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WATER-RESOURCES APPRAISAL OF THE CARSON RIVER BASIN, WESTERN NEVADA

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

English unit	Metric unit	Multiplication factor to convert from English to metric quantity
Inches (in)	Millimetres (mm)	25.4
Feet (ft)	Metres (m)	0.305
Miles (mi)	Kilometres (km)	1.61
Acres	Square metres (m^2)	4050
Square miles (mi^2)	Square kilometres (km^2)	2.59
Gallons (gal)	Litres (l)	3.78
Acre-feet (acre-ft)	Cubic metres (m^3)	1230
Cubic feet per second (ft^3/s)	Litres per second (l/s)	28.3
Do.	Cubic metres per second (m^3/s)	0.0283
Gallons per minute (gal/min)	Litres per second (l/s)	0.0631

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SUMMARY

The study area lies at the western edge of the Great Basin, and encompasses six major hydrographic areas and one hydrographic subarea, but excludes most of the Carson River drainage in California. Five of the hydrographic areas are part of the Carson River drainage basin; the sixth, White Plains, is the terminus of the Humboldt River basin and connects that drainage to Carson Desert. Packard Valley is tributary to Carson Desert, but not directly to Carson River. Altitudes in the Carson River basin range from 11,005 feet in the Sierra Nevada to about 3,800 feet in Carson Sink. Precipitation averages less than 6 inches per year at low Carson Desert altitudes, and more than 30 inches at high Sierra Nevada altitudes. The study area is hydrologically dominated by Carson River, Lahontan Reservoir, and the Truckee Canal, which carries Truckee River water into the basin for irrigation use on the Newlands Irrigation Project.

Table 1 summarizes selected quantitative hydrologic estimates of the study area. Most of the data of table 1 are described and, more importantly, qualified in the body of the text.

Lithologic units delineated for their hydrologic characteristics include consolidated rocks, and valley-fill deposits made up of younger and older alluvium. The valley-fill deposits constitute the principal aquifer system, and the consolidated rocks form most of the hydrographic area boundaries.

Table 1.--Hydrologic summary

[Reconnaissance estimates are in acre-feet per year, except as indicated, and are rounded]

Hydrographic area (in downstream order, with mainstem areas capitalized)	Area (mi^2)	Surface-water runoff at the mountain front	Potential ground-water recharge from precipitation	Inflow (I) and outflow (X) between areas via streams for reference period 1919-69	Imported water[1]	Subsurface inflow (I) and outflow (X) through alluvium	Ground water stored in upper 100 feet of saturated valley fill (acre-feet)
CARSON VALLEY (Nev. part only)	422	15,000	25,000	315,000 I 272,000 X	3,700	7,800 I 15 X	710,000
Eagle Valley[2]	71	13,000	8,700	none I 7,000 X	a 430	none I 2,200 X	200,000
DAYTON VALLEY	364	1,400	7,900	276,000 I b 268,000 X	a 220	1,600 I 70 X	440,000
CHURCHILL VALLEY	491	900	1,300	c 439,000 I 380,000 X	170,000	220 I unknown X	740,000
CARSON DESERT	2,016	2,300	1,300	d 391,000 I none X	10,000	1,200+I <1,000 X	8,000,000
Packard Valley	177	600	710	none I <100 X	none	none I 400 X	500,000
White Plains	158	100	<100	6,000 I 1,000 X	none	60 I 20 X	420,000

1. 1971 imports. There are no water exports from the study area.
2. Data from Worts and Malmberg (1966), except as noted.
a. Includes municipal imports as of 1971.
b. Includes 16,000 acre-feet per year through Buckland Ditch.
c. Includes 170,000 acre-feet per year through Truckee Canal.
d. Includes 10,000 acre-feet diversion from Truckee Canal in Hazen-Swingle Bench area and 1,000 acre-feet from White Plains.

Estimates of average annual water inflow to the study area during the 1919-69 reference period are as follows: (1) precipitation (about 1½ million acre-feet annually), (2) Carson River inflow (about 315,000 acre-feet annually), (3) Humboldt River tailwaste (about 6,000 acre-feet annually), (4) water imported from adjacent hydrographic areas (about 180,000 acre-feet annually), (5) natural subsurface inflow from adjacent hydrographic areas (about 8,200 acre-feet annually). Estimates of average annual water outflow from the study area during the reference period are as follows: (1) an undetermined quantity of precipitation that evaporates before it becomes salvable streamflow or ground-water recharge, (2) evapotranspiration losses from shallow ground-water discharge and consumptive crop use (about 300,000 acre-feet annually, or possibly more), (3) evaporation from surface-water bodies (about 250,000 acre-feet annually), and (4) subsurface outflow to adjacent areas (probably less than 1,000 acre-feet annually).

In contrast to the above long-term outflow estimates, the 1971 combined domestic, municipal, industrial, and livestock use was estimated at about 8,000 acre-feet, some of which was further available for additional uses.

Available data suggest that aside from riverflow, the Carson Valley ground-water reservoir is the best presently available source of large-quantity, high-quality water. In contrast, Carson Desert has a vast quantity of ground water in storage, but it is believed to be largely of unacceptable quality for most uses. Intervening hydrographic areas generally have significantly large quantities of stored ground water of intermediate quality. All hydrographic areas having generally good-to-high quality ground water also have localized areas of poor-quality water. All the presently imported sewage waste water, of varying quality, is being delivered to Carson Valley, the upstream hydrographic area of the river basin; also, much of the study area's rapidly increasing locally-generated sewage effluent is being injected into upper-basin hydrographic areas. Carson River water tends to deteriorate in quality downstream because of both natural and man-related effects. Reconnaissance data suggest abnormally high mercury concentrations in river-bottom sediments of Dayton and Churchill Valleys, which probably resulted from milling operations in the late 1800's.

The available ground-water supply of Carson Desert is unique in the study area and somewhat poorly understood. Fallon municipal and Naval Air Station supplies are obtained from a relatively deep basalt aquifer system, but the quantity of stored water and the replenishment mechanism of the system are not known. Most rural domestic supplies are obtained from a shallow aquifer system that may have originated mainly by infiltration of Newlands Reclamation Project irrigation water, in part imported from the Truckee River; however, that aquifer system is being increasingly threatened by sewage effluent from individual residences.

The rapid urban growth presently occurring in the Carson River basin not only stresses the natural hydrologic system, but, in turn, the natural system has great potential to stress the urbanizing environment. Principal geohydrologic hazards in the study area are seismic, flood, and mass earth-movement threats. The potentials for seismic and flood hazards are great throughout most of the area. Flood hazards consist of major river floods, generally restricted to the Carson River flood plain, and flash floods, which individually affect small areas but collectively are likely to occur over a large part of the area. Mass earth-movement hazards probably are common in some localized parts of the area. Unfortunately, all types of the above listed hazards might be expected to occur in varying combinations with each other, thereby further magnifying danger to lives and property through their cumulative and coincidental effects.

The Carson River basin is presently undergoing dramatic changes that depend on, and can be expected to influence, the hydrologic regime. Because of the dominance of the Carson River, stresses imposed on upper-basin hydrographic areas are very likely to be transmitted to lower-basin areas. Increased hydrologic knowledge is therefore a primary requisite to develop a needed understanding of the natural hydrologic system. A satisfactory understanding should be conducive to the efficient selection of planning alternatives that would aid in developing a compatible and beneficial symbiotic relationship between man and nature in the future.

INTRODUCTION

Purpose and Scope of the Study

Water-resource development in Nevada has increased substantially in recent years. Current increases relate strongly to urban and suburban population growth. The growing interest in ground-water development has created a substantial demand for information on ground-water resources throughout the State. Recognizing this need more than a decade ago, the State Legislature enacted special legislation (Chapter 181, Statutes of 1960) authorizing a series of reconnaissance studies of the ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources, Division of Water Resources. This is the 59th report prepared as part of the reconnaissance series (fig. 1 and p. iii).

In the early studies, little information was presented on surface-water resources. Later, the reconnaissance series was broadened to include preliminary quantitative evaluations of surface water in the areas studied.

The general objectives of the reconnaissance reports during recent studies have been to (1) describe the hydrologic environment, (2) appraise the source, occurrence, movement, and chemical quality of water, (3) estimate the amount of average annual potential recharge to, discharge from, and yield of the ground-water reservoirs, (4) quantify the surface-water resources, (5) provide preliminary estimates of the amount of stored ground water, and (6) estimate the magnitude of the present water-resources development. This report encompasses most of these objectives, and because of recent hydrologic development in the Carson River basin, several additional objectives as described below.

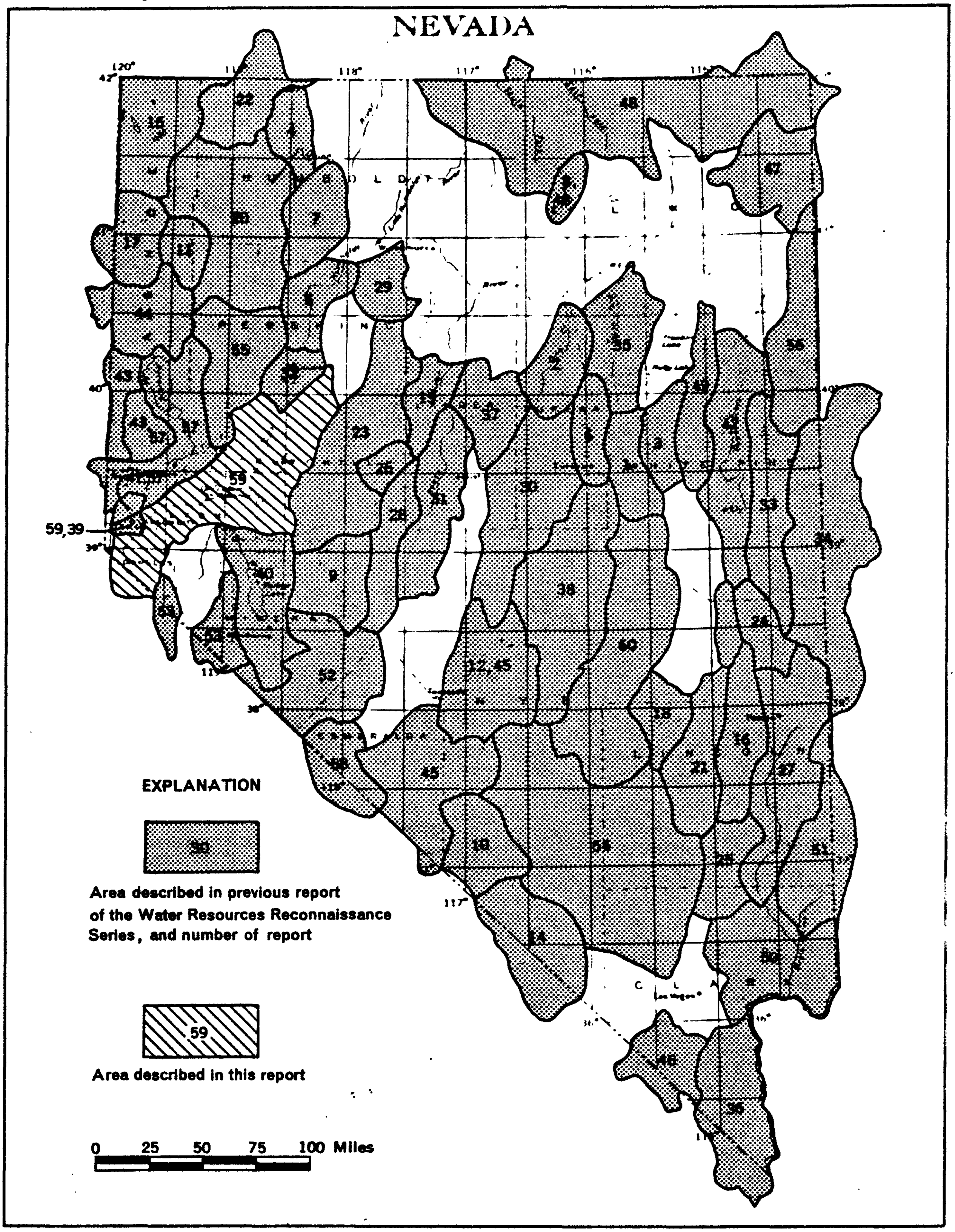

Figure 1.—Areas described in previous reports of this series, and the area described in this report

The Carson River basin is presently undergoing extensive changes caused by rapid population growth and accompanying development. These changes are reflected in the increasing utilization of water resources, growing problems of sewage disposal, increased citizen concern for maintenance of the desirable aspects of the natural environment, including river quality, and increasing risks from geohydrologic hazards. Therefore, this study also evaluates (1) present trends of water use, compared to traditional historical uses, (2) inter- and intra-basin sewage disposal problems, (3) problems related to water quality, and (4) geohydrologic hazards.

Most of the hydrologic field work for this report was done in 1970, 1971, and the early part of 1972.

Although the river basin encompasses parts of two States, most quantitative estimates of the water resources are limited to Nevada. California segments are included where records of Carson River streamflow are provided by gages in California, several miles upstream from the State boundary (pl. 1).

Location and General Geographic Features

The Carson River basin lies roughly between lat 38°32' and 40°16' N., and long 119°50' and 118°00' W. The basin, which together with Packard Valley and White Plains make up the study area, lies mostly in west-central Nevada, but includes some area in California. The river system consists of the East and West Forks and the mainstem of the Carson River. The basin comprises, in downstream order, five hydrographic areas in Nevada (Rush, 1968, p. 18-19): Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and Carson Desert (less Packard Valley subarea, 177 mi^2), which total about 3,365 square miles in Nevada (fig. 1, pl. 1). White Plains hydrographic area, about 160 square miles in the lowest part of the Humboldt River basin, drains to the Carson Desert. The total study area encompasses slightly more than 3,830 square miles including about 112 square miles in California.

Development has been intensive in recent years throughout the Carson River basin, with the primary emphasis on urbanization and a secondary interest in recreation. Principal towns within the area include Carson City, Gardnerville, Minden, Dayton, Virginia City, and Fallon--all in Nevada.

Other Studies and Data

The Carson River basin was one of the first settled and developed areas in Nevada. Continuous mining activity in the area, including the large-scale operations on the Comstock Lode, resulted in many geological studies during the past 100 years. Published results of these studies are numerous, but their relation to hydrology is not sufficient to justify mention in this report. However, several recently published geologic maps form the basis for the generalized geology shown on plate 1 of this study and these reports are identified in a later section.

U.S. Geological Survey hydrologic studies in the Carson River basin date back to the 19th century. Systematic streamflow measurements of Nevada streams began as early as 1889 when the U.S. Geological Survey began a streamflow measurement program on the Carson and Truckee Rivers (Chandler, 1905, p. 35). Results of most of these studies are referenced at appropriate places in this report.

Hydrologic data are also currently being collected in the area by other Federal and State agencies. Many hydrologic studies have also been made in areas immediately adjacent to the Carson River basin. A list of selected references is included following the main body of this report to provide a basic, but not exhaustive, list of published documents on local and regional hydrology that were not specifically cited in the text of this report.

