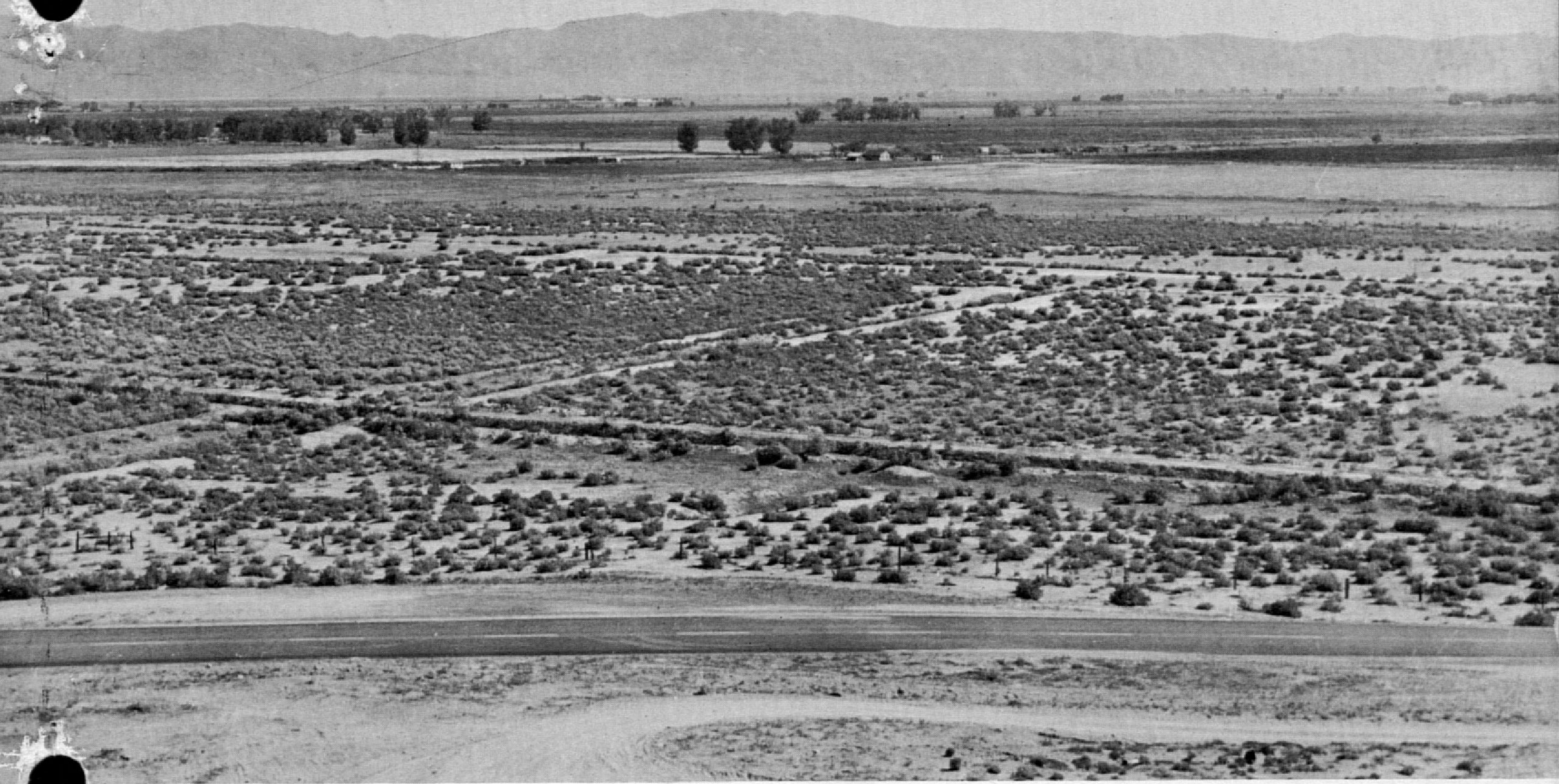
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of lower Lovelock Valley

WATER RESOURCES–RECONNAISSANCE SERIES

REPORT 32

WATER RESOURCES APPRAISAL OF LOVELOCK VALLEY, PERSHING COUNTY, NEVADA

By
D. E. EVERETT, Chemist
and
F. EUGENE RUSH, Geologist

Price $1.00

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

APRIL 1965

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PERSHING COUNTY, NEVADA

By

D. E. Everett and F. Eugene Rush

SUMMARY

Lovelock Valley is in west-central Nevada near the downstream end of the Humboldt River. For the purposes of this study the area was subdivided into the Oreana subarea, upper Lovelock Valley, and lower Lovelock Valley.

The total water supply available to Lovelock Valley is about 140,000 acre-feet per year, the bulk of which is supplied by the Humboldt River. Rye Patch Dam and Reservoir provide regulation and storage at the upstream edge of the study area. During the period 1936-61, an average of about 83,000 acre-feet per year was diverted for irrigation of alfalfa and other crops, although the range in diversions has been from about 17,000 acre-feet in 1961 to 123,000 acre-feet in 1953.

Most of the available ground water of suitable chemical quality for agricultural and domestic uses occurs in the alluvium in the Oreana subarea. Recharge to the Oreana subarea, from local sources is only about 2,000 acre-feet per year, and the minimum yield also is about 2,000 acre-feet per year. Ground water draft much in excess of this amount would cause water to be diverted from the river to the ground-water system. In 1964 pumpage from the subarea was about 1,500 acre-feet, and in large part was used by the City of Lovelock for a municipal supply.

Ground water in lower Lovelock Valley, where virtually all the irrigation occurs, is largely of unsuitable chemical quality for agricultural and domestic uses. The water contains excessive amounts of dissolved solids, fluoride, and boron. Therefore, little of it is used. Most of the ground water in upper Lovelock Valley is of suitable quality for most uses, but the recharge from local sources is small.

The total discharge from the valley is also about 140,000 acre-feet per year. Crops, and evapotranspiration from bare soil and by phreatophytes, consume an estimated average of 66,000 acre-feet per year. The irrigated area has increased from about 12,500 acres in 1936 to about 30,000 acres in 1964. Irrigation drain water, resulting from excess irrigation water applied to fields to maintain a tolerable salt balance, averages about 21,000 acre-feet per year. This water discharges to the Humboldt Sink.

An average of about 50,000 acre-feet per year of good quality flood water has wasted to the Humboldt Sink. The wastage has occurred principally in the 5 water years 1942, 1943, 1945, 1946 and 1952. This is about one-third of the total supply available. Consideration could be given to salvaging a substantial part of the flood water by increasing existing surface-storage facilities, and by the conjunctive use of surface- and ground-water storage.

INTRODUCTION

Purpose and Scope of the Study

Ground-water development in Nevada has shown a substantial increase in recent years. A part of this increase is due to the effort to bring new land into cultivation. The increasing interest in ground-water development has created a substantial demand for information on ground-water resources throughout the State.

Recognizing this need, the State Legislature enacted special legislation (Chpt. 181, Stats, 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the thirty-second report prepared as part of the reconnaissance study (fig. 1).

During the course of the ground-water studies to date, it was recognized that there also is a deficiency of information on the surface-water resources. Accordingly, this reconnaissance series has been broadened to include preliminary elevations of the surface-water resources in the valleys studied.

The objectives of the reconnaissance studies and this report are to (1) appraise the sources, occurrence, movement, storage, and chemical quality of water in the area, (2) estimate average annual recharge to and discharge from the ground-water reservoir, (3) estimate the average annual inflow and outflow of water from the study area, and (4) provide a preliminary estimate of the perennial yield.

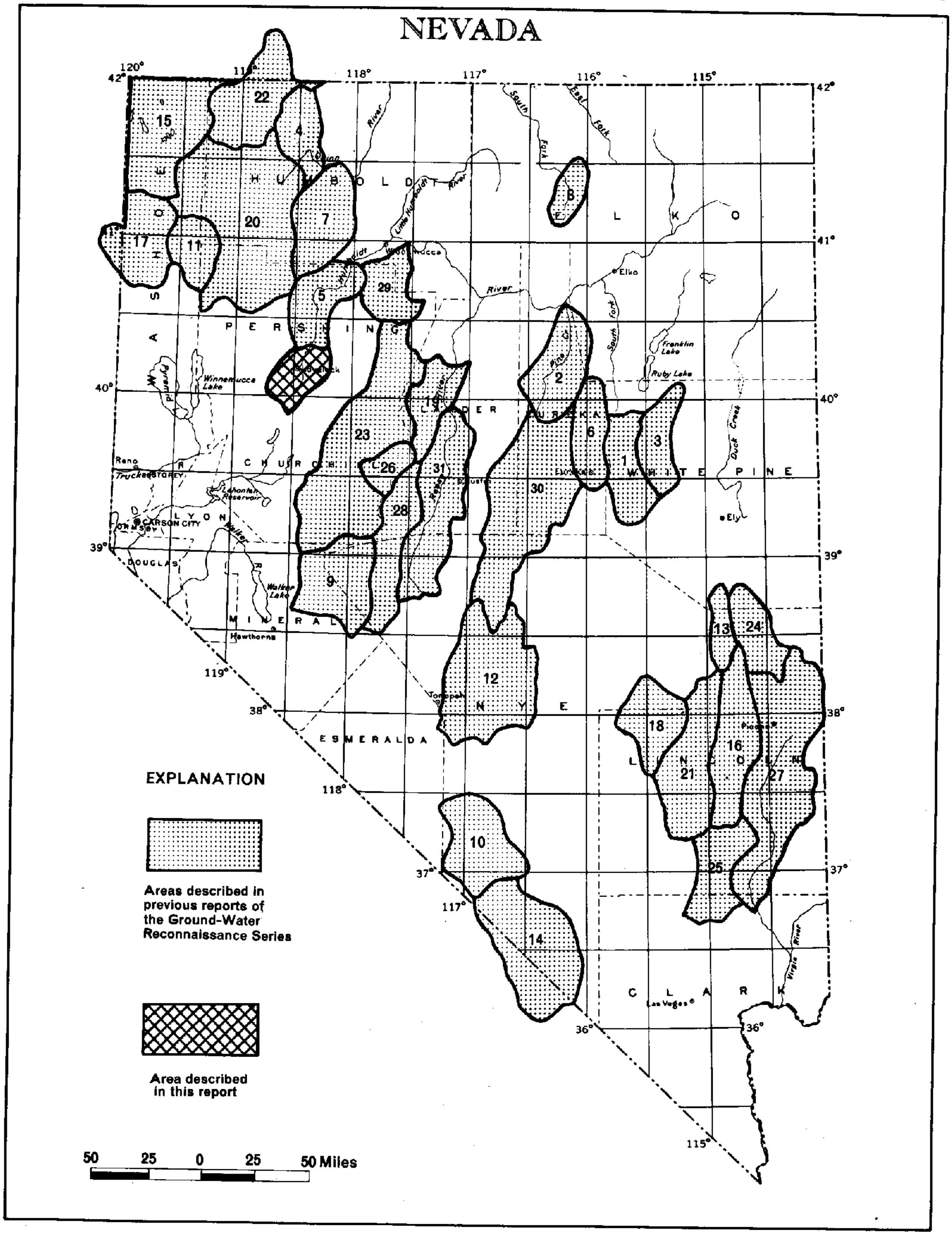

Figure 1. **MAP OF NEVADA**

showing areas described in previous reports of the Ground-Water Reconnaissance Series and the area described in this report

The investigation was made under the general supervision of G.F. Worts, Jr. District Chief in charge of hydrologic studies by the Geological Survey in Nevada.

