STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City

View of the north end of Grass Valley. The Sonoma Range is in the background.

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES

REPORT 29

A BRIEF APPRAISAL OF THE GROUND-WATER RESOURCES OF THE GRASS VALLEY AREA, HUMBOLDT AND PERSHING COUNTIES, NEVADA

By
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Geologist

Price $1.00

Prepared Cooperatively by the
Geological Survey, U.S. Department of Interior

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October

1964

FOREWORD

The program of reconnaissance ground-water resources surveys, of which this is the 29th report, was authorized by the 1960 Legislature to be carried on by the Department of Conservation and Natural Resources in cooperation with the U. S. Geological Survey. These two reports, together with two reports in manuscript form, cover 50 of the 70 or more valleys or areas which are scheduled for study under this program.

This report, entitled, "A Brief Appraisal of the Grass Valley Area, Humboldt and Pershing Counties, Nevada", was prepared by Philip Cohen, geologist with the U. S. Geological Survey.

These reconnaissance ground-water resources surveys make available pertinent information of great and immediate value to many State and Federal agencies. As development takes place in any area, demands for more detailed information will arise, and studies to supply such information will be undertaken. In the meantime, these reconnaissance-type studies are timely and adequately meet the immediate needs for information on the ground-water resources of the areas covered by the reports.

Elmo J. DeRicco
Director
Department of Conservation
and Natural Resources

October, 1964

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A BRIEF APPRAISAL OF THE GROUND-WATER RESOURCES OF THE GRASS VALLEY AREA, HUMBOLDT AND PERSHING COUNTIES, NEVADA

by

Philip Cohen

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SUMMARY

Grass Valley is a north-trending structural trough bordered by fault-block mountains; it is in the Great Basin section of the Basin and Range physiographic province. The valley is in north-central Nevada, and comprises an area of about 520 square miles. It drains northward into the Humboldt River valley--both on the land surface and in the subsurface.

The climate of the project area ranges from arid in the valley lowlands to subhumid in the mountains. Precipitation within the drainage basin of the valley is the ultimate source of practically all the ground water. The unconsolidated deposits of the valley fill and possibly a few interbedded basalt flows store and transmit most of the economically recoverable ground water. The unconsolidated deposits, which range in age from Miocene or Pliocene to Recent, consist mainly of fluviatile and lacustrine strata that range from highly permeable stringers of sand and gravel to moderately impermeable beds of silt and silty clay. Most of the deposits of the valley fill, which attain a maximum thickness of at least several thousand feet, are structurally deformed as are the consolidated rocks of the bordering mountain ranges.

The estimates of average annual natural recharge to and discharge from the ground-water reservoir of Grass Valley are about 12,000 to 13,000 acre-feet. Most of the recharge is derived from the infiltration of snowmelt runoff from the Sonoma Range and occurs principally on the alluvial apron bordering that range. From there, the ground water moves westward and northwestward toward the valley lowlands where part of it, an average of about 7,000 acre-feet per year, is discharged by evapotranspirasion. The remainder, an average of about 6,000 acre-feet per year, moves generally northward and discharges into the Humboldt River valley.

A large amount of ground water is in storage in the valley fill of Grass Valley--about 1.5 million acre-feet in the uppermost 100 feet of saturated material. All the ground water sampled in the valley is of good to excellent chemical quality and is suitable for agricultural and domestic use.

The study described in this report was undertaken and completed in the spring of 1964, and mainly was limited to an analysis of the available data rather than extensive additional field work. It was made under the direction of G. F. Worts, Jr., district chief in charge of hydrologic studies by the U.S. Geological Survey in Nevada.

Location and General Geographic Features:

In this report the phrase "Grass Valley area" is used to designate the entire area shown on plate 1; it comprises all of Grass Valley plus an approximately 25-mile long reach of the Humboldt River valley that borders and is continuous with the northern part of Grass Valley. To facilitate a quantitative analysis of the ground-water hydrology, the northern margin of Grass Valley is defined in this report by the heavy dashed line shown on plate 1. This line coincides with a segment of the southern margin of the "storage units" in the Humboldt River valley as defined by the writer in previous reports (Cohen, 1964, and Cohen, 1963b). Topographic drainage divides comprise the east, south, and west margins of Grass Valley.

As defined in the foregoing paragraph, Grass Valley is the northwest-trending topographic trough bordered on the north by the storage units in the Humboldt River valley, on the east by the crests of the Sonoma and Tobin Ranges, on the south by an alluvial divide and the crests of the East Range and the Goldbank Hills, and on the west by the crest of the East Range. Grass Valley, which is in Humboldt and Pershing Counties in north-central Nevada, is approximately enclosed by lines of latitude 40°30' N., and 41°00' N., and longitude 117°30' W. and 117°55' W. (fig. 1). It is about 30 miles in length, averages about 15 miles in width, and has an area of about 520 square miles.

U.S. Highway 40, which roughly follows the course of the Humboldt River, crosses the northern part of the project area and provides the principal access. A graded south-trending road along the east side of the valley provides the principal access to Grass Valley. In addition, numerous unimproved trails and dirt roads cross the valley.

Winnemucca, which formerly was the center of a thriving mining industry, is the only community within the project area; it had a population of about 3,500 in 1960. At present, little mining is done in the area, and farming, notably cattle raising and the production of forage crops, and the tourist business are the principal sources of income.

Previous Work:

Many published and unpublished reports have been prepared describing the hydrology, geology, and other physical features of parts of the project area. Only those reports of historic interest and those used in the preparation of this report are described in the following paragraphs.

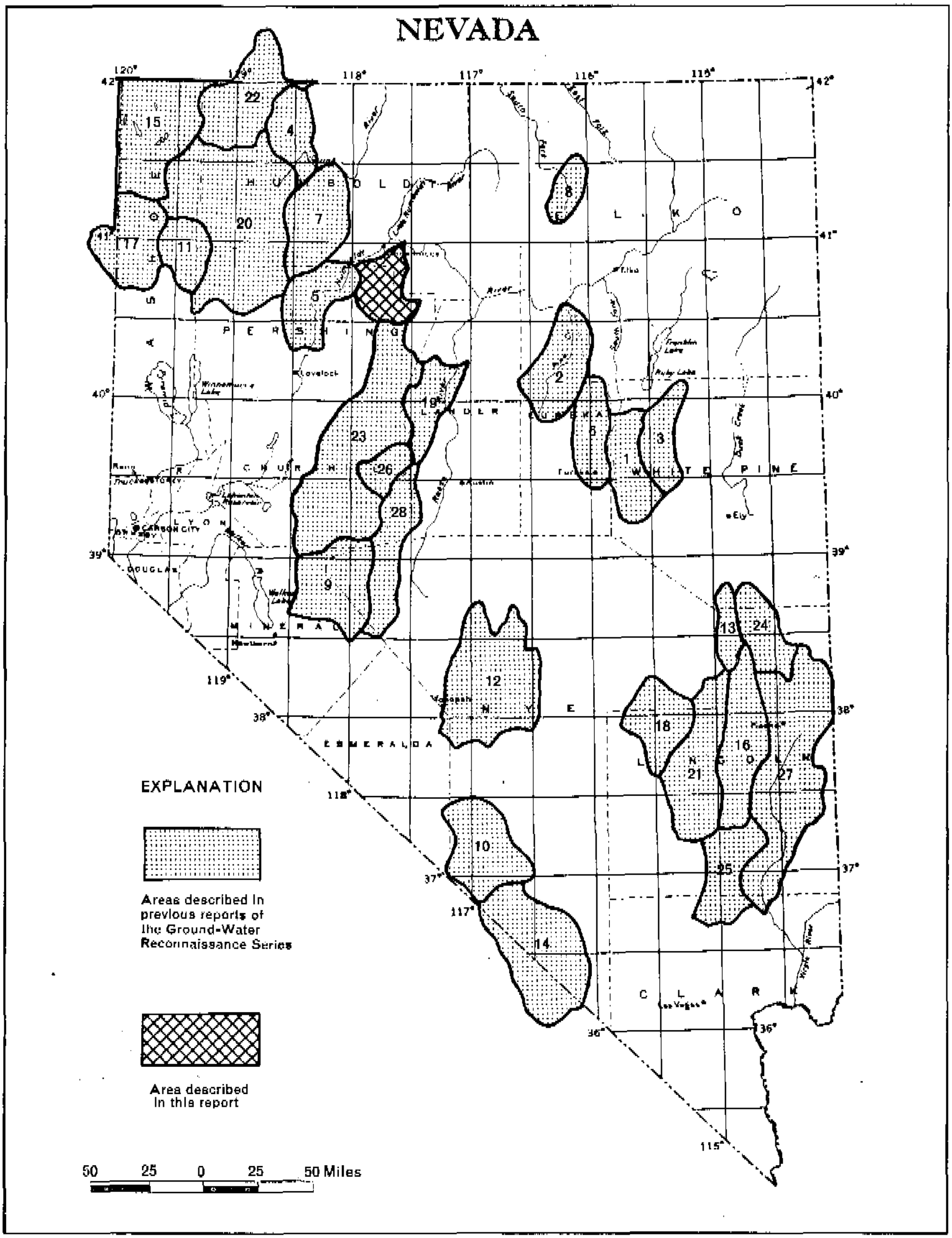

Figure 1. MAP OF NEVADA
showing areas described in previous reports
of the Ground-Water Reconnaissance Series
and the area described in this report

The geology of the northern part of the project area first was investigated by King (1878). Subsequently, Russell (1883 and 1885) described the geology of the Lake Lahontan deposits in Nevada, including those exposed in the Grass Valley area. Ferguson, Muller, and Roberts (1951) and Ferguson, Roberts, and Muller (1952) mapped the geology of the project area and vicinity with special emphasis on the stratigraphy and structure of the consolidated rocks. A reconnaissance geologic map of Humboldt County, which includes the northern part of Grass Valley, was prepared by Willden (1961).

The ground-water geology and hydrology of the Grass Valley area were considered in moderate detail by Robinson, Loeltz, and Phoenix (1949). In addition, several reports regarding the geology and hydrology of the northern part of the Grass Valley area have been published as a result of the Humboldt River Research Project. These include the results of geophysical studies by Dudley and McGinnis (1962), McGinnis and Dudley (1964), and Cartwright, Swinderman, and Gimlett (1964); the results of hydrogeologic studies by Bredehoeft (1963); and analyses of several aspects of the hydrology by Cohen (1961a, b, and c; 1962a, b, c, and d; 1963a and b; and 1964).

Unpublished reports or reports in process of publication as of June 1964, prepared as a result of the Humboldt River Research Project, include a summary of the hydrology of the area by Cohen (in review) and five graduate-school theses by G. M. Wilson (1960), Onuschak (1960), Cartwright (1961), Hawley (1962), and W. E. Wilson (1962).

Acknowledgments:

The writer is grateful for the cooperation and assistance of many of the residents of the Grass Valley area who permitted access to their property and who supplied data regarding wells, springs, and irrigated acreage. Personnel of the U. S. Department of Agriculture supplied valuable information regarding pumpage and irrigated acreage.

Numbering of Wells and Springs:

Numbers assigned to wells and springs in this report are based on the rectangular subdivisions of the public lands referenced to the Mount Diablo base line and meridian. Each number consists of three units; the first is the township north of the base line. The second unit, separated from the first by a slant, is the range east of the meridian. The third unit, separated from the second by a dash, designates the section number which, in turn, is followed by a letter that indicates the quarter section; the letters a, b, c, and d designating the northeast, northwest, southeast, and southwest quarters, respectively. Following the letter, a number indicates the order in which the well or spring was recorded within the 160-acre tract. For example, well 35/37-11c1 is the first well recorded in the southwest quarter of sec. 11, T. 35 N., R. 37 E., Mount Diablo base line and meridian.

Because of the limitation of space, wells and springs are identified on plate 1 only by the section number, quarter-section letter, and the number indicating the order in which the well or spring was located. Township and range numbers are shown along the margins of the plate.