Acknowledgments

Many individuals throughout the report area provided helpful information during this study. Critically important data were furnished by: Christopher Altemueller, Gardnerville-Minden Sewage Plant; Julio Alvas, Douglas County Water Reclamation Project; Leonard Anker, Buhel Heckathorn, Arlan Neal, William Dunning, and Duane Collins, U.S. Soil Conservation Service; J. Archambault, Lake Tahoe Area Council Lab.; Bill Berning and Walt Mandeville, Nevada State Prison; Roger Bialle, of Walters, Ball, Hibdon & Shaw, Consulting Engineers; Rob Roy Bittman, Twelfth Naval District, San Bruno, Calif.; Joseph D. Cushing and R. W. Rose, Naval Air Station, Fallon; James Dunn, Carson City Sewage Plant; J. D. Frank, Kennametals, Inc.; Clifford Girvan, Jr., Incline Village Improvement District; Dean S. Kingman, Kingman Engineers, Palo Alto, Calif.; Milton T. Lakey, Assistant City Engineer, Fallon; Pete Marshall, State Agricultural Extension Agent for Carson City and Storey Counties; Roger L. Mertens, U.S. Bureau of Land Management, Winnemucca; Richard Messier and Peter Stein, Lahontan National Fish Hatchery; William Mueller, City of Minden; Norman Murray, Mark Lawrence, and Kenneth Harrison, U.S. Bureau of Land Management; Mrs. Alton Park, Gardnerville Water Company; James Rankin, Carson City Engineer; John Schilling and Larry Garside, Nevada Bureau of Mines and Geology; James A. Smiley, U.S. Bureau of Indian Affairs; Thomas Sullivan, Edward King, and Robert Schriver, Carson Water Co.; L. A. Wolf, Lyon County Health Dept.; James Williams and Jack Sheehan, Nevada Division of Health; Hodges Transportation Corp.; employees of Nevada Division of Building and Grounds; J. Lyle Wightman and George Luke, Fallon area residents; and numerous other residents of the area. The help of all these people is greatly appreciated and enthusiastically acknowledged. The authors sincerely apologize to anyone who provided assistance, but whose name was inadvertently omitted from the foregoing list.

GENERAL HYDROLOGIC ENVIRONMENT

Physiographic Features

The Carson River basin is characterized by contrasting physiographic features; for example, rugged peaks and steep slopes of the Sierra Nevada contrast with the vast, flat playa surface of the Carson Sink; lush vegetated highlands of the Sierra Nevada contrast with the barren, rocky peaks of the southern Stillwater Range; and the green, vegetated floor of Carson Valley contrasts with the barren, salt-encrusted valley floors of Eightmile and Fourmile Flats in Carson Desert.

The Carson River drainage begins in the high alpine zone of the Sierra Nevada in California. Many small perennial streams, most of which are outside the study area, flow into the East and West Forks of the Carson River. Ephemeral stream channels are numerous throughout the entire basin, and commonly transmit thundershower and snowmelt runoff. The two main Carson River forks in the upstream part of the basin flow generally northward and join in the northern part of Carson Valley. There, the river progressively changes to a more northeasterly course as it flows through downstream hydrographic areas to terminate in the Carson Sink.

The four hydrographic areas through which the Carson River flows are mainly bounded by mountain masses, as shown on plate 1. The major mountain ranges trend generally northward. However, some ranges also trend northeastward.

The Sierra Nevada is the dominant mountain range at the western margin of the basin, and it provides the bulk of the streamflow for the Carson River system. Other mountain ranges within the basin are the Pine Nut Mountains, Virginia Range, Desert Mountains, Hot Springs Mountains, Stillwater Range, and the West Humboldt Range (pl. 1).

The surface configurations of valley floors in the headward areas of the basin (Carson Valley and Eagle Valley) are affected greatly by streamflow processes. However, effects of ancient Lake Lahontan as a land-surface shaping agent become increasingly dominant on valley floors east of Dayton, particularly in the Carson Desert.

In the Carson Desert (including Packard Valley), alluvial fans, flood plains, and playas compose about 80 percent of the hydrographic areas. They are much less widespread in the upstream hydrographic areas of the river basin, as the following areal percentages indicate: Carson Valley, 25 percent; Eagle Valley, 30 percent; Dayton Valley, 25 percent; and Churchill Valley, 30 percent. These features also cover about a third of the White Plains hydrographic area. Additional quantitative characteristics of the physiography are summarized in table 2. Figure 2, a sketch map of the area, shows some of the main physiographic features.

Hydrogeologic Units

A great variety of rock types occur in the report area; however, for this reconnaissance study the rocks were grouped into three units on the basis of their general geohydrologic character. The three generalized units include younger and older alluvium (the valley-fill deposits), and consolidated rocks. The surficial distribution of the lithologic units is shown on plate 1, and their general character, extent, and water-bearing properties are summarized in table 3. The distribution of lithologic units as shown on plate 1 was derived mainly through synthesis and minor modification of existing geologic maps of the area as indicated on the plate. The Tertiary sedimentary-rock unit of Moore (1969) in Carson, Dayton, and Churchill Valleys is included in most places with the older alluvium for

Table 2.—Selected quantitative physiographic data

Hydrographic area	Alluvial area (thousands of acres)	Consolidated rock area (thousands of acres)	Total area (square miles)	Percent of total study area	Approximate altitude (feet) highest	Approximate altitude (feet) lowest	Maximum relief (feet, rounded)
Carson Valley (Nev.)	88	182	422	11	11,005	4,620	6,400
Eagle Valley	a 13	32	71	2	9,214	4,600	4,600
Dayton Valley	55	178	364	10	7,856	4,215	3,650
Churchill Valley	92	222	491	13	8,763	4,080	4,700
Carson Desert[1/]	1,010	280	2,016	55	8,790	3,800	5,000
Packard Valley	63	50	177	5	8,210	3,950	4,250
White Plains	52	49	158	4	5,520	3,870	1,650
Entire study area (rounded)	1,370	990	3,700	100	11,005	3,800	7,200

a. From Worts and Malmberg, 1966, p. 11.

1. Does not include Packard Valley.

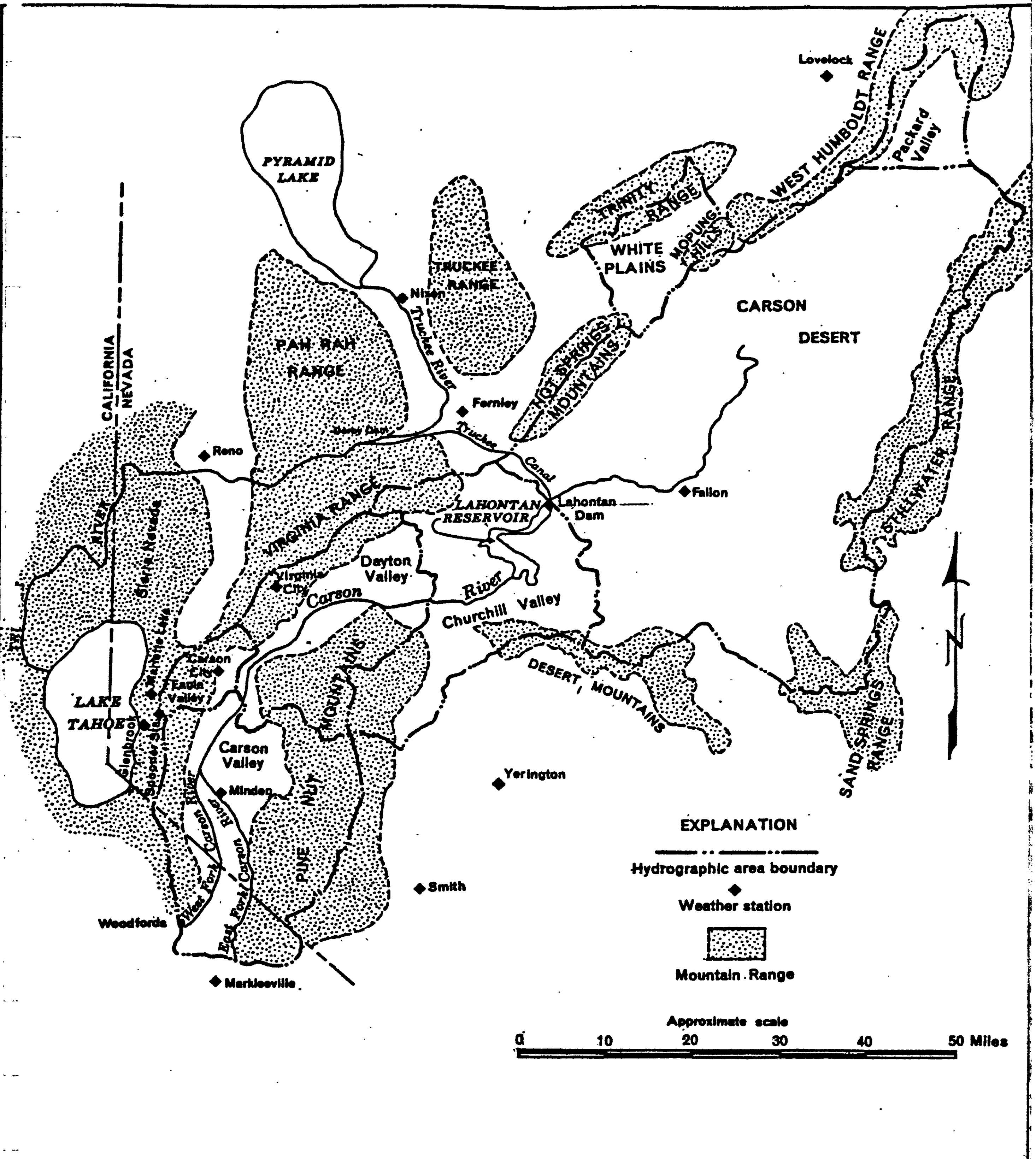

Figure 2.—Weather stations and general physiographic features in study area.

Table 3.--Generalized lithologic units and their water-bearing properties

Geologic age: Period	Geologic age: Epoch	Lithologic unit		Thickness (feet)	General characteristics and extent	Water-bearing properties
QUATERNARY	Holocene and Pleistocene	Valley fill	Younger alluvium	0-100±	Unconsolidated deposits of alluvium comprising silt, sand, gravel, and boulders derived primarily from mountain streams (perennial and ephemeral); flood-plain deposits from the Carson River, talus material, landslides, dune sand, and playa sediments. Source areas are mainly adjacent consolidated-rock uplands and older alluvium.	Younger and older alluvium together form the valley-fill reservoir, the principal source of water from wells in the area; the characteristics of recharge and the lithology of the deposits mainly control the quality and quantity of the contained ground water. Well yields range from a few gallons per minute to several thousand gallons per minute, and from very poor to excellent in quality.
TERTIARY AND QUATERNARY	Pleistocene to Miocene(?)	Valley fill	Older alluvium	0-several thousand(?)	Unconsolidated to semiconsolidated deposits of clay, silt, sand, and gravel exposed near mountain fronts and buried beneath younger alluvium elsewhere. Assumed thickest in valley troughs. Lacustrine deposits of Pleistocene Lake Lahontan are exposed throughout the Lower Carson River basin below Dayton. Tertiary sedimentary rocks of Carson, Dayton, and Churchill Valleys are included, and contain in addition to the above material sandstone, marl, mudstone, shale, diatomite, limestone, calcareous tufa, interbedded tuffaceous rocks, lava flows, and breccias.	
Y[illegible]					Igneous, metamorphic, and sedimentary rocks; igneous rocks are mainly [illegible]	Generally untested by wells except: in the Fallon area, a basalt of assumed [illegible]

purposes of this report. The authors recognize that Moore's unit includes substantial areas of consolidated rocks, but the scope of this reconnaissance precludes further differentiation.

Plate 1 does not show geologic structural features (mainly faults) that are illustrated in the existing geologic maps. These features were omitted because many of the faults cutting consolidated rocks may not influence hydrologic interpretations in this area, and the authors believe that the structural deformation of valley fill has not been adequately investigated at present. Ground-water hydrology and the development of ground-water resources are strongly dependent on geologic structure in the valley fill, and therefore, additional investigation is needed to develop the necessary data.

Valley-Fill Reservoirs

Extent and Boundaries

Younger and older alluvium (pl. 1) form the valley-fill reservoirs, which are the principal known sources of ground water in the area. The best known evidence of valley-fill thickness is contained in lithologic logs of wells drilled in the several valleys (table 40). The available evidence and resultant conclusions are as follows.

The deepest well in Carson Valley (1,268 ft) is at 13/19-22abb (see section describing numbering system for hydrologic sites) near Walley's Hot Springs (tables 39 and 40). It apparently did not fully penetrate alluvium, even though it was drilled less than one-tenth of a mile from the fault contact between alluvium and consolidated rock. However, the driller's lithologic log lacks detail (table 40). Numerous other wells, ranging from 300 to 800 feet deep, drilled a substantial distance from the valley-fill-consolidated-rock boundary, also bottom in valley-fill deposits. Therefore, the valley fill may be at least a thousand and perhaps several thousand feet thick in places.

Worts and Malmberg (1966, p. 9) concluded that valley-fill thickness in Eagle Valley is generally not more than 500 feet, although in some places it may exceed 600 feet. Recent data (1969) disclose an alluvial thickness greater than 800 feet at well 15/20-17dd (tables 39 and 40).

Dayton Valley includes several independent or semi-independent valley-fill reservoir systems (pl. 1). These systems, which are areally separated from each other by consolidated-rock divides, are as follows: (1) alluvium along the Carson River between the Carson River gage near Carson City (14/20-2bc) and the consolidated-rock river canyon just downstream from Empire; (2) alluvium in the Mound House area generally east of the Carson City-Lyon County border and west of Dayton; (3) alluvium generally north and south of the Carson River from just west of Dayton eastward to the bedrock divide bordering Stagecoach Valley subarea on the east; and (4) alluvium mainly north of the Carson River from the western bedrock boundary of Stagecoach Valley to the hydrographic area boundary of Churchill Valley on the east.

The two deepest wells in Dayton Valley (17/23-18dd, 822 feet, and 17/22-33ccbc, 633 feet) did not encounter bedrock; however, wells 16/23-3bd and 17/23-10bbb did at 178 feet and 234 feet, respectively. Valley-fill thickness may be as much as a thousand feet in some places but probably is thinner than 500 feet in most areas.

The principal areas of valley fill in Churchill Valley have not been deeply drilled, the greatest known well depth being 300 feet (18/24-27db) with no bedrock encountered. The thickness probably is at least several hundred feet throughout most of the area.

Carson Desert has the thickest known valley-fill deposits in the study area. Lithologic logs of several oil tests (17/29-18bd, 18/28-13ddc, 18/31-20c, and 22/30-14bbd) clearly show that alluvium is at least several thousand feet thick. One oil test (18/28-13aad) reportedly penetrated 8,001 feet with no evidence of bedrock (although the lithologic log lacks detail). Several other deep holes in the area (table 39) also apparently failed to reach bedrock. A test hole (16/32-19d) drilled for the U.S. Atomic Energy Commission near the playa at Fourmile Flat penetrated 780 feet of alluvium without encountering bedrock (table 40). Results of geological and geophysical studies suggest that the valley-fill deposits of Fourmile and Eightmile Flats are at least 1,950 feet thick in some parts of the valley (Nevada Bureau of Mines and others, 1962, p. 52). Therefore, valley-fill thickness over much of the Carson Desert probably is at least several thousand feet, and locally may exceed 8,000 feet.

No data are available to estimate valley-fill thickness in Packard Valley and White Plains.

External hydraulic boundaries of the valley-fill reservoirs are formed by the consolidated rocks (pl. 1) which underlie and surround the reservoirs. These boundaries are leaky to varying degrees. The principal internal hydraulic boundaries are stratigraphic changes and faults that may cut the valley fill. Because of a lack of adequate geologic and hydrologic data, the extent to which these lithologic and structural barriers impede ground-water flow is uncertain in most places.