Location and General Geographic Features

Lovelock Valley is in west-central Nevada and is approximately enclosed by latitute 39°55' and 40°30'N., and longitude 118°05' and 118°45'W. It is almost entirely in the southern part of Pershing County; however, the extreme southern part is in Churchill County (pl. 1). Lovelock Valley extends southwestward from Rye Patch Dam on the Humboldt River to the Humboldt Sink. The area is about 45 miles long and 18 miles wide; its total area is about 740 square miles.

For the purposes of this report, Lovelock Valley has been divided into three subareas: The Oreana subarea, upper Lovelock Valley, and lower Lovelock Valley (pl. 1). The Oreana subarea extends from Rye Patch Dam to about 2 miles south of State Highway 50 and from the Humboldt Range on the east to the flood plain of the Humboldt River. Upper Lovelock Valley extends from the Oreana subarea on the east to the Trinity Range on the west and from Rye Patch Dam to Woolsey. All the area south of Woolsey is included in the Lower Lovelock Valley.

Principal access to the area is by U.S. Highway 40, which passes through the entire length of the area from north to south. Improved and unimproved roads provide access to other points in the area.

The principal city in the area is Lovelock, which is on U.S. Highway 40 and the Southern Pacific Railroad. The population of Lovelock in 1960 was 1,948. The economy of the area is based on agriculture, principally hay, which in turn is dependent on Humboldt River water for irrigation. The flow of the Humboldt River has been regulated since the construction of Rye Patch Dam, which began in 1936 and was completed in 1937.

Physiography and Drainage

Lovelock Valley is in the Great Basin Section of the Basin and Range physiographic province. It is a northeast-trending valley bordered on the east by the Humboldt Range and the West Humboldt Range, and on the west by the Trinity Range. A prominent gravel bar, which separates the Humboldt Sink from the Carson Sink and which connects the West Humboldt and Trinity Ranges, forms the southern boundary. The Lower Humboldt Drain breaches this gravel bar and allows drainage into Carson Sink. Rye Patch Dam forms the northern boundary of the study area.

An unnamed peak, altitude 9,029 feet, in the Humboldt Range is the highest peak in the area. Other peaks have altitudes greater than 8,000 feet. Trinity Peak, altitude 7,332 feet, is the highest peak in the Trinity Range. The lowest point in the valley, 3,889 feet, is the surface of Humboldt Lake. The maximum relief is about 5,000 feet.

The principal surface drainage in Lovelock Valley is southward toward the Humboldt Sink. The Humboldt River in the report area has an average gradient of about 3 feet per mile. Gradients on the alluvial aprons, which lie between the mountains and the lowlands, commonly range from 100 to 300 feet per mile. In the mountains, erosion has produced steep-sided canyons, and stream-channel gradients generally are in excess of 300 feet per mile; locally, they may be as much as 1,000 feet per mile.

Climate

The climate in the project area generally is semiarid in the valleys and subhumid in the higher mountains of the Humboldt Range. Precipitation and humidity generally are low, and summer temperatures and evaporation rates are high. Precipitation varies widely in amount but generally is least on the valley floor and greatest in the mountains. Snow is common during the winter months and localized thundershowers provide much of the summer precipitation. The daily seasonal temperature ranges are relatively large.

The average annual precipitation at Lovelock during the period 1891-1963 was 5.78 inches (table 4). The recorded maximum annual precipitation, 11.93 inches, occurred in 1925, and the minimum annual precipitation, 0.85 inches, occurred in 1905. At Rye Patch Dam the average annual precipitation during the period 1936-1963 was 7.10 inches. The maximum annual precipitation, 12.48 inches occurred in 1938, and the minimum annual precipitation, 3.28 inches, occurred in 1959.

The average monthly and annual temperatures for the period of record at Lovelock and Rye Patch Dam are listed in table 1. The length of the growing season varies from year to year; however, Houston (1950, p. 14) states that the average growing season for Lovelock Valley is about 128 days (May 18 to September 23).

Table 1. --Average monthly and annual temperatures, in degrees Fahrenheit, at two stations in Lovelock Valley, Nev.

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

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Lovelock 1/	30.2	35.8	42.5	50.9	58.7	66.6	75.1	72.5	64.5	53.1	40.0	32.2	51.8
Rye Patch 2/ Dam	29.9	35.5	40.6	48.9	57.0	64.9	73.2	70.6	62.6	51.6	39.1	32.8	50.6

1/ Period of record 1931 - 1963.

2/ Period of record 1936 - 1963.

Previous Work

The geology of the Unionville Quadrangle, which is in the Humboldt Range, has been mapped by Wallace and others (1962). I.C. Russell (1885) described some of the characteristics of the Lake Lahontan lacustrine deposits in the area. A study of the ground-water resources of Lovelock Valley was made by Robinson and Fredericks (1946). M. R. Miller reported on the quality of Humboldt River water (1950). More recently a reconnaissance report was prepared by Bredehoeff (1963) on the hydrogeology of the lower Humboldt River basin, which includes Lovelock Valley.

Currently, a geologic reconnaissance of Pershing County is in progress under the cooperative program of the U.S. Geological Survey and Nevada Bureau of Mines.

Acknowledgments

The cooperation and assistance of various Federal, State, and local agencies are gratefully acknowledged. The Lovelock Municipal Water Works provided pumpage figures from municipal wells. Much of the well data and logs were provided by the Office of the State Engineer. The U.S. Bureau of Reclamation provided information on the drains in lower Lovelock Valley and surface-water discharge through Lower Humboldt Drain.

The writers are grateful to the residents of the project area who permitted access to their property and supplied information regarding wells and irrigated acreage.

Special scknowledgment is given George Moseley, Secretary-Manager, Pershing County Water Conservation District, who supplied much of the information on water distribution and use.

Numbering System for Wells

The numbering system for wells and springs in this report is based on the rectangular subdivisions of the public lands, referenced to the Mount Diablo base line and meridian. It 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 is separated from the second by a dash and designates the section number. The section number is followed by a letter that indicates the quarter section; the letters a, b, c, and d designating the northeast, northwest, southwest, and southeast 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 26/31-12bl in table 10 is the first well recorded in the northwest quarter of section 12, T. 26 N., R. 31 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 number indicating the order in which they were located. Township and range numbers are shown along the margins of the area on plate 1.

SURFACE WATER

Inflow

Surface-water inflow to the project area is the Humboldt River. The inflow has been evaluated on the basis of long-term streamflow data obtained at the Rye Patch gaging station. This station (Humboldt River near Rye Patch) is about 1,000 feet downstream from Rye Patch Dam and 1.5 miles northwest of Rye Patch on the SE1/4NE1/4 sec. 18, T. 30 N., R 33 E. The drainage area of the Humboldt River above the station is approximately 16,100 square miles.

The average annual discharge, or release of water from Rye Patch Reservoir for the period of record 1936-1961, was about 139,000 acre-feet and ranged from 21,170 acre-feet in 1955 to 461,322 acre-feet in 1943. The range in rate of discharge was from no flow at times in some years to 4,720 cfs (cubic feet per second) on May 11 and 12, 1952. The annual release of water from Rye Patch Reservoir are shown in table 2.

The amount of water which is eventually released from Rye Patch Reservoir is dependent upon inflow, storage, and loss in storage. These are shown in table 2. Inflow is measured at the Imlay gaging station (Humboldt River near Imlay), which is approximately 17 miles northeast of Rye Patch Dam. The storage capacity of the reservoir is approximately 180,000 acre-feet. Additional information on the Imlay area is presented in a report by Eakin (1962, p. 18-30).

Table 2. --Annual inflow, outflow, storage, and loss in storage, in acre-feet, for Rye Patch Reservoir, Pershing County, Nevada, 1936-61.
(Table from Pershing County Water Conservation District)

Water year	Flow of Humboldt River past Imlay	Stored in Rye Patch Reservoir as of Sept. 30	Loss in storage in Rye Patch Reservoir	Released from Rye Patch Reservoir
1936	97,670	9,790	5,660	82,220
1937	a 92,160	a 9,999	14,221	77,730
1938	a 120,060	a 37,902	26,687	65,470
1939	a 83,142	a 20,238	26,246	74,560
1940	a 68,218	a 12,844	15,332	60,280
1941	a165,646	a 53,277	52,693	72,520
1942	361,186	163,400	67,651	183,412
1943	500,230	145,700	56,608	461,322
1944	154,000	160,200	63,510	75,990
1945	433,000	168,400	54,000	370,800
1946	299,800	143,300	43,700	281,200
1947	a111,270	107,200	34,570	112,800
1948	73,710	51,970	30,420	97,520
1949	115,600	35,500	21,050	111,000
1950	132,400	29,030	20,590	118,300
1951	229,130	85,380	48,280	124,500
1952	552,329	146,000	53,109	408,600
1953	112,210	83,160	39,350	135,700
1954	41,050	1,350	19,860	103,000
1955	18,830	786	b 1,776	b 21,170
1956	193,400	31,190	25,296	137,700
1957	177,700	52,760	32,630	123,500
1958	a 249,610	108,900	58,270	135,200
1959	38,230	18,950	25,180	103,000
1960	31,510	3,920	1,810	44,730
1961	20,240	2,617	33	21,510
Average annual (rounded)	171,000	-----	32,000	139,000

a. Includes diversion and storage to Humboldt-Lovelock Irrigation, Light and Power Companies Reservoir.

b. Rye Patch Dam actually gained water this year. This probably is explained by the fact that the reservoir was drained and a considerable amount of bank storage was reclaimed. Gain in river is due to a large release caused by draining reservoir.

Outflow

The annual and average annual amount of Humboldt River water discharged into Humboldt Sink for the period of record 1936-61 is shown in table 3. The average annual discharge was approximately 51,000 acre-feet. The total discharge for the period was about 1,323,000 acre-feet; however, approximately 1,240,000 acre-feet, or about 94 percent, occurred in 5 water years of above normal flow (1942, 1943, 1945, 1946, and 1952). Because the capacity of Rye Patch Reservoir is only about 180,000 acre-feet, the excess flow during these years could not be contained. For the remaining 21 years of record, the average annual discharge was about 4,000 acre-feet. Chemical analyses suggest that at least part of this discharge in ordinary years is return flow from irrigation.

During floods, water discharges from the Humboldt Sink through the lower Humboldt Drain into Carson Sink. During the 1952 water year (October 1, 1951 - September 30, 1952), the outflow amounted to approximately 200,000 acre-feet. During the 1953 water year, approximately 25,000 acre-feet of water discharged into Carson Sink; however, nearly all the discharge occurred early in the water year and was a direct result of the 1952 flood. It is reported that no outflow has occurred since 1953. Although records prior to 1952 are not available, outflow probably occurred also in the 1942, 1943, 1945, and 1946 water years.