CLIMATE

The climate of the Grass Valley area is controlled mainly by the Sierra Nevada, about 100 miles to the west, and by the prevailing eastward flow of air. Warm, moist air masses moving eastward from the Pacific Ocean are forced aloft by the Sierra Nevada causing large amounts of precipitation in the mountains. As a result, the air masses moving across the Grass Valley area normally have a low moisture content. This, in turn, causes the climate of the valley lowlands of the project area to be arid to semiarid. Orographic effects similar to those of the Sierra Nevada but of a lesser magnitude cause the climate of the mountains of the project area to be subhumid.

Climatological data have been obtained by the U. S. Weather Bureau at and near Winnemucca since 1870. The weather station was in Winnemucca prior to 1948; in 1948 it was moved to the Winnemucca Municipal Airport, about 6 miles southwest of the city. Some of the pertinent climatological data collected at the Winnemucca weather station are summarized in table 1. For the period 1871-1962, average annual precipitation was 8.40 inches. Most of the precipitation on the valley lowlands occurs as snow in the winter and as rain from isolated but intense thunderstorms in the summer. In the mountains most of the precipitation, an average of probably more than 20 inches per year on the highest peaks of the Sonoma Range, occurs in the winter as snow.

The average daily temperature as recorded at the Winnemucca weather station is 49°F. The highest temperature of record, 108°F, occurred on July 30, 1931; the lowest temperature of record, -36°F, occurred on January 21, 1937. Extreme diurnal temperature fluctuations, commonly as much as 50°F, low relative humidity, and an abundance of sunshine further characterize the climate of the Grass Valley area.

Evaporation data have been obtained in the Winnemucca area only since the beginning of the Humboldt River Research Project in 1959. The average annual rate of evaporation cannot be estimated from these short-term data; however, data obtained in nearby areas and data given by Kohler, Nordenson, and Baker (1959) suggest that the average annual rate of evaporation from free-water surfaces in the valley lowlands is on the order of 4 feet. Accordingly, the estimated average annual rate of evaporation from free-water surfaces is nearly six times the average annual precipitation.

The length of the growing season in Grass Valley varies from year to year and from place to place within the valley. In addition, it depends on the type of crop; some crops can survive light frosts, others cannot. According to Houston (1950, p. 14), the average growing season in Grass Valley probably is about 130 days.

Table 1.--Monthly and annual precipitation and temperature data at and near Winnemucca, Nevada, 1871-1962

(from published records of the U.S. Weather Bureau)

Precipitation (in inches)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average monthly	1.05	.92	.90	.78	.88	.68	.22	.18	.36	.67	.77	.99	8.40
Maximum monthly	3.08	2.75	5.23	3.34	2.82	2.86	1.55	1.26	1.53	2.93	3.78	3.40	5.23
Minimum monthly	0	trace	0	.06	.02	0	0	0	0	0	0	trace	0
Temperature (in degrees Fahrenheit)													
Average monthly	28	34	40	47	55	62	72	69	60	48	38	30	49
Average monthly maximum	52	58	69	77	86	94	99	97	90	81	67	56	78
Average monthly minimum	-4	3	13	19	26	33	42	38	26	18	7	0	18

THE HYDROGEOLOGIC ENVIRONMENT

Many aspects of the hydrology and geology of the Grass Valley area are closely related. For example, the rate of ground-water movement and the amount of ground water in storage are closely related to the sizes and shapes of the pore spaces or openings in the rocks. Similarly, many flow characteristics of the streams in the area are dependent on geologic features, such as the shapes and gradients of the stream channels. Because of the previously described orographic effects, even the amount and distribution of precipitation are related to the geology of the area. Accordingly, before considering the quantitative aspects of the ground-water hydrology, pertinent features of the geology of the area are described briefly in the following paragraphs.

Landforms and Drainage:

Grass Valley is one of more than a hundred roughly north-trending valleys in Nevada and is in the Great Basin section of the Basin and Range physiographic province. This section of the province is called the "Great Basin" because it is a closed hydrologic unit. Precipitation within the watershed of the Great Basin is the source of all the water in the area, and evapotranspiration is virtually the sole means by which water is discharged naturally from the Great Basin.

Mountains: As is characteristic of most of the Great Basin, the mountains in the Grass Valley area are elongate, nearly north-trending, fault-block ranges. They are composed almost entirely of consolidated rocks, most of which have been moderately to intensely deformed by folding and thrust faulting. Nevertheless, the general outline of the ranges and the relief of the project area, a maximum of about 5,000 feet, are mainly the result of displacement along normal faults.

Most of the larger normal faults in the Grass Valley area dip westward. Accordingly, the western slopes of the ranges, which are deeply eroded fault scarps, commonly are steeper than the eastern slopes. The more subdued eastern slopes of the Sonoma and East Ranges are the so-called "dip slopes", and are modifications of the topography that existed prior to faulting.

Alluvial Apron: The alluvial apron is the area of intermediate slope between the steep, rugged mountains and the comparatively subdued valley lowlands; it includes two major physiographic features of hydrologic significance--alluvial fans and pediments.

Alluvial fans are cone-shaped deposits of unconsolidated material formed along the bases of the ranges. Individual fans initially were formed where streams discharged from the uplifted mountains onto the valley floor as a result of the abrupt flattening of the gradients and the consequent decrease in the carrying capacity of the stream. As the fans grew larger they eventually merged with one another forming the almost continuous apron girdling the ranges.

The overall shapes of the pediments in the Grass Valley area are similar to those of the alluvial fans; however, unlike alluvial fans, pediments are erosional features formed mainly as a result of lateral planation by streams draining the mountains. The largest and best developed pediments are along the western slope of the Sonoma Range, notably in T. 35 N., R. 38 E., and in T. 31 N., R. 39 E. In both locations the pediments are cut by moderately large fault scarps, ranging from about 20 feet in height in the southern part of the valley to slightly more than 100 feet in height in the northern part.

Valley Lowlands: In the southern two-thirds of Grass Valley, the valley floor is comprised mainly of coalescing alluvial fans that merge almost imperceptibly along the northwest-trending axis of the valley. Beginning at about the south end of T. 34 N., the valley floor flattens abruptly, until in the northern-most part of the valley it has a very gentle slope of about 3 to 4 feet per mile to the northwest.

This moderately flat area represents the former bottom of an ancient lake known as Lake Lahontan, which had a maximum altitude of about 4,400 feet (Russell, 1885). Shoreline features and deposits associated with the lake suggest that in gross aspect two deep stages and one intervening period of desiccation characterized the history of Lake Lahontan. (See Russell, 1885; Morrison, 1961; and Cohen, 1962c and 1963b). Beaches, bars, and wave-cut terraces and scarps associated with the lake occur at altitudes ranging from about 4,260 to 4,400 feet, and are best developed along the northwest margin of the Sonoma Range.

Streams: The Humboldt River is the largest stream in the project area. It heads near the eastern border of Nevada and flows westward and southwestward for nearly 300 miles before discharging into the Humboldt Sink, a playa in west-central Nevada.

In the project area, the Humboldt River is a sluggish and meandering stream during most of the year; however, in the spring and early summer during periods of high streamflow, it actively erodes its channel, scours deep floodflow channels, and cuts off meander loops. The average gradient of the river is about 1.7 feet per mile; that of the flood plain is nearly 3.5 feet per mile. The depth of the channel averages about 8 feet and ranges from about 6 to 15 feet; its width averages about 80 feet and ranges from about 40 to 150 feet.

The course of the Humboldt River is oblique to the roughly northtrending regional structure. Accordingly, it is presumed that the river is an antecedent stream, having eroded its channel about as rapidly as the fault-block ranges were uplifted.

The smaller streams in the area head in the mountains bordering Grass Valley; most of them drain radially towards the axis of Grass Valley, and thence northwestward along the axis toward the Humboldt River. Nearly all these streams locally are perennial in the mountains; however, all are ephemeral on the alluvial apron and on the valley floor, and they rarely discharge into the Humboldt River even during periods of intense flooding.

Lithology and Water-Bearing Properties of the Rocks:

In previous reports, the rocks in the Grass Valley area have been subdivided into more than 30 units (Ferguson, Muller, and Roberts, 1951; Cohen, 1963b; and Hawley and Wilson, 1964). However, in this report they are subdivided into four major units: consolidated rocks, older alluvium, intermediate alluvium, and younger alluvium. The latter three units are collectively termed "valley fill".

Consolidated Rocks: The consolidated rocks range in age from Paleozoic to Cenozoic, and include most common types of sedimentary and igneous rock. The Paleozoic rocks, which are best exposed in the Sonoma Range and in the southern two-thirds of the East Range, range in age from Early Cambrian to Permian, and have an aggregate thickness of nearly 60,000 feet. They are comprised mainly of sedimentary rocks, notably sandstone and limestone. Locally, the older Paleozoic rocks have been metamorphosed to slate, phyllite, and schist. In addition, the younger Paleozoic rocks (those of Permian age) locally are comprised mainly of volcanic rocks, such as rhyolite and trachyte lava flows, breccia, tuff, and andesite.

Most of the consolidated rocks of Mesozoic age are exposed in the northern part of the East Range where they attain an aggregate thickness of at least 10,000 feet. Most of these rocks are of sedimentary origin and are comprised mainly of shale, sandstone, and limestone, in decreasing order of abundance. The youngest Mesozoic rocks are of igneous origin and include granite, granodiorite, quartz monzonite, and diorite. These rocks are of unknown thickness and are best exposed in the central part of the Sonoma Range and in the southern part of the East Range.

Practically all the consolidated rocks of Cenozoic age are of igneous origin; they include rhyolitic lava flows and associated tuff and andesite of Tertiary age, basalt flows of Tertiary or Quaternary age, and spring sinter of Quaternary age.

Most of the rocks of Paleozoic and Mesozoic age have little or no interstitial porosity and permeability and, accordingly, they store and transmit negligible quantities of ground water. Locally, however, small to moderate amounts of water are stored and transmitted through fractures and solution openings, especially in the limestone. The Tertiary volcanic lava flows are moderately deformed and mainly are barriers to the movement of water. The younger basalt flows of Tertiary or Quaternary age are less deformed than the older volcanic rocks and locally form distinct topographic forms known as flatirons or louderbacks. Inasmuch as the basalt was formed from a cooling liquid, it has little or no interstitial porosity or permeability. However, moderately large quantities of water probably are transmitted through porous and permeable zones between lava flows. Both wells, 36/38-2b1 and 36/38-19d1, reportedly tap basalt flows (table 9). The latter well reportedly flows at a rate of 300 gpm (gallons per minute) and is one of four wells used to supply municipal water to the city of Winnemucca.

Valley Fill: The oldest unit of the valley fill, the older alluvium, ranges in age from Miocene or Pliocene to Pleistocene. The oldest strata of this unit include conglomerate, sandstone, and siltstone and lesser amounts of limestone, marl, and tuff. These strata are structurally deformed and deeply eroded and locally are highly metamorphosed and silicified. Accordingly, they are of low permeability and probably store and transmit only small amounts of water.

Also included in the older alluvium are thousands of feet of unconsolidated strata comprised largely of silt, sand, and gravel that were deposited mainly as alluvial fans along the margins of the valley and as stream-channel and lake deposits in the valley lowlands. These deposits also are moderately deformed and locally are partly cemented by calcium bicarbonate. For the most part, however, they are highly porous and are moderately to highly permeable.

The younger strata of the older alluvium comprise the principal aquifers or water-bearing deposits in Grass Valley. Wells that tap well-sorted sand and gravel strata of the older alluvium, such as 35/37-13d1 and 35/37-25b1, yield more than 1,000 gpm.

The intermediate alluvium was deposited around the margins of and within Lake Lahontan. It is comprised of at least five recognizable sub-units (Cohen 1963b, table 3); however, only two, the medial gravel and the upper silt and clay sub-units, are of hydrologic significance in the Grass Valley area.

The medial gravel sub-unit is recognized almost entirely in the subsurface. It attains a maximum thickness of about 100 feet beneath the channel of the Humboldt River, and thins markedly both northward and southward from the river. Accordingly, the maximum thickness of the sub-unit in Grass Valley is less than 10 feet. In the northern part of the project area the medial gravel sub-unit stores and transmits large amounts of water; its estimated average field coefficient of permeability (the ability to transmit water at the prevailing water temperature through 1 square foot of material under a unit hydraulic gradient) is 5,000 gpd/ft^2 (gallons per day per square foot). (See Cohen 1963b, p. 32-34).

