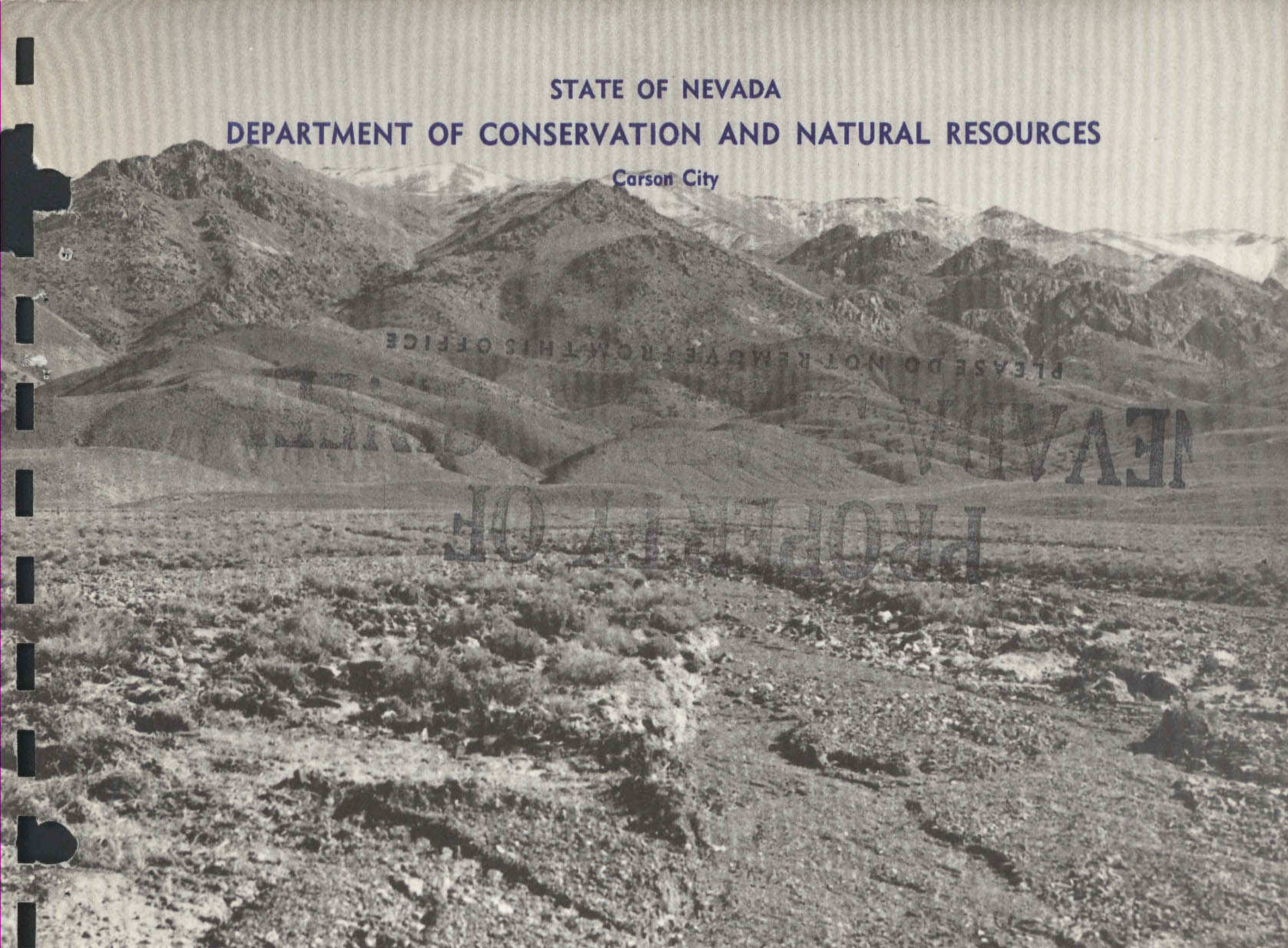
STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Carson City



Imlay area—View southeast of northern Humboldt Range

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES

REPORT 5

GROUND–WATER APPRAISAL OF THE IMLAY AREA, HUMBOLDT RIVER BASIN, PERSHING COUNTY, NEVADA

By

THOMAS E. EAKIN

Geologist

Price $1.00

Prepared cooperatively by the

Geological Survey, U. S. Department of the Interior

FEBRUARY

1962

VIEW ACROSS AREA OF PITT–TAYLOR RESERVOIRS

View northwest from sec 2, T. 31 N., R. 33 E. toward Antelope Range. Light area in right middle distance is part of Pitt-Taylor reservoirs. Upper part of Rye Patch reservoir lies beyond Pitt-Taylor reservoirs. Majuba Mountain is on left skyline. Humboldt House is at trees in right middle distance. Material from gravel pit on right edge is being used in construction of new highway alignment of U. S. 40. Alluvial apron is in foreground to about U. S. Highway 40; valley lowland is in the middle distance.

COVER PHOTOGRAPH

View southeast from sec. 2, T. 31 N., R. 33 E. toward north end of Humboldt Range. Gravel in foreground deposited from flash floods in August 1961. Slope in middle distance and foreground is part of alluvial apron. Note dissection in mountains.

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GROUND-WATER APPRAISAL OF THE IMLAY AREA, HUMBOLDT RIVER BASIN, PERSHING COUNTY, NEVADA.

by
Thomas E. Eakin

SUMMARY

The average annual recharge to and discharge from the ground-water reservoir of the Imlay area, Humboldt River basin is on the order of 7,000 and 5,000 acre-feet, respectively. Of the estimated amount of recharge, apparently about 4,000 acre-feet is derived from precipitation within the Imlay area and about 3,000 acre-feet from underflow from the valley of the Humboldt River upstream from the northern boundary of the area. The estimate excludes temporary recharge from the Humboldt River, which is classed as bank storage for separate identification in this report.

The 5,000 acre-feet of average annual ground-water discharge includes about 3,000 acre-feet which is estimated to be discharged by evapotranspiration of native vegetation. As an interim estimate, the amount of water equivalent to that discharged by evapotranspiration is considered to be available for development on a perennial basis in the Imlay area. To refine this estimate would require substantially more data than currently are available. Moderate ground-water development in the area would provide a means of obtaining part of the necessary data, and additional data could be obtained when an intensive investigation is appropriate.

Substantial ground-water development, perhaps in excess of 3,000 acre-feet per year, probably would decrease, in time, the fully appropriated flow of the Humboldt River. However, moderate development coupled with judicious location of wells probably could be sustained with negligible effect on the flow of the Humboldt River.

The amount of drainable water in the ground-water reservoir is estimated to be on the order of 800,000 acre-feet in the upper 100 feet of saturated valley fill that underlies the 250-square-mile surface area below an altitude of 4,400 feet. This amount of water is about 4.5 times the 179,000 acre-foot capacity of Rye Patch Reservoir. The drainable ground water in storage provides a large reserve for maintaining water supplies during extended periods of drought or for meeting high demands under emergency conditions for limited periods of time.

Data are not adequate to describe fully the chemical quality of ground water in the Imlay area. However, general geologic and hydrologic conditions together with a few chemical analyses in nearby areas, suggest that the chemical concentration of much of the ground water may be moderate to high. The most favorable areas for obtaining water of good chemical quality appear

to be along the middle parts of the alluvial aprons near the areas of principal recharge; that is, adjacent to the Humboldt and East Ranges and near the Eugene Mountains, and locally elsewhere, such as near the Majuba Mountains. However, exceptions to this generalization are to be expected.

The probable extensive occurrence of ground water of moderate or high chemical concentration is an important factor in determining the extent to which drainable ground water in storage can be effectively utilized.

Present use of ground water in the Imlay area is principally for domestic and irrigation purposes, and probably does not exceed a few hundred acre-feet a year.

Examination of streamflow records of the Humboldt River and of storage records of Rye Patch reservoir for the 10-year period 1951-60 indicate an average annual loss of about 5,000 acre-feet in the river section from the Pershing County line southward to the Imlay gaging station. The annual loss ranged from about 13,000 acre-feet in 1952 to 3,000 acre-feet in 1955. Most of the loss in this section of the river is due to evapotranspiration in the flood plain of the river.

In the section of the Humboldt River between the Imlay gaging station and Rye Patch dam, the average annual loss, including diversions to Pitt-Taylor reservoirs for the 10-year period ending September 30, 1960, was 26,000 acre-feet. Of this amount, probably somewhat more than 20,000 acre-feet was evaporated from the free-water surface of Rye Patch and Pitt-Taylor reservoirs. Water was diverted to the Pitt-Taylor reservoir in only 4 years of the 10-year period. The remaining loss, 6,000 acre-feet, in this section of the river apparently was due to evapotranspiration by native vegetation and to the carry-over effect of bank storage or error in the estimate of evapotranspiration from the reservoir.

Yearly differences between inflow and outflow in this section of the river ranged from a loss of about 48,000 acre-feet in 1958 to a gain of 7,000 acre-feet in 1954. Evaporation is related closely to the surface area of water in the reservoirs, and is estimated to have ranged from about 40,000 acre-feet in 1951 to about 2,000 acre-feet in 1955.

After adjustments are made for annual net changes in reservoir storage and evaporation from the reservoirs, the residual differences range from an annual loss of about 17,000 acre-feet in 1958 to a gain of about 15,000 acre-feet in 1954. Residual annual losses or gains result principally from evapotranspiration by native vegetation in the flood plain and from the effects of bank storage.

INTRODUCTION

The development of ground water in Nevada has shown a large increase in recent years. Part of the increased use of ground water is due to an effort to supplement surface-water supplies that have become deficient because of the drought of recent years, and part is due to the interest and efforts to bring new land under cultivation. As a result, the demand for information on ground-water resources increased substantially throughout the State.

The State Legislature, recognizing this need for additional information on ground water, enacted special legislation (Chap. 181, Stats. 1960) for beginning a series of reconnaissance studies of ground-water resources of Nevada. As provided in the legislation, these studies are made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources.

Interest in ground-water resources currently includes many areas and is extending to additional areas almost continuously. Thus, the objective of the studies is to provide a reconnaissance appraisal of the ground-water resources in particular areas where information is urgently needed as quickly as possible. For this reason each reconnaissance study is severely limited in time and most of the field work for this report was completed in about 1 week during May and June 1961.

The Department of Conservation and Natural Resources has established a special report series to expedite publication of the results of these reconnaissance studies.

This report is the fifth in the reconnaissance series. It describes the physical conditions of the Imlay area, in Pershing County, and includes observations and evaluations of the interrelation of climate, geology, and hydrology as they affect the ground-water reservoir. It includes also rough estimates of the average annual recharge to and discharge from the ground-water reservoir.

The investigation was made under the administrative supervision of O. J. Loeltz, District Engineer, in charge of ground-water studies in Nevada. The writer wishes to acknowledge his appreciation of the personnel of the district office for constructive discussions and review of the report, all of which have been most helpful.

Location and General Features

The Imlay area, for the purposes of this report, extends along the Humboldt River from the north line of Pershing County to the latitude of Rye Patch and between the drainage divides of the adjacent mountains. It includes the re-entrant northwest of Rye Patch reservoir. (See figure 1 and plate 1).

The Imlay area is about 35 miles long and about 20 miles wide in the latitude of Humboldt. The total area is about 750 square miles.

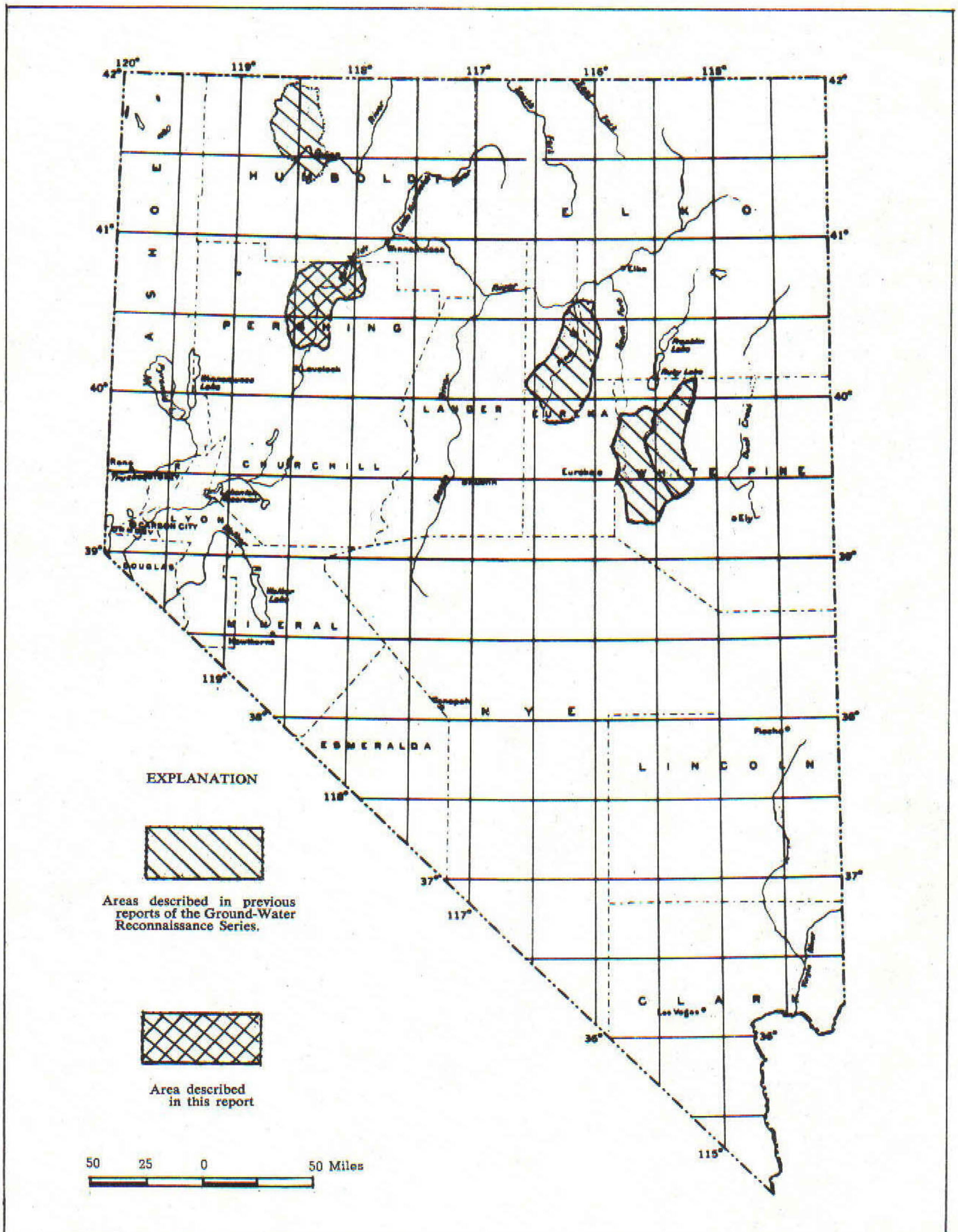


Figure 1.—Map of Nevada showing areas described in previous reports of the Ground-Water Reconnaissance Series and in this report.

