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EFFECTS OF GROUND-WATER DEVELOPMENT ON THE WATER REGIMEN OF PARADISE VALLEY, HUMBOLDT COUNTY, NEVADA, 1948-68, AND HYDROLOGIC RECONNAISSANCE OF THE TRIBUTARY AREAS

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Prepared cooperatively by the

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EFFECTS OF GROUND-WATER DEVELOPMENT ON THE WATER REGIMEN OF PARADISE VALLEY, HUMBOLDT COUNTY, NEVADA, 1948-68, AND HYDROLOGIC RECONNAISSANCE OF THE TRIBUTARY AREAS

By J. R. Harrill and D. O. Moore

SUMMARY AND CONCLUSIONS

This study appraises water resources of the three areas in the Little Humboldt River drainage: Little Humboldt Valley, Hardscrabble Area, and Paradise Valley. Emphasis is placed on evaluating effects of pumping ground water in Paradise Valley on the hydrologic system. A previous study by Loeltz and others (1949) described the ground-water flow system in Paradise Valley prior to any significant development by pumping. Their study indicated that the surface-water and ground-water supplies of the area were closely related.

This appraisal has led to the following estimates of inflow, outflow, system yield, decreed surface-water rights, annual use, and water still available for development:

(all estimates in acre-feet per year)

Item	AREA		
	Little Humboldt Valley	Hardscrabble Area	Paradise Valley
INFLOW:			
Runoff.	25,000	24,000	30,000
Inflow from Little Humboldt Valley:			
Surface	--	--	17,000
Subsurface. . . .	--	--	300
Inflow from Hardscrabble Area:			
Surface	--	--	22,000
Subsurface. . . .	--	--	Trace
Flow across bedrock-alluvial contact. .	2,000	--	1,000
Total	27,000	24,000	70,000
OUTFLOW:			
Evapotranspiration. .	8,500	300	71,000
Surface outflow . . .	17,000	22,000	2,000
Subsurface outflow. .	300	Trace	3,500
Total	26,000	22,000	76,000
SYSTEM YIELD	8,000	100	60,000
APPROXIMATE DECREED SURFACE WATER RIGHTS. . . .	9,200	44	120,000
AVERAGE ANNUAL USE (for the period 1948-68). . .	6,000	50	45,000

As of 1968, development in Little Humboldt Valley was virtually all surface water. Most of the unused part of the system yield is consumed by nonbeneficial evapotranspiration in areas adjacent to streams that supply irrigation water and may not be salvable by pumping without affecting streamflow.

Most development in the area is in Paradise Valley which probably will be the site for most additional future development. Because surface-water resources have been fully appropriated for many years, most future development will be by ground-water pumping. The principal conclusions regarding the valley-fill reservoir, existing ground-water development, and future development are as follows:

1. Average annual ground-water recharge and discharge in Paradise Valley are nearly 40,000 acre-feet each. Much of the recharge from infiltration of streamflow and irrigation diversions in the spring occurs in areas of shallow ground water where it is readily consumed by meadows of native hay and nonbeneficial phreatophytes during the summer months.

2. As of spring 1968, permits to pump 66,000 acre-feet per year have been issued by the State Engineer. These permits include 12,000 acre-feet per year to irrigate areas solely by pumping, and 54,000 acre-feet per year to supplement surface water. The estimated net pumpage in 1968 was nearly 8,000 acre-feet. The accumlated net pumpage of record (1948-68) of 60,000 acre-feet has been supplied mostly from infiltration of streamflow and reductions in evapotranspiration. During the summer months when streamflow is low, water may be pumped from storage. However, at the existing level of pumping, fall and winter streamflow has usually been sufficient to replenish the ground-water reservoir before the next irrigation season.

3. Under the existing (1968) pattern of development, water use varies greatly from year to year, depending largely on the availability of unregulated streamflow. Average beneficial consumption of water during the 20-year period 1948-68 is estimated to be about 45,000 acre-feet per year, about 75 percent of the estimated system yield. Full development of the system yield would allow water to be consumed at an annual rate of about 60,000 acre-feet. Barring construction of upstream storage facilities, conjunctive use of surface and ground water appears the most feasible means to attain the full system yield. Most of the estimated 15,000 acre-feet per year of unused water would be utilized if all existing permits to irrigate solely by pumping ground water were exercised.

4. Development of the entire system yield through conjunctive use of surface and ground water would result in a permanent depletion of about 470,000 acre-feet of

stored ground water in the southern half of the valley where most of the natural discharge salvable by pumping is located. During dry years, supplemental pumping in the northern half of the valley would cause temporary storage depletions that would be replenished during subsequent wet years.

5. If pumping in the southern half of the valley is not strategically located or exceeds about 15,000 acre-feet per year, resulting water-level declines may cause significant subsurface inflow from beneath the Humboldt River before the desired amount of natural discharge is salvalaged. It is not possible to salvage all ground-water discharge from the southern end of the valley by pumping without inducing some inflow from beneath the Humboldt River.

6. The present day (1968) quality of water is adequate for agricultural and domestic purposes. However, if the system yield is fully developed, recycling of ground water should cause an unfavorable salt balance in the southern part of the valley and a gradual deterioration in the quality of pumped water will result.

7. The cause-and-effect relations (pumpage versus the distribution and amount of water-level decline and associated factors) for the 20-year period spring, 1948-spring 1968, are first approximations developed from an estimated gross pumpage of 87,000 acre-feet (estimated net pumpage 53,000 acre-feet). Future refinements of these relations will require reasonably accurate records of annual pumpage, periodic water-level measurements in most wells (preferably before the irrigation season begins), periodic evaluations of streamflow and streamflow depletions (preferably before the irrigation season begins), and monitoring the chemical quality of pumped water from both shallow and deep wells.

Purpose and Scope

This study of the water resources of Paradise Valley and the tributary Hardscrabble Area and Little Humboldt Valley is concerned primarily with the effects of ground-water development on the hydrologic regimen of Paradise Valley. Hardscrabble Area and Little Humboldt Valley are studied at reconnaissance level so that adequate information will be available to describe the hydrology of all the Little Humboldt River drainage area.

A previous study by the U. S. Geological Survey, (Loeltz and others, 1949) described ground-water conditions in Paradise Valley as of 1947, and indicated that the ground-water supply is closely related to the surface-water supply. The need for the present study is evidenced by increased pumping of ground water to augment surface-water supplies and the possibility that sustained heavy pumping may be causing significant reduction in appropriated surface flows during the growing season.

Therefore, the objectives of this study are: (1) to reappraise the hydrology of the Little Humboldt River drainage area with special emphasis on the magnitude and effects of ground-water development in Paradise Valley since 1947; (2) to evaluate effects of the 1968 development; (3) to consider possible effects of future increased development; and (4) to appraise the chemical quality of the water to provide a basis for comparison in the future.

To accomplish these objectives, this report includes: (1) a reappraisal of the main elements of the natural hydrologic system, (2) an estimate of the magnitude and distribution of surface-water inflow, (3) descriptions of the alluvial ground-water reservoirs, (4) estimates of pumpage and net storage depletion of ground water during the period 1948-68, (5) estimates of the available surface- and ground-water supply, and effects of future development, and (6) a study of the chemical character of the water to establish a base for evaluating future changes.

Field work began in September 1967 when a reconnaissance was made of streams in the area and sites were selected for periodic measurement during the course of this study. Intensive field work began in March 1968 and was completed by November 1968. This consisted of canvassing most of the wells in the area, measuring water levels in these wells before and after the 1968 irrigation season, measuring discharges and pumping levels in irrigation wells, collecting water samples to determine chemical quality of the water, and drilling seven small-diameter test wells in undeveloped parts of the valley. Surface-water inflow to the area and stream depletion in Paradise Valley were evaluated from periodic streamflow measurements made during the course of this study.

The estimates developed in this study are subject to some errors that are inherent in applying point data to large areas and in the simplifying assumptions made in order to evaluate natural conditions. Estimates derived for large areas generally are considered to contain errors less than about 25 percent. However, additional specific data may be required to apply these generalized estimates to a small area without risking increased error.

Location and General Features

The drainage area of Little Humboldt River consists of three hydrographic areas, Paradise Valley, Hardscrabble Area, and Little Humboldt Valley. Hardscrabble Area and Little Humboldt Valley are tributary to Paradise Valley. Hardscrabble Area is essentially the drainage area of Martin Creek. Little Humboldt Valley is composed of the drainages of the North and South Forks of Little Humboldt River and Eden Valley. Location of the areas is shown in figure 1. Principal geographic features are shown on plate 1.

Total area of the Little Humboldt River drainage is about 1,740 square miles. This includes about 600 square miles in Paradise Valley, about 167 square miles in Hardscrabble Area, and about 975 square miles in Little Humboldt Valley (Rush, 1968, p. 16).

Granite Peak (altitude 9,770 feet) is the highest point in the area. The lowest point (altitude 4,300 feet) is where the channel of the Little Humboldt River crosses the southern boundary of the area.

Winnemucca, about 5 miles southwest of Paradise Valley, is the nearest large community (population 4,900, Nevada Office of Economic Opportunity estimate for 1967) and provides services required by people in the valley. The town of Paradise Valley, a small rural community at the north end of Paradise Valley, is the only town in the study area.

Acknowledgments

Acknowledgment is made of the cooperation of local residents of the valley in supplying data and permitting use of their wells for discharge measurements and water-level observations during the course of this investigation. Power consumption data were furnished by the California-Pacific Utilities Company. J. Kirk Day, Humboldt County Agricultural Agent, provided valuable information on development and water use prior to 1967. Wholehearted assistance was also received from Federal, State, and local governmental agencies. Most of the drillers' logs and data on well construction used in this investigation were furnished by the State Engineer of Nevada.

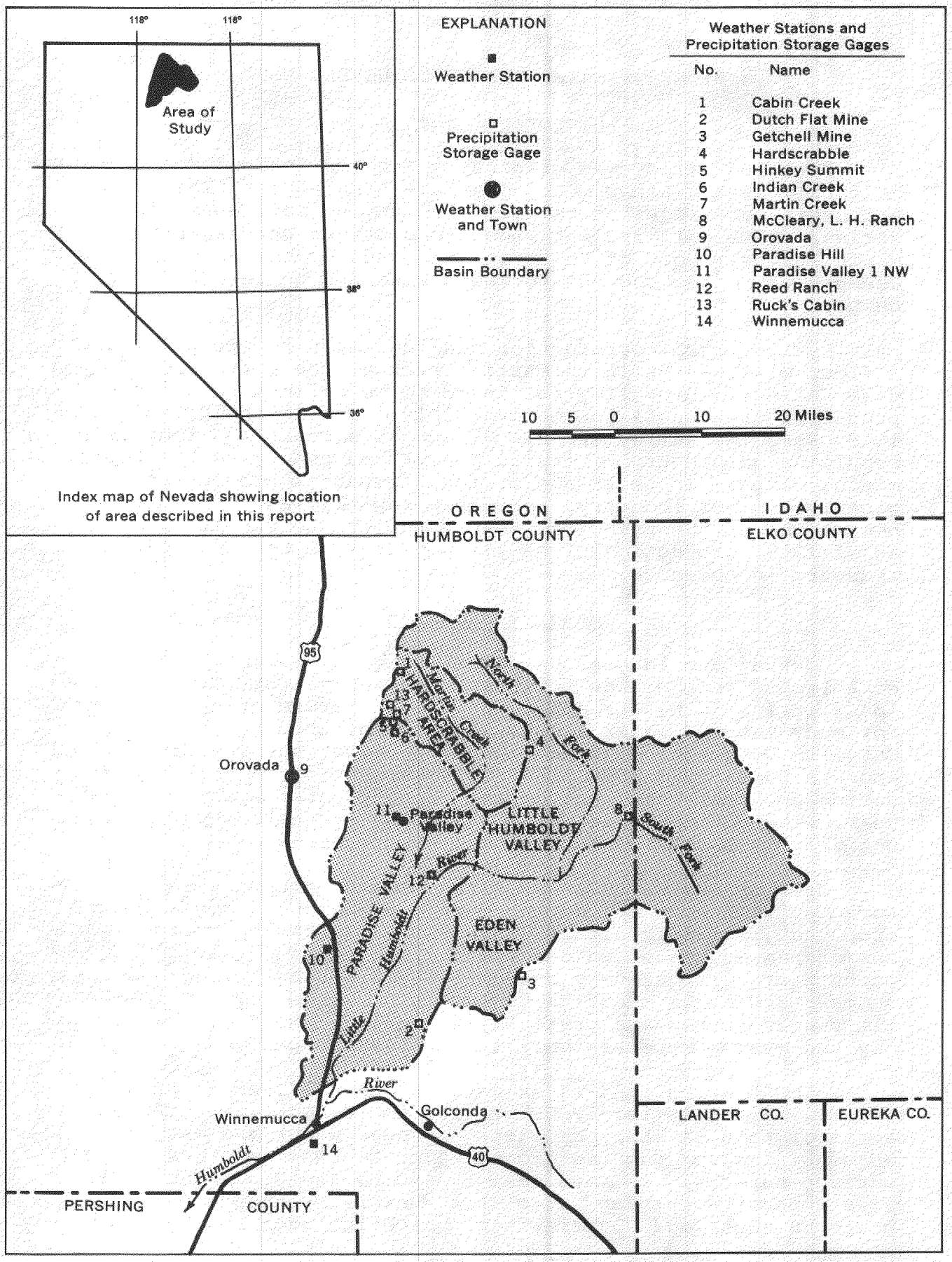


Figure 1. — Location of area, main roads, principle communities and weather stations

HISTORY OF WATER-RESOURCES DEVELOPMENT

Historical Sketch

Paradise Valley was originally settled in 1863 and developed primarily as a grain-producing area. Large quantities of hay and grain were required to feed the many animals used for pack strings or to pull freight wagons and stages serving nearby mining camps. Most of the grain was used by the Humboldt and Reese River mines and the northern Elko and southwest Idaho camps.

By 1868, grain production had increased to the point that a flour mill was built on Martin Creek at the north end of Paradise Valley. The valley continued to be an important grain-producing area until the early 1900's. During the period 1878-1918, Paradise Valley was also known as a fruit and produce area, supplying garden truck, fruit, honey, and poultry to the nearby mining camps. In this same period, livestock production, originally a minor industry, increased rapidly, and Paradise Valley became one of the principal meat suppliers to the mining camps. As of 1968, production of cattle and hay was the predominant industry in the area.

Land Use in 1968

Most of the land is used for agriculture, which has been established in the area for more than 100 years. Virtually all lands irrigable by streamflow have been farmed or used as pasture for many years. Water rights were established by the E. P. Carville Decree of 1935 (Mashburn, Mathews, and Thurston, 1935) and are summarized in table 1. The amount of land irrigated during any year, however, depends on the water available that year. The maximum acreage irrigated by streamflow during any one year is estimated to be about 39,000 acres.

Most of the water and related land development is in Paradise Valley, where during most years about 3,300 acres of cropland (primarily alfalfa hay) are irrigated by surface water and/or pumped ground water; about 8,000 acres of native hay and pasture are irrigated by streamflow during the spring and early summer; and up to about 23,000 acres of mixed hay and low-benefit phreatophytes are partially irrigated. Most of the native hay and meadow receives only one irrigation per year.

Almost all ground-water development has been in Paradise Valley. As of spring 1969, permits to irrigate about 3,000 acres of land entirely by pumping ground water and about 15,000 acres of land by pumping ground water to supplement existing surface-water rights have been issued by the State Engineer. If all permits to pump water were exercised, annual pumpage would be about 66,000 acre-feet, which includes about 12,000

acre-feet for land irrigated entirely by pumping and about 54,000 acre-feet of supplemental pumpage. Some additional wells were pumped for domestic purposes along the southwest side of the valley in 1968, where about 15 residences had been constructed on 1- to 5-acre homesites and land prepared for construction of about another 15 residences.

Table 1.--Summary of land acreage with decreed water rights from the Little Humboldt River and its tributaries

Class	Description	Irrigation season[1] (days)	Duty of water acre-feet/acre[2]	Approximate acres with decreed rights: Paradise Valley	Hardscrabble Area	Little Humboldt Valley
A	Harvest crops - all land adapted to cultivated crops; also all irrigated native or other grass lands that normally receive sufficient water to produce a crop that will justify cutting for hay, although it may sometimes be pastured and not cut.	a 180	3.6	30,300	--	2,000
B	Meadow pasture - all grass lands free from brush which receive sufficient water to produce what may be classed as good pasture, but not of a sufficient character to warrant cutting hay thereon.	b 90	1.8	1,200	--	120
C	Diversified pasture - lands from which the brush has not been cleared, but which are artificially irrigated to some extent for the production of grasses or pasturage; also this classification includes those areas in the irrigated fields that are grown up with willows and the depressions or other areas covered with tules and flags, if there is grass amongst them.	c 30	0.9	10,400	49	2,000
	Totals (rounded)			41,900	50	4,100
					46,000	

1. Providing water is available.
2. Based on continuous flow of .01 cfs per acre for the indicated irrigation seasons.

a. 15 March-15 September
b. 15 March-13 June
c. 15 March-28 April

HYDROLOGIC ENVIRONMENT

Principal Elements of the Hydrologic System

The principal components of the hydrologic system of the Little Humboldt River Basin are:

1. Mountains that receive more precipitation than other parts of the area and consequently generate most of the water supply.

2. Streams that transport excess water from the mountains toward, through, and out of the valleys.

3. Valley-fill reservoirs that store large quantities of transient ground water as it moves from areas of recharge to areas of discharge.

4. Discharge areas where water is discharged from the system by evapotranspiration or surface or subsurface outflow.

These components are the main features of the system; however, it must be emphasized that they all function together in a closely connected and interdependent manner.

Physiography

Areas in the Little Humboldt River drainage are characterized by two distinctive types of landforms: (1) deep canyons cut into comparatively flat-lying volcanic rocks in Hardscrabble Area and the North and South Fork drainages of Little Humboldt Valley, and (2) structural depressions partly filled by debris from surrounding mountains in Paradise and Eden Valleys.

The upstream areas (Hardscrabble Area and the North and South Fork drainages of the Little Humboldt River) are primarily areas of active erosion. Alluvial fill is limited to thin channel and flood-plain deposits along narrow canyon bottoms.

Landforms more typical of the Great Basin are present in Paradise Valley and Eden Valley. Fault-block mountains bound large alluvial valleys. Coalescing alluvial fans border the mountains and make up the major part of an alluvial apron which slopes away from the mountains toward the comparatively flat-lying valley floors. The flood plain of the Little Humboldt River covers much of the valley floor at the north end of Eden Valley and in Paradise Valley.

Dunes formed by sand blown in from Silver State Valley block the Little Humboldt River channel at the southern end of Paradise Valley and cause Gumboot Lake to form during exceptionally wet years.

Drainage

Little Humboldt River is the principal stream in the area. It originates in Little Humboldt Valley, flows into Paradise Valley, and then south to Gumboot Lake at the south end of Paradise Valley. During exceptionally wet years, when Gumboot Lake overflows or is drained, the Little Humboldt River flows into the Humboldt River. All other streams in the area are tributary to the Little Humboldt River. The drainage network and names of principal streams are shown on plate 1.

Lithologic Units

For the purposes of this report the eight lithologic units in Paradise Valley, Hardscrabble Area, and Little Humboldt Valley are divided into two major groups on the basis of their hydrologic properties: (1) unconsolidated deposits which form the valley fill, are highly porous, and commonly transmit water readily; and (2) consolidated rocks, which compose the mountains and underlie the valley fill, commonly have low porosity and permeability and do not reaily transmit water. The eight lithologic units are described in table 2; the descriptions are based on the work of Willden (1964), Compton (1960), and Tagg (1967). Distribution of the eight units is shown on plate 1.

Climate

Climate ranges from semiarid in the valleys to subhumid in the mountains. Precipitation rates range from about 8 inches per year in parts of the valleys to more than 20 inches per year in the mountains. Most of the precipitation in the mountains falls as snow during the winter and runs off during the spring thaw. Table 3 lists the average monthly and annual precipitation at 14 stations in and adjacent to the area. Locations of the stations are shown in figure 1.

Temperature is subject to large daily and seasonal variations. Daily fluctuations of as much as 40°F are not uncommon. Maximum summer temperatures sometimes reach 100°F and the lowest winter minimums are commonly below zero.

Table 4 lists freeze data for four stations in or near the area. Freeze data may be used to estimate the approximate length of the growing season, which is determined largely by temperature, and which varies with the type of crop. For example, a crop which injured by a frost at 28°F has an average growing season of about 123 days in the north end of Paradise Valley, whereas crops which are injured by the first 32°F frost have an average growing season of only about 94 days.

Table 2.--Principal lithologic units

Age		Unit designation	Estimated thickness (feet)	Lithology	Occurrence	General hydrologic properties
QUATERNARY	Holocene	Dune sand	0-75	Sand, medium grained, well sorted.	Occurs as eolian deposits at south end of Paradise Valley where dunes obstruct the channel of the Little Humboldt River.	Porosity estimated at 20-30 percent, permeability moderate to high. Water readily infiltrates from surface to saturated zone; may act as recharge area when Gumboot Lake is formed.
	Pleistocene and Holocene	Younger alluvium	0-150±	Unconsolidated alluvial and colluvial deposits of interbedded sand, gravel, silt, and clay. Materials generally moderately to well sorted and form lenticular bodies.	Occurs primarily as stream-channel deposits in the center of Paradise Valley and along the flood plains of major streams. Includes some slope wash and ephemeral-stream deposits around the margin of the valleys.	Sand and gravel deposits are highly permeable and may yield large quantities of water to wells. Stream channel deposits in Paradise Valley form the most productive aquifers. Finer grained or poorly sorted deposits less capable of yielding water.
	Pleistocene	Older alluvium	0-1,000±	Alluvial and colluvial deposits of gravel, sand, silt, and clay. Partially consolidated (cemented) locally and at depth. Deposits at depth in center of the valley generally moderately to well sorted.	Occurs along margins of valleys primarily as alluvial-fan deposits, also slope wash, talus deposits, and upland alluvial surfaces. Fan deposits have generally been dissected by younger stream channels. Occurs at depth in the center of Paradise Valley primarily as stream-channel deposits. Some lake or lake-associated deposits may be present at southern end of Paradise Valley. These deposits locally may overlie valley-fill deposits of older age not exposed in the area.	Permeability ranges from low to high zones of high permeability generally associates with buried-channel deposits of sand and gravel.

Valley fill

Table 2.--Principal lithologic units--Continued

Age	Unit designation		Lithology	Occurrence	General hydrologic properties
TERTIARY AND QUATERNARY	Consolidated rocks	Volcanic rocks	Primarily rhyolite, dacite, basalt, and andesite. Include some interbedded sedimentary rocks.	Occur as dominant rock type in Hardscrabble Area and North Fork, South Fork, and Mulligan Creek drainages in Little Humboldt Valley. Also occur as more restricted outcrops along the margins of the Santa Rosa and Hot Springs Ranges and the Osgood Mountains in Paradise Valley and Eden Valley.	Commonly have little or no interstitial porosity except where highly vesicular. May transmit water through joints and zones between flows.
TERTIARY		Younger sedimentary rocks	Include shale, sandstone, conglomerate, tuff, and diatomaceous shale.	Occur in Little Humboldt Valley where principal exposures are along lower reaches of the North Fork and South Fork Little Humboldt River. Commonly associated with volcanic rocks.	Finer grained materials generally do not transmit water readily. Sandstone and conglomerate beds may transmit moderate amounts of water in areas where materials are moderately to well sorted and voids are not filled by cementing material.
CRETACEOUS AND TERTIARY		Granitic rocks	Principally granodiorite.	Occur principally as intrusive masses exposed along the core of the Santa Rosa Range.	Virtually no interstitial porosity and permeability, may transmit small quantities of water through fractures and weathered zones.

Table 2.--Principal lithologic units--Continued

Age		Unit designation	Lithology	Occurrence	General hydrologic properties
TRIASSIC THROUGH CRETACEOUS	Consolidated rocks	Metamorphic rocks	Primarily phyllite, slate, quartzite, and mudstone with some calcareous shale, calcareous sandstone, and lenses of limestone and dolomite. Include Grass Valley Formation, Winnemucca Formation, an unnamed quartzite and mudstone formation, Rasberry Formation, and undifferentiated Triassic and Jurassic rocks as mapped by Willden (1964).	Occur primarily along the flanks of the Santa Rosa Range. Localized exposures in the Hot Springs Range and at northeast end of Paradise Valley.	Very low porosity and permeability; some water may be transmitted along fractures or other secondary feature.
CAMBRIAN THROUGH PERMIAN	Consolidated rocks	Older sedimentary rocks	Sedimentary sequences of quartzite, chert, limestone, dolomite, sandstone, shale, and conglomerate. Interstratified volcanics present in parts of the section. Include Osgood Mountain Quartzite, an unnamed chert unit, Harmony Formation, Comus Formation, Valmy Formation, an unnamed volcanic rock unit, Havallah(?) and Pumpernickel(?) Formations undivided, an unnamed sandstone, chert, and volcanic rock formation, Antler Peak Limestone, Highway Limestone, and Battle Formation undivided, and an unnamed fine clastic sedimentary rock formation as mapped by Willden (1964).	Occur as predominant rock type in the Hot Springs Range and Osgood Mountains.	Generally have low interstitial porosity and permeability. May transmit some water along fractures or where solution features have developed in carbonate rocks.

Table 3.--Average monthly and annual precipitation, in inches, at 14 stations in or adjacent to the area

[From published records of the U.S. Weather Bureau, and data collected by Nevada Dept. Conserv. and Nat. Resources]

Station[1/]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1 Cabin Creek	--	--	--	--	--	--	--	--	--	--	--	--	12.45
2 Dutch Flat Mine	--	--	--	--	--	--	--	--	--	--	--	--	8.02
3 Getchell Mine	--	--	--	--	--	--	--	--	--	--	--	--	13.28
4 Hardscrabble	--	--	--	--	--	--	--	--	--	--	--	--	9.79
5 Hinkey Summit	--	--	--	--	--	--	--	--	--	--	--	--	15.70
6 Indian Creek	--	--	--	--	--	--	--	--	--	--	--	--	25.10
7 Martin Creek	--	--	--	--	--	--	--	--	--	--	--	--	24.53
8 McCleary L.H. Ranch	--	--	--	--	--	--	--	--	--	--	--	--	9.76
9 Orovada	1.10	1.10	0.99	1.15	1.44	1.12	0.29	0.21	0.43	0.96	0.95	1.01	10.75
10 Paradise Hill	.94	.84	.65	.51	.66	1.02	.28	.28	.44	.44	1.29	.54	7.89
11 Paradise Valley 1 NW	1.29	1.13	.82	.60	.83	.83	.23	.25	.40	.43	.99	1.11	8.91
12 Reed Ranch	--	--	--	--	--	--	--	--	--	--	--	--	7.79
13 Rucks Cabin	--	--	--	--	--	--	--	--	--	--	--	--	25.41
14 Winnemucca WBAP	1.01	.89	.89	.82	.90	.75	.23	.21	.37	.67	.75	1.01	8.50

1. Stations listed alphabetically, locations shown in figure 1.

	Altitude	Location: Section	Location: Township	Location: Range	Period of record	Remarks[1/]
1	6,500	25	45 N	39 E	1960, 1962-64, 1966-67	Storage gage, NDCNR
2	5,500	17	38 N	40 E	1960-66	Storage gage, NDCNR
3	6,000	33	39 N	42 E	1960-67	Storage gage, NDCNR
4	6,000	29	44 N	42 E	1960, 1962-67	Storage gage, NDCNR
5	8,250	26	44 N	39 E	1953, 1956-67	Storage gage
6	6,800	2	43 N	39 E	1960-67	Storage gage, NDCNR
7	7,200	23	44 N	39 E	1960-67	Storage gage, NDCNR
8	4,800	35	42 N	44 E	1960-67	Storage gage, NDCNR
9	4,300	35	43 N	37 E	1911-67	
10	4,500	10	39 N	38 E	1960-67[a/]	
11	4,675	25	42 N	39 E	1954-67[b/]	
12	4,600	34	41 N	40 E	1961-67	Storage gage, NDCNR
13	7,500	22	44 N	39 E	1960-67	Storage gage, NDCNR
14	4,299	22	35 N	37 E	1878-1966[c/]	

a. Partial records during 1960, 1964, and 1965.
b. Partial records during 1949.
c. Average values for period beginning in 1878, not adjusted for changes in station location.
1. NDCNR is Nevada Dept. of Conservation and Natural Resources.

Table 4.--Longest periods, in days, in which temperatures did not go below the indicated temperature at four stations in and near the area

	Orovada			Paradise Hill			Paradise Valley 1NW			Winnemucca		
Year	24°F	28°F	32°F	24°F	28°F	32°F	24°F	28°F	32°F	24°F	28°F	32°F
1948	--	140	127	--	--	--	--	--	--	172	147	138
1949	--	--	--	--	--	--	--	--	--	183	157	134
1950	--	--	--	--	--	--	--	--	--	141	132	95
1951	177	--	89	--	--	--	--	--	--	144	144	83
1952	206	121	92	--	--	--	--	126	86	183	136	115
1953	145	129	112	--	--	--	--	--	--	144	133	83
1954	151	--	--	--	--	--	--	--	--	104	101	75
1955	163	117	115	--	--	--	148	127	74	152	127	56
1956	--	--	--	--	--	--	188	109	109	136	130	89
1957	190	145	121	--	--	--	139	139	108	139	139	84
1958	150	148	131	--	--	--	148	134	130	149	132	121
1959	180	145	120	--	--	--	148	109	97	135	114	107
1960	169	143	63	--	--	--	96	93	90	147	63	62
1961	--	140	--	--	--	--	143	129	99	130	119	93
1962	191	170	112	--	--	117	135	97	94	159	117	96
1963	--	179	165	183	182	160	183	178	116	179	176	135
1964	--	--	--	--	--	--	163	132	74	136	133	101
1965	--	--	--	--	--	--	134	122	103	134	125	106
1966	169	--	102	--	--	--	128	102	81	164	155	90
1967	123	123	--	176	145	122	156	122	103	123	123	101
1968	137	132	78	--	--	83	137	127	51	128	126	113
Average	165	141	110	--	--	--	146	123	94	147	130	98

The valley-floor slope toward the Humboldt River allows cold air to drain from the area. Consequently, thermal inversions, which may significantly affect growing seasons in the lower parts of many valleys in the State, have only minor affects on crops in Paradise Valley.

VALLEY-FILL RESERVOIRS

The valley-fill reservoirs contain the most productive known aquifers and are the only storage systems considered suitable as a source of ground water for any large-scale development. Moreover, they underlie most of the area irrigated by surface flow. There are two important valley-fill reservoirs in the area, one in Eden Valley and one in Paradise Valley. Virtually all existing and all anticipated future ground-water development is in Paradise Valley, which is discussed in greater detail than Eden Valley.

Extent and Boundaries

Paradise Valley

The valley-fill reservoir in Paradise Valley is about 35 miles long, ranges from about 4 to 12 miles wide and has a surface area of about 330 square miles. Subsurface extensions of the bedrock surfaces of the adjacent mountain blocks form the leaky lateral and bottom boundaries of the valley-fill reservoir. Recharge boundaries are formed by the live-stream segments of all streams that flow across the surface of the valley-fill reservoir.

The maximum thickness of valley fill and the configuration of the bottom of the valley-fill reservoir are not known. All known wells have bottomed in unconsolidated or semiconsolidated deposits. Table 5 lists locations of deep wells, depths, and lithologies of the bottom unit. The depths of these wells indicate that valley fill is at least 500 feet thick throughout much of the valley.

Eden Valley

The valley-fill reservoir in Eden Valley is roughly triangular in plan (pl. 1). It is about 15 miles long, and ranges in width from 8 miles at the north end to about 1 mile at the south end. The surface area is about 88 square miles.

The maximum thickness of fill in Eden Valley is not known. Deposits south of Little Humboldt River have been moderately dissected by present-day ephemeral streams, suggesting that the deposits may be thinner than comparable deposits in Paradise Valley, which is largely an area of deposition.