Table 3. -- Annual release, losses, and routing of water from Rye Patch Reservoir, in acre-feet, and the irrigated acreage in Lovelock Valley, Nevada, 1936-61.
(Table from Pershing County Water Conservation District)

Water year	Water released From Rye Patch Reservoir	Loss in river from Rye Patch Reservoir to Big 5 Dam	Water lost to Humboldt Sink	Water delivered to the heads of irrigation canals	Irrigated acreage (acres)
1936	82,220	4,847	c 2,500	d 74,873	12,500
1937	77,730	1,275	c 2,500	d 73,955	12,500
1938	65,470	a 213	c 2,500	d 63,183	12,500
1939	74,560	2,060	c 2,500	70,010	12,500
1940	60,280	713	c 2,500	57,067	12,500
1941	72,520	1,956	2,466	68,098	12,500
1942	183,412	b 4,829	112,815	b 65,768	12,500
1943	461,322	6,715	381,749	73,646	12,500
1944	75,990	b 3,959	c 2,500	b 69,531	17,000
1945	370,800	b 7,715	280,035	b 83,050	18,000
1946	281,200	1,087	178,105	102,022	22,000
1947	112,800	9,443	2,283	101,074	25,000
1948	98,520	3,406	1,132	93,982	25,000
1949	111,000	4,138	508	106,354	25,000
1950	118,300	11,089	1,601	105,610	25,000
1951	124,500	4,724	6,310	e 113,466	25,000
1952	408,600	a 276	297,300	e 111,376	25,000
1953	135,700	719	11,940	e 123,041	30,000
1954	103,000	a 32	5,840	e 97,192	30,000
1955	21,170	1,567	1,350	e 18,253	20,000
1956	137,700	12,606	3,760	e 121,334	30,000
1957	123,500	6,800	4,150	e 112,550	28,000
1958	135,200	12,488	6,620	e 116,092	30,000
1959	103,000	8,942	5,350	e 88,708	28,000
1960	44,730	3,004	c 2,500	39,226	22,000
1961	21,510	1,802	c 2,500	17,208	16,000
Average annual (rounded)	139,000	4,500	51,000	83,000	21,000

a. Rye Patch Reservoir actually gained water this year. This is probably explained by the fact that the reservoir was drained and a considerable amount of bank storage was reclaimed. Gain in river due to large releases.
b. Estimated.
c. Assumed by P.C.W.C.D. to be average loss to sink.
d. Taken from Bureau of Reclamation Project History calendar years 1936-38.
e. Taken from Crop Census Reports 1951-1959.

Streamflow Disposition and Routing

Seepage gains and losses along the Humboldt River

Because the Humboldt River is underlain by permeable deposits, seepage gains and losses are known to occur along the river in the study area. Seepage gains to the river occur when the head in the ground-water reservoir is higher than the head in the river, and of course the converse is also true. No seepage measurements were made during the course of this investigation and the time and places of gains or losses were not determined. However, according to the records of the Pershing County Water Conservation District, for the period 1936-61 there has been consistent loss, averaging about 4,500 acre-feet per year, between Rye Patch Dam and Big 5 Dam (table 3, and pl. 1).

Irrigation Routing

Amount Diverted to irrigate fields. -- Water released from Rye Patch reservoir is used principally for irrigation; very little is used for other purposes. The amount of water diverted for irrigation varies widely from year to year, depending upon upstream storage and current streamflow; for the period 1936-61 the average annual diversion was approximately 83,000 acre-feet (table 3). However, not all this water is applied to the fields, because some is lost by evaporation and transpiration and some by seepage from canals to the ground-water reservoir. As discussed in the ground-water discharge section of this report, on the average an estimated 20,000 acre-feet per year of the water diverted for irrigation is consumed by evapotranspiration. Accordingly, the average annual amount of water applied to the fields is on the order of 63,000 acre-feet.

Estimated Irrigation use. -- Since 1936 an average of about 21,000 acres (table 3) have been irrigated with about 3 acre-feet of water per acre (data from records of the Pershing County Water Conservation District). The main crop is alfalfa. According to Houston (1950, p.21), the annual consumptive use of water by alfalfa in Lovelock Valley is approximately 2 acre-feet per acre. Accordingly, the average annual consumption of water by irrigated crops is estimated to be about 42,000 acre-feet.

Drainage water. -- As just stated, during most years, 3 acre-feet of water per acre is applied to the fields, but the estimated consumptive use of water by alfalfa is only about 2 acre-feet per acre. The excess water applied is being used to leach soluble salts from the soil. This excess percolates downward to the water-table, then moves laterally into drainage ditches which discharge into the Humboldt Sink. These ditches not only carry off the excess leaching water but also drain the land to a depth of from 8 to 10 feet, which in large part prevents waterlogging. The amount of water discharged annually into these drains is indicated approximately by the difference of the amount diverted to the fields

(63,000 acre-feet) minus the consumptive use by crops (42,000 acre-feet), or about 21,000 acre-feet.

GENERAL GEOLOGY AND HYDROLOGY

Geomorphic Features

The mountain ranges of the report area are complexly folded and faulted mountain blocks of sedimentary, metamorphic, and igneous rocks. The present topographic relief is largely the result of movement along north-trending faults at the foot of the mountains.

Alluvial aprons, each composed of many small coalescing alluvial fans, have developed from debris washed from the mountain ranges. The aprons form the intermediate slopes between the mountains and the valley floor.

The valley floor of Lovelock Valley is a relatively flat surface, sloping southwestward at an average gradient of about 6 feet per mile. The valley floor has its most extensive development in the area south of the city of Lovelock, where the average land gradient is about 3 feet per mile.

Lithologic and Hydrologic Features of the Rocks

To describe the aquifer characteristics and the ground-water flow system, the rocks of the area were divided into three gross units: consolidated rock, older alluvium, and younger alluvium. The surface exposures of the rock units shown on plate 1 are based largely on interpretation of aerial photographs of the area and field observations made at widely scattered points. A geologic map of the Unionville Quadrangle (Wallace and others, 1962) was useful in identifying the lithology of the types of consolidated rocks in the northeastern part of the report area. The general characteristics of the lithologic units in the lower Humboldt River basin, which includes Lovelock Valley, are described in a report by Bredehoeft (1963, p. 20-28).

The consolidated rocks range in age from late Paleozoic to Cenozoic. Carbonate rocks of Mesozoic age have been mapped by Wallace and others (1962) in the northern part of the Humboldt Range. In T.30 N., Rs. 33 and 34 E., the carbonate rocks are the dominant type. To the south the proportion of carbonate rocks decreases. In T. 29 N., Rs. 33 and 34 E., the dominate rocks are volcanic flows, tuff, and breccia, mostly of late Paleozoic and early Cenozoic age. The Humboldt Range farther south, and the Trinity Range along the west side of the report area, appear to be composed chiefly of volcanic rocks.

Except for the carbonate rocks, the consolidated rocks of the report area have low permeability; hence, they are among the least economic sources of water in the area. Carbonate rocks commonly contain fractures and solution channels and locally may be highly permeable. Because of their unknown distribution beneath the valley fill, they were not evaluated as a potential source of water in this brief study.

The older alluvium is of late Tertiary and Quaternary age and consists mostly of gravel, silt, sand, and clay derived from the adjacent mountains. These deposits are adjacent to the mountain fronts and underlie the dissected alluvial aprons of the valley. They are characteristically unconsolidated to poorly consolidated, poorly sorted, and commonly deformed.

The younger alluvium, by contrast to the older alluvium, generally is unconsolidated, undissected, and structurally undisturbed. It is composed of gravel, sand, silt, and clay deposited by streams flowing from the adjacent mountains, by the Humboldt River, and by the ancient lake (Lake Lahontan) that formed in the area during Pleistocene time (Russell, 1885). The Pleistocene lake covered all the valley floor and much of the alluvial apron. The highest recognized lake level occurs at an altitude of about 4,380 feet. The fine-grained material that settled from the standing water produced the silt and clay beds of low permeability that generally blanket the area. These beds, as logged during well drilling, range in thickness from about 20 to 35 feet. Commonly the topsoil is developed in the upper part of these beds.

The alluvial deposits serve as a storage reservoir for the ground water in the valley. The maximum thickness of these deposits is unknown. A deep well, 26/31-12bl, was drilled to a depth of 1,386 feet. The driller's log (table 10) reports slate at a depth of 1,365 feet, indicating that at this location the alluvium is 1,365 feet thick. No other wells were drilled to a depth of more than about 400 feet, and the logs all indicate alluvium throughout their depth. Because of the very shallow depth to water along the axis of the valley, most wells were drilled to a depth of less than 100 feet. However, it generally was found necessary to drill through the superficial lake deposits to encounter a suitable water-baring zone.

The older alluvium is of low to moderate permeability and characteristically yields water to wells at low to moderate rates. The younger alluvium, beneath the valley floor, is moderately permeable and yields moderate to large water supplies to wells.

Sand and gravel beds were encountered at many depths, according to the well logs (table 10). Water-bearing zones that would yield small to moderately large supplies of water occur at depths of less than 100 feet. At greater depths, thicker sand and gravel beds commonly were encountered which would yield larger amounts of water. Most of the industrial, irrigation, and public-supply wells range in depth from about 200 to 400 feet.

Wells 27/31-9cl, 27/31-28al, and 28/31-34bl encountered large thicknesses of sand and gravel (table 10). These b eds probably would yield large supplies of ground water; however, the quality of the water has not been determined.

GROUND WATER HYDROLOGY

Source and Occurrence

The source of all the ground water in Lovelock Valley is from precipitation within the area, from subsurface underflow from the Imlay area to the north, from seepage loss from the Humboldt River as it crosses the area, and from recharge resulting from the downward percolate of irrigation water. Most of the ground water is contained in the older and younger alluvium and occurs under both artesian and water table conditions. Well 27/31-28cl, approximately 1 mile west of Lovelock, was the only flowing well located, and on October 6, 1964, the estimated flow was 5 gpm (gallons per minute) (table 9).

Although ground water occurs in large quantities in the project area, the water between Woolsey and the Humboldt Sink generally is too highly mineralized for agricultural and domestic uses. However, ground water north of Woolsey probably is suitable for both uses. Lovelock's water supply is obtained from four wells east of Oreana in what previously has been described as the Oreana subarea. These wells yield 400 to 600 gpm. Well 29/33-33cl, during a 48 hour pumping test in 1945, reportedly yielded approximately 400 gpm with a 15 foot drawdown.

Some ground water occurs in the consolidated rocks as is evidenced by springs discharging from them. However, due to their low permeability, yields from any wells tapping them probably would be small compared to those in the alluvium. An exception is the carbonate rocks, which locally would yield moderate to large quantities of water to wells.