Rye Patch dam, at the southern end of the area, is about 24 miles north of Lovelock. Pershing County line on the north crosses U.S. Highway 40 about 15 miles southwest of Winnemucca.

The water of the Humboldt River, stored in Rye Patch reservoir and to a minor extent in the adjacent Pitt-Taylor reservoirs is used for irrigating a maximum of approximately 44,000 acres of land owned by the Lovelock Irrigation District in the vicinity of Lovelock.

Mining is and has been important in the area since about 1859. Lincoln (1923) lists the Echo, Imlay, Mill City, and Sierra districts as four mining districts within the area and other mining districts are nearby. Gold, silver, tungsten, lead, and mercury have been mined in substantial quantity. Couch and Carpenter (1943) list the gross dollar yield production for these districts through 1940 as: Echo district, $1,343,959; Imlay district, $44,504; Mill City district, $7,483,024; and Sierra district, $297,389.

Transcontinental U.S. Highway 40 and the Southern Pacific Company railroad traverse the eastern side of the Imlay area, more or less parallel to the Humboldt River. A paved road connects the Nevada-Massachusetts tungsten mine and mill with U.S. Highway 40 at Mill City. Trails provide access to many of the outlying areas during good weather.

Climate

The climate of the Imlay area is arid. It is characterized by low precipitation and humidity and high summer temperatures and rates of evaporation. The adjacent mountains receive more precipitation than the lower part of the area largely because of orographic effects. Precipitation is generally irregular in areal distribution. Summer precipitation usually occurring as localized showers; and winter precipitation commonly occurring as snow. The temperature range is large both daily and seasonally. The growing season is of moderate length.

Records of precipitation and temperature for Imlay and Rye Patch dam in the Imlay area are published by the U.S. Weather Bureau.

The length of record of precipitation for the Imlay station is 63 years through 1960, and that of Rye Patch dam is 24 years. The Weather Bureau long-term mean annual precipitation for Imlay is 6.64 inches. A long-term mean of precipitation at Rye Patch dam has not yet been established by the Weather Bureau.

Table 1-a lists a long-term mean monthly and annual precipitation for Imlay. Table 1-b lists annual precipitation at Imlay and Rye Patch dam for the last 10-year period, 1951-60. The average annual precipitation at Imlay for this 10-year period is 6.74 inches.

SUMMARY OF PRECIPITATION RECORDS IN THE IMLAY AREA

Table 1-a. Long-term mean monthly and annual precipitation at Imlay, Nev.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Imlay	0.72	0.66	0.60	.61	0.83	0.67	0.19	0.10	0.21	0.69	0.58	0.78	6.64

Table 1-b -- Annual precipitation, in inches, at Imlay and Rye Patch dam, 1951-60

	Imlay	Rye Patch	Imlay 1/
1951	8.01	6.23	7.10
1952	e 10.19	10.45	14.37
1953	5.55	7.23	5.00
1954	4.77	3.47	4.77
1955	e 6.56	6.03	7.85
1956	e 6.01	5.85	5.87
1957	e 6.59	7.42	1.94
1958	8.35	8.80	10.79
1959	3.26	3.28	3.25
1960	8.08	5.77	5.96

1/ Annual precipitation at Imlay, for water years ending September 30.

e - Estimated by Weather Bureau.

Streamflow records commonly are reported by water years ending September 30 because much of the late fall (October to December) precipitation occurs as snow and does not produce runoff until the following spring. For comparison with streamflow records, the annual precipitation, based on the water year, also is shown in table 1-b for the 10-year period.

Weather Bureau records show that the maximum recorded annual precipitation at Imlay was 15.54 inches in 1890 and at Rye Patch dam, 12.48 inches in 1938. The minimum annual precipitation has been recorded within the last 10 years. The minimum annual precipitation at Imlay was 1.41 inches for 1953 and at Rye Patch dam, 3.28 inches in 1959.

The mean monthly and annual temperatures, in degrees Fahrenheit, at Imlay are shown in the following tabulation based on the Weather Bureau Climatic Summary of the United States (Nevada), supplement for 1931 through 1952. The recorded extremes of temperature at Imlay has ranged from 112°F to -35°F.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
29.1	34.0	41.2	48.5	56.5	65.5	74.2	71.4	60.6	49.1	39.2	30.6	50.0

Houston (1950, p. 14) lists the average growing season at Lovelock as 128 days (May 18 to September 23). The Imlay area presumably has about the same growing season as Lovelock. Because killing frost conditions vary with the type of crop, the Weather Bureau records in recent years list freeze data--the last spring minimum and the first fall minimum--for temperatures of 32°F or below, 28°F or below, and 24°F or below. Also listed are the number of days between the last spring minimum and the first fall minimum in the respective temperature groups. The latter are given for Imlay during the 10-year period 1951-60 as follows:

	Number of days between temperatures of:		
Year	32°F or below	28°F or below	24°F or below
1951	113	144	187
1952	90	142	184
1953	138	162	180
1954	102	116	178
1955	124	152	180
1956	130	130	202
1957	121	140	181
1958	131	146	151
1959	110	121	148
1960	92	144	149

Records of seasonal evaporation have been obtained in a standard class A pan (Weather Bureau) at Rye Patch dam for 20 years. The seasonal period includes May through September. The seasonal evaporation recorded during the past 10 years (1951-60) is as follows:

Year	Seasonal evaporation, in inches	Year	Seasonal evaporation, in inches
1951	65.10	1956	49.13
1952	52.48	1957	49.40
1953	53.20	1958	45.64
1954	56.57	1959	41.42
1955	54.82	1960	52.79

Physiography and Drainage

The Imlay area is a segment of the lower part of the Humboldt River drainage basin. The general alinement of the river is controlled by the adjacent mountain masses. Thus, the large S-shaped form of the river in the latitude of Mill City is controlled by the gap between the Eugene Mountains and the Humboldt Range.

Lake Lahontan of Pleistocene age, which covered a large area in this region of Nevada, occupied the Imlay area. A high stand of Lake Lahontan left a well preserved beach line at an altitude of 4,400 feet (plus or minus 20 feet) above sea level. Other beach lines, formed at other altitudes, are also readily apparent.

With the last gradual desiccation of Lake Lahontan the shoreline receded southward toward the Humboldt Sink, and the Humboldt River extended its course southward.

The desiccation of the lake resulted in a lowering of the base level of the river. The lower base level in turn provided the opportunity for the river to become entrenched in the sediments of Pleistocene age in the floor of the valley. The maximum entrenchment is on the order of 200 feet in the vicinity of Rye Patch dam. Except for the entrenchment of the Humboldt River, the floor of the Imlay area is generally at an altitude of about 4,200 feet.

The East Range and the northern part of the Humboldt Range (cover photograph) that border the area on the east, rise abruptly to altitudes of 8,000 feet or more. Star Peak, altitude 9,835, in the Humboldt Range is the highest point in the area.

Canyons are deeply dissected and commonly are occupied by streams during the spring runoff period. Streams lose much or all of their flow as they cross the alluvial apron which border the mountains.

The Eugene Mountains form an isolated mass area northwest of Mill City. Their highest point is about 7,200 feet above sea level. The Eugene Mountains receive much less precipitation than either the East or Humboldt Ranges.

Irregular topographic highs form the west side of the Imlay area. The northern end is called the Antelope Range (photograph 2). Southward is Majuba Mountain. From Majuba Mountain the topographic high continues southward and merges with the Trinity Range. The mountain areas on the west side of the Imlay area are less than 7,000 feet in altitude. Precipitation in these mountains, although probably somewhat more than on the valley floor, is much less than in the mountains along the east side of the valley.

Physiographically the Imlay area can be divided into three parts -- the mountain highlands, the alluvial apron, and the valley lowland.

The mountain highlands essentially coincide with the areas of bedrock shown on plate 1. The highlands are principal areas of erosion and generally are characterized by relatively steep slopes; the steepest slopes usually are adjacent to areas of maximum altitudes.

The alluvial apron largely defines areas of alluvial fans or intermediate slopes between the highlands and the valley floor. The alluvial apron is best developed along the east side of the area adjoining the East and Humboldt Ranges.

The valley lowland merges imperceptibly with the lower part of the alluvial apron (photograph 2). Its general graident is low except locally along the bluffs which bound the flood plain of the Humboldt River. For the purpose of this report, the flood plain is included in the valley lowland. Dune sand mantles the valley lowland adjacent to the flood plain. Although the dunes are partly fixed by vegetation, the general wind movement in the valley carries sand and dust upstream.

With the exception of the Humboldt River, most streams in the area are commonly ephemeral on the alluvial apron and flow only during the spring run-off period or for short times after periods of localized heavy rain showers. Some streams such as the creeks in Star, Prince Royal and Humboldt Canyons in the northern part of the Humboldt Range apparently maintain some flow in the mountains throughout the year.

GENERAL GEOLOGY

The rocks of the Imlay area may be divided into two gross units, the bedrock and the valley fill, on the basis of their general relation to topography and ground water.

The bedrock includes rocks of Paleozoic and Mesozoic age consisting principally of lava and tuff, limestone, shaly limestone and calcareous shale, conglomerate and sandstone metamorphosed in varying degrees, intrusive rocks of probable late Mesozoic age and intrusive and extrusive rocks of Tertiary age. These rocks crop out in the mountains along the margins of the Imlay area and underlie the valley fill.

The valley fill includes deposits that probably range in age from Tertiary to Quaternary. The valley fill probably has a maximum thickness of several thousand feet but thins out along the flanks of the mountains. The rock types are diverse and include stream-laid sand and coarse gravel, pyroclastics, and lacustrine clay, silt, and marl or limestone.

Bedrock in the Mountains

The geology of the mountains that border the Imlay area has been studied in part. Many of the earlier studies have been directed toward a better understanding of the mineral deposits that were being mined. Several publications are listed in the references cited.

Ferguson, Muller, and Roberts (1951) in their study of the geology of the Winnemucca Quadrangle show three formations of late Paleozoic age and six formations of Mesozoic age in the East Range. (See pl. 1.) R. E. Wallace and others (1959) recently made a study of the geology of the Humboldt Range which forms the southern part of the eastern boundary of the Imlay area. For the purposes of this report, the Paleozoic and Mesozoic formations listed in table 2, modified after Ferguson, Muller, and Roberts probably indicate the general character of Paleozoic and Mesozoic rock types in the mountains adjacent to the Imlay area.

The work of Ferguson, Muller, and Roberts in the East Range also shows the complex structure of the bedrock. Undoubtedly the structure of the bedrock in the other ranges in the Imlay area are complex also.

Table 2. -- Brief descriptions of selected formations of Paleozoic and Mesozoic age in the Imlay area (modified after Ferguson, Muller, and Roberts, 1951)

Age	Formation or group	Description
Late Jurassic (?)	Granitic Intrusive rocks	Granite, granodiorite, and quartz monzonite, in places with mafic border facies; numerous associated dike rocks, mostly not mapped.
Late Triassic	Raspberry Formation	Gray, black, buff, or green slate, locally phyllitic; limestone lenses and limestone conglomerate, especially in lower part; quartzite lenses a few inches to 100 feet thick form about 5 percent of the unit. Thickness in East

Table 2. -- (continued)

Age	Formation or group	Description
		Range approximately 3,000 feet; top and base not visible. Type locality, Raspberry Creek, northwestern part of East Range.
	Winnemucca Formation	Shale and sandstone, some limestone and dolomite. In Sonoma Range, lower part is shale or slate with numerous limestone and dolomite beds; sandstone prominent near top. In East Range, slate and quartzite, with some limestone in upper part. Basal contact drawn at lowest prominent clastic bed. Type locality, Mullen Canyon, west side of Sonoma Range, 8 miles south of Winnemucca, where it is about 2,000 feet thick. In East Range, about 3,000 feet thick.
Late Triassic	Dun Glen Formation	Dark-gray to black, massive dolomite, in part cross-bedded, standing in bold relief; interbedded limestone and shale in lower 100 feet. Thickness generally 500-600 feet, but reaches 1,150 feet in northwestern part of Sonoma Range. Type locality, Dun Glen Peak, East Range.
	Grass Valley Formation	Mainly shale, mostly slaty, in part micaceous, olive-drab or black, with prominent worm trails; interbedded white, gray, or black quartzite, locally cross-bedded, and at type locality, limestone lenses near top. Thickness may exceed 2,000 feet, but is indeterminate due to isoclinal folding and faulting. Type locality, mountain slope facing Grass Valley, northern part of East Range.

Table 2 -- (continued)

Age	Formation or group	Description
Middle and Late Triassic	Natchez Pass Formation	Light-to dark-colored, massive dolomite and limestone; basic lava flow and volcanic breccia generally present about 400 feet above base; massive siliceous conglomerate with pebbles from Koipato and Inskip Formation s about 200 feet below top. Type locality, Natchez Pass in East Range, where it is 1, 650 feet thick. In Sonoma Range, about 1, 000 feet thick.
Middle Triassic	Prida Formation	At base, conglomerate, coarse fanglomerate, or quartzcse sandstone; lower 50-100 feet, clastic sediments with interbedded brown dolomite; above is 100-200 feet of dark, bituminous and calcareous shale and thin-bedded limestone; at top, thick-bedded limestone. Type locality, East Range west of Prida Ranch, where it is 400 feet thick. Thinner elsewhere. In Sonoma Range, so thin it is mapped with Natchez Pass Formation.
Permian (?) and Early Triassic	Koipato Formation	Rhyolite and trachyte flows, breccias, and tuffs, some sandesite, small amounts of conglomerate, sandstone, and tuffaceous slate. In East Range, in lower plate, thickness over 4, 500 feet; in Sonoma Range, in upper plate, thickness 300 feet or less, in places missing.
Mississippian (?)	Inskip Formation	Lower half, mostly quartzite and slate with thin beds of limestone, some chert, a few greenstone flows; some graywacke, conglomerate, and quartsitic grit. Upper half, thin-bedded limestone interbedded with siliceous and calcareous slate and quartzite. Contains indeterminate crinoid stems. Type locality, Inskip Canyon, west flank of East Range, where it is more than 9, 000 feet thick.

