular boulders dot these upland surfaces. Those boulders have been weathered and eroded loose from the flows of lava rock that comprises the upland surfaces. An additional steplike appearance is present on a small scale, due probably to erosion of the edges of the successively higher lava beds. In general, the crest line of each fault block parallels the scarp face.

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Some of the upland areas that are otherwise generally undulating surfaces contain isolated conical peaks made up of lapilli tuff and basaltic or andesitic lava rock. These peaks apparently represent small volcanic cones that originally dotted the surface of volcanic materials prior to the main fault displacements that now dominate the physiography. Moyina Hill, a conical peak that rises to an altitude of 6,000 feet above sea level, and some 1,800 feet above the southeast corner of the floor of Swan Lake Valley, is a representative of that type of land form.

Valleys

General relations.- All of the present valleys and basins within the area described were formed originally as tectonic lowlands. The general outlines of the valley areas are due primarily to fault movements that have depressed the valley floors relative to the upraised blocks that bound the basins. The floor of Swan Lake Valley has been built up subsequently by much accumulated alluvium and is characterized by interior drainage. Yonna Valley and Poe Valley, however, are less thickly alluviated and are drained by creeks that reach Lost River temporarily during most years. In general, the valley floors are fairly "flat." The valley borders consist of a talus margin wherever a fault scarp fronts upon them and elsewhere consist of gentle inclines that extend more gradually upslope.

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Yonna Valley.— The Yonna Valley lowland proper has an area of about 48 square miles; a total area of about 34 square miles in the southern part of the valley is now under cultivation. The northern part of the valley lowland is partly timber and grass lands whose chief use is for grazing.

The valley floor has an average altitude of about 4,300 feet in its northern half and approximately 4,150 feet in its southern half. Buck Creek follows the central axis of the valley, which slopes to the south for about 16 miles with an average gradient of about 10 feet per mile. Its course contains several straight reaches where it apparently follows minor faults for short distances.

In the northern half of Yonna Valley the undulating topography contains a number of low mounds and hills of radially dipping tuff beds that apparently represent eroded volcanic cones. In the southern half of the valley the relief is that of a gently undulating surface crossed by three small parallel northwest trending swells that extend out from the western edge of the valley. Those elongate swells are made up of sedimentary rocks that are folded and faulted on a small scale, and modified by erosion. Between those ridges small playa flats are temporarily filled by runoff during the early spring of most years.

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At the southwest corner of the valley, just north of Horton Rim, an elliptical structural depression of about 5 square miles contains a marsh and a small permanent lake called Alkali Lake. The marsh and the lake are fed largely by the discharge of numerous springs located on the west edge of the basin. This small basin has at the present time no surface outlet as it is separated from Buck Creek to the east by a 15-foot-high north-south rim. From the appearance of the surrounding alluvial area it is thought that Alkali Lake was once larger and connected with the other small playas to the north.

Just below the town of Bonanza there are numerous large spring orifices along Lost River. These springs are known as the Bonanza Springs and supply most of the water that flows in the lower part of Lost River during its periods of low-water flow.

Swan Lake Valley.- Swan Lake Valley lowland proper has an areal extent of about 29 square miles. Its valley floor is approximately 4½ miles wide by 7 miles long with an average altitude varying from 4,200 to 4,180 feet. The valley is underlain by a deep alluvial deposit except in the northern part where beveled tuff layers of the Tertiary sedimentary beds form a wide bench standing 50 to 75 feet above the alluvial valley floor.

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Most of the valley is covered with grasses and sage and is used for grazing; only a small part around the edges is being cultivated. Anderson Creek, an intermittent stream, enters the northwest corner of the valley and runs southward onto the valley floor. It drains about 40 square miles of the hills and mountains which make up the northwest part of Modoc Ridge and the northern watershed of Swan Lake Valley. When it is flowing bank full it enters the valley floor and continues for about 3 miles east-southeast over the valley floor emptying into Swan Lake proper. This lake, which contains water only intermittently, occupies the lowest part of the valley floor and has a minimum lake-bed altitude of about 4,180 feet.

In Anderson Creek drainage area there are several springs, chief of which are the Whiteline Springs and Janssen Springs. Those springs feed small tributary creeks whose flow is used during the summer to irrigate fields in two small basins in this northwest part of the valley area. The two small basins are about ½ mile wide and approximately 1 to 2 miles long. They trend northwest to southeast as do the faults that bound their eastern and western edges.

Pine Flat.- The elliptical basin of Pine Flat lies south of, and is an extension of, the Swan Lake Valley. It is partially separated from the larger Swan Lake Valley by Hopper Hill and a small northwest trending basalt ridge. A hill-bordered gap only a fourth of a mile wide separates the basin of Pine Flat from the larger Swan Lake Valley depression. To the east, Pine Flat is separated from Yonna Valley by a low divide about 50 feet in height. Within the basin of Pine Flat there is a comparatively smooth alluvium-covered floor about 3 miles long and 1½ miles wide. Pine Flat has a gentle slope toward its center where its lowest part has an altitude of about 4,186 feet. A considerable part of the flat is under cultivation, though scattered pine woods cover small parts of it, particularly on its northern edge next to Hopper Hill. Pine Flat at the present time is an area of internal drainage.

Meadow Lake Valley.- On the west edge of Swan Lake Valley there is a narrow basalt-capped ridge about 4 miles long and 1/2 mile wide which separates Swan Lake Valley on its east from the smaller Meadow Lake Valley on its west. The ridge is interpreted to be a small horst elevated above the valleys on either side.

Meadow Lake Valley is a long flat-floored valley now used for summer grazing. It is about 3/4 of a mile wide and 2½ miles long and trends northwest. A small storage reservoir at its southern end catches spring runoff. During the spring of 1950 about 1/3 of the meadowland of the valley north of the reservoir was covered with a shallow body of water. Normally, by the middle of summer the valley floor is dry and supports a lush growth of grass.

Streams

Lost River, the master stream of the area, drains a large area east and south of the Klamath graben. Besides receiving the surface runoff of Yonna Valley, Lost River also is the principal stream draining the areas of Poe Valley and of Langell Valley. These latter valleys adjoin the Swan Lake-Yonna Valleys area on the south and southeast (see pls. 1 and 2). Yonna Valley is roughly the northward continuation of Langell Valley.

Above the Swan Lake-Yonna Valleys area, the Lost River has its source in Clear Lake, just south of the Oregon-California State line, and flows northwest to Langell Valley. In the alluvial cones of Langell Valley the Lost River disappears underground in marshy land and reappears at the lower end of the valley a short distance south and east of Bonanza. A shallow drainage canal now connects those two segments of the stream. The monthly average flow of Lost River below Bonanza Springs and its relation to the annual temperature conditions are shown on Plate 6. The river has several tributaries, the most important of which are Miller Creek, which enters Langell Valley from the east, Buck Creek, which drains Yonna Valley, and Lost River Slough, which joins the Klamath River with the Lost River. This last-named slough formerly flowed in either direction, depending upon which river was higher, but the flow is now artificially controlled by a dike and by the Lost River drain. Lost River makes a sharp turn to the southwest at Bonanza, flows through the narrows where Harpold Dam (see pl. 1) is located, and into Poe Valley where the stream turns northwest. It makes two almost right-angled bends to the southwest and the northwest before it again turns southwest and crosses the gap between the two fault blocks forming Modoc Ridge at Olene, where it enters Klamath Valley. At present it flows along the south side of its own alluvial deposits to reach Tule Lake. A canal from the Klamath River connects to the Lost River at a point a few miles west of Olene.

Unpublished records
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Buck Creek flows southward through Yonna Valley to enter Lost River just west of Bonanza. During the dry period of some years its bed is dry but it carries an average flow of several cubic feet per second during the months of March, April, and May of most years. The one measurement of its flow listed by the Office of the State Engineer is 40.8 cubic feet per second on March 28, 1911, near Yonna. That was apparently a flood-time measurement. The Surface Water Branch of the Geological Survey made one measurement of 1.4 cubic feet per second in the SW$\frac{1}{4}$ sec. 6, T. 39 S., R. 11 E., on November 22, 1950. A rough measurement of 2.50 cubic feet per second was made by the junior author at the bridge in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 18, T. 39 S., R. 11 E., on April 6, 1951.

Anderson Creek, which drains the back slope of part of Modoc Ridge and empties into the Swan Lake Basin, seldom carries a flow of more than a few cubic feet per second and its bed is dry in its lower course from late summer to the succeeding spring of most years. Plate 10 gives in graph form the flow of that stream at a point in the NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 23, T. 37 S., R. 10 E. Anderson Creek is believed to lose a considerable part of its volume downstream from the measuring station shown on plate 10, in passing across the beveled strata of the sedimentary beds of Tertiary age in sec. 24, T. 37 S., R. 9 E., and sec. 19, T. 37 S., R. 10 E. Apparently it adds some water to the playa and the perched ground water of Swan Lake Valley only during its periods of greatest flow.

Unpublished records
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GEOLOGY

General character of the rocks

Volcanic and sedimentary rocks of Tertiary and Quaternary age comprise the structural framework of the Swan Lake-Yonna Valleys area. Moore [1] described to some extent these rock materials and those of the greater Klamath region. In general, Moore's stratigraphic breakdown of the rock units is used in this report.

[1] Moore, B. N., Nonmetallic mineral resources of eastern Oregon: U. S. Geol. Survey Bull 875, pp. 35-39, 1937.

The oldest exposed rock unit in the area consists of basaltic flows of possibly early Pliocene age. These basaltic flows are overlain by lacustrine deposits and by fragmental volcanic rocks of middle Pliocene age. These sedimentary rocks are in turn capped by a series of basaltic and andesitic flows of late Pliocene age. Those three rock units of Tertiary age are the principal exposed rocks in the fault-block mountains of the area. In places where the Tertiary rocks have been depressed or downfaulted, they have been partly covered by later deposits of Pliocene (?) and Pleistocene age and by Recent alluvium. The lithology and stratigraphic position of these rock units are described in the following pages and the areal extent of all the rock units is shown on plate 2.

Rocks of Tertiary age

Lower lava rocks

The oldest rock unit exposed within the Swan Lake-Yonna Valleys area consists of a number of columnar-jointed olivine-basalt flows which include flow-breccia zones and thin interbeds of tuff. These rocks are designated the lower lava rocks for convenience in mapping (see pl. 2). They are exposed in only one locality within the area. They crop out in the banks of Lost River and form the narrows in the vicinity of the Harpold Dam site. At that locality the uppermost 136 feet of the unit can be seen. Those rocks have been exposed after elevation along a fault. By correlating beds of similar lithology, as those beds are exposed in the north bank of Lost River, a vertical section was compiled and the thickness estimated to the nearest foot. From the top of the unit to the surface of Lost River the following section, which probably represents only three separate flows, was observed.

Section of the lower lava rocks in the north bank of Lost River near the Harpold Dam site in the SW¼ sec. 19, T. 39 S., R. 11 E.

	Feet
Base of sedimentary rocks (detailed under section on Tertiary sedimentary rocks)	
Unconformity - contact is top of section	
Lower lava rocks	
Basalt, brown, highly weathered, vesicular, blocky jointing; vesicles are partly filled with calcite	8
Basalt, blue-black, dense, contains chloritized grains . .	10
Basalt, grayish-brown, vesicular, highly weathered	3
Tuff, red, fine-grained, friable	4
Tuff, brown, somewhat shaly and indurated	15
Basalt, columnar jointed, grayish blue, slightly vesicular near top, anhedral crystals of olivine occur as phenocrysts in fine-grained matrix	30
Basalt, flow breccia, red, scoriaceous and porous	10
Tuff, red, indurated	3

Section of the lower lava rocks in north bank of Lost River, etc., Continued.

	Feet
Basalt, grayish brown, vesicular; the vesicles are partially filled with calcite, highly weathered	8
Basalt, columnar jointed, grayish blue, anhedral crystals of olivine in fine-grained matrix; weathers reddish-brown on surface	45
Base of exposure is surface of Lost River (altitude about 4,105 feet)	
Thickness of measured section	136

Above the eroded surface of the uppermost flow of the measured section, and separated from it by an apparently slight erosional unconformity, tuffaceous sedimentary rocks extend upward. /For further details see the section on sedimentary beds of Tertiary age./ These sedimentary rocks are cut by the same faults that cut the lower lava rocks and the strata are inclined to the southwest at the same angle as the underlying basalt.

In general, the lower lava rocks exposed at the Harpold Dam site consist predominantly of columnar-jointed olivine basalt containing vesicular phases near the tops of the flows. Pentagonal columnar jointing is common but is obscure in many places. The joint columns are stained reddish brown.

On a freshly broken surface the basalt is fine-grained, has a grayish-blue color, is slightly vesicular, and has a conchodial fracture. The minerals that can be observed with a hand lens are anhedral crystals of olivine having a yellowish waxy luster, and feldspar as small anhedral crystals of white striated plagioclase. Those minerals occur as scattered phenocrysts within the fine-grained glassy and felted matrix of the basalt.

Unpublished records
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Moore_/ described basalt flows of similar lithology and stratigraphic

_/ Moore, B. N., op. cit., pp. 37, 42.

position as occurring in more extensive exposures west of Klamath Falls. He estimated the lower lava rocks there to be more than 1,000 feet in thickness and stated that it consisted predominantly of columnar-jointed olivine basalt covered in part by the diatomites and tuffs of the Pliocene sedimentary unit.

It is believed that the exposure of these lava rocks in the banks of Lost River at the Harpold Dam site at the base of Horton Rim, and their extensive areal distribution west of Klamath Falls, are sufficient justification for assuming that Moore's "Lower lavas" lie below the younger rock units which crop out in the faces of the fault scarps of the Swan Lake-Yonna Valleys area. If that assumption is correct, then the drillers' records indicate that these rocks have a thickness of at least 294 feet in Yonna Valley (see log for well 38/11-7C1 in table 3). The total thickness of this lower lava unit in the Swan Lake-Yonna Valleys area is unknown.

During this investigation the age of the lower lava rocks could not be fixed exactly. Nevertheless, they underlie sedimentary beds containing fossils of middle Pliocene age and are separated by an erosional unconformity from those sedimentary rocks, and therefore, they are probably at least as old as early Pliocene.

Sedimentary beds

Within the area mapped the basalts of the lower lava rocks are overlain everywhere by lacustrine sedimentary beds and fragmental volcanic rocks. This sequence consists essentially of two units: (1) a lower lacustrine unit of diatomite, stratified sandstone, laminated siltstone, water-laid ash, pumice, and semiconsolidated gravel, and (2) a rather thick upper unit of basaltic lapilli tuff, part of which was deposited in water. In general the lacustrine rocks are best exposed in the southern part of the area along the banks of Lost River, whereas the lapilli tuffs crop out more extensively in the northern half of the area. These two units are believed to interfinger with each other. Both units have been intruded by dikes and sills that are related in age to — and perhaps acted as feeders to — the upper lava rocks that cap the sedimentary beds in many places.

The two units of the sedimentary beds of Tertiary age were not differentiated in mapping the rocks of the area and are shown together on plate 2. However, areas of conical structure in the lapilli-tuff were differentiated on plate 2 in order to show some of the probable sources of the volcanic material and to indicate some places where the tuffs are extensively exposed. In general, the best exposures of the Tertiary sedimentary rocks within the area are found in the fault scarps and on the back slopes of the fault blocks in places where the slopes cut across the beds.

Lacustrine beds.- The base of the sedimentary beds of Tertiary age is well exposed in the vicinity of the Harpold Dam site on both the north and south banks of Lost River in the SW$\frac{1}{4}$ sec. 19, T. 39 S., R. 11 E. They lie unconformably on the eroded upper surface of the lower lava rocks previously described. Above the top of the last basalt flow described in the measured section of the lower lava rocks at the Harpold Dam site, (p. 22) and for about half a mile southwest of the dam, there are exposed in the right bank of Lost River small segments of the sedimentary rocks which form the lower part of the sedimentary rock unit. These segments have been broken by numerous small normal faults and the beds have been tilted to the southwest. By tracing beds of apparent similar lithology and thickness a vertical section was pieced together. That section is given below with the thickness of the individual beds estimated to the nearest foot.

Composite partial vertical section of the lower part of the sedimentary beds (Tertiary) exposed in the north bank of Lost River in the SW$\frac{1}{4}$ sec. 19, T. 39 S., R. 11 E.

	Feet
Top of section eroded	
Tuff, sandy, black, fine grained, laminated and friable	5
Ash, tan, fine grained, laminated and consolidated	4
Tuff, sandy, black, fine grained, laminated and friable	4
Ash, diatomaceous, white with intercalated thin gray sandy laminae and one 4-inch bed of coarse pumice	18
Lower lavas, base of section	
Total thickness of section	31

Unpublished records
subject to revision

About 50 yards north of the road junction near the bridge at the Harpold Dam site, and at an elevation of about 200 feet above Lost River, a 20-foot-thick dense black basalt sheet is exposed in a small rock quarry. Because the sedimentary rocks above and below are baked and indurated, along the contacts with the basalt the sheet is interpreted to be a sill. The basalt sheet itself has neither vesicular nor scoriaceous phases at its top or bottom.

Partial vertical section of the lower part of the sedimentary beds (Tertiary) exposed in the quarry on Horton Rim above Lost River near the Harpold Dam site in the NW$\frac{1}{4}$ sec. 19, T. 39 S., R. 11 E.

	Feet
Tuff, silty, tan, laminated, highly indurated, with a shaly fracture; scattered minute angular fragments of black glass, 1/8-inch seams of calcite and small dense black basaltic apophyses from the underlying basalt sill	20+
Basalt sill, black, dense, with fine-grained matrix containing small phenocrysts of olivine, pyroxens, and grains of green chorite. Rock is fractured conchodially, contains cubical and columnar jointing, and has dense solid contacts	20
Tuff, silty, brown, laminated, highly indurated, contains small fragments of black glass 1/10-inch in diameter in fine-grained matrix and contains thin interbeds of green siltstone	10+
Base of section - bottom of quarry floor	
Total thickness of section	50

Below the exposure is a slope about 100 feet high on which the exposed material consists of tan soil and an occasional outcrop of brown indurated tuff similar to that exposed in the quarry floor. Thus, the brown tuff underlying the sill is probably at least 110 feet thick.

Unpublished records
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About 1.1 miles southwest of the bridge junction near the Harpold Dam site and on the north side of the highway in the NW$\frac{1}{4}$ sec. 30, T. 39 S., R. 11 E., there is exposed a 15-foot-thick dense, cubically jointed basalt sheet resting on indurated brown tuff. Those rocks are similar to the previously described rocks exposed in the quarry near the Harpold Dam site. Still farther west, on the north side of the road sedimentary rocks crop out for a distance of 200 yards. Those rocks are faulted and tilted to the southwest. By following beds of similar thickness and lithology, the following vertical section was compiled.

	Feet
Top of section eroded	
Siltstone, grayish green, laminated and indurated, breaks with a shaly fracture	5
Ash, diatomaceous, gray, laminated	20
Tuff, grayish black, laminated and indurated	18
Siltstone, tuffaceous, brown, indurated; breaks with a shaly fracture	5
Basalt sill (?), blue black, dense, cubical or "brickbat" jointing	15
Tuff, brown, indurated, contains angular fragments of basalt and glass of about 1/10-inch diameter in fine-grained matrix	10
Base not exposed	
Total thickness of section	73

Soil and brush mask these sedimentary rocks north of the section just described. Farther west many small outcrops of these sedimentary rocks occur along the highway that crosses the Poe Valley north of Lost River. No attempt was made to correlate the rocks of these small exposures with the rocks of the above sections because of the many small northwest-trending faults that there cut the sedimentary rocks.