The upper silt and clay sub-unit comprises almost all of the intermediate alluvium exposed at land surface. It consists mainly of alternating beds of silt and silty clay, and attains a maximum thickness of nearly 60 feet along the axis of Grass Valley. This sub-unit, which was deposited in the second and most recent deep stage of Lake Lahontan, stores moderately large quantities of water; however, because the sub-unit is fine-grained, it transmits only small quantities of water and yields negligible amounts to wells.

The third major unit of the valley fill, the younger alluvium, is of Recent age and includes the flood-plain and terrace deposits of the Humboldt River (not shown on plate 1), stream-channel deposits, and alluvial-fan deposits. Most of these deposits in Grass Valley probably are less than 50 to 100 feet thick. Moreover, most of them are above the zone of saturation and, accordingly, contain no ground water. Where saturated, their texture and water-bearing character range from highly permeable stringers of sand and gravel to lenses and layers of silt and clay of very low permeability.

Mainly as a result of displacement along normal faults but partly because of erosion, the bedrock surfaces underlying and bordering the deposits of the valley fill are highly irregular. Accordingly, the range in thickness of these deposits is considerable. Along the axis of Grass Valley, the valley fill is at least several thousand feet thick; however, along the margins of the basin where unconsolidated deposits overlap the consolidated rocks of the mountains, these deposits thin to a feather edge.

Geologic Structure:

Grass Valley is a north-trending structural depression bordered by two structural highs, the Sonoma Range and its southward extension, the Tobin Range on the east, and the East Range on the west. The rocks of the mountains, which largely impede the movement of ground water, are tightly folded and are broken by low-angle thrust faults. In addition, these rocks, the younger Tertiary and Quaternary (?) consolidated rocks, and most of the deposits of the valley fill are cut by roughly north-trending, high-angle normal faults. Displacement and warping associated with movement along normal faults has resulted in the relative depression of the valley floor and the relative uplift of the bordering mountains. The term "relative" is used because it is uncertain to what extent the mountains were uplifted and the valleys were depressed with respect to each other.

As previously noted, joints and other fractures formed as a result of movement along faults allow water to move through some of the otherwise impermeable rocks. In addition, many of the solution openings, which locally store and transmit ground water through the carbonate rocks, were formed along fractures related to faulting.

Primary and secondary structures in the unconsolidated deposits of the valley fill significantly affect the movement and storage of ground water. Bedding probably is one of the most significant of these structures. Where strata of different lithology overlie one another, there normally are marked changes in hydraulic properties, notably porosity and permeability. For example, the irregular bedding surface that forms the contact between the medial gravel and the upper silt and clay subunits is an example of a market lithologic and hydrologic discontinuity.

The upper silt and clay subunit and other fine-grained lacustrine strata beneath the subunit contain secondary accretionary structures formed largely by chemical precipitation. These include nodules and layers of calcium carbonate, rosettes of calcium sulfate, and calcium carbonate root fillings. These structures decrease the porosity and permeability of the fine-grained strata.

<u>Geologic History:</u>

For the most part, the following brief summary of the geologic history of the Grass Valley area is adapted from a report prepared as a result of the Humboldt River Research Project (Cohen 1963b, p. 34-35).

1. Deposition of marine strata and lesser amounts of volcanic rocks during early and middle Paleozoic time.

2. Orogenic deformation characterized by tight folding and thrust faulting in early Pennsylvanian and again in Permian time.

3. Deposition mainly of marine strata in early Mesozoic time.

4. Orogenic deformation in middle and late Mesozoic time culminating with the emplacement of intrusive rocks, mainly of granitic composition, in Jurassic (?) time.

5. Volcanism and epirogenic deformation characterized by gentle warping and normal faulting in early Tertiary time.

6. Continued normal faulting, with possible vertical displacement of 5,000 feet or more, outlining the present gross topographic features including the Humboldt River drainage system.

7. Continued deposition of the older alluvium in late Pliocene and early and middle Pleistocene time, accompanied by intermittent normal faulting and volcanism.

8. Inundation of the valley lowlands in late Pleistocene time by Lake Lahontan. Deposition of the intermediate alluvium.

9. Desiccation of Lake Lahontan at the end of the Pleistocene Epoch. Entrenchment of the Humboldt River in response to the lowering of the level of Lake Lahontan. Deposition of the younger alluvium, accompanied by continued intermittent normal faulting.

SURFACE-WATER HYDROLOGY OF THE NORTH END OF GRASS VALLEY

The surface-water hydrology of the north end of Grass Valley and the adjoining segment of the Humboldt River valley is closely related to the ground-water resources of the study area. Cohen (1963b, p. 64-65) has demonstrated that the gain in the flow of the Humboldt River opposite the mouth of Grass Valley is mainly the result of ground-water outflow from Grass Valley. Thus, the magnitude, time distribution, and characteristics of the flow of the Humboldt River are pertinent elements in the quantitative evaluation of the ground-water resources of the study area. The material presented in the following paragraphs is taken in large part from a report by Hanson (1963, p. 39-57).

Humboldt River:

In 1962, the flow of the Humboldt River was measured at two gaging stations established by the U. S. Geological Survey in the project area. These are designated formally, "Humboldt River near Winnemucca" and "Humboldt River near Rose Creek", and in this report are referred to as the Winnemucca and Rose Creek gaging stations. They are in the NE 1/4 sec. 17, T. 36 N., R. 38 E., and in the NW 1/4 sec. 36, T. 35 N., R. 35 E., respectively. Streamflow records have been obtained at the Rose Creek gaging station since April 1948 and at the Winnemucca gaging station for the period October 1960-November 1963.

Long-Term Flow Characteristics:

Although streamflow data have been obtained at the Rose Creek gaging station only since 1948, correlation of these data with data obtained intermittently since 1895 at the Comus gaging station (about 22 miles east of Winnemucca) indicate that the short-term data obtained at the Rose Creek gaging station are reasonably representative of long-term flow characteristics of the Humboldt River.

As shown in table 2, the annual flow at the Rose Creek gaging station in water years 1949-62 ranged from a high of 535,800 acre-feet in water year 1952 to a low of 21,840 acre-feet in water year 1955. Accordingly, the maximum annual flow was nearly 25 times greater than the minimum. Inasmuch as there are no major upstream storage facilities on the river, the extreme range in annual streamflow mainly reflects yearly climatic variations.

Table 2. -- Yearly streamflow of the Humboldt River at the Rose Creek gaging station, water years 1949-62

Water Year	Streamflow (acre-feet)
1949	118,500
1950	135,000
1951	232,700
1952	535,800
1953	120,100
1954	44,270
1955	21,840
1956	197,200
1957	180,800
1958	243,200
1959	42,650
1960	36,290
1961	24,670
1962	242,900
Average	155,400

Seasonal and Short-Term Flow Characteristics: As shown in table 3, the flow at the Rose Creek gaging station at the beginning of the water year normally is the lowest of the year. (The water year is defined as the 12-month period beginning October 1 and ending September 30). From November through January the flow increases gradually as the weather turns cold, causing native plants to consume less water and causing evaporation to decrease. The flow commonly increases in February and March because of winter storms. In April the flow normally increases markedly as the weather begins to turn warm and as the snowpack that accumulated during the previous winter begins to melt; the spring snowmelt runoff usually reaches a peak in May. The snowpack commonly is almost entirely depleted by the end of June, causing the flow of the river to decrease markedly. It continues to decrease until the end of the water year.

Monthly streamflow in an individual year may differ significantly from the averages listed in table 3 mainly as a result of extreme climatic variations. For example, the flow in March 1962, about 32,000 acre-feet, was nearly ten times greater than the flow in March 1961 and about twice the average flow for March. Similarly, the flow in May 1952, about 249,000 acre-feet, was almost seven times greater than the average flow for the month and was more than the entire annual flow in each of the other years listed in table 2.

An especially pertinent feature of the flow of the Humboldt River in the project area is that during periods of low streamflow, the flow increases substantially between the Winnemucca and Rose Creek gaging stations, even though tributary streamflow very rarely discharges into this reach of the river. This feature was investigated intensively by means of periodic seepage measurements made as part of the Humboldt River Research Project. (See Hanson, 1963, p. 47-52). The results of a typical series of low-flow seepage measurements at nine stations, including the Winnemucca and Rose Creek gaging stations, are listed in table 4. As considered in a subsequent section of the report, the gain between stations and 0 and S in large part is caused by the ground-water outflow from Grass Valley.

Smaller Streams:

All of the smaller streams in the project area are dry most of the time throughout most of their lengths. Some of these streams, however, contain water during the entire year for short distances in the mountains where they receive year-round springflow. Nevertheless, even in the mountains most of the tributary streams normally flow only in the winter in response to increased rain and snow, and in the spring and early summer in response to the melting snow pack.

Very rarely does tributary streamflow discharge into the Humboldt River in the Grass Valley area. Rather, the flows evaporate, are transpired, infiltrate into the zone of aeration (the zone of unsaturated material above the water table), or percolate downward to the water table and recharge the ground-water reservoir. Even during intense summer thunderstorms or

Table 3.--Average monthly streamflow of the Humboldt River at the Rose Creek gaging station, water years 1949-62

Month	Average streamflow (acre-feet)
October	1,670
November	2,030
December	3,650
January	4,840
February	8,780
March	16,950
April	23,750
May	36,380
June	31,120
July	19,570
August	4,590
September	2,100

Table 4.--Low-flow seepage measurements along the Humboldt River between the Winnemucca and Rose Creek gaging stations, December 1961

Station letter 1/	Streamflow (CFS)	Gains (+) or loss (-) (CFS)
M (Winnemucca Station)	2.94	
		+2.13
N	5.07	
		-1.35
O	3.72	
		+ .56
P	4.28	
		+4.56
Q	8.84	
		+4.16
R	13.0	
		+1.8
S	14.8	
		- .8
T	14.0	
		- .5
U (Rose Creek Station)	13.5	

1/ See plate 1 for location of streamflow-measuring stations. Letters are consistent with those used in previously prepared reports.

periods of warm rain on frozen ground, the resulting floodflows do not reach the Humboldt River. For example, as a result of highly localized but intense thunderstorms in July 1961 an estimated peak flow of 1,320 cfs (cubic feet per second) occurred in Thomas Creek, and in August 1961 an estimated peak flow of 11,400 cfs occurred in Clear Creek near the mouth of that canyon (Hanson, 1963, p. 57). During both storms, none of the resulting stream-flow discharged into the Humboldt River.

As is described in the following section of the report, the infiltration of tributary streamflow is the source of most of the ground-water recharge in Grass Valley.

GROUND-WATER HYDROLOGY

Source:

Practically all the ground water in Grass Valley is derived from precipitation within the margins of the valley. Most of the deposits at land surface in the valley lowlands are fine grained and, therefore, have a high field capacity (the ability to retain moisture against the downward pull of gravity). Moreover, precipitation on the valley lowlands commonly occurs as scattered and infrequent showers. Accordingly, most of this water merely moistens the upper few inches of the zone of aeration from where it untimately is lost by evapotranspiration.

Nearly all the ground water in Grass Valley is derived from the infiltration of tributary streamflow, most of which, in turn, is derived from melting of the snowpack that accumulates during the winter. Some of this streamflow infiltrates into cracks or other openings in the consolidated rocks of the mountains and thence moves downgradient into the deposits of the valley fill. In addition, substantial quantities of ground-water recharge also result from the infiltration of tributary streamflow as it crosses the alluvial apron. Seepage measurements by Hanson (1963, p. 40) indicate that streamflow in the Grass Valley area normally decreases progressively downslope on the alluvial apron. Some of this decrease in flow, especially in the spring and summer, results from evapotranspiration. However, most of the streamflow that infiltrates into the unconsolidated deposits in excess of the field capacity of these deposits ultimately percolates downward to the water table and recharges the ground-water reservoir.

Occurrence:

Nearly all the ground water of economic significance in Grass Valley is in the pore spaces of the unconsolidated deposits of the valley fill. As previously noted, the Tertiary or Quaternary basalt flows locally yield moderately large quantities of water to several wells in the Humboldt River valley immediately north of Grass Valley. However, to date (1964) no wells in Grass Valley are known to have penetrated basalt.