Table 2. -- (continued)

Age	Formation or group	Description
Mississippian or older	Leach Formation	May be identical with Pumpernickel Formation. Altered basic volcanics (greenstone) and pyroclastics, with much dark chert and siliceous argillite, probably largely tuffaceous. Beds of dark vitreous quartzite at top. Interbedded slate, limestone, and conglomerate near forks of Leach Canyon, resemble the overlying Inskip Formation. Thickness may exceed 6, 000 feet; base not exposed. Named from Leach Canyon on west flank of East Range.

Valley Fill

The upper part of the valley fill has been described by Russell (1885) in a monograph of Lake Lahontan. Studies are being made currently by P. Cohen, U.S. Geological Survey, and others in the adjacent area near Winnemucca, as a part of the Humboldt River research project, in cooperation with the Nevada Department of Conservation and Natural Resources. These investigations provide the basis for the discussion of valley fill in this report.

Most of the Imlay area has been a site of deposition, possibly since Cretaceous time. Thus the fill may range in age from Tertiary to Quaternary. Considerable volcanic activity in nothern Nevada during Tertiary and Quaternary time is largely responsible for the lava and pyroclastic rocks in the area. The volcanic rocks have been described from exposures in adjacent bedrock areas. Similar rocks may be expected, in some place, beneath the valley floor, interbedded or associated with the sediments deposited under lacustrine or subaerial environments.

The maximum thickness of the valley fill in the Imlay area is not known but it might be several thousand feet. General consideration of the geology, structure, and topography of the area suggests that the bedrock surface on which the valley fill was deposited probably was as irregular as the present day bedrock surface exposed in the mountains. Thus the thickness of the fill varies considerably from place to place.

The following two stratigraphic sections described by Russell (1885, p. 130, 131) illustrate the character of the sediments of the valley fill which were deposited in or associated with a lacustrine environment.

Section F. West bank of Humboldt River, at Rye Patch (after Russell, 1885, p. 130)

		Feet
1.	Aeolian sand and alluvial gravel, variable	1 to 6
2.	Loam, sandy, light-colored, fine	12
3.	"Tufa mushrooms" (dendritic tufa)	0.9
4.	Ostracod and gastropod shells	0.2
5.	Sand, loamy, buff-colored, with small concretions of gypsum	16
6.	Gravel, rounded, cross-stratified	18.5
7.	Marl, buff-colored	6
8.	Gravel, cross-stratified	9
9.	Loam, with some cross-bedded gravel	7
10.	Gravel, cross-stratified	3
11.	Sand, cemented by carbonate of lime	0.4
12.	Loam, fine, cross-stratified	2
13.	Sand, white, marly (much thicker in east wall of canyon)	4
14.	Loam, with irregular strata of gravel	40
15.	Gravel, cemented	1
16.	Loam and fine gravel; to river	75
	Thickness of described section................	196 to 201

Section L. South (left) bank of Humboldt River, Mill City (after Russell, 1885, p. 131)

		Feet
1.	Weathered marl, aeolian sand at summit	2.5
2.	Marly clays, obscurely stratified, gray	3.0
3.	Marly clays, white, laminated	3.0
4.	Marly clays, sandy, brownish, obscurely cross-stratified	2.5
5.	Marly clay, white, laminated, jointed	9.0
6.	Sand and gravel, somewhat ferruginous, fossiliferous	0.5
7.	Sand, gravel, and pebbles, cross-stratified	5.0
8.	Sand and loam, massive, with pebbles	5.0
9.	Sand and loam, obscurely and irregularly stratified	4.0
10.	Sand and gravel with ferruginous cement	0.3
11.	Sand, cross-stratified, fine	3.0
12.	Marly clays regularly laminated, ash colored, jointed, with some tufa at summit; to river	3.0
	Thickness of described section...................	40.8

These two sections (F and L) are shown graphically in Plate 2 which is a reproduction of plate XXIII of Russell (1885). Several other sections described by Russell are shown graphically on Plate 2. Their relative locations are shown in the longitudinal geologic section at the top of Plate 2.

Russell (1885, p. 125) divided the sedimentary deposits of Lake Lahontan into three units; upper lacustral clay, medial gravel, and lower lacustral clay. Further, he stated, "Wherever any considerable section of Lahontan sediments is exposed these three divisions appear in unvarying sequence." P. Cohen (oral communication, 1961) found the same sequence in the Winnemucca area, where drilling has indicated a maximum thickness of 50 to 60 feet for the upper clay; and about 150 feet for the medial gravel. The test drilling penetrated only about 25 feet into the lower clay. Cohen also has found that most of the material that may be called clay, based on field inspection, is shown to be clayey silt by laboratory analysis.

Beach or shore-line deposits also commonly are associated with the various stillstands of Lake Lahontan. Beach deposits, gravel bars and spits typically are formed of coarse gravel and sand. The beach deposits parallel the shore lines of the various stages of Lake Lahontan, whereas the bar and spit deposits, which aline in response to currents, and in some places are parallel to the adjacent margins of the lake and in other places are normal to the margin. Alinements between these extremes also are common. In relatively narrow sections of the lake, such as at the mouth of a bay, a bar was sometimes formed completely across the narrows. Some of the beach and bar deposits may be buried by later deposits. The medial gravel deposit in the vicinity of Rye Patch (pl. 2), hypothesized by Russell (1885, p. 126, 127) as a gravel embankment (bar) formed across a relatively narrow section of Lake Lahontan at that point, illustrates the potential occurrence of such gravel deposits below the present land surface.

Lacustrine and beach deposits similar to those of Lake Lahontan undoubtedly occur at depth in the valley fill of the Imlay area. Although the distribution of these sediments is not known, the lake clay and silt probably are much more extensive, both vertically and laterally, than the coarse grained sand and gravel of the beach bar deposits.

The previously described sections of Lake Lahontan deposits do not indicate the occurrence of evaporite salts. However, south of the Imlay area, in the Humboldt and Carson Sinks where water of the Humboldt River is finally evaporated, evaporites do occur. Many of the lakes in this basin, which existed prior to Lake Lahontan, likely were desiccated and probably evaporites were deposited at least locally in the valley fill below sediments of Lake Lahontan age.

In addition to lacustrine and associated sediments, the valley fill includes alluvial fan deposits. The intermediate slopes between the mountains and the valley floor are underlain, in part, by these alluvial fan deposits. The deposits commonly consist of poorly sorted silt, sand, gravel and boulders, but locally may contain lenses or tongues of stream-laid sand and gravel. The present surfaces of the alluvial fans show beach features that were formed during Lake Lahontan time. Thus, the bulk of these fans were formed during early or pre-Lake Lahontan time.

Ferguson, Muller, and Roberts (1951) describe volcanic rocks of Miocene age and older, which are generally rhyolitic or andesitic composition, and volcanic rocks of Pliocene or Pleistocene age, which are generally of basaltic composition. These volcanic rocks have been structurally deformed. Similar rocks probably occur at least locally in the valley fill of Cenozoic Age.

In summary, the valley fill includes a wide range of lacustrine, subaerial and volcanic deposits. As yet however, the deposits below those of Lake Lahontan have not been well defined.

Geologic History

The geologic history of an area is useful to portray the sequence of events that bear on the interpretation of the occurrence and movement of ground water.

For this report, the studies of Ferguson, Muller, and Roberts (1951) and the study of Lake Lahontan by Russell (1885) provide a good basis, with some adaptation, for outlining a tentative geologic history of the Imlay area.

1. Deposition of many thousands of feet of clastic, carbonate, and volcanic rocks ranging from Paleozoic to early Mesozoic age. Deformation of these rocks by folding and faulting, including thrusting, which began in late Paleozoic time and culminated in Late Triassic time.

2. Intrusion of granitic rocks in Late Jurassic (?) time.

3. Erosion in topographically high areas and deposition in topographically low areas during Cretaceous (?) to middle (?) Tertiary time.

4. Extrusion or deposition of andesite and breccia followed by rhyolite flows and tuff in Miocene or possible pre-Miocene time.

5. Deposition of water-laid clastic rocks, some limestone, marl and tuff, partly contemporaneous with rhyolite flows, in Miocene and Pliocene (?) time.

6. Extrusion of basaltic lavas in Pliocene or Pleistocene time.

7. Generally normal faulting involving rhyolite lavas possibly starting prior to Tertiary time, and continuing intermittently to Quaternary time. This faulting evolved the general form of the present Basin and Range topography.

8. Erosion in the mountains and deposition in the valley areas in Quaternary time. Deposition, principally under a combination of subaerial and lacustrine environments, ranging from clay to coarse gravel and including lake

marl and evaporite, and some pyroclastic. Deposition in late Pleistocene Lake Lahontan of a lower clay, medial gravel and an upper clay unit. Russell (1885, p. 143) indicates in a generalized section of Lahontan deposits that the lower clay is 100 feet or more thick; the medial gravel, 50 to 200 feet; and the upper clay, 50 to 75 feet.

9. Since the deposition of the upper clay unit in Lake Lahontan, deposition has been relatively minor in the valley of the Imlay area and includes aeolian sand and Alluvial detritus. The Humboldt River has partially dissected the valley fill and exposed part of the sediments of Lake Lahontan. Near the county line in the northern part of the area, the present flood plain is as much as 50 feet below the general floor of the valley, but in the vicinity of Rye Patch dam the river has become entrended nearly 200 feet below the general floor of the valley.

Water-Bearing Properties of the Rocks

The rocks of Paleozoic and Mesozoic age are exposed in the East Range, Humboldt Range, Eugene Mountains, and probably locally in the mountains along the west side of the Imlay area. They include clastic carbonate and volcanic rocks which have been folded, faulted, and metamorphosed in varying degrees. As such, they are not good aquifers. However, the faulting, folding, and weathering of these rocks locally develop secondary openings which result in a secondary permeability. This secondary permeability is important because in some places it is the means by which ground water is supplied to many of the springs in the mountains. The driller's log of stock well 33/35-26C1 indicates that the water is obtained from shale. The shale probably is one of the bedrock formations that locally has secondary permeability. Knopf (1924, p. 43) in his study of the Rochester mining district at the south end of the Humboldt Range, reported that the water level in the Nevada-Packard mine was at an altitude of about 5, 355 feet. Presumably the ground water occurred in the Weaver Rhyolite. Knopf (1924, pl. 1) showed the Weaver Rhyolite to include tuffs and breccia. Wallace and others (1959) included this formation within the Kaipato group of Permian (?) and Triassic ages.

The granitic rocks of Late Jurassic (?) age (Wallace and others, 1959) are exposed in the East Range, Humboldt Range, Eugene and Majuba Mountains and locally in other parts of the mountains on the west side of the Imlay area. These rocks, being solidified from a magma, are nearly impermeable in their original form. Secondary permeability is developed by fracturing and weathering. This secondary permeability may provide the means to supply water to small springs. Generally, however, granitic rocks are highly effective barriers to the movement of ground water.

The volcanic lavas of Tertiary and Quaternary age are formed from a hot liquid and thus have little primary permeability. However, as they solidify upon cooling, fractures commonly develop. Further, as individual units congeal at the surface while they are still flowing, the flow commonly breaks near the bottom and top surface of the flow, all of which may result in secondary permeability. In this region of Nevada, the lavas seemingly tend to be barriers to the movement of ground water, as is indicated in parts of the Winnemucca area (Cohen, oral communication, 1961).

There are notable exceptions, however. For example, well 36/38-19D1, drilled for the city of Winnemucca, reportedly penetrated fissured lava from 499 to 525 feet (the bottom of the well) below land surface that, upon completion of the well, yielded part or all of the flow of 1,000 gpm (gallons per minute). Another example is the basalt in a well owned by the city of Fallon. This basalt reportedly yields water at rates as high as 2,000 gpm with a small drawdown. Whether or not lava that may occur in the valley fill of the Imlay area will yield water freely to wells is not known.

Deposits of Tertiary and Quaternary age that compose the valley fill of the Imlay area span a wide range of clastic, pyroclastic and chemical rock types. These deposits differ greatly in their capacity to store and transmit water. Collectively, however, they contain a large volume of ground water in storage below the zone of saturation.

A large part of the valley fill apparently is composed of relatively impermeable silty clay. However, sand and gravel strata in the form of beach or stream laid alluvial fan deposits yield water readily to wells. Irrigation well 32/33-28D1, near Humboldt, and well 34/35-31B1 which supplies water for mining and milling operations at the Nevada-Massachusetts tungsten mine are examples of the locally favorable water-yielding character of sand and gravel strata in the area. Unfortunately, the extent and distribution of potential sand and gravel aquifers in the Imlay area cannot be defined on the basis of available data. The distribution of the medial gravel of Lake Lahontan probably is somewhat systematic and therefore could be defined by appropriate investigations. Commonly the beach and bar deposits of Lake Lahontan are above the regional zone of saturation, but similar deposits associated with pre-Lahontan lakes probably occur at depth in the valley fill. Because pre-Lahontan lakes have not been studied to an appreciable extent in this area, there is little basis at present for estimating the possible locations of buried beach or bar deposits. One might postulate, however, that they will be found at increasing depths toward the position of maximum thickness of Pleistocene valley fill because the deposits are mostly shoreline features, and that extensive stillstands of pre-Lahontan lakes may have had lesser surface extent in this area.

STREAMFLOW RECORDS

Streamflow has or is being recorded at several locations in or adjacent to the Imlay area, as indicated in the following tabulation:

Station	Location	Period of record
1. Humboldt River near Rose Creek	NW 1/4 sec. 36, T. 35 N., R. 35 E.	May 1948, to present
2. Humboldt-Lovelock Irrigation, Light and Power Co. feeder canal near Imlay	NE 1/4 sec. 1, T. 32 N., R. 33 E.	1915-17, 1918-22, 1925-31, 1937-38, 1941 - to present
3. Humboldt River near Imlay	SE 1/4 sec. 25, T. 33 N., R. 33 E.	1935-41, 1945 to present
4. Humboldt River near Humboldt	Sec. 26, T. 32 N., R. 32 E.	April through August 1933
5. Humboldt-Lovelock Irrigation, Light and Power Co. outlet canal near Humboldt	SE 1/4 sec. 30, T. 32 N., R. 33 E.	1914-20, 1921-41
6. Humboldt River, near Rye Patch (downstream from Rye Patch dam)	NE 1/4 sec. 18, T. 30 N. R. 33 E.	1896-1922, 1924-32, 1935-41, 1943 to present

Records also have been maintained of the water stored in Rye Patch reservoir. The observations at various times have been made by the U. S. Bureau of Reclamation, Pershing County Water Conservation District of Nevada, and the U.S. Geological Survey. The records of streamflow and reservoir contents are published by the U.S. Geological Survey. Records prior to 1951 have been published in Water-Supply Paper 1314 (1960). Records for water years 1951-60 inclusive have been published in annual volumes of the U. S. Geological Survey water-supply paper series entitled "Surface Water Supply in the United States, the Great Basin" part 10. A report is in preparation by the Geological Survey that will present a compilation of records 1951-60.