Unpublished records
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In Yonna Valley there are extensive exposures of diatomite, laminated siltstone, stratified sandstone, and volcanic ash. Those rocks crop out in the cuts of State Highway 66 and the O. C. & E. Railroad where they cross the long swells in the valley floor north of Dairy. There, bedding of the sedimentary beds of Tertiary age show that they have been folded on a small scale and cut by numerous northwest-trending faults. In general, the siltstone and tuffaceous sandstone are comparatively hard and strong and are predominantly laminated, whereas the diatomite beds are friable and massive. A representative section of those rocks, measured in a railroad cut on the west edge of Yonna Valley about 1.5 miles northeast of Dairy, is given below.

Partial vertical section of the sedimentary beds of Tertiary age in a railroad cut on the west edge of Yonna Valley in the SE¼SE¼ sec. 22, T. 38 S., R. 11½ E.

	Feet
Top of section eroded	
Siltstone, grayish green, indurated, laminated, breaks with a shaly fracture	6
Lapilli, black, semiconsolidated, 1/10 to 1/4 inch subangular pebbles of basalt scoria, apparently water laid, friable	.3
Siltstone, grayish green, indurated, laminated, breaks with a shaly fracture	2
Sandstone, tuffaceous, brown, consolidated, fine grained	1
Ash, diatomaceous, tan, friable	.1
Sandstone, black, semiconsolidated, laminated, fine grained, waterlaid basaltic ash and lapilli, friable . . .	1
Siltsone, grayish green, indurated, laminated, breaks with a shaly fracture	2
Sandstone, tuffaceous, brown, fine grained with intercalated laminae of black basaltic ash	3

Unpublished records
subject to revision

Partial vertical section ***in railroad cut *** west edge Yonna Valley-Continued

	Feet
Lapilli, black, semiconsolidated, 1/10-to 1/4-inch subangular pebbles of basalt scoria, waterlaid, friable . .	.5
Siltstone, grayish green, indurated, laminated, breaks with a shaly fracture, laminae 1/4 to 1/2 inch thick consisting of black angular basaltic sands and minute tan and brown particles of silt size	12
Ash, diatomaceous, tan and buff, very light in weight, massive	15
Total thickness of section	42.9

The lacustrine unit of the sedimentary rocks of Tertiary age exposed in Yonna Valley appear to interfinger with the upper, or lapilli-tuff unit north of District School No. 13. In the face of the fault scarp at the northeast edge of the valley, in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 24, T. 37 S., R. 11$\frac{1}{2}$E., there are good exposures of tuffaceous sandstone and diatomite directly under the upper lava rocks.

North of Dairy, on the southwest edge of Yonna Valley in the NW$\frac{1}{4}$ sec. 27, T. 38 S., R. 11$\frac{1}{2}$ E., there are numerous small exposures of indurated laminated siltstone and tuffaceous sandstone. Those rocks appear to extend from under the lava rocks that cap Swan Lake Ridge. The contacts of the units are masked by soil and scattered residual boulders derived from the cliffs above. In a road cut on the north side of State Highway 66 and on the west side of the overpass that crosses from Pine Flat into Yonna Valley, about 0.7 mile west of the Dairy road junction, a massive bed of tan diatomaceous ash crops out beneath a basalt flow of the upper lava rocks. Those small rock outcrops are there terminated by northwest-trending faults. Other exposures of diatomite and indurated sedimentary rocks that appear to extend beneath the upper lava rocks and that are also faulted are found in and around the outskirts of Dairy.

Lacustrine rocks, consisting principally of diatomite, crop out along Lost River. From the standpoint of induration and deformation, some of those sedimentary rocks appear to be much younger than the sedimentary beds of Tertiary age heretofore described. In the banks of the water gap at Olene there are some excellent exposures of diatomite whose stratigraphic position is certain. There diatomite and waterlaid volcanic ash crop out under the upper lava rocks that form the block mountains to the north and south of the gap. The best exposure of these rocks in that locality is on the north side of Lost River in a railroad cut in the NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 14, T. 39 S., R. 10 E. The diatomite there contains a few intercalated thin gray ash stringers and is over 15 feet thick with its base not exposed. It has been faulted and tilted to the northwest as have the overlying lava rocks. Still other cuts along the railroad farther east expose diatomite and semiconsolidated gravels that have also been faulted. Those beds are not there covered by the lava rocks.

The northwest part of Modoc Ridge and the northern part of the area drained by Anderson Creek are the only other places where the lacustrine unit of the sedimentary beds of Tertiary age are known to crop out. In the scarp face of Modoc Ridge in the NW$\frac{1}{4}$ sec. 17, T. 37 S., R. 9 E., over 130 feet of the sedimentary rocks are exposed under the upper lava rocks. The rocks that crop out there consist principally of gray-green laminated siltstones, greenish-brown tuffaceous sandstones and some thin intercalated beds of white and buff diatomite. Thin fault slices and talus rubble there mask the base of the sedimentary rocks and the lower half of the scarp below an altitude of 4,600 feet.

Near the crest of Modoc Ridge, just inside the southern boundary of the Klamath Indian Reservation, in the NW$\frac{1}{4}$ sec. 6, T. 37 S., R. 9 E., a small gravel pit exposes semiconsolidated tuffs and gravels that have a different lithology than the other sedimentary rocks just described. The lower half of the exposure is laminated red and black volcanic ash and pumice and the upper half is tuffaceous sandstone and semiconsolidated basaltic gravels and cobbles. The two halves are separated by a marked angular unconformity of the stratifications. The gravels occur in a thin bed near the top of the exposure and may be of stream-laid origin. There is a poor size-sorting of the cobbles and gravels; the subrounded-to-rounded basalt pebbles and cobbles range from $\frac{1}{4}$ inch to 15 inches in diameter. A 10- to 15-foot-thick basalt flow covers these sedimentary rocks.

About 1 mile northeast of the gravel pit along the logging road that enters the southern edge of the Klamath Indian Reservation, there are other small exposures of sedimentary rocks that consist of almost flat-lying, semiconsolidated tuffs, pumiceous sandstones, siltstones and diatomites. Those rocks were everywhere observed to be overlain by lava rocks. Though the sedimentary rocks exposed in the gravel pit and those exposed along the road differ somewhat in lithology, they were thought to be continuous. To the east, below the level of the sedimentary rock exposures, there are numerous boulders of basalt that appear to be in part residual and in part alluvial. If the basalt exposed there is in place, then the sedimentary rocks which crop out near the crest of Modoc Ridge are either a part of the sedimentary beds of Tertiary age there lifted into an exposed position by cross faulting, or are a younger deposit of sedimentary materials interbedded with the flows in the upper lava rocks. It is thought that the fault hypothesis is the more likely explanation and this interpretation is shown on plate 2.

In the northernmost part of the Anderson Creek drainage area, near the southern boundary of the Klamath Indian Reservation in sec. 4, T. 37 S., R. 9 E., there are numerous exposure of diatomite and tuffaceous sandstone where it underlies a rather thick section of the upper lava rocks. Faults are common in this area and the exposures of the sedimentary rocks are discontinuous and irregular. Only a cursory attempt was made to outline the contacts there. On the east slope of Modoc Ridge, west of the small valleys drained by Anderson Creek, there are other small discontinuous exposures of diatomite and tuffaceous sandstones which underlie the upper lava rocks. There the sedimentary rocks have been brought to the surface by both erosion and faulting, but they are now largely covered by soil, rock mantle, and forest growth.

Lapilli tuffs.- Within the sedimentary rocks of Tertiary age a rather thick unit of basaltic lapilli tuffs lies above, and probably interfingers with, the lacustrine rocks. The tuffs are extensively exposed in the north end of Yonna Valley, and underlie the upper lava rocks in Swan Lake and Modoc Ridges. They occur also in parts of Swan Lake and Poe Valleys.

In Yonna Valley the lapilli tuffs are exposed north of District School No. 13. In some places, at least, their exposure apparently is due to removal of the upper lava rocks. In that part of Yonna Valley there are several low swells made up of the edges of lapilli tuff beds inclined outward in circular patterns that resemble truncated volcanic cones. Those truncated cones probably represent old vents from which much of the tuffaceous material originated. One of those beveled cones in the tuff forms Juniper Rock (pl. 7 B), a small eroded dome located in the SW$\frac{1}{4}$ sec. 36, T. 37 S., R. 11$\frac{1}{2}$ E. That hill rises to a maximum height of about 200 feet above the general level of the valley floor (see pl. 7 B).

In general, the composition of the tuff is fairly uniform although small variations in color and texture are present. A typical specimen of the thinly stratified layers of the tuff contains scattered grains of black glassy lapilli within a matrix composed of tan to greenish-brown, fine-grained, angular ash and pumice fragments. The greenish-brown, ashy matrix of the thicker and more massive layers contains more basaltic fragments, lapilli, and glassy scoriae than is the common content of the tuff. The basaltic inclusions range in diameter from 1/8 to 1/2 inch.

Along the northwest edge of Yonna Valley the tuffs underlie the upper lava rocks. On the central valley floor those tuff beds are covered in places by thin outlying caps of lava rock. One relatively small exposure of the lapilli tuffs was found on the west side of Swan Lake Ridge in the face of the fault scarp. The yellow-brown tuff beds there are fairly massive and show the lack of stratification common in the tuffs in Yonna Valley — an indication that the tuffs are probably continuous under the upper lava rocks that cap Swan Lake Ridge.

On the west side of the middle of Modoc Ridge and on the eastern slope of that ridge west of Meadow Lake Valley, scattered exposures of the lapilli tuffs crop out from beneath the upper lava rocks. The tuffs also crop out on the southeast side of Meadow Lake Valley at the base of Moyina Hill and under the lava rocks that cap the small horst separating Meadow Lake Valley from Swan Lake Valley. All these exposures of lapilli tuff are typically stratified and are identical in lithology with those described as occurring in Yonna Valley.

Near the northwest corner of Swan Lake Valley and just south of the Anderson Creek entrance onto the valley floor, there is a low benchland standing from 50 to 70 feet in height above the valley floor. A quarry pit on this benchland in the NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 30, T. 37 S., R. 10 E. has exposed about 20 to 25 feet of semiconsolidated, stratified lapilli tuff dipping uniformly (10° to 15°) to the southeast. The upper 5 feet of the section exposed here consists of tan-colored laminated, coarse- and fine-grained ash and pumice containing subangular to angular pebbles of basalt and scoria ranging from 1/4 inch to 4 inches in diameter. Below these beds there is about 20 feet of grayish-black to greenish-brown laminated and, in part, cross-bedded semiconsolidated ash and pumice containing angular fragments of glass and subangular to angular lapilli of 1/8- to 1/4-inch size. The material is separated into well-defined beds ranging from 1/2 foot to 2 feet in thickness. The cross-bedding in these strata and the subangular character of some of the pebbles suggests that these effusive volcanic materials may have been deposited in or worked over by water. At the surface above the quarry the same strata are beveled by the benchland terrace and are surficially indurated.

Interrelations of the sedimentary beds.- The belief that the lapilli tuffs mainly overlie the lacustrine rocks but in part may interfinger with them is based on the general position of the two in nearby outcrops and their association in outcrop with the overlying and underlying basaltic rock units. The succession of the strata and their relations to the other rock units, so far as they have been ascertained, are described here because of their importance in the location and development of ground-water-bearing zones.

Unpublished records
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About 1 mile northwest of District School No. 13 in the S½ sec. 35, T. 37 S., R. 11½ E., diatomite and tuffaceous siltstone crop out and apparently pass under the lapilli tuffs exposed in nearby outcrops. However, the rocks there are intricately faulted, and as a consequence, it is difficult to trace the beds any distance or to ascertain positively the interrelations of the two lithologic zones.

In the northwestern part of Yonna Valley lapilli tuffs alone are exposed and have an estimated thickness of over 500 feet. In sec. 33, T. 37 S., R. 11½ E. about 200 feet of indurated tuffaceous sandstones, probably lacustrine, are exposed underlying the upper lava rocks. Farther south from that section there is a thickness of at least 275 feet of lacustrine rocks, principally diatomite, as shown by the driller's log for well 38/11½-22G1. Thus, in Yonna Valley, the areal distribution of the sedimentary rocks indicates the following relationships: The coarse agglomeratic tuffs and lapilli tuffs are thickest in the northern part of the valley near former centers of eruption and the finer materials are more abundant in the lapilli tuff zone to the south. The diatomite and the tuffaceous siltstone resulted largely from deposition in lakes or ponds. These observations suggest the possibility of contemporaneous deposition of the tuffs and the lake sediments. This suggestion is strengthened by the presence of angular, partly sorted, tuffaceous material in the lacustrine beds, as well as by the fact that the tuffs in places partly overlie the lacustrine beds — a condition that would be a logical successor to the filling of the lakes in which the lacustrine beds accumulated.

Unpublished records
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A thickness of at least 300 feet of tuffs crops out on the scarp face of Swan Lake Ridge and about 200 feet of tuff is exposed on the western face of Modoc Ridge. In general, it is thought that the greatest thickness of the tuffaceous unit occurs in northern Yonna Valley near the former tuff cones.

The greater thickness of the tuff unit near a probable former center of volcanism is shown just outside the Swan Lake and Yonna Valleys area in the western scarp face of Plum Ridge, in the SE$\frac{1}{4}$ sec. 31, T. 38 S., R. 9 E. There an estimated maximum thickness of about 500 feet of lapilli tuff crops out and dips steeply in radial pattern that is suggestive of a former volcanic cone area. The tuff is there cut by a basaltic dike and capped by flat-lying upper lava rocks. Farther to the south on Plum Ridge near Klamath Falls there are extensive exposures of the lacustrine sedimentary rocks, over 500 feet in thickness, consisting principally of diatomite, siltstone, and tuffaceous sandstone.

In Poe Valley north of the Lost River only small exposures of the lapilli tuffs occur in the northern part of secs. 25 and 26, T. 39 S., R. 11$\frac{1}{2}$ E. The outcrops there show considerable faulting and weathering, but the beds in general are believed to dip to the southwest as do the lacustrine rocks exposed farther to the east near the Harpold Dam site. A driller's partial log for well 39/11$\frac{1}{2}$-22J1 (see table 3) shows 382 feet of "green shale", 18 feet of "hard basalt", 90 feet of "green shale", 36 feet of "broken lava", and over 122 feet of "hard basalt lava." Drilling was in progress at the time the well was visited and several samples of the bailings from the upper "green shale" unit were examined. The samples were a bluish-green, gritty sludge originally, but on drying they turned

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light greenish-brown. One of the sludge samples contained numerous small gritty scoria and fragments of black volcanic glass. The driller had recorded only the most obvious changes of lithology and the thickness of the smaller units were not described in his log; nevertheless, it is possible roughly to compare his log with the sections measured along the highway north of Lost River and west of Harpold Dam as described above. The thick "green shale" unit above the 18 feet of "hard basalt" probably compares with the siltstone and tuffaceous sandstone of the measured sections (listed above) and the gritty sample containing scoria might compare with the lapilli tuffs. The "hard basalt" may represent an extension of the sill (?) exposed near the Harpold Dam site, and the lower 90 feet of "green shale" may be equivalent to the basal part of the lacustrine rocks. In that log the driller reported no diatomite ("chalk rock"); it is possible that the diatomites observed in the measured sections may not extend horizontally as far as the well site.

Moore/ estimated a total thickness of over 500 feet for the diatomites

/Moore, B. N., op. cit., pp. 36-38.

and the tuff. However, the lapilli tuffs have a thickness of over 500 feet alone, and if they completely overlie the lacustrine rocks the total thickness of the complete sedimentary rock unit in places could be as great as 1,000 feet. The true over-all thickness is believed to be considerably less than the aggregate thickness of the two units.

Age and correlation of the sedimentary beds.- In general, the Tertiary sedimentary rocks of the area contain few fossils; in only one locality were specimens found. About 2 miles northwest of District School No. 13, in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 34, T. 37 S., R. 11$\frac{1}{2}$ E., numerous but poorly preserved, fresh-water invertebrate fossils and a few fish bones were found. Those fossils were found in a brown semiconsolidated tuffaceous sandstone that apparently interfingers with the lapilli tuff.

Specimens collected were identified by G. Dallas Hanna of the California Academy of Science as follows:

> "From a careful comparison with material from other western fresh-water deposits I am convinced that the age is Pliocene. It would be advantageous to date it closer but I do not believe there is sufficient evidence available.
>
> "The very large gastropod in your collection is Carnifex, the species being the one I noted on page 6 'Univ. Oregon Publ. Vol. 1, no. 12, Aug. 1922.' It has not yet been described specifically because of lack of suitable well-preserved material.
>
> "The abundant impressions of small gastropods are of a large, high-spired Amnicola similar to the living longinqua (Gould). A few fragments of Parapholyx of packardi (Hanna) and a few internal impressions of bivalve Sphaerium are present."

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Teng-Chien Yen of the U. S. Geological Survey examined a collection of specimens from the same site and identified the following forms of fresh-water mollusks:

Sphaerium	sp. undet.
Valvata	sp. undet.
Amnicola	sp. undet.
Lanx cf. L klamathensis Hannibal	
Physa	sp. undet.
Vorticifex binneyi (Meek)	
Lymnaea	sp. undet.

Yen concluded his analysis by stating that: "The occurrence of these related species seems to indicate a Pliocene age of its enclosing bed."

Mr. Charles R. Stark, manager of the Klamath Falls Chamber of Commerce, loaned to the writer, for identification, a peccary skull reportedly found in the "Wilson's quarry pit" located in the $NW\frac{1}{4}NW\frac{1}{4}$ sec. 32, T. 39 S., R. 10 E., near the south bank of Lost River and about 100 feet southeast of Wilson's Bridge (see pl. 2). That quarry pit exposes consolidated, iron-stained gravels and massive diatomites, all intricately faulted.

The exact position at which the fossil skull occurred in the pit is unknown as it was found while excavation of the gravel was in progress. However, the rock matrix enclosing the skull was a light gray consolidated sandy tuff which appeared to be lithologically similar to the tuffs now exposed in the quarry pit. The pig skull was identified by Jean Hough of the U. S. Geological Survey as that of Prosthennops oregonsis Colbert and its age placed as middle Pliocene. Mrs. Hough further states that Prosthennops is a common genus in the West Coast Pliocene formations and that the type specimen was found in the Rattlesnake formation of the John Day Valley of Oregon.

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Just south of the quarry pit (at Wilson's Bridge) a ridge rises some 700 feet above the surface of Lost River. That ridge is made up of a thick series of lapilli tuffs capped by lava rocks. Those tuffs are lithologically similar to the ones exposed in Yonna Valley. The exact relationship of the two units was difficult to ascertain, but it is concluded that the diatomite and the related sedimentary materials exposed in the quarry pit must represent the lacustrine unit of the sedimentary beds of Tertiary age and must underlie the lapilli tuff unit exposed in the ridge. Thus, in summary of the sedimentary beds of Tertiary age, the lower unit, the lacustrine rocks, is of middle Pliocene age, and the lapilli tuffs are of the same age or slightly younger.