The more significant water-bearing properties of the deposits of the valley fill, the porosity and permeability, largely are related to the sizes and shapes of the particles and to the degree of compaction and cementation of the material. All other factors being equal, coarse-grained materials have the greatest permeabilities, and well-sorted materials have the most numerous pore spaces. For example, although the upper silt and clay subunit is highly porous and contains a large amount of ground water, it has a low permeability and, therefore, yields little water to wells. Inasmuch as the medial gravel subunit is less than 10 feet thick in Grass Valley, the most productive aquifers in the valley (those that yield water most readily to wells) are lenses of sand and gravel deposited by the streams draining the Sonoma Range, especially by the larger streams, such as Clear and Thomas Creeks and the stream in Sonoma Canyon.

Ground water in Grass Valley occurs under both artesian (confined) and water-table (unconfined) conditions. Artesian conditions are present mainly as a result of the occurrence in the valley fill of alternating layers of fine and coarse-grained material of differing permeabilities. For example, water levels in wells in the northern part of the valley that tap the medial gravel subunit (within which ground water is confined by the upper silt and clay subunit) respond rapidly, within a few hours to a few days, to changes in the stage of the Humboldt River (Cohen, 1963b, p. 76-77). Inasmuch as these wells are about 5 miles from the river, they could not respond so rapidly to a change in the stage of the river unless one or more aquifers tapped by the wells were confined.

Artesian heads throughout most of the valley are insufficient to cause ground-water levels to rise to or above the land surface. The water level in only one well, 33/38-14c1, is above land surface.

Movement:

Ground water moves in the direction of least hydraulic head (downgradient) from recharge areas to discharge areas. Thus, the horizontal component of the direction of ground-water movement is perpendicular to water-level contours.

The water-level contours on plate 1 show the direction of ground-water movement in the Grass Valley area in December 1962. Although the shapes of the contours change from day to day and from season to season, the contours shown on the map are reasonably representative of the over-all direction of ground-water movement in the entire project area during most of the year, normally from about late July to mid-April (Cohen, 1963b, p. 60).

In the spring and early summer, when the flow of the Humboldt River increases markedly as a result of snowmelt runoff upstream from the Grass Valley area, ground-water levels beneath the flood plain of the river rise abruptly and substantially, locally more than 8 feet, and a ground-water ridge forms along the river. However, even during such times when the shapes of the water-level contours in the Humboldt River valley differ markedly from those shown on plate 1, the shapes of the water-level contours in Grass Valley are very similar to those shown on the map. Accordingly, the general direction of ground-water movement in Grass Valley is similar to that of surface water--from the mountains toward the valley lowlands, and thence northwestward toward the Humboldt River.

Recharge:

As previously noted, precipitation within the drainage basin is the ultimate source of practically all the ground water in Grass Valley. As was done in most of the previous reports of this series, a method described by Eakin (1951) is used to obtain a preliminary estimate of the average annual recharge to the ground-water reservoir of Grass Valley. The method is based on the assumption that a fixed percentage of a given average annual rate of precipitation ultimately recharges the ground-water reservoir.

In overall aspect the average annual precipitation in Nevada is related closely to altitude and can be estimated with a reasonable degree of accuracy by assigning precipitation rates to various altitude zones (Hardman, 1936). The altitude zones in Grass Valley, the estimated average annual precipitation on these zones, the assumed percentage of recharge, and the quantity of recharge to the ground-water reservoir are listed in table 5. The estimated average annual precipitation in Grass Valley is about 250,000 acre-feet; of this amount, an estimated average of about 12,000 acre-feet per year recharges the ground-water reservoir. Thus, only about 5 percent of the total average annual precipitation ultimately recharges the ground-water reservoir of Grass Valley.

Table 5.--Estimated average annual precipitation and ground-water recharge in Grass Valley, Nevada.

Average zone (feet)	Area (acs.)	Estimated average annual precipitation: Range (inches)	Average (feet)	Average (ac. ft.)	Estimated average annual recharge: Assumed percentage of precip.	(acre-feet)
Above 8,000	3,500	more than 20	1.75	6,100	25	1,600
7,000 to 8,000	16,300	15 to 20	1.46	23,800	15	3,600
6,000 to 7,000	52,800	12 to 15	1.12	59,100	7	4,100
5,000 to 6,000	109,000	8 to 12	.83	90,500	3	2,700
Below 5,000	151,200	less than 8	.50	75,600	0	0
Total (rounded)	332,800	--	--	250,000	--	12,000

Discharge:

Natural Discharge: Prior to the development of ground water by man, all the natural ground-water discharge from Grass Valley was a result of subsurface ground-water outflow to the Humboldt River valley and evapotranspiration.

Ground-water outflow: Ground-water outflow from Grass Valley can be estimated by evaluating (a) the increase in flow of the Humboldt River in the study area for selected time intervals, and (b) the differences between the amounts of underflow moving through key sections perpendicular to the river. Most of the time some of the ground-water outflow from Grass Valley is consumed by evapotranspiration in the storage area of the Humboldt River valley, some is discharged within the storage area by evapotranspiration, some is discharged by underflow out of the storage area near the Rose Creek gaging station, and the remainder discharges into the reach of the Humboldt River between stations 0 and S (pl. 1, and Cohen, 1963b, p. 64-65).

In December of most years very little ground water in the storage area is discharged by pumping and practically none by evapotranspiration. Moreover, in water years 1960 and 1961, ground and surface water in storage remained nearly constant in the storage area. Thus, in these years almost all the ground-water outflow from Grass Valley discharged into the Humboldt River between stations 0 and S, or discharged out of the project area near the Rose Creek gaging station. In December of water year 1961 the average increase in streamflow between stations 0 and S was about 11 cfs (table 4). Accordingly, subsurface outflow from Grass Valley into the Humboldt River valley in December of water year 1961 was equal to the gain in streamflow of 11 cfs minus the difference in underflow between stations 0 and S.

At station S, in the so-called Rose Creek constriction, consolidated rocks having little or no interstitial permeability underlie the flood plain of the Humboldt River at a depth of about 50 feet as a result of movement along a normal fault that borders the western slope of the East Range and that extends northward beneath the Humboldt River (Cohen, 1962a). Accordingly, almost all the underflow parallel to the Humboldt River near station S, about 3 cfs, is through the medial gravel subunit. The estimated underflow parallel to the Humboldt River past station 0, where the cross-sectional area of the medial gravel subunit is considerably more than that at station S, is about 6 cfs (Cohen, 1963b, table 16). Accordingly, the estimated subsurface outflow from Grass Valley is 11 cfs minus 3 cfs, or about 8 cfs.

As previously noted, the shapes of the water-level contours in Grass Valley remain about the same throughout the year. Thus, ground-water outflow from the valley remains about constant. Accordingly, the estimated average annual outflow from Grass Valley is about 6,000 acre-feet per year. This estimate is less than that given by Robinson, Loeltz, and Phoenix (1949, p. 60-63), who observed that the flow of the Humboldt River increased an average of about 23 cfs between stations 0 and T in September and October, 1947. Most of the increase in flow was attributed to subsurface outflow from Grass Valley. Largely on this basis, it was presumed that the average annual subsurface outflow from Grass Valley was somewhat less than 16,700 acre-feet. This estimate is considered too large because the results of the Humboldt River Research Project indicate that the increase in the flow of the river between stations 0 and T in September and October, 1947 probably resulted not only from subsurface outflow from Grass Valley but also from the return flow of bank storage.

Evapotranspiration: Phreatophytes, plants that derive at least part and commonly most of their water supply from the zone of saturation, discharge almost all the ground water lost by evapotranspiration in Grass Valley; a small amount is discharged by evaporation from bare soil in and adjacent to areas covered by phreatophytes. The most common phreatophtes, in decreasing order of abundance, are greasewood, native grasses, rabbitbrush, and willow. The distribution of these plants is shown on plate 1. Two groups are shown, one in which greasewood is the predominant plant and the other in which the grasses are predominant.

Table 6 summarizes the estimated natural evapotranspiration losses from Grass Valley in 1962. The estimated evapotranspiration rates from areas covered by the two major vegetative types are based mainly on the work of Lee (1912), White (1932), Young and Blaney (1942), and Robinson (1963).

In 1962 the activities of man, notably the clearing of land and the development of ground water for irrigation, had not appreciably affected natural evapotranspiration losses in Grass Valley. Accordingly, the estimated long-term average annual natural evapotranspiration losses from Grass Valley is 7,000 acre-feet.

Table 6.--Estimated natural evapotranspiration of ground-water from Grass Valley, 1962

Vegetative type	Depth to water (feet)	Area (acres)	Evapotranspiration (acre-feet per acre)	Evapotranspiration acre-feet
Greasewood	10 to 55	26,035	0.2	5,200
Grasses	3 to 10	3,225	.5	1,600
Totals (rounded)	--	29,250	--	7,000

Springflow.--Numerous small springs and seeps discharge ground water in the mountains and the foothills bordering Grass Valley; most of these discharge only a few gallons per minute. Springs along the eastern margin of the valley floor, notably 31/39-33cl, 32/38-36al, and 34/38-21cl, appear to be related to a major north-trending normal fault along the base of the Sonoma Range. Spring 31/39-33cl reportedly flows at a rate that ranges from about 5 to 15 gpm and discharges water having a temperature of 52°F.

Spring 32/28-36al represents a group of spring orifices and seeps, locally known as Leach Hot Springs, that discharge from the base of a fault scarp partly covered by dense siliceous spring sinter. The temperature of the water ranges from about 140°F to 207°F. Total springflow of Leach Hot Springs reportedly ranges from a high of about 0.3 cfs in the late winter to a low of about 0.2 cfs in the summer.

Spring 34/38-21cl, the so-called Sonoma Ranch Spring, also issues from the base of a fault scarp in alluvium. The flow of the spring in the early 1940's reportedly was more than 1,000 gpm. Robinson, Loeltz, and Phoenix (1949, p. 50) report that the flow was about 350 to 450 gpm in October 1947. In the summer of 1960 it was less than 100 gpm, and in the spring of 1964 it was about 150 gpm. The water issuing from this spring has a temperature of 54°F.

It is difficult to estimate the average annual natural ground-water discharge resulting from springflow in Grass Valley. Total average annual springflow may be on the order of 2,000 acre-feet. Much of this water eventually seeps back into the ground-water reservoir; the remainder, probably a few hundred acre-feet per year, is consumed by evapotranspiration.

Total average annual natural discharge.--The estimated total average annual natural ground-water discharge from Grass Valley, including ground-water outflow to the Humboldt River valley and evapotranspiration from areas covered by phreatophytes, is about 13,000 acre-feet.

Pumpage: Robinson, Loeltz, and Phoenix (1949, p. 63) report that total ground-water pumpage in Grass Valley in 1947 was less than 200 acre-feet. Since that time ground-water development for irrigation has increased substantially. The estimated area of land irrigated with ground water in the valley in 1962 was about 1,500 acres; the estimated total pumpage during that year was about 3,000 to 4,000 acre-feet. In 1963, the area irrigated with ground water reportedly had increased to nearly 2,500 acres. Part of this land also was irrigated with streamflow, namely from Thomas and Clear Creeks. The estimated total pumpage in 1963 was about 5,000 to 6,000 acre-feet.

Not all the pumpage is discharged from the valley by evapotranspiration. Some of it infiltrates beneath the root zone of the crops and eventually percolates downward to the zone of saturation. The amount of water that returns to the ground-water reservoir in this manner depends upon many complex factors and probably ranges from a few percent in some areas to as much as 40 to 50 percent of the pumpage in others.

Ground-Water Budget:

Prior to the development of ground water by man, the ground-water system in Grass Valley was in a state of long-term dynamic equilibrium--the long-term average annual recharge equaled the long-term average annual discharge. The estimates of average annual natural recharge and discharge, as listed in previous sections of the report, are 12,000 and 13,000 acre-feet, respectively. The inequality of the independently derived values of recharge and discharge reflects inaccuracies in the values used to compute the several estimates rather than an imbalance of the system. Moreover, the near equality of the two estimates should not be construed to indicate a high order of accuracy for either or both values. Because of the limited amount of available data and because of the empirical nature of some of the assumptions used in arriving at these estimates, they are considered to be preliminary and subject to refinement.