Alluvial-fill deposits are also present upstream from Eden Valley along parts of the channels of the North and South Forks of the Little Humboldt River. These deposits are typically less than 1 mile wide and occupy canyons cut in older Tertiary sedimentary deposits.

Table 5.--Depths and bottom-hole lithologies of selected deep wells in Paradise Valley

Location	Depth	Bottom-hole lithology[1]
38/39-28da	420	Clay, sandy
39/38-34dd	520	Gravel
39/39-24b2[a]	800	Unknown (was in clay at 700 ft)
40/40-19cb	436	Dirt, adobe
-30bc	405	Dirt, soft
41/39-2bd	602	Clay, some gravel
-11dc	735	Decomposed granite[2]
41/40-22da	435	Gravel, cemented, large rock
-22db2	512	Clay, hard, brown
42/39-14aa	500	Clay, very hard, sticky, yellow
42/40-14ab	300	Clay, red to brown

1. As described in drillers' logs
2. Probably semiconsolidated granitic sand and not bedrock.
a. Information from Loeltz, Phoenix, and Robinson (1949, p. 57).

Hydrologic Properties of the Valley Fill

Ability of the valley-fill deposits to store and transmit water is expressed in terms of their transmissivities and storage coefficients. These properties, in turn, are dependent largely on the types of material available for deposition, the distance and manner of transport, the depositional environment, and any post-depositional changes.

A discussion of some of the properties of source materials and the distribution of gravel deposits associated with major streams is presented for a better understanding of transmissivity and storage coefficients.

Source Materials

The granitic rocks and fine-grained metamorphic rocks exposed in the Santa Rosa Range (pl. 1) generally do not provide debris suitable for the formation of highly productive aquifers. Granitic rocks typically lose much of their cohesiveness when slightly weathered, and consequently form sand composed predominately of quartz and feldspar crystals and containing clay and silt formed in the decomposition process. The fine-grained metamorphic rocks tend to form fine sand or silt of similar mineral composition. Some gravel deposits are formed adjacent to the mountains, but particle size on the apron decreases rapidly away from the mountains. Clay formed by chemical decomposition of feldspar grains reduces the ability of these deposits to transmit water.

Volcanic rocks exposed throughout Hardscrabble Area and northern Little Humboldt Valley provide materials somewhat better suited for the formation of productive aquifers. Well-sorted volcanic gravel may be highly productive; however, finer grained or moderately sorted volcanic materials may be unproductive due to clay and other alteration products formed by the decomposition of feldspars and devitrification of volcanic glass.

The older sedimentary rocks in the Hot Springs Range and Osgood Mountains provide the materials best suited for the formation of high-yield aquifers. These materials are derived primarily from quartzite, chert, sandstone, and conglomerate which make up a significant part of the older sedimentary rocks in the area. These quartzite-rich rocks are highly resistant to chemical weathering and generally form gravels which, if well-sorted, are highly productive aquifers.

Because the valley fill is commonly composed of lenses of material from several sources, precise correlation between source and water-bearing characteristics is not possible. However, in Paradise Valley, valley-fill deposits composed predominantly of material from the Santa Rosa Range should be less productive than deposits composed predominantly of material from the Hot Springs Range.

Stream-Channel Deposits

Gravel generally forms the most productive deposits of the valley fill. Consequently, knowledge of the distribution of gravel should provide an indication of the most productive areas.

Bredehoeft (1963, p. 32) used standardized geologic interpretations of descriptions in drillers' logs to map the estimated (cumulative) thickness of gravel in the upper 100 feet of valley fill in Paradise Valley. Figure 2 shows the results of his analysis. Logs of wells drilled since 1963 are in reasonable agreement with his results. Thick accumulations of gravel are clearly associated with the two major streams. The thickest accumulations of gravel are just downstream from the points at which Martin Creek and the Little Humboldt River enter the valley.

The log for well 41/42-32ab, 80 feet deep, is the only one available for valley-fill deposits along the flood plain of Little Humboldt River in Eden Valley. This stock well penetrated an estimated total of only about 10 feet of gravel. Thicker gravel deposits may be present below the junction of the north and south forks where Little Humboldt River flows onto the valley-fill reservoir of Eden Valley.

Transmissivities and Storage Coefficients

The transmissivity, T (sometimes called coefficient of transmissibility), and storage coefficient, S, express certain water-bearing properties of the valley fill. Transmissivity is a measure of the ability of an aquifer or reservoir system to transmit water. It is dependent upon the hydraulic conductivity (permeability) and the thickness of the deposits that form the aquifer. The storage coefficient is a measure of the amount of water that will be released from storage, within a unit area, as water levels are lowered. Transmissivities and storage coefficients may be used for computing areal drawdowns and storage changes caused by pumping, or in the determination of subsurface flow.

Transmissivity may be estimated from specific capacities of wells, which are usually expressed as yield in gallons per minute per foot of drawdown. Properly designed wells in deposits with high transmissivities have higher specific capacities than wells in deposits with low transmissivities.

Transmissivities of the valley fill in Paradise Valley were estimated from the specific capacities of 10 wells measured during the course of this study, 23 specific capacities reported in drillers' logs, and from hydraulic conductivities for a shallow multiple-well system (Dylla and Muckel, 1967, p. 9). Estimated transmissivities ranged from less than 20,000 gpd (gallons per day) per foot along the west side of the valley to more than 80,000 gpd per foot in some gravel-rich deposits associated

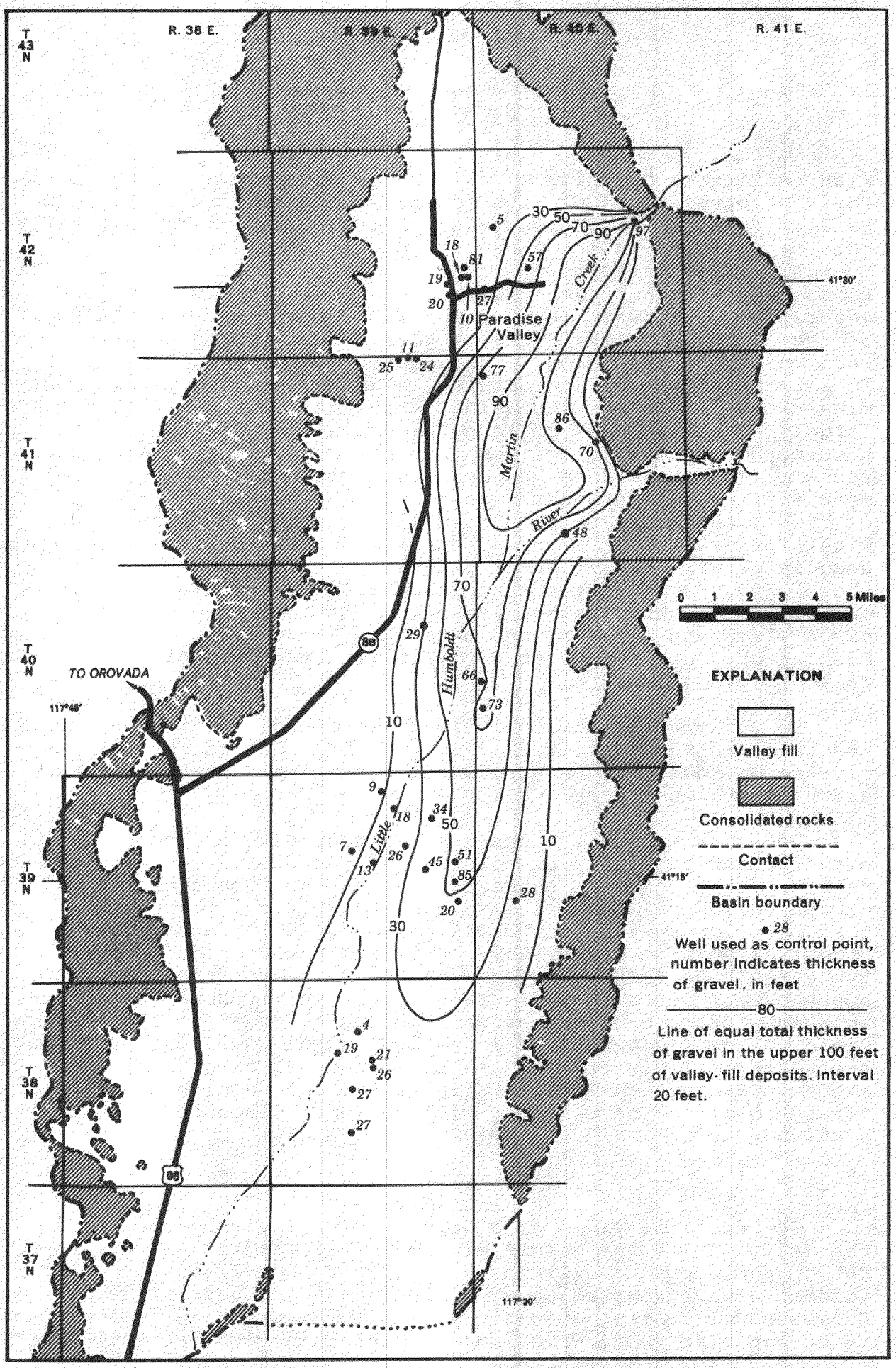


Figure 2. — Total thickness of gravel in the upper 100 feet of valley-fill in Paradise Valley

(Illustration adapted from Bredehoeft, 1963, p. 45)

with the Little Humboldt River. These values provide the basis for the approximate distribution of transmissivity in Paradise Valley (fig. 3). Transmissivity values shown are representative only of that thickness of the valley fill most affected by pumping. Transmissivities of the total thickness of valley fill probably are significantly higher than those shown in figure 3 and may range between 100,000 and 200,000 gpd per foot in much of the central valley. These higher values should be used when computing underflow in the central part of the valley or in estimating subsurface outflow. The comparatively low transmissivities along the west side of the valley are attributed largely to the absence of large perennial streams and to the tendency of sediments derived from the granitic and metamorphic rocks of the Santa Rosa Range to form clays and other impermeable alteration products, as previously discussed. The zone of high transmissivity is formed by gravel deposits associated with Little Humboldt River. Transmissivities of gravel deposits associated with Martin Creek generally may not be as high as those of gravel deposits associated with Little Humboldt River, owing to a slightly higher proportion of interbedded or intermixed clays and fine-grained materials; however, more information must be obtained before this possibility can be confirmed or disproved.

No estimates of transmissivity were made for the valley-fill reservoir in Eden Valley. It is probable that the most productive deposits are those associated with Little Humboldt River at the north end of the valley.

No storage coefficients were caluculated for deposits in either Paradise Valley or Eden Valley; however, the lenticular nature of the deposits suggests that the horizontal permeability of the valley fill is greater than the vertical permeability and that the flow system, for short periods, will respond to pumping stress as an artesian system. Artesian storage coefficients typically have values of less than 0.001. Over the long term, however, all deposits will drain slowly in response to pumping, and the storage coefficient will be nearly equal to the specific yield. Thus, in analyzing long-term cause-and-effect relations, the valley-fill reservoir must be considered as a water-table system. Storage coefficients in water-table aquifers are effectively equal to the specific-yield values, discussed in the next section.

Specific Yield

The specific yield of a deposit with respect to water is the ratio of (1) the volume of water which, after being saturated, the deposits will yield by gravity to (2) its own volume, usually expressed as a percentage (Meinzer, 1923, p. 28). Estimates of average specific yield of the upper 50 feet of saturated deposits (nonpumping water levels) in Paradise Valley were

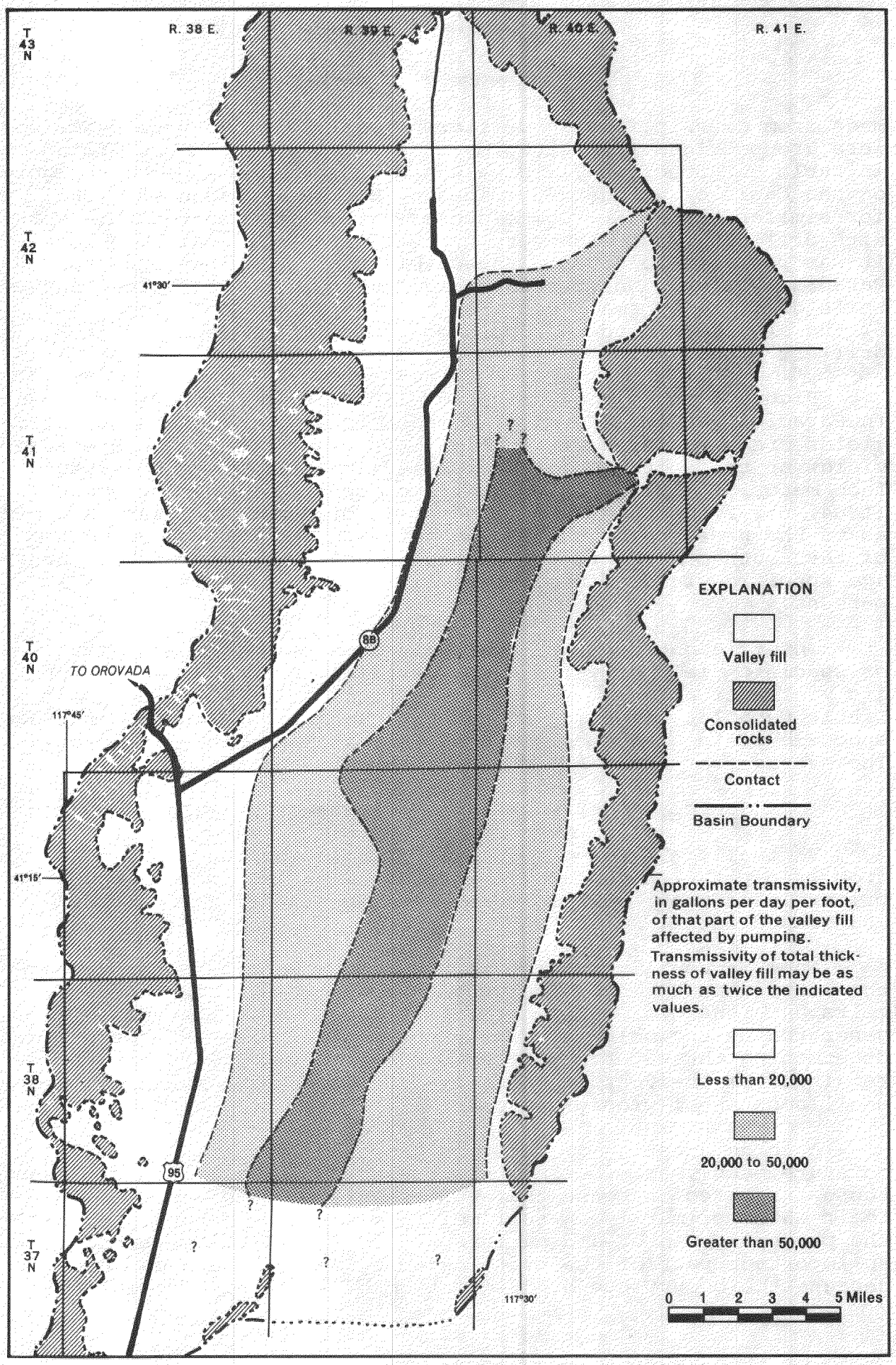


Figure 3. — Preliminary transmissivity map, Paradise Valley

made from descriptions in drillers' logs. The deposits described were grouped into five lithologic categories, which are listed in table 6. Specific-yield values were assigned to each category, on the basis of values determined by Morris and Johnson (1966) for similar deposits. Some interpretation is involved when working with drillers' logs; however, by evaluating all available logs, it was possible to develop reasonably consistent patterns for Paradise Valley. Observations made by the U.S. Geological Survey while drilling 15 small-diameter test holes in undeveloped parts of the area were used to supplement information obtained from drillers' logs.

Figure 4 shows the estimated distribution of specific yield in Paradise Valley. North of Gumboot Lake, the highest specific yields are associated with the major streams. The high specific yields at the south end of the valley are attributed to subsurface material similar to the terrace deposits mapped by Cohen (1964, pl. 2) north of the flood plain of Humboldt River as well as to the presence of buried channel deposits throughout much of the south-central part of Paradise Valley. The weighted average specific yield of the valley fill in Paradise Valley is 17 percent.

Insufficient data are available to make detailed estimates of specific yield of valley-fill deposits in Eden Valley. Specific yields of alluvial deposits along the flood plain of Little Humboldt River may average as high as 20 percent. Average specific yield of the remaining valley fill probably is lower. The average for Eden Valley may be about 15 percent.

Source, Occurrence, and Movement of Water

Virtually all water in Little Humboldt Basin is derived from precipitation that falls within the basin. Water occurs primarily as snow, soil moisture, surface runoff (streamflow), and ground water.

Snow is usually present in the higher mountains throughout the winter and spring. The winter snow accumulation generally melts and runs off during April, May, and June. Streamflow generated by snowmelt is usually the most significant factor in determining the water supply of the valleys. Flow during the remainder of the year is maintained by ground-water seepage and small amounts of precipitation.

A large quantity of water is temporarily stored as soil moisture each year. During the growing season all plants, except those irrigated or those that utilize ground water, depend for their water primarily on soil moisture that has accumulated during the preceding winter and early spring. Thus, soil moisture is an important part of the hydrologic regimen of the area; however, because the occurrence or utilization of soil moisture in non-

Table 6.--Specific yields of materials described in drillers' logs

Lithologic category (based on drillers' description)	Assigned specific-yield value[1] (percent)
Sand, fine, medium, and coarse	30
Gravel, sand and gravel	25
Sand, gravel, and clay; gravel and clay cemented; gravel	15
Sand and clay, sandy clay, silt, mud, muck	10
Clay, silt, mud, muck	5+

1. Assigned specific-yield values based on Morris and Johnson (1966).

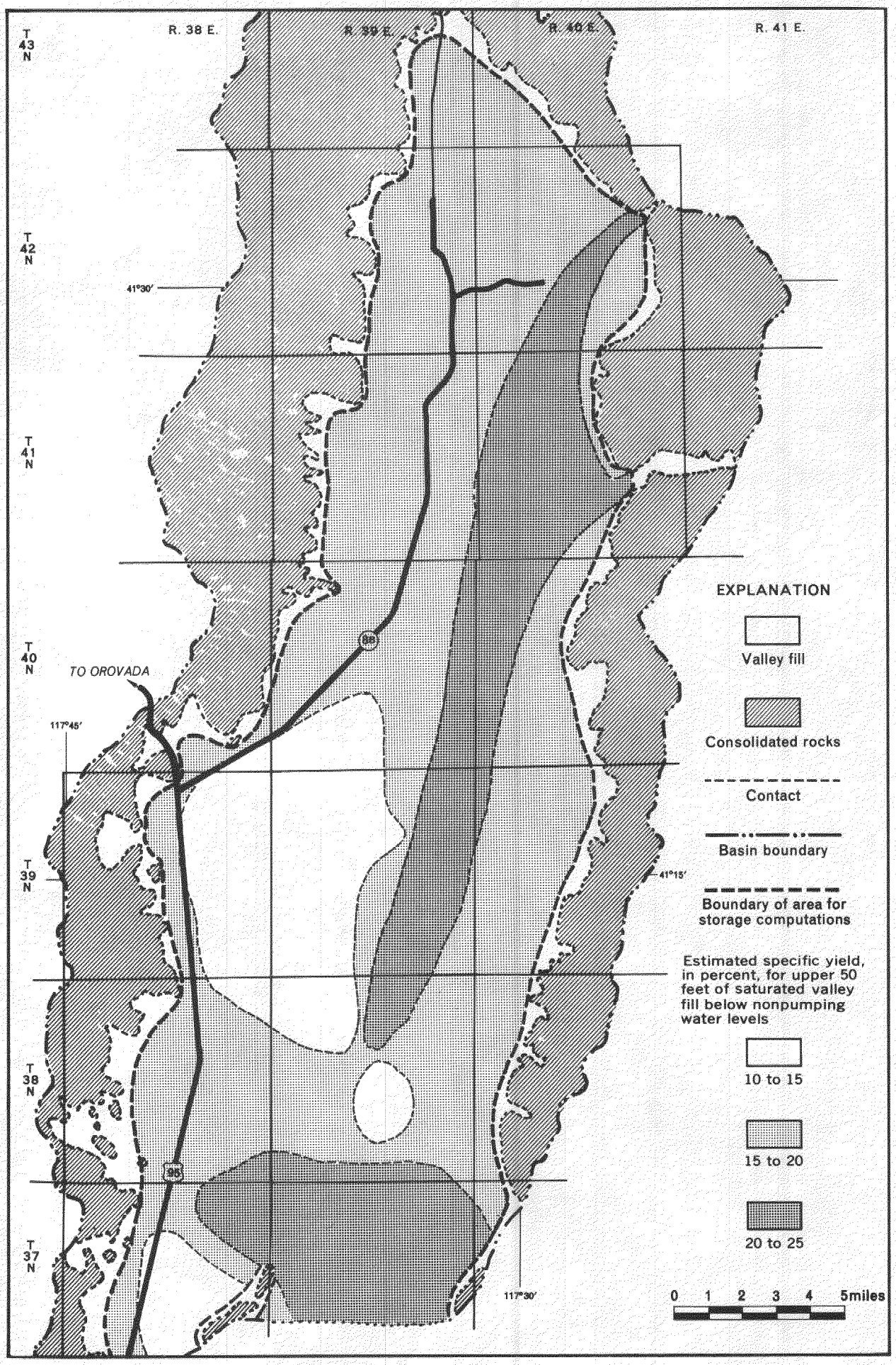


Figure 4. — Distribution of specific yield in Paradise Valley

irrigated areas will be virtually unaffected by pumping ground water or by surface-water diversions, it is not considered in the quantitative estimates of this report.

Ground water in the valley-fill reservoirs is derived from precipitation. Most deep infiltration (recharge) is from runoff and occurs on the upper slopes of the alluvial aprons or along the lower reaches of the major streams; however, some deep infiltration also occurs in the mountains where percolating water moves through bedrock fractures to the zone of saturation. During exceptionally wet years, significant amounts of moisture also may infiltrate to the zone of saturation directly from precipitation on the upper slopes of the apron and in the mountains. Much of the infiltration from streams on the floor of Paradise Valley occurs in areas of shallow ground water where ground water is also discharged by evapotranspiration. Consequently, recharge from streams or stream diversions on the valley floor may be discharged by evapotranspiration after only a short period of storage.

Recoverable ground water occurs primarily in the saturated parts of the valley fill where it occupies interstices in the granular clastic deposits under both water-table and artesian conditions. Artesian conditions occur where the saturated permeable deposits are overlain by less permeable strata and where the water at the top of the aquifer is under greater than atmospheric pressure. Water-table conditions exist where the saturated deposits are not confined and where the water at the top of the zone of saturation, the water table, is at atmospheric pressure.

Local artesian conditions are present at the southern end of Paradise Valley, where well 37/39-3dc flows (hot water) at about 2 gpm (gallons per minute). Artesian conditions also occur locally to the north where lenses of silt and clay partially confine the water in underlying deposits.

Ground water moves along the path of least resistance from areas of high hydraulic head to areas of lower hydraulic head. The rate of movement depends upon the hydraulic gradient and the permeability and porosity of the material through which water is moving. Typical rates in this area probably range from several feet per year to several hundred feet per year.

The horizontal movement of ground water in the valley fill generally is parallel to the direction of slope of the water surface. A downward component of movement occurs in areas of recharge and an upward component occurs in areas of discharge. In the spring of 1968, heads in shallow wells at the north end of Paradise Valley were significantly higher than heads in deep wells. This indicated a downward component of movement, or recharge at that time.

The slope of the ground-water surface in Paradise Valley during spring 1968 is indicated on plate 1 by contours of the approximate altitude of water levels in wells. In general, ground water moves from the principal areas of recharge near the mountains to low areas of discharge in the valleys. Ground water in Little Humboldt Valley moves toward Little Humboldt River and then west to Paradise Valley. Ground water in the Hardscrabble Area moves southward beneath the channel of Martin Creek as underflow to Paradise Valley.

Figure 5 shows the approximate depths to water in wells in Paradise Valley in the spring of 1968. Depths ranged from more than 100 feet near the mountains to within a few feet of land surface near the center of the valley. Depths to water shown at the north and northwest end of the valley are for wells greater than 100 feet deep; in shallow dug wells the water was commonly within 10 feet of land surface.

Very sparse depth-to-water data are available in Little Humboldt Valley. Along the flood plain of Little Humboldt River, ground water is generally within 10 feet of the land surface. Gains in streamflow where Little Humboldt River drains into Paradise Valley indicate that there the water table intersects the stream channel. Depth to water in Eden Valley increases south of the flood plain of Little Humboldt River. In section 35, T. 40 N., R. 41 E., the depth to water is estimated to be about 50 feet, whereas around the margins of the valley it probably is more than 100 feet.

Several stock wells drilled in the volcanic rocks at the northern part of Little Humboldt Valley indicate that there the depth to water may range from about 180 feet to more than 700 feet. Water-level altitudes in these wells suggest that the ground-water divide may not correspond precisely with the topographic divide and a slight gradient to the north may exist beneath part of the Milligan Creek and North Fork drainages. However, the quantity of water involved in any northward underflow from this basin to the Snake River basin (Owyhee River) probably is small in relation to the total water budget of the area.

Chemical Character of Water

Partial or detailed analyses of water samples from 16 wells, and seven specific conductance determinations of stream samples were made to evaluate the quality of water as of 1968, to relate variations in quality to the flow systems, and to determine the suitability of the water for use. These analyses are listed in tables 7 and 7a along with nine others made prior to this study.

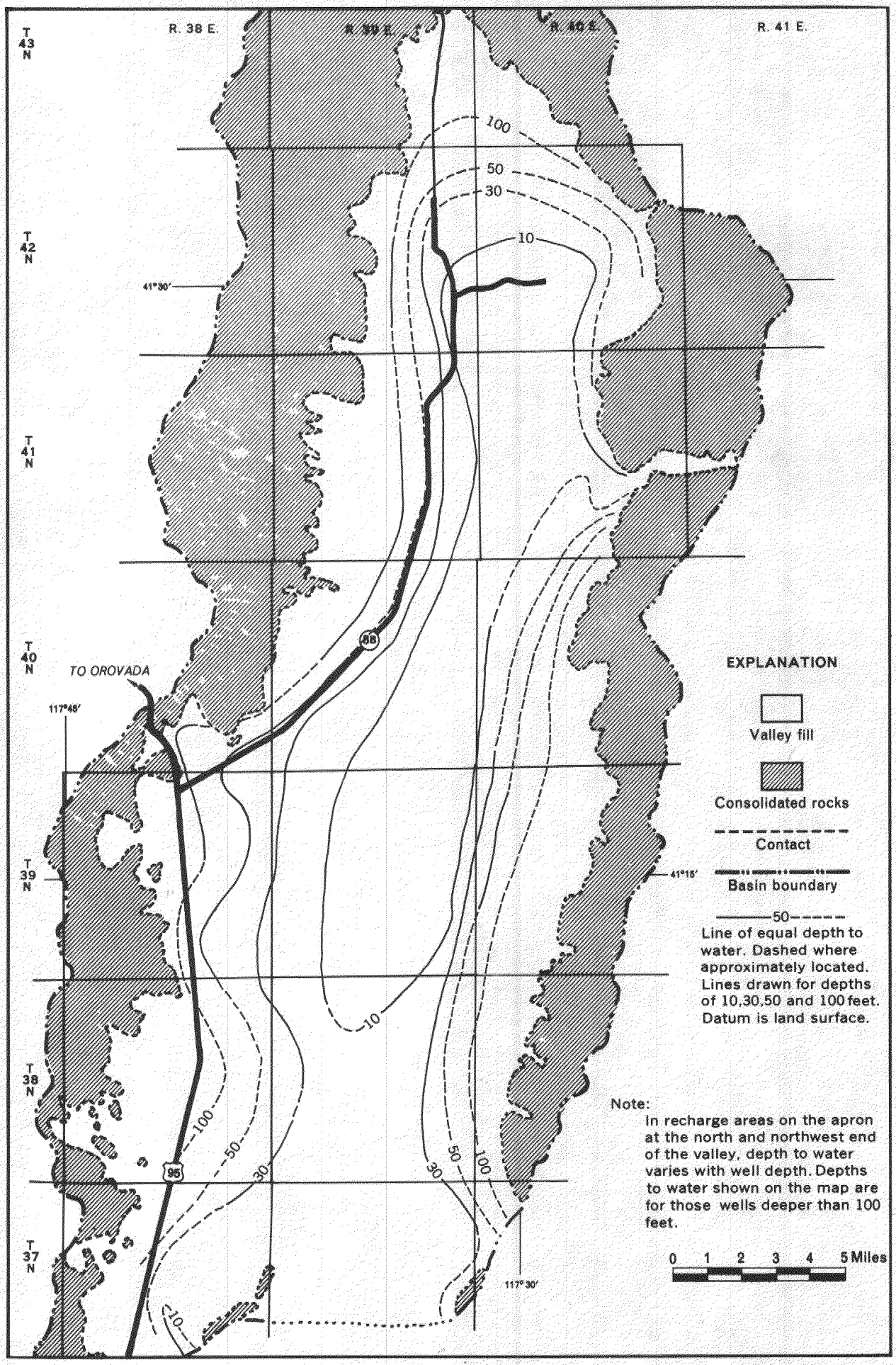


Figure 5. — Depths to water in wells, Spring 1968, in Paradise Valley

Table 7.--Partial chemical analyses of water from wells, springs, and streams

[Field-office analyses by the U.S. Geological Survey, except as indicated]