Upper lava rocks

Overlying the lapilli tuffs of the sedimentary beds are a number of volcanic lava flows and other extrusive volcanic rocks that are combined in this report and are called the upper lava rocks. That unit consists for the most part of flows of basalt, andesite, and locally some dacite (?). Also included in this unit are some fragmental volcanic agglomerates and several "cinder" cone deposits. Those rocks are separated from the underlying sedimentary rocks by an unconformity left, apparently by a considerable period of erosion.

Unpublished records
subject to revision

Basalt flows form most of the upper part of Modoc Ridge, Swan Lake Ridge, and Horton Rim. The individual lava flows range in thickness from about 20 feet to more than 80 feet. Some of the layers are columnar-jointed, but many of them show irregular blocky jointing and have flow-breccia and scoriaceous zones. Thin tuffaceous interflow zones a foot or less in thickness separate some of the flows. Interbedded with the basaltic flows and capping them are flows of andesite porphyry which in most places show either platy or blocky jointing. The andesitic flows are particularly numerous on Swan Lake Ridge and Horton Rim. In general, the individual andesitic layers are relatively thin and are usually less than 30 feet thick.

The basalt rock is dense and black near the center of the individual flows and highly vesicular near the top and outer edges. A typical hand specimen of this rock shows a dense black microcrystalline or glassy matrix containing small lath-shaped feldspar phenocrysts, anhedral olivine crystals, and occasionally grains of the minerals chlorite and iddingsite.

The andesites are typically gray-blue on weathered surfaces and have prominent small white phenocrysts of plagioclase which give the rock a porphyritic texture. The rock has a dense dark blue glassy matrix in which occur the numerous scattered euhedral crystals of striated plagioclase and the smaller lath-shaped crystals of a blackish-green pyroxene.

Unpublished records
subject to revision

Basalt flows are the predominant rocks making up the upper lava unit in ridges north of Bonanza. They are also the predominant rock type in the lower part of the upper lava rocks exposed in the unnamed ridge that outlines the northeast boundary of Yonna Valley. The higher part of the upper lava rocks, where exposed in the ridge on the northeast boundary of Yonna Valley, are andesite porphyry with the characteristically prominent platy jointing subparallel to the surface of the flows. Near the summit of the ridge in the NW$\frac{1}{4}$ sec. 22, T. 37 S., R. 11 E., and on the east side of State Highway 66 are several exposures of thin, platy-jointed, light-colored lava flows which lie on top of the basaltic and andesitic lava rocks The light-colored lava rocks have a dense purplish-gray matrix enclosing a few small crystals of quartz and some scattered small anhedral feldspar crystals. There are also occasional rusty-brown iron stains surrounding minute black grains in the matrix, indicating that a ferromagnesian mineral is present, possibly magnetite. This rock is probably a dacite. In no other part of the area, however, were similar rocks observed.

From the Lost River gap at Olene, north for about 4 miles to the base of Moyina Hill (see pl. 2), extends a long, narrow ridge made up almost entirely of a thick series of volcanic agglomerates and blocky flow breccia. Those rocks lie unconformably on top of the eroded surface of the sedimentary beds. Weathered outcrops of those rocks are blackish-brown and are extremely jagged, owing to differential weathering of the heterogeneous materials. A rude layering is present and small steplike benches mark the slope there. A typical specimen of the agglomerate shows black and red scoria, lapilli, and angular fragments of dense black basalt, all of which are imbedded in a brown volcanic ash matrix.

In the SW$\frac{1}{4}$ sec. 8, T. 38 S., R. 10 E., on the lower part of the eastern side of the ridge between Meadow Lake Valley and Swan Lake Valley, are several small cinder cones. Those cones are made up of red scoria and volcanic bombs and have central "necks" of red porphyritic basalt or andesite. Though exact relations are obscure, those cones are considered to be part of the upper lava rock as they appear to have been built up on an eroded surface over the lapilli tuffs.

All the hills rising above the general crest line of the fault blocks and the isolated peaks of Moyina Hill and Hopper Hill have conical or eliptical shapes and are made up of lava flows. These hills are believed to represent volcanic cones. The top of Moyina Hill has a small elliptical depression, from 50 to 100 feet deep and about a quarter of a mile long and 300 yards wide, which is apparently an eroded crated. A fault which has sliced through the depression, leaving it open on both its northern and southern ends modifies the otherwise crater-like shape of the hilltop.

In general, the greatest thickness of the lavas is found on the hills and along the crests of the fault blocks. However, the total thickness of the upper lava rocks seems to vary considerably. The maximum observed thickness of the upper lava rock is approximately 1,600 feet at Swan Lake Point. The generally thinnest zone of the upper basalt unit occurs in the north central part of Yonna Valley where a 20-foot-thick lava flow caps the lapilli tuff.

Both Moore_/ and Williams_/ have correlated these upper lava rocks

_/ Moore, B. N., op. cit., pp. 37, 155.

_/ Williams, H., The geology of Crater Lake National Park, Oregon: Carnegie Inst. of Washington, D. C. Pub. 540, pp. 17-19, 1942.

and the underlying units of Tertiary age with the volcanic rocks that make up the platform of the mountains of the high Cascade. On the basis of that structural position they tentatively assigned the age of Pliocene to these rocks. Their assignment of Pliocene age to these rocks has thus been in part substantiated by the middle Pliocene age placed on the underlying sedimentary rocks, as presented above. Moore_/ further states that

_/Moore, B. N., ibid.

"* * * the age of the lavas forming the present Cascade Range" are thus "believed to be Pliocene and younger." The author also believes from general observation that the upper lava rocks can be traced farther north beyond the area studied and that they there form the plateau surface upon which rest younger volcanic cones.

Intrusive igneous rocks

Largely contemporaneous with the upper lava rocks are several bodies of intrusive igneous rock noted during this study. These rock masses are andesite or basalt and have cut into or through the sedimentary beds of Tertiary age.

Unpublished records
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Several dikes are shown on plate 2. Those dikes have cut through the underlying sedimentary beds of Tertiary age and each can be traced to the lava flow originating from it. One of the dikes is exposed on the scarp face of Modoc Ridge in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 15, T., 38 S., R. 9 E. It is about 10 feet thick, is nearly vertical, and shows columnar jointing at right angles to the walls. The dike appears to be continuous upward into an almost flat lying basalt flow.

In Yonna Valley in the SE$\frac{1}{4}$ sec. 32, T. 37 S., R. 11$\frac{1}{2}$ E., a thin dike of prophyritic andesite cuts through green tuffaceous sandstone. That dike trends N 52°W and is visible for over 600 feet before it passes upward into a 15-foot-thick glassy andesitic flow.

A dike of porphyritic andesite was observed on the scarp face of Swan Lake Ridge in the SW$\frac{1}{4}$ sec 24, T. 37 S., R. 10 E. That dike is about 10 feet thick and nearly vertical, and it crosses a bed of red scoria.

In the range of hills northeast of Yonna Valley in the NE$\frac{1}{4}$ sec. 20, T. 37 S., R. 11 E., an intrusive plug or neck is exposed on the summit of an unnamed peak. The rock contains vertical flow lines and crops out at the apex of a radially sloping surface of eroded andesitic flows. It is thought that this plug is the upper part of a core of lava rock in the conduit of a former volcano. The basalt sill exposed in the quarry near Harpold Dam has already been described in the section on the sedimentary beds. That sill, like the other igneous intrusive rocks, is believed to have been emplaced during the time of the extrusion of the upper lava rocks.

Deposits of Quaternary age (and possibly in part of late Tertiary age)

Older alluvial deposits

A small thickness of poorly consolidated sedimentary materials, mostly diatomaceous earth and volcanic ash, underlie some terraces, partly fill some valleys, and underlie alluvial slopes. The position of these deposits indicates that they were laid down after the major part of the tectonic movements that formed the present mountains and valleys of the Swan Lake-Yonna Valleys region. They are characteristically older than the Recent alluvial materials which are still accumulating — herein called the younger alluvial deposits.

Large areas underlain by the older alluvial deposits occur as terraces along the sides of the valleys, where they have been isolated and preserved. Other remnants may occur at depth beneath the younger valley fill in the valley floor areas. The older alluvial deposits lie upon the upper lava rocks or the sedimentary beds of Tertiary age and are, in turn, overlain largely by the younger alluvial deposits. The older alluvial deposits lap irregularly over the upper lava rocks in railroad cuts 0.6 mile west of Dairy road junction. At that locality they are exposed to a depth of about 30 feet. The upper part is composed of fine-grained gray ashy sandstone and the lower part of fine-grained tan sandstone.

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In drillers' logs those materials of alluvial origin are recorded as clay, sand, and their semiconsolidated equivalents, shale and sandstone, as well as "chalk" (presumably volcanic ash or diatomite) and gravel. In several wells the thin gravel beds were found to be water-bearing in a minor way; however, the older alluvial deposits are mostly tight, nonporous materials, and the bedded deposits are in most places not productive of large quantities of ground water.

Younger alluvial deposits

The floors of Swan Lake Valley, Yonna Valley, Pine Flat, the Lost River lowlands, and the nearby Klamath Basin are underlain in large part by varying thicknesses of unconsolidated silt, clay, sand, and gravel which in many places are still accumulating during times of flooding. Those deposits are mapped on plate 2 and referred to herein as younger alluvial deposits.

In many places, as in Swan Lake Valley, the younger alluvial deposits overlie the older alluvial deposits, but in others, such as in the lower part of Yonna Valley, they lap up over the older consolidated rocks. In the lack of consolidation and in the types of materials the younger alluvial deposits in part resemble the older alluvial deposits and the distinction between the two is in some places arbitrary and vague, as in some of the well records listed in table 3. Some rocks, like the buried talus along the foot of Swan Lake Ridge, span the time of both the older and the younger alluvial deposits and interfinger with them. The blocky talus rubble occurs along the foot of Swan Lake Ridge and disappears beneath the alluvium. Judging from the fact that the valley fill is deep (known to be at least 800 feet in depth) the linear talus strip must form a considerable band of porous material at depth along the margin. It must also be present on the west side of the valley. Well 38/10-9N3 (see log, table 3) penetrated such blocky talus before entering the lava rock of the buried fault escarpment.

At most places in the valley flats the younger alluvial deposits are too fine grained to afford large yields of ground water even though they may be saturated and the ground may be swampy. Along the streams or in the vicinity of the mountain-stream debouchments the deposits are in part coarser-grained and in such places afford moderately large ground-water yields to shallow wells.

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STRUCTURE OF THE ROCK MATERIALS

The regional setting between the Cascade Mountains and the high plateau lands to the east suggests that in a broad sense this area lies in an over-all gentle structural sag. Its principal tectonic forms are tilted slabs of layered volcanic rock. A master or regional structure situation is evident only in the regularity of the type, extent, and pattern of the fracturing and tilting of the blocks of the earth's crust.

In this area volcanic and volcanic-sedimentary rocks constitute the known consolidated rock — or bedrock — to a depth of at least a few thousand feet. The strata are horizontal or tilted gently. Along controlling zones the horizontal continuity of the volcanic stratifications is interrupted by lines of fracture where vertical displacements have occurred. The master set of those faults trend about N 35° W. Subordinate northeast-trending "cross" faults in places separate the ridges into rectangular blocks bounding rectangular valleys. The most prominent faults are shown on plate 2; many others are believed to be present but are small or partially concealed.

The faults examined were all of the normal type, having downthrown the side that is above the inclined plane on which motion took place. Normal faults generally are associated with tensional, or stretching, forces of earth deformation. However, there may have been some thrust or reverse faulting in the Yonna Valley area. Certainly there was some crustal shortening there during the epoch of folding that formed the gentle anticline and synclines in the sedimentary rocks of Tertiary age (see pl. 2).

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Inasmuch as the principal faults trend northwest, the two main directions of inclination of the fault planes are to the southwest and northeast. So far as shown by outcrops and by topographic expression, the fault planes dip fairly steeply — all may be inclined more than 40° from the horizontal. The grooved or slickensided fault plane at the west foot of Plum Ridge, 1 mile south of Algoma, dips about 50° in a S 50° W direction.

Vertical displacement ranges from a few feet along minor faults to perhaps thousands of feet along major faults such as those along the foot of the Swan Lake Ridge and Plum Ridge escarpments. Vertical movement, without an appreciable horizontal component, is believed to have taken place along the faults. In most places the major faults are observed to comprise a number of parallel slippage planes that divide the fault zone into "splinter" blocks. This is especially evident in the large fault that defines the west side of Swan Lake Ridge. One of the larger fault zones defines the west escarpment of Modoc Ridge for several miles north of Algoma and forms the escarpment bounding Klamath Lake. Another, the Plum Ridge fault, is exposed in the railroad cuts 1 mile south of Algoma and forms the sharp escarpment along the west side of Plum Ridge just east of the city of Klamath Falls.

Fault zones in volcanic rocks in some places form barriers to ground-water movement and locally may be such in this area. The fault plane seen in the railroad cuts 1 mile south of Algoma has several feet of gouged, clayey, crushed material which is less permeable than the unsheared rock. However, the general accordance of ground-water level throughout this area, regardless of the position of some known faults (see water-level contours on pl. 1), suggests that the fault zones at best have only a minor control on the normal horizontal percolation of ground water. The principal effect of the faults on the ground-water occurrence arises from the relative positions those displacements have imposed upon the water-bearing rock strata. Fault or fold displacements have caused the lava rock below the valley floor to be near the surface, as in well 38/11½-23F1, or deep below the surface as in well 38/11½-24E1.

Because the lava rock is the principal water-bearing material, its depth below the surface and its position above or below the regional water table are factors of prime importance in planning the construction of wells.

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OCCURRENCE OF THE GROUND WATER

Sources of the water

As shown on plates 4 and 5, an average of about 12 to 13 inches of precipitation falls during the 7-month period October to April, inclusive, and an average of but 3 to 4 inches during the 5-month period May to September, inclusive. The relatively high evaporation and transpiration during the May-to-September period makes it unlikely that more than a very small part of the precipitation falling during that period passes through the soil to replenish the ground water of the area. During the cooler 7-month period, however, the precipitation averages nearly 2 inches per month, the evaporation and transporation are much lower, and the part of the water that passes through the soil zone and to the ground water of the region must be considerable. In the higher parts of the drainage basins, where rain and snow melt enter the sandy soils and reach the porous zones of the bedrock, an appreciable quantity of water is supplied each year to the ground water of the region.

The basin draining to Swan Lake Valley is about 80 square miles in extent, and only Anderson Creek and a few smaller intermittent creeks provide drainage routes for surface runoff. The discharge measurements of Anderson Creek, shown on plate 10, give the total runoff to the Swan Lake Valley floor as 30, 274, and 712 acre-feet for the water years 1946, 47 and 48, respectively.

The Yonna Valley drainage basin is about 135 square miles in extent and is in part drained by Buck Creek, which discharges an average flow of several cubic feet per second for several months of most years — in all, probably less than 1,500 acre-feet of water per year.

Lack of surface runoff, evaporation, and transpiration records for the area precludes accurate estimation of the average annual increment to ground water. However, the low surface runoff, low evaporation, and relatively low transpiration during the months of greatest precipitation, and the sandy soils and generally porous rocks of the upland areas, favor infiltration of a relatively high percentage of the precipitation. Of that which enters the soil, it is estimated that a substantial part, but probably not more than 2 or 3 inches, reaches the water table.

The Swan Lake-Yonna Valleys area probably does not receive a natural underflow of ground water from either the Sprague River valley to the north or from Klamath Lake to the west. The ground-water level in Sprague Valley, north of Yonna Valley, is at a slightly higher altitude than that in the lower part of Yonna Valley, but when the known gradient of the water table in the upper part of Yonna Valley (see pl. 1) is projected northward, it is seen that a ground-water divide probably exists between the valleys, at a considerably higher position than the 4,300±-foot altitude of the water table along Sprague River valley. Thus, an inflow from the Sprague River valley is considered unlikely. However, it must be noted that only fragmental and inconclusive information is available on wells and water levels in the uppermost part of Yonna Valley. Test wells are needed there to establish correctly the position of the regional water table beneath the area of the Yonna Valley-Sprague River divide. The water table in the upper part of Swan Lake Valley in recent years has stood near 4,145 feet. It stands a little above the level of Upper Klamath Lake and seems to deny the possibility of inflow from that direction.

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Ground-water body

Over-all shape of the regional ground-water body

A regional water table, whose shape beneath the lower valley areas is shown by contours on plate 1, occurs beneath the whole of the Swan Lake-Yonna Valleys area. This water table slopes gently down from a higher level beneath the upper parts of the drainage basins to the altitude of the terminal discharge into the Lost River.

The correlation of measured ground-water levels shows that the regional water table slopes down from the upland parts of Swan Lake and Yonna Valleys at the rate of about 20 feet per mile. Beneath the lowland valley "flats" the water table in the two valleys takes on different characteristics. Down slope, the water table beneath Yonna Valley retains a broad trough-shaped surface with a comparatively low gradient through the upper part of the valley "flats" until it merges with that from the lower part of Swan Lake Valley. Thence it slopes to Lost River on a broad, even front with a gradient of about 2 feet per mile. The regional water table beneath the Swan Lake Valley "flat" continues the steeper gradient of the upland water table through the deep valley fill. Through the valley-fill material, the water passes with a gradient of about 10 feet per mile to the buried talus material along its margins. From the valley fill it moves into the bedrock and into those linear talus strips in "French-drain" style and has a gradient of about 2 feet per mile. Toward the south it forms part of the broad front of the regional water table sloping to the level of the Lost River.

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As shown by the contours on the water table (see pl. 1), the ground water beneath the lower part of Yonna Valley is in balance with the Lost River, and at times water flows out into the river. Apparently the main flow of Bonanza Springs does not come from the ground water beneath Yonna Valley, but, judged on the basis of a still incomplete record of ground-water levels, represents largely ground water percolating down grade from Langell Valley and other up-river areas. The discharge of Bonanza Springs (see pl. 6) is substantially greater than any conceivable recharge to the ground-water body beneath the Yonna Valley drainage area alone.

Other characteristics of the regional ground water

Above the level of the regional water table the pores of the rocks and soils are partially occupied by water and the annual replenishment from precipitation passes by saturated and unsaturated flow downward through the pores. Under such conditions it is common for small bodies of ground water here and there to become suspended on impervious layers as perched water, part of which may be returned to the surface in "side hill" springs or may be transpired by plants. Relatively few such high-level perched bodies occur in this region, as compared with regions of less permeable rocks.

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Beneath the regional water table the pores of all the rock materials are saturated, but the lava-rock units (the upper and lower ones described previously) are almost the only materials having sufficient permeability to yield large quantities of water to wells and springs. Where relatively impervious strata, such as the sedimentary beds of Tertiary age or the fine-grained older alluvial deposits, overlie the lava rocks, they form a non-producing zone which in effect depresses, or confines, the ground water in the lava rocks below. When that confined ground water is released by the drilling of wells it rises to the level of the regional water table level in artesian_/ fashion. In a few wells near Alkali Lake, where the land surface is below the altitude of the regional water table, confined water flows from the wells at a height of as much as a few feet above the surface.

_/ The reader is reminded that hydrologists of the Geological Survey use the work "artesian" to mean any confined water. Most dictionaries still use the older definition of water that flows from the well at the surface. Also, popular usage sometimes erroneously takes the word 'artesian' to mean any well of large yield, or any deep well.

