Ground Water in the Alluvium of Kings River Valley Humboldt County, Nevada

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-L

Prepared in cooperation with the State of Nevada Department of Conservation and Natural Resources

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By C. P. ZONES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GROUND WATER IN THE ALLUVIUM OF KINGS RIVER VALLEY, HUMBOLDT COUNTY, NEVADA

By C. P. Zones

ABSTRACT

Kings River Valley is an intermontane valley in the Great Basin section of the Basin and Range physiographic province. The valley is drained by the Kings River, a tributary of the Quinn River, which forms the southern boundary of the valley. The climate is arid to semiarid, and precipitation on the floor of the valley is less than 5 inches annually.

The valley is bordered by mountain ranges composed principally of volcanic rocks of Miocene and Pliocene age. The mountains were uplifted by faulting and tilting. Material eroded from the uplands has filled the intermontane basin of the Kings River with at least 800 and possibly several thousand feet of alluvium. The alluvium is saturated nearly to the level of the valley floor, and the ground water in storage in the uppermost 100 feet of saturation amounts to several hundred thousand acre-feet.

The ground-water reservoir is recharged principally by streams that drain the bordering mountain ranges. Ground water moves from the areas of recharge toward the axis of the valley and southward. A small quantity of ground water is discharged by evaporation on the flood plain of the Quinn River, but under natural conditions most of the ground water is transpired by plants that send their roots either to the water table or to the capillary fringe above it. A small amount of ground water is discharged by springs. The average annual ground-water discharge under natural conditions is equal to the average annual recharge and is estimated to be about 15,000 acre-feet per year.

The chemical quality of the ground water in the northern and central parts of the valley is good, and the water is suitable for most uses. In contrast, the dissolved solids and the proportion of sodium to calcium and magnesium are greater in the southern part of the valley. Some of the water near the south end of the valley is of poor quality for irrigation.

Water from the Kings River and small perennial streams and springs has been used for many years for irrigation or domestic purposes. Only recently have large wells been drilled for irrigation. In 1958 the total annual pumpage from irrigation wells was about 17,000 acre-feet; in 1959 it was somewhat greater. In both years some of the pumped water returned to the ground-water reservoir by percolation through the overlying sediments.

It may not be economically feasible to intercept by wells and use for consumption, the approximate 15,000 acre-feet of ground water that is now being discharged by evapotranspiration. Furthermore, some ground-water movement

away from the irrigated areas is necessary to maintain a satisfactory salt balance.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The U.S. Geological Survey in cooperation with the Department of Conservation and Natural Resources, State of Nevada, is conducting a statewide study to evaluate the ground-water resources of Nevada. As part of the cooperative program, a valley-by-valley reconnaissance of ground-water conditions is being made in northwestern Nevada between lat 41° and 42° N., and long 118° and 120° W. This report presents the results of a study of one of the valleys—Kings River Valley—which is part of the larger project.

The purpose of this study is: (1) To determine the nature and extent of the aquifers, (2) to evaluate the occurrence and movement of ground water, including the sources of recharge and discharge, (3) to estimate the average annual recharge to the aquifers, (4) to estimate the quantity of ground water that can be developed perennially, and (5) to determine the chemical quality of the ground water and its suitability for irrigation and domestic use.

Fieldwork was done during parts of December 1958 and June, August, and October 1959. It consisted principally of inventorying the wells and springs, making aquifer tests, and mapping the area of vegetation that consumes ground water. In addition, a brief study was made of the physiographic features of the area and of the character of the water-bearing materials.

The investigation was under the supervision of O. J. Loeltz, district engineer for Nevada of the Ground Water Branch, U.S. Geological Survey. G. T. Malmberg assisted the writer in the field.

LOCATION AND EXTENT OF THE AREA

Kings River Valley is almost entirely in Humboldt County in northwestern Nevada, but a very small part of the area within the drainage basin extends north into Oregon (fig. 1). The valley trends approximately north. It is bordered by the Trout Creek Mountains on the east and by the Kings River Range on the west. The merging of the two mountain ranges delimits the north end of the valley and the Quinn River forms the south boundary.

The floor of Kings River Valley is about 25 miles long and averages 4 to 8 miles in width. The drainage area encompasses about 400 square miles.

One access to the valley is by a gravel road from Orovada, about 25 miles east of the valley. Entrance to the valley is through a gap in the Trout Creek Mountains. The valley is accessible also from the south by a dirt road that connects with State Highway 8A at Sod House.

Winnemucca, which has a population of 2,847 according to the 1950 census, is the nearest town. It is 44 miles south of Orovada and 45 miles southeast of Sod House. Winnemucca is served by both the Southern Pacific and the Western Pacific Railroads.

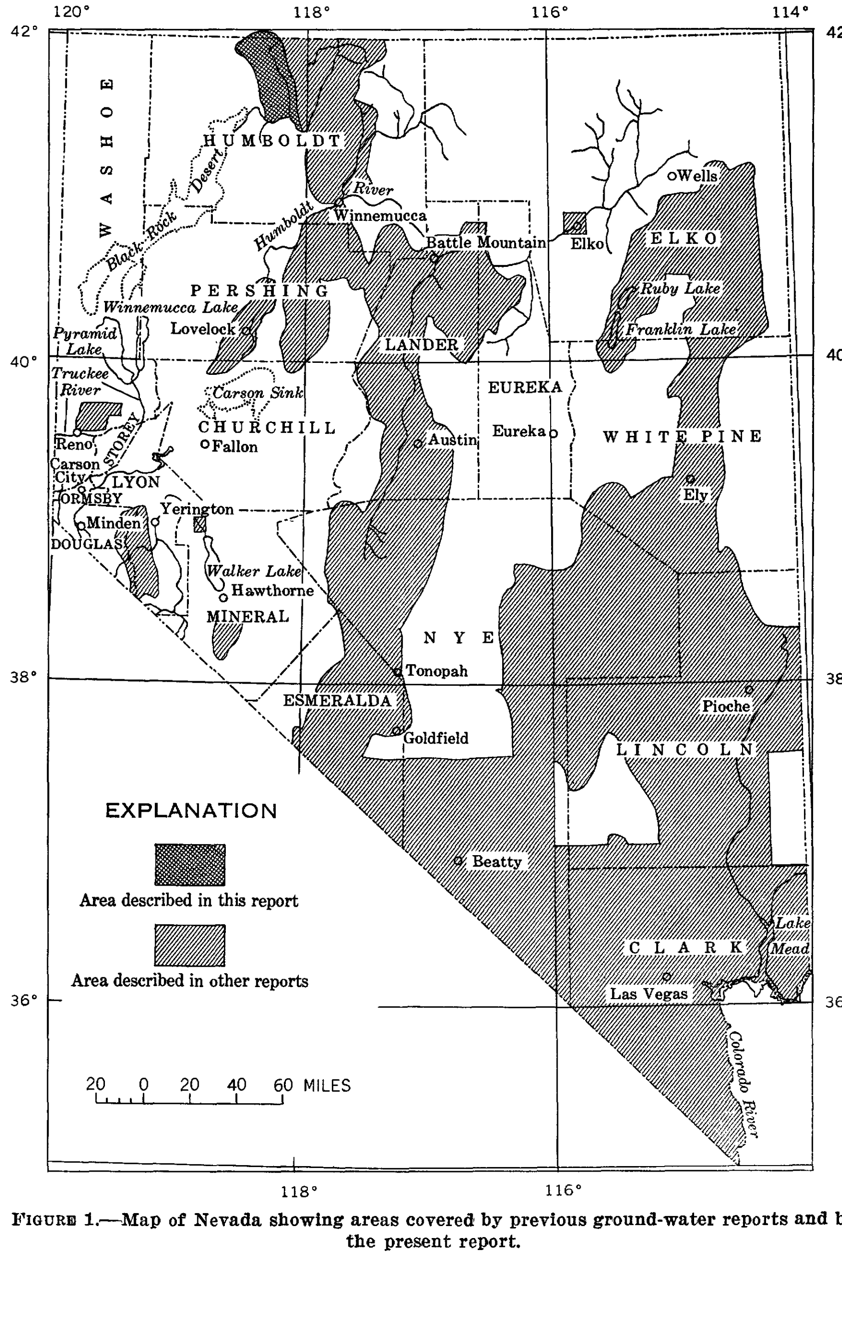

FIGURE 1.—Map of Nevada showing areas covered by previous ground-water reports and by the present report.

NUMBERING SYSTEM FOR WELLS AND SPRINGS

The number assigned to a well or spring in this report both identifies and locates the well or spring. The number is based on the Bureau of Land Management system of land division. A typical number consists of three units: the first is the township number north of the Mount Diablo base; The second, separated from the first by a slant, is the range number east of the Mount Diablo meridian; the third, separated by a dash, is the section number. This is followed by an uppercase letter to denote the quarter section in which the well or spring is located. The letters A, B, C, and D designate the northeast, northwest, southwest, and southeast quarter sections respectively. Finally, consecutive numbers show the order in which the well or spring was recorded in the quarter section. For example, the number 44/39–16A1 designates the first well recorded in the NE¼ sec. 16, T. 44 N., R. 39 E. Most of the wells in the valley are described in table 3 and are plotted on plate 1.

On plate 1, only that part of the number designating the quarter section is shown. The section number can be ascertained from the corresponding section number in T. 44 N., R. 32 E. Township and range numbers are shown on the edges of the figure.

GEOGRAPHIC FEATURES

LANDFORMS AND DRAINAGE

Kings River Valley is in the Great Basin section of the Basin and Range physiographic province. The Great Basin is an area of alternating mountain ranges and valleys which trend nearly north. The mountain ranges commonly are 50 to 70 miles long and 6 to 15 miles wide. The valleys have approximately the same dimensions. The crests of the mountain ranges are 3,000 to 5,000 feet above the valley floors and 7,000 to 10,000 feet above sea level. Typically, a range is a faulted and tilted block. One side of the block is a steep fault scarp; the other a more gently dipping slope.

The intermontane valleys are characteristically closed alluvium-filled basins, although some valleys are interconnected by drainage channels. Playas, or "dry lakes," are present in most of the valleys and receive runoff from the mountain ranges. Kings River Valley differs from the typical valley of the Great Basin in that it is not closed and has no playa. Runoff from the valley discharges into the Quinn River, which eventually flows onto the playas of the Black Rock Desert and evaporates (fig. 1).

Kings River Valley is the northern part of a much larger basin, the southern part of which is Desert Valley. The two valleys are separated by the Quinn River, which traverses the basin from east to west. The river enters and leaves the basin through a broad gap in each of the bordering mountain ranges.