Location	Source	Date sampled	Temperature °F	Temperature °C	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[3]	Bicarbonate (HCO_3)[4]	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$	Specific conductance (micromhos per cm at 25°C)	pH (lab. determination)	Salinity hazard	Sodium-adsorption ratio (SAR)	Sodium hazard	Residual sodium carbonate (RSC)
					Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]									Factors affecting suitability for irrigation[2]			
37/38-2aa[5]	Well	8-15-45	--	--	27 1.35	8 0.66	120 5.22	232 3.80	74 1.54	67 1.89	-- --	-- --	-- --	-- --	5.2 5.2	-- --	M (1.79) M (1.79)
-21dd[5]	Well	8- 1-61	--	--	34 1.70	7.1 .58	--	255 4.18	52 1.08	62 1.75	114 2.30	773	8.5	High	4.7	Low	U (3.27)
-24ac[5]	Well	4-28-62	57	14	64 3.19	25 2.07	--	618 10.13	163 3.37	311 8.77	263 4.75	2,170	7.5	High	10	High	U (4.87)
37/39-3dc[6]	Well	4-28-62	156	69	26 1.30	11 .88	--	1,230 20.16	71 1.48	16 .45	109 2.20	1,900	7.7	High	19	Very high	U(17.98)
-19aa[6]	Well	4-28-62	51	11	22 1.10	4.4 .36	--	446 7.31	210 4.37	86 2.43	73 1.47	1,240	7.9	High	15	High	U (5.85)
-28ad[6]	Well	4-28-62	58	14	32 1.60	9.7 .80	--	167 2.74	117 2.44	69 1.95	120 2.42	728	7.7	Medium	4.3	Low	S (0.30)
38/39-16aa[6]	Well	7-16-68	62	17	27 1.35	4 .33	--	160 2.62	23 .48	21 .59	84 1.68	430	8.2	Medium	1.9	Low	S (0.94)
-16cd[6 7]	Well	7-16-68	55	13	14 .70	8 .68	--	180 2.95	166 3.46	95 2.68	69 1.38	1,100	8.0	High	9.6	Medium	M (1.57)
-21aa	Well	7-16-68	58	14	31 1.55	6 .49	82 3.56	192 3.15	54 1.12	47 1.33	102 2.04	660	8.2	Medium	3.5	Low	S (1.11)
-28da[6]	Well	11-14-61	--	--	56 2.79	9.8 .81	--	156 2.56	91 1.89	79 2.23	180 3.62	703	8.0	Medium	2.3	Low	S (0)
-35aa[6]	Well	8-10-61	62	17	40 2.00	16 1.32	--	202 3.31	16 .33	66 1.86	166 3.34	557	7.9	Medium	1.5	Low	S (0)
39/39-3ba[6]	Well	7-17-68	58	14	33 1.65	3 .25	--	143 2.34	24 .50	26 .73	95 1.90	410	8.2	Medium	1.5	Low	S (0.44)
-3cb	Well	7-17-68	56	13	48 2.40	1 .08	49 2.13	164 2.69	34 .71	43 1.21	124 2.48	520	7.9	Medium	1.9	Low	S (0.21)
-13c[5]	Well	2- 5-48	--	--	38 1.90	9.7 .80	70 3.05	214 3.51	46 .95	45 1.27	--	--	--	--	--	--	--
-15aa	Well	7-16-68	63	17	42 2.10	10 .80	57 2.47	230 3.77	32 .67	33 .93	145 2.90	600	8.1	Medium	2.1	Low	S (0.87)
-16da[6]	Well	7-16-68	59	15	36 1.80	4 .34	--	159 2.61	25 .52	27 .76	107 2.14	440	8.0	Medium	1.4	Low	S (0.47)
40/40-18da[6]	Well	7-17-68	57	14	24 1.20	6 .50	--	145 2.38	28 .58	28 .79	85 1.70	440	8.2	Medium	1.9	Low	S (0.68)
-19da	Little Humboldt River	3- 1-68	53	12	--	--	--	--	--	--	--	340	--	Medium	--	--	--
-30bc	Well	7-17-68	53	12	45 2.25	10 .81	65 2.82	197 3.23	50 1.04	57 1.61	153 3.06	670	7.6	Medium	2.3	Low	S (0.17)
-31ca[6]	Well	7-17-68	55	13	31 1.55	6 .47	--	176 2.88	30 .62	32 .90	101 2.02	510	7.9	Medium	2.0	Low	S (0.86)
41/39-11dc[6]	Well	7-17-68	60	16	29 1.45	6 .49	--	126 2.07	20 .42	30 .85	97 1.94	400	8.3	Medium	1.5	Low	S (0.20)
-24bc	Well	7-17-68	60	16	30 1.50	7 .54	38 1.65	137 2.25	26 .54	32 .90	102 2.04	440	7.9	Medium	1.6	Low	S (0.21)
-36ac	Well	7-17-68	61	16	25 1.25	4 .35	23 .99	115 1.88	8 .17	19 .54	80 1.60	330	8.1	Medium	1.1	Low	S (0.28)
41/40-22da[6 7]	Well	7-18-68	71	22	23 1.15	6 .49	--	173 2.84	31 .65	29 .82	82 1.64	510	8.4	Medium	2.7	Low	M (1.43)
-23c[5]	Little Humboldt River	10- 5-48	--	--	33 1.65	8 .66	48 2.09	180 2.94	33 .69	27 .76	--	--	--	--	--	--	S (0.63)

Continued

Table 7.--Partial chemical analyses of water from wells, springs, and streams--Continued

Location	Source	Date sampled	Temperature °F	Temperature °C	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[3]	Bicarbonate (HCO_3)[4]	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$	Specific conductance (micromhos per cm at 25°C)	pH (lab. determination)	Salinity hazard	Sodium-adsorption ratio (SAR)	Sodium hazard	Residual sodium carbonate (RSC)
					Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]									Factors affecting suitability for irrigation[2]			
41/40-30aa	Martin Creek	3- 1-68	52	11	--	--	--	--	--	--	--	150	--	Low	--	--	--
-30bb	Cottonwood Creek	3- 1-68	58	14	--	--	--	--	--	--	--	420	--	Medium	--	--	--
-33ab[6]	Well	7-18-68	55	13	33 1.65	6 .51	--	161 2.64	41 .85	44 1.24	108 2.16	570	8.3	Medium	2.3	Low	S (0.65)
41/41-19ac	Spring	8-14-45	135	57	26 1.30	8.5 .70	334 14.53	920 15.08	34 .71	26 .73	--	--	--	--	--	--	U (13.08)
-19ac[5]	Little Humboldt River	10- 5-48	--	--	34 1.70	8 .67	40 1.74	165 2.70	31 .65	27 .77	--	--	--	--	--	--	--
-20d	Little Humboldt River	3- 1-68	53	12	--	--	--	--	--	--	--	340	--	Medium	--	--	--
42/39-3cc	Cottonwood Creek	2-25-68	46	8	--	--	--	--	--	--	--	140	--	Low	--	--	--
-14aa[6 7]	Well	7-18-68	--	--	24 1.20	7 .56	--	116 1.90	25 .52	38 1.07	88 1.76	420	--	Medium	1.8	Low	S (0.14)
-25bd[5]	Cottonwood Creek	10- 7-48	--	--	44 2.20	11 .90	63 2.74	323 5.22	10 .21	11 .31	--	--	--	--	--	--	M (2.12)
	Do.	2-25-68	53	12	--	--	--	--	--	--	--	140	--	Low	--	--	--
42/39-34c	Colony Creek	10- 7-48	--	--	11 .55	4 .33	9 .39	70 1.16	3 .06	2 .06	--	--	--	--	--	--	S (0.28)
42/40-12b[5]	Martin Creek	10- 7-48	--	--	19 .95	6 .49	28 1.22	110 1.80	18 .37	18 .51	--	--	--	--	--	--	S (0.36)
-12cb	Martin Creek	3- 1-68	51	11	--	--	--	--	--	--	--	140	--	Low	--	--	--
-16ac[5]	Well	8-14-45	49	9	52 2.59	13 1.07	126 5.48	329 5.49	45 .94	66 1.86	--	--	--	--	--	--	S (0)
-28ca	Martin Creek	2-25-68	47	8	--	--	--	--	--	--	--	120	--	Low	--	--	--

1. Milligrams per liter and milliequivalents per liter are metric units of measure that are virtually identical to parts per million and equivalents per million, respectively, for all waters having a specific conductance less than about 10,000 micromhos. The metric system of measurement is receiving increased use throughout the United States because of its value as an international form of scientific communication. Therefore, the U.S. Geological Survey recently has adopted the system for reporting all water quality data.

2. Salinity hazard is based on specific conductance (in micromhos) as follows: 0-750, low hazard (water suitable for almost all applications); 750-1,500, medium (can be detrimental to sensitive crops); 1,500-3,000, high (can be detrimental to many crops); 3,000-7,500, very high (should be used only for tolerant plants on permeable soils); >7,500, unsuitable. Sodium-adsorption ratio (SAR) provides an indication of what effect an irrigation water will have on soil-drainage characteristics. SAR is calculated as follows, using milliequivalents per liter: $SAR = Na/\sqrt{(Ca + Mg)/2}$. Sodium hazard is based on an empirical relation between salinity hazard and sodium-adsorption ratio. Residual sodium carbonate (expressed in milliequivalents per liter) is tentatively related to suitability for irrigation as follows: safe (S), 0-1.25; marginal (M), 1.26-2.50; unsuitable (U), >2.50. The several factors should be used as general indicators only, because the suitability of a water for irrigation also depends on climate, type of soil, drainage characteristics, plant type, and amount of water applied. These and other aspects of water quality for irrigation are discussed by the National Technical Advisory Committee (1968, p. 143-177), and the U.S. Salinity Laboratory Staff (1954).

3. Computed as the milliequivalent-per-liter difference between the determined negative and positive ions; expressed as sodium. Computation assumes that concentrations of undetermined ions--especially nitrate--are small.

4. All carbonate values 0 mg/l except: 37/38-2aa, 11 mg/l (0.37 me/l); 41/39-11dc, 2 mg/l (0.07 me/l); 41/40-22da, 7 mg/l (0.23 me/l); and 41/40-33ab, 5 mg/l (0.17 me/l).

5. Analysis by Nevada Department of Food and Drugs, Public Service Division.

6. Additional determinations from detailed analyses in table 7a.

7. Arsenic values: 38/39-16cd, 0.01 mg/l; 41/40-22da, 0.01 mg/l; 42/39-14aa, 0.00 mg/l.

Table 7a.--Additional constituents determined from water from wells, springs, and streams

[Laboratory analyses by the U.S. Geological Survey, except as indicated]

Location	Milligrams per liter (upper number) and milliequivalents per liter (lower number)1/						
	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved-solids content2/
37/38-2aa3/	--	--	--	--	--	0.51	430
-21dd	--	116 5.05	9.6 .25	--	--	--	--
-24ac	--	376 16.36	18 .46	--	--	2.8	--
37/39-3dc	--	452 19.66	26 .66	--	--	1.4	--
-19aa	--	284 12.35	9.6 .25	--	--	.9	--
-28ad	--	109 4.74	9.6 .25	--	--	.4	--
38/39-16aa	73	40 1.74	8.7 .22	0.4 .02	1.7 .03	0.1	278
-16cd	67	184 8.00	5.7 .15	0.5 .03	2.1 .03	.15	632
-28da	81	72 3.13	11 .28	.4 .02	1.7 .03	.1	479
-35aa	--	45 1.96	5.8 .15	--	--	--	--
39/39-3ba	--	33 1.44	5.4 .14	0.2 .01	0.4 .01	.06	--
-16da	--	34 1.48	6.4 .16	0.2 .01	0.9 .01	.06	--
40/40-18da	--	41 1.78	9.8 .25	0.6 .03	0.7 .01	.09	--
-31ca	--	46 2.00	9.8 .25	0.7 .04	0.7 .01	.16	--
41/39-11dc	--	34 1.48	4.9 .13	0.4 .02	3.5 .06	.02	--

Table 7a.--Additional constituents--Continued

Location	Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]						
	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved-solids content[2]
41/40-22da	83	57 2.48	13 .33	0.7 .04	2.0 .03	0.20	337
-23c[3]	--	--	--	--	--	.16	--
-33ab	--	54 2.35	10 .26	.8 .04	1.3 .02	.11	--
41/41-19ac	--	--	--	--	--	2.54	--
-19ac[3]	--	--	--	--	--	.09	--
42/39-14aa	44	38 1.65	4.5 .12	.5 .03	4.1 .07	.06	242
-25bd[3]	--	--	--	--	--	.19	--
42/40-16ac[3]	--	--	--	--	--	.40	--

1. See footnote 1, table 7. Where only one number is shown, it is milligrams per liter.

2. Calculated, with HCO_3 expressed as CO_3.

3. Analysis by Nevada Department of Food and Drugs, Public Service Division.

Types of Water

For purposes of this report, waters are classified on the basis of the predominate anion and cation. Sodium bicarbonate and calcium bicarbonate are the principal water types in the area. Generally, the sodium bicarbonate waters are derived from source areas composed primarily of volcanic rocks, whereas calcium bicarbonate waters are derived from source areas composed primarily of granitic, metamorphic, and older sedimentary rocks (pl. 1).

The five silica determinations listed in table 7a suggest that the sodium bicarbonate waters associated with volcanic rocks may also have comparatively high silica contents.

Relation to the Flow System

Water chemistry is not greatly modified in Paradise Valley as the water moves from the mountains to areas of evapotranspiration and outflow at the south end of Paradise Valley. This is attributed largely to two factors: (1) streams distribute good-quality water over much of the valley-fill reservoir each spring, and (2) subsurface and occasional surface outflow to Humboldt River removes sufficient salts to prevent the accumulation of large quantities of water with a high dissolved-solids content.

However, several significant changes do occur as the water moves toward the south end of the valley. The proportion of sodium in relating to calcium tends to increase and the calcium bicarbonate waters generated in parts of the Santa Rosa and Hot Springs Ranges generally are modified to sodium bicarbonate waters by the time they have reach the south end of Paradise Valley.

At the south end of Paradise Valley, the dissolved-solids content is greater in shallowwells than in deeper wells. For example, the water from well 38/39-16cd (78 feet deep) had a specific conductance of 1,100, whereas water from nearby well 38/39-21aa (280 feet deep) had a specific conductance of only 660. Samples from several shallow test holes drilled by the U. S. Geological Survey at the south end of the valley also had compartively high dissolved-solids contents. This increase in dissolved solids near land surface is attributed largely to evapotranspiration of shallow ground water and the consequent concentration of the salts in the upper part of the flow system.

Salt Balance

The salt balance of a basin is the relation between incoming and outgoing solutes. The balance is critical to the long-term maintenance of a successful irrigation operation; it is favorable when the outflow of salts from the basin exceeds the inflow (Hem, 1959, p. 243). If the quantity of salts carried by the drainage

water leaving the basin is less than the quantity entering, the stranded salts can accumulate within the basin, either in the soil or as constituents of ground water. In either case, the balance is unfavorable and ultimately detrimental to the continued practice of irrigation farming. On the other hand, the imbalance can be apparent rather than real if appreciable amounts of salts leave the basin as windblown dust or, to a lesser extent, as components of exported crops.

Insufficient information is available to evaluate quantitatively the salt balance in Paradise Valley. The large surface inflow and evapotranspiration compared to the small surface and subsurface outflow suggest an unfavorable salt balance during most years. Location of the large area of salt grass on plate 1 suggests that salts accumulate in soils downslope from irrigated areas during years of average and below average runoff. During exceptionally wet years some of these salts probably are redissolved and drained to Gumboot Lake or Humboldt River. Additional information on the quality of surface-water inflow and outflow and ground-water outflow must be obtained before the salt balance in Paradise Valley can be adequately evaluated.

Although an unfavorable salt balance may exist for the entire valley, the effects seem negligible for the existing (1968) development, as most excess salt accumulates in soils or shallow ground water downstream from the principal irrigated areas. In the event that the water supply is fully developed and utilized on a sustained basis, unfavorable salt balance may cause a slow deterioration in the quality of pumped water and of irrigated soils in the southern part of the valley.

Suitability for Use

Based on the data in tables 7 and 7a, all water samples, except some from shallow wells at the south end of Paradise Valley, were of suitable quality for irrigation and domestic use. Water from wells 37/38-21ad, 37/38-24ac, 37/39-3dc, 37/39-19aa, and 38/39-16cd (table 7) had high salinity and sodium hazards with respect to irrigation use and total dissolved-solids contents which exceed the limits recommended as drinking-water standards by the U.S. Public Health Service (1962) For more specific information regarding the suitability of water for use, the reader is referred to the following published references:

Type of Use	References
Agricultural	U.S. Salinity Laboratory (1954)
	Scofield (1936)
	McKee and Wolf (1963)
	Wilcox (1955)
	Bernstein (1964)
Domestic	U.S. Public Health Service (1962)

The bacteriological quality of drinking water is important but is outside the scope of this report. If any doubt exists regarding the suitability of a drinking-water supply, contact the Nevada Bureau of Environmental Health, Carson City.

INFLOW TO THE VALLEY-FILL RESERVOIRS

Precipitation

Precipitation is the source of virtually all the water entering the valley-fill reservoir in the Little Humboldt drainage. An average of about 520,000 acre-feet per year of precipitation falls in Little Humboldt Valley, 120,000 acre-feet per year in Hardscrabble Area, and 250,000 acre-feet per year in Paradise Valley. Of this precipitation, most is directly evaporated from vegetation or the ground surface, part runs off as surface flow, part infiltrates to shallow depths where it replenishes soil moisture, and part eventually infiltrates to the zone of saturation where it recharges the ground-water system.

This section deals primarily with that part of the total precipitation that becomes runoff and/or ground-water recharge to the valley-fill reservoirs.

Surface Water

Surface-water resources of the area are evaluated in terms of (1) variations and frequency characteristics of streamflow in the valleys, and (2) the total average annual runoff generated in the mountains. The distribution and loss of streamflow on the alluvial fans and valley floor of Paradise Valley is also briefly evaluated because it relates to both recharge and diversion of surface water for irrigation.

Streamflow Records Available

Two continuous recording streamflow gaging stations are operated in the study area, one on Martin Creek and one on Little Humboldt River. Table 8 lists names, locations, drainage areas, and periods of record of these stations and three additional stations that were operated for short periods and have been discontinued. Data for these stations prior to 1961 are published in U.S. Geological Survey Water-Supply Papers 1314 and 1734. Data from 1961 to 1968 are published in annual volumes of Water Resource Data for Nevada (U.S. Geol. Survey, 1961-68).

A crest-stage gage that records annual maximums has been in operation on Mullinex Creek from the 1962 water year to the present time. This gage, Mullinex Creek near Paradise Valley, is in NE¼ NE¼ Sec. 23, T. 42 N., R. 39 E., and 1¼ miles north of the town of Paradise Valley. The annual maximum discharges computed for this gage for the 1962-66 water years are as follows:

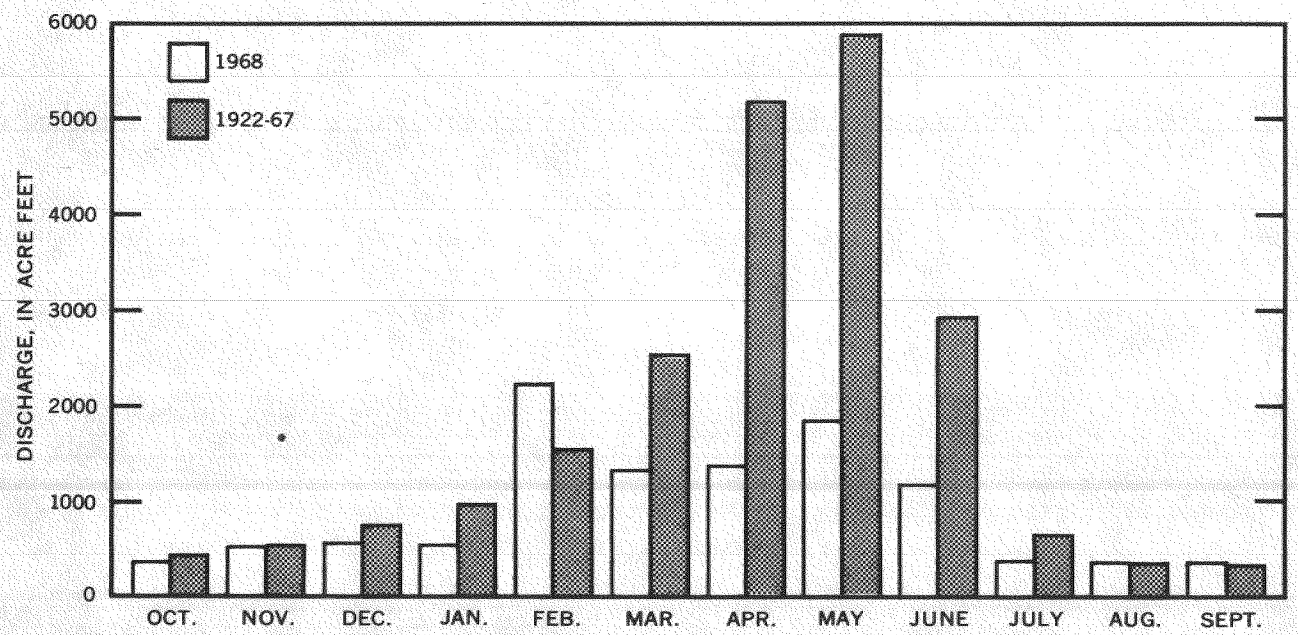


Figure 6. — Comparison of monthly discharges for the 1968 water year with average discharge for the period 1922-67 at the gaging station, Martin Creek, near Paradise Valley

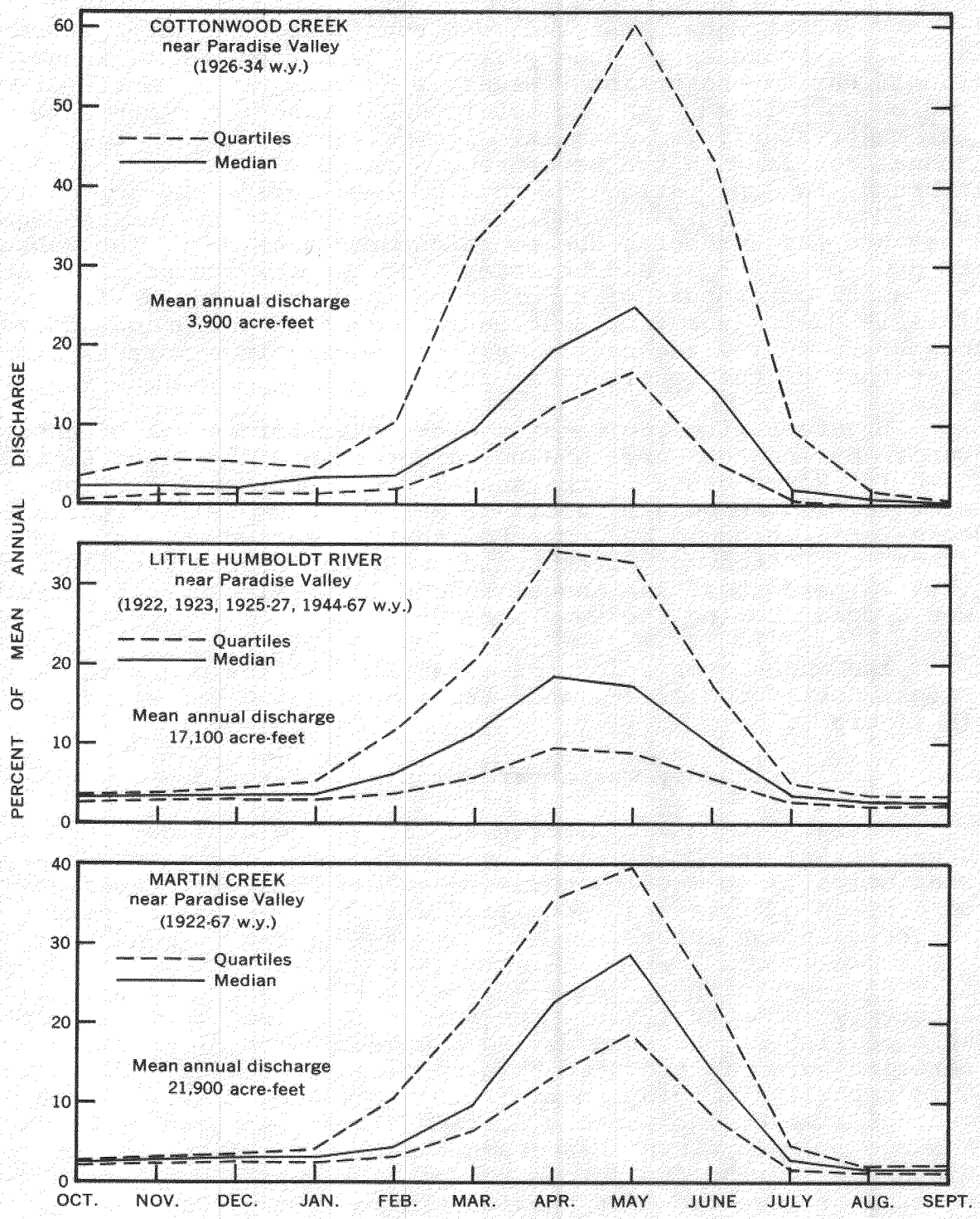


Figure 7. — Monthly discharge in precent of mean annual discharge of Cottonwood Creek, Little Humboldt River, and Martin Creek

Figure 7 shows that the most runoff for the three streams is in the February to June period. The percentage of annual runoff during the period February 1 to June 30 in Martin Creek can be correlated with the total annual runoff during years when the major runoff is snowmelt. Figure 8 shows the correlation of annual runoff with the percentage of runoff occurring during the February to June period for Martin Creek during the period 1922-67. Four years, 1943, 1956, 1963, and 1965, were not used as they had large runoffs due to rainstorms outside of the February to June period. It can be noted that the low annual flows have a smaller percentage of runoff than the higher annual flows. This is due to the fact that during years of low annual flows, base flow during the period July to January is a more significant part of the total annual flow.

Figure 8 also indicates the expected percentage of annual runoff during February to June on Cottonwood Creek and Little Humboldt River based on the annual runoff of Martin Creek. For example, if the annual runoff of Martin Creek is forecast as 20,000 acre-feet, it could be expected that 85 percent of the annual runoff of Cottonwood Creek would be during February to June and that 73 percent of the annual runoff of Little Humboldt River would occur during the same period.

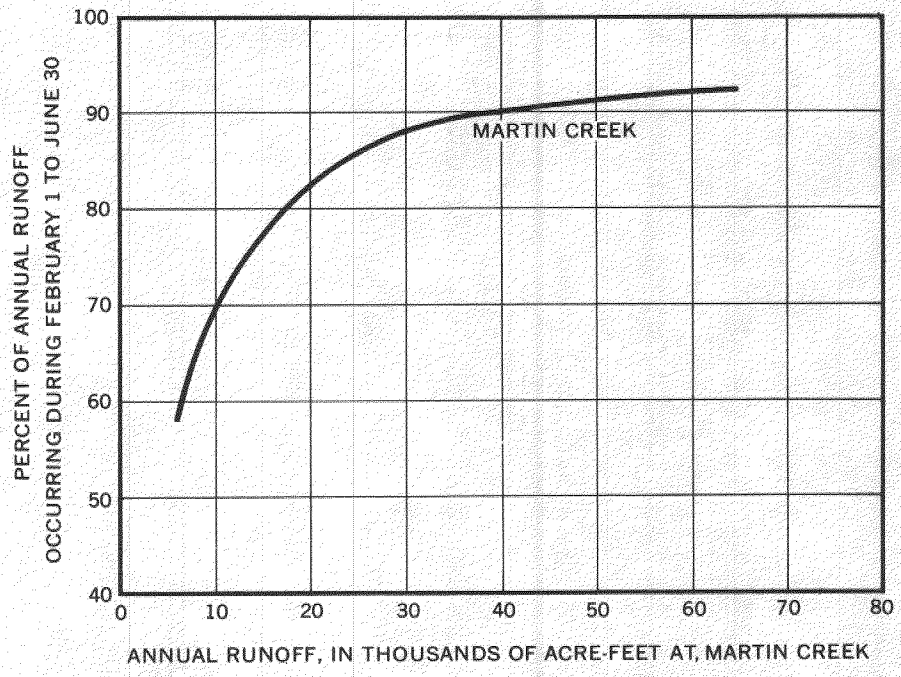
The annual variations of streamflow at the gages on Martin Creek, Cottonwood Creek, and Little Humboldt River are summarized in figure 9.

Frequency Characteristics of Streamflow

Streamflow data collected at the gaging stations on Martin Creek, Little Humboldt River, and Cottonwood Creek were analyzed statistically to develop curves that may be used to estimate the percentage of time that specified discharges might be equaled or exceeded in the future.

Flow-duration curves.--A flow-duration curve is a cumulative frequency curve that shows the percent of time specified discharges were equaled or exceeded during a given period of years. The flow-duration curve is prepared by arranging flows (daily flows in this report) according to their magnitude and computing the percent of time during which specified flows were equaled or exceeded. A curve is then drawn to average the plotted points of the specified discharges versus the percentage of time during which they were equaled or exceeded. It should be kept in mind that such a curve represents an average for the period used, rather than the distribution of flow within a single year or specified period of years.

Figure 10 shows the flow-duration curves for Martin Creek, Little Humboldt River, and Cottonwood Creek. For example, in the period 1922-63, the daily mean flow of Martin Creek was at least 5 cfs during 95 percent of the time, or at least 125 cfs



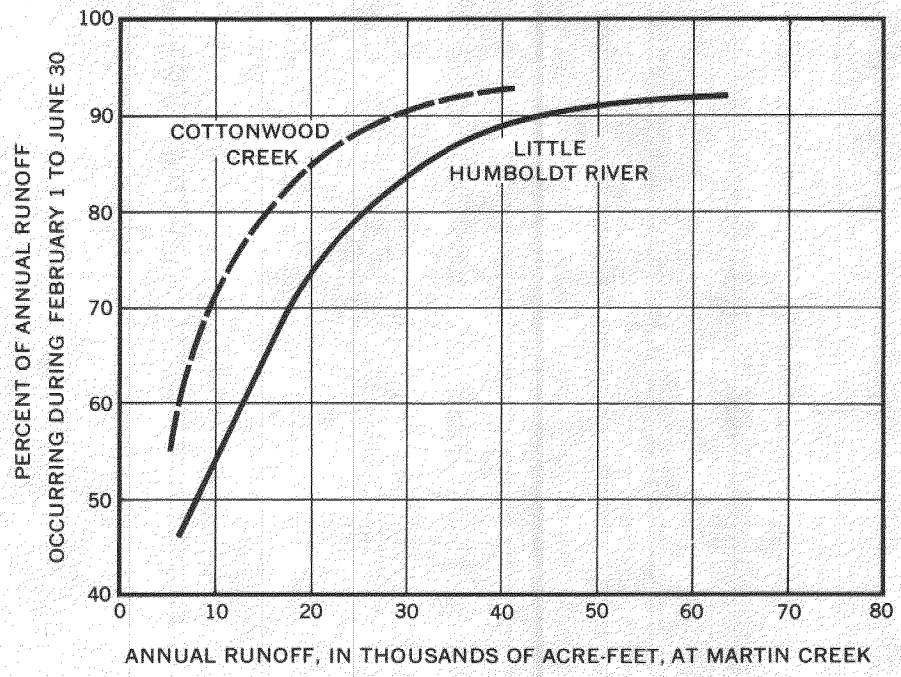


Figure 8.— Percentage of annual runoff occurring during the period February 1 to June 30 at Martin Creek, Cottonwood Creek and Little Humboldt River, based on annual flow at Martin Creek

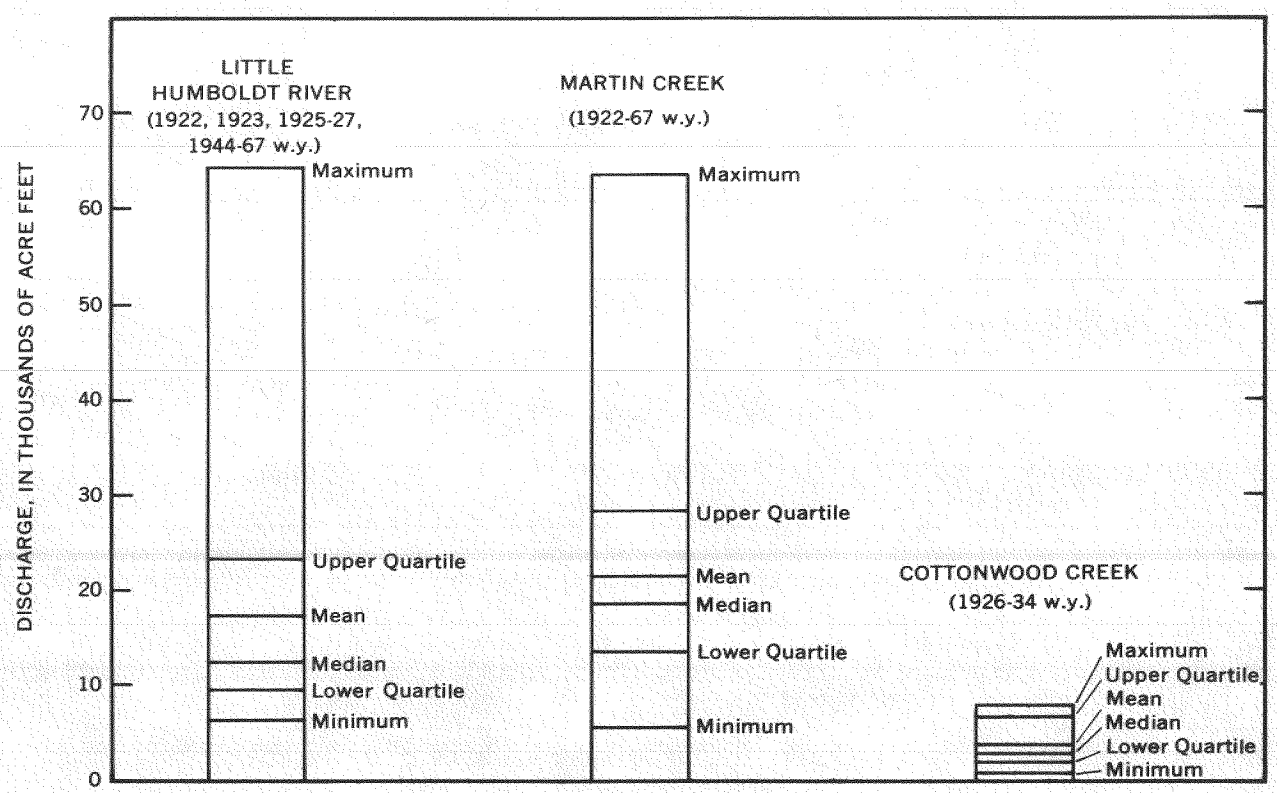


Figure 9. — Yearly variation of discharge at the gages on Little Humboldt River, Martin Creek and Cottonwood Creek for the period indicated

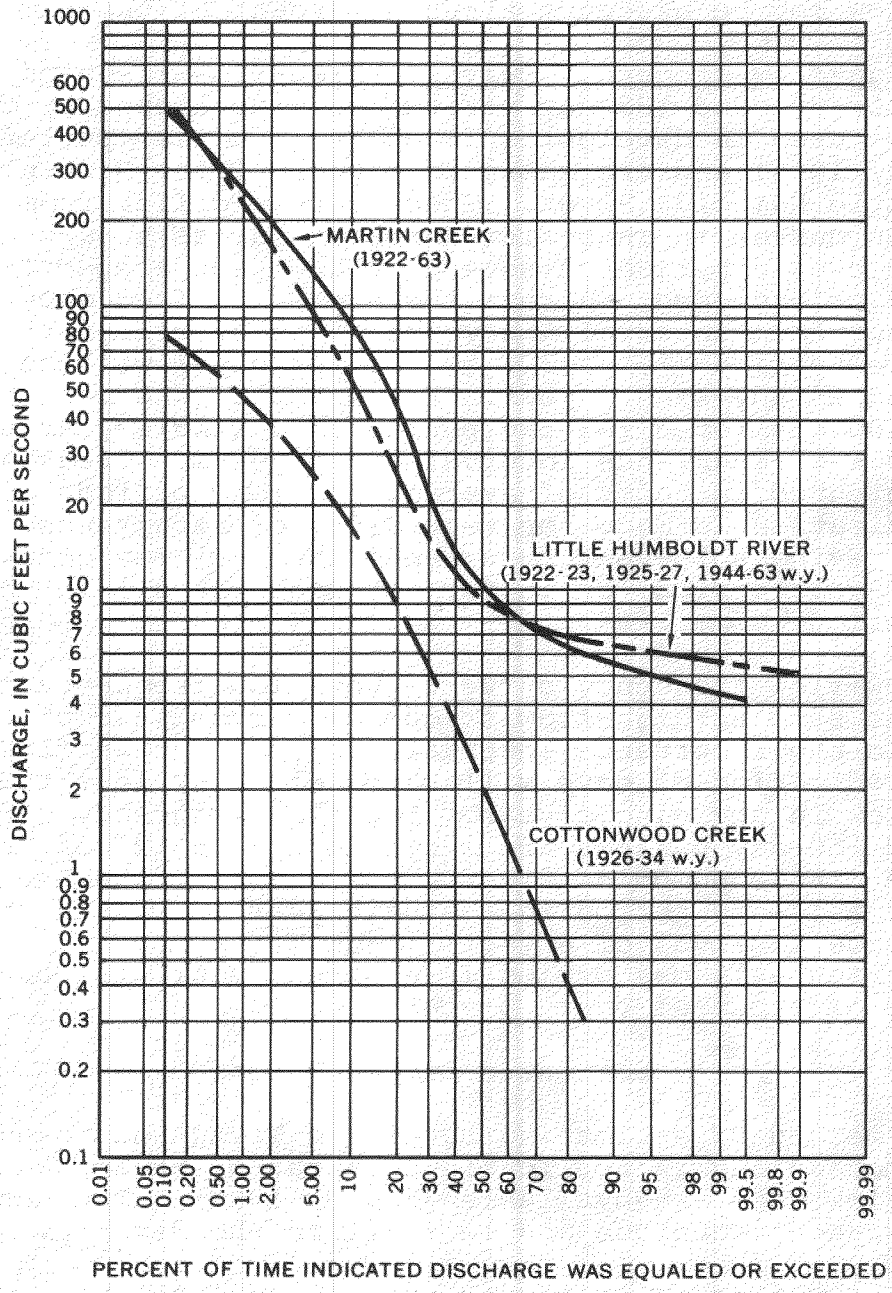


Figure 10. — Duration curves of daily flow for gaging stations at Martin Creek near Paradise Valley, Little Humboldt River near Paradise Valley, and Cottonwood Creek near Paradise Valley

during 5 percent of the time. Again, it should be noted that this does not infer that 125 cfs may be expected for 5 percent of the time each single year but rather that over periods of several years this flow may be expected about 5 percent of the time.