Thus, the principal ground-water reservoir system in Lovelock valley includes the younger and older alluvium. It is contained between the consolidated rocks on the east and west sides of the valley, which form the external boundaries of the system. The reservoir system is hydrologically continuous across the north and south boundaries of the study area. The thickness of the alluvium ranges from a few feet along the east and west sides to more than 1,000 feet along the axis of the valley.

Movement

Ground water, like surface water, moves from areas of higher head to areas of lower head. Unlike surface water, however, it moves very slowly; at rates ranging from a fraction of a foot to several hundred feet per year, depending on the permeability and hydraulic gradient.

In Lovelock Valley, ground water moves both from recharge areas in the mountains and from the Imlay area to discharge areas in the valley lowlands. The principal direction of movement is southward toward the Humboldt Sink and to a lesser extent from the bordering mountains toward the axis of the valley.

Recharge

Particularly all the ground-water recharge in the project area is derived from precipitation within the Lovelock Area, from subsurface under-flow from the Imlay area, from seepage losses from the Humboldt River, and from recharge resulting from irrigation.

Recharge from Precipitation within the Area.

Part of the recharge to the project area is derived from precipitation within the drainage basin. However, because most of the precipitation is lost through evapotranspiration, only a small percentage recharges the ground-water reservoir. The mountains receive more precipitation than the lowlands, and accordingly, contribute more runoff and recharge to the area. During the spring, as the snow melts, some of the resulting stream flow infiltrates into cracks in the consolidated rocks and moves toward the valley as ground-water underflow. A small part of the precipitation on the alluvial apron, and some of the streamflow crossing the alluvial apron, also infiltrates to the ground-water reservoir in the alluvium. Because average annual precipitation on the valley floor is small, virtually none infiltrates to the ground-water reservoir. However, during years of above-average precipitation, some rain probably percolates downward to the ground-water reservoir.

The estimated average annual recharge is computed as a percentage of the average annual precipitation within the area--a method developed by Eakin and others (1951, p. 79-81). The method is based on the assumption that a fixed percentage of the average annual precipitation ultimately re-charges the ground-water reservoir. Because of the numerous variables that influence the percentage of precipitation that becomes recharge in any particular locality, the computations based on this method provide only highly generalized estimates.

Precipitation data are available for Lovelock and Rye Patch Dam in the project area (table 4). Data from these stations indicate the general precipitation pattern in Nevada; that is, the station at the lowest altitude records the least precipitation. Precipitation in the topographically lowest part of Lovelock Valley averages less than 6 inches per year; however, that on the highest peaks may average more than 20 inches per year.

The precipitation map of Nevada (Hardman & Mason 1949, p. 10.) has been adjusted (Hardman, Oral communications, 1964) to the improved topographic base maps (scale 1:250,000) now available for the whole State. Hardman showed that the average annual precipitation is closely related to altitude. This map was used to estimate the precipitation at different altitude zones, because precipitation data in the area are available only for the lowest zone. The altitude zones, the estimated average annual precipitation, and the percentage in each zone that ultimately recharges the ground water reservoir are listed in table 5.

Table 4. --Average monthly and annual precipitation, in inches, at two stations in Lovelock Valley, Nevada.

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

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Lovelock 1/	0.81	0.75	0.55	0.52	0.48	0.61	0.13	0.14	0.20	0.53	0.42	0.64	5.78
Rye Patch Dam 2/	.74	.72	.65	.65	1.00	.73	.26	.19	.32	.65	.60	.59	7.10

1/ Altitude 3,977 feet. In Sec. 26, T. 27 N., R. 31 E. Period of Record 1891 - 1963.

2/ Altitude 4,135 feet. In Sec. 18, T. 30 N., R 33 E. Period of Record 1936 - 1963.

Table 5. --Estimated average annual ground-water recharge from precipitation in Lovelock Valley, Nevada

Altitude zone (Ft.)	Area (acres)	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average (feet)	Estimated annual precipitation: Average (Ac.-ft.)	Estimated recharge: Assumed percentage of precipitation	Estimated recharge: (acre-feet per year)
			Upper and Lower Lovelock Valley			
6,500-7,500	3,000	12-15	1.12	3,400	7	240
5,500-6,500	37,100	8-12	.83	30,800	3	920
Below 5,500	366,000	less than 8	.50	183,000	-	- -
Subtotal (rounded)	406,000	--	--	217,000	-	1,200
			Oreana subarea			
Above 8,500	920	more than 20	1.75	1,600	25	400
7,500-8,500	3,510	15-20	1.46	5,100	15	760
6,500-7,500	6,000	12-15	1.12	6,720	7	470
5,500-6,500	14,300	8-12	.83	11,900	3	360
Below 5,500	40,000	less than 8	.50	20,000	-	- -
Subtotal (rounded)	65,000	-	-	45,000	-	2,000
Total (rounded)	471,000	-	-	262,000	-	3,200

The estimated average annual precipitation for the project area is 262,000 acre-feet, and the estimated average annual recharge is 3,200 acre-feet. Thus, only a little more than 1 percent of the total precipitation recharges the ground-water reservoir. In the Oreana sub area, the estimated average annual precipitation is 45,000 acre-feet, and the estimated average annual recharge is 2,000 acre-feet (table 5). Thus, precipitation in the Oreana subarea contributes about 60 percent of the ground-water recharge for the entire area, even though the subarea constitutes only about 14 percent of the total area.

Subsurface Inflow from the Imlay Area

Subsurface inflow, or ground-water underflow, enters Lovelock Valley from the Imlay area, which is upstream along the Humboldt River. Eakin (1962, p. 32-33) estimated this underflow to be about 1,000 acre-feet per year.

Seepage Loss from the Humboldt River

Seepage loss from the Humboldt River recharges the ground-water reservoir. The most significant seepage losses probably occur in the spring and early summer when the stage of the river is highest. However, some water seeps to the ground-water reservoir during periods of low streamflow. According to the records of the Pershing County Water Conservation District, an average of 4,500 acre-feet, or about 3.2 percent of the water released from Rye Patch Dam, is lost annually between the dam and Big 5 Dam. However, some of this loss is due to evaporation from the river, and some adds to the soil moisture and is lost to phreatophytes (water-loving plants) along the banks.

Recharge from Irrigation

Humboldt River water is diverted for irrigation usually from mid-April to early October. The water is diverted into irrigation ditches from which some percolates downward and infiltrates to the ground-water reservoir. Some recharge also occurs by downward percolation of the water applied to the fields, because water commonly is applied in excess of the field capacity of the soil. As previously stated, the estimated average annual amount of deep percolation is on the order of 21,000 acre-feet. Nearly all this water is eventually discharged into drains, which convey the water to the Humboldt Sink.

Discharge

In lovelock Valley, g round water is discharged by evaporation, transpiration, pumping, and ground-water outflow to the Humboldt Sink.

Evapotranspiration

The ground water discharged by evapotranspiration is consumed by phreatophytes and evaporates from areas of bare soil. The area of evapotranspiration is shown in plate 1. The principal phreatophytes are greasewood, rabbitbrush, and saltgrass. Cottonwood, willow, and salt-cedar also grow principally along the banks of the Humboldt River and along the margin of the Humboldt Sink. The water losses by evapotranspiration in the Humboldt Sink area are supplied by drainage canals and the Humboldt River. Table 6 lists the estimated average annual evapotranspiration of ground water in Lovelock Valley north of a line connecting the north end of Toulon Lake and Big 5 Dam. These extimates are based on the rates of evapotranspiration in other areas determined by Lee (1912), White (1932), and Young and Blaney (1942), and for the Humboldt River Valley by Houston (1950) and Robinson (1963). The estimated average annual evapotranspiration of ground water is about 1,400 acre-feet in the Oreana subarea, 2,500 acre-feet in upper Lovelock Valley, and 20,000 acre-feet in lower Lovelock Valley; or a total of about 24,000 acre-feet.

In lower Lovelock Valley, the numerous irrigation canals and ditches contain phreatophytes, are in areas of shallow ground water, and are adjacent to large areas of phreatophytes. Most of the estimated evapotranspiration loss of 20,000 acre-feet per year is attributed to evaporation of canal and ditch water, transpiration from vegetation in or along the canals, and seepage losses from canals and ditches which support the large adjacent areas of phreatophytes.

Pumping

Pumpage in the report area is small, and is limited to a few wells in upper Lovelock Valley which supply domestic and stock needs, four municipal supply wells, and two irrigation wells in the Oreana subarea.

Total discharge by wells in 1964 was on the order of 1,500 acre-feet, and nearly all the discharge was from the municipal and irrigation wells. However, due to pipe leakage and deep percolation of irrigation water, about one-third of the pumped water returned to the ground-water reservoir. Thus, in 1964 the estimated net draft on the ground-water reservoir resulting from discharge by wells was about 1,000 acre-feet.

Table 6. --Estimated average annual evapotranspiration of ground-water Lovelock Valley, Nevada.

Subarea (Pl. 1)	Principal phreatophyte	Area (acres)	Areal density (percent)	Depth to water (feet)	Evapotranspiration: Acre-feet per acre	Evapotranspiration: acre-feet (rounded)
Oreana Subarea	Greasewood and rabbitbrush	7,000	10 to 25	10 to 40	0.2	1,400
Subtotal						1,400
Upper Lovelock Valley	Greasewood, rabbitbrush, and salt grass	5,000	20 to 30	2 to 10	0.5	2,500
	Cottonwood and willow	small	--	1 to 5	4	trace
Subtotal						2,500
Lower Lovelock Valley	Greasewood, rabbitbrush, and salt grass	40,000	20 to 30	2 to 10	0.5	20,000
	Cottonwood, willow and saltcedar	small	--	1 to 5	4	trace
Subtotal						20,000
Total (rounded)		52,000				24,000

Ground-water Outflow

Ground-water outflow from the agricultural area of Lovelock Valley to the Humboldt Sink is estimated to be on the order of 2,000 acre-feet per year. This estimate is based on the assumption that the alluvium may have a transmissibility of about 50,000 gpd (gallons per day) per foot, that the ground-water gradient is about 5 feet per mile, and that the effective under-flow width is about 8 miles.

Water Budget

In Lovelock Valley, the long-term net change of ground-water in storage is considered to be nearly zero. Therefore, the long-term average annual inflow and outflow of water should be equal. Inflow includes surface-water inflow, ground-water inflow, and recharge resulting from precipitation. Outflow includes surface-water and ground-water outflow to the Humboldt Sink, discharge by evapotranspiration, and net discharge by pumping. Each of these elements were estimated in the preceding sections of the report for the period 1936-61. The total average annual inflow and outflow are summarized in table 7 and are 143,000 and 141,000 acre-feet, respectively. The small imbalance between the two values is a result of the limited available data, the unresolved hydrologic problems, and the fact that one of the budget elements was determined by difference. Considering the reliability of the estimates and using the 26-year period 1936-61 as a base period, the total annual water supply available to Lovelock Valley probably is about 140,000 acre-feet per year.

Of the estimated average annual outflow of 141,000 acre-feet, 74,000 acre-feet was discharged by surface and subsurface outflow to the Humboldt and Carson Sinks. The remaining 67,000 acre-feet was discharged by evapotranspiration and pumping, in Lovelock Valley.