Occurrence and Movement of Ground Water

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

In the Carson River basin, ground water moves from recharge areas in the mountains or on the adjacent alluvial slopes to the lowlands, where the water is either consumed by evapotranspiration and man's activities, or leaves the valley as stream and ground-water outflow. Carson Desert, which is a "sink" area, receives ground-water flow from upstream and from Packard Valley and White Plains. Any ground water reaching the sink is discharged by evapotranspiration.

Downgradient movement of ground water from one valley to the next occurs through alluvium and possibly consolidated rocks. There is no firm evidence that sizeable quantities of ground water move between valleys of the study area through consolidated rocks. However, downgradient intervalley movement by way of alluvium involves every valley of the study area. Estimates of these quantities are made in the report sections dealing with intervalley subsurface flow.

Availability of ground water in the several valleys is indicated in general by well drillers' reports of the depth at which water was first encountered during drilling, by reported well yields, and by the water levels in the completed wells (table 39).

The ground-water systems of the larger valleys in the report area are complex in that several aquifers may exist at varying depths and within localized geographic areas. These various aquifers, although collectively part of the valley-fill reservoirs, may act semi-independently of each other with regard to their individual hydraulic characteristics. For example, Walters, Ball, Hibdon, & Shaw (1970, p. 16 and 23) recognized two distinct zones, or aquifers, in Carson Valley alluvium, which they refer to as a shallow zone and a deep zone. They note a lack of any continuous confining strata between the two zones as indicated by well-drillers' logs, but recognize that partial confinement of the deep zone by an apparent overlapping of various clay lenses causes static water levels of the shallow and deep zones to differ. There are several flowing artesian wells in Carson Valley.

The ground-water reservoir of Carson Valley is believed to be the most important in the study area because it contains large quantities of good-quality water.

Occurrence and movement of ground water in Eagle Valley are discussed by Worts and Malmberg (1966).

The several valley-fill reservoirs unique to Dayton Valley have already been briefly described in the report section dealing with extent and boundaries of the valley-fill reservoir. Hydraulic heads in these valley-fill reservoirs generally range from a few feet above to several tens of feet below the land surface (table 39). Ground-water movement is generally toward the river in the three upstream systems. Movement of water through the valley-fill deposits that include the Stagecoach Valley subarea is less certain, because available data are inconclusive regarding hydraulic continuity between Stagecoach Valley alluvium and Carson River alluvium to the south. Natural phreatophyte discharge of ground water and existence of an alkali-flat playa in Stagecoach Valley, plus the presence of a gently sloping divide of subdued relief and possibly thin alluvial cover between that valley and the Carson River flood plain, suggest Statecoach Valley may be hydraulically isolated from the Carson River. However, water-table altitudes beneath the playa and at the river are similar, suggesting a good possibility of hydraulic continuity between Stagecoach Valley and the Carson River. Resolution of this uncertainty is beyond the scope of this investigation.

No long-term records of static water levels are available for Churchill Valley; however, it is assumed that the filling of Lahontan Reservoir has caused a general rise in ground-water levels throughout much of the valley since 1915, when the dam was constructed. Ground-water levels measured in June 1970 in the vicinity of the reservoir were all within a few feet of the reservoir surface.

The regional ground-water flow system in the Carson River basin above Lahontan Dam is generally downstream toward the reservoir and is mainly controlled by the surface-water altitude. Katzer (1972) stated that some water probably is seeping from the reservoir through volcanic rocks and associated alluvial deposits that are present in the eastern subsurface of the reservoir in the vicinity of the dam. The magnitude of any subsurface leakage is unknown but probably is minor compared to surface-flow releases.

Static water levels of the shallow aquifer system in the Carson Desert indicate that ground-water flow is generally toward the major natural discharge areas, namely, Carson Sink, Carson Lake, and Fourmile and Eightmile Flats. The available static water levels (table 39) suggest that ground water in the Fourmile Flat area moves under gentle gradients from the peripheral mountain boundaries into the playa area (land-surface altitude about 3,890 feet, or lower) and is subsequently discharged naturally by evapotranspiration. Some ground water also may flow to Fourmile Flat from the northwest by way of the Turupah and Eightmile Flat areas, but water-levels and flow data are presently too scanty to allow a confident estimate of water volumes involved.

Morrison (1964, p. 117) discussed ground water in the Carson Desert and related ground-water occurrence and yield to his detailed knowledge of Quaternary stratigraphy of the Carson Desert area.

About 150 shallow wells were drilled, dug, and driven by the U.S. Geological Survey in the Carson Desert in 1904 (before Newlands Reclamation Project irrigation began) to investigate natural water quality in the shallow aquifer system (Stabler, 1904, p. 33). Water levels in these and other wells suggest that ground water moved generally in the same directions as surface flow (Stabler, 1904, map no. 6046), and followed the natural distributary system of the Carson River. Rush (1972) stated that in 1906, when extensive irrigation began in the area, the levels of Big and Little Soda Lakes began to rise, continuing until about 1930. The total rise in stage for the period was about 60 feet. The principal cause of the rise was attributed to seepage losses from canals, which carried water from the Carson River to fields in the Fallon area as part of the Newlands Project of the U.S. Bureau of Reclamation (Lee and Clark, 1916, p. 672-675).

Basalt in the Fallon Area

Wells that supply the city of Fallon and the U.S. Naval Air Station extract water from a basalt aquifer that is apparently interbedded with the valley-fill deposits about 500 feet below land surface (wells 19/29-30cba, 30cdb1 and 2, 33cbb1, 2, and 3; tables 24, 39, and 40). These wells reportedly yield 1,000 to 2,000 gal/min. The nonpumping artesian water levels of these wells range from about 25 to 35 feet below land surface. The dissolved-solids concentration of the water from the basalt is greater than that of Carson River water but is generally much less than that of many nearby wells in valley-fill deposits. The extent of the basalt aquifer, its source of recharge, and its dependable supply are not known.

INFLOW TO THE HYDROGRAPHIC AREAS

Precipitation

The Sierra Nevada exerts the dominant control over precipitation within the Carson River basin. As storms move upslope from west to east across the Sierra Nevada, much of their moisture is depleted on west-facing slopes. This, in turn, causes lower precipitation on the east-facing slopes. Because the Sierra Nevada forms the western boundary of the Carson River basin, the study area lies mainly in a zone of diminished precipitation (a "rain shadow") with respect to east-moving storms. Table 4 summarizes the average annual precipitation at selected Weather Bureau stations in and near the report area. Figure 2 shows the location of precipitation measuring sites in and near the study area.

Snow accounts for the greatest percentage of precipitation within the basin over the long term; however, the amount of water that results from winter rains can be significant, especially in the eastern and lower parts of the basin where snowfall is usually light. Also, intense, generally unpredictable winter rains on snowpacks commonly cause severe flooding. The resulting early depletion of the snowpack occasionally results in a water shortage during the late summer growing season. Summer thunderstorms usually affect small areas, often less than a square mile, but commonly deliver large volumes of water relative to the size of drainage area in a very short time. They are a relatively unimportant water source in augmenting the available supply, but because of their generally catastrophic nature, they commonly cause severe local floods, and are one of the main natural landforming agents.

Table 4.--Average annual precipitation at weather stations

Station	Approximate location	Altitude (feet)	Period of record (complete years)	Average annual precipitation (in inches) For period of record used[1]	Average annual precipitation (in inches) Adjusted to period 1930-69 (rounded)
Marlette Lake[2]	15/18-12	8,000	1930-44, 1948-52	28.5	29
Spooner's Station[2]	14/18-1	7,100	1940-42, 1954-67	27	26
Glenbrook[2]	14/18-15a	6,400	1945-69	19.1	19
Virginia City	17/21-29	6,002	1953-60, 1966	7.2	9.0
Woodfords	11/19-35	5,625	1938-69	20.3	20
Markleeville[3]	10/20-21	5,546	1931-36, 1944, 1947-48, 1953-60	17.8	20
Smith[2]	11/23-26	4,750	1930-43, 1945-65	7.3	6.5
Minden	13/20-32b	4,700	1930-38, 1940-69	8.7	8.6
Carson City	15/20-17	4,651	1930-69	11.2	a 11.2
Reno[2]	19/20-18d	4,404	1931-69	7.7	7.6
Yerington[2]	13/25-15d	4,375	1930-67, 1969	5.5	5.5
Lahontan Dam	19/26-33d	4,158	1930-34, 1936-50, 1952-69	4.4	4.4
Fernley[2]	20/24-11d	4,160	1955-69	6.1	6.6
Lovelock[2]	27/31-2bc	3,977	1930-35, 1937-66, 1968-69	5.7	5.7
Fallon Experiment Station	18/29-6b	3,965	1930-69	5.2	a 5.2
Nixon[2]	22/23-1	3,900	1930-47, 1949,1952, 1963-69	7.3	6.9

1. From published records of the U.S. Weather Bureau.
2. Outside of report area.
3. Record for 1961-68 estimated.
a. Index station used for estimating long-term data at other stations.

Surface Water

The surface-water resources of the Carson River are well documented at a few key stations. Streamflow records at these sites are available for many years—some records date from as early as the 1890's. Definition of streamflow characteristics is possible even though the basin has undergone extensive agricultural development and small reservoirs are operated in the headwater areas.

No surface water is exported from the Carson River basin, but a substantial amount is imported. Carson Valley receives treated sewage effluent from the Lake Tahoe Basin. Eagle and Dayton Valleys receive public water-supply imports from the Lake Tahoe Basin and Washoe Valley, and Churchill Valley receives a large amount of Truckee River water for irrigation use in Carson Desert. Churchill Valley also occasionally receives a minor amount of natural surface flow from the Walker River basin through Adrian Valley, and the Carson Desert receives overflow from the Humboldt River through White Plains.

Records Available

Four long-term gaging stations on the Carson River system have recorded river flow since about the turn of the century. In addition, several stations with short-term records have been, or currently are being, operated on the mainstem, tributary streams, and diversions. Table 5 summarizes available streamflow records for the basin, and plate 1 shows the locations of the gaging stations. The annual flows of the Carson River at specific sites are presented in table 6, and maximum and minimum recorded discharges at the principal Carson River gaging stations are given in table 7. Table 8 gives the average annual flows at the six main Carson River stations for several different base periods. Table 9 presents the annual flow records for nonmainstem gaging stations upstream from Carson Desert. Table 10 lists the maximum discharge at partial-record stations and shows flow variability. Table 11 presents data for surface-water reservoirs, including information for headwater reservoirs in California, outside the report area. Additional surface-water data are available in various U.S. Geological Survey publications and files, and some are also available in reports and files of the U.S. Bureau of Reclamation, Federal Court Watermaster, Nevada State Engineer, Carson Water Subconservancy District, and the Truckee-Carson Irrigation District.

Table 5.—Selected surface-water records

Station number[1/]	Station name (in downstream order)	Location (shown on pl. 1)[2/]	Approximate drainage area (mi^2)	Period of record (calendar years)[3/]	Refer to: Table	Refer to: Figure
10308200	East Fork Carson River below Markleeville Creek, near Markleeville, Calif.	10/20-15ac	276	1960-69+	6,8	
10308800	Bryant Creek near Gardnerville	11/21-30ba	31.5	1961-69++	9	
10309000	East Fork Carson River near Gardnerville	11/20-2ac	341	1890-93 1900-1906 a 1904-5 1908-10 a 1917 1925-28 a 1929 1935-37 1939-69+	6,7,8, 12,16	3a,4
10309005	Bodie Flat tributary near Gardnerville	11/21-9ab	0.46	1966-69+θ	10	
10310000	West Fork Carson River at Woodfords, Calif.	11/19-34db	65.6	1891, a 1892 1901-20 1939-69+	6,7,8, 12,16	3a,4
10310400	Daggett Creek near Genoa	13/19-28ac	4.07	b 1964 c 1965 1965-69+	9	
10310500	Clear Creek near Carson City	14/19-1ba	15.5	1948-62++	9,10, 12	
10311000	Carson River near Carson City	14/20-2bc	876	d 1939-69+	6,7,8, 12,16	3a
10311450	Brunswick Canyon near New Empire	15/20-13ab	12.7	1966-69+θ	10	
10311900	Buckland Ditch near Fort Churchill[4/]	17/24-32db	(e)	1962-69+	9,12	
10312000	Carson River near Fort Churchill	17/24-32dc	1,450	f 1912-69+	6,7,8, 12,16	3b
10312012	Adrian Valley tributary near Wabuska	16/25-31da	5.75	1967-69+θ	10	
10312015	Adrian Valley tributary near Weeks	16/25-30bb	0.12	1967-69+θ	10	
10312050	Lahontan Reservoir tributary near Silver Springs	18/24-32cd	4.39	1962-69+θ	10	

Table 5.—Selected surface-water records—Continued

Station number[1]	Station name (in downstream order)	Location (shown on pl. 1)[2]	Approximate drainage area (mi^2)	Period of record (calendar years)[3]	Refer to: Table	Refer to: Figure
10351400	Truckee Canal near Hazen	19/26-4ca	(e)	1963-69+	9,12	
10313100	Lahontan Reservoir near Fallon	19/26-33dc	--	g 1917-69+		5,6
10312150	Carson River below Lahontan Reservoir	19/26-34dd	h 1,950	1917-69+	6,8, 12,15	6
10312210	Stillwater Diversion Canal near Fallon	19/30-34aa	(e)	1966-69+	15	
10312220	Stillwater Slough cutoff drain near Stillwater	20/31-32cd	(e)	1966-69+	15	
10312240	Paiute Diversion Drain near Stillwater	20/30-36bc	(e)	1966-69+	15	
10312260	Indian Lakes Canal near Fallon	20/29-26ab	(e)	1966-69+	15	
10312280	Carson River below Fallon	21/30-19cd	(i)	1966-69+	6,15	

1. Gaging stations at which streamflow records have been collected are listed and numbered in a downstream direction along the mainstem of the river, with all stations on a tributary entering above a mainstem station listed before that station.
2. See explanation in section entitled "Numbering system for hydrologic sites."
3. Sources of non-Geological Survey data are listed by footnote. Records are not complete for all listed calendar years, and in some instances only monthly discharges are available. Symbol "+" indicates stations still in operation following water year 1969, and symbol "++" indicates coversion from a continuous recording station to a partial record station (peak discharge only). Symbol "θ" indicates a partial record station for the indicated period of record.
4. Station discontinued Sept. 30, 1971.
a. Gage heights only, some months.
b. Periodic measurements only in 1964.
c. Low-flow partial-record site in 1965.
d. For discontinued gage data see U.S. Geological Survey 1960, p. 355.
e. No drainage area listed for irrigation ditches.
f. Records for 1911-31 furnished by U.S. Bureau of Reclamation and those for 1931-50 furnished by Truckee-Carson Irrigation District.
g. Records furnished by Truckee-Carson Irrigation District.
h. Truckee River drainage not included.
i. No drainage figure due to diversions between the gage and the Carson River below Lahontan Dam.