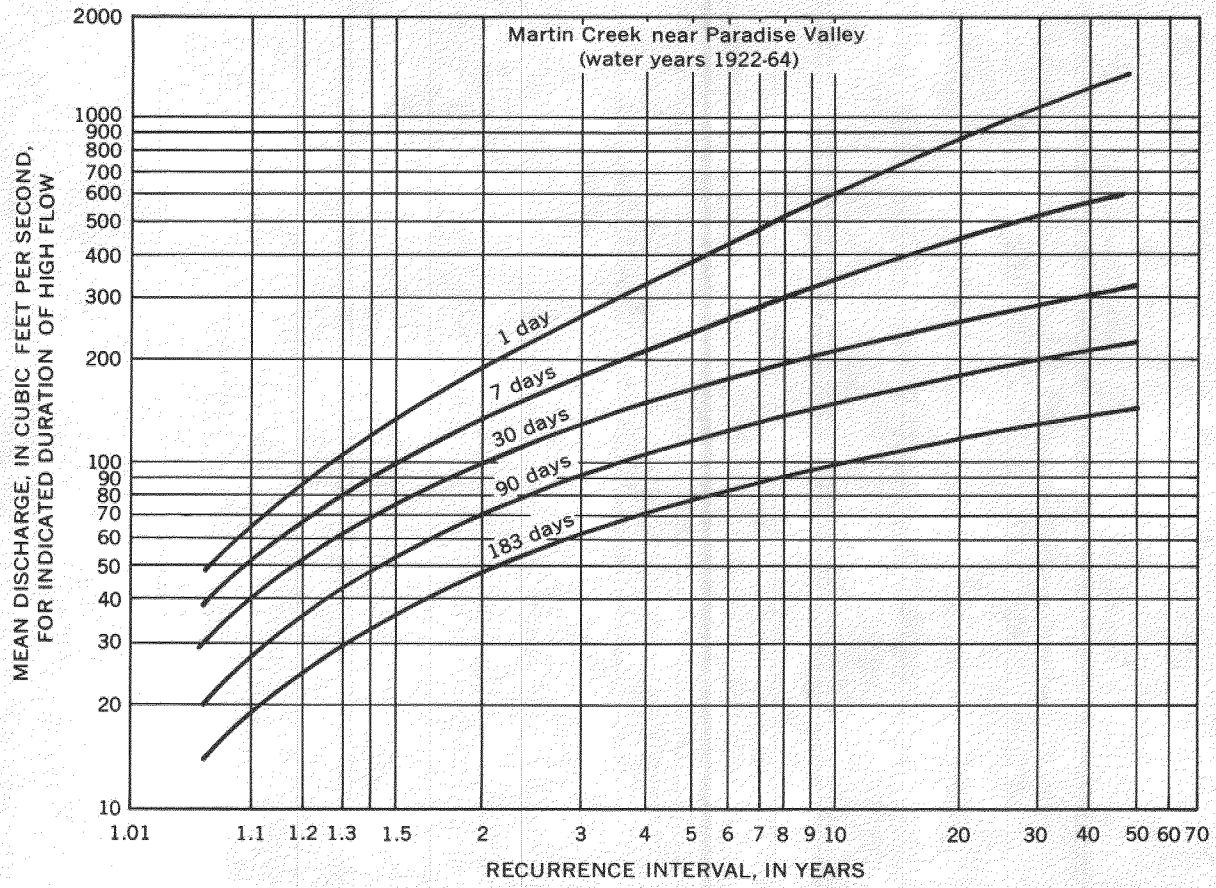
High-flow frequency curves.--High-flow frequency curves for 1, 7, 30, 90, and 183-day periods were developed by methods similar to those used in developing flood frequencies (Butler, Reid, and Berwick, 1966) and are shown in figure 11 for Martin Creek and the Little Humboldt River. These curves differ from the flow-duration curves in that flow-duration curves show the percentage of time over a period of several years that a specified flow was equaled or exceeded, whereas the high-flow frequency curves show the recurrence interval, in years, that specified flow during a specified period (1, 7, 30, 90, or 183 days) will be equaled or exceeded in any single year. For example, the mean flow of at least 100 cfs for a 183-day period in a single year on Martin Creek has a recurrence interval of 10 years. Frequency estimates are presented in terms of average for long periods of time, and no predication is made for regularity of recurrence. For example, a flow having a 10-year recurrence interval may occur three times in a 10-year period, or it may not occur at all in the next 20-year period.

Low-flow frequency curves.--Low-flow frequency curves are used the same as high-flow frequency curves, except that they indicate the recurrence interval, in years, that flow during a specified period of days will be equal to or less than a specified flow in any single year. Low-flow frequency curves for 14, 90, and 150-day periods are shown in figure 12 for Martin Creek and the Little Humboldt River. For example, the mean flow of 4 cfs for a 14-day period in a single year on Martin Creek has a recurrence interval of 6 years; that is, a mean flow of 4 cfs or less during a 14-day period in a single year will occur on the average of 1 out of every 6 years.

Estimated Annual Runoff

A method of estimating runoff in Nevada has been devised by D. O. Moore, and is applicable to areas of Nevada where few or no streamflow data are available (Moore, 1968). The method is a reconnaissance technique and is still in the development stage.

This method is explained briefly, as follows: Using the drainage areas that supply natural flow to streams where gaging stations have been or are being operated, recorded runoff is prorated by altitude zones (1,000-foot intervals) with regard to the proportional areas of the several zones and with increasing unit values of runoff for increasing altitude which are commensurate with increasing precipitation with altitude. The values of runoff are grouped into sets so that each set represents a single region. Eight sets of runoff values for eight regions have been developed for the State of Nevada. Paradise Valley lies within



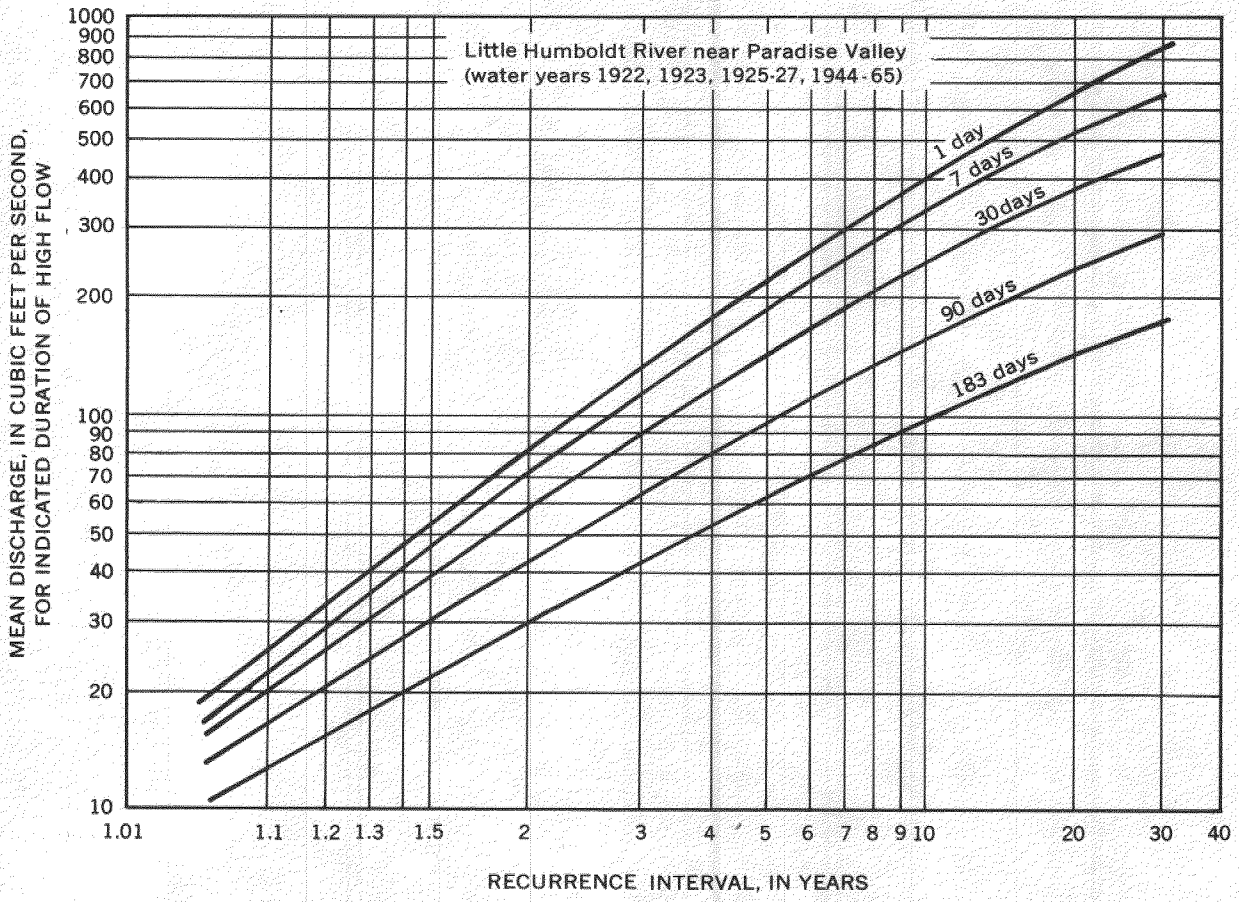
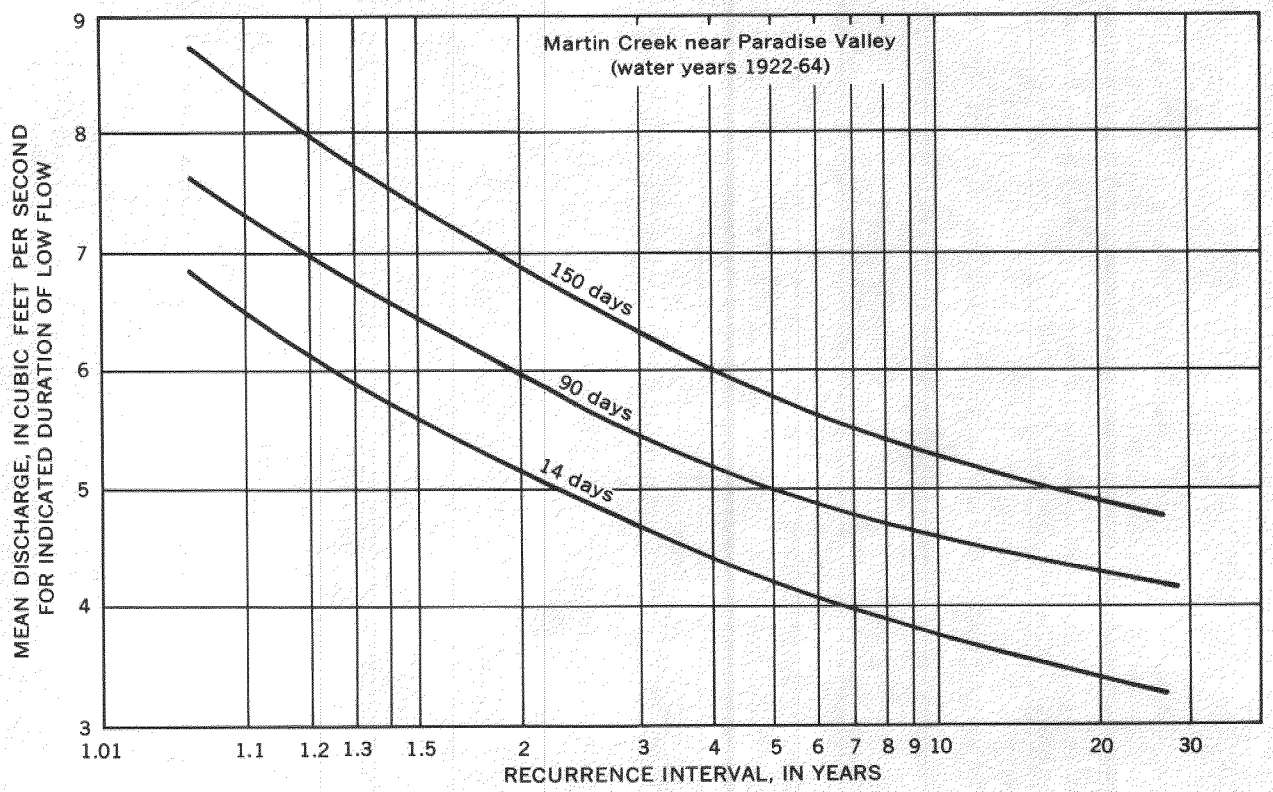


Figure 11. — High flow frequency curves of Martin Creek and Little Humboldt River



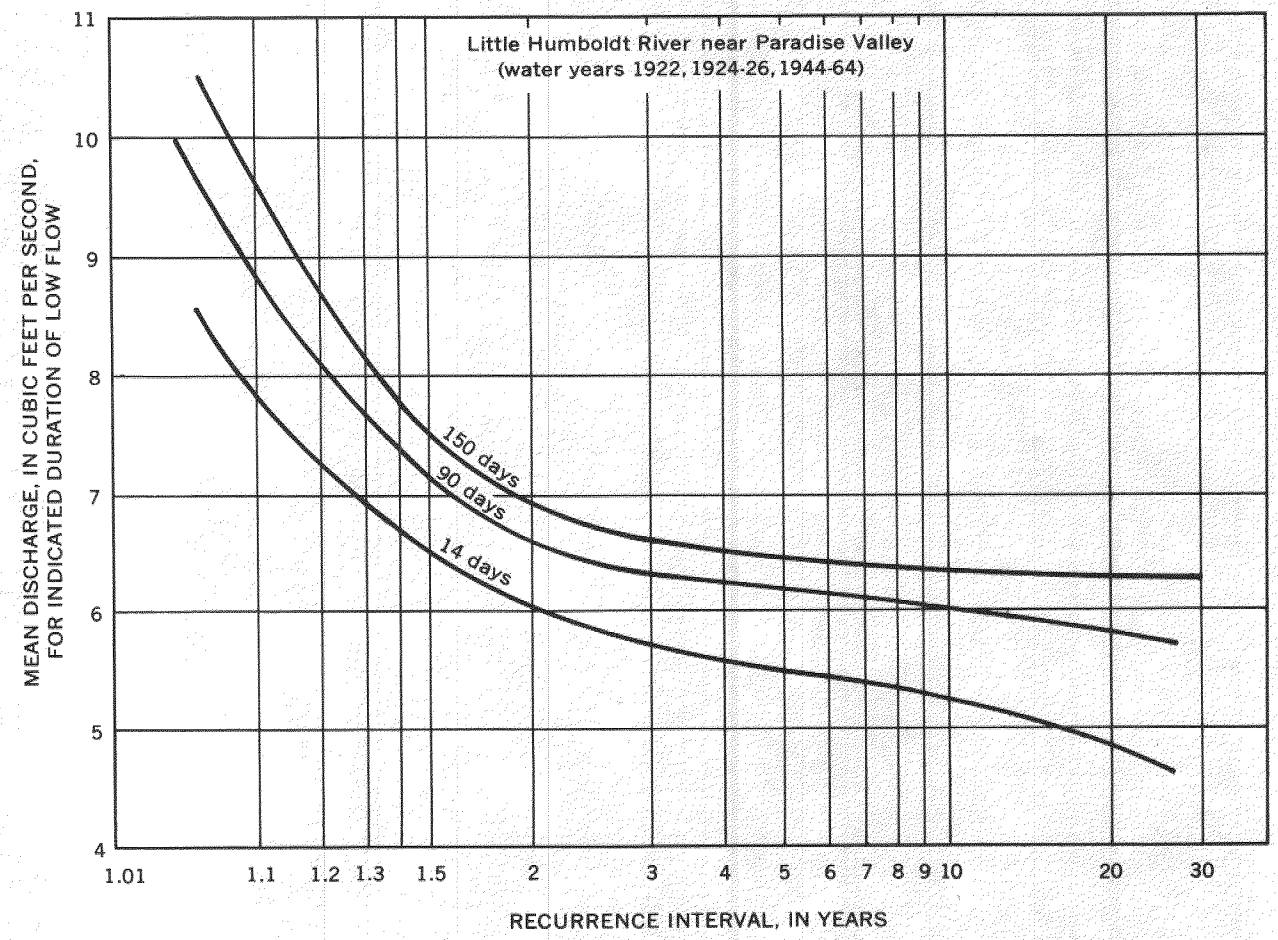


Figure 12. — Low flow frequency curves of Martin Creek and Little Humboldt River

two of these regions. The northern half of the valley, north of Little Humboldt River, has one set of values and the southern half of the valley another. Runoff values for Hardscrabble Area are the same as those for northern Paradise Valley and values for Little Humboldt Valley are the same as those for southern Paradise Valley.

As the different physical characteristics, such as vegetation, amounts of precipitation, geology, and types of soil, vary locally within large areas, the runoff for each altitude increment needs local adjustment. This adjustment of the runoff coefficients is based on streamflow measurements and channel geometry. The method of adjusting runoff coefficients involves determination of mean runoff on selected streams and comparing this mean with the estimated runoff computed using runoff coefficients. A detailed description of how the regional runoff coefficients are adjusted is given by Moore (1968).

The estimated runoff from the mountain blocks in Little Humboldt Valley, Hardscrabble Area, and Paradise Valley is computed as 80,000 acre-feet per year and is summarized in table 9. In Paradise Valley more than 90 percent of the annual runoff is generated in the northern half of the valley and less than 10 percent is generated in the southern half of the valley. About two-thirds of the estimated average annual runoff in Hardscrabble Area is generated from the east flank of the Santa Rosa Range. In Little Humboldt Valley, more than 80 percent of the estimated average annual runoff is generated above the confluence of the north and south forks of Little Humboldt River.

Annual runoff ranges through an order of magnitude, or from nearly four times the average, to about one-third the average. For example, flow of Little Humboldt River averaged about 24 cfs for 29 water years, but was about 89 cfs in 1952 and about 9 cfs in 1954.

About 67 percent (17,000 acre-feet) of the 25,000 acre-feet of estimated average annual runoff generated in Little Humboldt Valley flows into Paradise Valley and about 93 percent (22,000 acre-feet) of 24,000 acre-feet of estimated average annual runoff generated in Hardscrabble Area flows into Paradise Valley. Thus, the total average annual surface-water inflow to Paradise Valley is about 70,000 acre-feet. This agrees closely with the estimate of 70,500 acre-feet per year made by Loeltz and others (1949).

Distribution and Loss of Streamflow in Paradise Valley

Runoff generated in Paradise Valley and inflow of Martin Creek and Little Humboldt River is largely dissipated within the valley by diversions and infiltration to ground water. Only a small part leaves the valley as streamflow to Humboldt River. Little Humboldt River flows to Humboldt River only during excep-

Table 9.--Estimated average annual runoff generated above 5,000 feet in Little Humboldt Valley, Hardscrabble Area, and Paradise Valley[1/]

Valley segment	Location	Area: Acres	Area: Percentage of runoff area	Estimated runoff: Acre-feet per year	Estimated runoff: Percentage of total runoff
		LITTLE HUMBOLDT VALLEY			
North Fork Little Humboldt River Valley	Area upstream from Duck Creek	41,500	9	5,400	22
North Fork Little Humboldt River Valley	Area downstream from Duck Creek	93,500	19	5,600	22
Subtotal		135,000	28	11,000	44
South Fork Little Humboldt River Valley	Area upstream from Snowstorm Creek	46,700	10	6,100	24
South Fork Little Humboldt River Valley	Area downstream from Snowstorm Creek	56,100	12	2,900	12
Subtotal (rounded)		103,000	21	9,000	36
Milligan Creek	Area upstream from confluence with North Fork Humboldt River above 5,000 feet	176,000	36	a 1,100	4
Eden Valley	Area downstream from confluence of North Fork and South Fork Little Humboldt Rivers	71,500	15	3,900	16
Total (rounded)		486,000	100	25,000	100
		HARDSCRABBLE AREA			
East drainage	Area east of Martin Creek	57,700	52	7,800	33
Santa Rosa Range	Area west of Martin Creek	53,800	48	16,000	67
Total (rounded)		112,000	100	24,000	100

Continued

Table 9.--Estimated average annual runoff--Continued

Valley segment	Location	Area: Acres	Area: Percentage of runoff area	Estimated runoff: Acre-feet per year	Estimated runoff: Percentage of total runoff
		PARADISE VALLEY			
Bloody Run Hills	East flank of mountains	17,500	14	1,300	4
Santa Rosa Range	East flank of mountains between Highway 95 and Indian Creek	63,000	52	22,000	73
Santa Rosa Range	Southwest flank of mountains between Indian Creek and Little Humboldt River	22,600	19	5,200	17
Hot Springs Range	West flank of mountains	18,900	15	900	3
Total (rounded)		122,000	100	30,000	100
Totals, Little Humboldt River drainage area		720,000	100	80,000	100

1. Only minor average annual runoff is generated below 5,000 feet.

a. Estimated flow across 5,000-foot contour based on channel geometry. Estimated runoff based on unadjusted regional runoff coefficients for the same area is 8,800 acre-feet per year. The difference in estimates is probably due to flat gradients throughout much of the Milligan Creek drainage.

tionally high runoff, such as in 1953, 1958, and 1969.

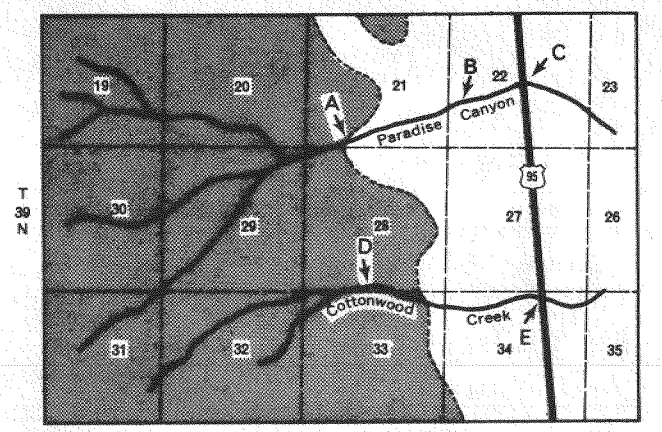
Most streamflow is diverted for irrigation on the valley floor in Paradise Valley. Streamflow also supplies water to native vegetation along stream channels, replenishes soil moisture on flood plains in the valley lowlands, and percolates to recharge the valley-fill reservoir.

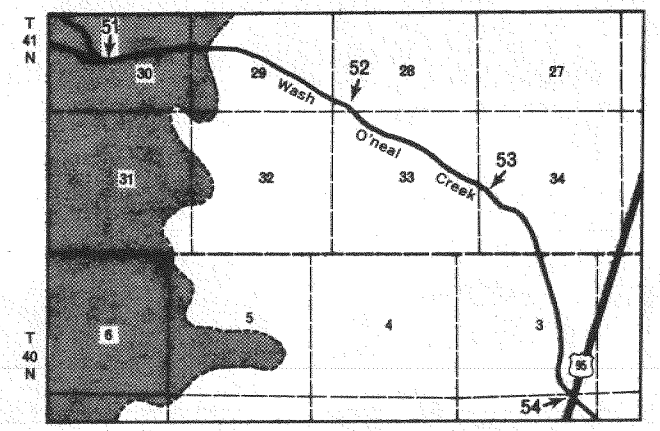
Distribution and loss on alluvial fans.--Streamflow in the mountains increases toward the mountain front and then decreases downstream from that point because of evapotranspiration and seepage to the valley-fill reservoir. Local streamflow may occasionally develop for short periods on the apron as a result of high-intensity storms, but generally this type of streamflow is so erratic in frequency and duration that it has little value for economic development.

Only part of the runoff generated in the mountains reaches the valley floor. The amount varies primarily with the total quantity generated in the mountains but is also affected by other factors, such as the slope and length of the apron, the permeability of materials underlying stream channels, and the intensity of the runoff.

Distribution and loss of runoff varies in different parts of the valley. In order to demonstrate variations in the percentage of runoff reaching the valley floor, the long-term mean streamflow was determined at several points along Paradise Canyon and Cottonwood Creek in the southern part of Paradise Valley and Wash O'Neal Creek in the northern part of Paradise Valley. Figure 13 shows locations along the stream channels were mean discharge was estimated from channel-geometry measurements, the cross-sectional areas between berms and point bars, and the estimated long-term mean discharge at each site. Only a very small percentage of the runoff in Paradise Canyon and Cottonwood Creek reaches the valley floor, but about 23 percent of the runoff generated in Wash O'Neal Creek reaches the valley floor.

Measurements of streamflow at selected times during 1967 and 1968 are used to demonstrate both the variation of runoff reaching the valley floor at different times during the year and the areal variation in the total amount of runoff that reaches the valley floor. The valley was divided into seven areas or reaches (fig. 14) and the runoff generated in each reach and percentages of the runoff reaching the valley floor were computed for several sets of measurements. The results are summarized in table 10. Generally, runoff during the low-flow periods is completely lost before reaching the valley floor and during high-flow periods less than 50 percent reaches the valley floor. Areas where significant runoff reaches the valley floor are limited to the northern half of Paradise Valley. During wetter years some runoff reaches the valley floor in the



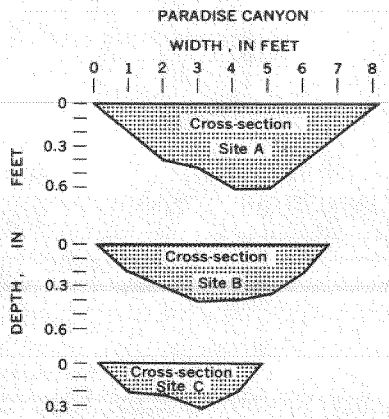


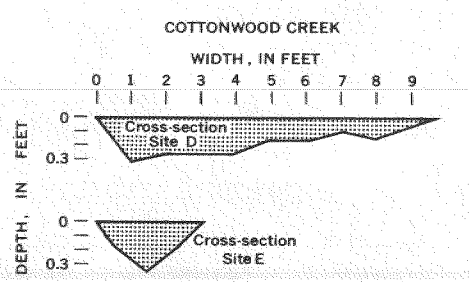
Alluvium

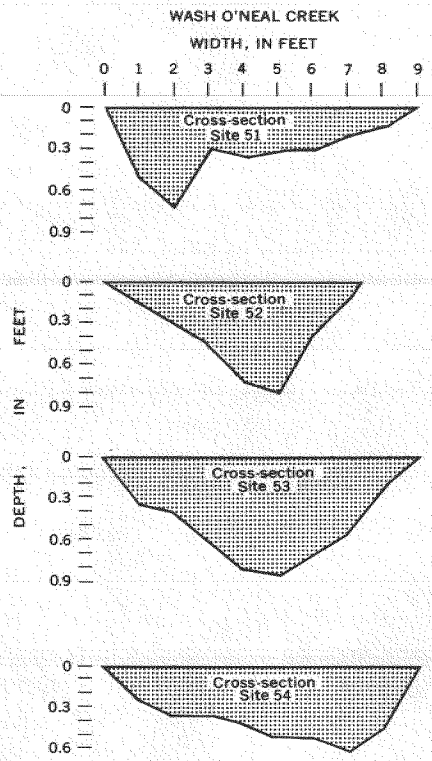
Consolidated rocks

0 0.5 1 mile

Scale







STREAM NAME	SITE ON STREAM	TYPE OF CHANNEL [2]	LONG-TERM MEAN DISCHARGE (acre-feet per year)
Paradise Canyon	A	Ephemeral	260
	B	do	70
	C	do	5
Cottonwood Creek	D	do	75
	E	do	2
Wash O'neal Creek	51	Perennial	1,100
	52	do	800
	53	Ephemeral	650
	54	do	250

Notes:

1. Only channel geometry measurements were made at lettered sites. These sites are not shown on Plate 1 or in Table 21. Miscellaneous streamflow measurements were made at numbered sites. These are shown on Plate 1 and are listed on Table 21.