Table 7. --Water budget for Lovelock Valley, Nevada, 1936-61.

Budget element	26 year average (acre-feet per year)
Inflow:	
Surface-water inflow	139,000
Ground-water inflow	1,000
Recharge from precipitation	3,200
Total (rounded) (1)	143,000
Outflow:	
Outflow of Humboldt River Water to Humboldt Sink	51,000
Outflow of irrigation-drain water to Humboldt Sink	a 21,000
Use of water by irrigated crops	42,000
Evapotranspiration by phreatophytes and from bare soil	24,000
Ground-water outflow to Humboldt Sink	2,000
Net discharge by pumping	1,000
Total (2)	141,000
Imbalance: (1) - (2)	2,000

a. This value was obtained indirectly by taking the difference between the estimated water applied to crops (63,000 acre-feet) and the estimated use by irrigated crops (42,000 acre-feet).

Perennial Yield

The perennial yield of a ground-water reservoir is the maximum amount of water of usable chemical quality that can be withdrawn economically each year for an indefinite period of time. If the perennial yield is continually exceeded, water levels will decline until the ground-water reservoir is depleted of water of usable quality, or the pumping lifts become uneconomical to maintain. The perennial yield, therefore, cannot indefinitely exceed the natural recharge to an area unless induced or artificial recharge is started. In the final analysis, the yield is limited to the amount of natural discharge that can be economically salvaged for beneficial use.

The perennial yield of the ground-water reservoir in Lovelock Valley is largely indeterminate at this time because of the existing hydraulic relation between the Humboldt River and the ground-water system. Any substantial drawdown of water levels caused by pumping near the river would induce recharge from the river as long as any flow existed.

Because most of the water in lower Lovelock Valley is highly mineralized and unsuitable for most uses, any additional pumping for the most part probably will be restricted to upper Lovelock Valley and the Oreana subarea, where the pumpage in 1964 was about 1,500 acre-feet. The estimated average recharge to the Oreana subarea from local sources is about 2,000 acre-feet per year (table 5). This recharge moves generally westward; most is evaporated and transpired in areas of shallow ground water largely east of U.S. Highway 40, and the remainder is discharged into the Humboldt River or is consumed by evapotranspiration along the narrow floodplain. The extent to which pumping has disturbed this natural regimen was not determined.

Although the yield could be limited to the salvable ground-water discharge in the Oreana subarea, it is a relatively small part of the total water supply available -- about 140,000 acre-feet per year for the period 1936-61. More pertinent to the water supply is an average of about 50,000 acre-feet per year of flood water that has wasted to the Humboldt Sink, principally in water years 1942, 1943, 1945, 1946, and 1952, which was about a third of the total supply available (table 3). Consideration could be given to salvaging a substantial part of the flood water by increasing existing surface-storage facilities and by the conjunctive use of surface- and ground-water storage. Use of the ground-water reservoir for storage would require well fields along the river to deplete the ground water in storage during dry periods to provide storage space for recharge from flood water. A feasibility study of such a plan was beyond the scope of this study. Thus, the potential water yield of the river, based on the supply during the period 1936-61, and the ground-water system combined is roughly 140,000 acre-feet per year. The yield from locally derived recharge to ground-water reservoirs is only about

2,000 acre-feet per year (the Oreana subarea). As of 1964, the developed yield of the two sources was about 85,000 acre-feet per year, or about two-thirds of the total available supply.

Storage

The amount of ground water in storage in Lovelock Valley is equal to the volume of saturated material multiplied by the specific yield of the material. Specific yield is the ratio of the volume of water that will drain by gravity from the zone of saturation to the volume of the saturated material drained, commonly expressed as a percentage.

The specific yield of the uppermost 100 feet of saturated material in the project area may be on the order of 10 percent. The estimated area underlain by 100 or more feet of saturated material is 200,000 acres, or about 80 percent of the 250,000 acres mapped as younger and older alluvium (pl. 1). Accordingly, the amount of ground water in storage in the upper-most 100 feet of the zone of saturation beneath this area is about 2,000,000 acre-feet. However, much of this water is highly mineralized and is unsuitable for irrigation or domestic uses.

The amount of ground water in storage in the Oreana subarea (pl. 1) has also been calculated, as this area contains ground water that is of suitable quality and has been developed to some extent. The specific yield of the saturated deposits also is estimated to be on the order of 10 percent and the estimated area underlain by 100 or more feet of saturated deposits is 22,000 acres. These estimates suggest that the amount of ground water in storage in the uppermost 100 feet of the zone of saturation is 220,000 acre-feet, or about 2,200 acre-feet for each foot of saturated material.

The amount of usable ground water in storage that is available on an economic basis depends in part on the distribution of water-storing deposits, the distribution and range in chemical concentration of the ground water, the number and distribution of wells, and the quantities of water withdrawn.

CHEMICAL QUALITY

Water samples were analysed as part of the present study to make a generalized appraisal of the suitability of the water for agricultural and domestic uses and to help define potential water-quality problems. Daily samples have been collected from the Humboldt River near Rye Patch for the period April 4, 1960 to the present time. Table 8 lists the annual weighted averages for the 1960-63 water years. In addition, 13 water samples were collected in October 1964 from wells, from the Lower Humboldt Drain, and from the Humboldt River at intervals below Rye Patch Dam (table 8).

Classification of Irrigation Water

According to the U.S. Department of Agriculture (1954, p. 69), the most significant factors with regard to the chemical suitability of water for irrigation are dissolved-solids content, the relative proporation of sodium to calcium and nagnesium, and the concentration of elements and compounds that are toxic to plants. Dissolved-solids content commonly is expressed as "salinity hazard", and the relative proportion of sodium to calcium and magnesium as "alkali hazard".

The Salinity Laboratory Staff suggests that salinity and alkali hazards should be given first consideration when appraising the quality of irrigation water, then consideration should be given to boron or other toxic elements, any one of which may change the quality rating.

Table 8.--Chemical analyses, in parts per million, of water from the Humboldt River, the Lower Humboldt Drain, and wells in Lovelock Valley, Pershing County, Nev.

(Analyses by the U.S. Geological Survey)

Location (well no. or stream)	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 (calculated)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	SAR	Specific conductance (micromhos at 25°C)	pH
Humboldt River near Rye Patch (Annual weighted average)																					
Humboldt River near Rye Patch	1960	--	37	--	51	21	199	21	325	0	115	201	--	0.3	0.9	a 507	214	0	5.9	1,330	--
Do.	1961	--	38	--	92	30	303	26	345	0	139	447	--	1.4	1.3	a1,280	353	71	7.0	2,150	--
Do.	1962	--	39	0.02	49	13	95	13	277	4	65	54	0.7	1.3	.4	a 480	178	0	3.1	727	--
Do.	1963	--	36	.01	47	17	116	15	331	5	76	71	.9	1.2	.4	a 552	190	0	3.7	874	--
Humboldt River below Rye Patch																					
Site A	10-6-64	66	38	.07	42	15	98	13	288	13	63	61	.7	1.3	.5	492	178	0	3.2	784	8.6
Site B	10-7-64	64	37	.09	40	18	100	13	291	13	69	62	.7	1.0	.5	497	176	0	3.3	811	8.7
Site C	10-8-64	60	41	.07	46	16	158	16	318	12	75	124	.9	1.4	.8	647	180	0	5.1	1,050	8.6
Site D	10-8-64	61	38	.02	45	25	1,190	29	329	27	177	1,590	.9	8.7	5.0	3,330	214	0	35	6,070	8.6
Lower Humboldt Drain																					
24/29-26dba	10-9-64	62	39	.03	62	158	3,040	369	1,160	47	578	3,890	1.3	19	15	8,570	805	0	47	14,300	8.5
Wells																					
26/30-27a1[1]	10-8-64	64	--	--	5.1	4.7	1,080		636	81	280	1,020	--	--	--	--	32	0	83	5,150	8.8
26/31-32c1	10-8-64	57	52	.25	122	37	375	39	302	0	349	451	2.0	63	1.4	1,640	457	209	7.6	2,820	8.0
27/31-28c1[1]	10-6-64	60	--	--	20	11	1,190		381	0	75	1,620	--	--	--	--	96	0	53	6,110	7.7
27/31-35d1	10-8-64	61	49	.60	97	31	492	44	458	0	175	650	1.5	3.9	2.1	1,770	370	0	11	3,020	8.1
28/32-33c1	10-8-64	150	76	.40	115	19	1,700	120	186	0	282	2,580	4.1	42	3.4	5,040	366	213	39	10,200	7.9
29/32-36a2	10-8-64	--	39	.81	61	15	132	3.6	239	0	135	131	.3	1.1	.5	637	213	17	5.2	1,070	8.2
29/33-21d1	10-6-64	65	23	.03	37	5.6	30	2.2	144	0	20	28	.0	1.1	.1	218	115	0	.8	365	8.2
29/33-33c1	10-6-64	64	27	.01	50	7.1	34	2.5	146	0	52	46	.0	2.0	.2	293	154	34	1.2	490	8.1

1. Field analyses by the U.S. Geological Survey.

a. Residue at 180°C.

Specific conductance is used to express the salinity hazard because of its ease of determination and its relationship to the dissolved-solids content. Salinity hazard and its relation to specific conductance are defined by the U.S. Department of Agriculture as follows:

Salinity hazard	Specific conductance (micromhos per centimeter at 25°C.)	Classification
Low	0- 250	C-1
Medium	251- 750	C-2
High	751-2,250	C-3
Very high	Greater than 2,250	C-4

Alkali hazard, as shown in figure 2, is related to both sodium-absorption-ratio (SAR) and specific conductance. Sodium-absorption ratio is a relation of sodium to calcium and magnesium, expressed in equivalents per million (epm), and is defined in the following equation:

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

The SAR value for water is related to the experimentally determined absorption of sodium by soil to which the water is added, and is a direct means of estimating possible results of using a water for irrigation.

Boron is one of the most critical elements in irrigation water. It is necessary for proper plant nutrition in small quantities but highly toxic in amounts only slightly greater than optimum. The permissible limit is dependent upon the soil and type of crop grown. The permissible limits for boron in irrigation water for semitolerant and tolerant crops, the types of crops currently raised in the area, are as follow (Scofield, 1936):

Classes of water	Boron content, in parts per million	
	Semitolerant crops	Tolerant crops
Excellent	less than 0.67	less than 1.00
Good	.67 to 1.33	1.00 to 2.00
Permissible	1.33 to 2.00	2.00 to 3.00
Doubtful	2.00 to 2.50	3.00 to 3.75
Unsuitable	more than 2.50	more than 3.75

Suitability for Agricultural Uses

The Humboldt River supplies virtually all the water used for irrigation in the project area. The salinity hazard of water released from Rye Patch reservoir ranges from medium during high-flow years to very high during low-flow years. Because the release of water from Rye Patch reservoir is controlled, no relationship exists between the quantity released and water quality. However, on a yearly basis a general relationship exists between the quantity of inflow to Rye Patch Reservoir and the quality of water released from the reservoir. A comparison was made of the flow at Imlay, 17 miles northeast of Rye Patch Dam, to the quality of the water released from Rye Patch Reservoir. Low flow occurred in the water years 1960 and 1961, above average-flow occurred in 1962, and average flow occurred in 1963, as shown below:

Water year	Discharge at Imlay (acre-feet)	Discharge at Rye Patch Dam (acre-feet)
1960	31,500	44,730
1961	20,200	21,510
1962	229,700	126,300
1963	127,000	100,000
24 - year average	118,000	- - -
49 - year average	- - -	140,500

Figure 3 shows that for the period 1960-63, the specific conductance exceeded 2,250 micromhos only 5 percent of the time and 750 micromhos 90 percent of the time. Figure 2 shows that the alkali hazard ranged from low to medium. However, during period of average or above average flow, the alkali hazard generally is low. The boron content of the water is within acceptable limits and only occasionally exceeds 1 ppm (part per million). With proper management and drainage, this water has proved to be suitable for irrigation.