Up gradient from places where ground water is being drawn off at a lower level in a much more pervious material, such as more permeable bed-rock of the valley walls and the buried talus strips along the sides of Swan Lake Valley, the regional water table seems to have sections with a steep hydraulic gradient. Down gradient from those steep-gradient sections are stretches of low hydraulic gradient where percolation takes place in the highly permeable buried talus materials. A well near the border of those strips may, in the upper part of the hole, especially in the valley alluvium, encounter water whose static level is higher than the level of water encountered in bedrock or the buried talus material at greater depth. That is the situation in some wells, such as 38/10-9N2 and -9M1, where the upper water descends in the well and runs out into the bedrock and buried-talus aquifer. Some of the water in the alluvium is obviously perched above water-table level, but the deeper water there is at or close to the true regional water table in at least the northern half of the valley.

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Nature of the aquifers

General classifications

In the wells for which reliable information afforded a description of the water-bearing materials, lava rocks give nearly all the large yields of water. The Coleman well, 37/10-30B1, in the pumiceous materials of the sedimentary beds of Tertiary age at the north end of Swan Lake Valley, is about the only irrigation well to obtain its water from consolidated rocks other than the lava rocks.

Of the smaller wells, drilled for only household use, about half obtain water from the lava-rock strata and half from the sedimentary beds of Tertiary age or from the later alluvial deposits.

Aquifers of the lava-rock units

As judged by the large percentage of flow breccia (cinders, broken lava, porous lava, etc.) recorded by drillers when penetrating the lava units, the upper and lower lava rocks must contain even more flow breccia and shattered lava rock than is evident from the sections of outcropping rocks (described in the section on Geology).

Both the upper and lower lava rocks contain many flows that were largely shattered and broken up during solidification, and in many places the blocks were rolled into place and now have an open-work texture. Also present are beds of fragmental effusive materials — pumice, scoria, and lapilli. The chilled tops and bottoms of otherwise solid flows are in many places observed to be shattered and vesicular enough to afford avenues of ready percolation. Many of the more nearly solid flows are severed by joints formed during cooling and deformation of the flows. These joint crevices allow water to pass through the rock. Few of the "solid" flows show any ability to confine the ground water in the adjacent more porous lava rocks.

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The aquifers that supply water to the large-producing wells are porous flows and beds in the lava rocks. That they should afford high yields where they occur below the regional water table is reasonable to one who examines the large pore spaces in the fragmental lava zones in surface exposures such as the flow breccia of the upper lava rocks in the railroad cut 0.6 mile west of Dairy. Some of the wells finished in flow-breccia aquifers have yielded at a rate commonly exceeded only by wells yielding from cavernous openings of lava rocks or limestones (see 38/11½-12B1 and -33L1 in table 1). Every porous zone by itself will not support a large-producing well; however, most porous zones of the lava units afford good water yields and when several are tapped by a single well the yield is large though some of the porous zones may be sufficiently isolated by less pervious elements of the lavas and the interbedded sedimentary materials as to preclude large sustained yields to wells.

Whether there are certain stratigraphic horizons in the lava rocks at which porous units are unusually abundant and persistent is not yet known, but apparently most sections of the lava rocks below the regional water table afford a generally similar chance for the development of large yielding wells. There are certainly some remarkable flow breccia zones in the upper lava rocks, especially the lowest hundred feet or so, as described above. Of the nearly 1,300 feet each of the upper and lower lava rocks described in drillers' logs in table 2, about two-thirds of the upper lava rocks was characterized as "porous water-bearing rock", whereas only a third of the lower lava rocks was similarly labeled. Such a rough

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classification may have a corraboratory value and help indicate that the upper lava rock is more highly pervious than the lower unit. The designation of approximately half the 2,600±-foot total of the two lava units as "porous, water-bearing" points to the high percentage of water-transmissive material in the lava rock units.

Some fault zones are relatively impervious and unable to transmit ground water rapidly. In general, fault zones should be avoided in locating wells that are to produce large quantities of water.

Aquifers in the sedimentary beds of Tertiary age

The fine-grained tuff, "chalky" diatomite volcanic ash, and silty and clayey zones of the Tertiary sedimentary beds do not yield ground water in adequate amounts for any but the smaller users. The coarser-grained tuffs and the agglomerates do, however, contain porous zones that readily yield water to wells. "Gravel" in these sedimentary beds also is reported to yield water, though, from lack of real water-rounded gravel in some well-drilling waste piles, it is believed that much of the reported "gravel" actually may be agglomeratic volcanic material.

The Coleman well in Swan Lake Valley (37/10-30B1) is one of the few wells that obtained a satisfactory yield of water from the sedimentary beds of Tertiary age. That well penetrates coarse-grained beds of pumiceous material. Outcrops in the quarry just west of the Coleman well show coarse pumice, tuff, and agglomerate beds dipping eastward toward the Coleman well where they probably form the aquifers from which water is taken. Well 37/10-8N1 apparently penetrated some of those beds as "black sand" was recorded in the 190- to 220-foot zone of its log.

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In Yonna Valley up to several hundred feet of "chalky" diatomaceous and volcanic-ash beds overlie the lower lava rocks and are involved in the faulted and folded structures there (see pl. 2). Apparently no wells produce water from those tight beds in sufficient quantity for other than domestic and stock uses. Even enough water for those small uses is difficult to develop from such zones of fine-grained materials in the sedimentary beds at most places.

Aquifers of the older and younger alluvial deposits of Tertiary (?) and Quaternary ages

The fine-grained alluvium is developed mostly by only shallow wells of smaller diameter. In a few wells, such as 37/10-18H1 near the mountain slope, gravel and sand have been encountered while the drilling was still in the alluvial fill. Virtually all the fill so far penetrated in the Swan Lake Valley is reported by drillers to be silt, clay, and sand.

The strips of coarse talus and slope wash that lie buried by the alluvial valley fill at the sides of the Swan Lake Valley are porous and highly permeable. A few domestic wells have been constructed in the sandy phases of the valley fill, but the buried talus strip forms the only known Quaternary alluvial deposits from which copious supplies of ground water now are obtained. As shown by the spacing of the successive contours on the ground-water table, the water level in the buried talus strip is at a lower altitude than it is in the finer valley fill, but the greater permeability of the buried talus material allows larger quantities of water to be obtained there.

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USE AND DEVELOPMENT OF THE GROUND WATER

General

About 150 wells and a few springs furnish the domestic and farmstead water supply and the irrigation water used in the Swan Lake and Yonna valleys north of the Horsefly Irrigation district. In all, 125 of these wells are described in table 1. Of those wells, 44 are used for stock watering or for household, and 20 for combined farmstead needs. A total of 15 wells are not in used at present. Irrigation-water supply was the sole use of 36 wells and the partial use of 7 wells in 1949; it accounted for by far the largest amount of ground water withdrawn in the area.

Irrigation

Present Development

In 1950, the 28 irrigation wells in use supplied a total of about 6,000 acre-feet of water to 3,800 acres of land. Those wells were pumped for irrigation during the period May 20 to September 15, with most pumpage confined to the 60-day period June 15 to August 15.

The tabulation of quantities of water pumped from irrigation wells and the acreage on which that water was applied in 1950 in the Swan Lake and Yonna valleys area is as follows (from report of owners or operators):

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Well Owner	Well Number	Acre-feet of water	Acres Irrigated
L. M. Hankins	37/10-25E1	Not used	
F. Coleman	37/10-30B1	100	100
L. M. Hankins	38/10-13D1	Not used	
Total for Swan Lake Valley proper		100	100
G. C. Mitchell	38/10-25A1	Not used	
D. Liskey Estate	38/10-26C1	do.	
G. Barton	38/11½-29J1	635	220
W. L. Whytall	38/11½-30Q1	207)	
Do.	38/11½-30R1	55)	159
L. L. Porterfield	38/11½-32G1	494	330
B. Lee	38/11½-33F1	5 (Est.)	3
G. Barton	38/11½-32L1	Not used	
L. L. Porterfield	39/11½-5D1	173	305
E. Metler	39/11½-6B1	200 (Est.)	197
Total for Pine Flat district of Swan Lake Valley,		1,769	1,179
L. Ritter	38/11-5P1	236	250
J. P. Colahan	38/11-6N1	157	140
C. Williams	38/11-7C1	162	120
L. Tofel	38/11-7M1	125	100
E. Ritter	38/11-18D1	89	70
Haskins & Co.	38/11-31B1	218	60
J. N. Drew	38/11½-3J1	225 (Est.)	150
J. C. Bradley Estate	38/11½-11H1	170 (Est.)	80
J. Vierra	38/11½-12B1	71	105
F. Challis	38/11½-12L1	20)	160 (Est.)
Do.	38/11½-12M1	257)	
R. M. Robertson	38/11½-13G1	106	142
W. Konig	38/11½-13P1	440	230
L. M. Hankins	38/11½-15R1	146	200
C. Sewald	38/11½-23F1	247	110
V. Schmoe	38/11½-24E1	Not used	
Haskins & Co.	38/11½-24P1	544	160
R. Hoeffer	38/11½-25E1	100 (Est.)	100
C. Sewald	38/11½-26H1	664	288
V. E. Grise	38/11½-34D1	4	2
L. J. Horton	38/11½-34P1	76	76
R. Hoeffer	38/11½-36D1	Not used	
Total for Yonna Valley,		4,107	2,563
Grand totals for Swan Lake-Yonna Valleys area,		5,976	3,842

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About 130 feet is the greatest height at which an irrigation well (38/10-26C1 and 38/11-5P1) has been located above the level of the regional water table, and, because the drawdown in those wells is less than 10 feet, the greatest pumping lifts to the land surface are now between 130 and 140 feet.

Of the large wells drilled for irrigation, all but five have received short-term pumping tests at yields of greater than 1,000 gallons per minute (equivalent to a rate of 4.44 acre-feet of water per day). The 35 irrigation wells average 325 feet in depth. Only five of these are more than 500 feet deep and only two are near 1,000 feet in depth. The variable thickness of non-water-bearing sedimentary beds of Tertiary are from place to place and the various structural settings — that is, the depth to the water-bearing lava bedrock — determines the depth to which wells must be drilled for irrigation water supplies. The probable height at which the water level will stand in a well located in the valley area can be deduced from the water-table contours on plate 1. The probable depth of drilling necessary to open up aquifers in the lava rock can be discerned from the geologic map, plate 2, and the record of neighboring wells given in tables 1 and 3.

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Fault zones should be avoided in the location of large wells. Inasmuch as most of the known fault planes dip in the direction of the downthrown side (except possibly for some of the small faults in Yonna Valley northeast of Dairy) at angles from 40° to 70° or 80° from the horizontal, the downthrown side closely adjacent to the fault may be an undesirable well site from the standpoint of the permeability of the rock to be encountered as well as from the standpoint of the greater depth necessary to reach the lava rock aquifers. A northwest-southeast strip through sections 14 and 24 of T. 38 S., R. 11½ E. is an example of such a depressed zone in the bedrock. There wells must be drilled to about 1,000 feet in depth to reach the lava bedrock and secure large yields.

Possible Future Irrigation Developments

Approximate area of land that may be dependent on ground water for irrigation.- Under present conditions a pumping lift of about 150 feet is about the maximum practical in most cases, although there may be many exceptions. Within the Yonna Valley north of the Horsefly Irrigation District there is an area of about 12,000 acres, mostly lying below an altitude of 4,300 feet in which the original pumping lift may be less than 150 feet. In that area about 2,500 acres now are irrigated with ground water. Similarly, about 3,500 irrigable acres in Pine Flat lie within the 150-foot ground-water-lift range, of which acreage about 1,200 acres are now so provided. Thus, about 12,000 acres in the Yonna Valley and Pine Flats districts may lie within the future probable area of ground-water development. Swan Lake Valley contains about 18,000 acres of valley land, of which only a few hundred acres are now irrigated.

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Aquifers containing additional ground-water supplies.- In Swan Lake Valley proper ground water for irrigation of additional land may be developed in wells that penetrate the buried talus material of the valley alluvium at the east (northeast) and west (southwest) sides of the valley, the coarser phases of the sedimentary beds of Tertiary age at the northern margin, the upper lava rocks which occur at relatively shallow depth at the southeast side (northern margin of the Hopper Hill rock mass) and the bedrock beneath the valley alluvium. In places the alluvium beneath parts of the valley floor proper may yield ground water in quantities adequate for irrigation when developed by means of properly constructed wells. As shown by the few fragmental well logs available, there is some water-saturated sand in places beneath the east side of the valley floor. When developed by wells using sand screens, gravel packs, or horizontal infiltration pipes, the ground water in places in the fine-grained valley alluvium possibly may be made available for irrigation. In several wells it has been found preferable to obtain water from the bedrock; well 37/10-26K1 penetrated only impervious "chalk rock" to a depth of 800 feet and obtained no water in the alluvium except that found in the uppermost 158 feet. The ground water in the valley alluvium, with its aforementioned drawbacks, has one advantage — a generally higher static water level than is present in the more pervious talus strips and bedrock at the sides of, and at depth beneath, the valley floor.

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In Yonna Valley, Alkali Flats, and the Pine Flat section of Swan Lake Valley, the irrigation wells must develop the ground water from the porous units of the lava rocks, especially from the upper lava rocks, as only those materials, so far, have been found to possess the permeability necessary for the development of large wells.

Estimates of quantities of ground water available locally.- The "safe yield" of a ground-water reservoir is the quantity that can (from a practical standpoint) be withdrawn perennially. The early determination of that quantity is of greatest importance to the wise development of the ground-water resources of the Swan Lake-Yonna Valleya area. In some places the safe yield can be computed from records of observed water levels and well yields; in others it must be empirically estimated until basic records permit more accurate methods. If it is estimated that an over-all aggregate of 2 inches of precipitation per year infiltrates and reaches the regional ground-water table, about 10,000 acre-feet of water will be added to the regional ground-water body in the Swan Lake Valley area (including Pine Flat) and about 13,000 acre-feet in the Yonna Valley area (north at the Horsefly Irrigation District) annually. Those figures are rough estimates warranted only by the present lack of data for closer approximations. As such they would suggest, broadly, that the ground-water resources at their maximum development, allowing 2 feet per acre for irrigation, would provide water for a maximum of about 5,000 acres in Swan Lake Valley and about 6,500 acres in Yonna Valley.

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Under natural conditions the water percolates out into the Lost River more or less uniformly during the year, as shown by the uniformity of the water-table level in valley areas. In order to withdraw all the average annual increment to the ground water, it would be necessary that a similar quantity be pumped each year. Such a withdrawal, when characterized by a lowering of the regional water table by the amount to which it would recover between irrigation pumping seasons, would utilize the whole of the ground water resource. For the preservation of that resource that amount of pumpage should not be continuously exceeded. It is roughly estimated at this time, on the basis of comparative areas, that an irrigation-season lowering of 5 to 10 feet in the water table under the valley floor areas will withdraw the "safe yield", the average annual ground-water recharge of the basin.

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CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE GROUND WATER

General

The ground water of the Swan Lake and Yonna Valleys in general is relatively low in dissolved mineral matter, soft or but slightly hard, free of excessive salinity, color, and odor. The ground water is slightly on the alkaline side and exceptions to the usual good quality do occur.

In studying the chemical character of the ground waters in the area five relatively complete analyses were obtained on representative samples from wells and springs (see table 4). Also, 82 additional samples were analyzed for hardness and chloride content (see tables 1 and 2, columns 16 and 17). The five relatively complete analyses were made according to methods regularly used by the Geological Survey. The field determinations were made by simple titration, with standard soap solution (for hardness) and silver nitrate solution and potassium chromate indicator (for chloride).

Hardness

The hardness of water is usually expressed as the amount, in parts per million, of calcium carbonate equivalent to all the calcium, magnesium, and other hardness-forming constituents. It is also roughly a measure of the soap-consuming nature of the water. The following table gives the descriptions commonly applied to the ranges of hardness [according to the U. S. Treasury Department standards for interstate carriers (1925)]:

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Hardness range (Parts per million)	Degree of hardness
0 to 55	Soft
56 to 100	Slightly hard
101 to 200	Moderately hard
201 to 500	Very hard

Excluding two wells (38/11½-24E1 and -E2, which are abnormally high in hardness and dissolved solids) practically all the well and spring waters are but slightly or moderately hard and relatively low in mineral content.

The water from the shallower wells tapping the alluvium is a little harder than that from deeper sources. Water from 5 wells in alluvium and from 17 wells whose aquifer was not known, but thought to lie at shallow depth, had an average hardness of 81 parts per million. The water from 38 wells drawing from lava rock had an average hardness of 69, and water from 15 wells in the sedimentary beds of Tertiary age had an average hardness of 71 parts per million. Ground water from the alluvium and the sedimentary beds is apparently rather uniform in hardness wherever encountered; that from the lava rock varies somewhat in hardness from place to place and from one depth zone to another. Besides the two wells that yield unusually hard water, most wells drawing water from the lava rock obtain either a soft or a slightly hard water having a hardness in the order of 50 to 85 parts per million, or a moderately hard water in the order of 140 to 150 parts.

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The softest water (in well 39/11½-11B1) has a hardness of 25 parts per million and is obtained from a bed of black sand in the sedimentary beds of Tertiary age. The hardest water (in well 38/11½-24E2) obtains water having a hardness of 900 parts per million, but the producing zone and other characteristics were not determined for that well.

The over-all average for 75 samples was 74 parts per million, falling in the "slightly hard" classification. The water flowing from springs is a little softer than that obtained from wells. Nine spring-water samples showed soft water averaging 51 parts per million. Olene Hot Springs, whose water is of much higher temperature, yields moderately hard water.

Salinity

The five comprehensive analyses (see table 4) indicate that the water from wells and springs is of exceptionally low salinity. The additional 73 chloride determinations (see tables 1 and 2, columns 16 and 17 also indicate a low content of chloride). In general, in most analyses, sulfate is low, chloride is negligible, and nitrate is low. The bicarbonate is the predominant acidic component present, but its content is moderate in most of the analyses. However, as shown by the analysis for well 38/11½-12M1 and by some of the higher chloride concentrations, there are zones where the ground water has considerable dissolved mineral content.

The analysis of ground water from the lava rocks in well 38/11½-12M1 shows more bicarbonate, sulfate, and nitrate (as well as calcium and magnesium) than is shown by the analyses of other well waters. The sulfate present is only a small part of the amount permissible in good drinking water, but the nitrate content of water in this and some other wells is unusually high for ground water in this area.

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Suitability of water for irrigation

Suggested limits for certain characteristics of irrigation water have been published by Scofield. _/ Among those characteristics if the percentage

_/Scofield, D. S., South Coastal Basin investigation, quality of irrigation waters: Calif. Dept. Public Works, Water Resources Div. Bull. 44, pp. 12-24, 1933.

of active dissolved bases comprised by the element sodium, the strongest and most active of the alkaline elements commonly present. The lower set of limits is such that, in general, waters within the specified range are not likely to be harmful when used in ordinary irrigation. The upper limits represent concentrations that are likely to be harmful when used in irrigation of most crops. The upper limits represent concentrations that are likely to make the waters entirely unfit for irrigation because of their effects on the soil or on the plants. Concentrations between the upper and lower limits may or may not cause injury to some crops and soils, their effect depending on the concentrations of the various constituents of the water, the characteristics of the soil, the crops, and the way the water is used. The following table shows the suggested limits:

Suggested limits for safe and unsafe waters
for irrigation (after Scofield)
(Parts per million except percent sodium)

Constituents	Safe	Unsafe
Dissolved solids	Under 700	Over 2,000
Percent sodium	Under 50	Over 60
Sulfate (SO_4)	Under 192	Over 480
Chloride (Cl)	Under 142	Over 355

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Percentage of sodium is calculated from analytical results expressed in equivalents per million. These equivalents are obtained by dividing the parts per million of sodium, potassium, calcium, and magnesium by 23, 39, 20, and 12.24 respectively.

$$\text{Percentage of sodium} = \frac{100 \text{ sodium (emp)}}{\text{Sodium} + \text{calcium} + \text{magnesium} + \text{potassium}}$$

(in equivalents per million)

Of the five ground waters from the Swan Lake-Yonna Valleys area that were analyzed, all were within the lower part of the safe zone on concentrations of dissolved solids, percent sodium, sulfate, and chloride as set forth by Scofield for irrigation waters.