MOUNTAINS

The northward-trending ranges bordering the east and west sides of Kings River Valley are fault-block mountains that merge at the north end of the valley. They consist mostly of Tertiary lava flows that dip gently eastward 10° to 15° because of faulting and tilting of the mountain blocks. Each range is low at the south end of the valley, and rises only about 1,000 feet above the valley floor. The altitudes of the crests increase toward the north to more than 8,500 feet above sea level, or more than 4,000 feet above the valley floor.

The Trout Creek Mountains, which border the east side of the valley, rise abruptly from the valley floor. In general, the crest of the range is 1 to 2 miles east of its western base, but at the north end the crest is more than twice that distance from its western base. The crest is not deeply notched and is progressively higher toward the north. Numerous streams have eroded V-shaped canyons and gullies on the west face of the Trout Creek Mountains. Many of the smaller gullies and interstream areas are covered with large volcanic rock fragments and blocks eroded from the mountains. These rubble strips are particularly numerous in the northern part of the range, where they cover large areas. Locally, the lava beds show well-developed columnar jointing and form vertical cliffs.

The east side of the Kings River Range bordering the west side of Kings River Valley presents a different type of topography. It is the dipslope of the mountain block and it is not as steep as the west side of the Trout Creek Mountains bordering the east side of the valley. Because the strike of the lava beds is parallel to the trend of the mountain range, erosion has produced a cuesta topography. Faulting parallel to the trend of the mountain range may have aided in the formation of this type of topography. The drainage pattern is rectangular.

The mountains that border the northern part of the valley consist principally of basic and intermediate volcanic rocks and older granitic rocks. These ranges are in a mature stage of dissection. The interstream divides generally are well rounded and the overall drainage pattern is dendritic.

PIEDMONT SLOPES AND VALLEY FLOOR

Piedmont slopes merge almost imperceptibly into the relatively flat floor of the valley. They consist of coalescing alluvial fans that have formed a continuous apron, ranging in width from less than one-half mile at the south end of the valley to about 2 miles at the north end.

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The gradients at the upper parts of the apron are steep, ranging from about 200 to 500 feet per mile. Streams descend the alluvial apron as numerous distributaries.

The perennial Kings River and several of its larger tributaries at the north end of the valley—Flat, China, Log Cabin, and House Creeks—have deposited large alluvial fans. In contrast, small ephemeral streams draining the southern part of the mountain ranges have deposited short steep fans.

The valley floor is the relatively flat area downslope from the alluvial fans. It is generally 4 to 8 miles wide, about 25 miles long, and has an area of approximately 180 square miles, or about 80 percent of the total area of alluvium. The gradient is southward and ranges from more than 30 feet per mile at the north end of the valley to almost 5 feet per mile at the south end.

Much of the surface of the valley floor in the southern part of the valley is coated with a white saline efflorescence as a result of the evaporation of water from the capillary zone. Numerous sand dunes are in the extreme southwestern part of the valley.

STREAMS

Most of the streams that drain the mountain ranges are ephemeral. Many of the smaller stream courses carry water only during and after storms; others have water in them only for a few months during late winter and spring. Several streams, however, are perennial in their upper reaches, although their flow may diminish to only a few tens of gallons per minute during dry years. The largest of the perennial streams is the Kings River. Although tributary to the Quinn River, the Kings River flows only as far as their junction during periods of high runoff. Normally, the Kings River flows only a few miles downstream from the bedrock-alluvium contact at the north end of the valley, because the water infiltrates into the alluvium.

Few estimates of the flow of the Kings River are available. In October 1949, the flow 4 miles below the bedrock-alluvium contact was estimated to be 1½ cfs (cubic feet per second). In January 1959, the flow 7 miles below the bedrock-alluvium contact was approximately 3 cfs; in October of the same year the stream was dry at that point but was flowing about 1½ cfs at the bedrock-alluvium contact. Both 1949 and 1959 were years of deficient precipitation, and consequently the flow during those years was below normal. No flow data are available for years of normal or above-average precipitation.

No perennial streams drain the mountains bordering the southern half of the valley. In October 1959 several of the larger streams tributary to the Kings River at the north end of the valley flowed at a rate estimated to range from 30 to 50 gpm (gallons per minute). At least six small streams that drain the steep western slope of the Trout Creek Mountains between Thacker Pass and a point 7 miles north of the pass are perennial also, and in October 1959 their flows were estimated to range from 20 to 75 gpm. These streams drain very small watersheds, but relatively permeable volcanic rocks in these watersheds absorb much of the precipitation and later discharge it into streams.

The Quinn River seldom carries an appreciable amount of water beyond Sod House, even during years of normal runoff. In November 1959 there was no flow near Sod House; at the extreme southwestern part of Kings River Valley, the Quinn River flowed about 10 gpm at the point where State Highway 8A crosses the river. The increase in flow probably was due to the contribution by ground-water underflow from Kings River and Desert Valleys.

The Quinn River, where it crosses the lower end of Kings River Valley, is incised to a depth of 10 to 15 feet, probably as a result of a lowering of base level during the desiccation of Lake Lahontan. (See p. L9.) The Kings River also is incised to about the same depth in the southern part of the Valley.

CLIMATE

Precipitation and temperature records are available for the U.S. Weather Bureau station at Quinn River crossing, 23 miles west of Sod House. The altitude of the station is 4,087 feet, which is comparable to the altitude of the floor of Kings River Valley. The records follow:

Normal monthly and annual precipitation at Quinn River crossing, Humboldt County, Nev.

[From records of U.S. Weather Bureau; length of record, 26 years through 1950]

Month	Precipitation (inches)	Month	Precipitation (inches)
January	0.94	August	0.20
February	.74	September	.34
March	.55	October	.43
April	.36	November	.38
May	.46	December	.66
June	.40	Annual	5.64
July	.18		

Normal monthly temperature at Quinn River crossing, Humboldt County, Nev.
[From records of U.S. Weather Bureau; length of record, 26 years through 1950]

Month	Temperature (°F)	Month	Temperature (°F)
January	25. 4	July	69. 6
February	31. 3	August	67. 2
March	40. 4	September	57. 6
April	46. 8	October	46. 6
May	54. 0	November	----------
June	61. 6	December	26. 9

The climate ranges from arid at the lower altitudes to semiarid in the mountains. Most of the precipitation occurs during the winter, largely in the form of snow. Ordinarily the snow on the valley floor melts in a few days, but at the higher altitudes it may remain several weeks or months. The summers are notably dry. Normal precipitation is only a small fraction of an inch during July and August, the driest months, and in some years there is no precipitation during these months. The evaporation, which is about 4 feet per year, far exceeds the precipitation.

July is the warmest month (normal temperature 69.6°F) ; January is the coldest (normal temperature 25.4°F). Daily fluctuations in temperature are large. The temperature range may be as great as 50°F during the summer, although a daily range of 30° to 40°F is more common. The daily range in temperature during the winter normally is 20° to 30°F.

CULTURAL FEATURES

There are no towns in the valley, and the only industries are stockraising, farming, and intermittent mining on a small scale. Much of the land is used for grazing cattle. The two long-established cattle ranches in the valley are dependent primarily on streams or springs for irrigating crops grown for cattle feed.

Farming on a large scale began in 1956. Since then, approximately 8,000 acres of land have been cleared for farming in the northern part of the valley. In November 1959, 5,000 acres was under cultivation, largely small grain, potatoes, and alfalfa and other legumes. About 25 pumped wells, having high to moderate yields, furnish most of the irrigation water that is used for farming. Most wells are pumped at rates of 1,000 to 2,000 gpm.

GEOLOGIC SKETCH

PREVIOUS GEOLOGIC INVESTIGATIONS

The geology of the area was mapped by C. R. Wilden (1961). The contact of the bedrock and alluvium and the distribution of the younger and older alluvium, as shown on plate 1, are taken from Wilden's map.

LATE TERTIARY AND QUATERNARY GEOLOGIC HISTORY

The geologic history, as it pertains to the evolution of the present landscape and the formation of the more economically important water-bearing rocks, began in the Miocene epoch. At that time, basalt and less basic volcanic rocks were extruded over a large part of northwestern Nevada. During late Miocene and Pliocene time, these volcanic rocks were faulted and tilted, and thus they outlined the present general shape of Kings River Valley. Alluviation of the basin began at this time. The character of the earlier sediments is not known, but the deposits may be similar to the lake sediments of late Miocene age that are exposed in the adjacent Quinn River valley, which include bedded tuff, shale, sandstone, and small lenses of conglomerate (Yates. 1942, p. 323–327).

Faulting continued through Pleistocene time and raised the mountains higher relative to the valley floor. The basin continued to fill and several hundred to several thousand feet of alluvium were deposited.

In late Pleistocene time, Lake Lahontan advanced and retreated several times, which resulted in the deposition of a veneer of lake sediments on the valley floor, the building of prominent gravel spits at the south end of each range bordering the valley, and the carving of shoreline features at higher elevations.

The time of formation of the Quinn River is not known. It is probably an antecedent stream, having been in existence before the mountain ranges were uplifted to their present altitude. Downcutting by the river through the gaps at the south ends of the ranges that border Kings River Valley probably kept pace with the uplifting of the mountains.

SEDIMENTS OF THE VALLEY FILL

The rocks of the valley fill consist of unconsolidated to moderately consolidated alluvial-fan material, lake sediments, stream-channel deposits, and dune sand.

Alluvial fans bordering the Trout Creek Mountains from the north end of the valley almost as far south as Thacker Pass and those bordering the Kings River Range to the west from the north end of the valley to about 6 miles south of Ninemile Ranch are composed of older alluvium of Quaternary age. Also the older alluvium occurs beneath the younger alluvium of Lake Lahontan and post Lake Lahontan age. In many places alluvium of Tertiary age probably underlies the older alluvium.

Characteristically, the older alluvium consists of rock fragments that become progressively smaller, less angular, and better sorted with increasing distance from the mountains. The coarsest and most angular fragments are near the apexes of the alluvial fans, where the alluvial material ranges in size from clay to boulders several feet in diameter. The finer grained sediments, composed largely of fine sand, silt, and clay, and some evaporites, are deposited beyond the toes of the fans.

The relation between decreasing grain size and increasing distance from the mountains is only general. The capacity of the streams to carry loads varies considerably in relatively short periods of time, depending on the amount of flow. Furthermore, the streams frequently change their courses on the alluvial fans, and abandon a channel when it becomes choked with debris. This irregular pattern of sedimentation produces a corresponding irregularity in the material that composes the alluvium. For example, a particular area that typically should be underlain by coarse material may be underlain only by silt and clay, and conversely, thick gravel beds may be found locally at the toes of fans and even in the center of the valley.