Table 6.--Annual flows of Carson River, water years 1891-1969, in thousands of acre-feet

[Measured flows are rounded to three significant figures above 100,000 acre-feet and to two significant figures below]

Water year[1/]	East Fork near Markleeville, Calif. (10/20-15ac)	East Fork near Gardnerville (11/20-2ac)	West Fork at Woodfords, Calif. (11/19-34db)	Main stem near Carson City (14/20-2bc)	Main stem near Fort Churchill (17/24-32dc)	Main stem below Lahontan Dam[2/] (19/26-34dd)	Main stem below Fallon (21/30-19cd)
1891		445	95				
1892		400					
1893		654					
1894-1900	No record						
1901		379	104				
1902		242	99				
1903		324	85				
1904		a 396	129				
1905		a 254	79				
1906		a 509	164				
1907		a 651	210				
1908		a 200	72				
1909		383	141				
1910		308	103				
1911		a 467	144				
1912		a 179	73		174		
1913		a 183	74		161		
1914		a 450	108		617		
1915		a 312	87		297		
1916		a 367	a 114		550		
1917		a 333	95	a 493	467		
1918		a 242	56	a 243	223	316	
1919		a 262	73	a 273	256	306	
1920		a 217	53	a 164	145	293	
1921		a 290	a 81	a 314	298	328	
1922		a 343	a 103	a 475	460	509	
1923		a 276	a 80	a 348	329	431	
1924		a 118	a 29	a 115	91	286	
1925		a 277	69	a 285	267	307	

Table 6.--Annual flows of Carson River--Continued

Water year1/	East Fork near Markleeville, Calif. (10/20-15ac)	East Fork near Gardnerville (11/20-2ac)	West Fork at Woodfords, Calif. (11/19-34db)	Main stem near Carson City (14/20-2bc)	Main stem near Fort Churchill (17/24-32dc)	Main stem below Lahontan Dam2/ (19/26-34dd)	Main stem below Fallon (21/30-19cd)
1926		143	a 53	a 131	114	284	
1927		320	a 94	a 360	341	a 360	
1928		187	79	a 190	170	a 360	
1929		a 149	39	a 112	92	a 260	
1930		192	a 52	a 168	149	310	
1931		a 121	a 31	a 86	65	162	
1932		a 292	a 82	a 326	307	284	
1933		a 163	a 43	a 142	122	287	
1934		a 128	a 39	a 98	76	140	
1935		a 254	a 69	a 230	210	241	
1936		252	a 82	a 296	275	274	
1937		228	a 74	a 281	262	321	
1938		a 460	a 127	a 592	580	541	
1939		a 163	39	a 163	140	311	
1940		273	76	285	279	331	
1941		250	78	263	244	330	
1942		355	106	428	403	456	
1943		331	90	425	403	474	
1944		177	47	177	169	365	
1945		307	76	332	310	399	
1946		255	76	287	262	415	
1947		181	48	180	165	348	
1948		190	56	170	152	273	
1949		196	51	187	167	354	
1950		254	77	263	260	333	
1951		349	99	434	423	555	
1952		459	127	576	587	534	
1953		256	78	286	240	511	
1954		200	53	197	177	488	
1955		160	49	134	114	390	
1956		436	124	550	533	573	
1957		228	69	243	224	557	
1958		340	98	376	341	583	
1959		147	42	128	108	453	
1960		128	38	90	60	268	

Table 6 .--Annual flows of Carson River--Continued

Water year[1]	East Fork near Markleeville, Calif. (10/20-15ac)	East Fork near Gardnerville (11/20-2ac)	West Fork at Woodfords, Calif. (11/19-34db)	Main stem near Carson City (14/20-2bc)	Main stem near Fort Churchill (17/24-32dc)	Main stem below Lahontan Dam[2] (19/26-34dd)	Main stem below Fallon (21/30-19cd)
1961	115	120	31	75	44	160	
1962	234	233	63	239	218	252	
1963	297	320	92	369	338	442	
1964	168	171	50	158	136	422	
1965	360	372	120	434	382	505	
1966	183	192	55	188	171	571	
1967	417	408	99	482	449	470	81
1968	181	186	60	183	162	354	8.4
1969	452	489	124	588	561	526	130
Average for available period of record	267	284	81	276	264	377	--
Adjusted average for base period of this study, 1919-69	241	251	71	272	252	b 380	--

1. A water year is from October 1 through September 30. Thus, December 1968 is in the 1969 water year.

2. Flow figures prior to 1967 furnished by U.S. Bureau of Reclamation.

a. Record synthesized by U.S. Bureau of Reclamation, Lahontan Basin Office, Carson City, Nev. (Nathan Geering, oral commun., 1971). Correlations are based on nearby streamflow records and snow-survey data; in some years monthly-flow data were available from records of the Nevada State Engineer.

b. Rounded.

Table 7.--Maximum and minimum recorded discharge at the principal Carson River measurement sites through 1969 water year

Hydrologic site number	Station name	Maximum discharge[1]		Minimum discharge[1]	
		Date	Cubic feet per second	Date	Cubic feet per second
11/20-2ac	East Fork Carson River near Gardnerville	Dec. 23, 1955	17,600	Dec. 4-10, 19-23, 1904	8
11/19-34db	West Fork Carson River at Woodfords, Calif.	Feb. 1, 1963	4,890	Dec. 23, 1961	5
14/20-2bc	Carson River near Carson City	Dec. 24, 1955	a 30,000	Aug. 7, 1961	3
17/24-32dc	Carson River near Fort Churchill	Feb. 2, 1963	15,300	(b)	0

1. Instantaneous.

a. Probably exceeded during the flood of March 18, 1907, which washed out the gage (see flood section).

b. No flow during some periods in nearly every year since 1923; flow affected by Buckland Ditch, which diverts 400 feet upstream.

Table 8.—Average annual streamflow at Carson River gaging stations, in thousands of acre-feet (rounded), for different reference periods

Period (water years)	Average annual streamflow	Period (water years)	Average annual streamflow
10/20-15ac East Fork Carson River near Markleeville, Calif.			
a 1961-69	267	bc 1919-69	241
11/20-2ac East Fork Carson River near Gardnerville			
a 1891-93, 1901-03, 1909-10, 1926-28, 1930, 1936-37, 1940-69	282	c 1919-69	251
		d 1917-50	236
		e 1931-60	251
		f 1918-67	247
b 1891-93, 1901-69	284	g 1919-69	245
11/19-34db West Fork Carson River at Woodfords, Calif.			
a 1891, 1901-15, 1917-20, 1925, 1928-29, 1939-69	84	d 1917-50	67
		e 1931-60	72
		f 1918-67	68
b 1891, 1901-69	81	g 1919-69	70
c 1919-69	71		
14/20-2bc Carson River near Carson City			
a 1940-69	279	c 1919-69	272
b 1917-69	276	d 1917-50	253
17/24-32dc Carson River near Fort Churchill			
a 1912-69	264	e 1913-60	255
c 1919-69	252	f 1918-67	246
d 1917-50	236		
19/26-34dd Carson River below Lahontan Reservoir, near Fallon			
a 1918-26, 1930-69	380	c 1919-69	378
b 1918-69	377	d 1917-50	343

a. Actual period of record.
b. Period of record including synthesized data.
c. Reference period used in this report.
d. U.S. Bureau of Reclamation, 1954, p. 38 of "Substantiating materials."
e. Pacific Southwest Inter-Agency Committee, 1972, p. 111, Flows modified for 1965 conditions.
f. Pyramid Lake Task Force, 1969, appended summary, p. 6.
g. Flows have been adjusted for conditions at the State line as follows; East Fork Carson River near Gardnerville: 250,000 acre-feet minus estimated 5,000 acre-feet inflow from Bryant Creek in California. West Fork Carson River at Woodfords: 71,000 acre-feet plus estimated 5,000 acre-feet inflow between gage and State line, and minus estimated 7,000 acre-feet consumptive use by vegetation between gage and State line (net State line total rounded).

Table 9.--Annual flow at nonmainstem gaging stations, in thousands of acre-feet

[Flows rounded to three significant figures]

Water year	Bryant Creek (11/21-30ba)	Daggett Creek (13/19-28ac)	Clear Creek (14/19-1ba)	Buckland Ditch (17/24-32db)	Truckee Canal near Hazen (19/26-4ca)
1949			2.89		
50			3.93		
1951			5.02		
52			8.14		
53			5.42		
54			3.45		
55			2.81		
1956			5.63		
57			3.53		
58			4.85		
59			2.98		
60			2.23		
1961			1.87		
62	4.25		2.27		
63	6.02			16.1	
64	2.67			14.8	b 262
65	5.00			16.5	b 250
1966	3.40	0.875		17.0	b 237
67	9.22	1.55		16.4	216
68	3.56	1.08		14.9	122
69	14.5	a 2.58		19.5	114
Average	6.08	--	3.93	16.5	200

a. Includes 400 acre-feet of imported sewage in 1969. See table 20.

b. Van Denburgh and others, 1973, p. 24.

Table 10.--Maximum discharge at partial-record stations[1]

Station name	Location[2]	Drainage area (sq mi)	Maximum annual discharge[3] Water year	Month	Cubic feet per second
Bodie Flat tributary near Gardnerville	11/21-9ab	0.46	1967	March	3
			1968	March	a 0.1
			1969	April	a 0.3
Clear Creek near Carson City	14/19-1ba	15.5	1963	January	170
			1964	—	35
			1965	—	58
			1966	April	9
			1967	March	110
			1968	February	130
			1969	April	87
Brunswick Canyon near New Empire	15/20-13ab	12.7	1966	August	a 4
			1967	March	63
			1968	May	a 0.1
			1969	January	60
Adrian Valley tributary near Wabuska	16/25-31da	5.75	1968	August	a 0.7
			1969	January	a 0.2
Adrian Valley tributary near Weeks	16/25-30bb	.12	1968	August	a 1
			1969	July	a 1
Lahontan Reservoir tributary near Silver Springs	18/24-32cd	4.39	1962	—	No flow
			1963	—	No flow
			1964	July	a 0.2
			1965	—	No flow
			1966	—	No flow
			1967	—	No flow
			1968	—	No flow
			1969	—	No flow

1. A partial-record station is operated to collect limited streamflow data on a systematic basis during high- and low-flow periods.

2. See report section describing hydrologic site numbering system.

3. Discharge determined by indirect methods unless otherwise noted.

a. Estimated.

Table 11.--Data for reservoirs and lakes in the Carson River basin

Name	Spillway location[1]	Spillway or maximum water-surface elevation above mean sea level (to nearest foot)	Maximum operating capacity[2] (acre-feet)	Tributary to
		EAST FORK CARSON RIVER		
Upper Kinney Lake[3]	8/20-7cb	8,536	328	Silver Creek
Lower Kinney Lake[3]	8/20-7bd	8,442	920	Silver Creek
Kinney Reservoir[3]	8/20-8cb	8,333	900	Silver Creek
Wet Meadows[3]	9/19-27ad	8,030	450	Pleasant Valley Creek
Summit Lake[3]	9/19-27db	8,022	31	Pleasant Valley Creek
Raymond Lake[3]	9/19-25aa	a 8,980	50	Pleasant Valley Creek
Tamarack Lake[3]	9/19-21cc	7,890	404	Pleasant Valley Creek
Upper Sunset[3]	9/19-27ba	7,858	68	Pleasant Valley Creek
Lower Sunset[3]	9/19-22dc	7,823	860	Pleasant Valley Creek
Heenan Lake[3]	9/21-3cb	7,084	2,948	Heenan Lake Creek
Indian Creek Reservoir[4]	10/20-4c	5,604	3,100	Indian Creek, a tributary to East Fork Carson River
Allerman no. 1[5]	13/20-26ca 13/20-35ba	4,856	437	Allerman Canal
Allerman no. 2	13/20-26cb	4,838	248	Allerman Canal
Allerman no. 4	13/20-14ba	4,836	867	Allerman Canal
		WEST FORK CARSON RIVER		
Upper or East Lost Lake[3]	9/18-12aa	8,598	92	Headwater of West Fork
Lower or West Lost Lake[3]	9/18-1dc	8,546	127	Headwater of West Fork
Crater Lake[3]	10/18-11ca	8,522	320	Crater Lake Creek
Scotts Lake[3]	10/18-2aa	8,001	736	Scott Creek
Red Lake[3]	10/18-23ac	7,867	1,103	Red Lake Creek
Mud Lake Reservoir	11/20-4ad	5,100	4,700	West Fork Carson River

Table 11.—Data for reservoirs and lakes in the Carson River basin—Continued

Name	Spillway location[1]	Spillway or maximum water-surface elevation above mean sea level (to nearest foot)	Maximum operating capacity[2] (acre-feet)	Tributary to
		MAIN STEM CARSON RIVER		
Ambrosetti Pond	14/20-30cc	a 4,660	200	Carson River
Unnamed pond in gypsum quarry	16/20-25bb	--	--	No surface outflow
Lahontan Reservoir	19/26-33dd	4,164 (1917 datum)	b 322,000	Carson River
Soda Lake[6]	19/28-7,8	3,988	35,000	No surface outlet
Sheckler Reservoir[2]	18/27-13ab	3,990	11,000	AA Canal
S Line Reservoir[2]	19/29-28ca	a 3,950	1,495	S Canal
Harmon Reservoir[2]	19/30-32aa	3,926	1,700	S-2 Canal
Ole's Pond[2]	19/29-14bd	3,939 (1917 datum)	2,000	Ole's Pond outlet
Stillwater Point Reservoir[2]	19/31-16ba	3,906	7,000	Canal
Old River Reservoir[2]	19/29-7bd	3,958	1,100	Canal

1. See report section describing hydrologic site numbering system.
2. From Decree No. D-183 and U.S. Bureau of Reclamation (oral commun., 1971).
3. Outside of study area, not shown on plate 1.
4. Reservoir contents dominated by imported sewage from Tahoe Basin.
5. Dual outlets.
6. From Rush (1972).
a. Estimated.
b. From Katzer (1972).

The variation of averages at a given streamflow measuring site for different base periods of record, shown in table 8, suggests that averages for different measurement sites are generally not comparable unless the same base periods are used. Therefore, this present study utilizes the base period 1919-69 of Van Denburgh and others (1973, p. 19), so that the hydrologic data, estimates, and budgets derived for the Carson River basin will be compatible with those of the adjacent Truckee River basin. No attempt has been made to adjust the flows to natural conditions. Compatibility of the quantitative data derived for both river basins is desirable because the direct hydrologic interplay between the two river systems makes them dependent on each other.

Techniques of Runoff Determination

Measured runoff.—The average annual river inflow to the hydrographic areas was determined using the available streamflow records for a specific site and then adjusting the averages to the 1919-69 base period. The adjusted annual averages were determined by synthesizing missing record periods through graphic and statistical regression correlation methods. The resultant streamflow averages are shown in table 12.

Estimates runoff.—Where stream-gaging records were not available, the ungaged runoff from tributary streams was estimated using the indirect methods developed by Moore (1968). The relationship between altitude, precipitation, and average annual runoff was defined for each hydrographic area at the mountain front. The resultant runoff estimate was refined using the channel-geometry technique (Moore, 1968). The accuracy of the runoff was checked by comparison with runoff estimates derived using actual streamflow measurements which were correlated for long-term average when such data were available. Data used in the checking process are shown in table 13. Table 14 summarizes the estimated runoff from tributary streams for the four mainstem hydrographic areas.

Table 12.--Estimates of average annual streamflow at hydrographic area boundaries, 1919-69 water years

Inflow to	From	Name of stream or canal	Location	Acre-feet per year inflow (rounded)
Carson Valley (Nevada)	Carson Valley (Calif.)	East Fork Carson River at Stateline	11/20-25bc	a 245,000
		West Fork Carson River at Stateline	11/20-8bc	a 70,000
Carson Valley	Eagle Valley	Clear Creek near Carson City	14/19-1ba	3,000
		Carson Valley total		318,000
Dayton Valley	Carson Valley	Carson River near Carson City	14/20-2bc	272,000
Dayton Valley	Eagle Valley	Kings and Ash Canyon Creeks plus Carson City sewage effluent	—	b 4,000
		Dayton Valley total		276,000
Churchill Valley	Dayton Valley	Carson River near Fort Churchill	17/24-32dc	252,000
		Buckland Ditch near Fort Churchill	17/24-32db	16,000
Churchill Valley	Walker River basin	Adrian Valley	16/24-35bc	1,000
Churchill Valley	Truckee River	Truckee Canal near Hazen	19/26-4ca	170,000
		Churchill Valley total		439,000
Carson Desert	Churchill Valley	Carson River below Lahontan Reservoir near Fallon	19/26-34dd	380,000
Carson Desert	Truckee River	Truckee Canal at diversions to Hazen and Swingle Bench areas for irrigation	20/26-32, 19/26-4, and 19/26-22	10,000
Carson Desert	White Plains	Lower Humboldt Drain	23/28-24c	c 1,000
		Carson Desert total		391,000

1. Outside study area.
a. Flows were determined for nearest gaging stations near Gardnerville, Markleeville, and Woodfords (table 8), and were then adjusted for conditions at the State line.
b. Sewage effluent estimated to average 500 acre-feet per year for period 1919-69.
c. Estimated by channel-geometry methods developed by Moore (1968).