Tables 3 to 6 give the monthly and annual streamflow, in acre-feet, at the gaging stations near Rose Creek, Imlay, and Rye Patch, and the flow in the feeder canal near Imlay for the 10 years 1951-60.

Table 7 gives the contents of Rye Patch reservoir, in acre-feet on the last day of the month, for the 10-year period ending September 1960.

Table 3 -- Monthly and annual streamflow, in acre-feet, of Humboldt River near Rose Creek, Nev., 1951-60

(Data from U.S. Geological Survey)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Annual
1951	2,020	3,050	14,600	13,790	25,520	38,480	35,930	39,220	35,390	17,070	4,920	2,670	232,700
1952	2,310	2,740	4,030	5,120	11,210	15,930	81,990	249,200	99,210	46,600	12,130	5,330	535,800
1953	3,560	4,000	6,090	10,240	12,270	21,690	13,780	5,330	11,250	23,240	6,230	2,410	120,100
1954	1,910	2,010	3,850	4,760	6,950	10,920	7,970	2,310	1,250	827	766	746	44,270
1955	778	998	1,130	1,110	1,160	2,130	3,190	2,490	4,940	2,660	714	541	21,840
1956	633	772	1,000	9,210	13,340	22,010	32,310	36,850	44,700	28,100	5,860	2,380	197,200
1957	1,990	2,100	3,170	3,660	5,970	23,240	17,930	20,530	46,240	44,270	8,140	3,550	180,800
1958	2,770	4,350	6,190	7,090	12,800	27,000	44,530	54,850	53,630	21,670	5,530	2,800	243,200
1959	2,390	3,110	5,110	6,520	7,220	8,390	3,390	2,740	1,130	1,080	803	764	42,650
1960	891	893	962	1,010	2,350	5,740	7,160	5,800	7,470	2,560	834	621	36,290
10-yr ave.	1,920	2,400	4,610	6,250	9,880	17,550	24,820	41,930	30,520	18,810	4,590	2,180	165,500

Table 4 -- <u>Monthly and annual streamflow, in acre-feet of Humboldt-Lovelock Irrigation, Light and Power Company's feeder canal near Imlay, Nev., 1951-60</u>

(data from U.S. Geological Survey)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1951	0	0	0	0	0	0	0	1,220	1,310	0	0	0	2,530
1952	0	0	0	0	0	0	129	0	0	0	0	0	129
1953	1,720	2,830	4,300	5,410	4,620	4,350	1,110	53	11	0	0	0	24,400
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	1,550	8,000	3,660	0	0	0	13,210
1959	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5 -- Monthly and annual streamflow, in acre-feet, of Humboldt River, near Imlay, Nev., 1951-60

(Data from U.S. Geological Survey)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1951	1,940	2,920	14,000	13,170	23,570	38,840	36,390	37,740	33,360	17,280	4,950	2,420	226,600
1952	2,210	2,510	3,770	4,770	11,020	14,860	63,940	248,100	101,500	50,590	13,660	5,320	522,200
1953	1,430	887	1,790	3,700	7,290	15,170	13,240	5,000	9,640	22,220	5,420	2,020	87,810
1954	1,940	2,050	3,730	4,680	6,350	10,860	8,120	1,710	780	71	203	555	41,050
1955	647	954	1,100	984	1,040	2,070	2,720	2,520	3,700	2,570	355	167	18,830
1956	407	686	1,060	7,570	12,450	20,610	32,070	37,590	42,730	29,890	6,020	2,340	193,400
1957	2,060	2,280	3,140	3,390	5,300	23,190	17,230	20,190	43,370	45,340	9,050	3,130	177,700
1958	2,760	3,880	5,740	6,420	11,260	26,330	39,750	47,850	50,290	23,940	5,450	2,860	226,500
1959	2,350	2,900	4,760	6,090	7,190	8,240	2,820	2,510	910	193	52	212	38,230
1960	686	811	797	803	2,000	4,960	6,270	5,320	6,620	2,260	577	408	31,510

Table 6 -- Monthly and annual streamflow, in acre-feet, of Humboldt River, near Rye Patch, Nev., 1951-60

(Data from U.S. Geological Survey)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1951	2,460	47	52	73	84	1,120	15,280	26,710	23,770	27,120	16,680	11,080	124,500
1952	4,060	201	131	149	142	2,270	32,050	206,300	89,550	43,670	18,310	11,750	408,600
1953	4,840	5,160	264	244	182	7,440	20,170	20,640	19,040	28,300	15,600	13,860	135,700
1954	5,060	1,470	1,040	153	141	3,400	19,100	25,740	13,700	20,790	11,220	1,220	103,000
1955	1.8	0	18	18	12	5.6	18	6,410	6,150	6,400	2,120	12	21,170
1956	6.1	6.0	10	9.1	5.8	6.1	15,770	41,130	21,550	32,290	14,490	12,460	137,700
1957	2,620	48	43	37	33	37	15,250	29,840	18,680	30,270	16,500	9,650	123,000
1958	6.1	6.0	6.1	6.1	5.6	3,620	24,860	32,240	11,680	33,270	10,690	19,100	135,200
1959	369	184	279	1,900	1,310	2,870	25,120	17,300	17,130	23,120	8,290	5,140	103,000
1960	29	34	27	30	31	2,450	13,610	13,450	4,610	9,580	338	542	44,730
10-yr. ave.	2,010	716	187	262	195	2,320	18,120	41,980	22,590	24,520	11,420	8,480	133,700

Table 7 -- <u>Contents, in acre-feet, on last day of month, of Rye Patch reservoir, near Rye Patch, Nev., 1951-60</u>

(Data from U.S. Geological Survey)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept. Annual
1950												29,030
1951	27,610	30,940	44,100	56,030	77,690	109,100	124,600	130,100	131,600	115,600	97,890	85,380
1952	82,420	83,900	87,260	92,300	101,900	114,800	137,200	159,100	167,400	168,400	155,500	146,000
1953	138,700	132,000	133,900	137,200	143,100	150,000	146,000	135,800	127,400	114,800	97,890	83,160
1954	78,390	77,690	80,200	84,640	89,590	95,860	82,050	53,180	37,030	13,680	1,780	1,350
1955	2,530	3,950	5,490	6,890	8,450	10,800	12,900	9,090	5,530	1,730	154	786
1956	1,390	2,370	3,640	10,070	21,430	40,180	52,290	44,790	59,090	52,650	43,420	31,190
1957	30,090	31,400	34,290	37,890	42,880	63,060	62,620	51,140	69,080	76,280	62,940	52,760
1958	54,880	58,340	63,430	69,740	80,800	100,300	110,400	119,800	148,500	141,300	131,100	108,900
1959	108,300	108,300	111,200	115,200	120,000	123,200	99,100	82,050	63,250	35,850	25,860	18,950
1960	19,050	19,760	20,420	21,650	25,730	27,750	18,950	10,270	11,890	3,750	4,170	3,920
1961	* 4,530											

*/ Provisional record, subject to revision

Examination of tables 3 to 5 shows that, during the 10-year period ending September 30, 1960, an average annual loss of about 5,000 acre-feet occurred between the gaging station near Rose Creek and the two downstream gaging stations near Imlay. Because diversions to the Pitt-Taylor reservoirs are taken from the Humboldt River upstream from the gaging station near Imlay, it is necessary to include measured flow through the feeder canal station (table 4) in order to determine streamflow losses for the section of the river between the gaging stations near Rose Creek and Imlay.

The term "losses" here includes evapotranspiration losses resulting from natural conditions and from diversions for irrigation in the section. The term "losses" then is used in the sense of evapotranspiration use by native or irrigated vegetation as a component of the hydrologic system.

Streamflow losses or gains in the section of the Humboldt River between the gaging stations near Rose Creek and Imlay vary from month to month and year to year. To illustrate the variations, the following tabulation (table 8) shows monthly and annual gains or losses for the average of the 10-year period 1951-60; for 1952 water year, a year of high streamflow; and for 1955 water year, a year of low streamflow.

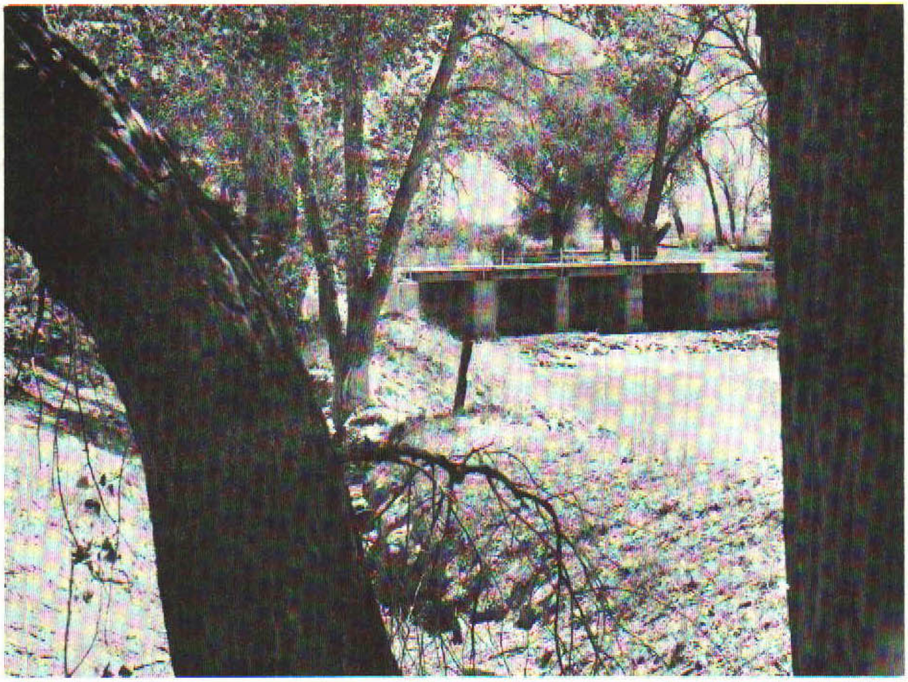
Table 8 -- Monthly and annual losses or gains, in acre-feet, between the gaging station near Rose Creek and the gaging stations near Imlay, Nev., 1951-70 1/

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Annual
10-yr. Ave.	-108	-127	-190	-549	-688	- 605	- 2,280	- 153	- 732	+ 630	- 20	-240	- 5,040
1952	-100	-230	-260	-350	-190	-1,070	-17,921	-1,100	+2,290	+3,990	+1,530	- 10	-13,420
1955	-131	44	- 30	-126	-120	- 60	- 470	+ 30	-1,240	- 90	- 359	-374	- 3,010

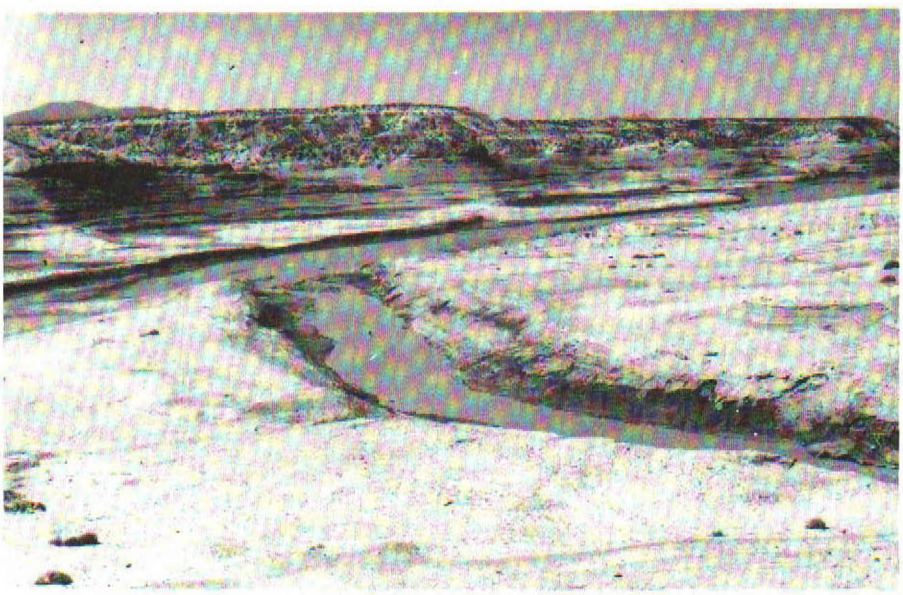
1/ Losses or gains determined by taking the difference of monthly discharge in acre-feet between that for the Humboldt River gaging station near Rose Creek and the combined discharge measured at the gaging stations on the feeder canal and the Humboldt River near Imlay.

The 10-year average annual loss of about 5,000 acre-feet is somewhat higher than the median annual loss of about 3,700 acre-feet because of the large annual loss in 1952. During 8 years of the 10-year period the annual loss ranged between about 3,000 and 4,800 acre-feet. The maximum annual loss for the period was in 1952 and the minimum annual loss was in 1955. The magnitude of monthly losses or gains vary from year to year but losses may occur in nearly all months. Gains generally occur in June, July, and August and appear to result mainly from return flow.

The annual losses and gains in the streamflow of the Humboldt River between the gaging stations near Imlay and Rye Patch (photographs 3 and 4) are shown in table 9. For this purpose, the annual streamflow measured at the gaging station on the feeder canal was added to the annual streamflow for the gaging station on the Humboldt River near Imlay (Column 1). The losses include: evaporation from Rye Patch reservoir; from Pitt-Taylor reservoirs when they contain water; evapotranspiration by phreatophytes in the flood plain of the Humboldt River in upstream parts of the Rye Patch reservoir and in the marginal areas of the Pitt-Taylor reservoirs that generally are not covered by water; and carry-over losses to bank storage. Net annual gains in this section result principally from reduction of storage in Rye Patch reservoir, from return flow of bank storage, and from inflow of ground water that has been derived largely within the area.



Photograph 3. View of Callahan bridge over Humboldt River. U. S. Geological Survey gaging station is a few hundred yards upstream from bridge. Discharge of Humboldt River about 25 cfs at time photograph taken in May 1961.