It is difficult to evaluate the character of the older, pre-Lake Lahontan alluvium buried at depth in the valley on the basis of drillers' logs (table 4), as they provide little information on the degree of sorting or roundness of the grains. The depth to the top of the pre-Lake Lahontan alluvium is not known, but it is probably not more than a few tens of feet.

Some of the older alluvium buried beneath the sediments of Lake Lahontan probably was deposited by the Kings River. These river deposits locally should be well sorted and highly permeable. However, the depth and extent of these deposits is not known.

The younger alluvium that covers most of the valley floor is thin and, as shown on plate 1, includes lakebeds, beaches, bars, spits, and dune sand.

The total thickness of the valley fill is not known. Well 46/33–27A1, drilled to a depth of 800 feet, did not reach bedrock.

WATER-BEARING CHARACTER OF THE ROCKS

ROCKS OF THE MOUNTAIN RANGES

Consolidated rocks of the mountain ranges generally are not an important source of ground water. Movement of ground water in them is largely in joints and other openings and in porous zones between lava flows. Because of the complex geology, a detailed geologic study should precede any attempt to develop large supplies of ground water in the mountain ranges.

YOUNGER AND OLDER ALLUVIUM

The younger and the older alluvium, where saturated, are the principal sources of ground water in Kings River Valley. However, the hydraulic character of the alluvium is not favorable everywhere for the development of large-capacity wells. For example, near the apexes of the alluvial fans the sediments commonly are poorly sorted and therefore they do not yield water readily to wells. Better sorted material which transmits water more readily and which usually yields moderate to large quantities of water to wells is ordinarily deposited nearer the toes of the alluvial fans.

The best aquifers underlie the larger alluvial fans, which generally are those deposited by perennial streams. The deposits of these fans contain many stringers of gravel, which transmit water readily. On the other hand, the short, steep fans commonly are underlain by poorly sorted material that was deposited during floods, and the yields of wells that tap these materials are usually small.

The sediments deposited by the Kings River probably include well-sorted and highly permeable sand and gravel. It is likely that wells tapping these sediments would yield large quantities of water.

Sediments of Lake Lahontan, which include much silt and clay, probably have poor water-transmitting properties. Locally, beach and shoreline deposits of sand and gravel should yield water freely to wells, where saturated. However, they are not extensive or thick enough to be important aquifers.

Three aquifer tests were made during the study to determine the coefficients of transmissibility of the aquifers. The coefficient of transmissibility is defined as the rate of flow of water, in gallons per day, at the prevailing water temperature, through a cross section of an aquifer having a width of 1 foot and height equal to the thickness of the aquifer, under unit hydraulic gradient. Thus, the coefficient of transmissibility indicates the water-transmitting property of an aquifer. Three irrigation wells were used in making the aquifer tests (wells 45/33–24D1, 45/33–25B1, and 46/33–26D1). Recovery tests of 1-hour duration were made at each well. The coefficients of transmissibility determined are, respectively, 80,000, 52,000 and 70,000 gpd (gallons per day) per ft. Each well penetrates the sediments of Lake Lahontan and several hundred feet of the older alluvium. Ordinarily, wells tapping aquifers that have a coefficient of transmissibility of 20,000 gpd per ft or more will yield sufficient water for irrigation. Generally, the specific capacity of these wells is about 10 gpm (gallons per minute) per ft. of drawdown.

Data pertaining to yield, drawdown, and specific capacity of 13 wells show that wells in the northern part of the valley yield moderately large to large quantities of water (table 1).

Aquifer characteristics for the southern part of the valley are not known, owing to the meager data. Wells 43/34–13C1 and 44/34–35D1 have specific capacities of about 12 and 7 gpm per ft of drawdown, respectively, indicating that moderate supplies of water may be obtained from wells in that area. Specific capacity is a rough indication of transmissibility; the specific capacity of these wells suggests that the transmissibility of the deposits tapped by the wells is roughly 20,000 gpd per ft.

TABLE 1.—*Yield, drawdown, and specific capacity of wells in Kings River Valley, Humboldt County, Nev.*

Well and location	Yield (gpm)	Drawdown (ft)	Specific capacity (gpm per ft of drawdown)
43/34–13C1	35	3	[1] 12
44/34–35D1	20	3	[1] 7
45/33–3B1	2, 200	105	[1] 21
3D1	1, 050	36	29
14C1	1, 300	126	10
14C2	2, 600	120	[1] 22
15A1	2, 500	99	[1] 25
25B1	1, 370	28	49
25C1	1, 950	52	38
26C1	2, 700	76	[1] 36
46/33–23B1	1, 250	165	[1] 8
23D1	2, 700	140	[1] 19
26C1	1, 900	141	13
26D1	1, 090	39	28

[1] Computed from yield and drawdown data reported in drillers' logs.

GROUND WATER

OCCURRENCE AND MOVEMENT

Ground water occurs in both the consolidated and unconsolidated rocks within the Kings River Valley drainage basin. Most of the ground water in the consolidated rocks of the mountain ranges that is available to wells occurs in joints, in vesicular zones in lava flows, in fractures along fault zones, and in other openings. Only small yields normally should be expected from wells drilled in the consolidated rocks.

Most of the ground water is in the unconsolidated sediments of the valley fill. These sediments, which consist largely of gravel, sand, silt, and clay, are saturated below the water table. The clay and silt yield only small quantities of water to wells, but the sand and gravel yield water readily.

Ground water occurs either under unconfined (water-table) or confined (artesian) conditions. Under the latter condition the water is under sufficient pressure to rise in wells above the bottom of the relatively impermeable formation or stratum that acts as the confining bed. Although there are no flowing wells in the valley, the drillers' logs indicate that in most of the deeper wells the water occurs under artesian conditions and will rise a few feet above the water table.

In general, the depth to water is greatest near the contact of the bedrock and the alluvium and least beneath the axis of the valley, where the water table is less than 10 feet below the surface.

Ground water moves from areas of recharge to areas of discharge. The direction of movement is indicated by the water-level contour in figures 2 to 4; ground water moves downgradient and perpendicular to the contours. Figure 2, based largely on water levels reported in drillers' logs, shows the approximate position of the water table before the beginning of heavy pumping in 1958. Figure 3 is based on water-level measurements made in January 1959; figure 4 is based on measurements made in September and October 1959. The contours show that ground water generally moves southward toward the mouth of the valley, although a component of movement is toward the axis of the valley.

The slope of the water table is steepest at the north end of the valley, where it is about 30 feet per mile. The slope flattens toward the south and at the south end of the valley it is only about 3 feet per mile.

The water table is steep at the north end of the valley, probably in part because the sediments there are less permeable than those in the central part of the valley, and in part because there is more ground water moving through this section of the valley. A smaller cross-sectional area of saturated sediments also would cause the gradient to be steeper. The quantity of ground water decreases southward because phreatophytes along the axis of the valley discharge water into the atmosphere. The low gradient in the southern half of the valley is due to several factors, the most predominant of which is the relatively small amount of water that is moving through the valley fill.

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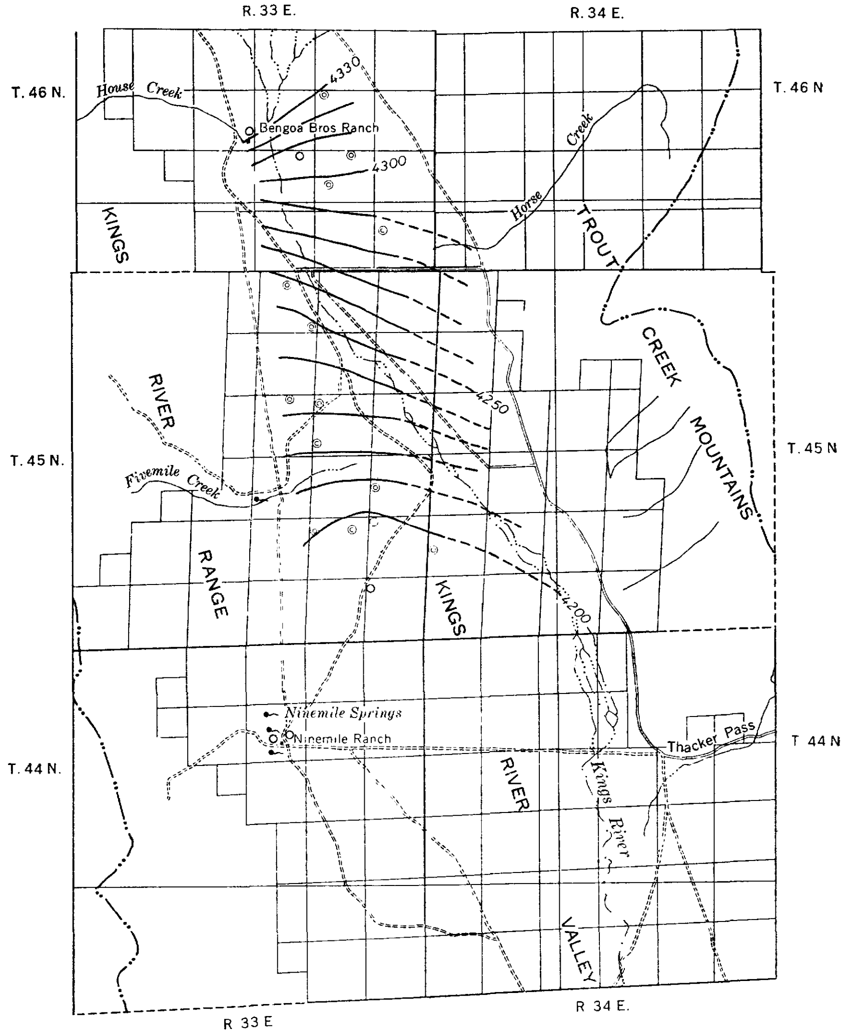

FIGURE 2.—Map showing water-level contours before the beginning of heavy pumping in 1958. See plate 1 for explanation of symbols.

RECHARGE

The ultimate source of practically all the recharge to the ground-water reservoir of Kings River Valley is the precipitation on the alluvial fans and the mountains that border the valley. Precipitation on the valley floor is estimated to be less than 5 inches per year, most of which is evaporated or transpired almost immediately. Thus, the contribution to ground-water recharge from precipitation on the valley floor is probably negligible.