The alkalinity, or its counterpart, the acidity of water, is generally given as the pH, a number expressing the relation of the concentration of hydrogen ions, the acid-forming constituents in water, to that in neutral water. A pH of 7 indicates a neutral, one less than 7 an acid, and one greater than 7 an alkaline, water. The values found for the five samples of ground water were all slightly above 7, which is normal for ground water in regions of semiarid climate such as the Swan Lake-Yonna Valleys area. Such slightly alkaline waters are not harmful for irrigation, though of course, they do not help neutralize the alkalinity of "alkali" soils.

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Important minor chemical and physical characteristics of the ground water

Boron

Boron is essential in very small amounts to healthy plant growth, but it is injurious to some plants when present in only slightly greater amounts. The water analyses show no boron for two of the samples, 0.01 part per million for two others, and "less than 0.10 part per million" for the fifth. Water with a content under 0.33 part per million boron is not considered detrimental in that respect even for sensitive crops.[/]

[/] Explanation and interpretation of analyses of irrigation waters, U. S. Dept. of Agri. Cir. no. 784, p. 5, May 1948.

Fluoride

Fluoride in drinking water in concentrations under 1.5 parts per million is considered beneficial to the development of children's teeth, especially so in the range 0.5 to 1.5 parts. Above that, it may be injurious, causing mottling of the enamel. All the analyses (table 4) showed 0.2 or 0.3 part — a concentration that is not harmful and may be beneficial.

Iron

The permissible limit of iron in good drinking water is commonly considered to be about .30 part per million. In concentrations much over that amount, it stains laundry and plumbing fixtures. Almost any concentrations are permissible for irrigation water.

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The predominant form of iron present in ground water is normally the bicarbonate, though the sulfate and other minor compounds are sometimes present. The iron present is often dissolved from peaty soils and from sulfides of iron such as are present in most volcanic rocks. Of the five ground waters analyzed, only one, that of Bonanza Springs, had a content over 0.04 part per million; it contained 0.22 part. Owners of several wells that obtain water from the lower and upper lava rocks or from "red cinders" report undesirable concentrations of iron compounds. The concentrations present in this area can doubtlessly be easily and cheaply removed by improvised or commercial iron-removal equipment.

Gaseous constituents

Owners of a few wells drawing water from the lava rocks report that the water has a slight to moderately strong odor of hydrogen sulfide. Such minor content of hydrogen sulfide gas is a normal thing in ground water from the volcanic rocks of the Pacific Northwest. At least some of the gas apparently arises from remaining volcanic emanations trapped in the rocks or from the decomposition of sulfides of iron in the lava rock. Decomposing vegetation in alluvium may also generate the gas. It is not commonly detrimental except for the offensive odor where it occurs plentifully in the water. Proper aeration will remove most of the gas, even from the water containing fairly high concentrations of hydrogen sulfide.

A few owners report wells yielding water containing other, non-oderiferous, gases. One of those waters, in alluvial deposits, was reported unsuitable for stock watering. Undoubtedly many peaty beds are incorporated in valley-fill type of sedimentary deposits and when penetrated by wells released a miscellaneous assortment of gases (methane, carbon dioxide, etc.). Such gases can usually be removed by aeration or cheaply removed by other means if necessary and desirable to render otherwise suitable water fit for certain specific purposes.

Temperature

The temperature of the ground water varies several degrees from place to place in the area.

Of the ground waters whose temperatures were measured, none yield water substantially lower in temperature than the mean annual air temperature (46° F. at Yonna) plus an amount due to the earth-temperature gradient (which varies slightly from place to place but is commonly taken as 1.8° F. for each 100 feet below the first 100 feet of depth). In addition to those given in table 4, the wells that yield water of a temperature higher than the "normal" and the water temperature observed in each case are: 38/10-13D1 (53°); 38/10-25A2 (52°); 38/11½-11H1 (54°); 38/11½-13P1 (52°); 38/11½-15C2 (54°); 38/11½-26H1 (57°); 38/11½-29J1 (56°); 38/11½-30Q1 (61°); 39/11½-11B1 (64°). The water temperature ranges from 14° F. above the "normal" earth thermal gradient in well 38/11½-30Q1 to 5° F. above "normal" in well 38/10-13D1. Four wells, 37/10-30B1,

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38/11½-12M1, -13P1, and 39/11-10N1, yield water with the approximately "normal" earth temperatures of 45°, 52°, 52°, and 48° F., respectively.

From the uniformity in chemical character of the ground water, it is evident that, in general, volcanic waters do not rise directly up into the fresh-water aquifers of the area. Deep circulation of some water may be responsible for abnormally high temperatures, but , because of the relatively shallow depth of some of the warmest of the ground waters, such deep circulation is considered as an unlikely cause for the higher temperature of some of the water. The cause of some of the slightly high water temperatures is apparently an irregular distribution of warmer rock, possibly due to a residium of frictional heat which had accumulated in the rocks during the comparatively recent faulting. The slightly abnormal warmth of the ground water in most wells is advantageous to irrigation and to some other common uses.

WELL AND SPRING RECORDS

The remainder of the report consists of the tables containing pertinent data on the ground water and the wells and springs by which it is now developed.

As shown in table 1, the depth of most wells is based on reports by owners or drillers, because few of the wells could be entered for measurement. Those depths shown to the nearest tenth of a foot were sounded by the Geological Survey. The depths shown with plus or minus signs (±) were estimated or were based on reports which may not be authentic.

Water levels are expressed in feet below a land-surface datum, a plane of reference at each well which coincides with the general level of the land immediately adjacent. Those levels given to the nearest whole foot and not followed by plus or minus signs are reported and are considered dependable within a few feet.

Except in those wells for which drillers' logs are given in table 2, the character of the water-bearing material (table 1, column 10) is largely that reported by the owner. Though it usually is a well-known feature of each well and the data are considered largely authentic, there probably are some discrepancies. Such discrepancies are most likely to occur in the records of wells that derive water from lenses of coarse permeable material within the sedimentary beds of Tertiary age. Also, the owners' descriptions of rock types are, in some cases, only descriptive of the ease of the drilling and the ensuing expense. The major terms used by the owners in describing the materials penetrated in the drilling of the wells of the area are:

"soft rock" generally believed to mean sedimentary materials; "hard rock," which usually refers to the lava rocks of the area; and "chalk," a term used both by drillers and the owners to describe the diatomite and volcanic-ash deposits of the sedimentary beds (Tertiary) and the older alluvial deposits Tertiary (?) and (Quaternary).

The statements on occurrence of the ground water at each well (table 1, column 11) have been interpreted from the record of that particular well and the geology of the area. The data on capacity of the pump (table 1, column 14) are necessarily approximate. They do not show the ultimate yield of the wells, of which some may have potential capacities much greater than the current rate of use.

During the field study 125 wells and 10 springs were examined and are described in the tables. The wells range in depth from 12 to 2,510 feet, but most are less than 300 feet deep. Only 10 wells are more than 500 feet, and most are less than 300 feet deep. Two wells, both of which were originally drilled as oil prospects, are more than 1,000 feet deep.

All the wells listed in the tables were either drilled or dug wells and range in diameter from 6 inches in the drilled wells for domestic use, to 5 feet in the dug wells. In general, the irrigation wells have diameters ranging from 12 to 20 inches, 16 inches being the most common. Casing is usually 6 inches in diameter in the wells drilled for domestic use. The casings of the drilled wells are mainly steel drive pipe and extend only to a depth of 40 feet or less. That hazardous dearth of casing reflects the well-casing shortage prevalent during the period 1946-48 when many of these wells were drilled.

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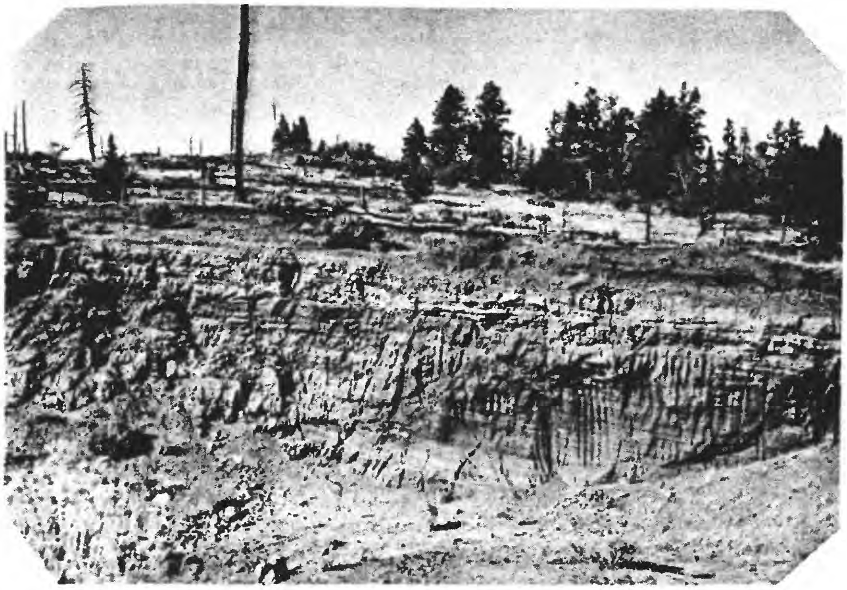


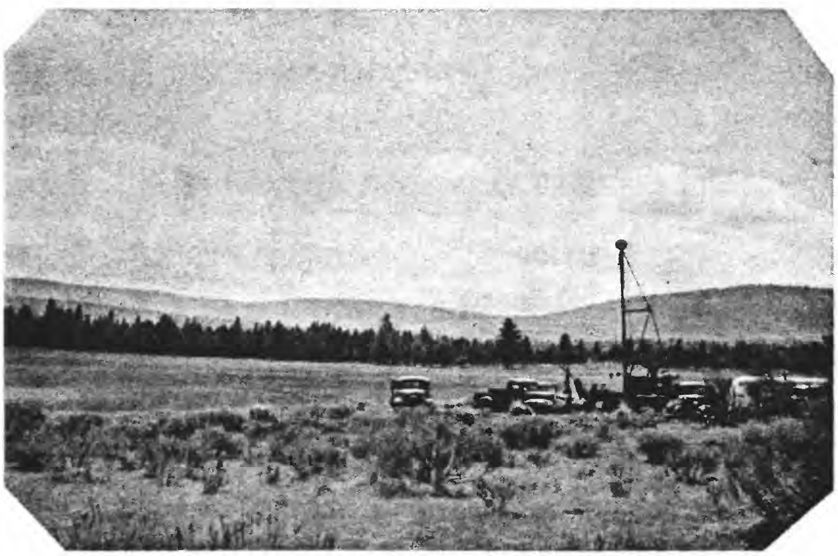
A. Sedimentary beds of Tertiary age exposed in pit at the top of Modoc Ridge in the NW$\frac{1}{4}$ sec. 6, T. 37 S., R. 9 E.

B. Outcropping lapilli-tuff beds in Juniper Rock in SW$\frac{1}{4}$ sec. 36, T. 37 S., R. 11$\frac{1}{2}$ E.

A. Beveled shale and diatomaceous earth laminae of sedimentary beds of Tertiary age exposed in road cut in NE$\frac{1}{4}$ sec. 27, T. 38 S., R. 11$\frac{1}{2}$ E., one mile northeast of Dairy.

B. Flow breccia of the upper lava rocks exposed in railroad cut in the SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 33, T. 38 S., R. 11$\frac{1}{2}$ E. Wells obtain high capacities where they tap water in "cinder" zones like this.

A. View west down valley toward Olene Gap through Modoc Ridge.



B. View southwest across Pine Flat from well 38/11½-29J1, in right foreground.

Table 1.- Hydrologic data for representative wells

Topography: S, slope to valley; Ts, talus slope; Uv, upland valley of minor
from barometric traverses.
Type of well: Dg, dug; Dr, drilled.
Depth of well
and water levels: Depths and water levels expressed in feet and decimals
by owner or driller; those with plus and minus signs
wells not known, "Flowing".
GW occurrence: C, confined; P, perched; Un, unconfined.
Type of pump: C, centrifugal; J, jet; P, plunger; T, turbine.
Use of water: D, domestic; Irr, irrigation; O, observation; S, stock.
Remarks: Hardness and chloride content determined by field analysis.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material (by driller or owner)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 37 S., R. 9 E.								
4B1	R. D. Dehlinger	Uv 4,500	Dr	353	6		316	34	Broken "porous lava".
6P1	C. C. Horn	Ts 4,160	Dr	85	6				Broken "lava"
10C1	R. D. Dehlinger	Uv 4,380	Dg	25.0	60	25			Valley alluvium
36H1	Jack Marshall	Vf 4,220	Dr	250	8	21	246	4	Broken "porous lava".
	T. 37 S., R. 10 E.								
8E1	A. R. Devincenzi	S 4,320	Dr	159.7	10				

stream; Vf, valley floor; altitudes interpolated from topographic maps or

were measured by the Geological Survey; those in whole feet are reported
are approximations reported by the owners. Static water level of flowing

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Un	331±	10/ /49		S				See table 3 for log.
Un	11.51	11/24/49	J	D		50	4	Sometimes pumps dry but fills within half hour; water from talus at foot of fault scarp.
Un	7.00	11/17/49	P	S		90	17	Now abandoned and partly filled.
C	45±	8/ /49		S				Driller reports bailing 50 gpm with drawdown of 15 ft.; see table 3 for log.
	130.10	11/17/49		N		60	3	To be test-pumped for irrigation when electric power available.

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Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 37 S., R. 10 E.- Continued								
8N1	A. R. Devincenzi	Vf 4,215	Dr	291	18		200	91	Lava rock
14N1	do.	Ts 4,220	Dr	123.0	10				Broken "lava"
16B1	do.	Vf 4,213	Dr	142	18		111	12.5	Lava breccia
18H1	Fred Coleman	Vf 4,220	Dr	120	10		115	5	"Gravel"
19A1	A. R. Devincenzi	Vf 4,205	Dr	400+	12				Basalt (?)
19H1	H. D. Whiteline	Vf 4,206	Dr	155	6	30	145	10	Black "gravel"
21D1	A. R. Devincenzi	Vf 4,190	Dr	49.2	6				
21M1	do.	Vf 4,184	Dg		48				

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute--gpm)	Use of well	Temperature of water (^{o}F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	48	9/ 4/52		Irr				Breccia and "cinders" 281-291 ft. form main aquifer
C	54.95	11/17/49	P	S				
C	45.66	9/ 4/52		Irr				Reportedly yields 4,200 gpm with less than 1 foot drawdown.
C	60±	7/ /48	P	D,S				Test pumped 180 gpm; owner reports "sands and gravels" above aquifer.
C	31.90	11/17/49		N		85	5	Well abandoned; neighbor reports that driller encountered caving sands near bottom before entering "hard rock."
C	33.20	do.	P	D,S		60	3	Yields 12 gpm with 2 ft. of drawdown; see table 3 for log.
	25.84	11/18/49	P	S				
P	8.80	do.		N				Abandoned; partly filled.

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Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 37 S., R. 10 E.- Continued								
23G1	L. M. Hankins	Ts 4,205	Dr		6				
25E1	do.	Vf 4,180	Dr	365	16	272			Brown "sand"
26D1	A. R. Devincenzi	Vf 4,180	Dr	71	6	20			"Sand"
27C1	do.	Vf 4,180	Dr	61	6	20			do.
29B1	do.	Vf 4,186	Dr	300±	6				
29K1	do.	Vf 4,187	Dr	100.1	10				
29K2	do.	Vf 4,186	Dr	800	16	20	135	20	"Gravel"
30B1	Fred Coleman	Vf 4,205	Dr	98.6	16	55	32	66	Black "cinders and gravel"

data for representative wells in Klamath County.- Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water ($^oF.$)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	87.26	7/20/49	P	S				
C	16.26	do.		S, Irr		65	5	Driller states well drilled to 615 ft. depth and it filled with sand to 365 ft.; test pumped 1,400 gpm with 93 ft. of drawdown.
	20±	7/ /49	P	S				Drilling reported in "sands" for entire depth.
	20±	11/ /49		S				
C	27.39	11/18/49	P	S		65	4	
P	9.98	7/20/49	P	S		65	5	See table 5 for water-level measurements.
Un	28.01	11/19/49	P	S		70	3	See table 5 for water-level measurements; deepened from 158 to 800 ft. in 1951; see table 3 for log.
C	23.11	8/22/49	T	Irr		50	3	Water level draws down 17 ft. when well pumped 2,000 gpm; see table 3 for log and table 4 for chemical analysis.

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Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 37 S., R. 10 E.- Continued								
30H1	Fred Coleman	Vf 4,190	Dr	74	8	12	72	2	"Gravel"
36D1	L. M. Hankins	Vf 4,181	Dr	54	6				
36H1	do.	Ts 4,190	Dr	125	6				"Gravel"
	T. 37 S., R. 11½ E.								
5Q1	Roy Wilson	Uv 4,400	Dg	12	36	10			"Sandstone"
16R1	J. C. Crawford	Uv 4,250	Dr	222	6	40			"Sand"
24H1	S. K. Hartzler	Uv 4,324	Dr	487	6	42	440	10	Porous lava rock
35H1	James Nail	Uv 4,230	Dr	235	6				
35N1	John Bodner	Uv 4,185	Dr	150±	6	20			

data for representative wells in Klamath County.- Continued

GW occurrence zones (11)	Water level: Feet below land-surface datum (12)	Water level: Date (13)	Type of pump and yield (gallons per minute--gpm) (14)	Use of well (15)	Temperature of water (°F.) (16)	Total hardness as $CaCO_3$ (ppm) (17)	Chloride (Cl) (ppm) (18)	Remarks (19)
C	8±	7/ /48	P	S		55	3	Owner reports "chalk" (diatomaceous ash) extends to aquifer.
P	18.12	11/18/49	P	S				
P	30.34	do.	P	S				
P	6	11/ /49		D				Owner reports little annual change in water level.
C	120+	do.	P	D,S				Owner reports well drilled in sedimentary materials entire depth and stopped in caving sands.
C	100.43	4/ 3/48	P	D,S				Unsuccessful test well for irrigation; see table 3 for log.
	97±	11/ /49	T	D,S		60	4	Water level draws down 41 ft. when well pumped at 50 gpm.
	60±	do.	P	D				Diatomaceous ash exposed at ground surface.