Table 13.--Instantaneous measured flow of several Carson River basin tributaries

Stream	Location	Date	Discharge (ft^3/s)	Tributary to
Thompson Canyon near Gardnerville	12/22-31cb	Apr. 9, 1969	2.24	Pine Nut Creek
Pine Nut Creek near Gardnerville 1/	12/22-31cb	Apr. 9, 1969	5.85	Carson Valley
	12/21-25ab	Apr. 9, 1969	9.35	
	12/21-10cb	Apr. 9, 1969	9.39	
		Sept. 8, 1969	.56	
	12/21-5bc	Apr. 9, 1969	10.9	
	12/21-6bc	Apr. 9, 1969	10.0	
		Apr. 14, 1969	14.8	
	12/20-2ad	Apr. 9, 1969	8.12	
		Apr. 14, 1969	14.0	
Buckeye Creek near Gardnerville 1/	13/21-24ba	Apr. 14, 1969	7.60	Carson Valley
	13/21-19ac	Apr. 14, 1969	7.94	
	13/20-24cc	Apr. 14, 1969	4.99	
Mott Creek near Genoa	12/19-4cc	Sept. 11, 1969	3.48	West Fork Carson River
		Oct. 2, 1970	2.26	
		Nov. 9, 1970	2.75	
		Dec. 9, 1970	2.84	
		Feb. 9, 1971	3.25	
		Mar. 5, 1971	3.26	
		Mar. 10, 1971	3.13	
		Mar. 24, 1971	3.89	
Genoa Canyon near Genoa	13/19-9cd	Sept. 11, 1969	.94	Carson River
Sierra Canyon near Genoa	13/19-4db	Sept. 11, 1969	2.06	Carson River
		Aug. 5, 1971	a 340	
Unnamed tributary to Lahontan Reservoir	18/25-13ba	July 19, 1971	a 460	Lahontan Reservoir
Unnamed tributary to Lahontan Reservoir	17/24-10ab	July 20, 1971	a 1,700	Lahontan Reservoir

a. Peak discharge determined by indirect measurement methods, and rounded to two significant figures.

1. Listed in downstream order.

Table 14.--Estimated average annual runoff at the mountain front from ungaged tributary streams in Nevada

Hydrographic area	Runoff area (acres)	Percentage of total river basin runoff area	Acre-feet of runoff	Percentage of total runoff
Carson Valley (Nev. part only)	61,000	13	a 15,000	75
Dayton Valley	130,000	28	1,400	7
Churchill Valley	98,200	22	900	4
Carson Desert	173,000	37	b 3,000	15
Total (rounded)	462,000	100	20,000	100

a. Estimated Carson Valley runoff from combined Nevada and California segments, downstream from the Markleeville and Woodfords river gages, is 34,000 acre-feet per year.

b. Includes 600 acre-feet from Packard Valley and 100 acre-feet from White Plains.

Local runoff into Carson Valley was estimated by Piper (1969, p. F7), who employed a statistical technique based on the relation between runoff and land-surface altitude, combined with coefficients for horizontal variations. For Carson Valley as a whole, the results of Piper's method and the methods used in this report to estimate runoff are compatible. However, there are minor disagreements in some of the subareas of Carson Valley, as might be expected when indirect techniques are used. Piper's water budget for Carson Valley is discussed in the Water Budget section of this report.

Streamflow Characteristics

The dominant hydrologic feature within the Carson River basin study area is the river. It generally flows perennially throughout most of its reaches. Many perennial tributaries in the river headwater areas drain the east slope of the Sierra Nevada, and although some other tributaries do not flow perennially in their lower reaches near confluence with the river, they do play a vital role in ground-water recharge. The number of perennial tributaries decreases in a downriver direction. Downstream from the head of Dayton Valley, all tributaries are ephemeral near their confluence with the river. Therefore, streamflow through these tributaries usually reaches the river as surface flow only during times of substantial runoff caused by large rainfall or snowmelt. The major source of water for the Carson River is the winter snowpack in the Sierra Nevada, but minor amounts of water are contributed locally by rainstorms. Streamflow characteristics for the various hydrographic areas are described below.

Carson Valley.—The time distribution of runoff within a given year at the stream-gaging stations above Lahontan Reservoir is, in general, believed to be very similar to that of the East Fork Carson River near Gardnerville (11/20-2ac, pl. 1). The streamflow records for this site are believed generally to typify natural runoff distribution from the headwaters of the river basin, because the East Fork Carson River is the largest tributary of the headwater drainage, and streamflow at this site is virtually unaffected by manmade diversions and impoundments.

Base flow is reached in late summer, and flow then increases slightly through the fall and winter months until the snowmelt season starts in early spring. Maximum annual flows can normally be expected in May and June. Surface-water runoff from April through July generally accounts for about 40 to 60 percent of the total annual flow. Figure 3a shows the monthly flow distribution for the East and West Forks of the Carson River, which together equal the total river inflow to Carson Valley. Also shown are similar data for the Carson River near Carson City (14/20-2bc), which document total river outflow from Carson Valley. The average annual flow of the East Fork Carson River near Gardnerville for the 1919-69 base period is 251,000 acre-feet, that of the West Fork Carson River at Woodfords (11/19-34db), 71,000 acre-feet, and Carson River near Carson City, 272,000 acre-feet. Outflow from Carson Valley generally exceeds inflow from November through March, mainly because of the combined effects of ground-water inflow, local runoff to the river, and reduced evapotranspiration losses. Usually, the irrigation season ends during late September or October; the weather at that time is considerably cooler, and evapotranspiration therefore decreases markedly. With the first warm weather of spring, generally in March, irrigation begins again, and river inflow to Carson Valley begins to exceed river outflow to Dayton Valley. This net reduction of streamflow is due mainly to the increase in evapotranspiration and ground-water recharge.

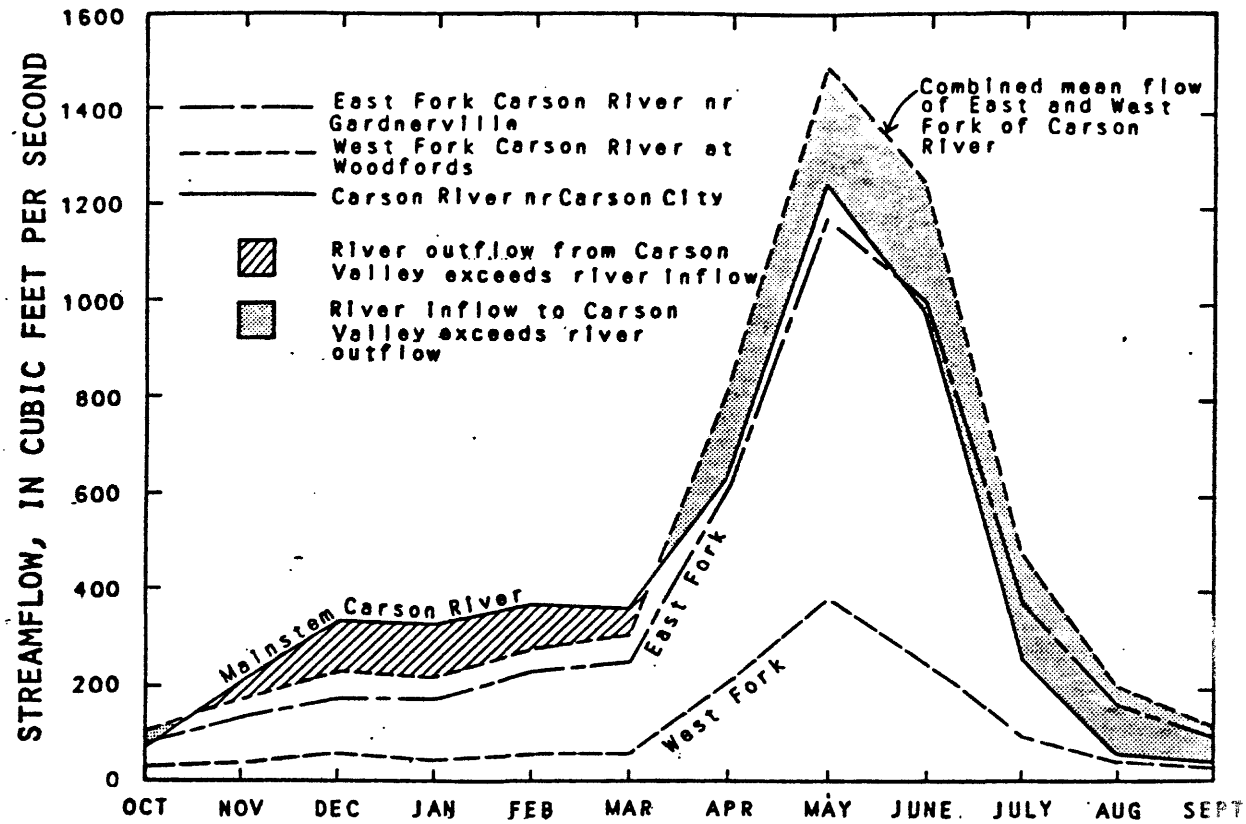

Figure 3a.—Mean monthly flow of Carson River into and out of Carson Valley, 1940–69 water years.

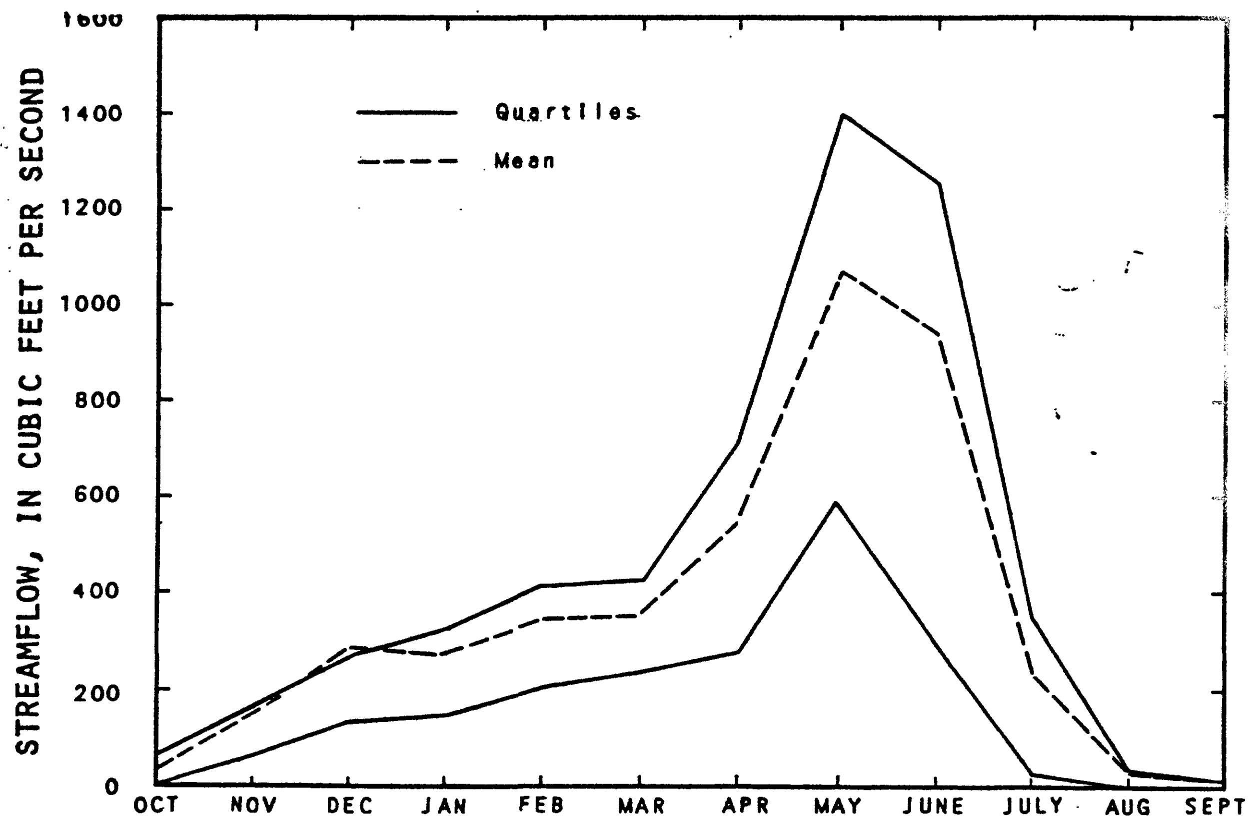

Figure 3b.—Average monthly flow distribution, Carson River near Fort Churchill, 1919–69 water years. Quartiles show 25 percent of the monthly flows were higher and lower than indicated.

Carson Valley receives a small amount of surface flow from Eagle Valley via a diversion from Clear Creek at 14/19-4cab (site not shown on pl. 1). That diversion is estimated to average about 100 acre-feet annually and is used to irrigate pasture on the Schneider Ranch in northern Jacks Valley (Harry Schneider, oral commun., 1972).

Flow-duration curves for the East and West Forks are shown in figure 4. These curves show the amount of time a given flow was equaled or exceeded; for example, a flow of 100 ft^3/s on the West Fork has been equaled or exceeded 26 percent of the time during water years 1939-69. This does not mean that in any given year this flow will be reached 26 percent of the time; but over the years, this flow will average about this value if conditions are approximately equivalent to the 1939-69 period.

Eagle Valley.—Eagle Valley is not traversed by the Carson River, but is tributary to the river. According to Worts and Malmberg (1966, p. 19) the surface-flow quantities entering the Carson River are about 3,000 acre-feet per year from Clear Creek (enters the river upstream from the Carson City gage), and about 3,500 acre-feet per year from the remainder of Eagle Valley. In addition, for the period 1919-69, an estimated average of about 500 acre-feet per year of Carson City sewage effluent flowed to the river.