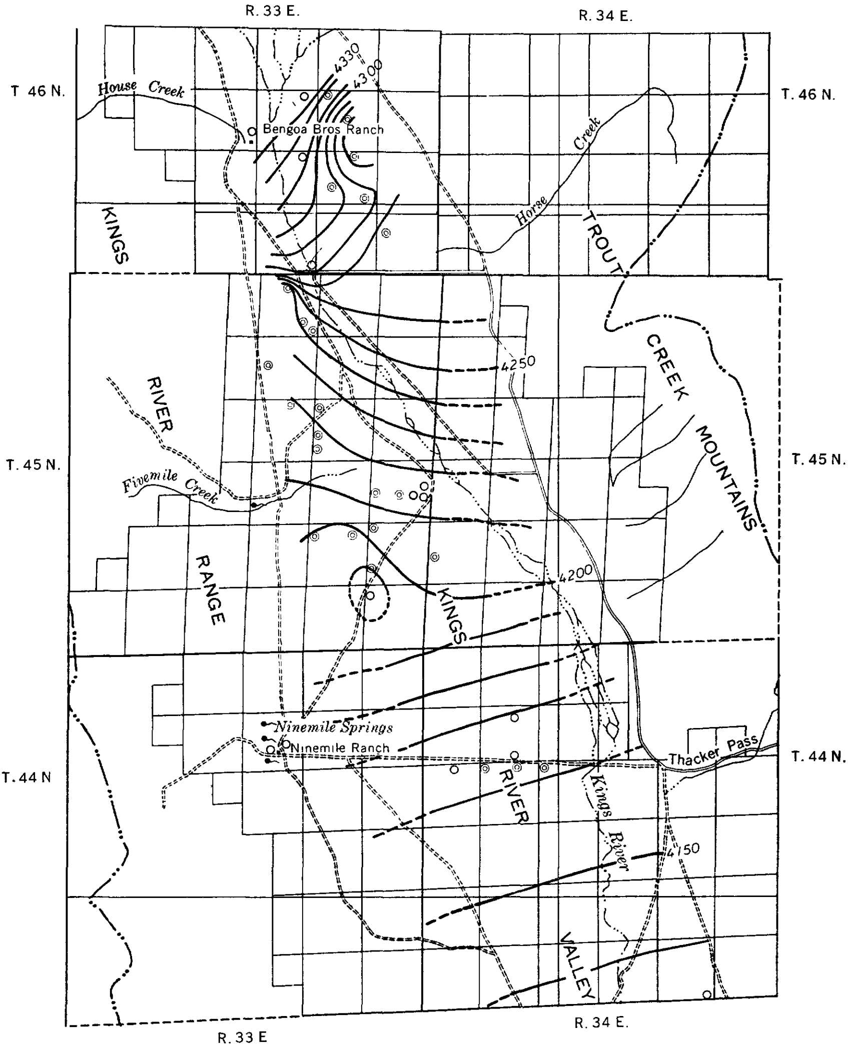

FIGURE 3.—Map showing water-level contours in January 1959. See plate 1 for explanation of symbols.

The approximate amount of precipitation within the Kings River Valley drainage area each year can be computed from a map showing precipitation zones in Nevada (Hardman, 1936). Hardman mapped the precipitation zones chiefly on the basis of elevation, type of vegetation, and precipitation data available from the relatively few U.S. Weather Bureau climatological stations in existence at that time.

The total annual precipitation, according to Hardman's map, is about 180,000 acre-feet. However, only a small part of this precipitation eventually reaches the ground-water reservoir in the valley.

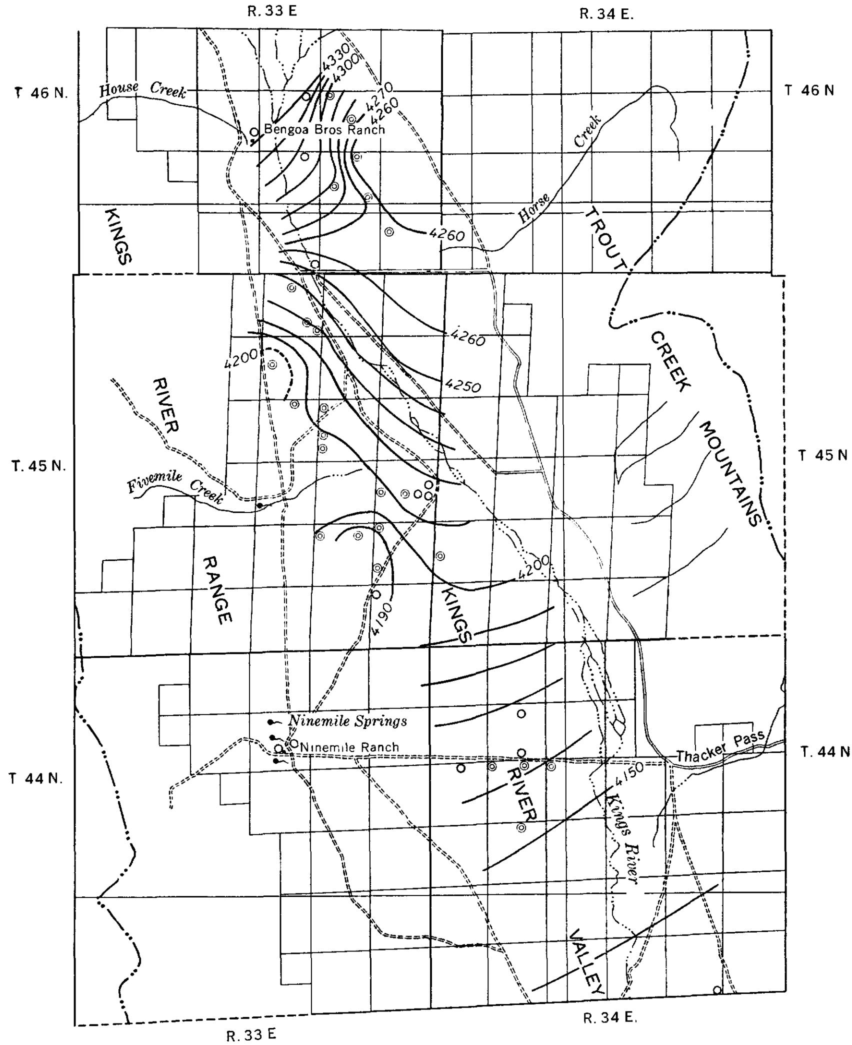

FIGURE 4.—Map showing water-level contours in September and October 1959. See plate 1 for explanation of symbols.

Most of it is quickly transpired or evaporated. Of the amount that is left, part runs off immediately and part infiltrates into the rocks of the mountain ranges and the alluvial fans, eventually moving directly into the valley fill or surfacing along stream courses and at springs. Further loss by evaporation and transpiration takes place along the stream courses.

Studies by Loeltz, Phoenix, and Robinson (1949, p. 35) indicate that the annual evapotranspiration requirement is 9 inches of precipitation in the Martin Creek drainage area in Paradise Valley, about 50 miles southeast of Kings River Valley. There, presumably, only precipitation in excess of 9 inches is available for runoff. In Kings River Valley, the amount of precipitation that runs off is about 15,000 acre-feet per year.

The study of the relationship between runoff and recharge to the ground-water reservoir in Paradise Valley (Loeltz, Phoenix, and Robinson, 1949, p. 42) suggests that in a typical valley in northern Nevada, somewhat less than 40 percent of the runoff ultimately recharges the ground-water reservoir. The remainder of the runoff either is evaporated from streams and other water surfaces such as ponds or shallow lakes that occasionally occupy playas, or is transpired by vegetation along stream courses before it reaches the ground-water reservoir. However, if 40 percent of the precipitation in excess of 9 inches is assumed to recharge the aquifers of the valley fill of Kings River Valley, the recharge is only about 6,000 acre-feet. This figure probably is considerably less than the actual amount of recharge, because the vegetative cover on the mountain ranges is sparser, particularly on the Trout Creek Mountains, than on the mountains bordering Paradise Valley. Consequently, the transpiration requirements are lower. In addition, the opportunity for infiltration of rainwater or snowmelt is greater in Kings River Valley than in Paradise Valley because columnar jointing is well developed in the rocks of the mountain ranges and the mountain slopes are covered with loose volcanic rubble. Under such conditions, a larger proportion of precipitation could percolate into rocks of the mountain ranges and eventually recharge the aquifers in the valley fill.

A higher than normal rate of infiltration of precipitation in the mountains bordering Kings River Valley is indicated by several perennial streams in the northern part of the valley, which drain small watersheds. The highest altitude of these watersheds is less than 7,000 feet. Ordinarily in northern Nevada, only large watersheds that include mountainous areas above 10,000 feet in altitude are drained by perennial streams. Also the perennial or near-perennial streams that drain the lower lying mountains bordering the valley indicate that an above-average percentage of precipitation infiltrates into the rocks of the mountains.

Because of this above-average infiltration of precipitation in the mountains, the percentage of precipitation that results in floodflows in Kings River Valley is smaller than in most other valleys in northern Nevada. The percentages of floodflows that recharge ground-water reservoirs usually are much smaller than the percentages of normal streamflow that recharge ground-water reservoirs, because a larger percentage of a floodflow either leaves the area or flows onto playas or sinks or into lakes where it evaporates.

Therefore, in Kings River Valley not only are the evapotranspiration requirements in the mountains less than in many other valleys in northern Nevada, but the opportunity for streamflow to recharge the ground-water reservoir is better, because the streamflow is more uniform. This combination of conditions probably increases significantly the percentage of precipitation that recharges the ground-water reservoir.

Because the relations between precipitation, runoff, and ground-water recharge in Kings River Valley is poorly understood, no estimate of average annual recharge was made. Instead, the average annual recharge was estimated on the basis of the average annual discharge under natural conditions (p. L21).

DISCHARGE

The natural discharge of ground water in Kings River Valley takes place by evapotranspiration, spring discharge, and underflow from the south end of the valley to the Quinn River. The artificial discharge of ground water is by pumping, but only recently has this discharge become significant.

EVAPORATION AND TRANSPIRATION

Evaporation from the ground-water reservoir occurs where the capillary fringe reaches or is near the land surface. The capillary fringe ordinarily reaches the land surface only where the depth to the water table is only a few feet below the surface. In the Kings River Valley a few areas have a shallow water table, and probably a small amount of ground water is evaporated in these areas.

Transpiration, on the other hand, accounts for most of the natural discharge in the valley. Large quantities of ground water are transpired by plants, known as phreatophytes, the roots of which descend to the water table or to the capillary fringe. Greasewood is the most common phreatophyte in Kings River Valley; others are saltgrass, ryegrass, rabbitbrush, meadow grasses, willows, and associated wild rose, buckbrush, and pickleweed. In addition, about 1,400 acres of meadow grasses and alfalfa are supported in part by flood irrigation and in part by roots that tap the ground-water reservoir.