Based on one water sample collected in October 1964, the salinity and alkali hazards of Humboldt River water below Big 5 Dam were very high, and the boron content of 5.0 ppm was greater than optimum. Accordingly, this water was unsuitable for irrigation.

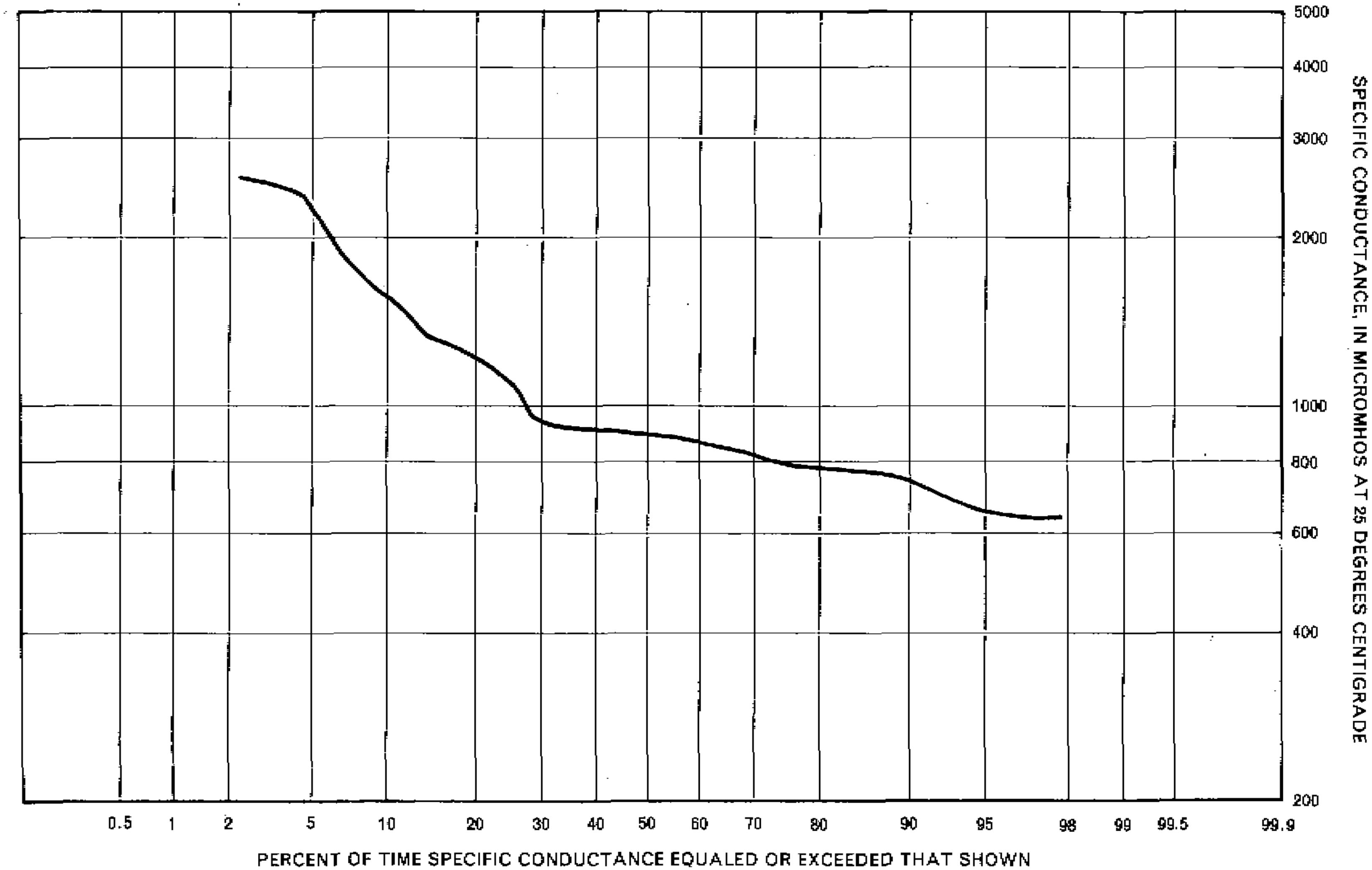

Figure 3.— Duration curve of specific conductance, Humboldt River near Rye Patch, Nevada (April 4, 1960-July 31, 1964)

Ground water in lower Lovelock Valley generally is too highly mineralized for agricultural use. Figure 2 shows that the alkali hazard is medium to high and that the salinity hazard is very high. Wells 26/30-27al and 27/31-28cl are not shown on figure 2; however, these wells yield water with conductance values of 5,150 and 6,110 micromhos, respectively. The alkali and salinity hazards as defined are very high. Also, it is reported by several farmers that much of the water contains boron in amounts greater than optimum. Accordingly, based on alkali hazard, salinity hazard, and boron content, this water is unsuitable for irrigation.

In the Oreana subarea chemical analyses of water from wells indicate that ground water is suitable for irrigation. The boron content is low, and as shown in fig. 2, the alkali hazard is also low, and the salinity hazard is medium.

Suitability for Domestic Uses

The limits recommended by the U.S. Public Health Service (1962) for water used on interstate carriers for drinking purposes commonly are cited as standards for domestic use. Listed below are some of the chemical substances which should not be present in water in excess of the listed concentrations where more suitable supplies are available.

Constitutents	Concentration (parts per million)
Chloride (Cl)	250
Iron (Fe)	0.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Fluoride (F)	a 1.7
Total dissolved solids	500 (1,000 permitted)

a. Varies with mean temperature in sense that higher temperature results in more water intake.

The city of Lovelock obtains its municipal water supply from four wells in the Oreana subarea. The concentration of chemical constitutents in water from well 29/33-33cl (table 8) are within the limits recommended by the U.S. Public Health Service. Humboldt River water, during periods of high flow, also meets these requirements; however, during periods of low flow, the dissolved-solids and chloride content exceed the recommended limits. Ground water in lower Lovelock Valley generally is unsuitable for domestic use because of the high sulfate, chloride, nitrate, fluoride, and dissolved-solids content. For example, water from well 26/31-32cl contains 349 ppm sulfate, 451 ppm chloride, 63 ppm nitrate, 2.0 ppm fluoride, and 1,640 ppm dissolved-solids (table 8)all of which are above the recommended limits.

Variations in Water Quality of the Humboldt River

Water quality of the Humboldt River varies with time and also varies as the water moves downstream. Chemical analyses of water released from Rye Patch reservoir (table 8) and streamflow data at the Imlay gaging station (table 2) show that the concentration of dissolved-solids varies inversely with streamflow. Base flow, or low sustained flow, of a stream generally is water that has entered the stream from the ground-water reservoir. This water has been in contact with rock and soil particles and has leached the soluble minerals. At high stages the more mineralized ground water entering the stream is diluted by large volumes of surface runoff. During the 1960 and 1961 water years, years of below average runoff, the specific conductance ranged from 1,010 to 2,550 micromhos. During the 1962 and 1963 water years, years of average or above average streamflow, the specific conductance ranged from 648 to 933 micromhos.

Chemical analyses of water at four locations on the Humboldt River below Rye Patch Dam, designated A, B, C, and D on plate 1, show that the water becomes more highly mineralized as it moves downstream. The dissolved-solids content increased from 492 ppm at station A to 3,330 ppm at station D (table 8). Sodium and chloride account for most of the increase, which is due mainly to return seepage from irrigation or from ground water in the nearby phreatophyte area.

Water Quality and its Relation to the Ground-Water System

The quality of ground water in the project area varies from place to place; however, in general, the dissolved-solids content is low in the recharge areas in the mountains and increases as it moves toward the area of discharge in the lower parts of the valley. For example, water from wells 29/33-21dl and 29/33-33cl have dissolved-solids contents of 218 and 293 ppm, respectively, and is a calcium bicarbonate type. The source of this water is recharge derived from precipitation on the nearby Humboldt Range. As the ground water moves westward, it dissolves additional mineral matter, and the dissolved-solids content of water from well 29/32-36a2 is 637 ppm. The movement of ground water is then southward toward the Humboldt Sink. Water from wells 26/31-32cl and 27/31-35dl has dissolved-solids of 1,640 and 1,770 ppm, repsectively, and is a sodium chloride type. These wells penetrate fine-grained lacustrine strata, and it is presumed that sodium and chloride were derived largely from evaporites in the lacustrine deposits.

Salt Balance

As pointed out by Hem (Halpenny and others, 1952, p. 147):

> "It has long been recognized that if an irrigation project is to be permanently successful, it must be so designed and operated that the drainage leaving the area of irrigation carries off the accumulating soluble salt from the whole area. Ideally, the amount of soluble mineral matter that must be removed should at least be equivalent to the amount entering the area in the irrigation water supply and from other sources. This is essentially the principal of 'salt balance'."

The principle of salt balance cannot be applied to the project area as a whole because there is little or no outflow; any salt carried into the valley by surface water or ground water must necessarily remain in the valley somewhere. Data are not available to show areas where salt is deposited; however, it is assumed that the vast majority of it is deposited in the Humboldt Sink.

During the 1963 water year, approximately 75,000 tons of dissolved-solids were transported into the project area by 100,000 acre-feet of flow in the Humboldt River. It is reported that about 30,000 acres were irrigated with approximately 3 acre-feet of water per acre. Therefore, about 90,000 acre-feet of water containing approximately 70,000 tons of dissolved-solids reached the irrigated areas through the application of irrigation water. In Lovelock Valley, excess soluble matter left in the soil from irrigation is r emoved by leaching the topsoil and allowing the resulting solution to pass downward into the ground-water reservoir. The process of leaching is achieved principally by the application of more irrigation water than the plants require. Drainage canals have been dug to facilitate the drainage of ground water and thus prevent waterlogging and accumulation of salts. These drains carry the water southward to the Humboldt Sink. The drainage water extracted is smaller in quantity than the amount of irrigation water applied, but is higher in dissolved solids because of concentration by evapotranspiration and the leaching of soluble matter from the soil. For example, water from the Humboldt River at station D, as shown in table 8, has a dissolved solids content of 3,330 ppm. Salt balance in Lovelock Valley is dependent on leaching and drainage and must be maintained if irrigation is to continue successfully.