Ground-Water in Storage:

Ground water in storage is the water in the zone of saturation that will drain by gravity when ground-water levels are lowered. It is equal to the product of the saturated thickness of the ground-water reservoir multiplied by the average specific yield of the deposits. Specific yield, expressed as a percentage, is the ratio of the volume of water that will drain by gravity to the total volume of the saturated material, multiplied by 100.

The specific yield of the material in the uppermost 100 feet of the zone of saturation probably ranges from nearly zero to more than 40 percent (Cohen 1963a, p. 19). These saturated deposits underlie an area of roughly 150,000 acres; therefore, their total volume is about 15 million acre-feet. If it is assumed that the average specific yield of the material in the uppermost 100 feet of the zone of saturation is 10 percent, then the total amount of ground water in storage therein is about 1.5 million acre-feet, or about 15,000 acre-feet for each foot of saturated thickness.

Perennial Yield:

The perennial yield of the ground-water reservoir in Grass Valley is the maximum rate at which ground water of suitable chemical quality can be removed permanently from the system without causing a continual lowering of ground-water levels and the eventual depletion of the reservoir. It is equal to the average annual natural ground-water discharge from the valley which, theoretically, is equal to the average annual recharge. The recharge and discharge estimates of 12,000 and 13,000 acre-feet, respectively, do not agree. Because the estimate of discharge is based on somewhat more reliable quantitative data, the recharge and discharge are each considered to be about 13,000 acre-feet per year. Accordingly, the estimated perennial yield of the ground-water reservoir of Grass Valley also is considered to be about 13,000 acre-feet.

The estimated pumpage in 1963 was 5,000 to 6,000 acre-feet, which is considerably less than the estimated perennial yield. As of 1964, pumping had not appreciably reduced either the natural evapotranspiration or the ground-water outflow to the Humboldt River valley.

To salvage all the natural ground-water discharge from Grass Valley and thereby develop ground water at a rate equal to the perennial yield, it would be necessary to lower water levels sufficiently, perhaps locally as much as 50 to 60 feet, to eliminate completely the natural evapotranspiration losses and the ground-water outflow from Grass Valley. Although it may be difficult to achieve in practice, theoretically natural evapotranspiration losses can be eliminated by a carefully located network of pumping wells. On the other hand, overdevelopment of ground water would cause a reversal in ground-water gradients which not only would eliminate ground-water outflow to the Humboldt River valley but eventually would induce seepage losses from the river. The economic and legal implications of this course of action are considered in the concluding section of this report.

CHEMICAL QUALITY OF THE GROUND WATER

Chemical analyses of 9 ground-water samples from Grass Valley and 31 samples from the segment of the Humboldt River valley immediately north of Grass Valley are listed in table 7. Most of these analyses were made as part of the Humboldt River Research Project. The small number of samples from Grass Valley precludes a comprehensive evaluation of the water quality of the area. However, sufficient data are available to make a preliminary generalized appraisal of the suitability of the ground water for use and to consider the chemical quality of the water and its relation to the hydrologic system.

Suitability for use:

All of the approximately 100 elements and the many thousands of compounds of these elements on and beneath the surface of the earth are, at least to some extent, soluble in water. In the small quantities in which they commonly occur, most of the dissolved substances in water are harmless to plants and animals, including man. In fact, many of these substances are necessary for proper plant and animal nutrition. In quantities only slightly higher than the optimum amounts needed, however, many of the materials found in naturally occurring water can be harmful.

Because the industrial use of ground water in the project area is negligible and because the standards for the chemical quality of water for such use are extremely variable, only the chemical suitability of the ground water for agricultural and domestic use are considered in this report.

Table 7.--Chemical analyses, in parts per million, of water from selected wells and springs in the Grass Valley area, Nevada.

(Analyses by the U. S. Geological Survey)

Location (well or spring number)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum of determined constituents)	Hardness as $CaCO_3$: calcium-magnesium	Hardness as $CaCO_3$: non-carbonate	SAR	RSC (epm)	Specific conductance (micromhos at 25°C)	pH
Wells																						
34/37-3d1	7-26-61	59	25	0.00	37	11	21	1.4	136	0	29	26	0.1	1.7	0.0	215	272	160	0.8	0.00	363	8.2
35/35-25d1	4-24-62	58	--	--	61	39	188	15	384	10	214	82	--	1.1	2.0	704	204	0	4.9	.94	1,250	8.3
35/36-13d1	4-25-62	59	--	--	84	34	167	10	352	0	107	96	--	--	.1	766	348	59	3.8	.00	1,360	7.5
35/36-15c2	4-24-62	56	--	--	56	26	71	3.6	290	0	61	34	--	--	.9	419	248	4	2.0	.00	732	7.9
35/36-19d1	4-24-62	57	--	--	91	27	90	16	164	0	280	60	--	--	.4	643	336	202	2.1	.00	1,050	7.5
35/36-24c2	7-18-61	60	30	.00	88	58	266	9	1,120	0	70	58	.2	.1	2.8	1,140	460	0	4.3	9.16	1,830	7.6
35/36-31d1	11-29-61	62	--	--	30	18	392	25	870	10	16	235	--	--	5.7	1,138	148	0	13.3	10.81	2,020	8.3
35/37-2a1	7-16-61	55	42	.03	50	16	97	11	282	18	77	52	.8	.0	.4	503	191	0	1.4	.90	805	8.4
35/37-4c2	4-25-62	--	--	--	72	14	111	8.4	364	0	79	67	--	--	.3	531	236	0	3.6	1.25	879	7.6
35/37-7d1	4-25-62	55	--	--	45	11	156	6.0	401	0	79	40	--	13	1.6	507	156	0	5.4	3.45	900	8.0
35/37-8d1	8-07-61	58	39	.00	55	11	30	2.2	204	0	41	20	.1	1.2	.3	299	181	14	1.0	.00	460	8.2
35/37-10a1	4-26-62	59	--	--	54	11	12	.8	164	0	33	21	--	--	.0	212	180	46	.4	.00	394	7.8
35/37-13c1	4-26-62	59	--	--	59	11	12	.9	178	0	48	18	--	--	.0	236	190	46	.4	.00	405	7.4
35/37-14d1	7-25-61	62	20	.00	38	16	21	1.1	170	0	38	15	.2	2.2	.1	236	162	23	.7	.00	395	8.2
35/37-15d1	11-17-50	--	44	.02	42	11	19	1.9	183	0	30	12	.3	4.2	.1	249	150	0	.7	.00	364	7.8
35/37-16b1	4-25-62	64	--	--	45	11	20	3.5	174	0	39	15	--	--	.0	220	155	26	.5	.00	329	7.6
35/37-22d1	4-26-62	57	--	--	61	17	44	6.4	252	0	40	20	--	--	.3	341	220	0	.7	.39	597	7.4
35/37-25b1	7-25-61	60	32	.00	40	15	17	2.2	175	0	30	14	.3	1.1	.0	238	162	18	.6	.00	390	9.2
35/37-26a1	4-26-62	59	--	--	30	13	21	1.8	130	0	36	16	--	--	.2	192	131	8	.8	.00	346	7.6
35/37-26a2	7-25-61	58	32	.00	40	17	20	3.1	193	0	35	14	.3	2.1	.0	258	168	10	.7	.00	406	8.1
35/37-26b1	6-16-53	58	44	.03	36	20	18	2.9	198	0	30	10	.3	2.6	.2	261	172	0	.6	.00	396	7.0
35/37-29a1	4-25-62	57	--	--	222	74	274	11	325	0	9	830	--	--	.2	1,580	860	594	4.1	.00	2,980	7.3
35/37-25b3	7-20-61	59	39	.04	102	40	192	5.2	204	0	215	325	.1	2.4	.1	1,020	420	253	3.7	.00	1,810	8.1
35/38-6b1	7-26-61	--	36	.00	38	9.5	30	1.8	133	6	39	32	.3	3.8	.1	262	134	13	1.1	.00	401	8.3
36/37-25b1	11-30-61	56	--	--	62	16	75	4.3	210	4	72	73	--	--	.4	413	220	41	2.2	.00	757	8.5
36/37-26c1	7-20-61	68	54	.00	69	19	77	6.8	347	9	91	80	.3	.0	.3	523	252	35	2.0	.00	822	8.4
36/37-30a1	7-20-61	63	68	.00	34	7.8	84	6.9	234	0	77	22	.6	2.5	.5	424	117	0	3.4	1.70	605	8.4
36/37-31a2	4-27-57	60	--	--	77	11	62	8.6	302	0	3.0	54	--	--	.4	394	236	0	1.5	.23	733	7.2
36/37-35a1	7-20-61	60	32	.02	76	15	78	6.8	392	0	74	57	.5	.0	.2	508	249	0	2.1	.69	821	7.9
36/38-2b1	7-28-61	54	48	.01	36	14	86	8.3	313	0	66	50	.6	1.4	.3	485	198	0	2.7	1.27	741	7.9
36/38-4a1	7-29-61	61	58	.00	65	19	103	8.7	342	0	86	67	.6	1.3	.3	577	240	0	2.9	.81	893	7.7
36/38-16d1	7-27-61	62	50	.00	52	11	65	6.4	260	0	48	46	.3	.8	.3	408	176	0	2.1	.74	664	8.2
36/38-19c1	11-17-50	65	44	.03	59	16	78	4.6	287	0	72	61	.8	.1	.2	477	215	0	2.3	.44	748	7.7
36/38-28b1	7-27-61	62	21	.00	142	41	30	1.5	128	0	108	233	.2	40	.0	680	525	420	.6	.00	1,310	7.9
36/38-30d1	7-26-61	73	31	.00	56	19	60	5.5	260	0	72	58	.3	.3	.4	452	218	5	1.8	.00	778	7.5
36/38-36b1	7-27-61	52	24	.00	94	21	34	2.5	245	0	151	45	.0	3.1	.2	486	321	120	.8	.00	778	7.8
Springs																						
35/36-28a1	7-18-61	82	50	.01	17	40	920	94	1,940	41	121	381	12	.8	15	2,650	207	0	27.8	30.03	4,090	8.3
35/36-28d1	7-18-61	83	73	.08	61	12	550	51	1,270	16	100	237	6	3.5	9.2	1,740	200	0	16.8	17.15	2,800	8.3
35/38-3d1	7-27-61	56	17	.00	47	13	15	.9	166	0	32	18	.3	.6	.0	226	170	34	.5	.00	374	7.5
35/39-6a1	7-27-61	53	24	.00	64	10	25	1.3	216	0	35	28	.0	1.7	.1	295	202	25	.8	.00	464	7.5

Wilcox (1955, p. 7) gives the following classification system for irrigation water based on figure 2:

C1. "Low-salinity water 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.

C2. "Medium-salinity water 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.

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

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

S1. "Low-sodium water 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 such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

S2. "Medium-sodium water 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.

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

S4. "Very high-sodium water is generally unsatisfactory for irrigation purposes except under special circumstances."

All the samples from Grass Valley had a low sodium hazard (S1); seven of the nine samples had a medium salinity hazard (C2), and the other two had a high salinity hazard (C3). Accordingly, if these samples are representative of most of the ground water in Grass Valley, some treatment of the water or the soil may be necessary in the future to alleviate difficulties resulting from the accumulation of excessive amounts of salt in the soil.