Phreatophytes are thickest along the axis of the valley, particularly at the north end. A few small, isolated areas of densely growing phreatophytes also occur at the base of the mountains. The phreatophytes in the valley usually are limited to areas where the depth to water is less than 25 feet. Their areal distribution and densities are shown on figure 2. The rate of use of ground water by the phreatophytes is based largely on work done by White (1932, p. 28–93) in

Escalante Valley, Utah and on more recent investigations by Young and Blaney (1942, p. 41–146).

The phreatophyte area has been divided into several subareas, according to the predominant type of vegetation. These types are greasewood, ryegrass-saltgrass, willow, and cultivated fields that are partly subirrigated.

The rate of use of the phreatophytes is summarized as follows:

Phreatophytes	Symbol on plate 1	Area (acres)	Depth to water (feet)	Density (percent)	Area adjusted to 100 percent density (acres)	Use (acre-feet per acre)	Ground-water use (acre-feet)
Greasewood, including some rabbitbrush, saltbush, ryegrass, saltgrass, pickleweed	GW	60, 000	10–25	2–30	7, 900	[1] 1. 5	12, 000
Ryegrass-saltgrass	RS	2, 800	<10	30	800	1. 5	1, 200
Willow and associated plants	([2])	200	<20	100	200	5	1, 000
Cultivated fields	CF	1, 400	10–40	100	1, 400	[3] 1	1, 000
Total, rounded							15, 000

[1] Use based on studies by White (1932) in Escalante Valley, Utah.
[2] Areas not delineated on pl. 1.
[3] About 50 percent of water requirement supplied by irrigation from wells; estimated 1 ft per acre per year supplied from ground water. Consumptive use based on information by Houston (1950, p. 21–22).

SPRINGS

The only large springs in the valley are thermal, and they discharge along the west side of the valley. Their combined discharge is about 1½ cfs or about 1,000 acre-feet a year. The Ninemile springs are at the Ninemile Ranch, and Fivemile spring is about 4 miles farther north.

The springs at Ninemile ranch issue from unconsolidated gravel immediately down gradient from the contact of the bedrock and the alluvium. The total flow is about 1 cfs. The temperature of the water is 79°F, or more than 15° warmer than water pumped from wells in the valley.

Fivemile spring issues from a single pool in gravel down gradient from the contact of the bedrock and alluvium. The pool is about 8 feet in diameter and 1 foot deep. Water rises from the bottom of the pool and overflows into a channel. The flow is about 0.5 cfs, and the water has a temperature of 83°F, or about 20° warmer than water pumped from wells.

Water from Ninemile springs is used to irrigate about 80 acres of cultivated land at Ninemile Ranch; water from Fivemile spring is used to irrigate about 20 acres downslope from the spring.

Part of the water that is not used for irrigation supports the growth of phreatophytes along the stream channels downstream from each spring area. Part of the flow is lost through direct evaporation and part probably percolates into the ground and eventually returns to the ground-water reservoir. It seems doubtful that more than several hundred acre-feet of the total flow of both springs returns to the ground-water reservoir.

UNDERFLOW TO THE QUINN RIVER

The general direction of movement of ground water in Kings River Valley is southward toward the Quinn River. That part of the average annual recharge to the valley that is not discharged by evapotranspiration, spring flow, or pumping, is discharged into the Quinn River and the flood-plain deposits and from there, moves westward toward the Black Rock Desert, where it is discharged by evaporation or transpiration.

The annual ground-water discharge to the valley of the Quinn River from the aquifers of Kings River Valley is not known, but it probably is small. The hydraulic gradient in the southern part of the valley is only about 3 feet per mile, the transmissibility of the aquifers tapped by wells 44/34–35D1 and 43/34–13C1 is on the order of 20,000 gpd per ft, and the width of the section through which the ground water moves near well 43/34–13C1 is about 3 miles. These data and estimates suggest that the average annual discharge to the valley of the Quinn River is about 200 acre-feet.

PUMPAGE

Prior to 1956 perennial streams and springs supplied water for irrigation, and only insignificant quantities of ground water were pumped from a few domestic and stock wells. In 1956 the first irrigation well was drilled, and by 1959 there were at least 25 irrigation wells in the valley. During 1956 and 1957 the amount of ground water pumped for irrigation was no more than a few thousand acre-feet. Ground-water withdrawals increased markedly in 1958, when about 17,000 acre-feet was pumped from 23 wells, all of which are in the northern part of the valley. The water was used to irrigate about 5,000 acres of wheat and other grains, potatoes, and alfalfa. Preliminary data indicate withdrawals in 1959 were at least as great as in 1958, and probably greater.

Part of the pumped water returns to the ground-water reservoir, the amount depending principally on irrigation methods used and the permeability of the soils. The amount of return may range from as little as 10 to as much as 50 percent.

The effects of the recent heavy pumping on the ground-water levels are noted in figures 2 to 4. Figure 2, based largely on water levels reported by drillers, shows the piezometric surface before heavy pumping began; figure 3 shows the piezometric surface in January 1959; and figure 4 shows it in October 1959. The maps indicate general declines of water level in the areas of heaviest pumping—10 to 30 feet in the southeastern part of T. 46 N., R. 33 E., and about 10 feet in the eastern part of T. 45 N., R. 33 E. The maps indicate also that ground water is being diverted from the areas of natural discharge—that is, from the phreatophyte areas toward the pumped areas.

INVENTORY

In a ground-water basin, such as Kings River Valley, the average annual recharge is equal to the average annual discharge plus or minus changes in the amount of ground water in storage. During a wet cycle, recharge exceeds discharge and ground-water levels rise; this relation indicates an increase in stored water. Conversely, during a dry cycle, discharge exceeds recharge and ground-water levels decline, owing to depletion of ground water in storage. However, over a period of many years, under natural conditions, the average annual recharge and average annual discharge are in balance.

If the recharge to Kings River Valley is estimated on the basis of rates of precipitation, stream runoff, and infiltration, the average annual recharge is 6,000 acre-feet per year (p. L17). This estimate probably is too low, because the vegetative cover and geologic conditions are more favorable for recharge in Kings River Valley than in most other valleys where the method has been used. A more accurate estimate of the average annual recharge to the ground-water reservoir is made indirectly by estimating natural ground-water discharge. The discharge by evapotranspiration in 1958 was estimated to be 15,000 acre-feet. Underflow to the Quinn River was about 200 acre-feet. Thus, the total average annual ground-water discharge, excluding pumpage, was on the order of 15,000 acre-feet. Because the pumping in 1958 had not significantly affected the amount of ground water discharged by phreatophytes and underflow, this estimate is considered to be the natural ground-water discharge from the valley.

The average annual recharge, then, also is approximately 15,000 acre-feet, rather than only 6,000 acre-feet as estimated directly from precipitation. A prolonged annual net draft (pumpage minus irrigation water that returns to the ground-water reservoir) in excess of 15,000 acre-feet would result in a continuing overdraft in the valley. Pumpage in 1958 was estimated to be 17,000 acre-feet and in 1959 somewhat greater (p. L20), but because a part of the pumpage returned to ground water each year, the net pumping draft was probably close to the estimated average annual recharge. Factors that affect the extent to which the natural water supply of the valley can be salvaged are discussed on page L29.

GROUND WATER IN STORAGE

The younger and the older alluvium in Kings River Valley underlie an area of more than 50,000 acres and contain a large quantity of ground water in storage. Part of this water is available for development because as water levels are lowered, part of the water in storage above the zone of saturation will drain to the water table. The amount of this potential recovery depends largely on the specific yield of the sediments of the drained section. The specific yield of a given volume of the sediments may be considered as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. It is usually expressed as a percent. For example, if it is assumed that the specific yield of the uppermost 100 feet of saturated deposits averages 10 percent, 500,000 acre-feet of recoverable water would be stored in the zone. Studies of similar alluvial deposits in California (Piper, 1939; Eckis, 1934) indicate that the average specific yield from basin to basin may range from 5 to 25 percent, depending principally on the degree of sorting, degree of weathering and cementation, and the grain size.

Development of ground water in Kings River Valley will reduce the amount of ground water in storage. (See p. L29.) The extent of the reduction will depend on where, when, and at what rate development takes place.

CHEMICAL QUALITY OF GROUND WATER

WATER FOR IRRIGATION

Water for irrigation is evaluated on the basis of the salinity hazard, the sodium (alkali) hazard, and the concentration of bicarbonate, boron, and other ions. Wilcox (1955, p. 7–12) describes the above properties of water, and that report is used as the basis for most of the following sections.

SALINITY HAZARD

The salinity hazard depends on the concentration of dissolved solids. It is normally measured in terms of the electrical conductivity, or specific conductance, of the water, expressed as micromhos per centimeter at 25°C. The electrical conductivity is an approximate measure of the total concentration of the ionized constituents of the water. Wilcox (1955, p. 7) divides water into four classes with respect to its conductivity. The dividing points between the four classes are at 250, 750, and 2,250 micromhos per centimeter (fig. 5). Generally