2. Moore (1968, P. 36) derived emperical relationships between discharge and mean depth and width of a stream channel at a cross-section between berms and point bars. Two sets of relations were derived, one for perennial channels and one for ephemeral channels. A perennial channel has a much higher discharge than an ephemeral channel with the same cross-section area

Figure 13. — Cross-sections between bars and berms on Paradise Canyon, Cottonwood Creek and Wash O'neal Creek used to compute mean runoff

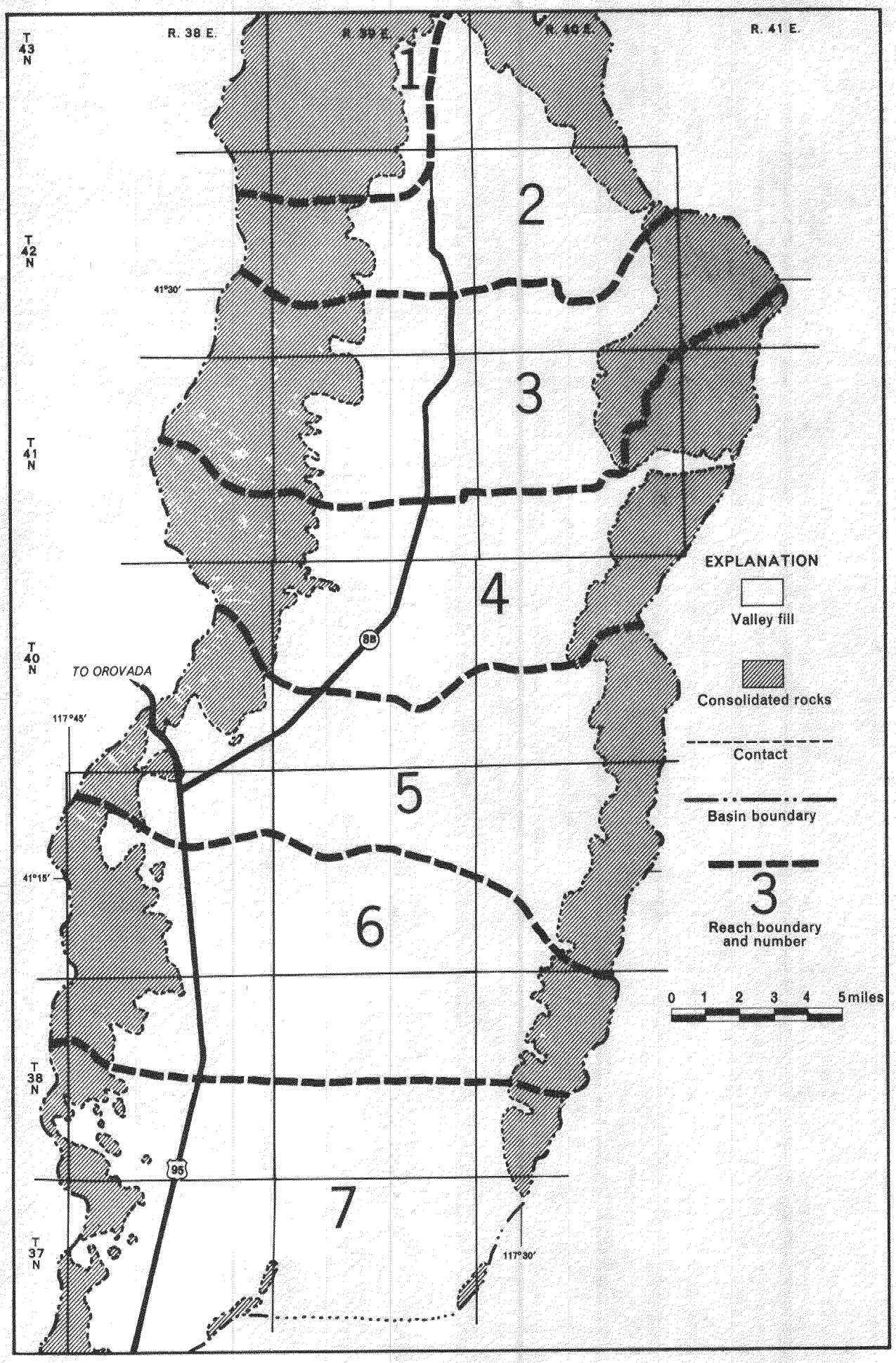


Figure 14. — Reaches used to evaluate distribution and loss of streamflow in Paradise Valley

Table 10.--Distribution of runoff generated in Paradise Valley

Reach	Date of measurement	Runoff generated in the mountains (acre-feet)[1]	Runoff reaching the valley floor (acre-feet)[1]	Runoff reaching the valley floor Percentage of runoff generated
1[a]	9-23-67	50	50	100
	3- 5-68	1,380	1,380	100
	5-27-68	1,010	1,010	100
	7-10-68	140	140	100
2	9-23-67	5	0	0
	3- 5-68	210	60	29
	5-27-68	230	40	17
	7-10-68	90	10	11
3	9-23-67	50	0	0
	3- 5-68	520	190	37
	5-27-68	430	0	0
	7-10-68	120	0	0
4	9-23-67	40	0	0
	3- 5-68	360	150	41
	5-27-68	110	0	0
	7-10-68	30	0	0
5	9-23-67	0	0	0
	3- 5-68	0	0	0
	5-27-68	0	0	0
	7-10-68	0	0	0
6	9-23-67	3	0	0
	3- 5-68	2	0	0
	5-27-68	2	0	0
	7-10-68	0	0	0
7	9-23-67	0	0	0
	3- 5-68	0	0	0
	5-27-68	0	0	0
	7-10-68	0	0	0
Total (rounded)		5,000	3,000	

1. Volumes are extended to an arbitrary 30-day period based on measurements made during a single day.

a. Reach 1 is primarily mountains and only a small amount of alluvial apron.

Note: Difference between runoff generated and runoff reaching the valley floor represents loss on alluvial fans. These losses are attributed primarily to infiltration to replenish soil moisture and recharge ground water as well as some evapotranspiration. In reaches 2 and 3, some water is diverted to irrigated areas on the alluvial fans.

southern half of Paradise Valley, but it is small compared to the amount that reaches the valley floor in the northern half of the valley.

Distribution and loss on the valley floor.-- Measurements of surface-water inflow and outflow in the valley floor part of each of the seven reaches in figure 14 were made at several different times during 1967 and 1968. Table 11 summarizes the inflow, outflow, and loss for each of these reaches based on several sets of measurements. Reach No. 1 is upstream from the irrigated area; therefore, no loss is shown in this reach. Most of the streamflow is lost in reaches 2, 3, 4, and 5, with very little water reaching reach No. 6 and no streamflow reaching reach No. 7 during the present investigation.

A good correlation existed between the water available in a reach and the amount of water loss within that reach. Figure 15 shows such a correlation for reaches 2, 3, and 4 during the 1968 water year. These curves show that about 50 percent of the water available in reach 2 was depleted. About 80 to 90 percent of the water available in reaches 3 and 4 was depleted.

The relations shown in figure 15 probably will vary somewhat from year to year in response to variations in evapotranspiration and the degree to which the valley-fill reservoir is saturated. For example, infiltration losses should be much greater after a prolonged dry period than after a series of wet years when the valley-fill reservoir remains virtually saturated. Future pumping should also affect future streamflow to some extent. Periodic evaluation of losses in the several reaches during the after periods of heavy pumping may show variations which could not be accounted for by slight changes in evapotranspiration rates or antecedent conditions and thus may be helpful in determining the extent to which pumping has affected surface-water supplies.

Surface-Water Inflow to Paradise Valley, 1948-67

Average surface-water inflow to Paradise Valley during the 20-year period 1948-1967, during which virtually all pumpage of record has occurred, is estimated to be about 74,000 acre-feet per year. This is slightly higher than the long-term estimate of 70,000 acre-feet per year (table 9). This estimate includes gaged average annual inflows of 17,000 acre-feet from Little Humboldt Valley and 24,000 acre-feet from Hardscrabble Area, and an estimated average annual runoff generated in Paradise Valley of 33,000 acre-feet. Average annual runoff in Paradise Valley for this 20-year period was estimated as about 110 percent of the long-term average shown in table 9. This adjustment is based on the fact that average discharge in Martin Creek during the 20-year period was about 110 percent of the 46-year average for the period of record.

Table 11.--Streamflow losses on the floor of Paradise Valley

Reach	Date of measurement	Inflow: from upstream reach (acre-feet)[1]	Inflow: Locally generated runoff reaching the valley floor (acre-feet)[1]	Outflow to downstream reach (acre-feet)[1]	Loss in reach: (acre-feet)[1]	Loss in reach: Percentage of inflow
1[a]	9-23-67	0	50	50	0	0
	1-18-68	0	1,150	1,150	0	0
	3- 5-68	0	1,380	1,380	0	0
	3-21-68	0	660	660	0	0
	4-17-68	0	1,170	1,170	0	0
	5-27-68	0	1,010	1,010	0	0
	6-18-68	0	410	410	0	0
2	9-23-67	b 470	0	190	280	60
	1-18-68	b 610	0	260	350	57
	3- 5-68	b 3,220	60	1,830	1,450	44
	3-21-68	b 1,610	10	890	730	45
	4-17-68	b 2,420	20	1,290	1,150	47
	5-27-68	b 2,830	40	1,720	1,150	40
	6-18-68	b 1,320	0	760	560	42
3	9-23-67	190	0	0	190	100
	1-18-68	260	0	60	200	77
	3- 5-68	1,830	190	440	1,580	78
	3-21-68	890	50	170	770	82
	4-17-68	1,290	20	190	1,120	86
	5-27-68	1,720	0	80	1,640	95
	6-18-68	760	0	0	760	100
4	9-23-67	c 350	0	70	290	84
	1-18-68	c 480	0	90	390	81
	3- 5-68	c 1,570	150	120	1,600	93
	3-21-68	c 1,000	40	100	940	90
	4-17-68	c 960	10	230	740	76
	5-27-68	c 800	0	150	650	81
	6-18-68	c 400	0	220	180	45

Table 11.--Streamflow losses on the floor of Paradise Valley--Continued

Reach	Date of measurement	Inflow: from upstream reach (acre-feet)1/	Inflow: Locally generated runoff reaching the valley floor (acre-feet)1/	Outflow to downstream reach (acre-feet)1/	Loss in reach: (acre-feet)1/	Loss in reach: Percentage of inflow
5	9-23-67	70	0	0	70	100
	1-18-68	90	0	6	84	93
	3- 5-68	120	0	5	115	96
	3-21-68	100	0	12	88	88
	4-17-68	230	0	0	230	100
	5-27-68	150	0	0	150	100
	6-18-68	220	0	0	220	100
6	9-23-67	0	0	0	0	--
	1-18-68	6	0	0	6	100
	3- 5-68	5	0	0	5	100
	3-21-68	12	0	0	12	100
	4-17-68	0	0	0	0	--
	5-27-68	0	0	0	0	--
	6-18-68	0	0	0	0	--
7	9-23-67	0	0	0	0	--
	1-18-68	0	0	0	0	--
	3- 5-68	0	0	0	0	--
	3-21-68	0	0	0	0	--
	4-17-68	0	0	0	0	--
	5-27-68	0	0	0	0	--
	6-18-68	0	0	0	0	--

1. Volumes are extended to an arbitrary 30-day period based on measurements made during a single day.

a. Reach 1 is primarily mountains and only a small amount of alluvial apron.

b. Includes Martin Creek inflow.

c. Includes Little Humboldt River inflow.

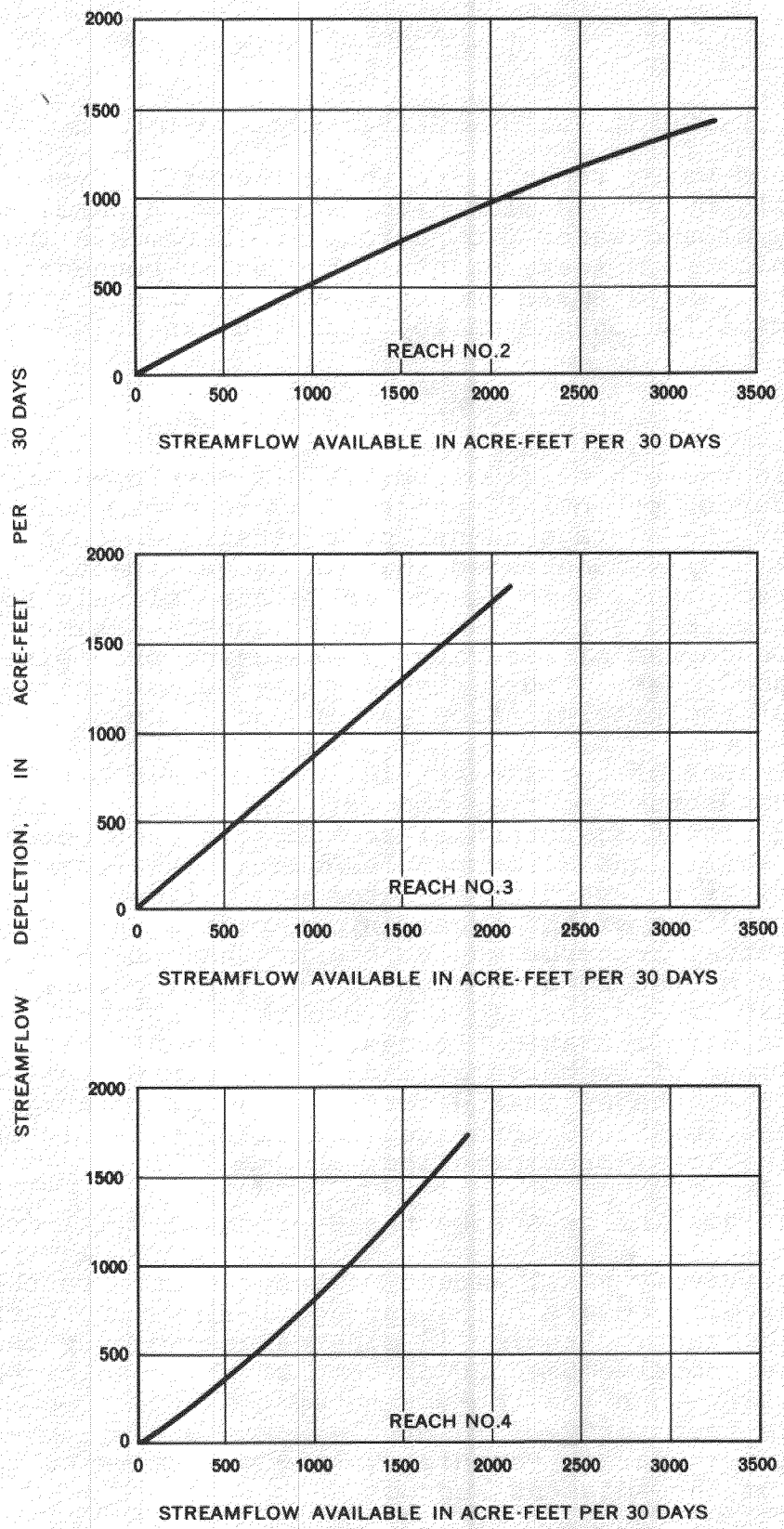


Figure 15. — Streamflow loss versus streamflow available in reaches 2, 3 and 4

Recharge to the Valley-Fill Reservoirs

Ground-water recharge to the valley-fill reservoirs is principally by seepage loss from streams. A small amount occurs by ground-water flow across the bedrock alluvial contacts, which form leaky external hydraulic boundaries of the reservoirs, and a small amount occurs by direct infiltration of precipitation on the valley floor in exceptionally wet years.

Estimated Potential Recharge

Eakin and others (1951, p. 79-81) developed an empirical method whereby potential recharge may be estimated as a percentage of the average annual precipitation within a basin. Hardman (1936) demonstrated that in gross aspect, the average annual precipitation in Nevada is related closely to the altitude of the land surface and that it can be estimated with a reasonable degree of accuracy by assigning precipitation rates to altitude zones. Thus, recharge may be estimated as a percentage of the precipitation within each zone.

Estimates of total potential recharge in Little Humbolt Valley, Hardscrabble Area, and Paradise Valley are listed in table 12. The term potential recharge is used because in Little Humboldt Valley and Hardscrabble Area a significant part of the streamflow is rejected as recharge as it flows across saturated deposits and out of the areas into Paradise Valley. In Paradise Valley, actual recharge may be higher than would be calculated by Eakin's method because most of the surface flow is spread for irrigation and therefore is probably subject to higher-than-average infiltration losses. Because of this, an independent estimate of recharge is made for Paradise Valley. Table 12 shows that the estimated total potential recharge for the three areas is 43,000 acre-feet per year, which is about 5 percent of the total precipitation.

Subsurface Inflow Across the Bedrock-Alluvial Contact

A relatively small amount of the recharge to the valley-fill reservoirs occurs by subsurface inflow across the bedrock-alluvial contact. Studies in other areas suggest that the amount may comprise 5 to 20 percent of the total recharge shown in table 12. Thus, of the estimated potential recharge, roughly 2,000 acre-feet per year in Little Humboldt Valley and 1,000 acre-feet per year in Paradise Valley may occur by subsurface inflow from the adjacent bedrock.

Recharge in Paradise Valley

Recharge to the valley-fill reservoir in Paradise Valley is estimated as (1) recharge from streams, plus (2) ground-water

Table 12.--Estimated average annual precipitation and potential ground-water recharge

Precipitation zone (feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average (feet)	Estimated precipitation: Average (acre-feet)	Estimated recharge: Percentage of precipitation	Estimated recharge: (acre-feet per year)
LITTLE HUMBOLDT VALLEY						
North Fork, South Fork, and Mulligan Creek						
More than 8,000	900	>20	1.8	1,600	25	400
7,000 to 8,000	20,700	15-20	1.5	31,000	15	4,600
6,000 to 7,000	114,000	12-15	1.1	130,000	7	9,100
5,000 to 6,000	279,000	8-12	.8	220,000	3	6,600
Less than 5,000	38,500	<8	.5	19,000	Minor	--
Subtotal (rounded)	453,000			400,000		21,000
Eden Valley						
More than 8,000	300	>20	1.8	450	25	110
7,000 to 8,000	1,700	15-20	1.5	2,600	15	390
6,000 to 7,000	8,000	12-15	1.1	8,800	7	620
5,000 to 6,000	61,500	8-12	.8	49,000	3	1,500
Less than 5,000	103,000	<8	.5	51,000	Minor	--
Subtotal (rounded)	174,000			110,000		2,600
Subtotal (rounded)	627,000			500,000		24,000
HARDSCRABBLE AREA						
More than 8,000	2,700	>20	1.8	4,900	25	1,200
7,000 to 8,000	15,600	15-20	1.5	23,000	15	3,400
6,000 to 7,000	47,400	12-15	1.1	50,000	7	3,500
5,000 to 6,000	45,700	8-12	.8	37,000	3	1,100
Less than 5,000	2,000	<8	.5	1,000	Minor	--
Subtotal (rounded)	113,000			120,000		9,000
PARADISE VALLEY						
More than 8,000	5,600	>20	1.8	10,000	25	2,500
7,000 to 8,000	14,300	15-20	1.5	21,000	15	3,200
6,000 to 7,000	29,400	12-15	1.1	32,000	7	2,200
5,000 to 6,000	72,800	8-12	.8	58,000	3	1,700
Less than 5,000	259,000	<8	.5	130,000	Minor	--
Subtotal (rounded)	381,000			250,000		10,000
Total (rounded)	1,120,000			900,000		43,000

flow across the bedrock-alluvial contact, plus (3) subsurface inflow beneath the channels of Little Humboldt River and Martin Creek.

Ground-water recharge from streams is the difference between the total surface-water inflow and the surface-water (consumptive) losses, plus surface outflow to Humboldt River. Most of the surface-water loss is by evapotranspiration of irrigation diversions on about 34,000 acres of cropland, native hay, and pasture. An additional 48,000 acres of low-benefit phreatophytes and grasses consumes surface water which it receives as a result of overflow, irrigation tail water, and flooding. During wet years, surface water is also evaporated from Gumboot Lake. Estimated total average annual evapotranspiration of surface water (table 14) is about 31,000 acre-feet, which includes about 25,000 acre-feet per year consumed on irrigated lands and about 6,000 acre-feet per year consumed by low-benefit phreatophytes or evaporated from Gumboot Lake. Stream diversions to irrigated areas are significantly higher; however, part of these diversions infiltrate to shallow ground water to be consumed later by native hay and pasture during summer months when no surface irrigation water is available. Average surface outflow to the Humboldt River was estimated by Eakin and Lamke (1966, p. 36) at about 2,000 acre-feet per year.

Subsurface inflow beneath the channels of Little Humboldt River and Martin Creek is estimated on the basis of the width and approximate thickness of alluvial deposits, the slope of the water surface, and the estimated permeability of the materials. Underflow beneath Martin Creek is considered negligible because the width of alluvial fill is only about 100 feet and the thickness about 5 feet or less. Underflow beneath Little Humboldt River is estimated to be about 300 acre-feet per year. This estimate is based on a width of alluvial fill of about a quarter of a mile, a thickness of about 50 feet, a hydraulic gradient of about 13 feet per mile, and an assumed transmissivity of 100,000 gallons per day per foot (fig. 4).

Table 13 summarizes the estimate of average annual ground-water recharge in Paradise Valley, which is about 40,000 acre-feet per year. Loeltz and others (1949) estimated that the total recharge was one-third to one-half the runoff, or roughly 25,000 to 35,000 acre-feet per year, which is about 25 percent less than this estimate and is in reasonably good agreement considering the several assumptions involved in both estimates.

Table 13.--Estimated average annual recharge to the valley-fill reservoir in Paradise Valley

	Acre-feet per year
1. Average annual surface-water inflow	
a. Little Humboldt River (fig. 7)	17,000
b. Martin Creek (fig. 7)	22,000
c. Across bedrock-alluvial contact (table 9)	30,000
Subtotal	70,000
2. Surface-water losses	
Surface-water evapotranspiration (consumptive) (p. 64)	31,000
Average annual surface outflow (p. 64)	2,000
Subtotal	33,000
3. Total recharge from streams: (1) - (2)	37,000
4. Ground-water inflow across bedrock-alluvial contact (p. 64)	1,000
5. Subsurface inflow beneath channels of:	
Little Humboldt River (p. 64)	300
Martin Creek (p. 64)	trace
6. Subtotal	1,300
Total recharge, all sources (rounded): (3) + (6)	40,000

OUTFLOW FROM THE VALLEY-FILL RESERVOIRS

Outflow from the valley-fill reservoirs occurs by evapotranspiration of surface and ground water, surface and subsurface outflow to the Humboldt River, and pumpage.

Evapotranspiration

Surface water is discharged from the system by direct evaporation from water surfaces, by evapotranspiration of irrigated crops and pasture, and by evaporation from bare soil wetted by surface water. Ground water is discharged by evapotranspiration of non-irrigated phreatophytes, by consumptive use of pump-irrigated and subirrigated crops, and by direct evaporation from the land surface where the capillary fringe extends to the surface.

Virtually all the precipitation that falls on the valley floor is removed from the soil by evapotranspiration before it can recharge the ground-water reservoir. This quantity, about 130,000 acre-feet per year in Paradise Valley, and about 51,000 acre-feet per year in Eden Valley, is generally consumed in the immediate vicinity of where it fell. This water is not included as one of the principal outflow components because it has only minor effects on the functioning of the valley-fill reservoirs. The various estimated rates of evapotranspiration by crops, pasture, and phreatophytes are adjusted to compensate for some additional evapotranspiration of direct precipitation during the growing season.

Areal distribution of the principal crops and native vegetation (phreatophytes) which consume surface and ground water is shown on plate 1. Table 14 lists estimates of the average annual evapotranspiration of surface and ground water in Paradise Valley, Little Humboldt Valley, and Hardscrabble Area. These estimates are based on rates of consumption described by Lee (1912), White (1932), Young and Blaney (1942), Houston (1950), Tovey (1963), Dylla and Muckel (1964), and Robinson (1965). The rates listed are estimated composite rates for all the vegetation in each respective group. Estimates are also made of that part of the total consumed water that is derived from ground water and surface water, respectively. These estimates, based on field observations of surface-water distribution in relation to monthly evapotranspiration requirements, are only rough approximations.

During most years, the amount of water that could potentially be consumed in the areas of evapotranspiration shown on plate 1 substantially exceeds the amount available. Consequently, evapotranspiration varies from year to year, largely in response to variations in the distribution and quantity of annual streamflow. For example, evapotranspiration in Paradise Valley may

Table 14.--Estimated average annual evapotranspiration of surface water and ground water

Vegetation		Area (acres)	CONSUMPTIVE USE: Feet per year: Surface water	Ground water	Both	Acre-feet per year (rounded): Surface water	Ground water	Total
		PARADISE VALLEY						
Cropland (primarily alfalfa). Irrigated in part by pumping ground water	Beneficial consumption	3,300	1	1.5	2.5	3,300	5,000	8,000
Irrigated hay and meadows. Includes local areas of willows and silver buffaloberry	Beneficial consumption	8,000	1	.5	1.5	8,000	4,000	12,000
Meadows and pasture, partly subirrigated. Includes local areas of silver buffaloberry, willows, saltgrass, and rabbitbrush	Beneficial consumption	23,000	.6	.5	1.1	14,000	12,000	26,000
Primarily rabbitbrush and native grasses. Includes some areas of silver buffaloberry, willow, and saltgrass	Largely nonbeneficial consumption	13,600	.2	.6	.8	2,700	8,000	11,000
Primarily saltgrass, includes some intermixed rabbitbrush and greasewood. Overflow from irrigated areas may pond in localized parts of this area during wet years	Largely nonbeneficial consumption	10,900	.2	.5	.7	2,200	5,400	7,600
Greasewood and rabbitbrush north of Gumboot Lake, moderate to low density	Largely nonbeneficial consumption	17,800	Minor	.2	.2	--	3,600	3,600
South of Gumboot Lake, low density	Largely nonbeneficial consumption	20,600	Minor	.1	.1	--	2,000	2,000
Gumboot Lake--free water surface during parts of wet years, bare soil during dry years	Largely nonbeneficial consumption	a 2,000	b .5	c .1	.5	1,000	200	1,000
Total (rounded)		100,000				31,000	40,000	71,000

Continued

Table 14.--Estimated average annual evapotranspiration--Continued

Vegetation		Area (acres)	CONSUMPTIVE USE: Feet per year: Surface water	Ground water	Both	Acre-feet per year (rounded): Surface water	Ground water	Total
		LITTLE HUMBOLDT VALLEY						
Grass, hay, and pasture, includes areas of willow growing along channels and ditches	Beneficial consumption	4,000	1	.5	1.5	4,000	2,000	6,000
Rabbitbrush, greasewood, and native grasses	(1)	3,000	.2	.6	.8	600	1,800	2,400
Rabbitbrush and greasewood		d 600	Minor	.2	.2	--	120	120
Total (rounded)		7,600				4,600	4,000	8,500
		HARDSCRABBLE AREA						
Primarily willow and native grasses growing along stream channel below 5,000 feet altitude (not shown on plate 1)		150	2	Minor	2	300	--	300

a. Estimated average area of lake. Area ranges from 0 in dry years to as much as 10,000 acres in a very wet year.

b. Estimated average rate. Evaporation may range from less than .1 foot when the lake is formed for only a short period of time to about 3.5 feet when the lake remained for a full year.

c. Estimated average annual evaporation of ground water from bare soil when the lake is not formed. A large quantity of soil moisture is also removed by evaporation each time the lake recedes.

d. An additional 1,500 acres of sparse rabbitbrush and greasewood are present along upper Milligan Creek above 5,000 feet altitude.

1. Largely non-beneficial consumption.

range from about 50,000 acre-feet per year in a drought period to nearly 100,000 acre-feet in a very wet year. The amount of ground water readily available to plants does not vary greatly from year to year. During extremely dry years, or after a series of dry years, water levels beneath subirrigated pastures may drop below the point where the grasses can efficiently obtain water and evapotranspiration will be reduced.

Surface-Water Outflow to the Humboldt River

Surface-water outflow to the Humboldt River is accomplished by intermittent flow in the lower channel of the Humboldt River. During most years the channel remains dry except after periods of local snowmelt or high-intensity rain. In extremely wet years, however, Gumboot Lake may break through or be bull-dozed through the sanddunes at the south end of Paradise Valley and a large quantity of water may drain into the Humboldt River. A report on the Chronology of Flood Years and High Water Years in the Humboldt River Basin, prepared by the Nevada Department of Conservation and Natural Resources and the U.S. Department of Agriculture (1962b), indicates that since 1875 (the first recorded report of the formation of Gumboot Lake in lower Paradise Valley subsequent to its settlement by whites) the lake has broken through in 1890, 1907, 1910, and 1914 and was drained as a result of dredging a channel in 1953, 1958, and 1969. Thus, significant quantities of water flowed from Gumboot Lake to Humboldt River about once in every 15 years. Cohen (1964, p. 30) states that a total of about 58,000 acre-feet of flood water was artificially drained from Gumboot Lake to Humboldt River in the 1953 and 1958 water years.[1] Average annual surface-water outflow to Humboldt River is estimated to be about 2,000 acre-feet. This value is the same as that estimated by Eakin and Lamke (1966, p. 36) in their reconnaissance of the Humboldt River Basin.

Subsurface Outflow to the Humboldt River

The water-level contours on plate 1 show that ground water moves south out of Paradise Valley to the flood plan of the Humboldt River. Gains in flow in the Humboldt River opposite the mouth of Paradise Valley suggest that much of the subsurface

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1. Gumboot Lake also formed in 1969 after field work on this project was completed. About 25,000 acre-feet of water was drained to the Humboldt River in April, May, and June of that year.

outflow is discharged into the Humboldt River. Loeltz and others (1949, p. 41) estimated that the underflow from Paradise Valley averages about 3,200 acre-feet per year on the basis of gains in streamflow measured in the late summer of 1947. Cohen (1963, p. 65) estimated the underflow out of Paradise Valley to be between 3,000 and 3,500 acre-feet per year, based on streamflow gains measured during low-flow periods in 1960 and 1961 plus estimated gains in underflow parallel to the Humboldt River. In this report the estimated average annual underflow from Paradise Valley is considered to be about 3,500 acre-feet.

Pumpage

Virtually all pumping in the Little Humboldt River drainage area is in Paradise Valley. Ground water is pumped for irrigation, stockwater, domestic, and minor industrial purposes. Pumping for irrigation accounts for all but a small part of the total. Table 15 lists estimates of pumpage for the 21-year period, 1948-68. Estimates of pumpage for domestic, stockwater, and industrial purposes in 1968 are based on field inventory and observation. Estimates for other years represent only approximate values and reflect the impression that pumping for purposes other than irrigation has increased only slightly above the 100 to 200 acre-feet estimated in 1947 (Loeltz and others, 1949, p. 39). Estimates of irrigation pumpage in 1967 and 1968 are based on a pumpage inventory and power-consumption data furnished by the California Pacific Utilities Co. Estimates prior to 1967 are based on information furnished by local residents, reported values, and the number of wells available for operation in any given year, and represent an average increase between 1948 and 1967.

Of the total quantity of water pumped, part is consumed and part is recirculated (returned to ground water). That part of the gross irrigation pumpage that returns to ground water varies from field to field, depending on the method of irrigation, character of the soil, slope of the field, experience of the irrigator, and other factors. The quantity recirculated in Paradise Valley probably ranges from about 25 percent of the total, where ground water is pumped through sprinklers, to about 60 percent in some fields where wells are pumped to supplement surface-water irrigation, and may average about 40 percent for the valley. Much of the water pumped for domestic, stock, and industrial purposes is returned to ground water. For the purposes of this report, recirculation from these uses is assumed to be the same as for irrigation pumpage.