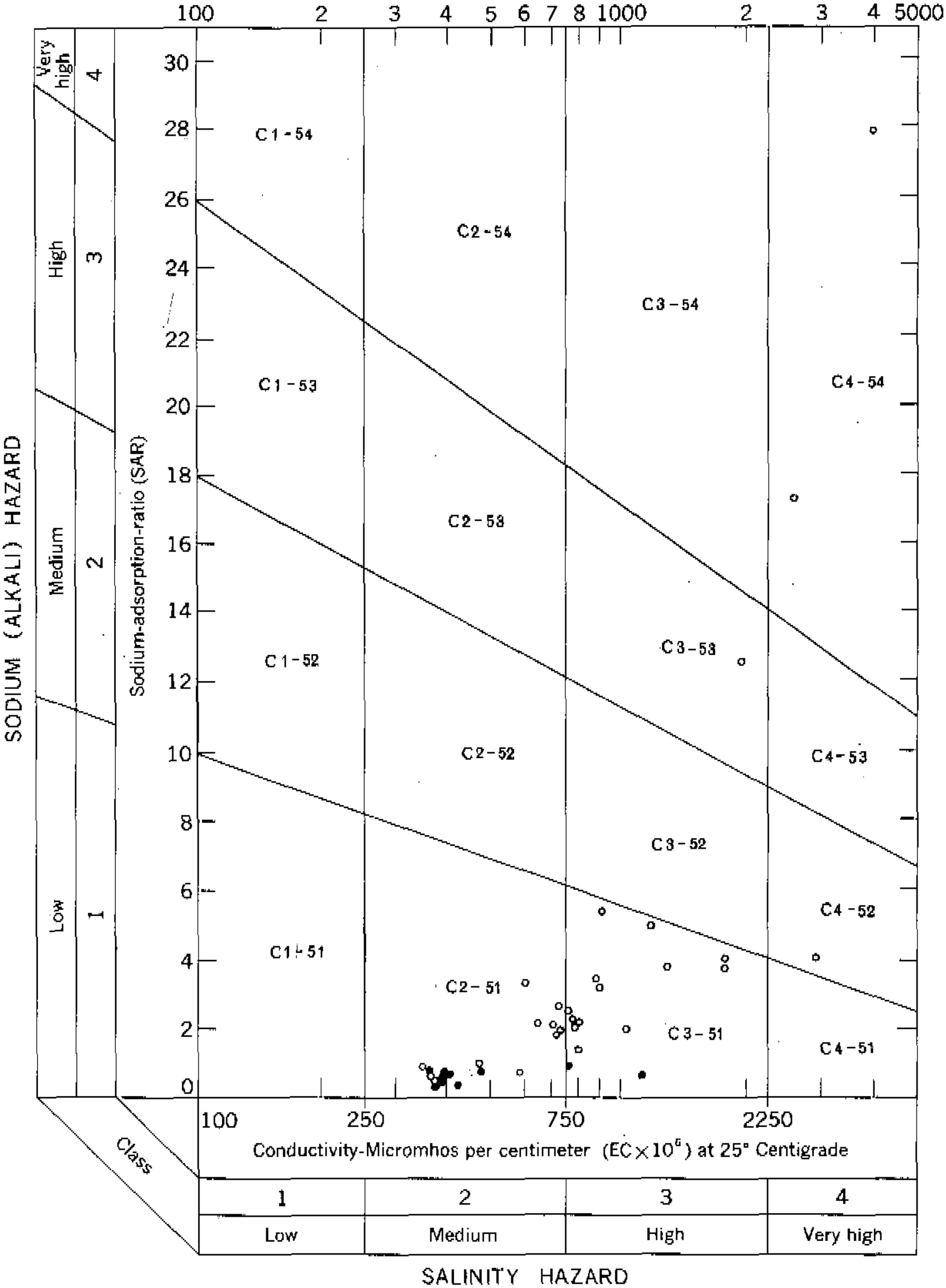

Figure 2.—Classification of irrigation water in the Grass Valley area, based on conductivity and sodium-adsorption ratio. (after U.S. Department of Agriculture, 1954) Open circles represent ground water from the Humboldt River Valley; solid circles represent ground water from Grass Valley.

Most of the samples from the Humboldt River valley immediately north of Grass Valley had both higher salinity and sodium-hazard values. In general, however, samples from wells closest to Grass Valley had characteristics similar to those from Grass Valley.

Residual sodium carbonate (RSC) is another factor that affects the chemical suitability of water for irrigation. It was defined by Eaton (1950) as:

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++}),$$

where the values are expressed in equivalents per million (epm). According to Eaton, water having an RSC value larger than 2.5 epm generally is unsuitable for irrigation because calcium and magnesium will be precipitated from the water thus causing the sodium hazard of the water to increase. Water having an RSC value of 1.25 epm to 2.5 epm is considered marginal, and water having an RSC value of less than 1.5 epm probably is safe. All the ground-water samples from Grass Valley had RSC values of zero and, accordingly, they are excellent for irrigation in this regard. The RSC values of most of the water from the Humboldt River valley north of Grass Valley was less than 1.25 epm. However, the RSC values of some of the ground water, especially the thermal water from springs 35/36-28a1 and 35/36-28d1, indicate that the water is unsuitable for irrigation.

Boron is one of the most critical constituents in irrigation water. It is essential for proper plant nutrition in small quantities but is toxic to many plants in amounts only slightly more than the needed amounts. Most of the crops raised in the area are classified by the U. S. Department of Agriculture (1954) as semitolerant and tolerant with respect to boron. The semi-tolerant crops include most small grains, potatoes, and some other vegetables. The tolerant crops include alfalfa, which is one of the important crops raised in the area. Scofield (1936) showed permissible boron concentrations for semi-tolerant and tolerant crops as follows:

Classes of water		Boron content	
Rating	Grade	Semi-tolerant crops (ppm)	Tolerant crops (ppm)
1	Excellent	less than 0.67	less than 1.00
2	Good	.67 to 1.33	1.00 to 2.00
3	Permissible	1.33 to 2.00	2.00 to 3.00
4	Doubtful	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	more than 2.50	more than 3.75

The boron content of the ground water from Grass Valley and most of the ground water from the Humboldt River valley was less than the amount that might be harmful to semi-tolerant crops. Exceptions were noted in the water from the previously described thermal springs and from wells down-gradient from the springs, where the boron content ranged from 2 ppm to 15 ppm.

Domestic Use: Although sediment and bacterial content may adversely affect the suitability of water for domestic use, these features were not studied and, accordingly, are not considered in this report. Only the chemical suitability of the water is considered.

Excessive amounts of some dissolved constituents in drinking water and in water used for cooking may be toxic or otherwise harmful to human beings. In most water-quality studies, as in this report, standards established by the U. S. Public Health Service (1962) for drinking water supplied by interstate carriers commonly are cited as standards for domestic use.

Excessive flouride may cause mottled tooth enamel in children. According to the U.S. Public Health Service (1962, p. 8), the recommended flouride concentration in drinking water is related to the mean annual air temperature-the higher the temperature the lower the permissible quantity of flouride in the water. In the Grass Valley area the recommended upper limit of flouride content in drinking water is about 1.7 ppm (parts per million); the optimum amount is 1.2 ppm, and the lower limit is 0.9 ppm. The flouride content of the samples from Grass Valley ranged from zero to 0.6 ppm. Accordingly, all these samples contained less than the minimum recommended amount of flouride. Children using this water for long periods of time presumably would not develop mottled tooth enamel nor flourosis of the bones. However, the deficiency of flouride may have other adverse affects.

Two of the samples listed in table 7, those from springs 35/36-28a1 and 35/36-28d1, contained excessive quantities of flouride, 12 ppm and 6 ppm, respectively. Accordingly, care should be exercised in attempting to develop ground water for domestic use in the vicinity of these springs.

The U. S. Public Health Service (1962, p. 7) also indicates that the chemical substances listed in table 7 should not be present in a water supply in excess of the following concentrations:

Substance	Concentration in ppm
Chloride	250
Iron	0.3
Nitrate	45
Sulfate	250
Total dissolved solids	500

Except for the sample from well 36/38-28b1, which had a dissolved-solids content of 680 ppm, all the samples from Grass Valley, and most of the samples from the Humboldt River valley contained less than the maximum permissible amounts listed above.

Excessive hardness of water, which is caused principally by calcium and magnesium, adversely affects the suitability of water for domestic use, especially for cooking and washing. The U. S. Geological Survey uses the following numerical ranges and adjective ratings for classifying water hardness:

Hardness range (ppm)	Classification
0 - 60	Soft
61 - 120.	Moderately hard
121 - 180	Hard
Greater than 181	Very hard

All the water from Grass Valley and practically all the water from the Humboldt River valley is hard or very hard. However, people in the area reportedly do not find this feature objectionable, and water softeners are not in use.

Relation of Water Quality to the Ground-Water System:

Although only limited data are available regarding the chemical quality of the ground water in Grass Valley, these data and the selected water-quality data for the Humboldt River valley that are listed in table 7 help verify some of the conclusions and interpretations regarding the ground-water system given in previous sections of this report. Specifically, the water-quality data are useful in evaluating both qualitatively and quantitatively the source and movement of ground water in Grass Valley.

All the samples from Grass Valley, except that from well 36/38-28b1, are calcium bicarbonate water having a dissolved-solids content ranging from about 220 ppm to 300 ppm. The water-level contours of plate 1 indicate that the Sonoma Range is the source of much of this water. The range is comprised largely of limestone ($CaCo_3$), and as is to be expected, the ground water moving therefrom is a calcium carbonate type.

As this water moves downgradient toward the Humboldt River, it dissolves additional material from the deposits of the ground-water reservoir. (For example, compare analyses of samples from wells 35/37-25b1 and 35/37-15d1.) In addition, locally it mixes with ground water of moderately high dissolved-solids content associated with saline flood-plain deposits of the Humboldt River. (See the analysis of the sample from well 35/36-24c2.)

As was previously noted, a fault passes beneath the flood plain of the Humboldt River near station S. The thermal water of high dissolved-solids content from springs 35/36-28a1 and 35/36-28d1 and the ground-water mound associated with the springs (pl. 1) are related to the fault (Cohen, 1962a).

In December 1961 water samples were collected from the Humboldt River at each of the streamflow measuring stations shown on plate 1. In addition, ground water from representative wells and springs was sampled. As the flow of the river changed from station to station (table 4), the water quality changed (Cohen, 1963b, fig. 35). In addition to the overall increase in the flow of the Humboldt River opposite the mouth of Grass Valley, the dissolved-solids content of the stream decreased as a result of the inflow from Grass Valley of the previously described calcium bicarbonate ground water of moderately low dissolved-solids content. The decrease in dissolved-solids content of the river plus additional water-quality data have been used to verify that the estimated average annual ground-water outflow from Grass Valley derived previously in this report, about 6,000 acre-feet, is of the correct order of magnitude (Cohen, 1963b, p. 92).

CONCLUSIONS

The ground-water resources of most of the valleys in Nevada currently are being administered under the concept of perennial yield. Insofar as possible Federal and State agencies concerned with the development of ground water in Nevada, principally the Bureau of Land Management and the Nevada Department of Conservation and Natural Resources, are attempting to prevent the overdevelopment of this valuable resource.

As previously noted, the estimated perennial yield of the ground-water system of Grass Valley is 13,000 acre-feet. To achieve this degree of development and to limit the development to the estimated perennial yield, a considerable amount of ground water would have to be withdrawn from storage so as to lower ground-water levels sufficiently to eliminate all natural evapotranspiration losses -- about 7,000 acre-feet per year. Moreover, it would be necessary to eliminate the estimated 6,000 acre-feet per year of ground-water outflow to the Humboldt River valley.

Two of several significant factors that should be considered when attempting to limit ground-water development to the perennial yield of a valley are the economic and technological feasibility of such development. It may be economically and technologically impractical or impossible to eliminate all natural evapotranspiration losses. For example, before any ground-water development of the alluvial apron bordering the Sonoma Range could have an appreciable effect on natural evapotranspiration losses along the axis of the valley, ground-water levels in some wells may have to be lowered to a point where it is no longer economical to pump.

It generally is acknowledged that in most areas an evenly spaced network of pumping wells eventually would salvage more natural evapotranspiration losses than would closely grouped wells. However, adverse soil conditions, economic considerations, water quality factors, or the inability to develop high-capacity wells locally may preclude the development of evenly-spaced irrigation wells in Grass Valley. These factors, in turn, might further decrease the amount of natural evapotranspiration losses that could be salvaged.

Nevada water law (Hutchins, 1955) prohibits the development of ground water if that development will infringe upon established surface-water rights. Any ground-water development that would result in a decrease in the amount of subsurface outflow from Grass Valley to the Humboldt River valley conceivably could decrease the flow of the river (whose water is entirely appropriated for downstream use) by an amount equal to the decrease in outflow (Cohen, 1963b, p. 98-100). Accordingly, because of legal considerations regarding ground-water outflow from the valley, it may be necessary to limit the net withdrawals from the ground-water system in Grass Valley to the natural evapotranspiration losses that can be salvaged -- an estimated maximum of about 7,000 acre-feet per year.