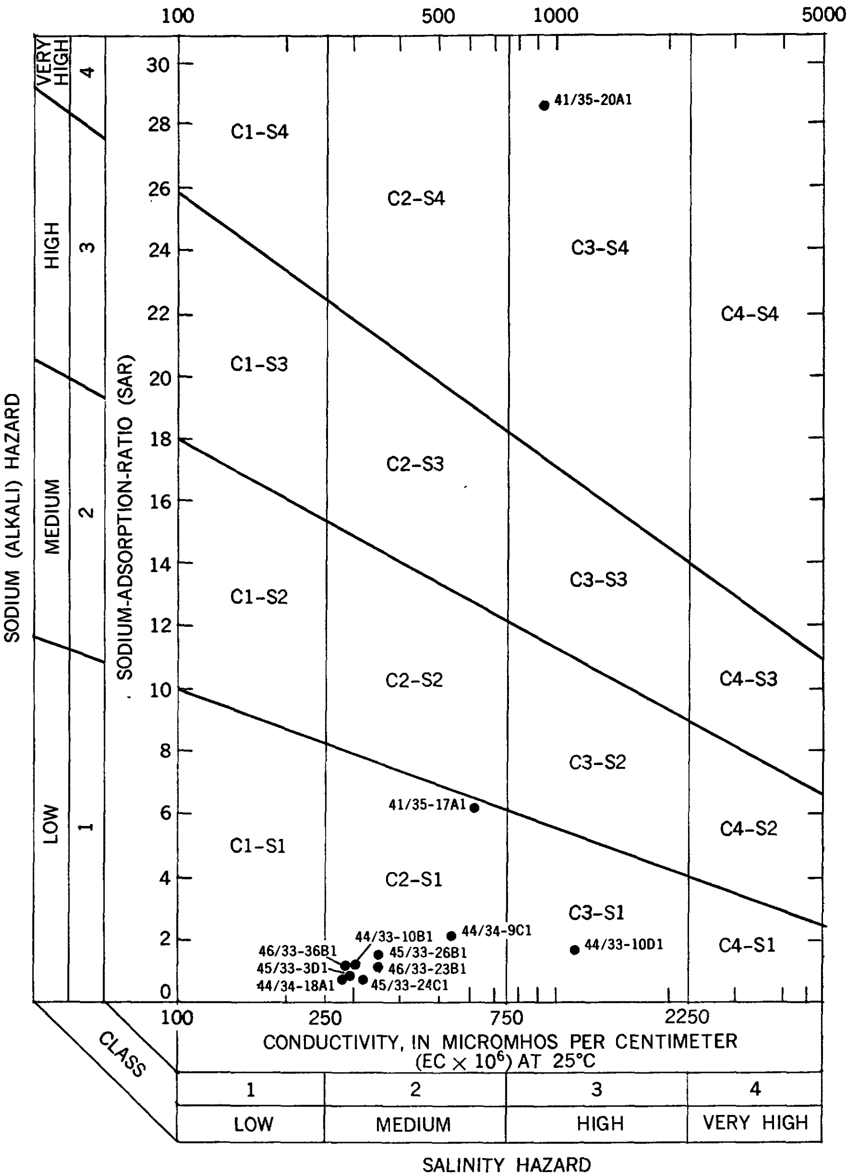

FIGURE 5.—Classification of irrigation water on the basis of conductivity and sodium-adsorption-ratio.

water of low conductivity is more suitable for irrigation than water of high conductivity. Wilcox provides the following classification of irrigation water with respect to salinity hazard:

1. Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

2. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

3. High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

4. Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances.

SODIUM (ALKALI) HAZARD

The sodium, or alkali, hazard is indicated by the sodium-adsorption-ratio (SAR), which may be defined by the formula

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

in which concentrations are expressed in equivalents per million (epm). If the proportion of sodium among the cations is high, the alkali hazard is high; but if calcium and magnesium predominate, the alkali hazard is low. Wilcox classifies irrigation waters, with respect to sodium hazard, as follows:

1.—Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops * * * may accumulate injurious concentrations of sodium.

2.—Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

3.—High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions.

4.—Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except under special circumstances.

BICARBONATE ION

Residual sodium carbonate (RSC), which may be defined by the formula $RSC=(CO_3^{--}+HCO_3^{-})-(Ca^{++}+Mg^{++})$ in which concentrations are expressed in equivalents per million, is a measure of the hazard involved in the use of high-bicarbonate water. If residual sodium carbonate is greater than 2.5 epm, the water is not suitable for irrigation. The water is marginal if the residual sodium carbonate is between 1.25 and 2.5 epm, and is probably safe if the residual sodium carbonate is less than 1.25 epm.

BORON

Nearly all natural water contains boron in amounts that range from traces to several parts per million. Although boron in small amounts is essential to plant growth, it is toxic at concentrations slightly higher than the optimum. Scofield (1936, p. 286) proposed limits for boron in irrigation waters, depending on the sensitivity of the crops to be irrigated. In general, boron in excess of 3 ppm (parts per million) is injurious to most crops.

WATER FOR DOMESTIC USE

The U.S. Public Health Service (1946) specifies the following concentration limits of some chemical substances in drinking water used on interstate carriers and for public supplies in general:

Constituent	*Maximum concentration (ppm)*
Iron and manganese (sum)	0.3
Magnesium	125
Sulfate	250
Chloride	250
Fluoride	1.5
Dissolved solids	500 (1,000 permitted)

Water containing dissolved mineral matter in concentrations exceeding these limits is not necessarily harmful, and the limits should be used only as a guide in determining the suitability of water for human consumption.

Hardness of the water also must be considered. A large quantity of soap is required to produce suds in hard water; however, the widely accepted use of synthetic detergents has greatly eliminated many problems associated with the use of hard water for domestic purposes. In addition, scale deposits in water heaters, radiators, and pipes are related to the hardness of the water used.

Hardness is caused almost entirely by calcium and magnesium. Iron, manganese, aluminum, some other metallic cations, and free acid, which also cause hardness, generally are not present in sufficient quantities to affect appreciably the hardness. No rigid limits have been set as to what constitutes hard water, although water that has a hardness of 60 ppm or less, expressed as calcium carbonate, is generally considered soft. Water that has a hardness between 60 and 200 ppm is considered moderately hard to hard; water that has a hardness greater than 200 ppm is considered very hard and ordinarily must be softened before it is satisfactory for most uses.

CLASSIFICATION AND INTERPRETATION OF ANALYSES

The chemical analyses and other significant characteristics of water from 10 wells and 1 spring are given in table 2. Included in the table is an analysis of water from well 41/35–20A1, which is immediately south of the Quinn River and adjacent to the Kings River Valley, as defined for this study. In addition, the specific conductances of water from wells 43/34–13C1 and 44/33–25C1, which are not listed in the table, were determined in the field as 446 and 317 micromhos, respectively.

TABLE 2.—*Chemical analyses and classification of water in King's River Valley, Humboldt County, Nev.*

[Analysis by U.S. Geological Survey, Quality of Water Laboratory, Salt Lake City, Utah. Source of sample: S, spring; W, well. Carbonate (CO_3), Manganese (Mn), Copper (Cu), Zinc (Zn), Phosphate (PO_4), Lithium (Li), Strontium (Sr), Aluminum (Al); 0.00 ppm unless indicated otherwise in "Remarks" column]

Well or spring and location	Source of sample	Depth of well (ft)	Date collected	Specific conductance (micromhos at 25° C)	Dissolved solids (ppm)	Sodium-adsorption-ratio (SAR)	Residual sodium carbonate (RSC)—(epm)	Classification for irrigation (fig. 6)	Constituents (ppm): Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)
41/35-17A1	W	------	6-23-59	622	431	6.1	1.9	C2-S1	69	0.17	22.	3.9	116
20A1	W	112	10-26-54	941	541	29	4.6	C3-S4	4.8	15	2.2	.8	215
44/33-10B1	S	------	6-22-59	303	219	1.2	.2	C2-S1	54	.14	25	5.8	33
10D1	W	------	6-22-59	1,130	705	1.8	0	C3-S1	55	.63	99	33	90
9C1	W	------	6-22-59	530	298	2.2	.5	C2-S1	4.9	2.41	28	18	61
18A1	W	------	6-22-59	285	218	.7	.2	C2-S1	59	.10	27	13	19
45/33-3D1	W	------	6-22-59	293	208	.9	.4	C2-S1	48	.18	28	11	20
24C1	W	------	6-22-59	309	218	.8	.2	C2-S1	49	.05	30	12	20
26B1	W	------	6-22-59	353	259	1.4	.3	C2-S1	64	.03	30	9.2	34
46/33-23B1	W	------	6-22-59	352	235	1.2	.2	C2-S1	42	.05	31	11	29
36B1	W	------	6-22-59	291	204	1.1	.4	C2-S1	45	.13	29	7.1	24

Well or spring and location	Constituents (ppm): Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$: Total	Noncarbonate	pH	Remarks
41/35-17A1	200	64	54.	1.0	0.8	0.31	70	0	7.9	Al, 1.5 ppm.
20A1	211	70	106	1.4	.2	------	9	0	9.0	Mn, 0.23; Zn 1.2 ppm; CO_3 36 ppm.
44/33-10B1	117	20	22	.1	.2	.07	86	0	8.0	Flows 50 gpm. Temp 79° F.
10D1	228	107	152	.0	56	.16	382	198	7.4	Al, 0.42 ppm.
9C1	208	28	50	.2	.0	.13	145	0	8.1	Mn, 0.85; Cu 0.6; Zn 0.3; Al 1.1 ppm.
18A1	156	10	9.5	.2	2.6	.04	120	0	7.8	PO_4, 0.02 ppm.
45/33-3D1	164	9.7	8.6	.1	.4	.10	115	0	7.5	PO_4, 0.16; Al 0.42 ppm.
24C1	171	11	9.9	.2	.6	.07	126	0	7.5	PO_4, 0.30; Al 0.85 ppm.
26B1	156	22	21	.1	1.7	.10	113	0	7.5	PO_4, 0.07 ppm.
46/33-23B1	157	22	19	.1	2.6	.08	122	0	7.4	PO_4, 0.24; Al 1.5 ppm.
36B1	145	13	13	.2	.7	.07	102	0	7.6	PO_4, 0.10; Al 0.21 ppm.

The data indicate an increase in specific conductance, and consequently, an increase in the concentration of dissolved solids toward the south, in the direction of movement of the ground water. The specific conductances of the samples from the northern part of the valley generally ranged from slightly less than 300 to slightly more than 350 micromhos and the dissolved solids from 200 to 260 ppm. Exceptions to the general range of specific conductances were those of water samples from wells 44/33–10D1 and 44/34–9C1, which were 1,130 and 530 micromhos, respectively. Well 44/33–10D1 is a shallow stock well in a pasture. The relatively high concentration of nitrates in the water, 56 ppm, can be explained on the basis that the soil zone in the immediate vicinity of the well probably is rich in nitrogen because of the concentration of animal excrement at the watering site. As the water percolates through this nitrogen-rich soil zone some of the nitrates are taken into solution. Another possibility is that the nitrogen-rich dust is blown into the dug well by the wind.

Water from well 43/34–13C1, in the south-central part of the valley, has a specific conductance that is somewhat higher than that of water from the northern part of the valley, which indicates that the concentration of dissolved solids may be higher in the south-central part of the valley. Ground water in the Sod House area at the south end of the valley had still higher concentrations of dissolved solids, 431 and 541 ppm, respectively, for water from wells 41/35–17A1 and 41/35–20A1.

This increase in the concentration of dissolved solids toward the south is to be expected. Most of the mineral matter in ground water is dissolved from the rocks with which the water comes in contact. The longer water is in contact with the rocks the more highly mineralized it becomes, so that ordinarily the concentration of dissolved solids increases with increasing distance from an area of recharge.

In addition to the increase in the dissolved-solids content of the water toward the south, a change in the chemical composition of the dissolved solids is shown by the analyses. Although the dissolved mineral matter in water is predominantly calcium bicarbonate at the north end of the valley, it is sodium bicarbonate in the Sod House area. This difference may be due to a process of ion exchange in which some of the calcium ions in solution in the ground water are exchanged for sodium ions in the sediments, as the water migrates southward.