Photograph 4. View of Rye Patch reservoir from Rye Patch dam. Picture taken late May 1961 at time of no reservoir storage. Run-of-river flow is 20 to 25 cfs.

Table 9 -- Estimated annual losses and gains, in acre-feet, between gaging stations near Imlay and the gaging station near Rye Patch, Nev., 1951-60

	Inflow in acre-feet Imlay and feeder canal stations (from tables 3,4)	Outflow in acre-feet Rye Patch station (from table 5)	Change in storage, Rye Patch reservoir (from table 6)	Net loss (-) or gain (+), in acre-feet	Estimated lake evaporation, Rye Patch reservoir (rounded) (See p. 45)	Residual difference, acre-feet (rounded) (See p. 46)
	(1)	(2)	(3)	(4)	(5)	(6)
1951	229,100	124,500	+56,350	-48,250	40,000	- 8,000
1952	522,300	408,600	+60,620	-53,080	38,000	-15,000
1953	112,200	135,700	-62,840	-39,340	34,000	- 5,000
1954	41,050	130,000	-81,810	+ 7,140	8,000	+15,000
1955	18,130	21,170	- 564	+ 2,480	2,000	+ 4,000
1956	193,400	137,700	+30,400	-25,300	15,000	-10,000
1957	177,700	123,000	+21,750	-33,130	22,000	-11,000
1958	239,700	135,200	+56,140	-48,360	31,000	-17,000
1959	38,230	103,000	-89,950	-25,180	11,000	-14,000
1960	31,510	44,730	-15,030	- 1,810	3,000	+ 1,000
	1,604,020	1,363,600	-25,114	-264,830	204,000	-60,000
10-yr. ave. (rounded)	160,000	136,000	- 2,500	- 26,000	20,000	- 6,000

A detailed analysis of all the components indicated above is not within the scope of this report. However, the following partial analysis provides some indication of the distribution of losses or gains on an annual basis.

Column 5 of table 9 is the estimated evaporation from Rye Patch reservoir by years. The estimate was made by multiplying the seasonal (May to October) records of pan evaporation for each year, as published by the U.S. Weather Bureau, by a coefficient to convert it to an equivalent rate of evaporation from the reservoir. This coefficient was derived from information in Kohler, Nordenson and Baker (1959, p. 11, and pl. 2). Their map showing average annual lake evaporation in the United States indicates an average of about 52 inches. Table 1 of that report lists average seasonal pan evaporation as 59.5 inches. Thus, the indicated average lake evaporation divided by the average seasonal pan evaporation gives a coefficient of 0.87. The seasonal pan evaporation at Rye Patch dam was multiplied by this coefficient for each of the 10 years to obtain the estimated annual rate of lake evaporation. The annual rate then was multiplied by the average reservoir surface area during the 6-month period, May to October, to obtain the estimated annual evaporation from Rye Patch reservoir. The above method for obtaining an estimate of evaporation from Rye Patch reservoir is not rigorous but probably it gives a reasonable approximation to two significant figures.

Column 6 of table 9 is the annual residual difference of losses or gains, in acre-feet. The losses indicated in this column may result from one or more of the following: Greater lake evaporation than that estimated; loss into bank storage; or evapotranspiration of phreatophytes in the flood plain or lowland area in the upstream area of this reach of the Humboldt River.

The gains indicated in column 6 may result from one or more of the following: Less evaporation from Rye Patch reservoir than estimated, as might occur if the average surface area was less than the area used for computation during a given year; return flow from bank storage which had been stored during the preceding year or years; or inflow of ground water derived from recharge in the area.

The 10-year average annual residual loss of about 6,000 acre-feet between the gaging stations near Imlay and Rye Patch probably resulted from evapotranspiration by phreatophytes in the flood plain and lowland area between the gaging station near Imlay and the upstream water's edge of Rye Patch reservoir, and from unaccounted-for evaporation from the reservoirs, especially when the Pitt-Taylor reservoirs contain water.

Obviously the substantial complexities in this system would require considerable investigation to explain adequately. However, as a simplified example, by arranging the inflow in order from greatest to least and the residual differences in order from greatest loss to greatest gain, as in the following tabulation:

Annual inflow		Residual difference	
Year	(acre-feet)	Year	(acre-feet) Loss (- ; gain (+)
1952	522,300	1958	- 17,000
1958	239,700	1952	- 15,000
1951	229,100	1959	- 14,000
1956	193,400	1957	- 11,000
1957	177,700	1956	- 10,000
1953	112,200	1951	- 8,000
1954	41,050	1953	- 5,000
1959	38,230	1960	+ 1,000
1960	31,510	1955	+ 4,000
1955	18,130	1954	+ 15,000

it is seen that the 2 years of greatest inflow also were the years of greatest residual loss. Furthermore, of the 4 years of least inflow, 3 years showed residual gains. Although the sequence by years is not identical, the general grouping suggests a tendency for the larger residual losses to occur in years of substantial inflow, and for the greatest residual gains to occur in years of least inflow. That this relationship is not uniform and simple is not surprising. Modification of the simple relationship should be expected on the basis of antecedent reservoir stages, time distribution of annual inflow, time distribution of annual outflow, antecedent bank storage, area of evapotranspiration of vegetation as controlled by higher stages of the reservoir, annual rates of evaporation from the reserv oir, and evapotranspiration by vegetation not directly affected by the stage of the reservoir.

The quantity of streamflow and of evaporation from the reservoir generally would obscure the effect of the relatively small amount of ground-water inflow derived from recharge within the area. However, some suggestion of the magnitude of ground-water inflow might be indicated by the residual gain the second or third year of deficient streamflow and low storage levels. Thus, part of the residual gain indicated for 1955 and perhaps most of the indicated residual gain in 1960 may be derived from ground-water inflow rather than from bank storage.

The complexities of the interrelationship of surface water and ground water in this area warrant additional investigation to further the understanding of the hydrology of the Humboldt River basin. One type of investigation is suggested in the section "Proposals for additional hydrologic investigations."

GROUND-WATER APPRAISAL

General Conditions

Ground water in the Imlay area originates from precipitation within the area, seepage losses from the Humboldt River, and from underflow into the northern part of the area of ground water through the valley fill. Precipitation along the west flanks of the Humboldt and East Ranges and the Eugene Mountains probably supplies most of the local recharge to the ground-water reservoir in the Imlay area.

Recharge from the Humboldt River is effected only when the stage of the river or reservoir is higher than the ground-water level adjacent to the banks of the river or reservoir. These stage relations are most favorable during flood stages of the river or rising stages of Rye Patch reservoir. At other times, however, the water table slopes toward the river.

The valley fill is the principal reservoir for ground water in the area. The amount of ground water in storage in the valley fill is substantial and is many times the volume of water that is annually recharged to and discharged from the ground-water reservoir.

Some water occurs in fractures in the bedrock and in possible solution openings in the carbonate units in the bedrock. Water in the bedrock and in the soil or deposits along stream channels in the mountains maintain the flow of springs in the mountains.

Ground water in the valley fill varies in chemical concentrations and character from place to place both laterally and vertically. In part, this is due to the fact that this area is near to the Humboldt Sink, the lowest part of the Humboldt River basin. The Humboldt Sink is the final place where water can be removed from the basin by transpiration or evaporation. Evapotranspiration losses that occur as the water moves toward the Sink from the headwater area tend to increase the concentration of chemical constitutents of the remaining water. Because this process has been operating since at least late Pleistocene time ground water of poor quality should be expected locally. However, the process is modified in part and in some areas where relatively fresh water is recharged to the ground-water reservoir, such as in the marginal parts of the valley floor adjacent to the higher mountain area.

The water table generally is within a few feet of land surface beneath the flood plain of the Humboldt River. It therefore slopes in a general southerly direction along the Humboldt River drainage axis of the area. The water table generally also slopes toward the river from the mountains along the margins of the valleys. The slope toward the river commonly is less than the overlying slope of the land surface; thus, the depth to water beneath the alluvial apron increases toward the mountains.

Most of the ground water is discharged by evapotranspiration, by discharge to the Humboldt River, and by underflow southward out of the area. The rates of evapotranspiration are greatest in the flood plain where the depth to water is least, and the density of phreatophytes (water-loving vegetation) tends to be greatest. When water in Rye Patch reservoir is at relatively low stages, some ground water apparently discharges into the river. Springs in the banks of the river below Rye Patch dam also discharge ground water.

Estimated Average Annual Recharge

An estimate may be made of the average annual recharge to the ground-water reservoir as a percentage of the average annual precipitation within the area. The general method is described in an earlier report (Eakin and others, 1951, p. 79-80). Briefly, it is as follows: Zones in which precipitation ranges between specified limits are delineated on a map and a percentage is assigned to each zone which represents the probable average recharge from the average annual precipitation on that zone. The degree of reliability of the estimate so obtained is, of course, related to the degree to which the values approximate the actual precipitation and the degree to which the assumed percentages represent the actual percentages of recharge. Neither of these factors is known precisely enough to assume a high degree of reliability for any one valley. However, the method has proved useful for reconnaissance estimates, and experience suggests that in a number of areas the estimates are relatively close to actual long-time average annual recharge.

The precipitation map of Nevada (Hardman and Mason, 1949, p. 10) was adapted to the better controlled and larger scale topographic base used for the base of Plate 1. The division between the zones of less than 8 inches and 8 to 12 inches of precipitation was selected at the 5,500-foot contour; between the zones of 8 to 12 and 12 to 15 inches of precipitation at the 6,500-foot contour; and between 12 to 15 and more than 15 inches of precipitation at the 7,500-foot contour.

The average precipitation assumed for the respective zones, beginning with the zone of less than 8 inches of precipitation, is 7 inches (0.58 ft.), 10 inches (0.83 ft.), 13.5 inches (1.12 ft.), and 17.5 inches (1.46 ft.).

Table 10 summarizes the computation. The approximate average annual recharge, in acre-feet (column 5), for the zone 12 to 15 inches of precipitation is obtained by multiplying the area of the zone (column 2) times the average precipitation, in feet (column 3), times the percent recharge (column 4), divided by 100, and rounding the product. Thus, for the zone of 12 to 15 inches of precipitation: 17,900 x 1.12 x 7 ÷ 100 = about 1,400 acre-feet. Estimates for the other zones are computed in a similar manner.

In addition to the recharge from precipitation within the area, there is some underflow that enters the area from the next segment upstream along the Humboldt River. In connection with his work on the ground water phase of the Humboldt River project, P. Cohen (oral communication, 1961) estimates the underflow in the vicinity of the gaging station near Rose Creek to be on the order of 1,000 acre-feet a year on the average. On the basis of later data, P. Cohen (oral communication, 1962) revised this estimate to be between 2,000 and 3,000 acre-feet per year. The section for which this estimate was made is only a short distance upstream from the Pershing County line. The conditions affecting the movement of ground water at the above sites appear to be reasonably similar and therefore it is assumed that ground-water underflow into the Imlay area at the Pershing County line also is on the order of 2,000 to 3,000 acre-feet per year.

Although the general hydrologic conditions of the Imlay area suggest that the Humboldt River contributes some water to the ground-water reservoir as temporary bank storage, this storage is returned to the river essentially in its entirety at a later date and therefore it is not considered as ground-water recharge for the purposes of this report.

The combined estimates of recharge to the ground water in the Imlay area thus are about 4,000 acre-feet from precipitation and 3,000 acre-feet from underflow, or a total of about 7,000 acre-feet a year on the average.

Table 10.--Estimated average annual ground-water recharge from precipitation and underflow in the Imlay area, Nevada.

Precipitation zone (inches)	Approximate acreage of zone	Estimated average annual precipitation (feet)	Estimated percent of recharge	Approximate recharge (acre-feet) (2 x 3 x 4 ÷ 100)
(1)	(2)	(3)	(4)	(5)
15+	5,550	1.46	15	800
12-15	17,900	1.12	7	1,400
8-12	65,300	.83	3	1,600
8-	393,000	.58	0	--
	480,000			(3,800)
	750 sq. mi.			
			Total (rounded)	4,000
Estimated ground-water underflow across Pershing County line from up river (2,000 to 3,000 acre-feet)				3,000
Estimated total recharge				7,000

Estimated Average Annual Discharge

An estimate of the natural discharge of ground water may be made by estimating the amount of ground water that is transpired and evaporated (exclusive of pumpage), and that which is discharged from the valley by surface and underground flow. Table 11 summarizes the computation of the estimates of ground-water discharge from the valley.

Several investigators have made studies of evapotranspiration by certain species of phreatophytes. The studies of Lee (1912) and White (1932) made in the Great Basin, and Young and Blaney (1942) made in southern California, form the basis for the estimates used in the reconnaissance studies in Nevada.

Rates of ground-water use by phreatophytes were assigned on the basis of the principal species of phreatophyte, the approximate average density of the phreatophytes, and the average depth to the water table.

The principal areas of phreatophytes were outlined roughly by field reconnaissance using the Lovelock and Winnemucca Quadrangles (topographic map scale 1:250,000) as a base (Plate 1). The principal area includes most of the flood plain of the Humboldt River between the Pershing County line on the north and about the latitude of Humboldt on the south. South of about the latitude of Humboldt water is commonly stored behind Rye Patch dam and therefore this part of the flood plain is excluded as an area in which ground water is regularly discharged by phreatophytes.

Table 11.--Estimated average annual ground-water discharge from the Imlay area, Nevada

Process of ground-water discharge	Area (acres)	Approximate discharge (acre-feet per year)
Evapotranspiration		
Phreatophytes on the flood plain 1/	14,000	2,100
Phreatophytes on the benchlands 2/	13,000	1,300
Ground-water discharge to Humboldt River as springs or seeps		1,000
Ground-water underflow from south end of area		1,000
Estimated average annual discharge . .		(5,400)
(rounded)		5,000

1/ Mixed meadow grasses, salt grass, willow, salt cedar, rabbitbrush, and some greasewood. Depth to water 0 to 10 feet. Estimated average annual rate of use of locally derived ground water is 0.15 foot. Additional use of surface water by this vegetation is contingent on availability. Locally rates of surface water consumptive use may be 2 feet or more but the average rate of use over the 14,000-acre area probably is somewhat less than 1 foot.

2/ Generally greasewood from sparse to moderate density and averaging low density. Depth to water may average 25 feet but may be as much as about 35 feet. Rate of use of ground water estimated to be 0.1 foot a year on the average.