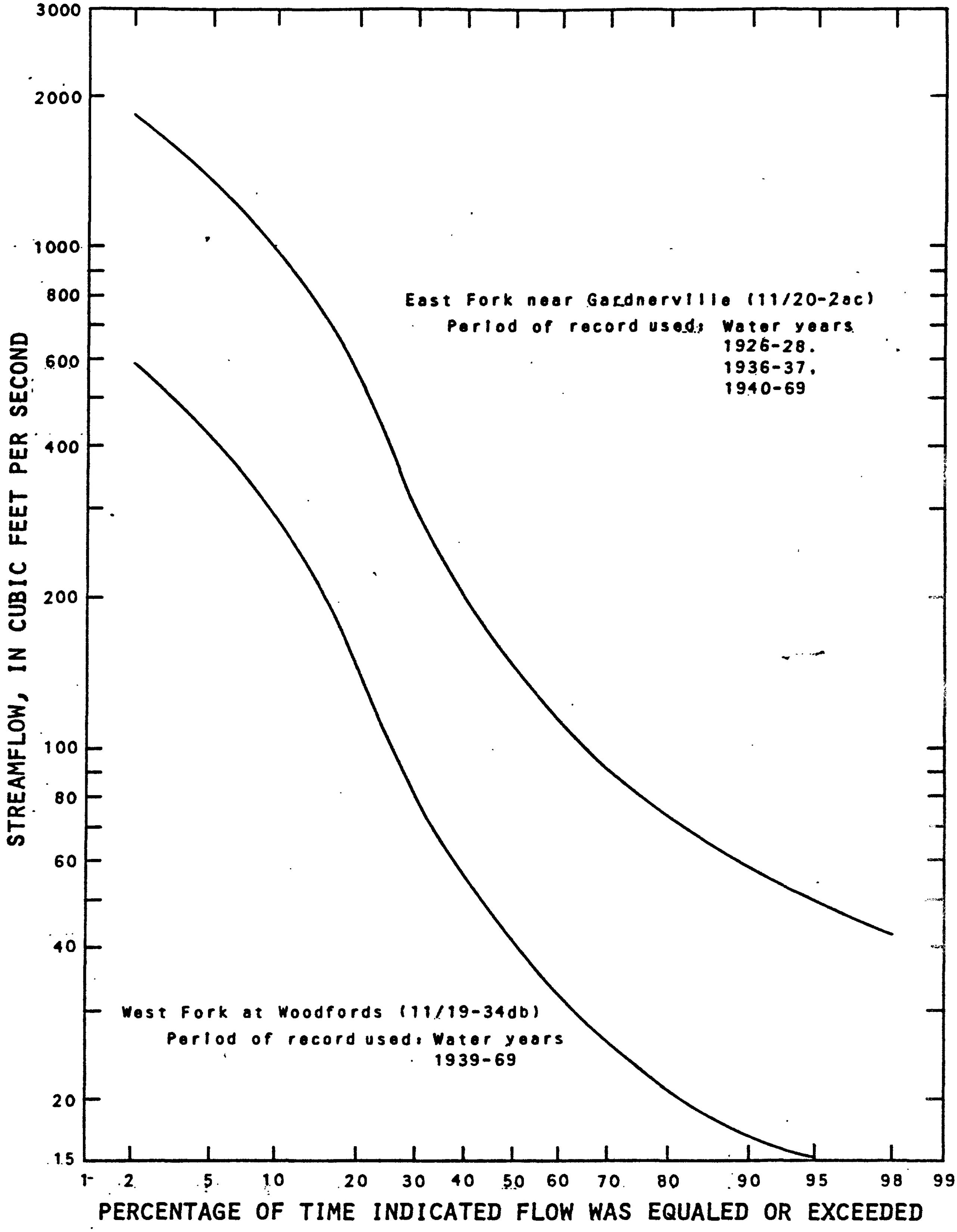

Figure 4.--Flow duration curves for East and West Forks Carson River.

Dayton Valley.—The Carson River gage near Carson City (14/20-2bc) records river flow from Carson Valley to Dayton Valley. This flow averages about 272,000 acre-feet annually. The river furnishes the major part of streamflow entering Dayton Valley. Runoff from Eagle Valley, excluding Clear Creek, enters Carson River below the Carson City gage, as discussed in the previous report section. This inflow, principally from Kings and Ash Canyon Creeks and Carson City sewage effluent, is estimated to have averaged about 4,000 acre-feet per year. Therefore, the combined streamflow entering Dayton Valley from Carson and Eagle Valleys is about 276,000 acre-feet annually (table 12).

Churchill Valley.—The combined flow of Carson River (252,000 acre-feet annually) past the gage near Fort Churchill (17/24-32dc) plus Buckland Ditch (16,000 acre-feet annually, 17/24-32db) represent total surface-water outflow from Dayton Valley and are the major inflow components to Churchill Valley. Often during summer months, river reaches between the Carson City gage ~~and the Fort Churchill gage are dry. River flow at the Fort Churchill~~ gage also commonly ceases in late summer, as shown in figure 3b. The lack of flow at the Fort Churchill gage, however, is because the Buckland Ditch, which diverts just upstream from the Fort Churchill gage, often carries the entire river flow during late summer. The combined average annual flow of the river and ditch represents the cumulative flow at this hydrographic boundary; it averaged about 268,000 acre-feet annually for the 1919-69 base period.

Huxel (1969, p. 22) estimated an average annual flow of about 1,000 acre-feet per year from the Walker River in Mason Valley through Adrian Valley to the Carson River in Churchill Valley, downstream from the Fort Churchill gage. However, this quantity represents an estimated long-term average; flow occurs only during extremely wet years.

Lahontan Reservoir is the largest surface-storage facility on the Carson River, and has a flashboard capacity of 322,000 acre-feet. Figure 5 shows the annual maximum and minimum stages of the reservoir for the period 1917-72 calendar years. Most of the Truckee Canal water diverted from the Truckee River at Derby Dam enters Lahontan Reservoir near Lahontan Dam. The amount of water reaching the study area was estimated by Van Denburgh and others (1973, p. 48, 57) to be 180,000 acre-feet per year for the base period 1919-69. Of this total, about 10,000 acre-feet was diverted to the Hazen-Swingle Bench area (in the Carson Desert hydrographic area), and the estimated amount entering Churchill Valley through the Truckee Canal (19/26-33dc) enroute to Lahontan Reservoir was 170,000 acre-feet per year.

Carson Desert.--The Carson River gage below Lahontan Dam (19/26-34dd) measures surface-water flow from Churchill Valley to Carson Desert. Streamflow at this site is controlled by reservoir releases, and averaged about 380,000 acre-feet annually for the base period. Figure 6 shows reservoir releases during the 1917-72 calendar years. This water is used primarily for irrigation in the Fallon area (pl. 1), but some also provides habitat for wildfowl in the Stillwater Wildlife Management area and adjoining areas. These uses are more fully discussed in later sections of this report.

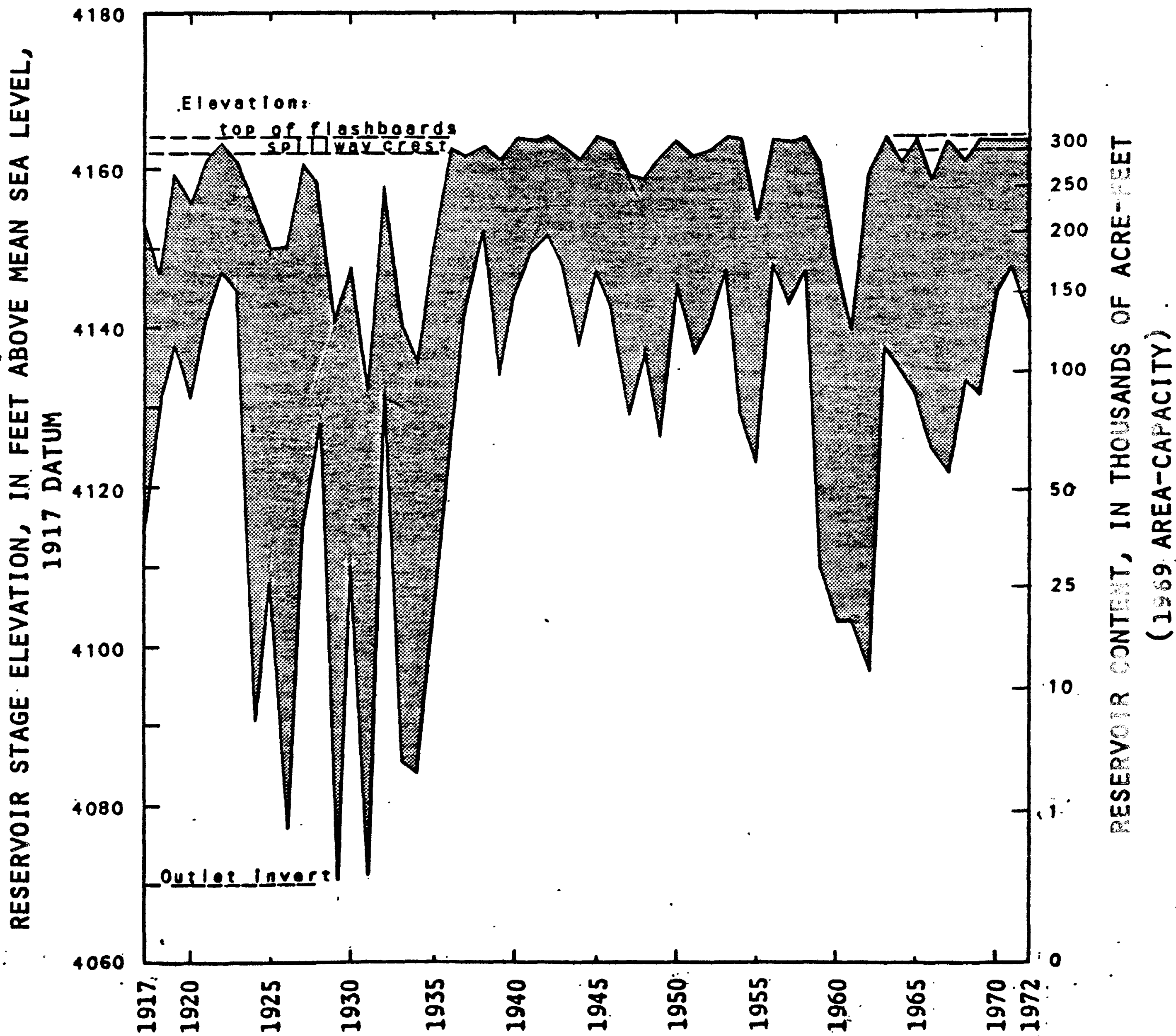

Figure 5.—Annual maximum and minimum stages and volume of stored water in Lahontan Reservoir, 1917-72 calendar years. (Data furnished by Truckee-Carson Irrigation District.)

As previously mentioned, during the 1919-69 base period, about 10,000 acre-feet per year was diverted from the Truckee Canal for irrigation in the Hazen-Swingle Bench area (pl. 1).

The surface-water outflow from the Newlands Irrigation Project is not completely accounted for by direct flow measurement. Since 1967, the Geological Survey has recorded Carson River flow just upstream from the Carson Sink (21/30-19cd), and also has recorded the flow of four canals tributary to the Stillwater Wildlife area (sites 19/30-34aa, 20/31-32cd, 20/30-36bc, and 20/29-26ab). Table 15 summarizes available flow data for these five sites. Additional flow data for Carson Desert are available from the Truckee-Carson Irrigation District in Fallon and the U.S. Bureau of Reclamation in Carson City.

Packard Valley and White Plains.--Some streamflow reaches the Carson Sink of Carson Desert from Packard Valley and White Plains. The flow from Packard Valley probably is less than 100 acre-feet per year and generally occurs as the result of thunderstorms. The flow into White Plains, which represents terminal discharge of the Humboldt River, is estimated to average about 6,000 acre-feet per year. The flow from White Plains into Carson Sink is estimated to average about 1,000 acre-feet per year. The inflow-outflow quantities were estimated by a channel-geometry technique developed by Moore (1968, p. 36-68) and natural discharge evidence.

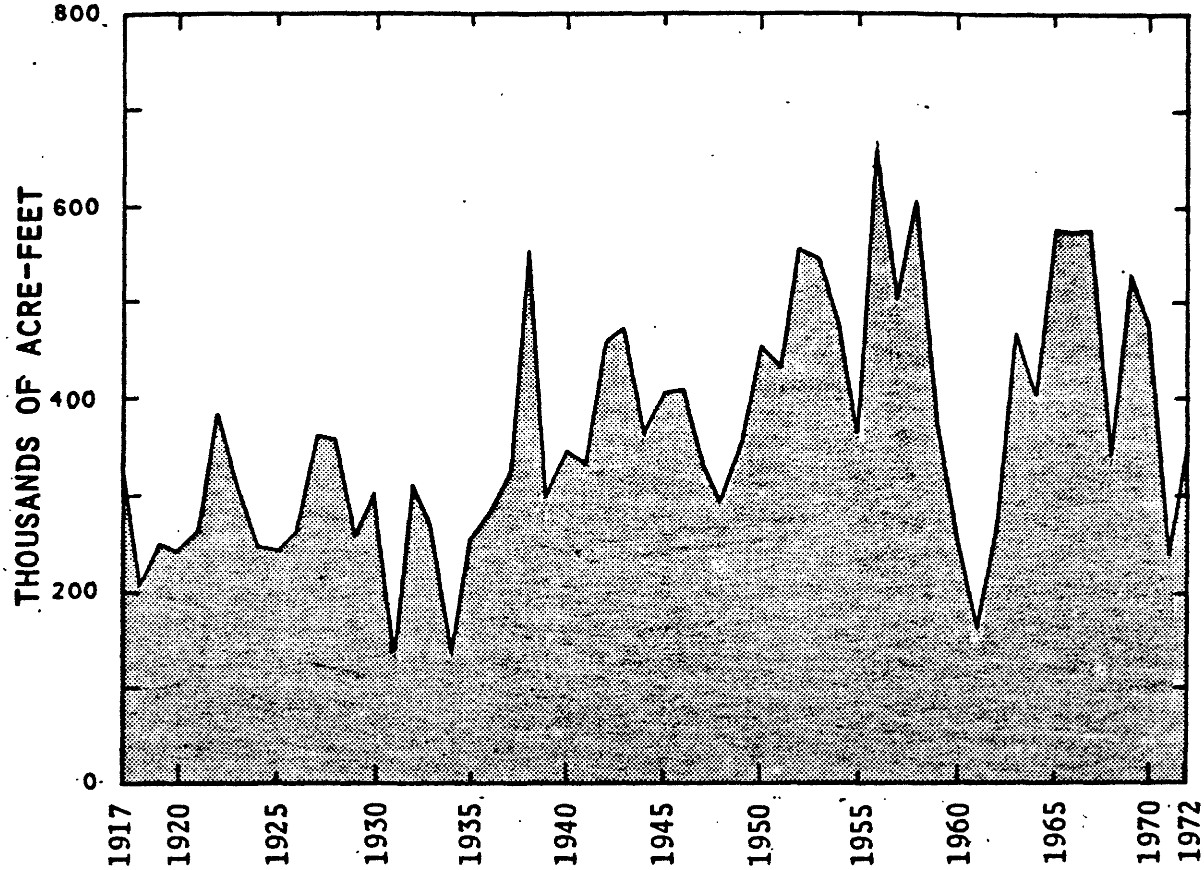

Figure 6.--Lahontan Reservoir releases to Carson River, 1917-72 calendar years. (Data furnished by Truckee-Carson Irrigation District.)

Table 15.--Measured Carson Desert streamflow, return flow from irrigated lands, and flow from reservoir spills (thousands of acre-feet)[1]

[Flows rounded to three significant figures]

Flow measurement site	Hydrologic site number	Water year 1967	1968	1969	1970	1971	1972	1973
Carson River below Lahontan Reservoir[2]	19/26-34dd	470	354	526	471	374	363	328
Carson River below Fallon[3]	21/30-19cd	81.1	8.41	130	68.3	74.9	6.03	6.66
Stillwater Diversion Canal near Fallon[3]	19/30-34aa	35.7	29.0	35.9	62.6	44.3	32.7	26.8
Stillwater Slough Cutoff Drain[3]	20/31-32cd	23.8	26.0	28.9	31.1	21.0	22.8	21.3
Paiute Diversion Drain near Stillwater[3]	20/30-36bc	7.45	5.25	7.22	9.59	6.45	6.35	6.44
Indian Lakes Canal near Fallon[3]	20/29-26ab	18.2	10.4	16.7	16.2	18.5	15.7	8.90

1. Records for other years and other stations are available from Truckee-Carson Irrigation District, Fallon, and U.S. Bureau of Reclamation, Carson City.
2. Measures outflow from Lahontan Reservoir.
3. Measures flow to Carson Sink and Stillwater Wildlife Management area.