Table 15.--Estimated pumpage in Paradise Valley, 1948-68

(Columns may not cross-total due to independent rounding)

Year	Estimated gross pumpage (acre-feet)					Estimated net pumpage[2] (acre-feet)	Cumulative net pumpage (acre-feet)
	Irrigation[1]	Domestic	Stock	Industrial	Annual total (rounded)		
1948	200	30	100	5	240	140	140
1949	400	30	100	5	540	320	460
1950	900	30	100	5	1,000	600	1,100
1951	800	30	100	5	940	560	1,600
1952	700	30	100	5	840	500	2,100
1953	1,000	30	100	5	1,100	660	2,800
1954	2,000	30	100	5	2,100	1,300	4,100
1955	3,000	30	100	5	3,100	1,900	6,000
1956	3,800	30	100	5	3,900	2,300	8,300
1957	4,200	30	100	5	4,300	2,600	11,000
1958	4,800	30	100	5	4,900	2,900	14,000
1959	6,000	30	100	5	6,100	3,700	18,000
1960	6,200	30	100	5	6,300	3,800	21,000
1961	6,100	30	100	5	6,200	3,700	25,000
1962	6,600	30	100	5	6,700	4,000	29,000
1963	7,100	35	100	5	7,200	4,300	33,000
1964	7,300	35	100	5	7,400	4,400	38,000
1965	7,200	35	100	5	7,300	4,400	42,000
1966	8,200	40	100	10	8,400	5,000	47,000
1967	9,200	40	120	10	9,400	5,600	53,000
1968	13,000	40	120	10	13,000	7,800	60,000
Totals (rounded)	99,000	700	2,100	120	100,000	60,000	60,000

1. Estimates for 1967 and 1968 based on pumping inventory and power consumption data furnished by the California-Pacific Utilities Co. Estimates prior to 1967 based on information furnished by local residents, reported values, and the number of irrigation wells available for operation in any given year.

2. Net pumpage estimated as 60 percent of gross pumpage.

GROUND WATER IN STORAGE

A large quantity of potentially recoverable ground water is in transient storage in the valley-fill reservoirs in Eden and Paradise Valleys. This quantity is the amount of water that will drain from the valley fill in response to pumping. It may be estimated as the product of an area, a specified depth of dewatering, and the specific yield of the deposits composing the valley-fill reservoir.

The area of the valley-fill reservoir in Eden Valley is about 56,000 acres, which is slightly less than the area of valley fill shown on plate 1, and the thickness selected is the uppermost 50 feet of saturated valley fill. Thus, using an average specific yield of 15 percent (p. 32), about 400,000 acre-feet of water is stored in this uppermost zone. A significant quantity of additional stored ground water may be present in the Tertiary sedimentary rocks and alluvial channel deposits exposed east of Eden Valley (pl. 1).

About 1.8 million acre-feet of water is stored in the upper 50 feet of saturated deposits in Paradise Valley. Available alternatives for utilizing both the surface- and ground-water resources may require varying amounts of storage depletion in different parts of the valley. In order to assist in evaluating the affects of ground-water storage depletions on these various alternatives, the valley was divided into east-trending subdivisions, or strips, each bordered on the north and south by township lines. The estimated amount of stored water that must be withdrawn from each subdivision to drop water levels one foot was computed from the distribution of specific yield shown in figure 4. Table 16 lists the estimated recoverable water per foot of storage in the upper 50 feet of saturated valley fill in Paradise Valley. The table illustrates that a one-foot decline in water levels throughout the valley-fill reservoir would require removal of about 36,000 acre-feet of stored water.

Table 16.--Estimated recoverable water in storage in the upper 50 feet of saturated valley fill in Paradise Valley

East-west strip bordered by township boundaries	Area (acres)	Recoverable water in storage		
		Specific yield (percent)	Per foot of storage (acre-feet)	In upper 50 feet (acre-feet)
T. 43 N.	6,400	17	1,100	55,000
T. 42 N.	27,000	17	4,700	240,000
T. 41 N.	30,000	19	5,700	280,000
T. 40 N.	33,000	17	5,800	290,000
T. 39 N.	46,000	15	7,000	350,000
T. 38 N.	40,000	17	6,700	340,000
T. 37 N.	28,000	18	5,100	260,000
Total (rounded)	210,000	17	36,000	1,800,000

EFFECTS OF MAN'S ACTIVITIES ON THE VALLEY-FILL RESERVOIR IN PARADISE VALLEY

Response to Spreading Surface Water for Irrigation

Land in Paradise Valley has been developed for agricultural purposes since the end of the 19th century. Prior to 1948 this development consisted primarily of diverting streamflow to irrigate crops or pasture. Consequently, water that formerly flowed to areas of evapotranspiration in the central or southern parts of Paradise Valley, or flowed out of the valley, was diverted and spread over fields in the northern part of the valley. This resulted in increased evapotranspiration and recharge (from irrigation water) in the northern part of the valley and a complementary reduction in evapotranspiration, recharge, and outflow in the southern part of the valley. Irrigation water has been diverted and spread for many years; consequently, ground-water gradients, water levels, and types of native vegetation have adjusted to accommodate these changes. The hydrologic system in Paradise Valley has approached a new state of equilibrium where the increased evapotranspiration in the irrigated areas is compensated for by reductions in natural evapotranspiration or surface outflow at the southern end of the valley.

Response to Pumping Ground Water

General Effects of Pumping

Prior to large-scale development by pumping, the ground-water reservoir was in an approximate state of equilibrium. Over the long-term, recharge equaled discharge and there was no net change in storage. Pumping initially creates an imbalance where pumping plus natural discharge exceeds recharge. Consequently, water is removed from storage. This storage depletion continues until resulting water-level declines are sufficient to change the pattern of ground-water flow and redirect water toward the wells. In most ground-water basins of the State this is accomplished primarily by reduction (salvage) of natural ground-water discharge. In Paradise Valley, however, pumping may induce additional recharge from streams and stream diversions as well as cause reductions in ground-water discharge. When combined reductions in discharge and additional induced recharge are equal to pumpage, the system may approach a new equilibrium. Although the system may approach a new equilibrium over the long term, the cyclic nature of pumping and seasonal and year-to-year variations in streamflow will result in short-term nonequilibrium conditions and consequent changes in ground-water storage. For example, heavy pumping during a dry year may result in storage depletions that will not be completely replenished until the next high runoff year. If pumping continually exceeds natural recharge plus the potential additional induced

recharge from streamflow, then no new quilibrium is possible. Water will be pumped from storage until the ground-water reservoir is depleted or pumping rates are reduced.

Response to Ground-Water Development, as of 1968

The exact manner in which the valley-fill reservoir will respond to pumping varies with the magnitude of pumping and the degree to which pumping is localized, as well as the location of pumping with respect to salvable natural discharge and recharging boundaries, such as streams.

Generally, moderate pumping in the northern and central parts of the valley would primarily affect streamflow and ground-water discharge with only temporary effects on storage because fall and winter streamflow is usually sufficient to resaturate any deposits dewatered by pumping. However, concentrated heavy pumping may also affect storage to the extent that economically undesirable depletions of spring runoff and reductions of summer ground-water evapotranspiration by native hay may occur. Pumpage in the southern end of the valley would initially be derived from storage. This will eventually cause decreases in evapotranspiration of ground water and subsurface outflow. Sustained heavy pumping at the southern end of the valley could eventually reverse the natural ground-water gradient and cause water to flow into the area from beneath the Humboldt River flood plain. Recharge during years of high runoff would tend to reduce the rate of water-level decline and net storage depletion at the southern end of the valley. Pumping along the sides of the valley away from streams and areas of natural discharge (such as the area east of Paradise Station) would result in water being withdrawn from storage until water levels decline sufficiently to reduce natural discharge or induce some additional recharge in the center of the valley.

The net decline in water levels due to pumping during the period 1948-68, as measured in the spring of 1968, (fig. 16) was considerably less than the seasonal net changes between March 1968 and November 1968 (fig. 17). The seasonal changes measured in 1968 are of about the same magnitude as the seasonal fluctuations in water levels during 1946 and 1947 (Loeltz and others, 1949, fig. 2 and p. 43).

Using the specific-yield distribution shown in figure 4, and the net declines shown in figure 16, net storage depletion due to a pumping draft of about 53,000 acre-feet (table 15) during the period spring 1948-spring 1968 (includes irrigation pumping during the 20 summer seasons, 1948-67) is estimated to be only about 1,500 acre-feet. The computed storage depletion of about 3 percent of the estimated net pumpage is also negligible when compared to possible errors in estimates. Moreover, the area of maximum water-level decline shown in figure 16 is

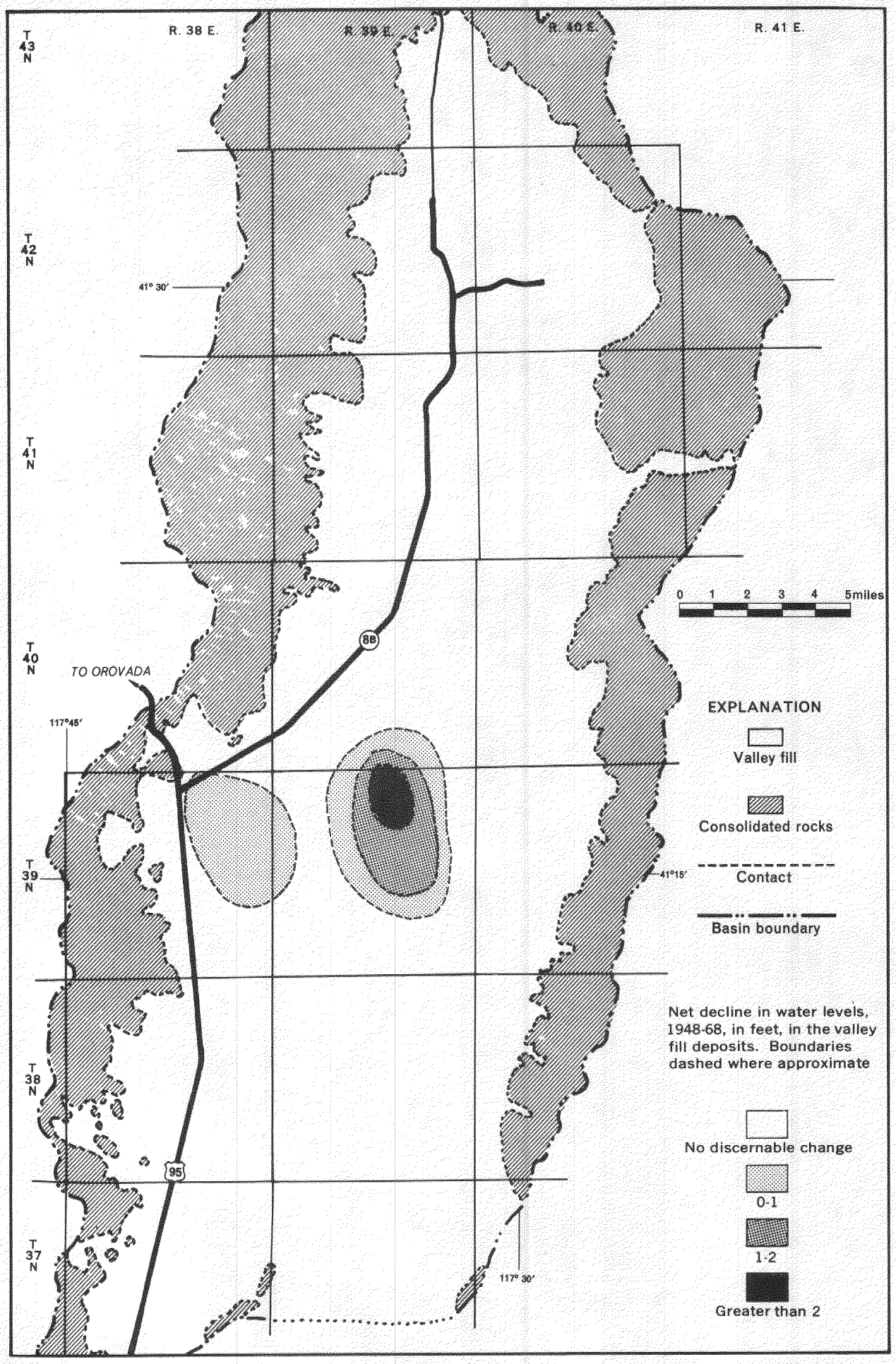

Figure 16. — Approximate net decline of water levels in Paradise Valley 1948-68

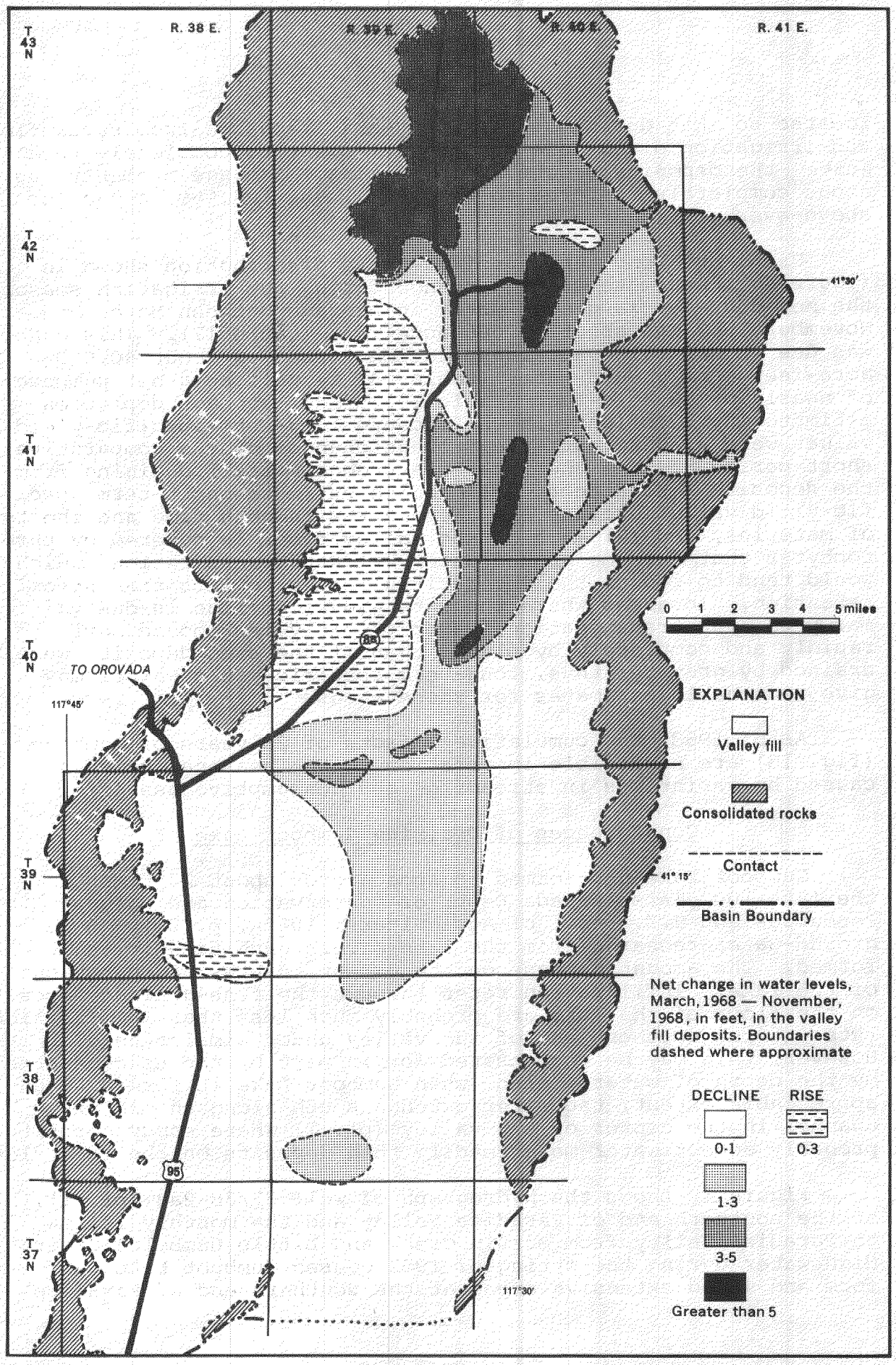

Figure 17. — Net change in water levels in Paradise Valley March, 1968 — November, 1968

located so that during high water years, recharge from streamflow and irrigation diversions may be sufficient to completely resaturate the deposits dewatered by pumping. Storage probably was about completely restored to the 1948 level in 1969, a year of above-average recharge.

Using the long-term specific-yield distribution shown in figure 4 to estimate storage change during the irrigation season, the net decrease in ground water in storage between March and November 1968 was about 50,000 acre-feet (table 17). This change was due to natural evapotranspiration losses of about 40,000 acre-feet from ground water (table 14) as well as a net pumpage of nearly 8,000 acre-feet (table 15). This storage depletion estimate may be slightly high, because long-term specific-yield values were used to estimate storage changes over a comparatively short period of time and water was probably still draining from the deposits. No attempt was made to estimate short-term specific-yield values because (1) they vary with both time and the type of material, and (2) much of the valley floor is covered by phreatophytes that consume ground water by evapotranspiration, which would tend to reduce the interstitial water to less than specific retention. In areas where the water-level decline is due primarily to evapotranspiration, water probably is removed more rapidly and completely by plants than if the same deposits were drained by gravity; thus, long-term specific-yield values may give reasonable estimates for these areas.

As of 1968, the cumulative effects of 20 years of pumping (fig. 16) are negligible in relation to the seasonal changes caused by variations in streamflow and consumptive use (fig. 17).

Consequences of Draining Gumboot Lake

Gumboot Lake has formed to some degree about 23 times in the last 100 years (Nevada Dept. of Conservation and Natural Resources and U.S. Dept. of Agriculture, 1962a, p. 22). Some ground-water recharge from the lake occurs each time it is formed. The amount depends on the extent, depth, and duration of the lake. Infiltration rates through the fine-grained deposits on the floor of the lake are probably much less than infiltration rates at the northern end of the valley under similar head. However, this may be compensated for in part by the head created by the depth of water. Also, when Gumboot Lake is formed to an appreciable extent, the water extends south along an old river channel in the center of the valley (pl. 1) where sandy deposits probably accept water more readily than deposits on the lake floor.

Figure 18 shows the hydrograph of well 37/38-2aa (pl. 1), at the southern end of Paradise Valley and the monthly inflow to Paradise Valley from Martin Creek and Little Humboldt River. High water during the spring of 1952 caused Gumboot Lake to form and flood extensive areas at the southern end of Paradise

Table 17.--Estimated seasonal change in storage, March 1968-November 1968

East-west strip bordered by township boundaries	Recoverable water per foot of storage[1] (acre-feet per foot)	Weighted average water-level decline[2] (feet)	Approximate storage change (acre-feet, rounded)
T. 43 N.	1,100	5.8	6,000
T. 42 N.	4,700	3.4	16,000
T. 41 N.	5,700	1.8	10,000
T. 40 N.	5,800	.9	5,000
T. 39 N.	7,000	1.2	8,000
T. 38 N.	6,700	.6	4,000
T. 37 N.	5,100	.5	3,000
Total (rounded)			50,000

1. As listed in table 16.

2. Determined from figure 17.

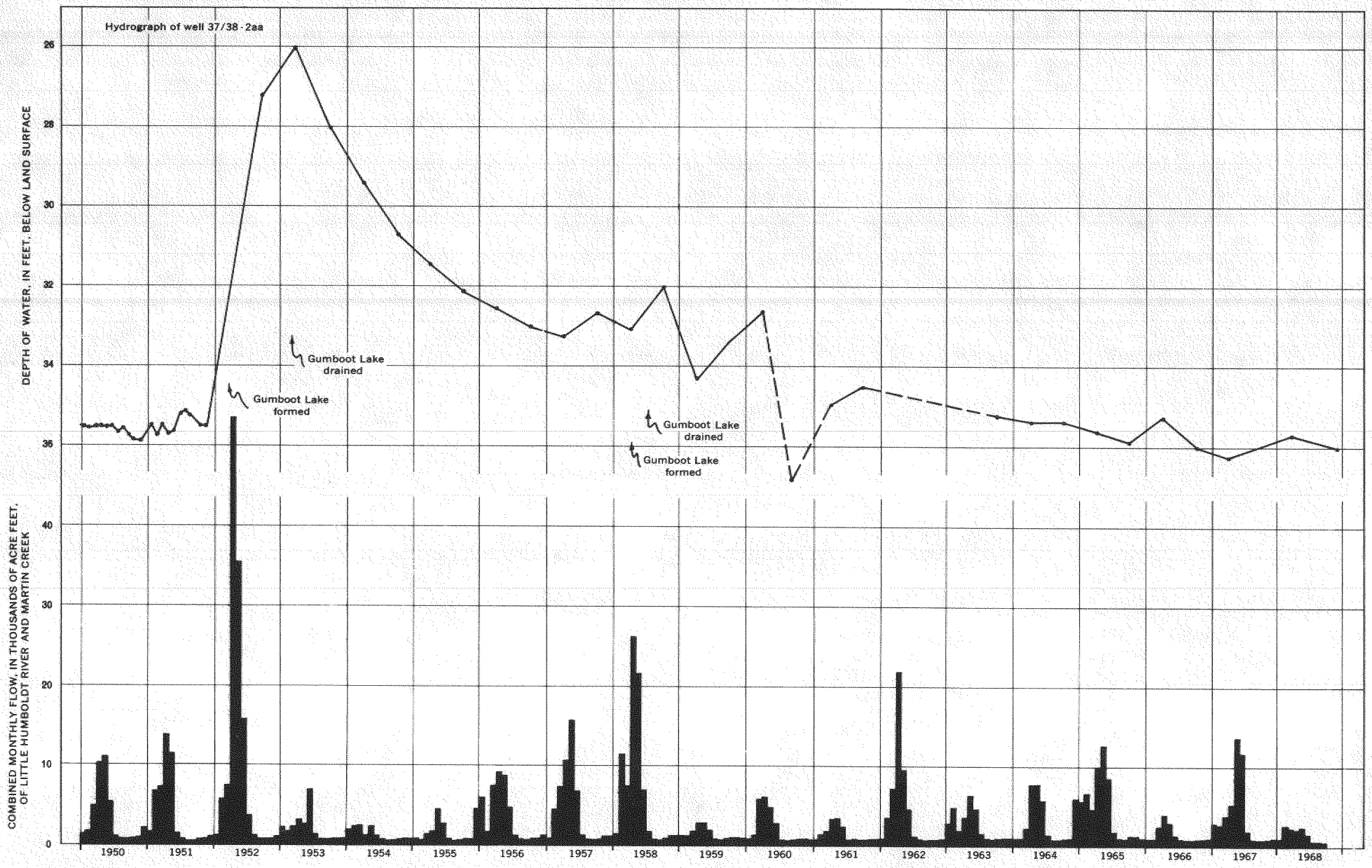

Figure 18. — Hydrograph of well 37/38-2aa and surface inflow to Paradise Valley

Valley. The lake did not break through the sand dunes and remained ponded until the spring of 1953 when a channel was dredged and the lake drained. Sufficient recharge occurred during this time to raise the water level in well 37/38-2aa more than 10 feet. The slow sustained decline in water levels following 1953 represents gradual drainage to Humboldt River and consumption by phreatophytes. Gumboot Lake also formed as a result of high water in April and May 1958; however, this time the channel through the dunes was dredged in June and July and the lake was drained very shortly after it was formed. Consequently, there was only minor recharge. Not shown is the ponding and draining that occurred in the 1969 water year.

In 1952-53, there was significant recharge from Gumboot Lake. Field observation of high-water marks (evidenced principally by dead vegetation) suggest that the water-surface altitude of the lake was about 4,320 feet, and covered an area of about 10,000 acres, and may have averaged 4 to 5 feet deep. The lake extended north as far as well 38/39-4bb (pl. 1), which is reported to have been flooded through March 1953. A measurement made in September 1953 indicated that the water level in this well was about a foot above the last measurement made in November 1951. Recharge from Gumboot Lake during this period is estimated by assuming an average water-level rise of 5 feet beneath the 10,000-acre surface of the lake, and an average specific yield of about 12 percent (fig. 4). Assuming that virtually all of the local water-level rise is attributable to recharge from the lake, local recharge during 1952-53 is estimated at about 6,000 acre-feet. This estimate may be low, because there was probably some additional recharge in the central part of Paradise Valley east of the sand dunes (pl. 1) along about 5 miles of an old abandoned channel where water also was ponded. Alluvium in this area is sandy, so significant additional recharge may have occurred. If the lake had not been drained in March 1953, recharge would have continued and ultimately may have been as much as 10,000 acre-feet.

Because Gumboot Lake forms to some degree only about once in 5 years and there are large accumulations of water only about once in 15 years, average annual recharge from Gumboot Lake (with no artificial drainage) is small, perhaps about 1,000 acre-feet. However, as evidenced in 1958, rapid artificial draining of the lake greatly reduces the time for recharge to occur. Consequently, future recharge from Gumboot Lake may be negligible. This would reduce the total estimate of recharge by only about 2½ percent. However, water levels at the southern end of the valley may decline more rapidly in response to pumping than if occasional recharge from Gumboot Lake continued to occur in the future.

WATER BUDGETS

Table 18 contains water budgets for Paradise Valley; table 19 contains water budgets for Little Humboldt Valley and Hardscrabble Area. The budgets were prepared to illustrate relations between the several elements of inflow and outflow in each area, to point out the magnitudes of the differences in estimates, and to select a value representative of the average annual inflow and outflow in each area. Imbalances in the budgets result from either errors in individual estimates or from unresolved hydrologic factors.

In Paradise Valley the principal effect of 20 irrigation seasons of pumping has been to reroute some water through wells that otherwise would have been consumed by evapotranspiration elsewhere in the valley. This is illustrated in the 20-year budget where estimated storage depletion due to pumping is negligible when compared to the imbalances in the estimates of inflow and outflow. The estimated long-term average annual inflow was considered more representative of both inflow and outflow than the estimated long-term average outflow, which was based largely on the distribution of vegetation as mapped in 1968.

There has been virtually no development by pumping ground water in Little Humboldt Valley and Hardscrabble Area. Consequently, the systems are in a state of approximate equilibrium where over the long term, inflow to the system equals outflow and there is no net change in ground-water storage. For example, the total inflow of 27,000 acre-feet per year in Little Humboldt Valley should ideally equal the estimated total outflow of 26,000 acre-feet.

Table 18.--Water budget, in acre-feet, for Paradise Valley

(All values estimated as described in text)

Budget item	20-year period, spring 1948-spring 1968 Total	Average annual	Long-term average annual
INFLOW			
Runoff generated in Paradise Valley (table 9)	660,000	33,000	30,000
Surface inflow			
from Little Humboldt Valley (table 13, p. 58)	340,000	17,000	17,000
from Hardscrabble Area (table 13, p. 58)	480,000	24,000	22,000
Flow across alluvium-bedrock contact (p. 62)	a 20,000	a 1,000	1,000
Total (rounded): (1)	1,500,000	75,000	70,000
OUTFLOW			
Evapotranspiration (table 14)			
Surface water	b 620,000	b 31,000	b 31,000
Ground water[1/]	b 800,000	b 40,000	b 40,000
Surface outflow (p. 70)	58,000	2,900	2,000
Subsurface outflow (p. 70)	70,000	3,500	3,500
Total (rounded): (2)	1,540,000	77,000	76,000
IMBALANCE: (1) - (2) = (3)	-40,000	-2,000	-6,000
STORAGE DEPLETION: (p. 76): (4)	-1,500	-100	0
DIFFERENCE BETWEEN METHODS: (3) - (4)	-38,500	-1,900	-6,000
VALUE SELECTED TO REPRESENT INFLOW AND OUTFLOW	--	--	70,000

a. Based on long-term average.

b. Based on distribution of irrigated cropland and phreatophytes as mapped in 1968.

1. Includes net pumpage of 53,000 acre-feet for the 20-year period.

Table 19.--Water budget for near-natural conditions in Little Humboldt Valley and Hardscrabble Area

Budget item	Acre-feet per year
LITTLE HUMBOLDT VALLEY[1]	
INFLOW	
Runoff (table 9)	25,000
Flow across bedrock-alluvial contact (p. 62)	2,000
Total (rounded): (1)	27,000
OUTFLOW	
Evapotranspiration (table 14)	
Surface water	4,600
Ground water	4,000
Surface outflow (fig. 7)	17,000
Subsurface outflow (table 13)	300
Total (rounded): (2)	26,000
IMBALANCE: (1) - (2)	+1,000
VALUE SELECTED TO REPRESENT INFLOW AND OUTFLOW	26,000
HARDSCRABBLE AREA[2]	
INFLOW	
Runoff (table 9)	24,000
Total (rounded): (1)	24,000
OUTFLOW	
Evapotranspiration of surface and ground water along stream channel (table 14)	300
Surface outflow (fig. 7)	21,900
Subsurface outflow (table 13)	Trace
Total (rounded): (2)	22,000
IMBALANCE: (1) - (2)	+2,000
VALUE SELECTED TO REPRESENT INFLOW AND OUTFLOW	22,000

1. Budget for Little Humboldt Valley is for the valley-fill reservoir in Eden Valley and the lower reaches of the north fork and south fork.

2. There is no significant alluvial ground-water reservoir in Hardscrabble Area; budget compares estimated total runoff with gaged outflow.

THE AVAILABLE WATER SUPPLY

The available water supply in Little Humboldt Valley, Hardscrabble Area, and Paradise Valley can be expressed in terms of: (1) the system yield, (2) the quantity of stored ground water which will be withdrawn from storage prior to attaining the system yield, and (3) the probable future development and its relation to the available supply. These are discussed in the following sections.

System Yield

The yield of a hydrologic system has been defined as the maximum amount of surface and ground water of suitable chemical quality that can be obtained economically and legally each year from sources within the system for an indefinite period of time (Worts and Malmberg, 1967, p. 37). The system yield cannot be more than the inflow to or outflow from a system; it ultimately is limited to the maximum amount of surface-water, ground-water, and water-vapor discharge that can be salvaged each year for beneficial use.

For purposes of this report, flow from Little Humboldt Valley and Hardscrabble Area into Paradise Valley is considered part of the system yield of Paradise Valley, as that is where most of the future development probably will be located. Yield in the two tributary areas is estimated as that water in excess of outflow to Paradise Valley that could be economically developed for an indefinite period of time.

In the event that reservoirs are constructed in either Little Humboldt Valley or Hardscrabble Area, the distribution of water between the upstream areas and Paradise Valley may be changed; however, the total quantity of water available would be reduced by the increased evaporation from the water surfaces of the reservoirs.

The average annual outflow from Little Humboldt Valley consists primarily of about 17,000 acre-feet of streamflow to Paradise Valley (fig. 7) and about 8,500 acre-feet of evapotranspiration by hay, pasture, and phreatophytes (table 14). If phreatophytes were replaced by beneficial vegetation where land and soil conditions permitted, as much as 8,000 acre-feet per year of beneficial discharge may be obtained without reducing outflow to Paradise Valley. Thus, although about 26,000 acre-feet per year of water is generated in Little Humboldt Valley (table 19), only about 8,000 acre-feet per year could be developed without reducing the yield of Paradise Valley.

All but a small amount of water generated in Hardscrabble Area flows to Paradise Valley. An arbitrary yield in this area is only about 100 acre-feet per year. Development in excess of this amount would reduce the yield of Paradise Valley.

Long-term average inflow to and outflow from Paradise Valley is about 70,000 acre-feet per year (table 18). As of 1968, about 45,000 acre-feet per year was being used to a moderate or high degree of benefit (table 14). Probably not all of the 70,000 acre-feet per year could be converted to beneficial use. The part that probably could not be converted includes evapotranspiration by willow and buffaloberry along major streams and along irrigation diversions in the northern part of the valley, some of the evaporation from Gumboot Lake and the bare soil of the lake bottom, and some of the phreatophytes growing at the southern end of the valley. It is not considered feasible to salvage all phreatophyte discharge at the southern end of the valley by pumping, as water-level declines sufficient to eliminate all consumption of ground water by phreatophytes would also reverse the ground-water gradient and divert water already appropriated from beneath the flood plain of Humboldt River into Paradise Valley. However, if the natural gradient out of the valley were reduced nearly to zero by pumping in the southern end of the valley, then subsurface outflow of about 3,500 acre-feet per year (table 18) could be salvaged for use in the valley.