WATER FOR IRRIGATION

Consideration should be given first to the salinity and sodium (alkali) hazards in appraising water for irrigation. Accordingly, the salinity and alkali hazards of all the samples that were analyzed are plotted on a diagram proposed by Wilcox for the classification of irrigation water (fig. 5). As shown on the diagram, most of the water is in class C2–S1; that from well 44/33–10D1 is in C3–S1, and that from 41/35–20A1 is in class C3–S4. On the basis of salinity and sodium hazards alone, all the water, except that from the last two sources, can be used safely for the irrigation of most crops. Water from well 44/33–10D1 should be used only under favorable conditions of drainage and plant tolerance. Water from well 41/35–20A1 is unsuitable for irrigation.

Water from well 41/35–17A1 contains 1.9 epm of residual sodium carbonate and must be considered marginal on that basis. The concentration of residual sodium carbonate (4.6 epm) of the sample from well 41/35–20A1 is greater than the limits considered safe for irrigation. The high concentration of residual sodium carbonate in the Sod House area may indicate problems in the irrigation of crops in the southern part of the valley. All samples of water from the northern part of the valley are within safe limits with respect to residual sodium carbonate.

The low boron content of all the samples is within the safe limits for all crops (Scofield, 1936).

WATER FOR DOMESTIC USE

Except for water from wells 44/33–10D1 and 44/34–9C1, all the samples of water analyzed are suitable for domestic use. Water from well 44/33–10D1 is very hard and would require softening to be satisfactory for domestic use. In addition, the iron content of the water is about twice the recommended limit, as given on page L25. Also, the concentration of nitrates (56 ppm) exceeds the upper limit of 44 ppm which tentatively has been considered as safe for use in feeding formulas for infants. Water containing a greater concentration of nitrates may cause cyanosis, a so-called blue-baby disease. Water from well 44/34–9C1 is suitable in all respects except for the concentration of iron and manganese, which totals 3.3 ppm, or more than 10 times the maximum limit of 0.3 ppm recommended by the U.S. Public Health Service (1946).

All the other samples are moderately hard to hard, and the harder waters may have to be softened for certain domestic uses.

In all the samples, fluoride is within the limit of 1.5 ppm, the maximum permitted by the U.S. Public Health Service for interstate carriers and public supplies. Its concentration is much higher in the Sod House area than elsewhere in the valley. Water from well 41/35–

20A1, about half a mile northwest of Sod House, contains 1.4 ppm of fluoride, and that from well 41/35–17A1, about 1½ miles northwest of Sod House, contains 1.0 ppm, whereas the water from wells in the northern part of the valley contains only a few tenths part per million.

DEVELOPMENT OF GROUND WATER

The net amount of ground water that can be pumped perennially in Kings River Valley without causing a continuing decline in ground-water levels is the amount of natural discharge that can be salvaged. Through 1959, ground water has been withdrawn mostly from storage in and near the areas of pumping, because the water table has not been lowered sufficiently to affect materially the rate of transpiration of phreatophytes, and only a few acres of land supporting phreatophytes have been cleared for farming. Thus, water levels have declined and will continue to do so until the decline in the phreatophyte areas is sufficient to effect a reduction in the use of ground water by phreatophytes equal to the net pumpage in the valley.

To stop all transpiration by phreatophytes, it may be necessary to lower the ground-water level to at least 40 or 50 feet below the land surface throughout most of the phreatophyte area in the valley. Such a lowering may not be practical economically because in some parts of the valley the cost of pumping lifts would be excessive. For example, depending on where the withdrawals are made, it may be necessary to lower the ground-water level as much as 200 feet in the northern part of the valley.

Some ground-water movement away from the irrigated areas is necessary to maintain a satisfactory salt balance in the soil. Another factor that must be considered is the possibility that heavy pumping in the northern part of the valley could reverse the normal southward hydraulic gradient, thus causing water of poor quality in the south end of the valley to move northward toward the pumping wells. Therefore, the net rate of water that can be indefinitely pumped is less than the estimated rate of natural recharge and discharge, although how much less cannot yet be evaluated from available data.

TABLES OF SELECTED WELL DATA

Table 3 contains a summary of the 43 wells in Kings River Valley. The drillers' logs of wells in the valley are give in table 4. In addition, other logs are available for inspection in the files of the Geological Survey, 809 North Plaza Street, and the Department of Conservation and Natural Resources, State of Nevada, State Office Building, Carson City, Nev.

TABLE 3.—*Record of wells in Kings River Valley, Humboldt County, Nev.*

[Type of well: Dg, dug; Dr, drilled. Use of water: D, domestic; Irr, irrigation; N, none; S, stock]

Well and location (pl. 1)	Owner	Type of well and year completed	Diameter (inches at land surface)	Depth (feet)	Measuring point: Altitude (feet)	Measuring point: Above land surface (feet)	Measuring point: Description	Water level: Below measuring point (feet)	Water level: Date	Use	Remarks
41/35-17A1	P. Lueder	Dr								Irr	Analysis.
43/34-13C1	Bengoa Brothers Ranch	Dr, 1948	6	76						S	Log.
43/35-31C1	do	Dr	6		4,132	1.0	Top of casing	9.47	1-22-59	S	
								8.90	11- 3-59		
44/33-10D1	Ninemile Ranch	Dr	6							S	Do.
10D2	do	Dg	60	16		0	Top of board cover	11.18	1-20-59	N	
44/34-8A1	Unknown	Dr	16		4,187	1.5	Top of casing	17.83	1-22-59	N	
								18.54	10-14-59		
8D1	do	Dg	48	19	4,178	0	Top of wood platform	17.35	10-14-59	D	
9C1	do	Dr	16		4,176	1.0	Top of casing	14.95	1-22-59	N	Do.
								16.16	10-14-59		
16B1	do	Dr	16		4,176	.6	do	17.05	10-14-59	N	
17A1	do	Dr	16		4,185	4.6	do	24.31	10-14-59	Irr	
17B1	do	Dr	16		4,180	0	Top of concrete pump base	17.72	1-21-59	Irr	
								18.91	10-14-59		
18A1	do	Dr	16		4,182	1.2	Slot in casing	19.12	1-20-59	D	Analysis.
								20.25	10-14-59		
20A1	do	Dr	18		4,170	.5	Top of casing	17.79	10-14-59	Irr	
35D1	Bengoa Brothers Ranch	Dr, 1948	6	76	4,156	.5	do	21.24	1-22-59	S	Log.
								21.60	10-16-59		
45/33-3B1	R. Sierra	Dr	16		4,322	3.0	do	74.60	1-21-59	Irr	
								86.47	10-15-59		
3D1	Belle Curtis	Dr, 1959	16	710	4,281	1.0	Top of casing collar	51.24	10-15-59	Irr	Analysis; log
3D2	do	Dr	16		4,293	1.0	do	61.91	10-15-59	Irr	
10B1	do	Dr, 1959	16	500	4,317	1.0	do			Irr	Log.
14B1	Curtis M. Rocca	Dr, 1957	16	400	4,277	1.5	Top of casing	54.90	1-21-59	Irr	Do.
								62.38	10-16-59		
14C1	Archie L. Till	Dr, 1957	16	410	4,279	3.0	do	64.70	1-21-59	Irr	Do.
14C2	Clifford V. Scott	Dr, 1958	16	400	4,274	1.0	do	59.55	1-21-59	Irr	Do.
								67.37	10-16-59		
15A1	Belle Curtis	Dr	16		4,306	1.0	Top of casing collar	98.30	10-16-59	Irr	
24A1	Bengoa Brothers Ranch	Dr	6			.5	Top of casing	13.60	1-20-59	S	
24C1	Rio King Land and Development Co.	Dr, 1956	16	410	4,239	.4	do	25.66	1-20-59	Irr	Analysis; log.
								30.75	10-16-59		
24D1	Peggy A. Till	Dr, 1956	16	748	4,232	.2	do	18.16	1-20-59	Irr	Log.
								21.50	10-16-59		

24D2	H. Scott	Dr	14		4,229	.8	do	13.82	1-20-59	N	
								16.18	10-16-59		
24D3	do	Dr	16			1.0	do	13.83	1-20-59	D	
25B1	Harriet L. Scott	Dr	16	446	4,241	.4	do	37.75	1-20-59	Irr	Do.
								48.67	10-16-59		
25C1	B. Rocca, Jr	Dr	16		4,242	2.0	do	51.55	1-20-59	Irr	
								53.08	10-14-59		
26A1	B. T. Rocca	Dr	16		4,261	.8	do	63.65	1-20-59	Irr	
								75.62	8-26-59		
26B1	do	Dr, 1958	16	601	4,291	.5	Slot in casing	93.22	1-20-59	Irr	Analysis; log.
36B1	Grace Harwood	Dr, 1959	16	400	4,236	.5	Top of casing collar	48.67	10-14-59	Irr	Log.
45/34-30C1	James B. Scott	Dr, 1957	16	282	4,222	.6	Top of casing	18.34	1-20-59	Irr	Do.
								21.99	8-26-59		
								19.87	10-16-59		
46/33-21D1	Bengoa Brothers Ranch	Dr	6	25	4,353	1.0	do	17.97	1-21-59	N	
								21.79	10-15-59		
22A1	John C. Harley	Dr	18		4,388	.5	do	51.90	1-21-59	N	
								59.51	10-15-59		
23B1	do	Dr, 1959	16	670	4,385	1.0	do	69.59	1-21-59	Irr	Analysis; log.
								86.48	10-15-59		
23D1	Marilynn Knaur	Dr, 1958	16	580	4,350	1.0	do	69.64	1-21-59	Irr	Log.
								77.92	10-15-59		
26A1	J. Steckle	Dr	16		4,349	.5	do			Irr	
26C1	Fred Vandyke	Dr, 1957	18	400	4,328	.4	Hole in pump base	32.80	1-21-59	Irr	Do.
								38.52	10-15-59		
26D1	Burrafeto	Dr	16		4,316	.2	Top of casing	33.49	1-21-59	Irr	
								47.53	10-15-59		
27A1	Jane Steckle	Dr, 1957	18	800	4,347	1.0	do	34.75	1-21-59	N	Do.
								40.46	10-15-59		
34D1	Bengoa Brothers Ranch	Dg			4,299	1.0	Floor of porch	17.76	1-21-59	N	
36B1	Nora Cunningham	Dr, 1958	16	580	4,315	1.9	Top of liner	48.63	1-21-59	Irr	Analysis; log.
								54.30	10-15-59		

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*

43/34-13C1

[Bengoa Brothers Ranch. Drilled stock well; 6-in. casing to 76 ft; perforated 22 to 76 ft with ⅛-in. slots. First water at 15 ft; static level reported at 15 ft. Pumped 35 gpm with 3 ft drawdown. Drilled by Claude R. Keener, Winnemucca, Nev. Completed Jan. 27, 1948]