Based solely on hydrologic considerations, it may be desirable to continue to allow ground-water outflow from Grass Valley. Inasmuch as Clear Creek probably has not discharged any water from the valley in historic time (Hanson, 1963, p. 40), ground-water outflow is the principal means by which potentially injurious salts are removed, or flushed, from the valley lowlands.

It is possible and perhaps likely that any ground-water development that would result in a decrease in natural evapotranspiration losses, especially in the northern part of the valley, also would decrease the amount of subsurface outflow to the Humboldt River valley. In any event, if it is desired to limit development in Grass Valley so as not to cause a continual depletion of the ground water in storage and if it is desired to maintain the amount of ground-water outflow discharging into the Humboldt River valley, net withdrawals from the ground-water reservoir should not exceed the amount of natural discharge by evapotranspiration -- an estimated maximum of 7,000 acre-feet per year. Total pumpage may exceed this quantity to the extent that some of the pumped water will return to the ground-water reservoir.

Table 5.--Records of selected wells in the Grass Valley area, Nevada

Type of well: Dr., drilled; Dg., dug; A, augered.
Water level: M, measured; R, reported.
Use: D, domestic; I, irrigation; S, stock; O, observation; Ind., industrial; U, unused; PS. Public Supply.
Depth: M, measured; R, reported
Discharge: M, measured; R, reported; E, estimated

Well number or location	Owner	Type of well and date completed	Casing diameter (inches)	Depth (feet)	Water level: Below land-surface datum (feet)	Water level: Date measured or reported	Use	Discharge (gpm)	Temperature (°F)	Remarks
31/38-26a1	U.S. B.L.M.	Dr, 1940	6	197, R	157.34, M	7-12-47	S	- -	-	Log
31/39-32b1	Clifford Raney	Dr, 1958	16	296, R	138 , R	5-22-58	I	2,100, R	-	- -
32/38-18b1	do	Dr, 1939	6	125, M	79.98, M	9-22-55	S	7, R	-	Log
32/38-36b1	Mr. Kerlee	Dr, 1946	12	110, R	80.15, M	9-27-56	U	- -	-	Log
33/37- 4d2	None	Dr, - -	10	102, R	- -	- -	U	- -	-	- -
33/37-22b1	U.S. B.L.M.	Dr, 1939	6	205, R	169.30, M	3-15-48	S	- -	-	- -
33/37-24a1	Mr. Sweeney	Dg,Dr,1924	10	63, M	12.72, M	3-30-60	U	- -	49	- -
33/37-24d1	do	Dr, 1924	14	73, M	17.94, M	3-23-61	U	- -	-	- -
33/38-14c1	Clear Creek Ranch	Dr, - -	-	- -	- -	- -	D,I,S	- -	-	Flowing
33/38-17c1	Nevada Land and Irrigation Co.	Dr, 1962	14	600, R	35 , R	6-23-62	I	- -	- -	- -
33/38-19b1	Mr. Sweeney	Dr, 1929	18	96, M	23.80, M	5- 6-47	U	- -	-	- -
33/38-30d1	Mr. Kerlee	Dr, 1951	14	100, R	35 , R	5-14-53	U	- -	-	- -
33/38-32b1	U.S. B.L.M.	Dr, 1939	6	54, M	30.07, M	10- 3-61	S	5, R	-	- -
33/38-32b2	Unknown	Dr, 1951	12	100, R	33.14, M	9- 9-52	I	700, E	-	- -
34/37- 2a1	U.S. B.L.M.	Dr,Dg, --	10	70, M	16.94, M	10- 3-61	S	- -	-	- -
34/37- 3d1	Sonoma Ranch	Dr, 1960	10	160, R	11 , R	7-26-61	I	1,000, M	59	Log, Chemical analysis
34/37-10a1	U.S. B.L.M.	Dr, 1939	10	67, M	10.05, M	1- 6-48	S	5, R	56	- -
34/37-22a1	None	Dr, - -	6	50, M	11.93, M	10- 3-61	U	- -	-	- -
34/37-27a1	None	Dr, - -	6	75, R	4.34, M	3-22-50	S	- -	-	- -
35/35-25c1	U.S.G.S.	A, 1959	1¼	20, M	10.18, M	12-14-62	O	- -	-	Log
35/35-25d1	do	A, 1959	1¼	22.5,M	11.68, M	12-14-62	O	- -	58	Log, chemical analysis
35/36-13d1	do	A, 1960	1¼	117.5,M	51.46, M	12-15-62	O	- -	59	do
35/36-14c1	C. Hillyer	Dr, - -	12	18 ,M	14.55, M	9-25-61	U	- -	57	- -
35/36-15c2	D. McNinch	Dr, - -	8	60, R	12 , R	7-19-61	D,S	5, R	64	Chemical analysis
35/36-19a1	U.S.G.S.	A, 1959	1¼	17.5,M	11.86, M	12-14-62	A	- -	58	Log, chemical analysis
35/36-24c2	C. Martin	Dr, 1951	-	212, R	67 , R	7-16-61	I	900, E	60	Chemical analysis
35/36-31d1	U.S.G.S.	A, 1960	1¼	108, M	73.36, M	12-13-62	O	- -	62	Log, chemical analysis
35/37-2a1	State of Nevada	Dr, 1960	6	22, M	12 , R	7- 8-61	-	- -	-	Chemical analysis
35/37- 4c1	G. Amos	Dr, 1957	8	50, R	11 , R	7-24-61	D,S	- -	64	Chemical analysis
35/37-5a1	U.S.G.S.	Dr, 1960	1¼	70, M	58.43, M	12-15-62	O	- -	-	Log
35/37- 5b1	do	Dr, 1960	1¼	110, M	55.48, M	12-15-62	O	- -	-	Log
35/37- 7d1	C. McNinch	Dr, 1957	8	97, R	11 , R	7-26-61	S	- -	58	Chemical analysis
35/37- 8d1	do	Dr, - -	12	78, R	15.15, M	8- 7-61	I	700, M	59	Chemical analysis
35/37-11c1	U.S.G.S.	A, 1960	1¼	62.5,M	47.17, M	12-13-62	O	- -	-	Log
35/37-13a1	U.S. B.L.M.	Dr, - -	6	107, M	- -	- -	S	- -	-	Chemical analysis
35/37-13d1	V. Ryan	Dr, 1960	12	300, R	95.53, M	7-25-61	I, D	1,350, R	59	Chemical analysis
35/37-14d1	E.W. Westmoreland	Dr, 1958	10	280, R	50 , R	7-25-61	I	400, E	62	Log, chemical analysis
35/37-15d1	Dept. of Commerce	Dr, 1949	6	160, R	50 , R	7-21-49	D	- -	-	Log, chemical analysis
35/37-16b1	D. O'Connor	Dr, 1933	8	100, R	57 , R	7- 2-53	D	- -	-	Log, chemical analysis
35/37-22d1	U.S.G.S.	A, 1959	1¼	62.5,M	38.89, M	12-14-62	O	- -	54	Chemical analysis
35/37-25b1	E.W. Westmoreland	Dr, 1960	16	620, R	76 , R	8- 1-60	I	1,500, E	60	Chemical analysis
35/37-26a1	Grass Valley Farms	Dr, 1955	16	520, R	59.25, M	7-25-61	I	800, E	60	Log, chemical analysis
35/37-26a2	do	Dr, - -	16	384, R	48 , R	5-14-58	I	1,200, E	58	Chemical analysis
35/37-26b1	do	Dr, 1952	12	630, R	39.32, M	3-17-53	I	- -	58	Log, chemical analysis
35/37-28a1	U.S.G.S.	A, 1960	1¼	117.5,M	31.00, M	12-13-62	O	- -	55	Log, chemical analysis
35/37-28b1	None	Dr, 1927	12	73, M	40.10, M	10-24-62	U	- -	59	Chemical analysis
35/37-34a2	do	Dr, - -	10	82, M	24.94, M	8-29-60	U	- -	-	- -
35/38- 6b1	Mr. Anderson	Dr, 1958	8	120, R	104 , R	7-18-58	D	20, R	-	Log, chemical analysis
36/37-25b1	U.S.G.S.	A, 1959	1¼	32.5,M	24.64, M	12-15-62	O	- -	56	Log, chemical analysis
36/37-25d1	do	A, 1959	1¼	22.5,M	6.75, M	12-15-62	O	- -	-	Log.
36/37-26c1	Q. W. Murdock	Dr, 1958	8	87, M	56.67, M	7-20-61	D	- -	-	Chemical analysis
36/37-30a1	K. Kelly	Dr, 1955	16	500, R	102.92, M	7-20-61	U	- -	63	Log, chemical analysis

Table 8.--Records of selected wells in the Grass Valley area, Nevada - Continued

Well number or location	Owner	Type of well and date completed	Casing diameter (inches)	Depth (feet)	Water level: Below land-surface datum (feet)	Water level: Date measured or reported	Use	Discharge (gpm)	Temperature (°F)	Remarks
36/37-30d1	U.S.G.S.	A, 1959	1½	92.5, M	71.93, M	12-15-62	O	- -	-	Log
36/37-31a1	U.S.G.S.	A, 1959	1½	92.5, M	60.24, M	12-15-62	O	- -	60	Log, chemical analysis
36/37-35a1	C. I. Casteel	Dr, 1955	10	72 , R	13 , R	7-20-61	D	- -	60	Chemical analysis
36/38- 2b1	J. Kearns	Dr, 1948	12	314 , R	17 , R	7-28-61	U	- -	54	Log, chemical analysis
36/38- 4d1	Baer Ranch	Dr, 1955	12	208 , R	9 , R	6-24-55	I	1,000, E	61	Chemical analysis
36/38- 5d1	U.S.G.S.	A, 1959	1½	27 , M	12.68, M	12- 4-62	O	- -	-	- -
36/38-16d1	M. Pedroli	Dr, 1957	16	319 , R	90 , R	7-27-61	I	1,550, R	52	Chemical analysis
36/38-19d1	Calif. Pacific Utilities Co.	Dr, 1936	16	525 , M	- -	- -	PS	1,000, R	62	Log, chemical analysis
36/38-19d2	U.S.G.S.	A, 1960	6	18 , M	6.84, M	12-15-62	O	- -	-	- -
36/38-26d1	U.S. B.L.M.	Dr, - -	8	- -	- -	- -	S	- -	73	- -
36/38-28b1	D. Peterson	Dr, - -	-	245 , R	- -	- -	D	- -	63	Chemical analysis
36/38-30d1	Calif. Pacific Utilities Co.	Dr, 1953	14	495 , R	63.60, M	9- 1-54	PS	1,100, R	73	Chemical analysis
36/38-36b1	P. Pedroli	Dr, 1956	8	68 , R	11 , R	7-24-56	D,S	- -	52	Chemical analysis

Table 9 -- Drillers' logs of representative wells in the Grass Valley area, Nevada

Material	Thickness (feet)	Depth (feet)
31/38-26a1		
Hardpan, light yellow	125	125
Boulders, very hard, light yellow	44	169
Limestone, very hard, light brown	28	197
32/38-18b1		
Clay	20	20
Gravel, cemented	80	100
Clay and gravel	30	130
32/36-36b1		
Silt and clay; some hardpan	75	75
Gravel	35	110
34/37-3d1		
Sand and silty clay	4	4
Silty clay, blocky and dense	50	54
Gravel, water	1	55
Silty clay, yellowish-brown	15	70
Sandy gravel, water	3	73
Silty clay	9	82
Gravel and coarse sand	2	84
Silty clay	1	85
Gravel and sand; some silty clay	10	95
Silty clay	20	115
Sand and gravel	22	137
Silty clay	13	150
Sand	10	160