DEVELOPMENT

Development in Lovelock Valley began in about 1860 with the raising of cattle and the irrigation of meadow grasses. During the early years of water use, small retention basins were constructed to conserve water. However, the ranchers were still dependent on the flow of the Humboldt River for irrigation water in late summer. With the completion of Rye Patch Dam in 1937, a more consistent and dependable supply of water has been available for irrigation, especially in late summer.

Present development of surface water consists of the irrigation of approximately 30,000 acres in lower Lovelock Valley. The acreage varies from year to year, depending on streamflow and storage in Rye Patch Reservoir. The major crop is alfalfa; however, wheat, oats, barley, and sugar beets are also grown. Since Rye Patch Dam has been in operation, more water has been applied over a longer irrigation season. The result has been a gradual rise in water levels. However, this condition has been corrected by constructing a system of open drains which ultimately discharge to the Humboldt Sink.

The only important ground-water development in the valley is in the Oreana subarea. The city of Lovelock and the Big Meadows Water Association obtain their water supplies from four wells in this area. Some ground-water in this area is also used for irrigation.

Table 9.--Records of selected wells in Lovelock Valley, Pershing County, Nevada

Type of well: Dr, drilled; Dg, dug
Water level: M, measured; R, reported
Depth: M, measured; R, reported

Use: D, domestic; Ps, public supply;
I, irrigation; S, stock;
Ind, industry; U, unused

Well number or location	Owner	Type of well	Date completed	Casing diameter (inches)	Depth (feet)	Water level: Below land surface datum (feet)	Water level: Date measured or reported	Use	Remarks
24/30- 1c1	--	Dr.	--	6	--	40.87 M	10- 7-64	U	
25/29-24d1	Toy Milling Co.	Dr.	1955	8	41 R	6.5 R	5- 9-56	Ind.	Log
25/30- 1b1	Civil Aeronautics Admin.	Dr.	1951	8	50 R	7.60 M	10- 8-64	U	Previously used for fire protection
25/30- 8c1	Rare Metals Corp.	Dr.	1936	-	210 R	14.2 M	1-10-46	Ind.	
25/30-36a1	--	Dg.	--	60	--	4.00 M	10- 7-64	U	
25/31- 2b1	--	Dg.	--	72	--	6.70 M	10- 8-64	U	
25/31- 8b1	T. Derby	Dr.	--	8.5	14.5 M	2.98 M	1-10-46	S	
26/30-27a1	J. and H. Livestock Co.	Dr.	1953	8	34 R	17 R	1-20-54	U	
26/31- 9a1	Big Meadow Cemetary Assn.	Dr.	--	-	44 M	9.70 M	10-12-45	I	
26/31-12b1	W. U. Barnes	Dr.	1962	16,12,10	1,386 R	11 R	1-29-62	I,S	Log; 80 gpm per foot drawdown
26/31-22c1	Chester A. Anker	Dr.	1948	8	48 R	9 R	10-27-48	-	
26/31-32c1	--	Dg.	--	48	--	9.3 M	10- 8-64	U	
27/31- 1c1	Tom Hay	Dr.	1955	12	50 R	10 R	6- 9-55	I	Log
27/31- 2d1	Victor Sebbas	Dg.	--	42	20 M	6.42 M	10- 7-64	S	
27/31- 3d1	--	Dg.	--	48	--	9.20 M	10- 7-64	S	
27/31- 9c1	Turrillas Flat Ranch	Dr.	1961	16	251 R	18 M	4- 5-61	I	Log; 100 gpm per foot drawdown
27/31-10d1	Antone P. Johnson	Dr.	1954	8	42 R	12 R	7-12-54	S	Log
27/31-12a1	--	Dr.	--	8	19 M	4.17 M	6-28-45	S	
27/31-13d1	Louise Bonarcorsi	Dr.	1952	8	40 R	4.60 M	10- 8-64	U	Log
27/31-15c1	Green Brothers	Dr.	1948	10	35 R	9.5 R	2- 5-48	S	
27/31-16c1	H. J. Murrish	Dr.	1936	-	40 R	10.8 M	10-11-45	U	
27/31-20d1	B. L. M.	Dr.	1936	6	48 M	34.54 M	10- 6-64	S	
27/31-22b1	Joe Tenente	Dr.	--	8	--	10.85 M	1- 8-46	S	
27/31-26c1	Pershing General Hospital	Dr.	--	8	37 M	6.50 M	10-12-45	I	
27/31-28a1	W. U. Barnes	Dr.	1961	14	389 R	4 R	4-28-61	I	Log; 62.5 gpm per foot drawdown
27/31-28c1	--	Dr.	--	6	200 R	Flowing	10- 6-64	D	Estimated flow, 5 gpm
27/31-29c1	Pacific States Savings & Loan Co.	Dg.	--	72	20.5 M	2.41 M	10- 6-64	S	
27/31-31d1	Kuhn and Mills	Dr.	1947	10	65 R	8 R	1- 8-48	D	
27/31-35d1	--	Dg.	--	48	--	7.5 M	10- 8-64	U	
27/32- 7a1	C. Elgas	Dr.	--	8	19.0 M	4.76 M	6-28-45	-	
27/32-18a1	Carl Hightower	Dr.	1948	8	40 R	8 R	4-14-48	D,S	Log
27/32-30d1	Glen Baird	Dr.	1951	8	50 R	22 R	1-22-51	D	Log
28/31-34b1	Metropolitan Finance Co.	Dr.	1961	16	325 R	27 R	4-24-61	I,S	Log; 113 gpm per foot drawdown
28/32-10c1	Bidge Duncan	Dr.	1961	8	56 R	22.6 M	10- 6-64	D	Log
28/32-28a1	Herman Marker	Dr.	--	8	24 M	17.05 M	10-11-45	D	
28/32-29a1	H. T. Brink	Dr.	1954	14	199 R	18 R	10-25-54	I	Log
28/32-33c1	Mineral Materials	Dr.	1956	8	80 R	60 R	5- 9-56	U	Log
28/33- 3b1	Grazing Service	Dr.	--	10	--	110.2 M	11- 3-52	S	
28/33- 4a1	B. L. M.	Dr.	1938	6	278 R	95.6 M	10- 6-64	-	Log
29/32-36a1	George Brown	Dr.	--	8	--	20.8 M	10- 8-64	I	
29/32-36a2	George Brown	Dr.	1961	8	70 M	28.3 M	10- 8-64	D	
29/33-17c1	Dodge Construction Co.	Dr.	1961	8	340 R	80 R	8- 3-61	Ind.	Log
29/33-21d1	Oreana Development Co.	Dr.	1951	14	442 R	63 R	4-25-51	I	Log; 580 gpm per foot drawdown
29/33-27b1	Oreana Development Co.	Dr.	1953	14	270 R	92 R	9-21-53	I	Log
29/33-31a1	Lamb Brothers	Dr.	--	-	85 R	20.2 M	10- 6-64	U	Log
29/33-33a1	City of Lovelock (old well 1)	Dr.	1929	-	336 R	83.45 M	1- 9-46	-	Log; destroyed
29/33-33a2	City of Lovelock, well 3 (old well 2)	Dr.	1934	-	350 R	90 R	10-11-45	PS	
29/33-33a3	Big Meadows Water Association (City of Lovelock, well 4)	Dr.	1954	12	345 R	109 R	11- 3-54	PS	
29/33-33a4	City of Lovelock, well 2	Dr.	1963	12	408 R	134 R	1-28-63	PS	
29/33-33c1	City of Lovelock, well 1 (formerly Southern Pacific Co., Oreana well 2)	Dr.	1945	12	432 R	66.17 R	1- 9-46	PS	Yield 400 gpm with a 15 foot drawdown.

Table 10. --Drillers logs of selected Wells in Lovelock Valley, Nevada

Material	Thickness (feet)	Depth	Material	Thickness (feet)	Depth
25/29-24d1 Toy Milling Co.			27/31-1c1 Tom Hay		
Gravel & Sand	38	38	Clay	18	18
Gravel, coarse	3	41	Sand, coarse	20	38
26/31-12b1 W. U. Barnes			Clay	4	42
Topsoil	5	5	Sand & Gravel	8	50
Hardpan	21	26	27/31-9c1 Turrillas Flat Ranch		
Sand, black	4	30	Topsoil	1.5	1.5
Clay, gray blue	23	53	Hardpan	28.5	30
Sand, salt water	32	85	Sand & gravel	5	35
Mud	40	125	Hardpan & gravel	15	50
Clay, gray	51	176	Sand & gravel	15	65
Sand & gravel, water salty	14	190	Clay, brown	15	80
Gravel, cemented	60	250	Gravel, cement	70	150
Clay, blue & gray	310	560	Sand & gravel, coarse	101	251
Clay & Gravel, black	240	800	27/31-10d1 Antone P. Johnson		
Clay, gray & Brown	120	920	Clay	35	35
Gravel, brown, cemented	350	1,270	Gravel & Sand	7	42
Shale & limestone	65	1,335	27/31-13d1 Louise Bonarcorsi		
Sand, water	30	1,365	Clay	35	35
Slate, brown, fractured	21	1,386	Gravel	5	40

Table 10. --Driller's Logs (Continued)

Material	Thickness (feet)	Depth
27/31-28a1 W. U. Barnes		
Topsoil	7	7
Hardpan	25	32
Sand & gravel	5	37
Clay, gray	75	112
Sand & Gravel	28	140
Clay, gray	10	150
Sand & gravel	10	160
Gravel, cemented	175	335
Sand & gravel	54	389
27/32-18a1 Carl Hightower		
Topsoil, brown	10	10
Clay, gray	10	20
Sand 10	10	30
Sand & gravel	10	40
Clay, blue	--	
27/32-30 d1 Glen Baird		
Clay	22	22
Sand	10	32
Gravel	18	50
28/31-34b1 Metropolitian Finance Co.		
Topsoil	25	25
Sand & gravel	22	47
Gravel, cemented	213	260
Sand & Gravel	65	325
28/32-10c1 Bidge Duncan		
Topsoil	20	20
Sand & gravel	36	56
28/32-29a1 H. T. Brink		
Topsoil	35	35
Sand, green	20	55
Gravel	2	57
Clay, tight	80	137
Sand & Gravel	7	144
Clay	6	150
Sand, water bearing	10	160
Sand & gravel	12	172
Gravel, coarse	6	178
Sand & gravel	14	192
Clay	5	197
Gravel, pea	2	199

Table 10. --Driller's Logs (continued)

Material	Thickness (feet)	Depth	Material	Thickness (feet)	Depth
28/32-33cl Mineral Materials			29/33-17cl Dodge Construction Co.		
Clay	60	60	Topsoil	6	6
Gravel	20	80	Clay	24	30
28/33-4al B.L.M.			Rocks	4	34
Sand & Gravel, Yellow	15	15	Clay, sandy	46	80
Clay & Boulders, hard	49	64	Sand & Gravel	6	86
Clay, soft yellow	4	68	Clay, sandy	114	200
Clay, cemented sand and rock	32	100	Clay	34	234
Sand & clay, gray, soft	22	122	Hardpan and rocks	6	240
			Sand & gravel	40	280
Talc, red, soft	8	130	Clay, brown	60	340
Rock, cemented, gray	110	240			
Rock, cemented, red	18	258			
Boulders, gray, hard	20	278			