Greasewood characterizes a second group of areas in which ground water is discharged by phreatophytes. The principal areas of greasewood are shown on plate 1. Typically, greasewood grows on benchlands, commonly beginning some distance away from the river bluffs. It terminates on the lower alluvial slopes where the depth to water ordinarily may be 35 feet or more below land surface. Thus the greasewood areas tend to occur as elongate bands roughly parallel to the river bluffs. The bands, however, are not continuous, they do not occur everywhere in this topographic position due in part to locally excessive depth to water or to adverse soil conditions.

No data are available to define precisely the amount of locally derived ground water that discharges directly to the Humboldt River from springs or seeps. This discharge does not include bank storage, that is, Humboldt River water that had seeped into adjacent sediments during high stages of the river or reservoir. In general, the discharge of locally derived ground water probably is small. On the basis of general physical conditions it is estimated to be about 1,000 acre-feet a year on the average. The residual gain for 1960 shown in column 6, table 9, tends to support this estimate.

Ground-water underflow, or subsurface flow from the south end of the area, also considered to be small, based on general physical conditions. Thus, perhaps 1,000 acre-feet a year of ground water is discharged by underflow from the south end of the valley.

The foregoing estimates indicate that average annual discharge of ground water from the area may be on the order of 5,000 acre-feet a year.

Perennial Yield

The perennial yield of the ground-water system is ultimately limited by the annual recharge to and discharge from the system. It is the upper limit of the amount of water than can be removed from that system for an indefinite period of time without permanent depletion. The average recharge from precipitation, through flowing streams and underflow into the area and the average discharge by evapotranspiration, to outflowing streams, and by underflow from the area are measures of the natural ground-water inflow to and outflow from the ground-water system.

In an estimate of perennial yield, consideration should be given to the effects that ground-water development by wells may have on the natural circulation of the ground-water system. Development by wells may, or may not, induce recharge in addition to that received under natural conditions. Part of the water discharged by wells may re-enter the ground-water reservoir by downward percolation, especially if the water is used for irrigation. Ground water discharged by wells usually is offset eventually by a reduction of the natural discharge. In practice, however, it is difficult for well discharge to offset the natural discharge fully, except when the water table has been lowered to a level that eliminates discharge to streams, underground outflow, and evapotranspiration in the natural areas of discharge. The complexities of the numerous pertinent factors are such that, in effect, specific determination of the perennial yield of a valley or area requires an extensive investigation based in part on data that can be obtained economically only after several years of substantial development of ground water.

Final determination of the perennial yield of the ground-water system in the Imlay area is complicated by the existing interrelationship between the ground-water system and the Humboldt River with its reservoir storage upstream from Rye Patch dam. The principal factors of the interrelationships are:

1. The amount of Humboldt River water that is placed in temporary bank storage during extended periods of high-river and high-reservoir stages and later removed from bank storage during extended periods of low-river and low-reservoir stages;

2. The effect on ground-water gradients of the varying and wide range of stages (about 60 feet) of Rye Patch Reservoir; and

3. The availability of water from the Humboldt River and Rye Patch reservoir as a source of ground-water recharge, if future development of ground water permanently depresses the water level below the level of the Humboldt River.

These interrelations could be described with reasonable reliability by a detailed analysis of existing streamflow data supplemented by a moderately extensive additional investigation of surface- and ground-water conditions in the southern part of the Imlay area. The general pattern of such an investigation will be outlined in the later section on "Proposed additional hydrologic investigations."

As an initial guide for ground-water development, the perennial yield of the ground-water system can be based on the estimates of average annual natural ground-water recharge and discharge that were previously discussed.

An estimated average of 5,000 acre-feet a year, is discharged from the ground-water system in the Imlay area. Of this amount, about 1,000 acre-feet leaves the system as underflow from the southern end of the area. It seems unlikely that more than about 1,000 acre-feet a year of locally derived ground water discharges direcly to the Humboldt River. The remaining 3,000 acre-feet is estimated to be discharged by phreatophytes. Thus the 3,000 acre-feet annually discharged by evapotranspiration might be considered as an interim estimate of perennial yield in the Imlay area.

Theoretically, the removal of any ground water from the area would change the existing ground-water regimen and its relationship to the Humboldt River, the water rights of which are fully appropriated. Practically, however, limited development probably would have no measurable effect on the present regiment of the Humboldt River, provided that the development is well distributed at some distance, perhaps a mile or more, from the river. Determination of the effect of specific ground-water development on the flow of the Humboldt River would require extensive field controls and detailed studies.

Storage

A large amount of ground water is stored in the valley fill of the Imlay area. It is many times the volume of the estimated average annual recharge to and discharge from the ground-water reservoir. Some concept of the magnitude of the ground water in storage may be obtained by the following calculation. The surface area of the valley fill lying below the 4,400-foot contour is approximately 250 square miles or 160,000 acres. Assuming that the upper part of the valley fill is composed in large part of clay and silt-sized sediments and that the average specific yield (drainable pore space) of the saturated sediments is about 5 percent, then theoretically about 800,000 acre-feet of water can be obtained from storage in the uppermost 100 feet of saturated deposits.

On this basis, the amount of ground water recoverable from storage in the volume of sediments given in the example would be about 160 times the estimated average annual recharge to the ground-water reservoir and about 4.5 times the 179,000 acre-foot capacity of Rye Patch reservoir.

The physical dimensions of the cited example are less than the total volume of saturated sediments of the valley fill; also, the bedrock probably contains some recoverable ground water. Thus, the total amount of drainable or recoverable ground water in storage may be much more the volume indicated in the example.

The substantial volume of ground water recoverable from storage in even a few tens of feet of saturated sediments provides a large reserve for maintaining adequate supplies for pumping during extended periods of drought or for limited periods of high demand under emergency conditions. The chemical quality of much of the ground water in storage probably is poor, however, as discussed in the following section, and thus a limit is placed on the development of ground water for many uses, unless it is treated.

A word of caution is warranted in using the above example of the amount of ground water in storage. Much of the reliability of such estimates is contingent on the degree of reliability to which the assumed specific yield represents the average field specific yield. The determination of the average specific yield of any large volume of unconsolidated or semi-consolidated sediments is a complex problem. Assuming that the specific yield of each of the grain-size samples, representing definite sedimentary units, can be determined precisely, there still remains the determination of the actual volume of the sedimentary units. Many laboratory studies of specific yield for different sediment sizes have been made. A wide range of values have been obtained in the silt and clay sizes. The range tends to decrease with the larger and more uniform sand and gravel. P. Cohen (oral communication, 1961) indicates that specific yield laboratory determinations for samples of sediments in the Winnemucca area having a median grain diameter in the silt size, generally described as clayey silt, ranged from 1 to 34 percent. Piper and others (1939, p. 121) list a range of 0.5 to 12.2 percent for the specific yield of sediments composed of very fine sand, silt, and clay. Piper and others also obtained values of 34.1 and 34.9 percent for two samples of gravel and coarse sand.

In estimating storage capacity in the San Joaquin Valley, Davis and others (1959, table 5, p. 209) assigned specific-yield values to sediment groups as follows:

Gravel; sand and gravel; and related coarse gravelly deposits	25 percent
Sand, medium- to coarse-grained, loose, well-sorted	25
Fine sand; tight sand; tight gravel; and related deposits	10
Silt; gravelly clay; sandy clay; Sandstone; conglomerate; and related deposits	5
Clay and related very fine grained deposits . .	3
Crystalline bedrock (fresh)	0

Based on the probable Pleistocene history of predominately lacustrine sediments being deposited in the upper few hundred feet of valley fill in the Imlay area, a specific yield of 5 percent for the upper 100 feet of saturated sediments probably is a reasonable value to represent the average percentage of water, by volume, that would drain under field conditions from the volume of sediments given in the example in the text.

Quality

The chemical quality of the water commonly varies considerably from place to place in most ground-water systems in Nevada. In the areas of recharge from precipitation, the chemical content of the water normally is low. However, as ground water moves through the system to the areas of discharge it is in contact with rock materials which have different solubilities. The extent to which the water dissolves chemical constituents from the rock materials is governed in large part by the solubility, volume, and distribution of the rock materials, the time the water is in contact with these materials, and the temperature and pressure in the ground-water system.

No samples of water were collected for chemical analysis during this brief investigation. However, some generalizations may be made based on the geology of the area, and selected chemical analyses from the Humboldt River and the adjacent areas of Lovelock to the south and Winnemucca to the north.

The geologic environment of the valley fill in the Imlay area is dominated by deposition in lakes under varying climatic conditions during Quaternary time. Part of the time the lakes were completely or partially desiccated, and because they had no outlets even partial desiccation sometimes resulted in the deposition of relatively soluble salts, either in separate beds or mixed with fine grained clastic sediments. These salts are available for solution in ground water moving through the Quaternary deposits.

In the Humboldt Sink, some 25 miles south of Rye Patch dam, the ground water generally has relatively dissolved solids content. Elsewhere, such as in the Imlay area, ground water in the fine-grained sediments generally may be expected to contain moderate to high concentrations of chemical constituents, due in large part to the solubilities and exchange capacities of the complex minerals in these deposits. The analyses of water from well 25/30-8C1, (table 12), which is about 10 miles south-southwest of Lovelock, is an example that possibly illustrates the higher range of concentration and chemical character of ground water that might be expected.

Close to the areas of recharge adjacent to the bordering mountains, especially the Humboldt and East Ranges, the chemical content of the ground water should be low, because it either has not been in contact with lake sediments or the exchange capacity of salts of the lake deposits locally is limited. The analyses for the city of Lovelock well 2 (29/33-33A2) and the Southern Pacific Co. Oreana well 2 (29/33-33C1) shown in table 12 illustrate the relatively low concentrations of ground water that has been obtained from wells relatively close to an area of recharge in the Humboldt Range. Similarly the analysis for well 35/36-23D1 at the Rose Creek station of the Southern Pacific Company may be somewhat indicative of the chemical character of ground water adjacent to the East Range.

Table 12.--Chemical analyses, in parts per million, of water in and adjacent to the Imlay area, Nevada

Well number or sampling point	Owner	Dissolved solids	Silica (SiO_2)	Iron and Aluminum (Fe and Al)	Calcium (Ca)		Sodium (Na) 1/	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Iron (Fe)	Manganese (Mn)	Floride (F)	Nitrate (NO_3)	Boron (B)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)
25/30-8C1 2/	Rare Metals Corp.	3370	58	tr.	tr.	0.0	1290		151	608	260	1260							
29/33-31B1 2/	Southern Pacific Co. Oreana No. 1	415	32	tr.	46	16	73		0	176	78	81						144	181
29/33-33A2 2/	City of Lovelock well No. 2	298	23	tr.	55	10	30		0	154	51	45						126	178
29/33-33C1 2/	Southern Pacific Co. Oreana No. 2	283	28	tr.	49	3.0	39		0	115	53	49						94	135
35/36-23D1 3/	Rose Creek R.R. Station	588	21		90	44	38	0.8	0	248	73	135	0.07	0.00	0.3	31	0.02		406
At Callahan Bridge 4/ Sec. 25, T. 33 N.R. 33 E.	Imlay		36		42	25	106	8.4		325	85	69			.8				

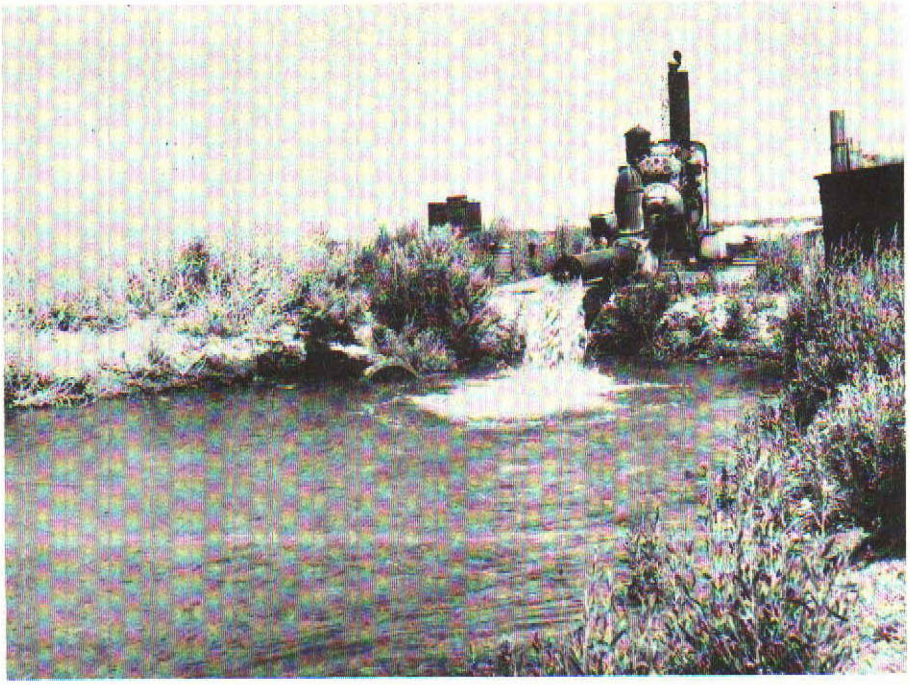
1/ Sodium, potassium calculated as sodium.
2/ Analysis reported in Robinson, T.W., and Fredericks, J.C., 1946, Ground Water in Lovelock Valley, Nevada. Nevada State Engineer, Water Resources Bull. 2, p. 23.
3/ Analysis by Salt Lake City Laboratory, U.S. Geological Survey.
4/ Analysis by J. H. Feth, Menlo Park, U.S. Geological Survey.

The chemical quality of water of the Humboldt River varies with the rate of discharge. The dissolved solids content tends to be lowest during periods of peak discharge and greatest during periods of low flow. The analysis data shown for the Humboldt River near Imlay is from a sample which was one of a group of samples collected along the Humboldt River by J. H. Feth and others of the U.S. Geological Survey in October 1958, as a part of a project on regional geochemical studies. At this point the Humboldt River was flowing at about 40 percent of its mean discharge at the time the sample was collected. A dissolved solids content of 512 ppm (parts per million) was reported by the U.S. Geological Survey (Water-Supply Paper 1380, p. 156) for the period December 21-31, 1951 at the chemical sampling station just downstream from Rye Patch reservoir. Because samples of water discharging from Rye Patch reservoir represent a mixture of water of varying quality of the Humboldt River it seems likely that the listed 512 ppm is somewhat, though perhaps not much higher, than the minimum concentration of run-of-river water in the Imlay area.