Surface outflow from the valley cannot be entirely salvaged without the construction of extensive upstream storage facilities. Pumping should increase infiltration demands from streams and thus reduce the amount of water that reaches Gumboot Lake during high water years. However, during flood, large quantities of water would still reach Gumboot Lake and drain to Humboldt River. The average annual surface-water outflow to Humboldt River of about 2,000 acre-feet (table 18) may be reduced by about 50 percent due to increased infiltration demands in the central and northern part of the valley.

System yield in Paradise Valley is estimated as the 45,000 acre-feet per year now being used plus 3,500 acre-feet per year of subsurface outflow, 1,000 acre-feet per year of surface outflow, and about 10,000 acre-feet per year of low benefit evapotranspiration in the southern part of the valley, or a total of about 60,000 acre-feet per year. This is about 85 percent of the estimated average annual inflow.

Storage Depletion

No ground-water source can be developed without causing some storage depletion. The magnitude of potential depletion in Paradise Valley is considered below in relation to concepts of transitional storage reserve, system yield under near equilibrium conditions, and conjunctive use.

Transitional storage reserve has been defined by Worts (1968, p. 50) as the quantity of water in storage in a ground-water reservoir that can be extracted and beneficially used

during the transition period between equilibrium conditions in a state of nature and the new equilibrium conditions under the perennial yield (or system yield) concept of ground-water development. Thus, the transitional storage reserve is a specific amount of the total ground water in storage; it is water in addition to and developed along with the long-term amount provided by the recharge.

Transitional storage reserve is generally computed assuming an idealized distribution of pumping. The storage depletion thus calculated includes the assumption that all natural discharge will be salvaged as efficiently as possible and that the resulting water-level declines will be as small as possible. The transitional storage reserve, in this sense, is primarily a property of the ground-water reservoir. A more extensive discussion of transitional storage reserve in relation to ground-water development and perennial yield has been given by Worts (1968).

Ground-water development in Paradise Valley will affect both streamflow and natural ground-water discharge. Salvage of all natural ground-water discharge by pumping requires that a significant part of the surface flow be diverted to ground water and then utilized by pumping. However, because much of the surface flow is used to irrigate hay and pasture, it probably would be undesirable to divert all this surface water to ground water. Consequently, two estimates of storage depletion are developed in this report. Estimate (A) is that of the transitional storage reserve which assumes that all natural ground-water discharge, as well as most of the streamflow currently used for surface-water irrigation, would be diverted to wells. The second estimate (B) is of the storage depletion that would result if ground-water development is strategically located so as to salvage only as much natural ground-water discharge as possible without significantly effecting streamflow at the northern end of Paradise Valley or inducing any significant underflow into the area from beneath the flood plain of Humboldt River. In both cases, system yield would be developed by use of both surface and ground water; however, pumping in the first case would be at a higher rate than the second case.

The following assumptions are made to obtain estimates: (1) In case A, wells would be situated throughout the valley in, near, and around areas of natural discharge so that evapotranspiration could be stopped and subsurface outflow reduced with a minimum of water-level drawdown in pumped wells. In case B, pumping in the northern part of the valley would be sparse and would be primarily to supplement surface-water use. Heaviest pumping would be in T. 38 N., Rs. 38 and 39 E., where water-level declines could salvage much of the ground-water evapotranspiration in the southern half of Paradise Valley and reduce subsurface outflow and yet would have only small effects on streamflow and summer consumption of shallow ground water in T. 40 N., R. 39 E.

(2) A perennial water level, 50 feet below land surface, would eliminate virtually all evapotranspiration from ground water; ground-water consumption by grasses would be virtually eliminated by a perennial water level at least 12 feet below land surface.

(3) In case A, over the long term, natural evapotranspiration plus pumping at a net rate equal to system yield (60,000 acre-feet per year) would cause a moderately uniform depletion of storage throughout most of the valley fill. In case B, supplemental pumping in the northern half of the valley would not be large enough to cause permanent lowering of water levels there. However, pumping in the southern part of the valley at a net rate about equal to the potentially salvable natural discharge south of T. 40 N. (about 15,000 acre-feet per year), would result in water levels ultimately being lowered to 40 or 50 feet below land surface in T. 38 N., Rs. 38, 39, and 40 E. At that time, ground-water evapotranspiration by saltgrass would be eliminated and consumption by rabbitbrush and greasewood greatly reduced. Subsurface outflow from the area would be eliminated. Average water-level declines would range from nearly 10 feet in the southern part of T. 40 N., R. 39 E., to about 40 feet in the southern part of T. 39 N., R. 39 E., and the northern part of T. 38 N., R. 39 E. Average weighted declines for the units listed in table 17 would be about 2 feet in T. 40 N., Rs. 38, 39, and 40 E., 30 feet in T. 39 N., Rs. 38, 39, and 40 E., and 10 feet in T. 37 N., Rs. 38, 39, and 40 E.

(4) Specific-yield values of the dewatered interval would be about the same as those shown in figure 4.

(5) The water levels would remain in the range of economic lift for the intended use.

(6) Pumping would not divert water from adjacent Humboldt River Valley into the area.

(7) The water would be of suitable quality for the desired use.

Table 20 summarizes the estimates of storage depletion. If the area were fully developed on the basis of conjunctive use of surface and ground water (case B) the ultimate result would be the permanent removal of about 470,000 acre-feet of stored ground water (largely in the southern part of the valley) plus temporary storage depletion in the northern half of the valley during dry periods when ground water is pumped because the surface-water supply is insufficient. The depleted storage in the northern half of the valley would be replenished during wet years. This storage depletion would be only about one-third of the depletion that would result if the system yield were developed primarily by pumping ground water.

Table 20.--Estimated storage depletion that would result from two hypothetical patterns of development

Estimate	Area affected (acres) (1)	Water-level decline (feet) Range	Water-level decline (feet) Weighted average (2)	Average specific yield1/ (percent) (3)	First approximation (acre-feet, rounded) (1)x(2)x(3)
(A) Storage depletion if system yield were developed by pumping ground water.	a 211,000	40	40	17	1,500,000
(B) Storage depletion if system yield were developed by pumping ground water to supplement existing use of surface water.	b 147,000	0-40	20	16	470,000

1. Determined from figure 4.

a. Valley-fill storage unit shown in figure 4.

b. Valley-fill reservoir south of the north boundary of T. 40 N.

Considerable time would be required to approach equilibrium conditions in both cases. The exact time cannot be estimated in Case A, as pumping would initially take water primarily from streamflow and cause only small changes in storage. However, in Case B, where there would be minimal effects on streamflow, it is possible to assume uniform rates of storage depletion and salvage of natural discharge so that the annual pumpage (Q) and the time in years (t) during which depletion would take place can be approximated from the following equation:

$$Q = \frac{\text{Storage depletion}}{t} + \frac{\text{Salvaged discharge}}{2}$$

Using (1) the estimated storage depletion of 470,000 acre-feet (table 20, case B), (2) the estimated salvable discharge of 15,000 acre-feet, and (3) a pumping rate equal in quantity to the estimated salvable discharge, the time (t) to deplete the storage is computed to be roughly 60 years.

Thus, the development in case B predicates an average annual pumpage of about 15,000 acre-feet in the valley south of the north boundary of T. 40 N., and conjunctive use of surface-water diversions and supplemental ground-water pumpage totaling about 45,000 acre-feet per year north of that line.

Future Development

Undeveloped Water

The area has been developed for agricultural purposes for many years. As of 1968, beneficial consumption of water averaged about 6,000 acre-feet per year in Little Humboldt Valley (table 14), about 50 acre-feet per year in Hardscrabble Area (table 1), and about 45,000 acre-feet per year in Paradise Valley (table 14). Assuming that development will not exceed the system yield, then water not used as of 1968 is about 2,000 acre-feet per year in Little Humboldt Valley, 50 acre-feet per year in Hardscrabble Area, and about 15,000 acre-feet per year in Paradise Valley (most of which is in the southern part of the valley.)

In Little Humboldt Valley, development of this water would involve eliminating low-benefit evapotranspiration. Any pumping would have to be strategically located so as to affect primarily this low-benefit evapotranspiration with little effect on the existing irrigation use of water or on outflow to Paradise Valley. This would be difficult to do; thus, the most feasible means of utilizing the full system yield may be to attempt to replace low-benefit vegetation with high-benefit vegetation without pumping.

In Paradise Valley, future development for agricultural purposes probably will involve (1) improvement of facilities to

distribute surface water, and (2) additional pumping of ground water. This should improve the dependability of the supply and should salvage water now consumed by low-benefit evapotranspiration. Most of the estimated 15,000 acre-feet per year of unused water would be utilized if all existing permits to irrigate solely by pumping ground water were exercised.

Conjunctive Use

As of 1968, conjunctive use of surface and ground water seems to be the most feasible means of attaining the system yield in Paradise Valley. Under the general concept of conjunctive use, a quantity of water equal to the system yield is beneficially used each year. During average and wet years, most of the water used is derived from streamflow. During dry years when streamflow is inadequate to supply the system yield, ground water is pumped until the system yield is attained. This results in a temporary depletion of ground water in storage during dry years which is replenished by excess water during subsequent wet years.

In Paradise Valley, perennial pumpage of about 15,000 acre-feet per year in the southern half of the valley would utilize ground water otherwise discharged in the southern part of the valley. In the northern part of the valley, pumping would vary according to the availability of streamflow. During average and wet years, pumpage probably would not exceed 5,000 acre-feet; however, during prolonged dry periods, such as a several-year drought, as much as 40,000 acre-feet per year may have to be pumped to supplement below-average surface-water supplies. Pumping at such a rate for several years would result in a significant depletion of stored ground water. Consequently, streamflow and beneficial evapotranspiration of ground water would be effected to some degree. During subsequent wet years, however, above-average streamflow would replenish the ground-water reservoir and streamflow losses and evapotranspiration of ground water by native hay would be approximately the same as before the drought.

Decreed surface-water rights in Paradise Valley of about 120,000 acre-feet per year exceed the estimated system yield. Under the existing pattern of development, all rights are fully satisfied only during high water years. During average and below-average years, the available water is distributed according to priorities established in the E. P. Carville Decree of 1935. Development of system yield through conjunctive use of surface and ground water would result in the beneficial consumption of about 60,000 acre-feet of water each year. However, because the concept of conjunctive use requires that the water pumped from storage during dry years be replenished by above-average infiltration of streamflow during wet years, some water which formerly satisfied low-priority water rights during wet years would replenish storage or satisfy higher-priority rights until the ground-water reservoir was replenished.

Increased Domestic Use

Domestic use of ground water should increase in the future after more of the privately owned land in Paradise Valley has been developed for tract homes or 1- to 5-acre homesites. However, if domestic use increases several fold during the next 10 to 20 years, it would still remain a comparatively minor element in the hydrologic budget of the area.

Surface-Water Storage

The existing National Forest in the Santa Rosa Range area has great potential for recreational development. It is possible that future demands for water-based recreation would justify construction of reservoirs in either Little Humboldt Valley or Hardscrabble Area that previously could not be justified solely on the basis of flood control and storage of irrigation water. Construction of storage facilities upstream from Paradise Valley would greatly affect the distribution of flow into the valley and, depending on the size of the reservoir, could also affect the quantity of inflow to the valley.

NUMBERING SYSTEM FOR WELLS AND SPRINGS

The numbering system for wells and springs in this report is based on the rectangular subdivisions of the public lands, referenced to the Mount Diablo base line and meridian. It consists of three units: the first is the township north of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; and the third unit, separated from the second by a dash, lists the section number followed by two letters that designate the quarter section, and the quarter-quarter section, respectively. The northeast quarter of a subdivision is designated by the letter a, the northwest quarter by the letter b, the southwest quarter by the letter c, and the southeast quarter by the letter d. Following the letters, a number indicates the order in which the well or spring was recorded within the 10-acre subdivision. For example, well 37/38-2aa1 is the first well recorded in the NE¼NE¼ sec. 2, T. 37 N., R. 38 E., Mount Diablo base line and meridian.

Because of the limitation of space, wells and springs are identified on plates only by that part of the number which designates the subdivision of the section and, if two or more wells are in one subdivision, the order in which the well or spring was recorded in that section. Township and range numbers are shown along the margins of the area on the plate.

Table 21.--Streamflow measurements

Stream name	Location	Map no.	Date	Discharge (cfs)
North Fork Little Humboldt River	45/41-19a	1	9-25-67	0.30
Unnamed tributary	45/41-16a	2	9-25-67	0.16
North Fork Little Humboldt River	44/42-16c	3	9-25-67	1.75
North Fork Little Humboldt River	42/43-28c	4	9-24-67	2.46
North Fork Little Humboldt River	41/43-18b	5	9-24-67	3.97
			5-28-68	5.54
South Fork Little Humboldt River	41/45-16a	6	9-24-67	1.46
South Fork Little Humboldt River	42/44-35c	7	9-24-67	2.20
Milligan Creek	42/45-7c	8	9-24-67	0
South Fork Little Humboldt River	41/43-20b	9	9-24-67	0.05
			5-28-68	1.02
Little Humboldt River	41/42-36b	10	9-24-67	0.45
			5-27-68	6.28
Eden Creek above Little Humboldt River	41/41-36c	11	9-24-67	0
Little Humboldt River	41/41-26cb	12	5-28-68	4.66
Little Humboldt River	41/40-13dd	13	5-28-68	9.97
Cabin Creek	44/40-5b	14	9-25-67	0.23
Dutch John Creek	44/40-8c	15	9-25-67	0.19
Martin Creek	43/41-21a	16	9-25-67	2.51
Little Humboldt River	40/40-19a	17	9-23-67	1.60
			1-18-68	1.44
			2-21-68	1.10
			3- 5-68	1.13
			3-21-68	1.04
			4-17-68	3.72
			5-27-68	2.54
			6-18-68	3.69
			7- 9-68	1.10
			8-21-68	0
			10- 2-68	0.43

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Little Humboldt River	39/39-14d	18	9-23-67	0
			1-18-68	0.11
			2-21-68	0.68
			3- 5-68	0.08
			3-21-68	0.20
			4-17-68	0
			5-27-68	0
			6-18-68	0.15
			7- 9-68	0
			8-21-68	0.13
			10- 2-68	0
Irrigation ditch	39/39-14c	19	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0.45
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Martin Creek	42/40-28d	20	9-23-67	0
			1-18-68	0
			2-25-68	16.8
			3- 5-68	16.8
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Martin Creek diversion	42/40-28d	21	9-23-67	2.69
			1-18-68	4.13
			2-25-68	15.9
			3- 5-68	6.86
			3-21-68	11.4
			4-17-68	10.5
			5-27-68	18.6
			6-18-68	8.25
			7- 9-68	0.85
			8-21-68	3.87
			10- 2-68	4.22

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Martin Creek	41/40-19d	22	9-23-67	0
			1-18-68	1.05
			2-21-68	6.13
			3- 5-68	7.16
			3-21-68	2.89
			4-17-68	3.18
			5-27-68	1.35
			6-18-68	0
			7- 9-68	0
			8-21-68	0.67
			10- 2-68	1.12
Unnamed tributary	41/40-20d	23	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Martin Creek	40/39-24c	24	9-23-67	0
			1-18-68	0
			2-21-68	1.22
			3- 5-68	0.74
			3-21-68	0.28
			4-17-68	0.05
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Irrigation ditch	40/39-24c	25	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0.38
			4-17-68	0.09
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Unnamed tributary	40/39-23d	26	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0.13
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Indian Creek	43/39-13cb	27	9-23-67	0
			1-18-68	0.67
			3- 5-68	8.23
			3-21-68	3.10
			4-17-68	5.00
			5-27-68	5.70
			6-18-68	1.70
			7- 9-68	0.40
			8-21-68	0
			10- 2-68	0
Indian Creek	42/40-19d	28	9-23-67	0
			1-18-68	0
			2-25-68	4.13
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Mullinex Creek	43/39-35a	29	3- 4-68	8.21
			3- 6-68	6.10
			7-10-68	0.05
			10- 2-68	0
Mullinex Creek	43/39-35db	30	9-24-67	0
			3- 4-68	6.46
			3- 6-68	6.34
			7-10-68	0
			10- 2-68	0
Coleman Creek	43/39-26da	31	3- 4-68	0.81
			7-10-68	0
			10- 2-68	0

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Coleman Creek	43/39-36cb	32	9-24-67	0
			3- 4-68	0.67
			7-10-68	0
			10- 2-68	0
Mullinex Creek	43/39-36cb	33	9-24-67	0
			1-18-68	0.28
			2-25-68	22.2
			3-21-68	2.54
			4-17-68	5.04
			5-27-68	2.78
			6-18-68	0.61
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Unnamed tributary	42/39-11ac	34	9-24-67	0
			1-18-68	0
			2-25-68	0.50
			3- 5-68	0.23
			3-21-68	0.05
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Cottonwood Creek	42/39-3c	35	9-24-67	0.88
			1-18-68	1.60
			2-25-68	14.5
			3- 5-68	9.41
			3-21-68	5.49
			4-17-68	9.60
			5-27-68	8.51
			6-18-68	4.66
			7- 9-68	1.96
			8-21-68	1.68
			10- 2-68	1.95
Little Cottonwood Creek	42/39-8dc	36	9-26-67	0.06
			3- 6-68	2.14
			5-28-68	2.49
			7-10-68	0.96
			10- 2-68	0.22

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Lamance Creek	42/39-17db	37	3- 6-68	0.39
			5-28-68	0.36
			7-10-68	0.24
			10- 2-68	0.04
Lamance Creek	42/39-16cb	38	3- 6-68	0.51
			7-10-68	0.08
			10- 2-68	0
Lamance Creek	42/39-16ad	39	3- 6-68	0.37
			7-10-68	0
			10- 2-68	0
North Fork Hanson Creek	42/39-21dd	40	3- 7-68	0.64
			5-28-68	0.96
			7-10-68	0.32
			10- 2-68	0
South Fork Hanson Creek	42/39-21dd	41	3- 7-68	0.27
			5-28-68	0.06
			7-10-68	0
			10- 2-68	0
Irrigation ditch	42/39-26bd	42	9-24-67	0
			1-18-68	1.26
			2-25-68	3.83
			3- 5-68	2.50
			3-21-68	0.64
			4-17-68	0.30
			5-27-68	0
			6-18-68	0
			7-10-68	0
			8-21-68	0
			10- 2-68	0
Cottonwood Creek	42/39-25b	43	9-23-67	0.45
			1-18-68	0.24
			2-25-68	31.7
			3- 5-68	3.16
			3-21-68	2.18
			4-17-68	6.72
			5-27-68	5.61
			6-18-68	3.08
			7- 9-68	0.23
			8-21-68	0.13
			10- 2-68	0.14

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Adams Slough	42/40-28b	44	9-23-67	0
			1-18-68	0
			2-25-68	22.8
			3- 5-68	1.48
			3-21-68	0.80
			4-17-68	4.50
			5-27-68	4.82
			6-18-68	1.43
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Singas Creek	42/39-33db	45	3- 7-68	1.91
			5-28-68	3.55
			7-10-68	1.40
			10- 2-68	0.34
Cottonwood Creek	41/40-19c	46	9-23-67	0
			1-18-68	0
			2-21-68	77.2
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Abel Creek	41/38-12cb	47	9-24-67	0.42
Unnamed tributary	41/38-12cb	48	9-24-67	0.02
Stonehouse Creek	41/39-20ad	49	9-24-67	0.50
			3- 4-68	5.77
			3- 7-68	3.96
Stonehouse Creek	41/39-21dd	50	1-18-68	0.22
			2-21-68	31.2
			3- 4-68	4.42
			3- 7-68	4.52
			3-21-68	1.82
			4-17-68	3.48
			5-28-68	3.70
			6-18-68	0.76
			7-10-68	0.55
			8-21-68	0.22
			10- 2-68	0.15

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Wash O'Neal Creek	41/39-30ca	51	9-24-67	0.67
			1-18-68	0.81
			2-21-68	24.8
			3-21-68	1.95
			4-17-68	2.56
			5-28-68	1.58
			6-18-68	0.70
			7-10-68	0.46
			8-21-68	1.29
			10- 2-68	1.15
Wash O'Neal Creek	41/39-28cc	52	9-24-67	0.63
			3- 3-68	4.39
			3- 6-68	3.77
			7-10-68	0.15
Wash O'Neal Creek	41/39-34cb	53	9-24-67	0
			3- 3-68	3.72
			3- 6-68	3.11
			7-10-68	0
			10- 2-68	0
Wash O'Neal Creek	40/39-10aa	54	9-24-67	0
			3- 3-68	2.10
			3- 6-68	1.62
			7-10-68	0
			10-2-68	0
Provo Canyon	40/38-1ba	55	9-24-67	0
			3- 3-68	0.72
			7-10-68	0
			10- 2-68	0
Provo Canyon	41/39-31dc	56	9-24-67	0.03
			3- 3-68	1.37
			5-28-68	0.20
			7-10-68	0.05
			10- 2-68	0.07
Provo Canyon	40/39-5bd	57	9-24-67	0
			3- 3-68	1.58
			7-10-68	0
Provo Canyon	40/39-4dc	58	9-24-67	0
			3- 3-68	0.94
			7-10-68	0
			10- 2-68	0
Provo Canyon	40/39-10ac	59	9-24-67	0
			3- 3-68	0.63
			7-10-68	0
			10- 2-68	0

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Cottonwood Creek	40/39-26bb	60	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Irrigation ditch	39/39-16cc	61	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Irrigation ditch	39/39-15d	62	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
Irrigation ditch	39/39-17d	63	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0

Table 21.--Streamflow measurements--Continued

Stream name	Location	Map no.	Date	Discharge (cfs)
Little Humboldt River	38/39-17d	64	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0
China Garden Creek	38/38-8dc	65	9-26-67	0.04
			3- 4-68	0.04
			7-10-68	0
China Garden Creek	38/38-17ad	66	9-26-67	0.03
			1-18-68	0
			2-21-68	0.54
			3- 4-68	0.04
			3-21-68	0.04
			6-18-68	0.02
			7-10-68	0
			8-21-68	0.01
			10- 2-68	0.02
Piute Creek	38/38-18dd	67	9-26-67	0
			3- 4-68	0
			7-10-68	0
			10- 2-68	0
Piute Creek	38/38-20ab	68	9-26-67	0.01
			3- 4-68	0
			7-10-68	0
			10- 2-68	0
Little Humboldt River	37/38-21d	69	9-23-67	0
			1-18-68	0
			2-21-68	0
			3- 5-68	0
			3-21-68	0
			4-17-68	0
			5-27-68	0
			6-18-68	0
			7- 9-68	0
			8-21-68	0
			10- 2-68	0

Table 22.--Records of selected wells

Owner: USGS, U.S. Geological Survey, testhole; BLM, Bureau of Land Management
Use: D, domestic; I, irrigation, M, mining; O, observation; S, stock; U, unused
Specific capacity: In gallons per minute (gpm) per foot of drawdown; R, reported
Altitude: Determined from topographic maps
Water-level measurements: Depth, in feet, below land-surface datum; +, water stands above land surface, well may flow; R, reported by driller
Remarks: Dis, discharge; Des, destroyed; SLN, State log number, from the files of the State Engineer

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
37/38-2aa	Toll House Well	--	79	6	O	--	--	4,334	2-26-68	35.78	
									4-27-68	35.80	
									11- 6-68	36.07	
-21dd	USGS	--	--	--	--	--	--	--	--	--	Des.
-22dd	USGS	1959	35	1¼	O	--	--	4,323	2-26-68	26.09	
									11- 5-68	26.75	
-24ac	USGS	1960	38	1¼	O	--	--	4,317	2-26-68	21.07	
									11- 5-68	21.35	
-34ab	USGS	1959	10	1¼	O	--	--	4,291	2-26-68	2.22	
									11- 5-68	4.33	
37/39-3dc	--	--	61	6	S	--	--	4,330	2-26-68	+	Flows about 2 gpm Temperature 158°
-12cb	USGS	1968	52	1½	O	--	--	4,334	11- 5-68	37.86	
-15cb	USGS	1968	30	1½	O	--	--	4,326	11- 5-68	24.45	
-19aa	USGS	1959	30	1¼	O	--	--	4,323	2-26-68	25.20	
									11- 5-68	25.51	
-24bc	--	--	46	--	S	--	--	4,334	2-26-68	30.91	
									11- 5-68	31.22	
-30dd	USGS	1959	23	1¼	O	--	--	4,311	2-26-68	14.87	
									11- 5-68	15.22	
-34ca	USGS	1959	28	1¼	O	--	--	4,322	2-26-68	18.60	
									11- 5-68	19.15	
37/40-18ad	USGS	1968	67	1½	O	--	--	4,358	11- 5-68	54.44	
-32bb	USGS	1960	39	1¼	O	--	--	4,346	2-26-68	36.79	
									11- 5-68	36.95	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
38/38-36ac	Kinney, James	1958	--	--	S,D	--	--	4,337	2-26-68	36.17	
									11- 6-68	37.05	
-36ad	Kinney, James	1968	240	16	I	27 R	--	4,328	4-28-68	23 R	SLM 10,075
									11- 6-68	28.46	
38/39-4bb	--	--	37	12	S	--	--	4,322	2-27-68	8.40	
									11- 6-68	9.52	
-9ca	Vedder, D. G.	1960	112	10	S	--	--	4,317	2-27-68	14.58	SLM 4999
									11- 6-68	11.35	
-16aa	Hill, W. S.	1961	280	16	I	31 R	--	4,317	2-27-68	10.98	SLM 6028
									11- 6-68	11.64	
-16bc	Hill, W. S.	1968	--	16	I	--	--	4,316	11- 6-68	11.01	
-16cd	Hill, W. S.	--	78	10	D	--	--	4,315	2-26-68	9.51	
-17aa	Hadfield, S. W.	1955	256	16	I	32 R	--	4,322	2-27-68	14.80	SLM 3252
									11- 6-68	15.43	
-18cc	USGS	1968	57	1½	O	--	--	4,358	11- 6-68	50.46	
-20ad	--	--	--	8	S	--	--	4,314	2-26-68	11.52	
									11- 6-68	11.97	
-21aa	Grady, C. F.	1949	280	16	I	10 R	118	4,316	12- 5-49	12 R	SLM 1138
									2-26-68	11.72	
									11- 6-68	12.35	
-22ab	--	--	--	12	S	--	--	4,317	2-26-68	12.83	
									11- 6-68	13.44	
-22da	--	--	--	10	S	--	--	4,319	2-26-68	15.94	
									11- 6-68	16.69	
-28aa	Etchart, George	1955	327	12	I,D	52 R	--	4,319	2-26-68	15.26	SLM 3316
									11- 6-68	15.88	
-28ba	Barber, Louis	1949	240	20	I	35 R	--	4,317	7-22-49	13.5 R	SLM 1022
									2-26-68	11.88	
									11- 6-68	12.39	
-28cd	Long, W. G.	1956	256	16	I	--	--	4,317	2-26-68	13.74	SLM 3464
									11- 6-68	15.26	
-28da	Etchart, George	1959	420	16	I	11 R	--	4,320	2-26-68	17.98	SLM 5289
									11- 6-68	18.53	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
38/39-35aa	--	--	64	6	S	--	--	4,339	2-26-68	37.36	
									11- 6-68	37.75	
-35cc	USGS	1968	25	1½	O	--	--	4,327	11- 6-68	23.25	
38/40-17bb	Dutch Flat Mine	--	--	12	M	--	--	4,690	11- 6-68	297.8	
39/38-1cb	--	--	--	12	I,D	--	--	4,380	2-27-68	47.99	
-3aa	Brooks, Victor	--	150	--	I,D	--	--	4,415	--	--	
-10ba	Jones, Frank	--	190	--	D	--	--	4,475	2-27-68	136.53	
-11bb	--	--	--	--	D	--	--	4,425	2-27-68	91.02	
-12ac	Brooks, Victor	1967	255	12	I,D	--	--	4,368	2-27-68	44.88	SLN 9676
									11- 6-68	45.12	
-12bc	Legge, Leslie	1964	160	12	I,D	10 R	--	4,382	2-27-68	57.41	SLN 8084
									11- 6-68	57.55	
-12cc	Brown, R. J.	--	286	--	I	--	--	4,388	2-27-68	64.29	
									11- 6-68	64.35	
-34da	Nelson, Charles	1968	290	16	I	--	--	4,401	2-27-68	57.94	SLN 10,267
									11- 6-68	56.98	
-34dd	Nelson, Charles	1968	520	14	I	--	--	4,420	2-27-68	46.05	SLN 10,287
									11- 6-68	50.63	
-35bb	--	--	--	8	S	--	--	4,392	2-27-68	48.76	
									11- 6-68	49.04	
-36dd	King, John	--	--	--	D	--	--	4,342	2-27-68	28.55	
									11- 6-68	28.44	
39/39-3ba	Miller, Gerhard	--	--	--	I	--	--	4,341	2-28-68	11.67	
									11- 7-68	13.00	
-3bd	Miller, Gerhard	--	--	--	D	--	--	4,343	2-28-68	12.10	
-3ca	Miller, Gerhard	--	--	--	D	--	--	4,339	9-15-47	11.42	
									2-28-68	14.78	
									11- 6-68	13.48	
-3cb	Miller, Elmer	1955	225	16	I	23	83	4,338	2-28-68	9.56	SLN 3396
									11- 7-68	10.84	
-3dd	Miller, Gerhard	--	20	18	S	--	--	4,342	2-28-68	11.86	
-4bd1	Miller well	--	90	6	S	--	--	4,338	9-29-47	9.56	
-4bd2	Test plot well	--	--	4	O	--	--	4,338	2-28-68	6.66	
									11- 7-68	10.13	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
39/39-10ab	Martin-Mickelson Ranch	1949	299	20	I	16 R	--	4,342	2-28-68	11.18	SLN 1476
									11- 7-68	12.43	
-11ac	Miller, Elmer	1959	84	10	S	--	--	4,337	2-28-68	11.71	SLN 4846
									11- 7-68	10.05	
-12bb	--	--	24	12	S	--	--	4,342	2-28-68	9.09	
-13cc	Martin-Mickelson Ranch	1941	225	--	I	--	--	4,334	2-28-68	8.91	
									11- 7-68	10.13	
-14ba	--	--	--	--	S	--	--	4,335	2-28-68	9.37	
									11- 7-68	10.08	
-14cd	Martin-Mickelson Ranch	1949	310	20	S,I	13 R	--	4,331	2-28-68	9.61	SLN 1477
									11- 7-68	10.69	
-15aa	Martin-Mickelson Ranch	1948	307	20	I	33	89	4,335	2-28-68	12.27	SLN 782
									11- 7-68	13.47	
-15cd	--	--	--	10	S	--	--	4,331	11- 7-68	9.91	
-16da	Martin-Mickelson Ranch	1948	291	20	I	22	115	4,333	11- 7-68	10.91	SLN 666
-17ca	Willow Point well	--	--	--	S	--	--	4,336	2-27-68	9.94	
									11- 7-68	10.57	
-25bb	Vedder, D. G.	1958	60	8	S	--	--	4,332	2-28-68	10.28	
									11- 7-68	11.57	
-26cb	--	--	--	8	S	--	--	4,324	2-28-68	8.09	
									11- 7-68	9.51	
-36cd	USGS	1968	66	1½	O	--	--	4,365	11- 7-68	48.31	
39/40-19bb	USGS	1968	47	1½	O	--	--	4,362	11- 7-68	40.76	
40/38-34ba	Paradise well	--	140	--	S	--	--	4,478	2-27-68	77.53	
									11- 6-68	77.72	
40/39-2dd	Wash O'Neal Ranch	--	--	8	S	--	--	4,397	2-29-68	24.10	
									11- 8-68	26.45	
-3bb	Provo Creek well	1960	--	--	S	--	--	4,561	2-28-68	168.24	
									11- 8-68	164.55	
-9bd	--	--	--	--	S	--	--	4,539	--	147 R	Des. 2-28-68
-11da	McCleary, Frank	--	--	--	S	--	--	4,378	9-15-47	11.52	
									2-29-68	9.46	
									11- 8-68	14.13	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
40/39-13ad	--	--	--	--	S	--	--	4,372	11- 8-68	14.51	
-13da	Nevada Garvey Ranches	--	--	--	I	--	--	4,372	2-28-68	8.86	
									11- 8-68	14.85	
-14dd	--	--	19	10	S	--	--	4,367	9-15-47	9.00	
									11- 8-68	9.78	
-22cb	--	--	--	--	S	--	--	4,370	2-28-68	20.14	
									11- 6-68	17.66	
-22dc	--	--	33	--	S	--	--	4,359	9-15-47	8.08	
									11- 7-68	8.69	
-25ac	--	--	--	10	S	--	--	4,359	9-15-47	10.22	
									11- 9-68	11.68	
-26ac	--	--	--	10	S	--	--	4,358	11- 7-68	20.8	
-29ab	--	--	33	8	S	--	--	4,376	2-28-68	29.32	
									11- 6-68	30.26	
-31cb	Patton, Walter	1965	205	12	I	23 R	--	4,365	2-28-68	31.73	SLN 9310
									11- 6-68	34.18	
-34ab	--	--	--	10	S	--	--	4,350	11- 7-68	10.61	
-35bd	--	--	--	--	S	--	--	4,346	2-28-68	7.95	
									11- 7-68	11.50	
40/40-7da	Nevada Garvey Ranches	--	--	--	I	--	--	4,384	11- 8-68	16.58	
-9cc	Bidart Bros.	--	--	--	M	--	--	4,440	--	--	
-18cc	Nevada Garvey Ranches	--	--	--	U	--	--	4,371	2-28-68	10.09	
									11- 8-68	9.41	
-18da	Nevada Garvey Ranches	1959	415	16	I	23	82	4,375	2-28-68	13.14	SLN 5978
									11- 8-68	14.41	
-19cb	McCleary, Frank	1957	436	16	U	30 R	--	--	--	--	SLN 3809
-30bc	Nevada Garvey Ranches	1956	405	16	I	42	59	4,362	2-28-68	12.78	SLN 3480
									11- 8-68	13.31	
-31cb	Nevada Garvey Ranches	--	--	--	I	35	82	4,360	2-28-68	10.33	
									11- 8-68	11.50	
41/39-1aa	Ferraro, Edith	--	--	--	U	--	--	4,482	9-18-47	11.77	
									2-29-68	8.06	
									11- 8-68	11.23	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
41/39-1ac	Ferraro, John	--	--	--	S	--	--	4,471	2-29-68	8.16	
									11- 8-68	11.67	
-2bd	Gavica, Frank	1955	602	16	I	7 R	--	4,555	--	--	SLN 3397
-2da	Gavica, Frank	--	--	--	S	--	--	4,502	9-18-47	6.77	
									2-29-68	2.10	
-2ca	Gavica, Frank	--	36	72	S	--	--	4,548	9-18-47	31.02	
									2-29-68	12.78	
									11- 8-68	9.13	
-11ab	McNeal, Wayne	1967	400	12	D	8 R	--	4,495	8-16-67	28 R	SLN 9684
-11dc	Ferraro, Edith	1960	735	16	I	5	230	4,490	2-29-68	34.94	SLN 6833
									11- 8-68	38.88	
-12ab	Gavica, Fermin	1962	105	10½	S	--	--	4,460	11- 8-68	15 R	SLN 6876
-12cc	Ferraro, John	--	26	--	S	--	--	4,462	2-29-68	19.26	
									11- 8-68	19.60	
-23db	Miller, George	--	--	--	I	--	--	4,468	2-29-68	44.77	
									11- 8-68	48.69	
-24bc	Miller, George	--	--	--	I	--	--	4,448	2-29-68	22.10	
									11- 8-68	26.05	
-24cc	Miller, George	1947	190	6	S	--	--	4,445	12-29-47	18 R	
									2-29-68	18.74	
									11- 8-68	19.83	
-24cd	Miller, George	--	--	--	D	--	--	4,423	2-29-68	17.05	
-27ab	Stonehouse well	--	200	8	D	--	--	4,556	9-17-47	115.90	
-36ac	Nevada Garvey Ranches	--	--	--	S	--	--	4,401	2-29-68	9.00	
									11- 8-68	12.99	
-36bb	Nevada Garvey Ranches	--	--	--	I	--	--	4,424	2-29-68	28.77	
									11- 6-68	31.75	
41/40-4bc	Stocks Farming Co.	--	--	--	D	--	--	4,479	3- 2-68	10.18	
									11- 9-68	14.07	
-7db	McDermitt, Robert	--	--	12	S	--	--	4,445	2-29-68	10.01	
-15ca	Stocks Farming Co.	1957	54	8	S	--	--	4,452	9-12-57	9 R	SLN 3902
-18cc	Stocks Farming Co.	--	40	8	S	--	--	4,418	9-17-47	12.32	
-19aa	Stocks Farming Co.	--	30	--	S	--	--	4,420	3- 1-68	5.49	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
41/40-21dc	Gondra, E. W.	--	78	8	S	--	--	4,425	2-29-68	11.09	
									11- 8-68	12.51	
-22da	Gondra, E. W.	1962	435	16	I	--	--	4,435	2-29-68	10.16	SLN 6730
									11- 8-68	14.61	
-22db	Gondra, E. W.	1964	512	18	I	34 R	--	4,431	2-29-68	9.60	SLN 8073
									11- 8-68	18.72	
-28ad	Thomas, Robert	1966	331	18	I	--	--	4,418	2-29-68	12.18	SLN 9466
									11- 8-68	14.58	
-30ab	Shelton School well	--	27	8	O	--	--	4,414	2-29-68	5.07	
									11- 8-68	10.83	
-30bc	--	--	--	8	S	--	--	4,413	2-29-68	7.88	
									11- 8-68	10.94	
-33ab	Thomas, Robert	1959	303	17	I	17	120	4,416	2-29-68	11.02	SLN 4908
									11- 8-68	15.15	
42/39-11dd	Storey, Clarence	--	35	--	S	--	--	4,637	3- 1-68	4.71	
									11- 9-68	27.41	
-12bc1	Storey, Clarence	--	62	--	S	--	--	4,680	3- 1-68	1.69	
									11- 9-68	41.62	
-12bc2	Storey, Clarence	--	150	6	S,D	--	--	4,679	3- 1-68	36.90	
									11- 9-68	40.85	
-13ca	Richards, Donnell	1968	132	8	S	--	--	4,605	1- 8-68	11 R	SLN 9882
-14aa	Pasquale-Richards	1966	500	16	I	5	196	4,636	3- 1-68	12.87	SLN 9280
									11- 9-68	27.50	
-14dd	Pasquale-Richards	--	--	--	D	--	--	4,590	3- 1-68	5.98	
									11- 9-68	11.28	
-15dd1	Schwartz	--	34	72	U	--	--	4,650	3- 1-68	9.58	
									11- 9-68	13.64	
-15dd2	Schwartz	--	250	8	S	--	--	4,649	3- 1-68	65.61	
									11- 9-68	66.43	
-22ca1	Miller, Lewis	--	--	--	S	--	--	4,713	11- 9-68	7.54	
-22ca2	Miller, Lewis	1960	410	16	S	--	--	4,719	3- 1-68	120.28	
									11- 8-68	132.75	
-23dc	Schwartz, Lyman	1962	235	--	D	--	--	4,575	3- 1-68	27.11	
									11- 9-68	29.50	