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Table 1.- Hydrologic

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or: Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 10 E.								
8C1	Frank Riley	Vf 4,205	Dr	169.5	6	35			
9M1	do.	Vf 4,187	Dr	150	10				
9N1	do.	Vf 4,200	Dr	150	10				
9N2	do.	Vf 4,190	Dr	221	12	60			Lava rock
9N3	do.	Vf 4,210	Dr	131	6	25	123	8	do.
12J1	L. M. Hankins	Vf 4,185	Dr						

data for representative wells in Klamath County. - Continued

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	104.03	7/20/49		N		60	3	
	22.57	do.				65	3	
	102.80	do.	J	D,S		70	3	Owner reports this water level to have lowered 10 ft. since 1947.
	63.45	do.	P	S		70	7	Test pumped 260 gpm; agitation of water in well evident when pump not operating; deepened from 208 to 221 ft. in 1951; test pumped at 2,000 gpm; has static level of 90 ft.; see table 5 for water-level measurement.
Un	110.54	11/19/49	J	S, Irr		70	5	Test pumped at 85 gpm with 7 ft. of drawdown; may be deepened 20 ft. for irrigation well; see table 3 for log and table 5 for water-level measurements.
		do.	P	S		70	5	Sealed off; owner has no data on well.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 10 E.- Continued								
13D1	L. M. Hankins	Vf 4,192	Dr	220.9	16	40	216	5	Red cinders
14K1	do.	Vf 4,185	Dr	424	12				Sand
15N1	Klamath County	Vf 4,198	Dr	73.9	5	50			
16Q1		Vf 4,202	Dg	45.2	36				
16R1	L. B. House	Vf 4,200	Dr	70.8	6				Cemented fine gravel
20D1	Dave Liskey Estate	Vf 4,400	Dr	1,140	12				
25A1	G. C. Mitchell	Vf 4,190	Dr	524	14	329	520	4	Lava boulders and cinders
25A2	do.	Vf 4,190	Dr	113	6		82	3	Gravel and cinders

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	77.29 79.70	7/21/49 11/19/49		S, Irr		90	12	After 3 hours' pumping at 1,600 gpm water level draws down 19 ft.; see table 3 for log.
P	11±	7/ /49		N				Owner reports well back-filled to depth of 140 ft.; well in "sands" entire depth..
P	18.38	7/18/49		O		65	4	Located in county right of way; see table 5 for water-level measurements.
Un	14.55	7/18/49		N		65	6	Abandoned; starting to cave at bottom.
P	20.44	do.	P	D		70	5	
		7/ /49		N				Dry hole.
C	83	9/ /49		Irr				Test-pumped 2,048 gpm with drawdown of 7 ft. after 5 hours; see table 3 for log.
P	23.05	11/19/49		N		70	3	Drilled alongside well 38/10-25A1 gravel packed from 85 to 103 ft. to shut off sand.

Unpublished records subject to revision

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 10 E.- Continued								
26C1	Dave Liskey Estate	Vf 4,221	Dr	582	16	15	560	21	Porous lava rock
36B1	K. F. McManus	Vf 4,195	Dg	25.3	48	20	23	2	Gravel
	T. 38 S., R. 11 E.								
5P1	Leonard Ritter	Uv 4,252	Dr	200	16	12	181	19	Broken lava rock
6B1	Freida Woelk	Vf 4,240	Dr	245	8	20	135		Sand
6N1	J. P. Colahan	Vf 4,198	Dr	325	16	18	315	10	Cinders

data for representative wells in Klamath County. - Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	126.55	7/19/49		Irr				Test pumped 700 and 2,165 gpm when bottom at 282 and 560 ft. depth, respectively; drawdown was 2.5 ft. at the latter rate.
Un	21.05	11/20/49				60	3	Diatomaceous ash over aquifer.
C	129.38	4/ 2/48	T, 1,600	Irr				Well yields 1,600 gpm with drawdown of 2 ft. after 5 minutes; see table 3 for log.
P	82.80	11/15/49	J	D		85	3	Reported drilled in sedimentary materials entire depth.
C	82	5/ /49	T, 1,600	Irr				Test pumped at 1,000 gpm with drawdown of 15 ft. after 2 hours; see table 3 for log.

Unpublished records subject to revision

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11 E.- Continued								
7C1	Christine Williams	Vf 4,200	Dr	586	16	42	567	19	Broken lava rock
7M1	Louis Tofel	Vf 4,205	Dr	260	12		242	18	Red and gray cinders
9J1	Cox Brothers	S 4,370	Dr	320	8		310	10	Broken lava rock
18D1	C. W. Fyock	Vf 4,182	Dr		12	100			
19D1	Leonard Ritter	Vf 4,180	Dr	86.5	6				
31B1	Haskins and Company	S 4,183	Dr	178	16	20	55	120	Broken lava rock
31B2	do.	S 4,183	Dr	180.0	6				Broken lava rock

data for representative wells in Klamath County. - Continued

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	84.92	7/20/49	T	Irr				Test pumped 1,400 gpm with drawdown of 19 ft.; static water level of 94 ft. at depth of 367 ft. during drilling in April 1949; see table 3 for log.
C	88.64	do.	T	Irr				Yields 1,000 gpm; see table 3 for log.
C	297±	1951	P	S				Soil and alluvium is 61 ft. deep over lava rock.
	66.24	7/20/49	T	Irr		48	2	Yields 2,000 gpm.
Un	65.97	11/16/49	P	S		75	5	
C	68.68	do.	T	S, Irr		50	3	Yields 1,200 gpm with drawdown of 2.8 ft.; driller reports "sandstone" over aquifer.
C	68.68	7/20/49		N		50	3	Test well; reportedly entered contact area between basalt and "sandstone."

Unpublished records subject to revision

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11 E.- Continued								
31R1	Fred Rueck	Vf 4,156	Dr	226.8	10		85	77	Sandstone seams in yellow shale
31R2	do.	Vf 4,160	Dr	211	6	178	210	1	Broken lava rock
	T. 38 S., R. 11½ E.								
2C1	John Bodner	Vf 4,180	Dr	100	6	20			Sand
2P1	R. Angel	Vf 4,172	Dr	404	6	40	388	16	Lava rock
3J1	J. N. Drew	Vf 4,190	Dr	194	16	20	110	84	Broken porous lava
6E1	L. M. Hankins	Vf 4,188	Dr	224	16		174	50	Lava breccia

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
P	33.89	11/16/49	P	N		150	13	Abandoned; owner states cattle will not drink water because of gaseous nature.
C	45±	6/ /49	J	D,S				Yields 300 gpm; cased through "bad water" at 87- to 164-foot level.
C	60±	11/ /49	P	D,S				
C	44.15	11/15/49	J	D		80	3	Diatomaceous earth and associated sedimentary materials overlie aquifer.
Un	70.91	7/19/49	T	Irr				Yield 2,500 gpm; driller reports mostly "chalk" overlies aquifer.
C	89.65	4/23/52		Irr				Reported silt beds and talus blocks to 174 ft., water-bearing breccia layers in rock below; bailer samples from aquifer were water-rounded cobbles.

Unpublished records subject to revision

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11½ E.- Continued								
7Q1	L. M. Hankins	Vf 4,200	Dr	200±	16				Lava breccia
10F1	J. N. Drew	Vf 4,178	Dr	285	6	40	272	13	Broken lava rock
10H1	do.	Vf 4,157	Dg	13.4	72				Sand
11H1	Jack C. Bradley Estate	Vf 4,160	Dr	224	16	20	214	10	Broken porous lava rock
12B1	Joe Vierra	Vf 4,180	Dr	280	16	8	272	8	Broken lava rock
12L1	Frank Challis	Vf 4,155	Dr	389	6	22	385	4	Porous lava rock
12M1	do.	Vf 4,156	Dr	425	12	18	401	24	do.

data for representative wells in Klamath County. - Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	100.15	4/23/52		Irr				
C	33.62	7/19/49		S		85	3	Driller states all "chalk" down to aquifer.
P	5.4	do.	C	S		65	3	
C	45.36	4/ 1/48	T, 1,700	Irr		65	3	Water level drew down 10 ft. after pumping 1,650 gpm for 3 minutes; see table 3 for log.
C	64.84	4/ 3/48	T, 1,100	Irr				Drawdown 6 in. after 3 hours pumping at 1,500 gpm; see table 3 for log.
C	37.11	4/15/50		D				Owner reports only blue "chalk" penetrated down to aquifer.
C	41.44	4/ 1/48	T, 1,200	D,S				Drawdown 10.5 ft. when pumped at 300 gpm; water reported in motion when pump idle; see table 3 for log and table 4 for chemical analysis.

Unpublished records subject to revision

Table 1.- Hydrologic

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11½ E.- Continued								
12M2	Frank Challis	Vf 4,162	Dr	150	12	5	148	2	Red porous lava rock
13G1	R. M. Robertson	Vf 4,159	Dr	183	16		161	22	Broken lava rock and cinders
13N1	William Konig	Vf 4,155	Dr	600	20	16			Diatomaceous ash
13P1	do.	Vf 4,151	Dr	475	16	16	468	17	Broken lava rock and cinders
15C2	Orrin Hankins	S 4,200	Dr	60	6	22	19	41	Broken lava rock

data for representative wells in Klamath County. - Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	46.58	8/22/49		N		145	5	Test pumped 500 gpm with drawdown of 73 ft.; owner plans to deepen; see table 3 for log and table 5 for water-level measurements.
C	45.35	4/ 1/48	T, 1,600	Irr				Yields 1,600 gpm with drawdown of 6.5 ft. immediately after pumping begins; see table 5 for water-level measurements.
P	22.52	4/ 2/48		N		95	5	"Dry"; has shallow water only; "chalk" extends to bottom; see table 5 for water-level measurements.
C	36.67	do.	T, 1,600	Irr		60	11	Reported to draw down 5 ft. while pumping; see table 3 for log.
		7/21/49				50	3	
C	2.20	11/13/49		D,S		50	4	Test pumped 300 gpm with 10 ft. of drawdown after pumping 3 hours; 19 ft. of blue clay over aquifer.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11½ E.- Continued								
15E1	L. M. Hankins	Vf 4,198	Dr	495	12		362	133	Lava rock and cinder zone
22G1	Cliff Sewald	S 4,200	Dr	275	6	20	245	10	Black sand
23F1	do.	Vf 4,170	Dr	286	12	14	225	61	Porous lava rock zone
24E1	Virgil Schmoe	Vf 4,166	Dr	996	20		880	119	Lava rock and cinder zone
24E2	do.	Vf 4,163	Dr		5				
24P1	Haskins and Company	Vf 4,150	Dr	984	18	40	984	11	Broken burnt lava rock

data for representative wells in Klamath County. - Continued

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	78.05 77.91	4/ 2/48 7/19/49	T	Irr		145	3	Test pumped 1,200 gpm with drawdown of 5 ft.; see table 3 for log and table 5 for water-level measurements.
	68.78	4/22/52		S				See table 3 for log.
C	51±	8/ /48	T, 1,600	Irr		55	3	Yields 1,600 gpm; drawdown is 17 ft. after 1 minute pumping; water sample for field analysis taken 7/19/49; see table 3 for log.
C	53.20 52.83	7/19/49 8/22/49	T	Irr		325	75	Test pumped at 2,000 gpm with 26 ft. of drawdown after 4 hours; chemical analysis of water from dipped sample; see table 3 for log and table 5 for water-level measurements.
C	50.22	7/19/49	P	N		900	90	
C	37.67	do.	T	Irr		75	7	Test pumped 2,100 gpm with 42 ft. of drawdown; see table 3 for log.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11½ E.- Continued								
25E1	Richard Hoeffler	Vf 4,149	Dr	276			194	82	Lava rock
26H1	Cliff Sewald	Vf 4,162	Dr	191	20	20	183	8	Broken lava rock
29B1	L. M. Hankins	Vf 4,206	Dr		16				
29J1	Guy Barton	S 4,200	Dr	136	16	60	100	36	Porous lava rock
30M1	L. M. Hankins	Vf 4,215	Dr	281	16		223	22	Broken lava rock and cinders
30Q1	W. L. Whytall	Vf 4,217	Dr	175	14	120	157	18	do.
30Q2	do.	Vf 4,222	Dr	165			115	50	Cinders

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	33.80	7/19/49	T, 1,600	Irr				Driller reports 194 ft. of "chalk" over aquifer.
C	47.02	7/18/49	T	Irr		50	4	Yields 3,000 gpm with 7 ft. of drawdown; see table 3 for log.
	110	4/23/52	T	Irr				Water level taken by air gauge.
Un	94	9/ /49	T	Irr		75	10	Test pumped 1,450 gpm with 4 ft. of drawdown; water sample taken 5/21/48 while drilling was in process.
Un	94.42	4/23/52	T	Irr				Clay and soil to 85 ft. depth over lava rock.
Un	103.43	4/ 2/48	T, 1,100	Irr		60	10	Yields 950 gpm; see table 3 for log; see table 4 for chemical analysis, and table 5 for water-level measurements.
Un	110±	1946		N				Abandoned because of trouble in drilling; believed to be on fault zone; see table 3 for log.

Table 1.- Hydrologic

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 38 S., R. 11½ E.- Continued								
30E1	W. L. Whytall	Vf 4,190	Dr	145	12		123	22	Cinders
31E1	E. Metler	Vf 4,189	Dg	15	5		5	10	Sand
32G1	L. L. Porterfield	Vf 4,185	Dr	197	16	64	130	67	Cinders
33F1	Bud Lee	S 4,210	Dr	96	6				Basalt
33L1	Guy Barton	S 4,230	Dr	200+	16				do.
34D1	V. E. Grise	S 4,135	Dr	57	10				do.
34G1	W. L. Bell	Vf 4,121	Dr	230	6	40			Sedimentary rocks

data for representative wells in Klamath County. - Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Un	85±	1933	T, 1,000	Irr				Yields 875 gpm.
P	8	1945	J	D		95	5	Owner reports a 4-in. silty clay layer at depth of 3 ft.
C	72.20	4/ 2/48	T, 2,000	S, Irr				Yields 1,500 gpm with 8 ft. of drawdown; see table 3 for log and table 5 for water-level measurements; drainage water recharged into well, 1952.
	66±	1946	J	D,S Irr		55	4	Yields 100 gpm; water sprinkled on small field.
	117.80	11/19/49		Irr		60	4	Test pumped 1,400 gpm with drawdown of 1 foot; to be equipped with turbine pump.
	22.22	do.	J	D,S, Irr		75	4	Supplies irrigation water for sprinkling small field.
	8±	1938	J	D,S		60	3	

Unpublished records subject to revision

Table 1.- Hydrologic

Well number (1)	Owner or occupant of property (2)	Topography and approximate altitude (feet above sea level) (3)	Type of well (4)	Depth of well (feet) (5)	Diameter of well (inches) (6)	Depth of casing (feet) (7)	Water-bearing zone or: Depth to top (feet) (8)	Water-bearing zone or: Thickness (feet) (9)	Water-bearing zone or: Character of material (10)
	T. 38 S., R. 11½ E.- Continued								
34P1	L. J. Horton	S 4,121	Dr	55.1	16		18	39	Broken lava rock and cinder zone
35E1	L. Toffell	Vf 4,128	Dr		6				
36D1	R. Hoeffler	Vf 4,158	Dr	470	18				
36H1	F. Rogers	Vf 4,132	Dr	252	6	80	224	28	Lava rock
	T. 39 S., R. 11 E.								
3M1	J. Haseltine	S 4,165	Dr	400	6	100	360	40	Lava rock
5M1	W. Haley	Vf 4,145	Dr	316	6	68	288	28	Broken lava rock and red cinders

data for representative wells in Klamath County. - Continued

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Un	8.55	7/18/49	T	Irr		50	4	Test pumped at 3,000 gpm.
	14.82	11/20/49	J	D,S		60	3	
C	45.66	8/22/49		Irr		225	9	Drilled for oil prospect; 30-in. hole to 1,580 ft.; now cleaned out to 470 foot depth; reported yield 1,500 gpm; chemical tests made on a dipped sample.
C	22±	1949	J	D,S		105	14	Driller reports sedimentary materials over aquifer; iron in water stains fixtures.
C	55	1949	T	D,S		60	15	Yields 20 gpm with drawdown of 15 ft.; driller reports "chalk" to aquifer.
C	36	1943	J	D		85	4	See table 3 for log.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or: Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 39 S., R. 11 E.- Continued								
5Q1	W. Oberheide	Vf 4,145	Dr	157	6	153	155	2	Red cinders
6D1	R. House	Vf 4,130	Dr	96	6	71	92	4	do.
6G1	Frank Toefell	Vf 4,148	Dr	247	6	48	230	17	Gravel
7H1	L. M. Hankins	Vf 4,117	Dr	125	6				
8D1	W. McCartye	Vf 4,150	Dr	110	6	8			Sedimentary rock
8J1	W. H. Casebeer	S 4,138	Dr	460	8		450	10	Lava rock
9J1	L. Schooler	Vf 4,121	Dr	112.3	6	40	110	2	Sand seam in yellow chalk
9R1	J. Davidson	Vf 4,117	Dr	283	6	40	276	7	Brown lava rock

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	36.54	11/16/49	J	D,S		85	3	See table 3 for log.
C	20±	1943	J	D,S		150	10	Iron in water stains fixtures; see table 3 for log.
P	12±	4/ /40	J	D,S		85	10	Driller reports 230 ft. of "chalk" over aquifer.
	5.10	11/21/49		D,S		45	3	Chemical analysis from dipped sample.
P	25	7/ /49	P	S		75	5	Owner reports that the water increases in hardness after continued pumping.
C	30.10	11/22/49		S		65	13	Iron in water stains fixtures; driller reports "chalk" down to aquifer.
	10.00	do.	J	D		60	3	Driller reports static level of water was approximately 9 ft. below surface in 1939.
C	9	1943	J	D				Driller encountered sedimentary rocks for entire depth to aquifer.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 39 S., R. 11 E.- Continued								
10A1	J. Brown	Vf 4,123	Dr		6				
10L1	R. Wagner	Vf 4,133	Dr	211	6	40	208	3	Broken lava rock
10M1	Bonanza School	S 4,140	Dr	90	8	40	88	2	Gray cinders
10N1	Bob Hartley	Vf 4,110	Dr	166	6	40	163	3	Brown lava rock
10N2	Bill Hartley	Vf 4,111	Dr	176	6	40	167	9	do.
10P1	W. Puddy	Vf 4,115	Dr	75	6				Broken lava rock
10P2	Frank Markham	Vf 4,116	Dr	31	6	25	30	1	Cinders
11L1	H. W. Hodges	Vf 4,115	Dr		6				
14E1	Donald Ralph	Vf 4,120	Dr	150	6				

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water ($^{\circ}F.$)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	9.16	4/16/50	J	D		76	4	
C	4.68	11/23/49	J	D		55	3	Driller reports 208 ft. of chalk over aquifer.
Un	31±	1948	C	D		60	3	See table 3 for log.
C	2	11/ /49	J	D		60	2	Yields 300 gpm with 1.5 ft. of drawdown; see table 3 for log.
C	3	do.	J	D				Driller reports materials penetrated almost identical with those in well 39/11-10N1.
Un	6.7	11/23/49		D		55	3	
Un	8	1941	J	D		60	3	Driller reports "broken lava rock" to aquifer; well yields 300 gpm.
	3.7	4/16/50	P	S		68	3	
Un	9.58	do.	P	D,S		64		

Unpublished records subject to revision

Table 1.- Hydrologic

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character of material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 39 S., R. 11 E.- Continued								
14D1	J. E. Whitlatch	Vf 4,130	Dr	400	6				
	T. 39 S., R. 11½ E.								
5B1	L. L. Porterfield	Vf 4,183	Dr	270	16		98	172	Lava rock
5D1	do.	Vf 4,205	Dr	260	16	21	150	110	Basalt
6B1	K. Metler	Vf 4,190	Dr	455	16	170	380	75	Lava rock and cinders
10B2	L. J. Horton	S 4,115	Dr	50.9	16	30	14	47	Broken lava rock and cinders

data for representative wells in

GW occurrence zones	Water level: Feet below land-surface datum	Water level: Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	17	1946	J	D		120	6	
C	72	4/ /52		Irr				Unfinished, used also for drainage - recharged into well.
C	93.67	11/19/49	T	Irr				Yielded 1,800 gpm with drawdown of 25 ft. after 4 hours; see table 3 for log; drainage recharged into well, 1952.
C	78.68	do.		Irr				Test pumped at 1,480 gpm with drawdown of 26 ft.; drill tailings show diatomaceous ash overlies aquifer.
C	Flowing	11/22/49	T	Irr		55	6	Flow on surface estimated at 400 gpm when first drilled; gradually dropped off to about 50 gpm; ceases flow during summer season; yields 2,500 gpm with 5 ft. of drawdown; see table 3 for log and table 4 for chemical analysis.