Table 10. --Selected drillers logs (Continued)

Material	Thickness (feet)	Depth
29/33-21dl Oreana Development Co.		
Silt, fire	15	15
Silt, & Gravel, fine	40	55
Sand & clay, mucky	35	90
Gravel & Clay, soft	12	102
Soft clay with small gravel	22	124
Sand & gravel, water-bearing	16	140
Clay & gravel	5	145
Gravel, water bearing	12	157
Clay, soft sandy	43	200
Gravel, water-bearing	7	207
Clay, sticky & gravel	8	215
Clay & gravel	15	230
Clay, soft sandy	10	240
Gravel	4	244
Clay, soft sandy	7	251
Gravel, cemented	3	254
Clay & gravel	5	259
Clay, soft sandy	9	268
Gravel, large, water-bearing	3	271
Gravel, fine, water-bearing	4	275
Clay	6	281
Gravel & clay	9	290
Clay & gravel	10	300
Clay & Gravel, some cemented gravel	10	310
Clay, Soft Sandy & Gravel cemented	7	317
Gravel, hard cemented	8	325
Clay & gravel	2	327
Gravel, cemented	4	331
Gravel & Sand, some clay	5	336
Clay, soft sandy & some gravel	8	344
Gravel & sand, water-bearing	5	349
Clay & gravel	4	353
Sand & gravel, some clay, water-bearing	3	356
Clay & gravel, soft	11	367
Clay & gravel	11	378
Gravel, clean	7	385
Clay & rock fragments	1	386
Gravel, small cemented	6	392
Clay & rock fragments	5	397
Gravel, medium hard, cemented	3	400
Gravel, very hard, cemented	5	405
Clay & rock fragments	2	407
Rock fragments very hard cemented	4	411
Clay & Rock fragments	9	420
Clay, hard and rock fragments	11	431
Clay & rock fragments	2	433
Gravel, large & small and some clay	6	439
Gravel & boulders, large	3	442

Table 10. --Selected driller's logs (continued)

29/33-27bl Oreana Development Co.

Material	Thick Ness (feet)	Depth
Silt & boulders	27	27
Gravel & boulders	6	33
Gravel	7	40
Clay & boulders	11	51
Clay & gravel	12	63
Gravel, coarse	6	69
Clay, red	6	75
Clay & boulders	6	81
Clay	16	97
Clay & gravel	6	103
Gravel & boulders	9	112
Clay & gravel	6	118
Gravel, water-bearing	3	121
Clay & gravel, fine	12	133
Gravel	4	137
Clay, gravel, & boulders	16	153
Clay & boulders	14	167
Gravel, coarse, water-bearing	4	171
Clay & gravel	16	187
Gravel, coarse, water-bearing	6	193
Clay & gravel	4	197
Clay & gravel, tight	4	201
Gravel, coarse	3	204
Bedrock, or cemented gravel	66	270

29/33-31al Lamb Brothers

Material	Thick ness (feet)	Depth
Topsoil	20	20
Topsoil & gravel, fine	10	30
Sand & gravel	5	35
Soil, brown, sand & gravel	30	65
Gravel & sand	5	70
Gravel, Rocks & sand	15	85

Table 10. --Selected driller's logs (continued)

Material	Thickness (feet)	Depth	Material	Thickness (feet)	Depth
29/33-33a1 Big Meadows Water Association					
Topsoil	5	5	Rock, hard	9	267
Sand & gravel	15	20	Granite, decomposed	15	282
Rock, broken	8	28	Rock, broken & sand	30	312
Rock, solid	8	36	Rock, hard	9	321
Sand, hard, packed	19	55	Sand	4	325
Rock broken	3	58	Rock, hard & sand	47	372
Sand & clay	28	86	Clay, yellow	23	395
Rock, broken	16	102			
Clay, yellow	8	110			
Boulders	3	113			
Clay, yellow sandy	13	126			
Rock, hard, broken	2	128			
Clay & rock layers	8	136			
Rock hard,	4	140			
Clay, yellow	4	144			
Rock, hard	42	186			
Clay, hard, yellow	6	192			
Boulders & sand	30	222			
Clay, yellow	8	230			
Rock, medium hard	18	248			
Clay & boulders	10	258			

REFERENCES CITED

Bredehoeft, F. D., 1963, Hydrogeology of the lower Humboldt River basin, Nevada: Nevada State Engineer Water Resources Bull. 21, 50 p.

Eakin, T. E., and others, 1951, Contributions to the hydrology of eastern Nevada: Nevada State Engineer Water Resources Bull. 12,

Eakin, Thomas E., 1962, Ground-water appraisal of the Imlay area, Humboldt River basin, Pershing County, Nevada: Nevada State Dept. Conserv. and Nat. Resources, Ground-Water Reconnaissance Report 5, 54 p., 1 fig., 2 pls.

Halpenny, L.C., and others, 1952, Ground water in the Gila River basin and adjacent areas, Arizona- a summary: U.S. Geol. Survey open-file report, 224 p.

Hardman, George, and Mason, H. G., 1949, Irrigated Lands in Nevada: Univ. Nevada Agricultural Expt. Sta. Bull, 183, 57 p.

Houston, C. E., 1950, Consumptive use of irrigation water by crops in Nevada: Nevada Univ. Bull. 185, 27 p.

Lee, C. H., 1912, An Intensive Study of the Water Resources of Part Of Owens Valley, California: U. S. Geol. Survey Water-Supply Paper 294, 135 p.

Miller, M. R. 1950, the Quality of the Waters of the Humboldt River: Univ. Nevada Agricultural Expt. Bull. 186, 31 p.

Robinson, T. W., and Fredericks, J.C., 1946, Ground Water in Lovelock Valley, Nevada: Nevada State Engineer Water Resources Bull. 2, 25 P.

Robinson, T. W., 1963, Water-use studies utilizing evaporation tanks, In Cohen, Phillip, An evaluation of the water resources of the Humboldt River Valley near Winnemucca, Nev.: Nevada Dept. Conserv. and Nat. Resources Bull. 23, p. 69-73.

Russell, I. C., 1885, Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U.S. Geol. Survey Mon. 11, 228 p., 46 pls.

Scofield, C. S., 1936, The Salinity of irrigation water: Smithsonian Inst. Ann. Rept. 1935, p. 275-287.

U. S. Department of Agriculture, 1954, Diagnosis and improvement of saline and alkaline soils: Agricultural Handbook No. 60, 160 p.

U. S. Public Health Service, 1962, Public Health Service drinking water Standards 1962: Public Health Service Pub. No. 956, 61 p.

Wallace, R. E., Tatlock, D. B. Silberling N.J., and Irwin, W. P. 1962, Preliminary geologic map of the Unionville quad., Nevada: U.S. Geol. Survey Mineral Inv. Field Studies, Map MF-245.

White, W. N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U.S. Geol. Survey Water-Supply Paper 659-A, 165 p.

Young, A. A., and Blaney, H. F., 1942, Use of Water by native vegetation: California Dept. Pub. Works Bull. 50, 154 p.

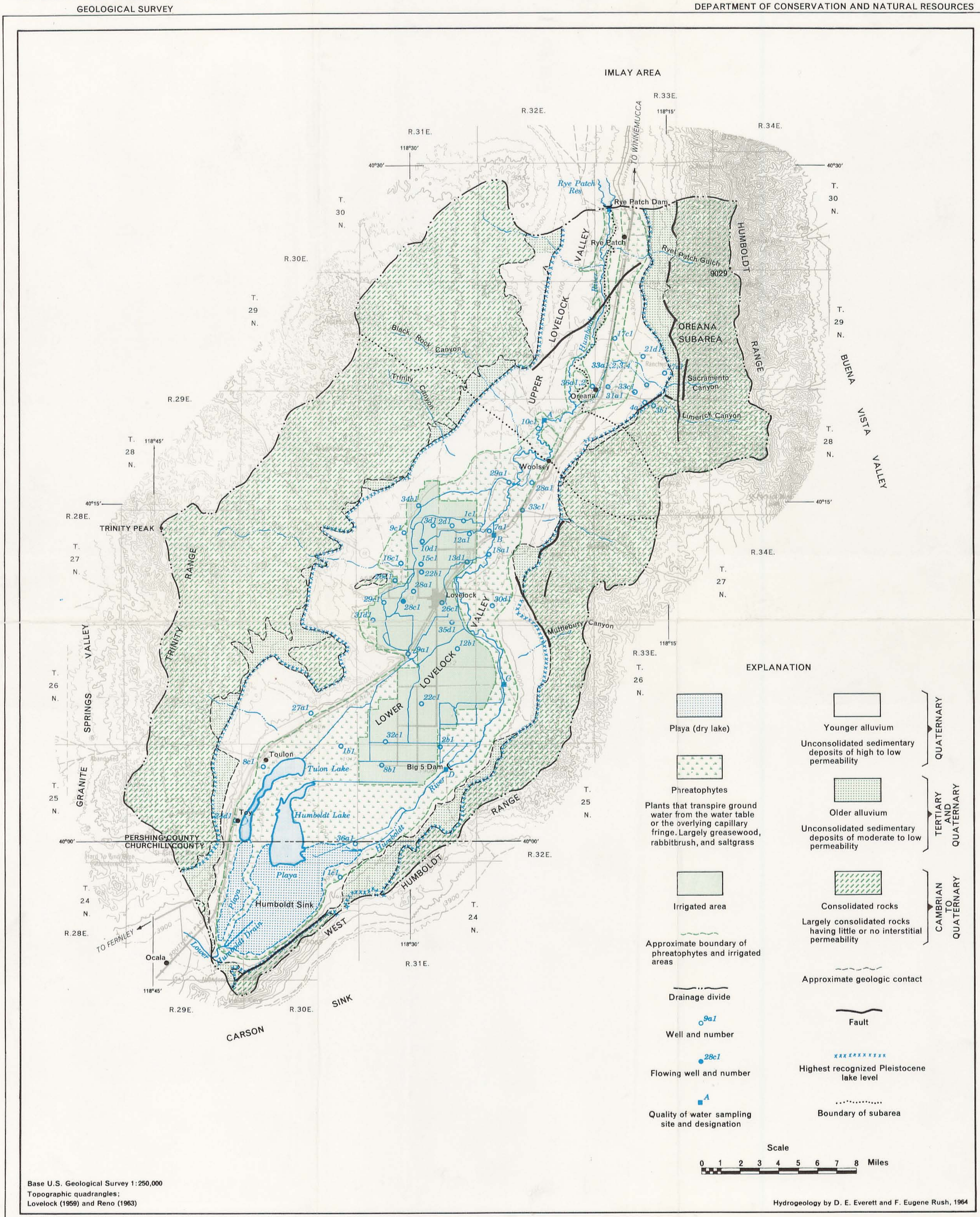

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE LOVELOCK AREA, NEVADA