Table 22.--Records of selected wells--Continued

Location	Name or owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Pumping lift July 1968	Land surface altitude (feet)	Water-level measurement Date	Water-level measurement Depth	Remarks
42/39-25ca	CCC Camp well	--	18	--	U	--	--	4,512	3- 1-68	5.52	USGS observation well
									11- 9-68	9.28	
-26ad	Cemetery well	--	42	--	--	--	--	4,548	3- 1-68	12.92	
									11- 8-68	13.49	
42/40-8cc	Lye Bros.	--	17	--	S	--	--	4,635	3- 1-68	10.78	
-14ab	Machado, Lucille	1960	300	16	D,I	17 R	--	4,800±	3-23-60	78 R	SLN 5122
-16ac	Cerri	--	51	60	D	--	--	4,650	8-14-45	16.05	
									3- 1-68	29.39	
									11- 8-68	17.03	
-18db	McCleary, Frank	1948	240	10	S	--	--	4,600	3- 1-68	11.60	SLN 661
									11- 9-68	14.87	
-20bb	Recanzone, Carlo	--	--	--	S	--	--	4,570	3- 1-68	8.25	
-20db	Cerri, Giovanni	1957	670	16	I	--	--	4,558	3- 1-68	6.16	SLN 3689
									11- 8-68	15.00	
-28ad	Stocks Farming Co.	--	18	24	D	--	--	4,533	8-14-45	9.10	
									4-25-46	7.35	
-30dc	McCleary, Frank	--	14	120	S	--	--	4,496	9-25-47	7.32	
				LITTLE HUMBOLDT VALLEY							
40/41-4d	BLM	1968	236	8	S	--	--	--	6-28-68	177 R	SLN 10,127
-20a	BLM	1948	312	6	S	--	--	--	11- -48	295 R	SLN 847
41/41-25c	Bullhead Cattle Co.	--	--	--	--	--	--	--	--	10 R	
41/42-32a	Bullhead Cattle Co.	1958	80	8	S	--	--	--	9-10-58	8 R	SLN 4261
43/42-3	Sagehen well	1966	503	8	S	--	--	--	7-31-66	361.5 R	SLN 9200

Table 23.--Selected drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
38/38-36ad James Kinney		
Clay, sandy	8	8
Clay, hard	13	21
Clay, soft	6	27
Granite sand, loose	38	65
Sand, hard	45	110
Sand and gravel, loose	37	147
Sand, fine	18	165
Gravel and sand, clean	44	209
Sand, hard, dry	31	240
38/39-16aa W. S. Hill		
Soil	6	6
Sand, fine, water-bearing	16	22
Pea gravel and sand	37	59
Clay, hard, sandy	1	60
Free sand	3	63
Free pea gravel	11	74
Clay, sandy	22	96
Sand and pea gravel	14	110
Sand, fine	10	120
Sand and free pea gravel	6	126
Clay, hard, sandy	30	156
Free sand, fine	12	168
Clay, sandy	10	178
Free pea gravel, sand	18	196
Clay, hard	2	198
Free sand, pea gravel	4	202
Sand, hard	4	206
Free pea gravel	2	208
Clay, hard	8	216
Free sand, pea gravel	12	228
Clay, yellow, sticky	4	232
Pea gravel, tight, and sand	16	248
Free pea gravel, sand	6	254
Clay, yellow, sticky	4	258
Free sand	5	263
Pea gravel, sand	4	267
Clay, sandy	2	269
Free pea gravel and sand	8	277
Pea gravel, solid	3	280
38/39-21aa W. E. Crawford		
Soil	2	2
Sand, hard	2	4
Clay	12	16
Sand and clay	50	66
Clay, sandy	6	72
Sand and gravel	9	81
Gravel and layers of clay	7	88
Clay, yellow	18	106
Sand and gravel	3	109
Sand, tight	6	115
Sand, loose, and fine gravel	7	122
Clay, yellow	3	125
Sand, mucky, and gravel	25	150
Clay, yellow	5	155
Clay, sandy, and gravel	7	162
Sand and gravel	4	166
Clay, yellow	10	176
Clay streaks and gravel	26	202
Sand and gravel	15	217
Clay, sandy	29	246
Sand and gravel	25	271
Clay, sandy	9	280
38/39-28cd W. G. Long		
Soil	4	4
Clay, yellow	8	12
Sand, coarse	10	22
Sand rock, cemented	16	38
Clay, sandy	18	56
Sand, hard (soft sand rock)	22	78
Pea gravel (water)	12	90
Clay, hard	16	106
Gravel, cemented	15	121
Clay and sand	13	134
Sand, medium (water)	39	173
Gravel	6	179
Clay, yellow	27	206
Sand, coarse (water)	6	212
Gravel, water	16	228
Clay, yellow	9	237
Sand, coarse (water)	11	248
Clay, yellow	8	256

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
39/38-12ac Victor Brooks		
Topsoil	10	10
Clay, sandy	79	89
Clay	31	120
Clay, sandy	14	134
Sand and gravel	46	180
Sand	29	209
Sand and gravel	40	249
Clay	6	255
39/39-3cb Elmer Miller		
Soil	10	10
Clay, gray	10	20
Sand and gravel	16	36
Sand and clay stringers	13	49
Clay, gray	10	59
Clay, brown	10	69
gravel	1	70
Clay, gray	10	80
Clay, brown	8	88
Clay, blue	13	101
Clay, gray	9	110
Gravel, cemented	10	120
Clay, brown	12	132
Gravel	9	141
Clay, gray	9	150
Gravel	8	158
Clay, gray	12	170
Gravel	9	179
Clay, gray	12	191
Gravel	3	194
Clay	5	199
Gravel	7	206
Clay, brown	2	208
Gravel (water)	12	220
Clay	5	225
39/39-15aa Martin-Mickelson Ranch		
Soil	10	10
Silt	11	21
Sand and small gravel, cemented	29	50
Clay, yellow	11	61
Sand and small gravel, cemented	23	84
Clay, yellow	16	100
Sand, fine	2	102
Clay, brown	16	118
39/39-15aa--continued		
Sand, gravel, and clay in alternating layers	87	205
Sand and gravel, water	10	215
Clay	5	220
Sand and small gravel, water	10	230
Clay	4	234
Sand and small gravel, water	12	246
Clay	16	262
Sand and gravel, water	43	305
Clay	2	307
39/39-16da D. G. Vedder		
Soil	9	9
Silt	7	16
Clay, yellow	4	20
Gravel, small	1	21
Clay, yellow, soft	28	49
Gravel, small, and sand	11	60
Clay, yellow	9	69
Gravel, small, and sand	6	75
Clay, yellow	3	78
Sand and gravel	8	86
Sand, light gray	8	94
Silt and clay	11	105
Sand and gravel	30	135
Silt or clay	2	137
Sand and gravel	1	138
Silt and clay	4	142
Sand and gravel	20	162
Silt and clay	5	167
Gravel, cemented	9	176
Sand and gravel	8	184
Clay with small seams of gravel	23	207
Sand and gravel	25	232
Silt and clay	14	246
Sand and gravel	26	272
Clay	4	276
Sandstone, soft	14	290
Clay	1	291

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
39/39-25bb D. G. Vedder		
Soil	3	3
Silt and clay	17	20
Gravel	2	22
Clay, gray	5	27
Gravel	5	32
Sandstone	8	40
Gravel	5	45
Clay, gray	5	50
Sandstone	10	60
40/39-31cb Walter Patton		
Clay topsoil, sandy	12	12
Clay	32	44
Clay, hard	2	46
Sand	3	49
Clay and small seams gravel	95	144
Gravel, fine, clean	61	205
40/40-18da Garvey Ranches		
Topsoil	15	15
Gravel	15	30
Clay, yellow	5	35
Gravel	84	119
Clay	2	121
Gravel	11	132
Sand	28	160
Gravel	12	172
Clay, yellow	2	174
Sand and gravel	14	188
Gravel and clay	76	264
Clay and gravel	32	296
Gravel	16	312
Pea gravel, clean	62	374
Gravel, cemented	12	386
Pea gravel	18	404
Clay	11	415
40/40-30bc Frank McCleary		
Soil, black	8	8
Gravel, cemented	5	13
Gravel, clean, loose	9	22
Gravel, fine, cemented	18	40
Sand, hard, dry	12	52
Gravel, fine, clean	8	60
Gravel, big, coarse	30	90
Gravel, cemented	8	98
Sand, fine, loose	4	102
Gravel, red, heavy	14	116
Clay, tough, sticky	2	118
Gravel, coarse, loose	24	142
Clay, brown, sticky	2	144
Gravel, coarse, loose	56	200
Gravel, cemented	12	212
Sand, fine	4	216
Clay, yellow, tough	10	226
Gravel, coarse, loose	44	270
Gravel, fine, cemented	20	290
Sand, fine, and gravel	70	360
Dirt, soft	45	405
41/39-2bd Frank Gavica		
Soil	5	5
Clay and gravel	50	55
Clay	10	65
Clay and gravel	30	95
Gravel, cemented	30	125
Clay and small gravel	10	135
Clay, sandy	20	155
Gravel and clay	35	190
Gravel, hard	50	240
Clay	45	285
Gravel, cemented, and clay	20	305
Gravel and sand	8	313
Gravel, cemented	24	337
Clay	10	347
Gravel, cemented	48	395
Clay	3	398
Gravel, cemented	24	422
Clay with gravel	26	448
Gravel	7	455
Clay with gravel	30	485
Gravel, cemented	17	502
Clay	11	513
Gravel, cemented	7	520
Clay	4	524
Gravel and coarse sand, water	12	536

(continued)

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
41/39-2bd--continued		
Clay, some gravel	16	552
Gravel and coarse sand, water	14	566
Clay	8	574
Gravel, cemented	18	592
Clay with some gravel	10	602
41/39-11dc Edith Ferraro		
Topsoil	16	16
Gravel and clay, mixed	139	155
Clay, sandy	20	175
Gravel and clay, mixed	30	205
Clay, sandy	95	300
Gravel and sand	6	306
Clay, sandy	34	340
Sand and gravel	8	348
Clay, sandy	104	452
Granite, decomposed	68	520
Clay, brown	17	537
Granite, decomposed	68	605
Clay, brown, sandy	67	672
Clay, brown, sandy, firm	63	735
Granite, decomposed	Bottom	735
41/39-12ab Fermin Gavica		
Topsoil	7	7
Clay, sandy	3	10
Clay, rocky	4	14
Sand and gravel	6	20
Clay, blue, soft	6	26
Sand, packed	7	33
Clay, blue, soft	13	46
Sand and gravel	9	55
Sand, hard	8	63
Clay, brown, soft	15	78
Clay, brown, tough	6	84
Granite, decomposed, and sand	21	105
41/40-22db Quarter Circle Y Ranch		
Topsoil	2	2
Sand and gravel	23	25
Clay, brown	7	32
Gravel and clay, mixed	26	58
Lava gravel	12	70
Gravel and clay, mixed	42	112
Lava gravel	10	122
Clay and gravel, mixed	28	150
Lava gravel	11	161
Clay and gravel, mixed	15	176
Lava gravel	5	181
Clay and gravel, mixed	15	196
Clay, brown, hard	10	206
Gravel, cemented	9	215
Clay and gravel, mixed	13	228
Clay and boulders, mixed	17	245
Boulders and sand	40	285
Clay, brown	15	300
Clay, brown, and gravel, mixed	48	348
Clay, brown	36	384
Gravel and clay, mixed	21	405
Sand and gravel	15	420
Gravel and clay	32	452
Clay, brown, hard	23	475
Gravel, cemented	7	452
Clay, brown, hard	30	512
41/40-33ab Robert Thomas		
Topsoil and clay	12	12
Gravel, loose, clean	13	25
Gravel, hard, cemented	80	105
Clay, light, and sand	25	130
Gravel, loose	25	155
Gravel, cemented, and sand	80	235
Sand and fine gravel	15	250
Gravel, loose, and streaks of hard cemented sand	25	275
Gravel, loose, clean	28	303

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
42/39-14aa Donnell Richards		
Loamy topsoil	5	5
Sand, fine to coarse, with rounded gravels to 4 inches and approximately 2 percent silt	6	11
Cobbles, rounded, and boulders to 12 inches, some coarse sand	2.5	13.5
Sand, fine to coarse, with rounded gravels to 1½ inches and some yellow clay lenses	8.5	22
Sand, fine to coarse, with rounded gravels to 3 inches and some inconsistent streaks of sand and gravels mixed with yellow clay	43	65
Sand, fine to coarse, with rounded gravels to 2 inches, some streaks of sandy yellow clay to 8 inches thick	10	75
Sand, fine to coarse, with semirounded gravels to 2 inches and approximately 2 percent silt, few inconsistent yellow clay lenses	30	105
Clay, yellow, soft	10	115
Sand, fine to coarse with semirounded gravels to grounded gravels to 1 inch, very clean and loose	3	118
Clay, yellow, soft	2	120
Sand, fine to coarse with semirounded gravels to 1½ inches and approximately 2 percent silt, occasional rounded gravels to 3 inches	20	140
Sand, fine to coarse with semirounded gravels to 1½ inches and approximately 2 percent silt, occasional rounded gravels to 3 inches as well as occasional yellow clay lenses	6	146
Clay, yellow, sandy, soft	3	149
Sand, fine to coarse with rounded gravels to 2 inches, very loose and clean, occasional yellow clay streaks to 10 inches in thickness starting from 157 feet	14	163
Clay, yellow, sandy, hard and soft, sometimes very sticky, sometimes with coarse sand lenses	23	186
Sand, fine to coarse with rounded gravels to ½ inch, very clean	3	189
Clay, yellow, hard and soft	8	197
Sand, fine to coarse with small rounded gravels to 3/8 inch and approximately 2 percent silt	5	202
Clay, yellow, sandy, hard and soft, sometimes very sticky	9	211
Sand, fine to coarse with small rounded gravels to 3/8 inch, approximately 2 percent silt, very loose, inconsistently water-bearing, some sticky yellow clay lenses	31	242
Sand, fine to coarse with approximately 2 percent silt and small rounded gravels to 3/8 inch, sometimes heaving	20	262
Clay, yellow, sandy, hard and soft with fine gravel lenses, sometimes sticky	19	281
Sand, fine to coarse with rounded gravels to ½ inch and approximately 2 percent silt	24	305
Clay, yellow, sandy, hard and soft with inconsistent streaks of sand and rounded gravels to ½ inch	15	320
Clay, yellow, hard and soft, very sticky	21	341

(continued)

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
42/39-14aa--continued		
Sand, fine to coarse with rounded gravels to 3/8 inch and approximately 2 percent silt, some inconsistent sticky yellow clay lenses, formation very loose and does not appear to be water-bearing	20	361
Clay, yellow, hard, sticky	4	365
Sand, fine to coarse with approximately 1 percent silt and rounded gravels to 2½ inches, very loose and probably water-bearing	22	387
Clay, yellow, sandy, hard and soft	11	398
Sand, fine to coarse with rounded gravels to 3 inches	17	415
Same as above with the addition of consistent hard and sticky yellow clay streaks to 12 inches in thickness	33	448
Sand, fine to coarse with rounded gravels to 1½ inches, some inconsistent sticky yellow clay streaks to 12 inches in thickness	8	456
Sand, fine to coarse with approximately 2 percent silt and semirounded to rounded gravels to 1 inch, some inconsistent sticky yellow clay streaks to 12 inches in thickness	24	480
Sand, fine to coarse with approximately 1 percent silt and semirounded gravels to 3/8 inch, some sticky yellow clay lenses	15	495
Clay, yellow, sticky, very hard	5	500

Material	Thickness (feet)	Depth (feet)
42/40-14ab Lucille Machado		
Soil	3	3
Gravel, coarse, loose	4	7
Gravel, coarse, cemented	48	55
Gravel, coarse, tight, with some water	15	70
Gravel, loose, with water	54	124
Gravel with dry clay binder	13	137
Clay, dry, red to brown	163	300
42/40-18db Frank McCleary		
Topsoil	4	4
Clay and gravel	4	8
Gravel and clay (water)	4	12
Clay and gravel	63	75
Clay	5	80
Clay and gravel	13	93
Clay, sand, and small gravel	39	132
Clay	5	137
Clay and small gravel	12	149
Clay	5	154
Clay and gravel	56	210
Gravel, sand, and clay (water)	15	225
Clay	13	238
Clay and gravel	2	240
42/40-20db Giovanni Cerri		
Soil	8	8
Gravel, cemented	8	16
Gravel and clay	20	36
Gravel, slightly loose	8	44
Gravel and clay	28	72
Gravel, cemented, slightly loose	6	78
Gravel and clay	24	102
Gravel, cemented, slightly loose	22	124
Gravel, cemented, tight	14	138
Gravel, cemented, slightly loose	12	150
Clay, brown, soft, dry	22	172
Gravel, cemented, slightly loose	13	185
Gravel, cemented, tight	10	195
Clay, brown, sand, and gravel	20	215
Clay, brown	15	230
Gravel, coarse	15	245

(continued)

Table 23.--Selected drillers' logs of wells--continued

Material	Thickness (feet)	Depth (feet)
42/40-20db--continued		
Clay, brown	5	250
Gravel, brown, clay	42	292
Sand and gravel, loose	14	306
Clay, brown	34	340
Gravel, cemented	25	365
Gravel and clay	25	390
Sand and gravel, cemented	52	442
Gravel and clay	33	475
Sand and gravel, cemented	35	510
Gravel and clay	15	525
Sand and gravel, cemented	15	540
Gravel and clay	35	575
Sand and gravel, cemented	30	605
Clay, brown	30	635
Sand and gravel, loose; sand in bottom	35	670

Material	Thickness (feet)	Depth (feet)
40/41-4d Bureau of Land Management		
Sand and gravel	180	180
Gravel, sand, water-bearing	56	236
40/41-20a Bureau of Land Management		
Soil and embedded rock	63	63
Clay soil	17	80
Clay, brown, washed gravel	20	100
Clay, gray, sandy	20	120
Lava, streaked with brown clay	35	155
Clay, gray, sandy	45	200
Shale, gray, sandy	60	260
Clay, orange	30	290
Sand, brown, gray	12	302
Sand with small gravel	10	312
41/42-32ab Bullhead Cattle Co.		
Soil, black	9	9
Clay, sandy	8	17
Sand and very fine gravel	2	19
Gravel, hard, cemented	5	24
Clay, sandy, hard	20	44
Gravel, fine, clean	2	46
Clay, brown, sticky	32	78
Gravel, small, clean	2	80
43/42-3 Bureau of Land Management		
Sand, gravel, cinders	160	160
Gravel, limestone, sand	20	180
Cinders	19	199
Rhyolite	182	381
Wolframite (water)	122	503

Table 24.--Generalized logs of U.S. Geological Survey test wells

Material	Thickness (feet)	Depth (feet)
37/38-21dd (94)[a]		
Silt, sandy	2.5	2.5
Clay, silty	12.5	15
37/38-22dd (95)		
Silt, sandy	5	5
Silt	6.5	11.5
Clay, silty	44.5	56
Sand	1.5	57.5
37/38-24ac (106)		
Silt, sandy	20	20
Sand, silty	17.5	37.5
37/38-34ab (93)		
Clay, silty	7.5	7.5
Clay, sandy	5	12.5
37/39-12cb (P-3)		
Sand, fine, light brown	27	27
Sand, some gravel	5	32
Gravel and sand	5	37
Gravel	10	47
Sand and gravel	5	52
37/39-15cb (P-1)		
Sand, fine, light brown	15	15
Gravel and sand	1	16
Sand, brown	5	21
Gravel, sandy	1	22
Sand and gravel	5	27
Gravel, sandy	5	32
Sand and gravel	12	44
37/39-19aa (105)		
Sand	2	2
Clay, silty	4	6
Sand	18	24
Gravel	2.5	26.5
Clay, silty	6.5	33
Sand and gravel	9.5	42.5
37/39-30dd (104)		
Silt, sandy	8	8
Sand and gravel, silty	19.5	27.5
37/39-34ca (109)		
Sand and gravel, silty	12.5	12.5
Gravel, sandy	50	62.5
37/40-18ad (P-4)		
Sand, fine silt	17	17
Sand and gravel	10	27
Sand	10	37
Sand and gravel	30	67
37/40-32bb (119)		
Silt, sandy	10	10
Sand, silty	15	25
Sand and gravel	25	35
Sand and silt	17.5	52.5
38/39-18cc (P-5)		
Sand, fine, light brown	57	57
38/39-35cc (P-2)		
Sand, fine	7	7
Clay, sandy	5	12
Clay, silty, some fine brown sand	5	17
Clay, silty	8	25
39/39-36cd (P-6)		
Sand and silt	17	17
Sand, medium-grained	5	22
Gravel	10	32
Sand and gravel	34	66
39/40-19bb (P-7)		
Sand, fine	1	1
Gravel	11	12
Sand and gravel	5	17
Clay, sandy	10	27
Sand, clay, and gravel	10	37
Sand and gravel	8	45
Clay, sandy	2	47

a. USGS field number.

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES

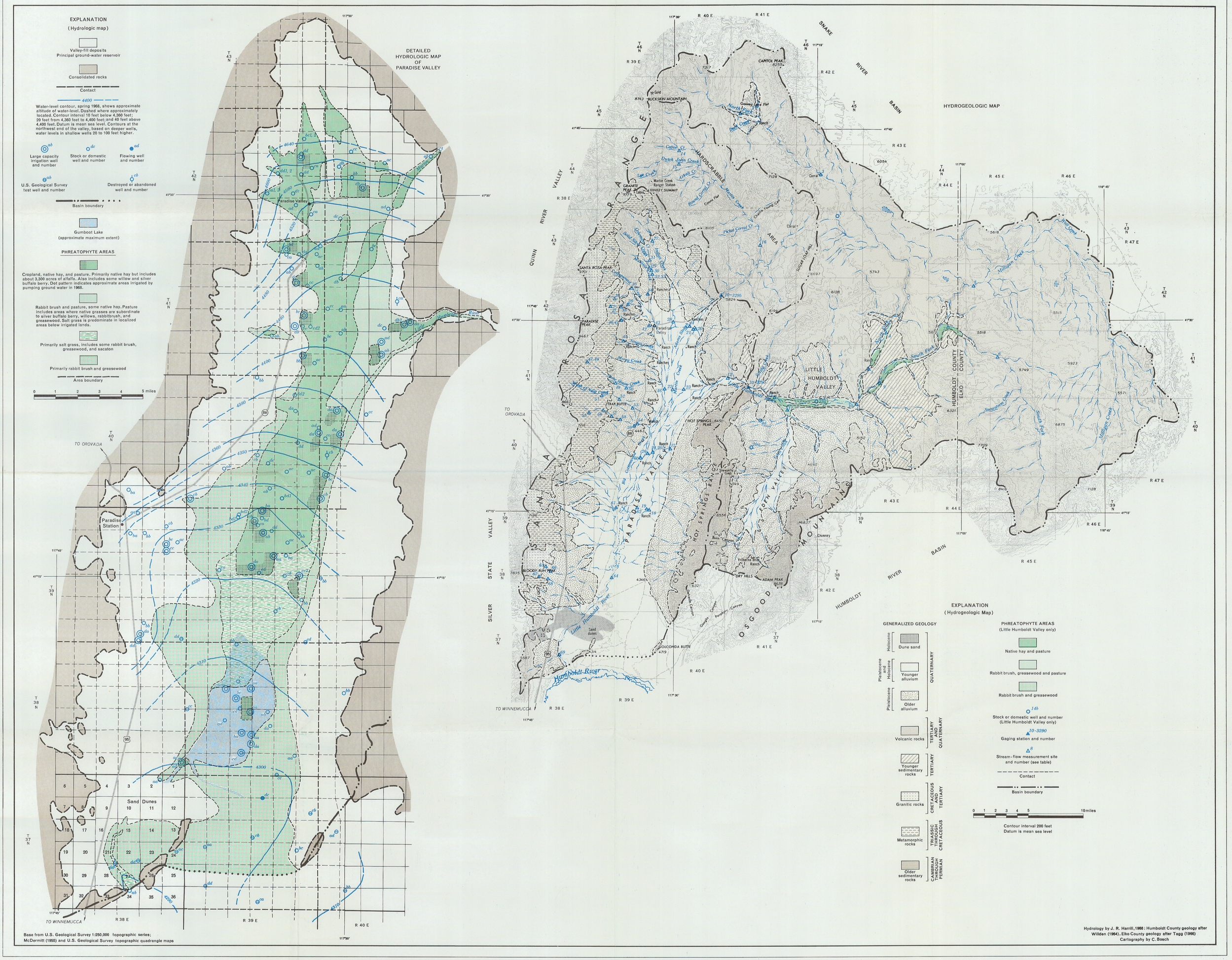

PLATE 1.—HYDROGEOLOGIC MAP OF LITTLE HUMBOLDT RIVER BASIN AND HYDROLOGIC MAP OF PARADISE VALLEY, HUMBOLDT AND ELKO COUNTIES, NEVADA