Floods

Carson River floods.—Many floods have occurred on the Carson River since settlement of the area began in the middle of the 19th century. Table 16 lists quantitative data for a select group of recorded floods. The floods listed in table 16 generally represent the major floods recorded at the various streamflow measurement sites in the river basin. The U.S. Department of Agriculture (1973) presents a more complete listing of specific floods and also describes interesting historical details of each individual flood. The data of table 16 and those of U.S. Department of Agriculture (1973) show that floods cannot be accurately predicted on the basis of a cyclic pattern of recurrence; for example, since 1890, the longest flood-free period (about 14 years) apparently occurred between January 1914 and March 1928, whereas more than one flood occurred during several individual years of record. The last major recorded flood occurred in 1964; therefore, the historical record suggests that statistical odds favor recurrent flooding in the not too distant future.

Nearly all known floods on the Carson River were caused by heavy rains falling on a substantially heavy snowpack, and the flooding resulted from the combined effects of rainfall, runoff, and snowmelt.

Records are sketchy regarding floods prior to 1890 and quantitative flow data are unavailable. However, several qualitative summaries of early floods have been published. Thompson and West (1958, p. 34) provide a brief account of a very early flood:

> "On the twenty-fourth of December 1852, it commenced to snow in Carson Valley; in two days three feet of it was lying over the whole face of the country, and six days later the ground was bare. The sudden melting of the vast field of snow caused a greater flood in the Carson River to usher in the year 1853 than has since occurred [through about 1880]."

Table 16.-- Summary of quantitative streamflow data for selected historic floods of the Carson River

Date of peak flow	East Fork near Gardnerville (Peak flows, in cubic feet per second[1])	West Fork at Woodfords	Mainstem near Carson City	Mainstem near Fort Churchill	Remarks
1890					
May 28	a 4,260 maximum observed		No record	No record	Snowmelt
June 9		b 1,280			Snowmelt
1892					
Dec. 25	a 5,540 maximum observed	No record	No record	No record	Rain on snow
1907					
Mar. 18	No record		d 4,000 maximum daily[2]	No record	Rain on snow
May 17		c 1,450 maximum daily			
1914					
Jan. 23	No record		e 5,160		Rain on snow
26				e 6,150 maximum daily	
May 2		e 1,050			
1937					
Dec. 11	f 10,300	g 3,500	No record		Rain on snow
14				f 5,500 maximum mean daily	
1943					
Jan. 21	g 5,420				Rain on snow
22			g 8,500		
24				g 6,300	
Apr. 28		g 1,290			
1950					
Nov. 20		h 4,730			Rain on snow
21	h 12,100				
22			h 15,500		
23				h 7,850 maximum daily	

Table 16.—Summary of selected historic floods of the Carson River—Continued

Date of peak flow	Peak flows, in cubic feet per second[1/] East Fork near Gardnerville	West Fork at Woodfords	Mainstem near Carson City	Mainstem near Fort Churchill	Remarks
1950					
Dec. 3	h 4,640 mean daily	h 1,880 mean daily			Rain on snow
4			h 7,280 mean daily		
5				h 7,100 mean daily	
1955					
Dec. 23	i 17,600	i 4,810			Rain on snow
24			i 30,000		
26				i 9,680 maximum daily	
1963					
Feb. 1	j 13,360	j 4,890	j 21,900		Rain on snow, ground frozen
2				j 15,300	
1964					
Dec. 23	j 8,230	j 3,100			Rain on snow
25			j 8,740		
26				j 7,220	

1. Momentary maximum discharge, except as noted.
2. Gage washed out after daily reading was taken.
a. From Newell, 1894, p. 116.
b. From Newell, 1891, p. 351.
c. From U.S. Geological Survey, 1913, p. 165.
d. From U.S. Geological Survey, 1910, p. 126
e. From U.S. Geological Survey, 1917, p. 218 and 219.
f. From U.S. Geological Survey, 1939, p. 78 and 79.
g. From U.S. Geological Survey, 1945, p. 142, 155-157.
h. From U.S. Geological Survey, 1953, p. 186, 188, 190, 191.
i. From U.S. Geological Survey, 1958, p. 170, 171, 174, 175.
j. From U.S. Geological Survey, 1970, p. 714, 717, 722, 727.

The flood of 1862 was apparently extreme, with disastrous consequences. Rain or snowfall occurred for 54 consecutive days after December 24, 1861. This caused intermittent flooding during the period, but the peak flow occurred between January 9 and 12, 1862, as a result of general rainfall. The towns of Empire (now an abandoned townsite northwest of the river just upstream from Brunswick Canyon) and Dayton were particularly hard hit. Several persons were reportedly drowned at Dayton, and a number of buildings were washed away. Parts of the Empire area were inundated by 6 to 8 feet of water during the flood peak (McGlashen and Briggs, 1939, p. 476). Bridges and other property belonging to settlers in Carson Valley were also seriously damaged (Grace Dangberg, oral commun., 1972). It was probably the greatest known flood up to that time in the area of Dayton and downstream. It may well have been greater than the floods of 1852 and 1955, but quantitative data are unavailable.

Thompson and West (1958, p. 364) also discussed the 1862 flood, but their description is limited to its effects in Carson Desert as follows:

> "The Carson River overflows annually. The most noted occurrence of the kind took place in January 1862. Before then, the waters of the Carson emptied directly into the Upper Sink, and passed thence through Carson Slough and Stillwater Slough, into Lower Sink. The dry river bed could be plainly seen in 1861, through which Old River now flows, carrying with it direct into the Lower Sink a great part of the waters of the Carson, instead of by the Upper Sink, and thence by the sloughs. The same flood cut a channel where New River now runs, and also changed the outlet of the Upper Sink into an inlet, taking some of the water from New River and emptying it into the Upper Sink. The remainder flows by Stillwater Slough into the Lower Sink thus flowing past the west side of the town of Stillwater."

The major channel changes apparently caused by this flood, as recounted above, reinforce the conclusion that the 1862 flood was indeed a major flood.

River flooding again damaged the towns of Dayton and Empire in 1867. Peak flow occurred on December 26, but the river remained at flood stage for several days. Peak flood stage at Empire was 2 feet lower than the 1862 peak (McGlashen and Briggs, 1939, p. 477).

U.S. Department of Agriculture (1973, p. 7-10) described interesting details of floods during 1874, 1875, and 1886.

Extensive flooding also occurred in January 1890. Again, flooding was caused by heavy rains on a thick snowpack. Although runoff was general throughout the upper Carson River basin because of the combined rain and snowmelt runoff, the flooding was locally intensified by ice-jam damming. Flooding recurred in early February after warm weather caused release of the ice jams and increased snowmelt runoff. Parts of Empire were flooded on February 6 and the gold mills along the river were put out of operation by the high water. More flooding occurred again during early May 1890, when the unusually heavy snowpack melted quickly in upper basin areas (McGlashen and Briggs, 1939, p. 477 and 478).

The flood of 1907 also resulted from rain on snowpack. Grace Dangberg (oral commun., 1972) witnessed the flooding in Carson Valley. She recalls that some of the local flooding in the Minden-Gardnerville area originated from the rains rapidly melting snowpack in the Pine Nut Mountains. Data of table 16 show only a 4,000 ft^3/s discharge at the gage near Carson City (gage was located about 8 miles downstream from present location). However, the gage washed out after the daily reading was taken, and therefore the peak flow was apparently not recorded. The magnitude of this flood may rank with the 1862 and 1955 floods. The greatest flood of record occurred in late December 1955; again heavy rains on a thick snowpack caused the flood.

Upper Carson River basin areas, particularly Carson, Dayton, and Eagle Valleys, are at a critical stage in planning history with regard to decisions involving Carson River flood hazards. If construction in such areas continues, flood-protection measures may be required.

The Carson River basin is now somewhat unusual, compared to many river basins of similar size, in that it has no major upstream flood-storage reservoirs above Lahontan Reservoir. In addition, much of the flood-plain area is not yet extensively developed. However, upstream storage facilities might be subject to earthquake hazards, a possibility that has yet to be adequately investigated.

Regardless of future changes in river-management policy, the historical record demonstrates that major river floods must be expected, but that their timing and magnitude cannot be predicted.

Local flash floods.--Flash flooding, although probably the most common geohydrologic hazard in the Carson River basin, is also probably the hazard least recognized by the general populace. Most flash floods in populated areas achieve a degree of short-term notoriety, but are quickly forgotten. Urban and other land-use planning, to date (1972), seems to have generally not addressed the problem of flash flooding in western Nevada.

Flash floods can result from winter rains and summer thundershowers. The winter events frequently cover extensive areas, affect numerous small streams simultaneously, and usually contribute to major river floods. They generally result from moderate to heavy rains on a heavy snowpack or on frozen ground, and the rains commonly continue for a period of many hours or even days. In contrast, the flash floods associated with summer thundershowers, commonly referred to as "dry mantle floods" by the U.S. Department of Agriculture, usually result from extremely intense rainfall on a much smaller geographical area and for a much shorter time duration, often less than an hour. The resulting flood is frequently more intense and usually of a much shorter duration. It quickly mobilizes quantities of sediment and debris that combine with the water to form a mixture that moves as a potentially destructive flood wave. The crest of this flood wave frequently exceeds normal winter peak flood-flow quantities, and it therefore inundates areas not usually considered part of the stream's normal flood plain. Occasionally the water-sediment mixture completely abandons the normal stream channel and seeks a new route downhill. This redirected flow occurs because the moving debris commonly clogs normal channels and conveyance structures. Therefore, definition of flood plains and restrictive zoning of hazardous areas with regard to summer flash floods is normally much more difficult than that for winter floods. Risk to lives and property form the summer floods is just as real as that from winter floods—and possibly even greater, because victims are usually subjected to additional hazards from the debris, and because warning of an impending summer flood is usually much shorter than that of a winter flood.

Qualitative and quantitative data have been collected for several flash floods in the Carson River basin during recent years by the U.S. Geological Survey. These data and accompanying interpretations are planned for future publication in a special report on flash flooding in Nevada.

Ground-Water Recharge

Most recharge is provided by precipitation on mountainous areas, with the water reaching the valley-fill reservoirs by seepage loss from streams on the alluvial slopes and by underflow from the consolidated rocks. Even in the mountains and on alluvial slopes, however, most of the precipitation evaporates before infiltration, whereas some of the remainder adds to soil moisture, and some reaches already-saturated lowland areas. Thus, only a small percentage actually finds its way to the ground-water reservoir. On most valley floors in the study area, precipitation quantities are small, and infiltration to the ground-water reservoir is generally minimal.

Potential recharge is estimated in this report using the general method described by Eakin and others (1951, p. 79-81). The method assumes that for any given altitude zone, a particular percentage of total precipitation potentially recharges the ground-water reservoir, with that percentage depending on the average amount of precipitation within the zone. The term "potential recharge" is used because not all of the computed recharge (table 17) actually reaches the ground-water reservoirs in the hydrographic areas. Along the western side of Carson Valley, runoff from the Sierra Nevada, a part of which represents potential ground-water recharge, reaches the river, marshes, and bog areas before it can infiltrate to the ground-water reservoir. Similarly, in the upstream part of Dayton Valley, some potential ground-water recharge water (runoff from Eagle Valley and Brunswick Canyon) enters the Carson River before it can infiltrate into consolidated rocks or reach any valley-fill deposits. Likewise, a minor amount of peripheral streamflow enters Lahontan Reservoir in Churchill Valley before it can enter the ground-water system and therefore becomes a part of the surface-water system.

Table 17 lists the estimated potential recharge in the Carson River basin. The table shows an estimated 16,000 acre-feet of potential ground-water recharge in the Carson Valley part of California below the Markleeville and Woodfords gages. An unknown part of this quantity probably is rejected as recharge because of the limited extent of valley-fill deposits in this area (pl. 1), or because the water is intercepted by the river before it reaches the valley fill.

Table 17.--Estimated potential ground-water recharge

Precipitation zone (feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average, Feet	Estimated precipitation: Average, Acre-feet	Estimated potential recharge: Percentage of total precipitation	Estimated potential recharge: Acre-feet per year
CARSON VALLEY - CALIFORNIA						
West Fork Carson River						
10,000-10,823	370	>40	3.3	1,200	25 (10,000-10,823 to 6,000-7,000)	300
9,000-10,000	3,060	30-40	3.0	9,200		2,300
8,000-9,000	4,260	27-30	2.4	10,000		2,500
7,000-8,000	4,180	25-27	2.2	9,200		2,300
6,000-7,000	3,880	20-25	1.9	7,400		1,800
5,000-6,000	9,920	12-20	1.3	13,000	10	1,300
4,820-5,000	2,320	8-12	.8	1,900	3	57
Subtotal (rounded)	28,000	--	--	52,000	20	10,600
East Fork Carson River						
9,000-9,500	78	>24	2.0	160	25	40
8,000-9,000	4,180	20-24	1.8	7,500	20	1,500
7,000-8,000	11,620	15-20	1.5	17,000	15	2,600
6,000-7,000	11,000	12-15	1.1	12,000	7	840
5,150-6,000	17,000	8-12	.8	14,000	3	420
Subtotal (rounded)	43,900	--	--	51,000	11	5,400
Total, Calif. (rounded)	71,900	--	--	100,000	16	16,000
CARSON VALLEY - NEVADA						
East of Carson River						
9,000-9,450	791	>24	2.0	1,600	25	400
8,000-9,000	6,880	20-24	1.8	12,000	20	2,400
7,000-8,000	22,600	15-20	1.5	34,000	15	5,100
6,000-7,000	53,000	12-15	1.1	58,000	7	4,100
5,000-6,000	74,600	8-12	.8	60,000	3	1,800
4,620-5,000	41,400	<8	.5	21,000	minor	minor
Subtotal (rounded)	199,000	--	--	190,000	7	14,000

Table 17.--Estimated potential ground-water recharge--Continued

Precipitation zone (feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average, Feet	Estimated precipitation: Average, Acre-feet	Estimated potential recharge: Percentage of total precipitation	Estimated potential recharge: Acre-feet per year
West of Carson River						
9,000-9,591	481	>30	2.6	1,300	25 (9,000-6,000 zones combined)	325
8,000-9,000	3,720	27-30	2.4	8,900		2,200
7,000-8,000	5,580	25-27	2.2	12,000		3,000
6,000-7,000	6,510	20-25	1.9	12,000		3,000
5,000-6,000	14,400	12-20	1.3	19,000	10	1,900
4,620-5,000	40,300	8-12	.8	32,000	3	960
Subtotal (rounded)	71,000	--	--	85,000	13	11,000
Total, Nevada (rounded)	270,000	--	--	270,000	9	25,000
Grand total, Carson Valley, Calif. and Nev.	342,000	--	--	370,000	11	41,000
DAYTON VALLEY						
8,000-8,763	698	>20	1.8	1,300	20	260
7,000-8,000	10,600	15-20	1.5	16,000	15	2,400
6,000-7,000	43,900	12-15	1.1	48,000	7	3,400
5,000-6,000	74,900	8-12	.8	60,000	3	1,800
4,215-5,000	103,000	<8	.5	52,000	minor	minor
Total (rounded)	233,000	--	--	180,000	4	7,900

Table 17.--Estimated potential ground-water recharge--Continued

Precipitation zone (feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average Feet	Estimated precipitation: Average Acre-feet	Estimated potential recharge: Percentage of total precipitation	Estimated potential recharge: Acre-feet per year
CHURCHILL VALLEY						
8,000-8,763	775	>15	1.5	1,200	15	180
7,000-8,000	4,530	12-15	1.1	5,000	7	350
6,000-7,000	32,000	8-12	.8	26,000	3	780
4,070-6,000	277,000	<8	.5	138,000	minor	minor
Total (rounded)	314,000	--	--	170,000	0.8	1,300
CARSON DESERT[1]						
8,000-8,790	450	>15	1.5	680	15	100
7,000-8,000	6,980	12-15	1.1	7,700	7	540
6,000-7,000	26,800	8-12	.8	21,000	3	630
3,845-6,000	1,260,000	<8	.5	630,000	minor	minor
Total (rounded)	1,290,000	--	--	660,000	0.2	1,300
WHITE PLAINS						
5,500-6,000	125	>8	.8	100	3	<100
3,875-5,500	101,000	<8	.5	51,000	minor	
Total (rounded)	101,000	--	--	51,000	minor	<100
PACKARD VALLEY						
7,500-8,206	930	>15	1.5	1,400	15	210
6,500-7,500	3,560	12-15	1.1	3,900	7	270
5,500-6,500	9,760	8-12	.8	7,800	3	230
3,950-5,500	98,800	<8	.5	49,000	minor	minor
Total (rounded)	113,000	--	--	62,000	1	710

1. Excluding Packard Valley.

Total precipitation and potential recharge for the entire Carson River basin in Nevada (not including White Plains) are about 1,300,000 and 36,000 acre-feet per year, respectively. Therefore, only about 3 percent of the overall precipitation is estimated to make up potential recharge. For the Nevada parts of the individual hydrographic areas, potential recharge estimates range from 0.2 to 9 percent of total precipitation. The lowest percentages are for valleys in the eastern part of the area, where precipitation is small and catchment areas with potential recharge capability are limited in extent.