Material	Thickness (Feet)	Depth (feet)
35/35-25c1 (U.S.G.S. auger hole)		
Sand	2.5	2.5
Sand, silty	4.9	7.4
Sand and gravel	10.1	17.5
Sand and gravel; some silty clay	2	19.5
Sandy clay	5	20
35/35-25d1 (U.S.G.S. auger hole)		
Sandy silt	2.5	2.5
Silty sand; some clay	5.7	8.2
Silty sand	2.3	10.5
Sand and gravel; some silt	12	22.5
35/36-13d1 (U.S.G.S. auger hole		
Silty clay; some fine to very fine sand	60	60
Sand; some silt & clay	30	90
Sand	27.5	117.5
35/36-19d1 (U.S.G.S. auger hole)		
Clayey silt; some very fine sand	3	3
Silty clay	2	5
Silty clay; some very fine sand	2.5	7.5
Sand; some silt & clay	7.5	15
Silty clay; some sand	2.5	17.5
35/36-31d1 (U.S.G.S. auger hole)		
Silty clay; some fine sand	10	10
Clayey silt; some fine sand	30	40
Sand, very coarse to fine; some silt and clay	68	108

Material	Thickness (feet)	Depth (feet)
35/37-5a1 (U.S.G.S. auger hole)		
Road fill	5	5
Silty clay; some fine to very fine sand	5	10
Clayey silt; some fine to very fine sand	20	30
Silty clay; some very fine sand	30	60
Sand, very coarse to very fine; some silt and clay	10	70
35/37-5b1 (U.S.G.S. auger hole)		
Sand, medium to very fine; some silt and clay	10	10
Silty clay; some very fine sand	5	15
Silty clay; some medium to very fine sand	5	20
Silty clay; some very fine sand	10	30
Silty clay	20	50
Silty sand; some clay	20	70
Sand and gravel	40	110
35/37-11c1 (U.S.G.S. auger hole)		
Silty clay; some fine to very fine sand	10	10
Silty clay; trace of very fine sand	10	20
Clay and silt; some medium to very fine sand	5	25
Silt and clay; some medium to very fine sand	5	30
Clay, silty and sandy	20	50
Sand and gravel	12.5	62.5
35/37-14d1		
Topsoil	3	3
Ash	.5	3.5
Clay	16.5	20
Gravel, cemented	8	28
Clay, brown	17	45
Clay and rocks	19	64
Gravel	2	66
Clay, gray	14	80
Gravel and sand, water	6	86
Clay	6	92
Gravel and sand, water	4	96
Clay and rocks, dry	96	192
Gravel and clay	68	260
Gravel and sand, water	20	280
35/37-15d1		
Sandy clay	12	12
Sand and clay	4	16
Sandy clay	49	65
Gravel, cemented	5	70
Gravel and clay, water	3	73
Sandy clay	31	104
Gravel and clay	1	105
Sand; some clay, water	21	126
Gravel and clay	1	127
Gravel and sand, water	21	148
Gravel and clay	12	160
35/37-16b1		
Topsoil	3	3
Clay, hard	20	23
Clay, soft	34	57
Gravel, water	7	64
Clay	6	70
Sand, water	20	90
Clay, sandy, water	8	98
Gravel, water	2	100

Table 9 -- continued

Material	Thickness (feet)	Depth (feet)
35/37-26a1		
Topsoil	5	5
Clay	18	23
Gravel	17	40
Clay	10	50
Gravel	3	53
Clay	4	57
Gravel	23	80
Clay	7	87
Gravel and boulders	65	152
Gravel, with layers of clay	14	166
Gravel and boulders, layers of clay	49	215
Lava rock, porous	305	520
35/37-26b1		
Topsoil and clay	22	22
Gravel, coarse, dry	5	27
Clay	14	41
Gravel, coarse, water	1	42
Clay, with layers of gravel	163	205
Gravel, coarse, with clay	10	215
Clay and sand	225	440
Hardpan	20	460
Sand, fine, water	20	480
Sand and clay	150	630
35/38-6b1		
Sand	8	8
Gravel	8	16
Boulders	2	18
Gravel and clay	34	52
Boulders	28	80
Clay and gravel	25	105
Sand and boulders	11	116
Gravel, fine	4	120
35/38-28a1 (U.S.G.S. auger hole)		
Silty clay; some fine to very fine sand	10	10
Silty clay; some coarse to very fine sand	47.5	57.5
Silty clay; some very coarse to very fine sand	5	62.5
Sand and gravel; some silty clay	15	77.5
Clay; some silt and sand	22.5	100
Silty clay; some sand	17.5	117.5
36/37-25b1 (U.S.G.S. auger hole)		
Clayey silt; some very fine sand	2.5	2.5
Silty sand	4.5	7
Gravel	14	21
Silty clay	11.5	32.5
36/37-25d1 (U.S.G.S. auger hole)		
Silty clay	10	10
Silty clay; some very coarse to very fine sand	8	18
Sand and gravel	4.5	22.5
36/37-30a1		
Sand	12	12
Gravel, dry	4	16
Clay, hard	8	24
Gravel, dry	4	28
Clay, hard	12	40
Gravel, dry	5	45
Clay, hard	15	60
Clayey gravel	40	100
Clay, sandy	14	114
Gravel, water	4	118
Sand and gravel	28	146
Clayey gravel	74	220
Clay, blue; thin sand layers	280	500

Table 9 - contd.

Material	Thickness (feet)	Depth (feet)
36/37-30d1 (U.S.G.S. auger hole)		
Silty sand	5	5
Clayey silt; some sand	30	35
Gravel; some sand and silt	2	37
Silty sand	21	58
Sandy gravel	7	65
Sand	3	68
Gravel	14.5	82.5
Silty sand	3.5	86
Sand and gravel	1.5	87.5
Silty clay	5	92.5
36/37-31a1 (U.S.G.S. auger hole)		
Silty sand	3	3
Silty clay; some very fine sand	3	6
Silty clay	9	15
Silt and very fine sand	16.5	31.5
Silty sand and gravel	2.5	34
Sand and gravel	31	65
Sand and gravel, silty	10	75
Clay, silty & sandy	9	84
Sand and gravel	8	92
36/38-2b1		
Sand and gravel	30	30
Sand and gravel; some red clay	10	40
Sand and gravel; some silt & clay	35	75
Silty sand and gravel	50	125
Coarse sand and gravel, silty	35	160
Coarse sand and gravel, silty and clayey	40	200
Sand and gravel	51	251
Rock, broken, brown	13	264
Rock, broken, gray clay	12	276
Rock, broken; brown clay	8	284
Rock, broken; green clay	20	304
Rock, broken; main water	10	314
36/38-19d1		
Loam	4	4
Sand	11	15
Gravel	4	19
Sand and clay	3	22
Sand and gravel	91	113
Gravel and boulders	12	125
Conglomerate	10	135
Sand and clay	15	150
Cemented gravel	54	204
Sandy clay	193	397
Sand and gravel	6	403
Clay	67	470
Sand	5	475
Cemented "cap"	19	495
Lava, gravel	5	499
Fissured lava	26	525

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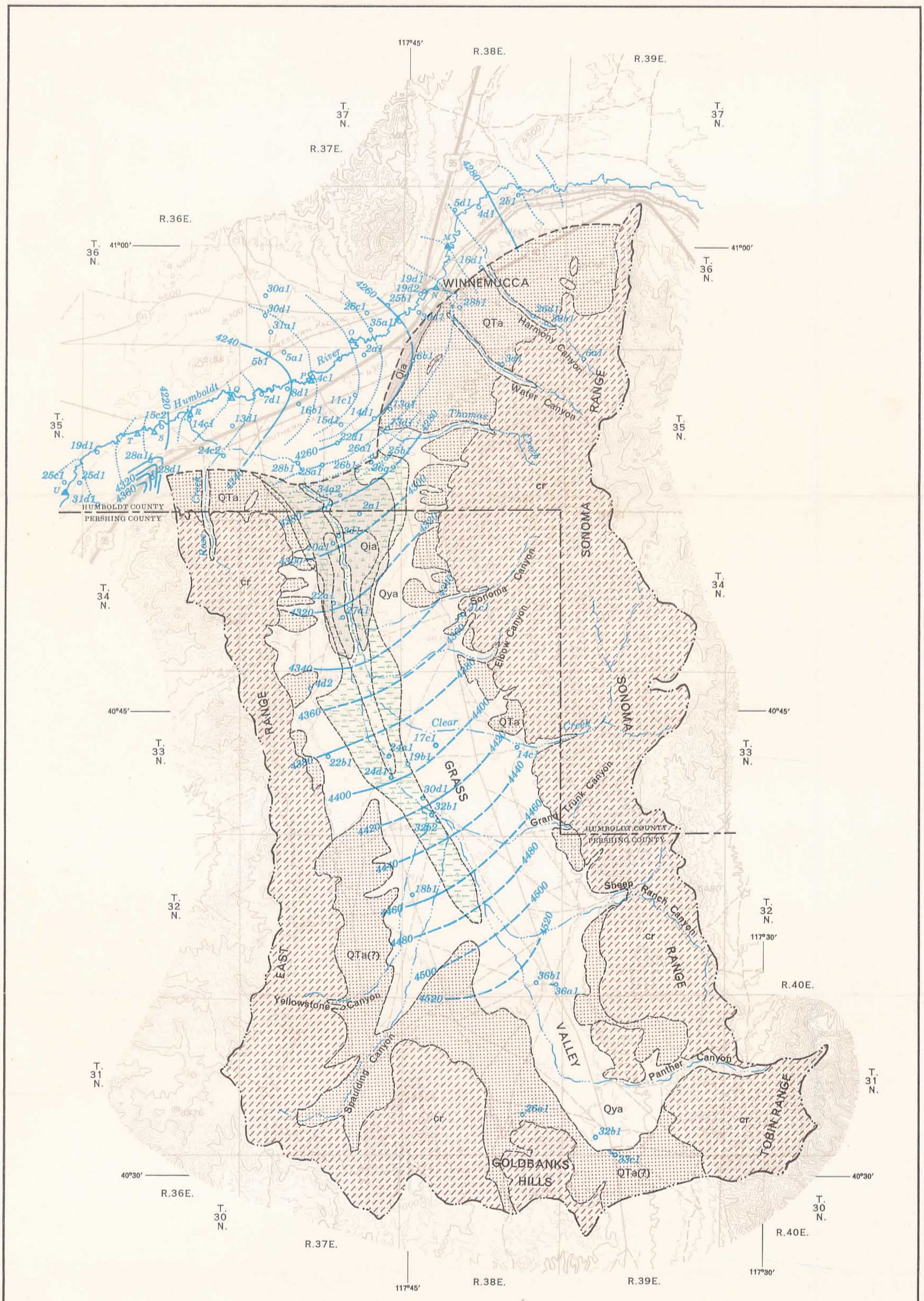
UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES



EXPLANATION

Recent	**Qya** Younger alluvium. Unconsolidated sedimentary deposits of high to low permeability	QUATERNARY
Pleistocene	**Qia** Intermediate alluvium. Mostly fine-grained lake deposits of high porosity and low permeability. Locally includes lenses of highly permeable sand and gravel	QUATERNARY
Miocene or Pliocene to Pleistocene	**QTa** Older alluvium. Mostly unconsolidated to partly consolidated deposits of high to low permeability. Includes some beds of highly altered and compacted conglomerate, sandstone, limestone, and tuff.	TERTIARY AND QUATERNARY
	cr Consolidated rocks. Mainly consolidated rocks of little or no interstitial permeability. Locally includes basaltic rocks and limestone that transmit moderate quantities of water.	CAMBRIAN TO QUATERNARY

Phreateophytes

Mainly greasewood and rabbitbrush

Mainly grass

Contact
Approximately located

Drainage divide

Northern margin of Grass Valley

32b1
Well and number

33c1
Spring and number

S
Streamflow measuring station equipped with staff gage

U
Streamflow measuring station equipped with recorder

4420
Generalized water-level contour and altitude as of December, 1962
Dashed where approximately located; Contour interval 20 feet; dotted contour represents 5-foot interval; datum is mean sea level

1 0 1 5 10

Scale in miles

Base: U.S. Geological Survey 1:250,000 topographic quadrangles; Winnemucca (1958) and McDermit (1959)

Hydrogeology by Philip Cohen, 1964; partly adapted from Robinson, Loeltz, and Phoenix (1949), Ferguson, Muller, and Roberts (1951), Bredehoeft (1963), and Hawley and Wilson (1964)

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE GRASS VALLEY AREA, HUMBOLDT AND PERSHING COUNTIES, NEVADA