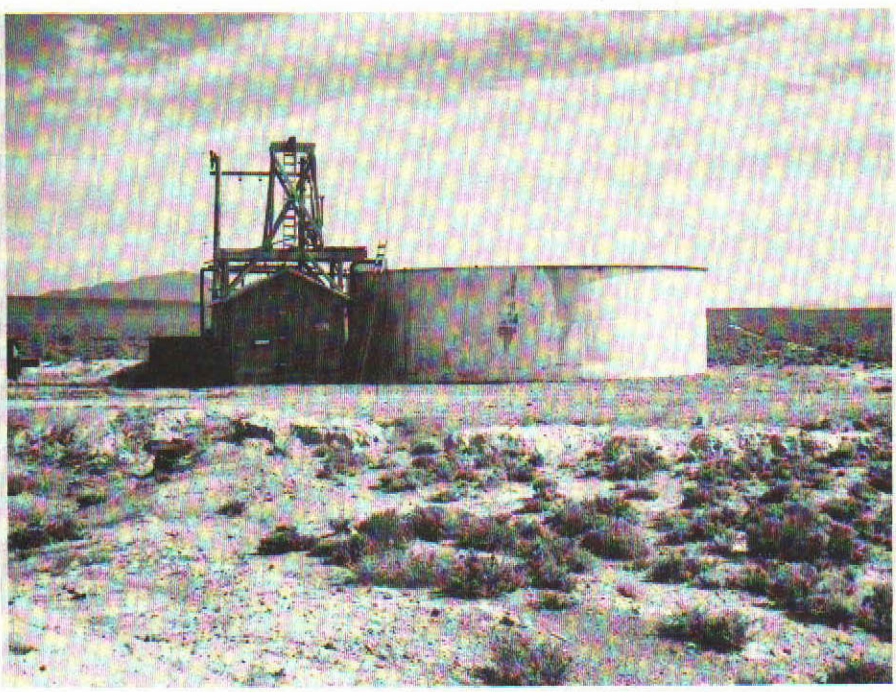
In and adjacent to the flood plain of the Humboldt River the chemical quality of ground water may be modified by water from the river. River water enters the ground-water reservoir when the stage and streamflow of the river increases and by infiltration of river water diverted for irrigation. As optimum conditions for recharge from the river occur when the river and reservoir stage is highest and the chemical content of the river water is least, such recharge would tend to dilute ground water of higher chemical concentration. However, the area in which recharge from the river is significant under existing conditions probably is limited to the flood plain segment between the northern line of Pershing County and about the Imlay gaging station. Rising water is temporarily stored in the banks adjacent to Rye Patch reservoir but this bank storage of water probably does not extend more than one-half to 1 mile beyond the bluffs which border the reservoir area. Thus, chemical change of ground water by Humboldt River water in the Imlay area probably is limited to a narrow band that closely parallels the river.

Gravel and sand strata of the valley fill ordinarily should be able to transmit water freely, and strata generally should contain only a small or negligible percentage of soluble salts. Under favorable conditions therefore, ground water in these sand and gravel strata should be of somewhat better chemical quality than water in adjacent lacustrine sediments. Whether or not gravel and sand strata contains water of good chemical quality at a specific site depends on the quality of water that is supplied to the sand and gravel strata. If the sand and gravel strata are in relatively direct hydraulic continuity with sources of local ground-water recharge, the chemical quality may be good. However, if the water is supplied to the sand and gravel strata through adjacent lacustrine sediments the quality probably will be poor.

Ground water has been developed along the middle part of the alluvial apron, adjacent to U.S. Highway 40, from Humboldt House to Mill City. It is used for irrigation and domestic purposes with apparent success. Adequate analysis of the water from this area is not available to identify the chemical composition.



Photograph 5. View of Campbell irrigation well 32/33–28D1 near Humboldt. Dicharge of about 1,000 gpm is used to irrigate about 55 acres of alfalfa.



Photograph 6. View of pumphouse and tank of Nevada-Massachusetts Tungsten Mine. Well 34/35–31B1 beneath pumphouse provides principal water supply for domestic and mill requirements. Reported yield of well is about 400 gpm.

The above discussion suggests that variations in the chemical concentration of ground water in the Imlay area are considerable, but that moderate to high concentrations, that is, several hundred to a few thousand ppm, may be the general rule in the central part of the valley fill. Data are not available to adequately define the specific distribution and variation of chemical quality in the Imlay area. This, coupled with recent efforts to develop supplemental ground-water supplies in the Lovelock area, forms the basis of one of the proposals for additional hydrologic studies in a later section of this report.

In summary, present information indicates that generally ground water of relatively good quality that is, on the order of a few hundred ppm, may be expected along the middle parts of the alluvial apron near the principal areas of local ground-water recharge, that is adjacent to the Humboldt and East Ranges and the Eugene Mountains. Ground water of possibly somewhat greater chemical concentration should be available adjacent to the Humboldt River where river water may favorably modify the chemical quality of the ground water. Exceptions to this generalization are to be expected.

Development

Present development of ground water in the Imlay area probably does not exceed several hundred acre-feet per year. Imlay obtains most of its water by surface diversion from Prince Royal and Star Creeks in the northern end of the Humboldt Range. Star Creek is in the eastern part of T. 31 N., R. 34 E. A 10-mile pipeline conveys water from Star Creek to Imlay. The development of these creeks largely resulted from the need for water in former years for railroad operations of the Southern Pacific Company. Similarly, a pipeline from Humboldt Canyon supplied water to Humboldt, which also was an active station on the rail line. However, ground water from wells is being used increasingly for domestic, garden, and commercial purposes adjacent to U. S. Highway 40 from Humboldt northward to the vicinity of Mill City. Widely scattered wells also supply water for range stock.

Well 32/33-28D1 on the ranch near Humboldt provides water for irrigating 58 acres (1961). (See photograph 5) The well reportedly was drilled to a depth of 288 feet and reportedly yields water at the rate of more than 1,000 gpm.

Well 34/35-31B1 is used to provide water for mining and milling operations at the Nevada-Massachusetts tungsten mine (photograph 6). According to report, this well yielded 450 gpm with a drawdown of about 20 feet upon completion in 1942. Little water has been pumped in the last few years, because little mining has been carried on since about 1957.

Efforts to develop ground water for irrigation have been made at the old Duncan Ranch. Well 32/33-13B1 reportedly was drilled to a depth of 324 feet. A prospect hole was continued to an additional depth of 40 feet. When tested upon completion, the well reportedly yielded about 90 gpm. Well 32/33-13A1 reportedly was drilled 625 feet deep. When tested upon completion, the well reportedly yielded 500 gpm with a drawdown of 125 feet. Well

32/34-10B1, drilled for water supply at the Nevada State Highway Maintenance station near Imlay, reportedly yields about 3 gpm. It was drilled to a depth of 300 feet, according to the driller's log. Each of the above wells reportedly penetrated a considerable thickness of clay or fine-grained sediments in proportion to the total depth of the well.

Of the four wells drilled for irrigation, the most successful is the one nearest the mountains of the Humboldt Range. Seemingly, its water yielding zone is composed of either beach or alluvial sand and gravel. The unsuccessful wells probably were not drilled deep enough to penetrate older beach deposits of sand and gravel.

The success of future development of relatively large supplies of water of satisfactory chemical quality probably is dependent in large part on careful selection of sites based on all the current information. Commonly, too, it may be expected that the type of well construction and the effectiveness of development of the well will play important roles in the successful completion of large-yield wells.

PROPOSALS FOR ADDITIONAL HYDROLOGIC INVESTIGATIONS

In compliance with the request of Hugh A. Shamberger, Director, Department of Conservation and Natural Resources, State of Nevada, suggestions for special studies are listed below for obtaining needed basic data and for developing a better understanding of the factors that influence or control ground water in the Imlay and other areas of Nevada. These studies are separate from the normal areal investigations commonly needed after ground-water development in a given area becomes substantial.

1. A detailed investigation of the relationship of surface and ground water in the Imlay area. This study would be divided into an upper area, Mill City northward to the Pershing County line; and a lower area downstream from Mill City to Rye Patch dam.

The purpose of the investigation would be to provide data for quantative definition of the interrelationship between surface water and ground water along the Humboldt River.

The project would closely parallel the nature and aims of the present Humboldt River research project in the Winnemucca area--in fact, it would be a logical extension of that investigation.

The approach to obtaining these data would be different from that used in the study of the Winnemucca area because the quantity of water available for input to bank storage is susceptible to better control than was available in the Winnemucca area and because the range of reservoir stage of about 60 feet contrasts to a range in river stage of about 10 feet in the Winnemucca area. This study would not adversely affect the normal operating schedules of deliveries from Rye Patch reservoir.

The upper area forms a relatively straight and narrow flood plain; contribution of locally derived ground water to the river should be quite small; overland runoff to the river within the area is almost negligible; diversions within the area are limited and could be monitored with considerable reliability; temporary bank storage should be relatively small; the area of the flood plain is not large; Humboldt River inflow is being measured at the gaging station near Rose Creek, and outflow is being measured at the gaging station near Imlay. These features combine to provide a potentially reliable control of the factors that determine the character and pattern of losses and gains in this through-flowing segment of the Humboldt River. From the preliminary analysis in this report, the average loss for the past 10 years has been about 3,000 acre-feet a year. However, there is considerable variation from year to year and month to month, and in some years, a net gain may be recorded.

A detailed and well-controlled investigation would be beneficial in demonstrating and determining the natural loss of river water flowing through a flood-plain segment.

The lower area provides a unique setting for studying the effect, quantity, and distribution in time and space of bank storage derived from the Humboldt River. The preliminary analysis of records suggests that as much as 17,000 acre-feet of river water may go into or out of bank storage in a given year. A determination of the manner, nature, extent, and quantity of temporary bank storage would be a valuable aid for obtaining optimum management of Rye Patch reservoir. Definition of the distribution in time and space of bank storage also would provide valuable data on the movement of water through the sediments of the upper part of the valley fill in this area. Furthermore, it could provide valuable data on the effective seasonal or annual (relatively short-time) drainable storage capacity of the sediments in this area.

The proposed investigation in the Imlay area can be developed in detail at a later date. However, among other elements, several lines of test and observation wells normal to the general alinements of the Humboldt River would be required. The wells, a number of which should be drilled to depths of several hundred feet, would permit careful sampling and analysis of the sediments encountered, tests on the water-yielding character of the several lithologic units, and the collection of samples of water for chemical analysis at various depth intervals during drilling operations. This latter item also would provide valuable data for the following proposed investigation.

2. A detailed investigation of the chemical quality of ground water in the Imlay and Lovelock areas. This study might be called a hydro-geochemical investigation. The principal purpose would be to delineate adequately the distribution in space of the chemical constituents in the ground water in the two areas. It would seek to determine the character and magnitude of the changes of chemical constituents within the ground-water system in these

areas. The study would include geologic, hydrologic, hydraulic, and chemical phases to provide the necessary framework for optimum results. It would involve considerable test drilling to obtain direct data as well as the utilization of indirect techniques to control and extend the data obtained from test drilling.

DESIGNATION OF WELLS

Wells and springs in this report are designated by a single numbering system. The number assigned to a well or spring is both an identification and a location number. It is based on the Mount Diablo base line and meridian network of surveys established by the General Land Office.

A typical number usually consists of three units. The first unit is the township number north of the Mount Diablo base line. The second unit, separated from the first by a slant, is the range number east of the Mount Diablo meridian. The third unit, separated from the second by a dash, is the number of the section in the township. The second number is followed by a capital letter, which designates the quarter section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section. Finally, a number designates the order in which the well was recorded in the quarter section.

Thus, well number 32/33-28D1 indicates that this well was the first well recorded in the SE 1/4 sec. 28, T. 32 N., R. 33 E.

Owing to limitation of space, wells on plate 1 are identified only by the section number, quarter section letter and serial number. The township in which the well is located can be ascertained by the township and range numbers shown in the margin of Plate 1. For example, well 32/33-28D1 is shown on Plate 1 by 28D1 and is within T. 32 N., R. 33 E.

Table 13.--Records of selected wells in the Imlay area

32/33-13A1. Owners, Muller Bros. Drilled, unused well, depth 625 feet, casing diameter 18 inches, to 500 feet, factory perforated from 60 to 500 feet with 3/16- x 1 1/2-inch slots. Test pumped at reported rate of 500 gpm with a drawdown of 125 feet. Measuring point is top of casing which is about 2 feet above land surface. Depth to water below measuring point, 36.87 feet, May 24, 1961. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top soil	10	10
Sand coarse	10	20
Clay, yellow	65	85
Clay, yellow, and boulders	10	95
Clay, yellow	10	105
Clay, yellow, and boulders	190	295

32/33-13A1. (continued)

Clay, blue	140	435
Clay, blue and boulders	45	480
Clay, blue	60	540
Shale, black, brittle, caving	10	550
Clay, blue	75	625
Total depth		625

32/33-13B1. Owners, Muller Bros. Drilled, unused well, depth 324 feet, casing diameter 12 inches. Reported test yield of about 90 gpm.
Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Light surface clay	66	66
Gravel, water	3	69
Clay, dark	10	79
Quicksand	5	84
Clay, light	3	87
Sand	37	124
Quicksand	22	146
Clay, brown with little rocks, very hard	41	187
Clay, white with little rocks	33	220
Gravel, solid, no water	2	222
Clay, brown with rocks	24	246
Gravel, light, no water	2	248
Clay, blue	76	324
(drilled 6-inch hole about 40 feet more in clay)		
Total depth of 12-inch well		324

32/33-28D1. Owners, C. and C. Campbell. Drilled, irrigation well, depth 288 feet, casing diameter 14 inches to 236 feet. Equipped with G. M. diesel engine and Johnston turbine pump. Reported yield about 1,250 gpm at 150 feet. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top soil	3	3
Clay, gray	29	32
Quicksand	16	48
Clay, blue	45	93
Clay, blue, and gravel	5	98
Clay, brown and gravel	6	104
Clay, sandy, brown, and gravel	34	138
Clay, brown, sticky	10	148
Clay, sandy and gravel	9	157
Sand and gravel	4	161
Clay, sandy, brown	7	168
Clay, yellow, sticky	12	180
Clay, yellow, and gravel	29	209
Sand and gravel	23	232
Gravel and clay	56	288
Gravel and sand at		288
Total depth		288

32/33-28D1--continued.