Well number	Owner or occupant of property	Topography and approximate altitude (feet above sea level)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone or		
							Depth to top (feet)	Thickness (feet)	Character material
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	T. 39 S., R. 11½ E.- Continued								
11B1	L. J. Horton	Vf 4,109	Dr	616	6	60			Black sand (?)
12H1	A. E. Burgdorf	Vf 4,128	Dr	217	6	42	177	40	Broken blue lava rock
14H1	Virgil Schmoe	Vf 4,107	Dr	2,510	12				Basalt (?)
22J1	P. T. Hatchett	S 4,205	Dr	660+	12				Lava rock

zones	Water level							
GW occurrence	Feet below land-surface datum	Date	Type of pump and yield (gallons per minute-gpm)	Use of well	Temperature of water (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
C	Flowing	4/ 2/48		S		25	10	Flow estimated at 80 gpm; driller states flow reduced from what it was in 9/46; water gives off odor of hydrogen sulfide gas.
C	20±	1940	J	D,S		50	4	See table 3 for log.
C	Flowing	7/ /48		N				Originally drilled as oil test well; reported to flow 50 gpm; log not available but driller states that it was 915 ft. to basalt; may have been drilled in fault zone.
C	85	11/20/49	T	Irr				Well unfinished when visited. See table 3 for log.

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Table 2.—Hydrologic data for representative springs

Topography: S, slope to valley; Ts, talus slope; Vf, valley floor.
Yield: (e) estimated; (r) reported.
Use of water: D, somestic; Irr, irrigation; S, stock.
Chemical character: Hardness expressed as $CaCO_3$ (determined by field methods of

Location	Owner or occupant of property	Name	Topography and approximate altitude (feet above sea level)	Water-bearing material
(1)	(2)	(3)	(4)	(5)
37/9-6E1	Klamath County	Barclay Springs	Ts 4,145	Basalt talus
37/9-7F1	C. C. Horn		Ts 4,160	do.
37/9-7K1	Tom Brown	Humming-bird Springs	Ts 4,160	do.
37/9-11K1	C. L. Janssen	Janssen Springs	S 4,820	Basalt
37/9-22E1	J. Whiteline	Whiteline Springs	S 4,500	Permeable layer in Tertiary sedimentary deposits
37/10-6L1	A. R. Devincenzi	Edgewood Springs	S 4,500	Basalt
38/11½-15C1	Orrin Hankins		S 4,200	Basalt overlain by impervious clay

of soap analysis)

Occurrence	Yield: Gallons per minute	Yield: Date	Use	Temperature (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
At foot of fault scarp	500(e) 763(r)	11/24/49 8/ 8/10	S	54	50	4	Concrete catchment tank west edge US Highway 97.
do.	200(e)	11/24/49	D,S, Irr	49	50	3	100-foot rocked-up tunnel into talus; water ditched to irrigate approximately one acre of land.
do.	100(e)	do.	D,S	49	50	3	Covered and piped to storage tank.
Between basalt flows	500(e)	11/17/49	S	50	40	3	Yield varies with precipitation.
Outcrop of aquifer	500(r)	do.	D,S	50	45	4	Reported to fluctuate with a lag of about one year behind precipitation.
Between basalt flows	2,500(e)	11/18/49	D,S	52	40	3	
May be on trace of fault		11/13/49	D	51	50	4	See also data on well 38/11½-15D2

Unpublished records subject to revision

Table 2.--Hydrologic data for representative springs

Location	Owner or occupant of property	Name	Topography and approximate altitude (feet above sea level)	Water-bearing material
(1)	(2)	(3)	(4)	(5)
39/10-14M1	Leo Donovan	Olene Hot Springs	S 4,150	Tertiary sedimentary deposits
39/11-10Q1	Cecil Hunt	Bonanza Springs	Vf 4,107	Thin covering of valley alluvium
39/11½-10B1	L. J. Horton	Shook Springs	S 4,110	Vesicular basalt

Occurrence	Yield: Gallons per minute	Yield: Date	Use	Temperature (°F.)	Total hardness as $CaCO_3$ (ppm)	Chloride (Cl) (ppm)	Remarks
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
On trace of major fault		11/24/49	D	125±	115	38	Several orifices on south bank of Lost River steam during winter months; all orifices located on same fault trace.
On trace of intersecting fault zones in underlying bedrock	8,980 to 9,870(r)	1949	D,S	59			Includes several orifices on north bank of Lost River; discharge of all orifices included in 8,980 to 9,870 gpm flow reported by owner; see table 4 for chemical analysis.
Between basalt	1,122	11/20/49	S, Irr	55	50	3	Springs consist of over 100 orifices which feed into a reservoir; see also data on well 39/11½-10B2.

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 (page 125 follows)

Table 3.—Materials penetrated by representative wells
/Tentative designations by J. D. Meyers/

37/9-4B1. R. D. Dehlinger. In Anderson Creek valley near the Klamath Indian Reservation. Altitude about 4,500 feet. Drilled by W. Hartley and R. Hartley, 1949

Materials	Thickness (feet)	Depth (feet)
Sedimentary beds:		
"Chalk" (diatomite or volcanic ash)	158	158
Sandstone and boulders	54	212
Lower lava rocks:		
Cinders, red	39	251
Rock, gray, and cinders	65	316
Lava, porous, broken; water bearing	34	350
Basalt, hard	3	353

37/9-36H1. Jack Marshall. Near northwest edge of Swan Lake Valley. Altitude about 4,220 feet. Drilled by K. Hartley, 1949

Alluvium, undifferentiated:		
Soil	4	4
Clay, yellow	19	23
Clay, yellow, and small boulders	2	25
Clay, yellow	10	35
Sedimentary beds:		
Sand, black	Trace	35
Shale, blue	23	58
Sandstone	6	64
Clay, blue, with sandstone streaks	48	112
Sandstone, yellow	4	116
Shale, blue	74	190
Clay, sandy, brown	5	195
Sand and shale layers, blue	22	217
Shale, blue	5	222
Sandstone, blue	24	246
Lower lava rocks:		
Lava, porous; water bearing	4	250

Table 3.- Materials penetrated by representative wells - Continued

37/10-19H1. H. D. Whiteline. At northwest edge of Swan Lake Valley. Altitude about 4,205 feet. Drilled by C. Coleman, 1946

Materials	Thickness (feet)	Depth (feet)
Sedimentary beds:		
"Chalk" (diatomite or volcanic ash)	24	24
Sand, black, layered with "gravels" (some water).	91	115
Clay, white	30	145
Sandstone, black, and "gravel" water bearing . .	10	155

37/10-29K2. A. R. Devincenzi. In northwest part of Swan Lake Valley. Altitude about 4,185 feet. Drilled in 1949

Alluvium undifferentiated:		
"Chalk," white, green, and red (diatomite and/ or volcanic ash)	135	135
Gravel, water bearing	20	155
Sand, black	3	158
"Chalk rock"	642	800

37/10-30B1. Fred Coleman. Near northwest corner of Swan Lake Valley. Altitude about 4,205 feet. Drilled by K. Hartley, 1949

Soil, sandy, brown	5	5
Sedimentary beds:		
Sandstone and "gravel"	28	32
Cinders, black, and "gravel," water bearing	66	98
Lower lava rocks or interflow (?):		
Basalt, hard	2	100

Unpublished records
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Table 3.- Materials penetrated by representative wells.- Continued

37/11½-24H1. S. K. Hartzler. Near northeast edge of Yonna Valley. Altitude about 4,325 feet. Drilled by C. M. Vochatzer, 1949

Materials	Thickness (feet)	Depth (feet)
Sedimentary beds with basalt interflow (?):		
Sandstone, yellow	45	45
Shale, blue	70	115
Basalt, hard, black	25	140
Shale, blue	194	334
Lower lava rocks:		
Basalt, hard, black	8	342
Clay, soft, blue	11	353
Basalt, hard, black	87	440
Lava, porous, water bearing	10	450
Basalt, hard	37	487

38/10-9N3. Frank Riley. Near southwest edge of Swan Lake Valley. Altitude about 4,210 feet. Drilled by C. M. Vochatzer, 1949

Younger alluvial deposits:		
Soil	2	2
Clay	10	12
Older alluvial deposits (covered talus?):		
Lava rock	11	23
Shale	6	29
Lava boulders	36	65
Lava rock	6	71
Boulders	9	80
Upper lava rocks:		
Lava rock	5	85
Basalt	31	116
Lava rock, water bearing at 123 feet	15	131

Table 3.- Materials penetrated by representative wells.- Continued

38/10-13D1. L. M. Hankins. At northwest edge of Hopper Hill in Swan Lake Valley. Altitude about 4,190 feet. Drilled by K. Hartley, 1949

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil	3	3
Clay, yellow	28	31
Upper lava rocks:		
Lava rock, black, porous	45	76
Ash, black	11	87
Lava rock, porous	53	140
Basalt, hard, blue	40	180
Lava rock, porous	36	216
Cinders, red	5	221

Casing, 16-inch, set to 40 feet depth. Well is 16 inches in diameter to 143 feet and $12\frac{1}{2}$ inches below.

Unpublished records subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/10-25A1. G. C. Mitchell. Northern edge of Pine Flat. Altitude about 4,190 feet. Drilled by Wilson Brothers Drilling Co., 1949

Materials	Thickness (feet)	Depth (feet)
Soil, sandy, brown	5	5
Alluvium, undifferentiated:		
Sand and clay, brown	19	24
Sand, coarse, brown (some perched water)	4	28
Clay, blue	27	55
Clay with sand, brown	15	70
Sandstone and "shale," brown	12	82
Gravel and "cinders," 1/8- to 1/2-inch diameter (some water)	3	85
Sandstone, blue	2	87
Clay, blue, and sand	1	88
Clay, yellow	5	93
Gravel, colored, contains obsidian pebbles (some water)	3	96
Clay, tan	2	98
Gravel, colored, 1/8- to 1-inch diameter (some water)	3	101
Sand, coarse, colored	2	103
Clay, yellow	5	108
"Chalk" gray (diatomite or volcanic ash)	22	130
"Shale," blue, "semihard"	37	167
Clay, brown, "very sticky"	4	171
"Chalk," blue	27	198
Clay, rusty color	4	202
"Chalk," blue	6	208
"Shale," sandy, black	4	212
Clay, rusty color, "semihard"	38	250
Clay, gray	60	310
Clay, brown	4	314
"Shale," gray	2	316
Gravel, mixed colors	1	317
Sandstone, hard, mixed colors	6	323
Clay, brown	4	327
Sandstone, hard, mixed colors	2	329
Upper lava rocks:		
Lava, broken, and boulders	5	334
"Chalk," white (volcanic ash?)	4	338
Lava rock, hard, black	8	346
"Chalk," gray (volcanic ash?)	8	354

Table 3.- Materials penetrated by representative wells.- Continued

38/10-25A1.- Continued

Materials	Thickness (feet)	Depth (feet)
Upper lava rocks.- Continued:		
Lava rock	6	360
"Chalk," green (volcanic ash?)	29	389
Lava rock	14	403
"Chalk," gray (volcanic ash?)	10	413
Shale, black (volcanic ash?)	5	418
"Chalk," green and "rock shells"	11	429
Lava rock, hard, black	56	485
Basalt	3	488
Rock and cinders, red; water bearing	12	500
Lava rock, water bearing	20	520
Lava boulders and cinders, water bearing	4	524

Well is 14 inches in diameter to 329 feet and 12 inches below 329 feet.

Unpublished records
subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/10-26C1. Dave Liskey. Near southwest edge of Swan Lake Valley. Altitude about 4,220 feet. Drilled by K. Hartley, 1949

Materials	Thickness (feet)	Depth (feet)
Alluvium, undifferentiated:		
Soil	2	2
Clay, yellow	3	5
Sandstone, brown	5	10
Clay, yellow	9	19
Shale, blue	11	30
Clay, yellow	35	65
Sandstone, yellow	35	100
Sandstone, yellow, and clay, red, hard	50	150
Upper lava rocks:		
Lava rock, porous, black	25	175
Clay, red, and sandstone	23	198
Lava rock, porous, black (water bearing)	199	397
Cinders, red	4	401
Lava rock, porous, black, water bearing	27	428
Basalt, hard, blue	14	442
Lava rock, porous, black, water bearing	45	487
Basalt, hard	16	503
Lava rock and cinders, red	8	511
Lava rock, porous, black, water bearing	13	524
Basalt, hard	13	537
Lava rock, porous, black, water bearing	22	559
Sand, coarse, black	1	560
Lava rock, porous, black, water bearing	21	581
Basalt, hard, blue	1	582

Casing, 16-inch, set to 16 feet. Well is 16 inches in diameter to 200 feet, 12 inches to 560 feet, and 8 inches below.

Table 3.- Materials penetrated by representative wells.- Continued

38/11-5P1. Leonard Ritter. Near east side of Yonna Valley. Altitude about 4,250 feet. Drilled by F. Hilton, 1948

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil, sandy	4	4
Clay	26	30
Sedimentary beds (?):		
Shale, blue	35	65
Sandstone	2	67
Shale, blue (some water at 128 feet depth)	111	178
Sandstone, black	4	182
Lower lava rocks:		
Lava rock, rust-coated, "gravel in cracks in rock" (water bearing)	18	200

38/11-6N1. J. P. Colahan. In east-central part of Yonna Valley. Altitude about 4,200 feet. Drilled by F. Hilton, 1947

Soil, sandy	8	8
Sedimentary beds:		
"Chalk" (diatomite and/or volcanic ash)	87	95
Sand, fine, black, some water	1	96
"Chalk" (diatomite or volcanic ash)	45	141
Sandstone, brown	12	153
"Chalk" (Diatomite or volcanic ash)	57	210
Lower lava rocks (?):		
Rock, lava, hard, red	75	285
Shale, brown	20	305
Sand, brown, some water	5	310
Rock and cinders, water bearing	15	325

Unpublished records subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/11-7C1. Christine Williams. In north-central part of Yonna Valley. Altitude about 4,200 feet. Drilled by K. Hartley, 1949

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Sand	31	31
"Shale," blue	3	34
Sand	5	39
Sedimentary beds (?):		
"Shale," blue	106	145
Sand, black	5	150
"Shale," blue	32	182
"Shale," gray, hard, with blue shale interbedded	28	210
"Shale," blue	82	292
Lower lava rocks (?):		
Lava rock, black and red	54	346
Lava rock, black	29	375
Cinders, red	5	380
"Basalt," hard	18	398
Cinders, red, and rock, red	20	418
Lava rock, hard, red	37	455
Rock, porous, red, and cinders	20	475
Rock, hard, red	11	486
Rock, black	2	488
Cinders, red	14	502
Lava rock, hard, red	5	507
Lava rock, hard, brown	10	517
"Basalt," hard, green	7	524
"Sandstone," red, and sand, brown (volcanic ash?)	43	567
Lava, black, broken, water bearing	19	586

Well is 18 inches in diameter to 380 feet and 12½ inches below 380 feet.

Table 3.- Materials penetrated by representative wells.-Continued

38/11-7M1. Louis Tofel, Jr. North-central part of Yonna Valley. Altitude about 4,205 feet. Drilled by owner, 1948

Materials	Thickness (feet)	Depth (feet)
Sand	1	1
Older alluvial deposits:		
Sandstone	28	29
"Chalk," yellow (diatomite or volcanic ash)	66	95
Gravel, some water	2	97
Upper lava rock:		
Rock (lava rock?)	40	137
Lava rock, broken, red, some water	92	229
Rock (lava rock?)	8	237
Clay, gray	5	242
Cinders, red, gray; water bearing	18	260

38/11-31R2. Fred Rueck. Near southeast edge of Yonna Valley. Altitude about 4,160 feet. Drilled by W. Hartley, 1949

Soil	2	2
Older alluvial deposits:		
Sandstone, brown	18	20
"Chalk," green (volcanic ash)	67	87
"Shale," yellow, with seams of sandstone (some water)	77	164
Sandstone, dark green	10	174
Upper lava rocks:		
Lava rock, hard, blue	36	210
Lava rock, broken, water bearing	1	211

38/11½-11H1. Jack C. Bradley. In north-central part of Yonna Valley. Altitude about 4,160 feet. Drilled by F. Hilton, 1948

Older alluvial deposits:		
Soil, sandy	7	7
Clay, brown, "hardpan"	½	7½
"Shale," blue	42½	50
Sandstone, brown	2	52
"Shale," blue	142	194
Sedimentary beds (?):		
Sandstone, black	20	214
Lower lava rocks:		
Lava rock, porous, broken, black, water bearing	10	224

Unpublished records subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-12M1. Frank Challis. In north-central part of Yonna Valley. Altitude about 4,155 feet. Drilled by G. Hartley, 1942

Materials	Thickness (feet)	Depth (feet)
Older alluvial deposits:		
Soil, sandy	10	10
"Chalk," blue (volcanic ash?)	60	70
Gravel, and fine sand (some water)	3	73
"Chalk," blue (volcanic ash?)	227	300
Gravel, coarse	8	308
"Chalk," blue (volcanic ash?)	72	380
Sandstone, yellow	1	381
"Chalk" (diatomite or volcanic ash)	19	400
Upper lava rock (?):		
Lava rock, hard	1	401
Lava rock, porous, blocky, water bearing	24	425

38/11½-12M2. Frank Challis. In north-central part of Yonna Valley. Altitude about 4,160 feet. Drilled by Stuart, 1942

Older alluvial deposits:		
"Chalk" (diatomite or volcanic ash)	140	140
Upper lava rocks:		
Cinders	8	148
Lava rock, porous, red, water bearing	2	150

38/11½-13G1. R. M. Robertson. In north-central part of Yonna Valley. Altitude about 4,160 feet. Drilled by W. Hartley and R. Hartley, 1948

Older alluvial deposits:		
"Chalk" (diatomite or volcanic ash)	128	128
"Shale" and ash, black	33	161
Upper lava rocks:		
Lava rocks and cinders, broken, red, water bearing	22	183

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-13P1.- William Konig. In north-central part of Yonna Valley. Altitude about 4,155 feet. Drilled by F. Hilton, 1938