Material	Thickness (feet)	Depth (feet)
Unknown	26	26
Clay and gravel	34	60
Gravel and clay	16	76

44/34-35D1

[Bengoa Brothers Ranch. Drilled stock well; 6-in. casing to 62 ft; perforated 12 to 62 ft with ⅛-in. slots. First water at 21 ft; static level reported at 21 ft. Pumped 20 gpm with 3½ ft drawdown. Drilled by Claude R. Keener, Winnemucca, Nev. Completed Jan. 28, 1948]

Material	Thickness (feet)	Depth (feet)
Clay	15	15
Clay and gravel	35	50
Gravel and sand	12	62

45/33-3D1

[Belle Curtis. Drilled irrigation well; 16-in. casing to 280 ft; perforated 120 to 270 ft, with ½- by 2-in. slots. First water at 70 ft; static level reported at 51 ft. Pumped 3,700 g.p.m. from 110 ft. Drilled by Armstrong Brothers, Marysville, Calif. Completed Feb. 17, 1959]

Material	Thickness (feet)	Depth (feet)
Topsoil	18	18
Gravel and sand	4	22
Clay	18	40
Sand and gravel	13	53
Clay	14	67
Gravel and clay	8	75
Clay	10	85
Sand and gravel	17	102
Clay	20	122
Gravel and sand	10	132
Clay	16	148
Sand and gravel	14	162
Clay	10	172
Clay and gravel	26	198
Sand and gravel	12	210
Clay	10	220
Gravel and sand	10	230
Gravel and clay	25	255
Gravel, cemented	17	272
Gravel and clay	8	280
Gravel, cemented	20	300
Gravel and clay	10	310
Gravel, cemented	10	320
Clay	20	340
Gravel, cemented	27	367
Gravel and clay	13	380
Gravel, cemented	20	400
Gravel and clay	15	415

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*—Continued

45/33-3D1—Continued

Material	Thickness (feet)	Depth (feet)
Clay	20	435
Gravel and clay	20	455
Hard material	5	460
Gravel, cemented	75	535
Gravel and clay	15	550
Gravel, cemented	15	565
Clay	7	572
"Lava"	12	584
Gravel and clay	16	600
"Lava"	20	620
Clay and gravel	25	645
"Lava"	42	687
Clay and gravel	5	692
Clay	18	710

45/33-14C2

[Clifford V. Scott. Drilled irrigation well; 16-in. casing to 307 ft; 10-in. to 400 ft; perforated 80 to 227 ft with ½- by 3-in. slots; 227 to 400 ft with ⅛- by 2-in. factory perforations. First water at 80 to 85 ft; static level reported 55 ft. Pumped 2,600 gpm from 120 ft. Drilled by M. C. Nichols, Winnemucca, Nev. Completed June 19, 1958]

Material	Thickness (feet)	Depth (feet)
Topsoil and clay	70	70
Gravel	5	75
Clay and silt	5	80
Sand and gravel; "first water"	5	85
Clay	45	120
Gravel	10	130
Clay and silt	20	150
Gravel	5	155
Clay	10	165
Gravel, fine	5	170
Sand and clay	5	175
Gravel, coarse	5	180
Clay and silt	10	190
Gravel and sand	60	250
Gravel and clay	25	275
Gravel	5	280
Cobbles	5	285
Cobbles and clay	5	290
Gravel	30	320
Gravel and cobbles	5	325
Cobbles and clay	10	335
Sand, gravel, and cobbles	15	350
Cobbles and gravel	15	365
Gravel and sand	5	370
Gravel	10	380
Clay and gravel	15	395
Gravel and clay	5	400

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*—Continued

45/33-24D1

[Peggy A. Till. Drilled irrigation well; 16-in. casing to 184 ft; 14-in. 164 to 360 ft; 10-in. 346 to 426 ft; perforated 164 to 426 ft. No casing record below 426 ft. Static level at 34 ft; 12-in. pump yield 2,000 gpm. Drilled by Lee Smith, Reno, Nev. Completed May 7, 1956]

Material	Thickness (feet)	Depth (feet)
Topsoil	3½	3½
Clay, sandy	19½	23
Sand; water	3	26
Clay	8	34
Clay, sandy	58	92
Clay and sand; water rose to 8 ft	1	93
Clay and sand	30	123
Clay, sand, and gravel; water	3	126
Clay and sand	30	156
Clay	33	189
Gravel, cemented	11	200
Clay	5	205
Gravel, cemented	10	215
Clay	33	248
Gravel, cemented	8	256
Clay	2	258
Gravel, cemented	19	277
Clay	29	306
Gravel, cemented	20	326
Clay	7	333
Gravel	4	337
Clay	13	350
Gravel	6	356
Clay	28	384
Clay and gravel	3	387
Clay	23	410
Gravel	12	422
Clay	37	459
Gravel	8	467
Clay	9	476
Gravel	6	482
Clay and gravel	21	503
Gravel	17	520
Clay	6	526
Gravel	7	533
Clay	15	548
Gravel	5	553
Clay	4	557
Gravel	4	561
Clay	29	590
Gravel	5	595
Clay	28	623
Gravel	13	636
Clay	34	670
Gravel	12	682
Clay	2	684
Gravel	13	697
Clay	7	704
Gravel	21	725
Clay	23	748

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*—Continued

45/33-26B1

B. T. Rocca. Drilled irrigation well; 16-in. casing to 288 ft; perforated 153 to 283 ft with ½- by 2-in. slots. First water at 110 ft; static level reported at 79 ft. Drilled by William R. Flynn, Sutter, Calif. Completed Oct. 10, 1958]

Material	Thickness (feet)	Depth (feet)
Topsoil	55	55
Gravel	145	195
Hard material	30	225
Gravel, small	12	237
Hard material	9	246
Gravel, small	16	262
Gravel, large	24	286
Gravel, cemented	61	347
Gravel	17	364
Gravel, cemented	8	372
Hard material	19	391
Gravel	8	399
Gravel, cemented	23	422
Gravel and clay	25	447
Gravel, cemented	12	459
Hard material	5	464
Gravel	9	473
Gravel and clay	22	495
Gravel	6	501
Gravel and clay	11	512
Gravel, cemented	9	521
Gravel	11	532
Gravel and clay	53	585
Gravel	12	597
Clay	4	601

45/33-36B1

[Grace Harwood. Drilled unused well; 16-in. casing to 255 ft; perforated 147 to 237 ft with ½- by 2-in. slots. First water at 60 ft; static level reported at 42 ft. Drilled by H. A. Sevey, Vale, Oreg. Completed Sept. 24, 1959]

Clay	60	60
Sand, fine	60	120
Gravel	75	195
Clay, sandy	45	240
Gravel	15	255
Gravel and clay	135	390
Gravel, coarse	10	400

46/33-23B1

[John C. Harly. Drilled irrigation well; 16-in. casing to 318 ft; 14-in. to 365 ft; perforated 235 to 312 ft. First water at 105 ft; static level reported at 60 ft. Pumped 1,250 gpm from 165 ft. Drilled by William R. Flynn, Sutter, Calif. Completed March 1959]

Topsoil	8	8
Gravel	35	43
Clay, yellow	62	105
Clay and gravel; water	6	111

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*—Continued

46/33-23B1—Continued

Material	Thickness (feet)	Depth (feet)
Clay	56	167
Gravel and clay; water	6	173
Clay	38	211
Hard material	4	215
Clay	19	234
Gravel	5	239
Hard material	5	244
Gravel	13	257
Gravel and clay	16	273
Hard material	9	282
Gravel and clay	15	297
Gravel	18	315
Clay	6	321
Gravel	5	326
Hard material	1	327
Gravel	4	331
Hard material	2	333
"Solid layer"	3	336
Clay, yellow	5	341
Hard material	64	405
Hard material and clay	3	408
Hard material	6	414
"Rock" and yellow clay	38	452
Gravel and hard material	18	470
Gravel and clay	43	513
Clay, yellow	13	526
Hard material	12	538
Gravel and clay	48	586
Hard material	8	594
Clay, yellow	4	598
Gravel	11	609
Gravel and clay	26	635
Hard material	12	647
Gravel and clay	3	650
Hard material	13	663
Gravel and clay	7	670

46/33-27A1

[Jane Steckle. Drilled unused well; 18-in. casing to 198 ft.; 16-in. 196 to 400 ft.; perforated 125 to 364 ft. with ¼- by 3-in. mills perforations and ¼- by 1½-in. factory perforations. First water at 29 ft.; static level reported at 34 ft. Drilled by Chet Weaver, Orovada, Nev. Completed Dec. 14, 1957]

Material	Thickness (feet)	Depth (feet)
Topsoil	8	8
Sand and gravel; water	24	32
Clay, yellow, and gravel	62	94
Sand and gravel	100	194
Clay, yellow	10	204
Sand and gravel	136	340
Clay, yellow	10	350
Gravel and sand	30	380
Clay, yellow	5	385
Gravel and sand	15	400
Deepened to 800 ft. No log available, but material reportedly is largely clay, gravel, and cobbles.		

TABLE 4.—*Drillers' logs of wells in Kings River Valley, Humboldt County, Nev.*—Continued

46/33-36B1

[Nora Cunningham. Drilled irrigation well; 16-in. casing to 336 ft; 14-in. to 500 ft; perforated 150 to 306 ft with ½- by 2-in. slots. First water at 72 ft; static level reported at 55 ft. Drilled by Armstrong Bros., Marysville, Calif. Completed Sept. 16, 1958]

Material	Thickness (feet)	Depth (feet)
Clay	32	32
Gravel and clay	40	72
Sand	6	78
Clay and gravel	42	120
Clay	54	174
Gravel, cemented	19	193
Clay	30	223
Clay, hard	30	253
Clay	17	270
Clay, hard	10	280
Clay, sandy	10	290
Clay	10	300
Sand	9	309
Clay	3	312
Sand	8	320
Gravel, cemented	10	330
Sand and gravel	6	336
Clay	6	342
Gravel, cemented	3	345
Clay	25	370
Gravel, cemented	10	380
Gravel and clay	10	390
Clay	15	405
Sand and gravel	5	410
Gravel and clay	20	430
Clay	10	440
Sand and gravel	15	445
Clay	12	457
Clay, hard	8	465
Gravel and clay	18	483
Clay	6	489
Clay and gravel	6	505
Sand and gravel	5	510
Clay, sticky	7	517
Gravel and clay	28	545
Sand and gravel	11	556
Gravel and clay	4	560
Clay	15	575
Sand and gravel	5	580

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