Measurements of water level in feet below land surface

Date	Depth	Date	Depth
April 26, 1950	42.47	Mar. 21, 1956	44.91
Oct. 17, 1950	43.40	Sept. 27, 1956	45.44
Sept. 17, 1951	43.72	Mar. 11, 1957	45.42
Mar. 26, 1952	43.88	Sept. 8, 1957	45.96
May 15, 1952	43.82	Mar. 16, 1958	45.68
Mar. 20, 1953	43.33	Sept. 2, 1958	46.20
Sept. 28, 1953	43.22	Mar. 8, 1959	45.58
Oct. 28, 1953	43.22	Sept. 17, 1959	46.70
Mar. 11, 1954	43.05	Aug. 27, 1960	47.52
Sept. 20, 1954	43.70		

32/34-6B1. Owner, unknown. Drilled or augured stock well, depth about 30 feet, casing diameter 6 inches. Equipped with windmill and cylinder pump. Measuring point top of 6-inch casing, which is about 2 feet above land surface. Depth to water below measuring point, 27.66 feet, May 23, 1961.

32/34-8A1. Owner, Bob Dick (?). Drilled, unused well, depth 100 feet, casing diameter 6 inches. Measuring point is top of casing, which is 1 foot above land surface. Depth to water below measuring point, 29.04 feet, May 24, 1961. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top Soil	4	4
Hardpan	20	24
Clay, white	16	40
Clay, blue	20	60
Sand and clay in thin layers (sand is water-bearing)	24	84
Clay, brown with angular rocks (dry)	16	100
Total depth		100

32/34-8A2. Owner, Muller Bros. Drilled domestic well, reported depth 100 feet, casing diameter 6 inches. Equipped with electric driven jet pump and pressure tank. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top Soil	6	6
Clay, sticky	44	50
Clay, blue	33	83
Clay, with rocks, water	17	100
Total depth		100

32/34-10B1. Owner, Nevada Department of Highways, Imlay Maintenance Station. Drilled domestic well, depth 300 feet, casing diameter 8 inches, perforated 1/8- by 2-inch chisel slots from 90 to 300 feet. Reported yield, about 3 gallons a minute. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Rocks and gravel	50	50
Clay, brown	40	90
Clay, blue, with small gravel, water	2	92
Clay, brown	28	120
Stringers of light fine sand in clay, (sand is water-bearing)	18	138
Clay, reddish brown	12	150
Clay, reddish brown with occasional stringers of sand	150	300
Total depth		300

33/33-16C1. Nelson well. Owner, Bureau of Land Management. Drilled stock well, depth 102 feet, casing diameter 8 inches. Equipped with windmill and cylinder pump. Measuring point is top of 4- by 4-inch wood clamp on pump column which is about 1.5 feet above land surface. Depth to water below measuring point, 72.35 feet, May 24, 1961. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Clay, sandy, soft, gray	40	40
Sand, soft	6	46
Clay, soft	46	92
Gravel, medium coarse	10	102
Total depth		102

33/33-3D1. Tungsten well. Owner, Bureau of Land Management. Drilled, stock well, depth 85 feet, casing diameter 6 inches. Equipped with windmill and cylinder pump. Measuring point top of timber clamp on pump column, which is about 2 feet above land surface. Depth to water below measuring point, 61 feet, May 23, 1961. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Soil, soft	9	9
Silt, soft	18	27
Gravel, medium fine	25	52
Clay, sandy	13	65
Sandy gravel and clay	11	76
Sand, fine	9	85
Yellow clay at 85 feet		
Total depth		85

33/34-34B1. Muller Bros. Drilled, garden well, depth about 60 feet, casing diameter 8 inches. Reportedly encountered in succession top soil, white clay, gravel, clay (nearly black at 45 feet) black sand at 57 feet. Flows about 5 gallons a minute. Nonflowing water level about 3 feet above land surface.

33/35-26C1. Mill City well. Owner, Bureau of Land Management. Drilled, stock well, depth 170 feet, casing diameter 6 inches. Equipped with windmill and cylinder pump. Reported depth to water, 125 feet. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Soil, soft, brown	5	5
Gravel, medium, gray	5	10
Hard, gray sand and boulders	10	20
Clay, sandy, soft red	35	55
Clay, soft, blue	65	120
Shale, soft, blue, little water	5	125
Clay, soft, blue	25	150
Shale, medium lime, gray	8	158
Shale, hard, gray, water	7	165
Limestone, hard, blue	5	170
Total depth		170

33/35-33B1. Owner, Midway Station. Drilled, unused well, depth 180 feet, casing diameter 8 inches. Measuring point is hole in plate on top of casing which is 1.5 feet above concrete floor. Depth to water below measuring point, 114.76 feet, May 23, 1961. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top soil	12	12
Boulders and cemented gravel	102	114
Blue limestone and "granite"	6	120
Gravel and sand, water	4	124
Limestone and "granite" in layers	56	180
Total depth		180

34/33-28D1. Bonita well. Owner, Bureau of Land Management. Drilled, stock well, depth 175 feet, casing diameter 6 inches. Equipped with windmill and cylinder pump. Reported depth to water, 21 feet. Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Gravel, medium, water at 33 feet	40	40
Clay, medium, sandy, water at 75 and 165 feet	129	169
Medium sandy clay and gravel	6	175
Total depth		175

34/35-8A1. Owner, unknown. Drilled, stock well, depth 143 feet, casing diameter 8 inches. Equipped with windmill and cylinder pump. Measuring point is top of casing, which is about 1 foot above land surface. Depth to water below measuring point, 54.34 feet, May 23, 1961.

34/35-31B1. Well No. 2. Owner, Nevada-Massachusetts Tungsten Co. Drilled, industrial well, depth 324 feet, casing diameter 10 inches. Equipped with electric motor and turbine pump. Pumping test, 420 gpm with drawdown 21 feet (from 103 to 124 feet). Driller's log:

Material	Thickness (in feet)	Depth (in feet)
Top soil	10	10
Clay, hard	15	25
Hardpan	5	30
Sand, cemented, hard	13	43
Cement sand	2	45
Clay	33	78
Boulder	3	81
Hard cement gravel and sand	9	90
Clay, yellow	11	101
Gravel, black	2	103
Clay, yellow, soft	8	111
Rock	5	116
Clay	7	123
Rock	5	128
Boulders and clay	2	130
Clay, hard	12	142
Gravel, loose	4	146
Clay, hard	9	155
Clay	35	190
Gravel	3	193
Hardpan	19	202
Clay, yellow, hard, sticky	3	205
Boulders	5	210
Clay, yellow, hard, sticky	2	212
Clay, hard	6	218
Gravel, loose, traces of yellow clay	9	227
Gravel and sand, loose	14	241
Clay	8	249
Gravel	11	260
Clay, yellow	21	281
Sand, gray	3	284
Clay, yellow	12	296
Clay, yellow, hard	7	303
Clay, yellow	2	305
Sand, running	3	308

Material	Thickness (in feet)	Depth (in feet)
Gravel	3	311
Clay and gravel	1	312
Gravel	6	318
Clay	6	324
Total depth		324

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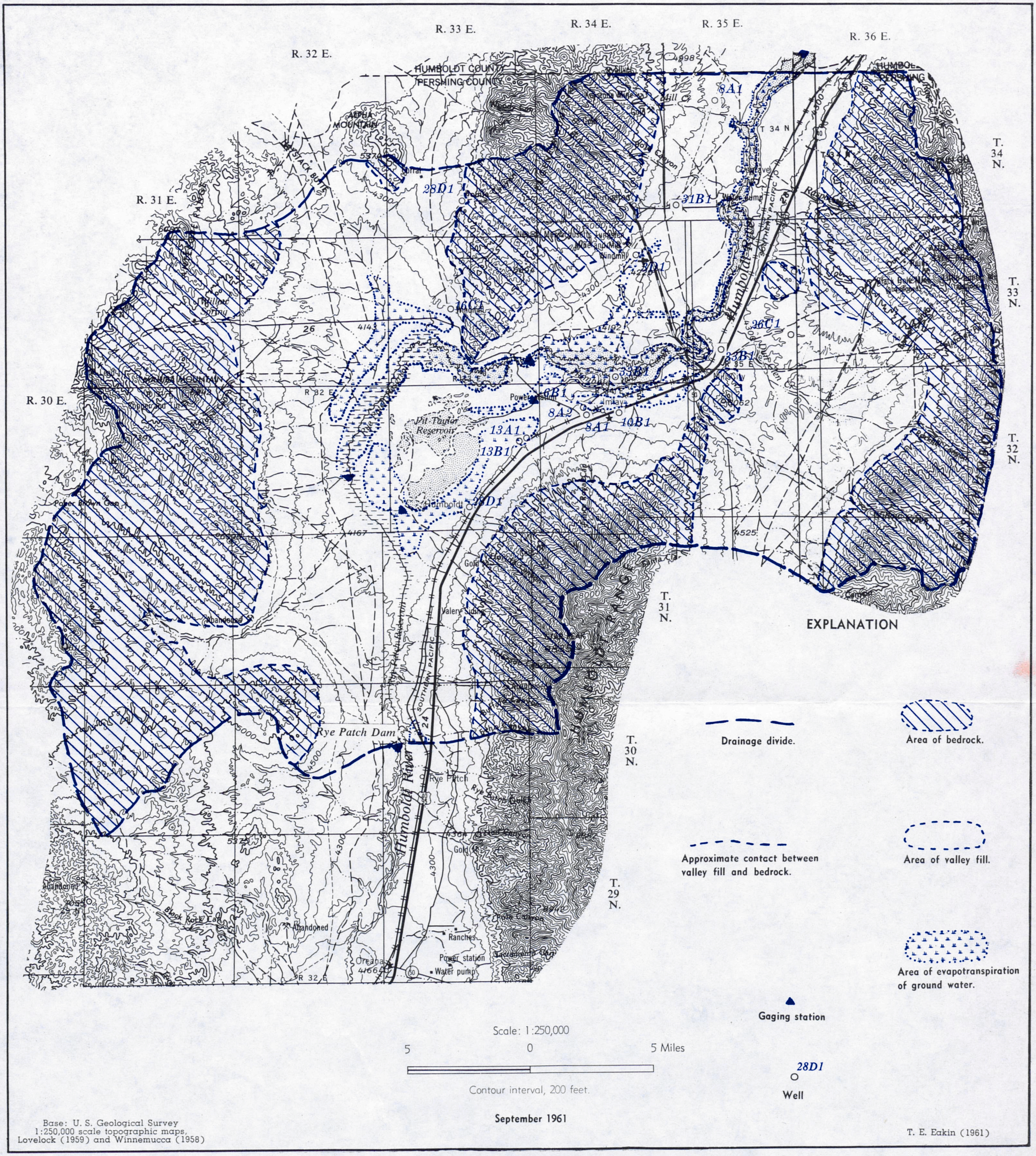

PLATE 1. MAP OF IMLAY AREA, HUMBOLDT RIVER BASIN, PERSHING COUNTY, NEVADA

SHOWING AREAS OF BEDROCK, VALLEY FILL, AND EVAPOTRANSPIRATION, AND LOCATION OF WELLS

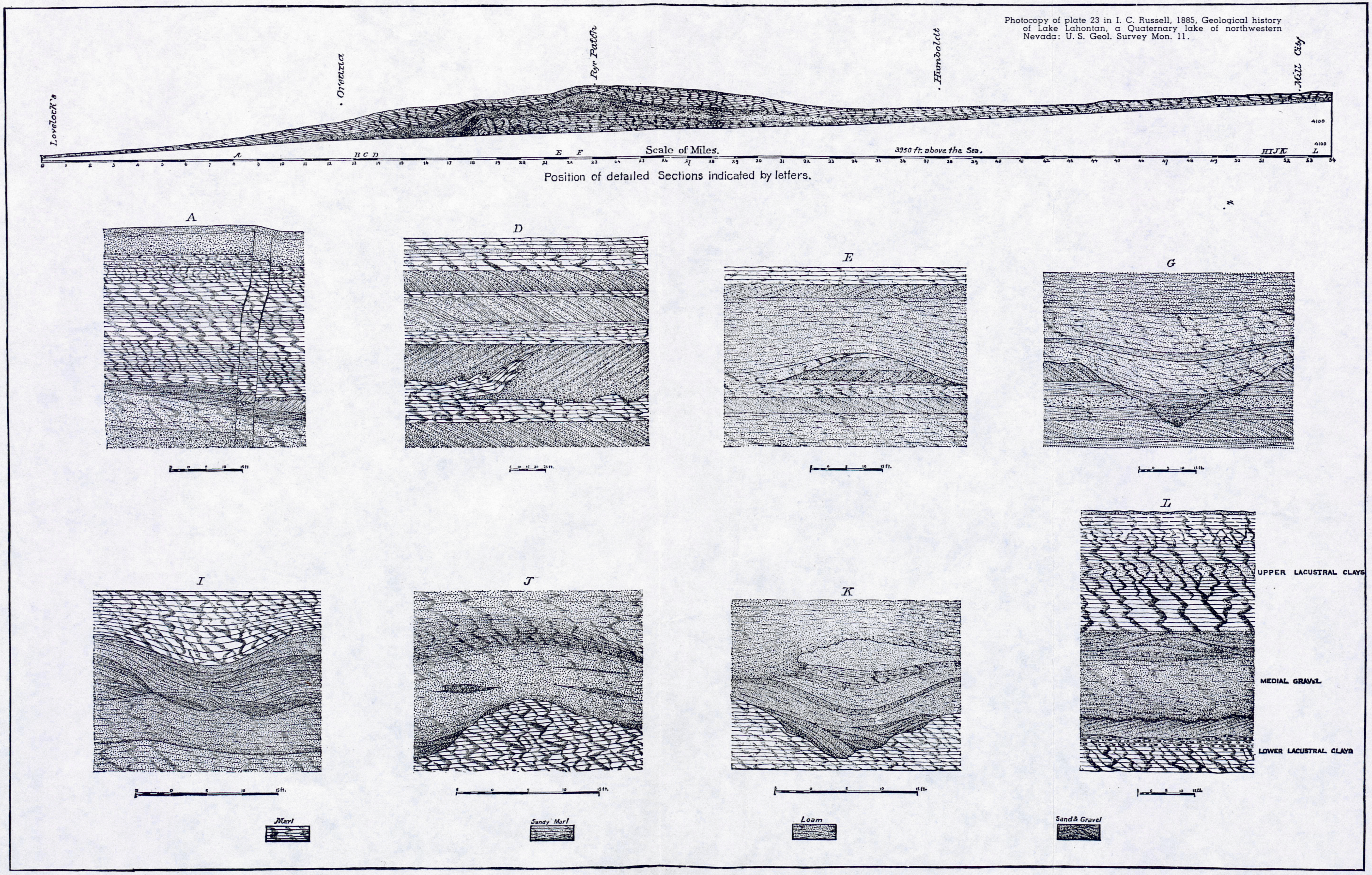

PLATE 2. Sections of Lake Lahontan deposits between Rye Patch Dam and Imlay.