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil, sandy	6	6
Older alluvial deposits (?):		
"Chalk" (diatomite or volcanic ash)	54	60
Sand with some water	½	60½
"Chalk" (diatomite or volcanic ash)	189½	250
Sand, black, fine, with some water	2	252
"Chalk" (diatomite or volcanic ash)	216	468
Lower lava rocks:		
Lava rock and cinders	2	470
Cinders, round	5	475

38/11½-15R1. L. M. Hankins. At west edge of Yonna Valley. Altitude about 4,200 feet. Drilled by C. M. Vochatzer, 1948

Soil	2	2
Older alluvial deposits:		
Sand	4	6
Clay	32	38
Uncorrelated:		
Rock	12	50
Shale (a little water)	2	52
Sand	2	54
Shale	191	245
Rock, black	6	251
Shale	21	272
Rock	16	288
Shale	10	298
Rock	20	318
Shale	10	328
Rock	5	333
Shale	5	338
Rock	5	343
Shale	19	362
Lower lava rock:		
Lava rock, water bearing	70	432
Cinders, red, water bearing	15	447
Cinders and brown clay	7	454
Lava rock and cinders, water bearing	41	495

Unpublished records subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-22G1. Cliff Sewald. At west edge of Yonna Valley. Altitude about 4,200 feet. Drilled by F. Hilton, 1938

Materials	Thickness (feet)	Depth (feet)
Soils	7	7
Sedimentary beds:		
Sandstone, brown with clay streaks	8	15
"Chalk" (diatomite or volcanic ash)	180	195
Sandstone, broken, brown	5	200
"Chalk" (diatomite or volcanic ash)	45	245
Sand, black, fine (a little water)	10	255
"Chalk" (diatomite or volcanic ash)	20	275

38/11½-23F1. Cliff Sewald. At west edge of Yonna Valley. Altitude about 4,170 feet. Drilled by F. Hilton, 1946

Top soil	1	1
Sedimentary beds:		
Sandstone and clay seams	13	14
"Chalk" (diatomite or volcanic ash)	31	45
Sand, black, some water	1	46
"Chalk" (diatomite or volcanic ash)	154	200
Sand and "chalk" (a little water)	25	225
Lower lava rocks (?):		
Lava rock, porous, black, water bearing	30	255
Sand, black, fine, some water	1	256
Lava rock, porous, black, water bearing	14	270
Sand, black, fine, some water	2	272
Lava rock, porous, black, water bearing	13	285
Sand, black, fine	1	286

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-24E1. Virgil Schmoe. Near center of Yonna Valley. Altitude about 4,165 feet. Drilled by F. Hilton, 1949

Materials	Thickness (feet)	Depth (feet)
Alluvium, undifferentiated:		
Soil, sandy	2	2
Gravel, cemented	2	4
Clay, brown	31	35
Sedimentary beds:		
Shale, green	20	55
Sand	1	56
Shale, blue	157	213
Sand, black	3	216
Shale, green	478	694
Sandstone, green	2	696
Shale, green	3	699
Sandstone, green	2	701
Shale, green	64	765
Sandstone, black	18	783
Shale, green	14	797
Sand	3	800
Shale, sandy	57	857
Lower lava rocks:		
Lava rock, black	20	877
Cinders, red	3	880
Lava rocks, black	104	984
Lava rocks, broken, and yellow cinders	12	996

38/11½-24P1. Haskins and Company. Near center of Yonna Valley. Altitude about 4,150 feet. Drilled by W. Hartley, 1949

Materials	Thickness (feet)	Depth (feet)
Sedimentary beds (?):		
"Chalk" (diatomite?)	487	487
Sandstone and shale	275	762
Lower lava rocks:		
Lava rock	67	829
Sandstone and shale	19	848
Lava rock	125	973
Lava rock, broken, "burnt" looking, water bearing	11	984

Unpublished records subject to revision

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-26H1. Cliff Sewald. Center of Yonna Valley. Altitude 4,160 feet. Drilled by F. Hilton and K. Hartley, 1948

Materials	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy	15	15
Lower lava rocks (?):		
Boulders, hard, and cinders, loose	125	140
Lava rock, black	17	157
Boulders, loose, and cinders	8	165
Cinders	10	175

38/11½-30Q2. W. L. Whytall. At north side of Pine Flat. Altitude about 4,220 feet. Drilled by F. Hilton, 1947

Alluvium undifferentiated:		
Soil, and sand	35	35
Upper lava rocks:		
Lava rock, bouldery	20	55
Clay, yellow	10	65
Lava rock, porous	45	110
Clay, yellow	5	115
Lava rock, porous	10	125
Cinders and lava rock, crumbly	40	165

Casing, 14-inch, set to 120 feet, perforated 100 to 120 feet.

38/11½-30R1. W. L. Whytall. At north side of Pine Flat. Altitude about 4,190 feet. Drilled by G. Hartley, 1933

Alluvium undifferentiated:		
Soil, sandy	33	33
Upper lava rocks:		
Lava rock, black	23	56
Clay	9	65
Lava rock, black	45	110
Clay	8	118
Lava rock, black	5	123
Cinders, broken	22	145

Table 3.- Materials penetrated by representative wells.- Continued

38/11½-32G1. L. L. Porterfield. Near center of Pine Flat. Altitude about 4,185 feet. Drilled by Pat McGinley, 1948

Materials	Thickness (feet)	Depth (feet)
Alluvium, undifferentiated:		
Soil, sandy	10	10
"Shale," blue	120	130
Upper lava rocks:		
Rock, gray, and cinders	65	195
Cinders, red, water bearing	2	197

38/11½-34P1. L. J. Horton. At southwest edge of Yonna Valley. Altitude about 4,120 feet. Drilled by F. Hilton, 1949

Materials	Thickness (feet)	Depth (feet)
Older alluvial deposits:		
Soil, black	3	3
Hardpan, brown	2	5
Clay, yellow	4	9
Shale, blue	9	18
Upper lava rocks:		
Lava rock, broken, with gravel mixture, water bearing	4	22
Basalt, boulder, water bearing	3	25
Lava rock, broken, and cinders, water bearing	28	53
Basalt boulder, water bearing	4	57

39/11-5N1. W. Haley. Near southeast edge of Yonna Valley. Altitude about 4,145 feet. Drilled by W. Hartley, 1943

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil	8	8
"Quicksand"	6	14
Older alluvial deposits (?):		
"Chalk," blue (volcanic ash?)	274	288
Upper lava rocks:		
Lava rock, broken, and red cinders, water bearing	28	316

Table 3.- Materials penetrated by representative wells.- Continued

39/11-5Q1. W. Oberheide. At southeast edge of Yonna Valley. Altitude about 4,145 feet. Drilled by W. Hartley, 1946

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil	6	6
"Quicksand"	8	14
Older alluvial deposits:		
Clay, yellow	103	117
Upper lava rocks:		
Lava rock, water bearing	38	155
Cinders, red, water bearing	2	157

39/11-6D1. R. House. Near southeast edge of Yonna Valley. Altitude about 4,130 feet. Drilled by W. Hartley, 1943

Younger alluvial deposits:		
Soil	8	8
Upper lava rocks:		
Lava rock, broken, and "chalk" seams	84	92
Cinders, dark red, water bearing	4	96

39/11-9J1. L. Schooler. In town of Bonanza. Altitude about 4,120 feet. Drilled by W. Hartley, 1939

Younger alluvial deposits:		
Soil	5	5
"Quicksand"	6	11
Older alluvial deposits:		
"Chalk," yellow (diatomite)	99	110
Sand, water bearing	2	112

39/11-10M1. Bonanza School. In Bonanza. Altitude about 4,140 feet. Drilled by W. Hartley, 1949

Alluvium, undifferentiated:		
Soil	8	8
Upper lava rocks:		
Lava rock, broken	80	88
Cinders, gray	2	90

Unpublished records
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Table 3.- Materials penetrated by representative wells.- Continued

39/11-10N1. Bob Hartley. In town of Bonanza. Altitude about 4,110 feet. Drilled by R. Hartley, 1946

Materials	Thickness (feet)	Depth (feet)
Younger alluvial deposits:		
Soil	8	8
"Quicksand"	7	15
Older alluvial deposits:		
"Chalk," yellow (diatomite or volcanic ash)	23	38
"Chalk," green (volcanic ash?)	122	160
"Sandstone," brown	3	163
Upper lava rocks:		
Lava rock, brown	3	166

39/11½-5D1. L. L. Porterfield. In south end of Pine Flat. Altitude about 4,205 feet. Drilled by P. McGinley, 1946

Younger alluvial deposits:		
"Dirt," black	19	19
Boulders	2	21
"Dirt" (a little water at 50 feet)	31	52
Upper lava rocks:		
"Basalt" rock	89	141
Sand (a little water)	9	150
"Basalt" rock, water bearing	110	260

39/11½-10B2. L. J. Horton. At southwest edge of Yonna Valley. Altitude about 4,115 feet. Drilled by F. Hilton, 1949

Alluvium, undifferentiated:		
Soil, black	3	3
Hardpan, yellow (clay)	11	14
Upper lava rocks:		
Lava rock, broken and yellow cinders	47	61

Casing perforated 0 to 30 feet.

Table 3.- Materials penetrated by representative wells.- Continued

39/11½-12H1. A. E. Burgdorf. In southern part of Yonna Valley. Altitude about 4,128 feet. Drilled by W. Hartley, 1930

Materials	Thickness (feet)	Depth (feet)
Alluvium, undifferentiated:		
"Chalk," yellow (diatomite or volcanic ash)	31	31
"Chalk," blue (volcanic ash?)	146	177
Upper lava rocks:		
Lava rock, broken, blue	40	217

Casing, 6-inch, set to 42 feet.

39/11½-22J1. P. T. Hatchet. In north part of Poe Valley. Altitude about 4,205 feet. Drilled by R. and W. Hartley, 1949

Younger alluvial deposits:		
Soil, sandy	12	12
Sedimentary beds:		
Shale, bluish green	382	394
"Basalt," hard (sil or interflow)	18	412
Shale, bluish green	90	502
Lower lava rock:		
Lava rock, broken (some water)	36	538
Basalt, hard	122	660
Drilling incomplete when well visited		

Unpublished records
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Table 4.- Chemical analyses

[Analyses by C. S. Howard and J. D. Hem

Number	Source	Date of collection	Temperature (°F.)	Dissolved solids	Silica (SiO_2)
37/10-30B1	Fred Coleman. Drilled irrigation well 98.6 feet deep. Water from coarse zone in lapilli tuff	11/19/49	45	158	51
38/11½-12M1	Frank Challis. Drilled irrigation well 425 feet deep. Water from fractured vesicular basalt	4/ 1/48	51	264	32
38/11½-30Q1	W. L. Whytall. Drilled irrigation well 175 feet deep. Water from fractured basalt and basalt flow breccia	11/20/49	61	161	47
39/11½-10B2	L. J. Horton. Drilled irrigation well 50.9 feet deep. Water from fractured basalt and flow breccia zone	11/22/49	55	141	48
39/11-10Q1	Bonanza Springs. Sampled at orifices on property of Cecil Hunt. Located on south edge of Lost River opposite the town of Bonanza. Outlet for the upriver regional ground water and some ground water from Yonna Valley	10/23/49	59	129	38
39/11-30	Lost River (Bonanza Springs?) water which comes from a large number of springs at F. J. Brown pumping plant (1904) f/	1904			22

a/ Total iron present in sample. b/ Percentage of all bases present, derived
0.02 part in solution. d/ When analyzed contained 0.03 part in solution.
report of irrigation and drainage investigations, 1904, U. S. Dept. of
g/ Reported as combined Fe_2O_3 and Al_2O_3. h/ Reported as carbonate.

of waters from wells and springs
of the Geological Survey, unless otherwise shown/

Parts per million (by weight)

Iron (Fe) a/	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Total hardness as ($CaCO_3$)	Hydrogen ion concentration (pH)	Percent sodium b/	Specific conductance (Micromhos at 25° C.)
0.03 c/	15	11	13		128	1.4	1.4	0.2	1.9	0.00	83	7.7	25	200
.04	38	21	21		229	16	6.2	.2	17	less than 0.10	182	7.5	20	409
.04 d/	14	8.8	20		124	2.9	6.6	.2	.4	.01	71	7.7	38	200
.02	11	9.4	14		108	2.1	2.4	.3	.9	.00	66	7.8	31	175
.22 e/	13	7.2	14		106	2.5	1.7	.2	.6	.01	62	7.9	33	165
5.2 g/	31.0	26.3	427	207	114.8 h/	8.9	3.18				185			

from reactive values in milligram equivalents. c/ When analyzed contained
e/ When analyzed contained 0.03 part in solution. f/ Kent, F. L. - Annual
Agriculture, Office of Experiment Stations, Bull. no. 158, p. 263, 1905.

Unpublished records subject to revision

(page 147 follows)

Table 5.- Measurements of depth to water in observation wells 1948-51

37/10-29K1. A. R. Devincenci. Measuring point, top of casing, 0.4 foot above land surface; altitude 4,187 feet (barometer)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1949		1951	
July 20	12.48	Apr. 4	12.55
Aug. 22	13.93	Sept. 6	14.90
Nov. 19	16.02	1952	
1950		Jan. 4	15.22
Apr. 14	13.81	Apr. 22	12.72
July 11	14.18	June 19	11.00

37/10-29K2. A. R. Devincenci. Measuring point, top of casing, 0.4 foot above land surface; altitude 4,186 feet (barometer)

1949		1951	
Nov. 19	28.41	Apr. 4	26.71
1950		Sept. 6	28.90
Apr. 14	27.03	1952	
July 11	27.95	Apr. 22	25.78
		June 19	25.54

Unpublished records
subject to revision

Table 5.- Measurements of depth to water, etc.- Continued

38/10-9N2. Frank Riley. Measuring point, top of casing even with land surface; altitude 4,190 feet (barometer)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1949		1951	
July 19	63.45*	Jan. 5	64.19
1950		12	64.29
Apr. 14	63.64	19	64.39
21	63.73	26	64.49
28	63.83	Feb. 2	64.49
May 5	63.85	9	64.59
12	63.90	16	64.59
19	63.95	23	64.66
26	63.89	Mar. 2	64.70
June 2	63.87	9	64.71
9	63.83	16	64.73
16	63.79	23	64.75
23	63.77	30	Well pumped
30	63.83	Apr. 4	66.94*
July 7	63.83	6	66.6
11	63.78*	13	66.7
14	63.67	20	66.9
21	63.67	27	67.1
28	63.68	May 4	64.4
Aug. 4	63.69	11	64.8
11	63.71	18	65.2
18	63.72	25	66.4
25	63.73	June 1	66.4
Sept. 1	63.73	8	66.1
8	63.72	15	66.0
15	63.71	22	65.8
22	63.70	29	65.88
29	63.69	July 6	65.7
Oct. 6	63.67	13	65.7
13	63.66	20	65.6
20	63.65	27	65.5
27	63.64	Sept. 6	64.75
Nov. 1	63.96*	Oct.	Deepened to 221 feet
3	63.92	1952	
10	63.93	Jan. 4	96.44
17	63.94	Apr. 22	94.99
24	63.94		
Dec. 1	63.95		
8	63.96		
15	63.97		
22	63.98		
29	64.09		

*Hand tape measurement; remaining figures were from float-gage tape.

Unpublished records subject to revision

Table 5.- Measurements of depth to water, etc.- Continued

38/10-9N3. Frank Riley. Measuring point, top of casing, 0.7 foot above land surface; altitude 4,211 feet (barometer)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1949		1951	
Nov. 19	111.24	Sept. 6	110.88
1950		1952	
Apr. 14	110.98	Jan. 4	111.05
July 11	111.03	Apr. 22	109.65
1951		June 9	109.5
Apr. 4	109.4		

38/10-15N1. Klamath County. Measuring point, top of casing, 0.9 foot above land surface; altitude 4,199 feet (barometer)

1949		1951	
July 18	19.28	Apr. 4	13.66
Aug. 22	19.48	Sept. 6	15.80
Nov. 17	20.60	1952	
1950		Apr. 22	11.10
July 11	17.10	June 19	12.69
Nov. 13	18.03		

38/11½-12M2. Frank Challis. Measuring point, top of casing at land surface; altitude 4,162 feet (barometer)

1949		1951	
Aug. 22	46.58	Apr. 4	46.80
1950		Sept. 6	46.90
Apr. 15	46.95	1952	
July 11	47.17	Apr. 22	45.70
Nov. 1	47.04	June 19	45.43

Unpublished records
subject to revision

Table 5.- Measurements of depth to water, etc.- Continued

38/11½-13G1. R. M. Robertson. Measuring point, top edge airline hole in pump base, 1.2 feet above land surface; altitude 4,160 feet (barometer)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1948		1951	
Apr. 11	46.45	Apr. 5	45.85
Aug. 6	46.31	Sept. 6	46.22
1949		1952	
Aug. 22	46.17	Jan. 4	46.56
1950		Apr. 22	45.18
Apr. 15	46.55	June 19	51.68
July 11	52.00*		
Nov. 1	46.39		

*Pump operating.

38/11½-13N1. William Konig. Measuring point, top of casing, 0.42 foot above land surface; altitude 4,155 feet (barometer)

1948		1951	
Apr. 2	22.97	Apr 4	22.15
1949		Sept. 6	24.66
July 18	25.26	1952	
Aug. 22	25.70	Jan. 4	23.99
1950		Apr. 22	20.60
Apr. 15	24.49	June 19	20.73
July 11	26.62		

38/11½-15R1. L. M. Hankins. Measuring point, top of casing, 0.9 foot above land surface; altitude 4,199 feet (barometer)

1948		1951	
Apr. 2	78.95	Apr. 4	78.60
July 18	78.81	Sept. 6	78.85
1950		1952	
Apr. 15	78.80	Apr. 22	77.88
July 11	83.69*	June 19	77.36

*Pump operating.

Unpublished records subject to revision

Table 5.- Measurements of depth to water, etc.- Continued

38/11½-24E1. Virgil Schmoe. Measuring point, top of casing, 1.2 feet above land surface; altitude 4,167 feet (barometer)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1949		1951	
July 19	54.40	Apr. 4	54.05
Aug. 22	54.03	Sept. 6	54.10
1950		1952	
Apr. 15	54.31	Apr. 22	53.17
July 11	54.42		

38/11½-30Q1. W. L. Whytall. Measuring point, top of casing, 0.7 foot above land surface; altitude 4,218 feet (barometer)

1948		1951	
Apr. 2	104.13	Apr. 4	104.50
1949		Sept. 6	107.25**
Nov. 19	105.54	1952	
1950		Jan. 4	105.50
Apr. 15	104.82	Apr. 22	103.55
July 11	106.31*	June 11	103.70

*Pump just shut off after 3 days in operation.
** Pump off 6 hours after 3 months continuous pumping.

38/11½-32G1. L. L. Porterfield. Measuring point, top of airline hole in pump base, 0.4 foot above land surface; altitude 4,185 feet (barometer)

1948		1951	
Apr. 2	73.35	Apr. 5	74.67
Aug. 6	74.87	Sept. 6	73.13**
1949		1952	
Aug. 22	84.13*	Jan. 4	75.57
1950		Apr. 22	Field drain water being recharged to well
Apr. 14	84.16*		
July 11	83.39	June 19	80.99*
Nov. 1	75.78		

*Pump operating.
**Some water draining into well.

Unpublished records subject to revision