A comparison of estimated mountain-front runoff with estimated potential recharge for other hydrographic areas in Nevada discloses that runoff averages about twice the potential recharge. Considerable variation occurs in individual hydrographic areas throughout the State, with presently available ratios of runoff to recharge ranging from about 0.04 to about 8. Ratios computed for the Carson River basin are as follows: Carson Valley (Calif. and Nev. parts combined), 0.8; Eagle Valley, 1.5; Dayton Valley, 0.2; Churchill Valley, 0.7; and Carson Desert (excluding Packard Valley), 2.7. The overall ratio for the river system is 0.9, which is considerably below the statewide average. The overall ratio reflects the dominance of the wetter upstream hydrographic areas of the Carson River basin. The generally low runoff-recharge ratios of the upper Carson River basin are similar to those for most of the upstream hydrographic areas of the Walker and Truckee River drainages (Glancy, 1971, and Van Denburgh and others, 1973).

The trend of lower-than-average runoff-recharge ratios generally common to contiguous hydrographic areas along the front of the Sierra Nevada has several possible explanations: (1) the estimates of recharge, runoff, or both may be in error because of inaccuracies inherent in the presently used estimating techniques, (2) the lack of high-altitude precipitation data may have caused overestimates of precipitation, and hence excessive recharge estimates, in areas immediately adjacent to the Sierra mountain front, or (3) the geologic character of the consolidated-rock uplands may induce above-average recharge in the consolidated rocks, accompanied by reduced runoff quantities at the mountain fronts, thereby reducing the runoff-recharge ratio. Thus, users of these estimates should be aware of their limitations.

Natural Subsurface Inflow

Natural subsurface inflow to the valley-fill reservoirs can be of three general types: (1) inflow from the surrounding consolidated rocks within a valley watershed, which originates as infiltrated precipitation and runoff; (2) underflow from an adjacent watershed mainly through surficially exposed consolidated rocks, with subsequent subsurface leakage into the valley-fill reservoir; and (3) inflow from an adjacent upgradient valley through valley-fill deposits (alluvium) and (or) through consolidated rocks buried by the valley fill.

The first type of inflow is included in the estimates of recharge in table 17; the proportionate amount recharged in this manner is unknown. The second type of inflow may occur more frequently than originally assumed in the Great Basin Region. However, the evidence is generally indirect: for example, a notable imbalance in the hydrologic budget of an adjacent valley, and (or) favorable flow gradients between the valley-fill reservoirs of adjacent valleys. Favorable gradients in themselves are only suggestive; however, combined with obvious hydrologic budget imbalances, they become stronger evidence for leakage. Although no inflow of this type to the Carson River basin is known or suspected on the basis of available evidence, some outflow may occur to Rawhide Flats (p. 77).

The third type of ground-water inflow, through alluvium (valley fill), can be computed using a form of Darcy's law:

$$Q = 0.00112\ TIW$$

in which $\underline{Q}$ is the quantity of flow, in acre-feet per year; $\underline{T}$ is the transmissivity, in gallons per day per foot; $\underline{I}$ is the hydraulic gradient, in feet per mile, $\underline{W}$ is the width of the flow section, in miles; and the factor 0.00112 converts gallons per day to acre-feet per year. Table 18 summarizes this type of ground-water inflow to valleys of the study area.

Imported Water

The Carson River basin receives water imports for irrigation and municipal supply. It also receives sewage effluent from the Lake Tahoe basin.

Table 18.--Estimated ground-water inflow to valleys of the study area through alluvium

Inflow to: (in downstream order)	From:	Location of flow section	Assumed transmissivity [(gal/d)/ft] (T)	Estimated hydraulic gradient (feet per mile) (I)	Approximate width of section (miles) (W)	Estimated subsurface flow (ac-ft/yr, rounded) (Q)
Carson Valley (East Fork)	California	East Fork Carson River channel at Stateline	50,000	27	0.1	150
Carson Valley (West Fork)	California	West Fork Carson River at Stateline	50,000	85	1.5	7,000
Carson Valley	Eagle Valley	Clear Creek underflow[2]	30,000	40	0.50	600
Dayton Valley	Carson Valley	Carson River channel at Carson City gage	25,000	10	0.05	15
Dayton Valley	Eagle Valley	Two separate sections[2]	20,000 and 50,000	70 and 25	1.0 and 0.05	1,600
Churchill Valley	Dayton Valley	Carson River channel at gage	50,000	5	0.25	70
Churchill Valley	Mason Valley	Adrian Valley (15/25-18)[3]	50,000	15	0.2	150
Carson Desert	Churchill Valley	Seepage from Lahontan Reservoir	--	--	--	Unknown
Carson Desert	Fernley Area	Alluvium near Hazen[4]	50,000	7	2	800
Carson Desert	Packard Valley	Alluvium	5,000	20	4	400
White Plains	Lovelock Valley (Humboldt Sink)	Beneath Humboldt drain	5,000	2.5	4	60
Carson Desert	White Plains	Alluvium	5,000	1	3	20

1. River channel is on or very close to bedrock.
2. Data from Worts and Malmberg, 1966, table 9, p. 29.
3. Data from Huxel, 1969, table 13, p. 29.
4. Data from Van Denburgh and others, 1973, p. 47.

Irrigation water enters the basin from the Truckee River by way of the Truckee Canal. This import is one of the main irrigation supplies to the Newlands Irrigation Project lands of the Fallon area. Average annual import by way of the canal has been an estimated 180,000 acre-feet for the period 1919-69 (Van Denburgh and others, 1973, p. 48, 57). About 10,000 acre-feet is diverted from the Truckee Canal to irrigate about 1,400 acres of Carson Desert land in the Hazen and Swingle Bench area. Therefore, about 170,000 acre-feet per year reaches Lahontan Reservoir in Churchill Valley.

Imports for municipal use come to Eagle Valley and Virginia City areas by way of the Marlette-Hobart component of the State-owned Marlette Water System. Presently (1971), the imports are mainly from the Hobart Reservoir watershed which is tributary to Washoe Valley, but during the past century significant amounts were imported to the Virginia City area from Marlette Lake (not shown on pl. 1), which is part of the Lake Tahoe drainage basin. Table 19 lists quantities of water imported from the Marlette Water System during recent years. Several estimates of the average annual yield of the system are as follows (rounded to the nearest hundred acre-feet):

(1) 5,200 acre-feet (Montgomery Engineers of Nevada, 1965, p. V-3 and appendix III).

(2) 8,100 acre-feet (Nevada Legislative Commission, 1969, p. 24).

(3) 7,100 to 7,400 acre-feet (Creegan and D'Angelo, Consulting Engineers, and Christoph J. Altemueller, Consulting Engineer, _in_ Nevada Legislative Commission, 1971, p. IV-3).

Table 19.—Water imported from the Marlette Water System[1]

Water year	Imports to Carson River basin (acre-feet)				
	State distribution system	Purchased by Carson Water Co.	Purchased by Virginia City	Purchased by Lakeview development	Total
1966	253	331	166		750
1967	182	124	136		442
1968	278	400	160		838
1969	256	340	164		760
1970	255	212	191	3	661
1971	253	168	220	5	646

1. Data from records of Nevada Division of Buildings and Grounds. The data update table 5 of Worts and Malmberg (1966).

The average imports from that system to the Carson River basin (Eagle Valley and Virginia City areas combined) during recent years (table 19) range from about 440 to 760 acre-feet, annually. Therefore, based on the above estimates, the Marlette Water System is currently (1971) utilizing only about one-tenth of the estimated average annual water supply.

Sewage water has been exported to Carson Valley from the Lake Tahoe basin for several years. A planned program of total sewage export from the Tahoe Basin to protect its unique environment is well underway; as a result, Carson Valley since 1968 has become the recipient of effluent from three major sewage treatment plants located around the east and south shores of the lake. The South Tahoe Public Utility District began exporting its treated effluent by pipeline to Indian Creek Reservoir (table 11) in 1968. The Douglas County Water Reclamation Project began to export treated effluent from its Round Hill treatment plant to Carson Valley by way of Daggett Creek in 1969. In January 1972, the Douglas County facility discontinued use of Daggett Creek and began exporting its treated effluent directly to the Carson River through a new pipeline system (Julio Alvas, Plant Manager, oral commun., 1972). According to Mr. Alvas, some future diversion of the treated effluent from the pipeline for irrigation in Carson Valley is probable. The Incline Village General Improvement District plant began export of its treated effluent to Carson Valley in 1971. The District had, as of December 1971, delivered at least 98 percent of its effluent to the U.S. Bureau of Land Management and the Harry Schneider Ranch in Jacks Valley for stock-watering and irrigation. However, a pipeline allows effluent to be discharged directly to the river.

The combined import of sewage effluent from all three sources in 1971 was about 3,700 acre-feet (table 20). The maximum capacity of the present Incline system is 3.5 million gallons daily, or about 3,900 acre-feet per year (Cliff Girbon, Jr., oral commun., 1972). That of the Douglas County Water Reclamation Project is 6 million gallons daily, or about 6,700 acre-feet per year (Julio Alvas, oral commun., 1972). The South Tahoe Public Utility District may be exporting nearly 14,000 acre-feet annually by the year 2006 (Lake Tahoe Area Council, 1970, p. 5). This means that within just a few decades Carson Valley could be receiving about 25,000 acre-feet of imported sewage effluent annually from the Lake Tahoe basin.

Table 20.—Estimated imports of waste water to Carson River basin

Import system	Inflow per water year (acre-feet)			
	1968	1969	1970	1971
South Tahoe Public Utility District via Luther Pass to Indian Creek reservoir1/	a 1,280	2,470	2,640	2,930
Douglas County Water Reclamation Project via Daggett Creek to Carson River2/	0	a 400+	550	520
Incline Village General Improvement District via Spooner's Summit to Carson River basin3/	0	0	0	a 290
Total (rounded)	1,300	2,900+	3,200	3,740

1. Data from Lake Tahoe Area Council (1970, p. 23) and Jack Archambault of Lake Tahoe Area Council Laboratory (oral commun., 1971).

2. Data from Julio Alvas, plant manager, Douglas County Water Reclamation Project (oral commun., 1971).

3. Data from Cliff Girbon, Jr., plant manager, Incline General Improvement District Treatment Plant (oral commun., 1971).

a. First year of system operation; therefore imports took place only part of the year.

OUTFLOW FROM THE HYDROGRAPHIC AREAS

Surface and Subsurface Outflow

All surface-water flow between hydrographic areas within the Carson River basin is listed in table 12. No surface water flows from the Carson River basin to adjacent areas, as all water not percolated or discharged by evapotranspiration flows to the Stillwater Wildlife Management area or to the sink areas.

Subsurface flow between areas is discussed mainly in the section titled "Subsurface inflow," (see table 18). Possible subsurface leakage from the Carson Lake area of Carson Desert to Rawhide Flats in the Walker River drainage (not shown on pl. 1) was postulated by Everett and Rush (1967, p. 17), because the estimated annual discharge from Rawhide Flats was about five times greater than the estimated recharge. This imbalance resulted in an apparent water deficiency in Rawhide Flat of about 650 acre-feet per year. Two shallow wells were drilled in 1971 in the Bass Flats area, near Carson Lake in Carson Desert; this area is separated from Rawhide Flats by the Blow Sand Mountains. The static water-table surface inferred from water levels in these and nearby wells in Carson Desert suggests that ground-water movement in the shallow aquifer system is toward Carson Lake rather than toward Rawhide Flats. However, the water table in Rawhide Flats is about 20 feet lower than that in southern Carson Desert. Therefore, although available evidence refutes interbasin ground-water movement from Carson Desert to Rawhide Flats through shallow aquifers, the possibility of leakage through deeper aquifers still exists. The leakage requirement to satisfy estimated budget deficiencies in Rawhide Flats, only about 650 acre-feet per year, is completely masked by the great natural discharge in the Carson Desert.

Public, Domestic, and Industrial Supplies

Most of the residents in the study area, as well as industrial and commercial enterprises in the cities and most communities, are served by public water supplies. Table 21 gives estimates of public, domestic, and industrial water use during the 1971 water year in the Carson River basin. Where possible, annual estimates were made on the basis of records of water diverted or delivered to consumers. These records were not adjusted to reflect true consumptive use. When no records were available, consumptive use was estimated through population estimates and application of an average use rate of 110 gallons per day per person in most instances. For Minden and Gardnerville, a higher use rate of 120 gallons per day per person was applied to compensate for increased water consumption by a tourist population assumed greater than that of other unmetered rural communities.

Table 22 gives a summary of estimated ground-water pumpage for public supply, domestic, and industrial purposes during 1971. Tables 23 and 24 document the municipal water-supply histories of Carson City and Fallon, respectively, during recent years.

A few small industrial concerns in the larger municipalities generally satisfied their limited water needs as of 1971 from the municipal-supply systems. Kennametal, Inc., operates a plant about 10 miles north of Fallon. They obtain part of their water supply from a well at the plant site which produced about 50 acre-feet of water in 1971. They supplemented this water with about 6 acre-feet purchased from the city of Fallon (J. D. Frank, Mgr., oral commun., 1972).

Table 21.--Estimates of public, domestic, and industrial water use during 1971 water year

Population group or facility served	Source of supply	Estimated 1971 use (acre-feet)	Basis of estimate
	Carson Valley		
Gardnerville Ranchos[1/]	2 wells	160	Estimated population of 1,000. Golf course of about 20 acres at use rate of 2 feet annually.
Gardnerville	4 wells	110	Estimated population of 820.
Minden	2 wells	70	Estimated population of 500.
Genoa	Flow of Genoa Canyon[1/], springs in Schoolhouse Canyon[1/], some piped water from Sierra Canyon[1/], and individual wells.	20	Estimated population of 135 plus unknown number of livestock.
Carson Valley (rural)	Individual wells	180	Estimated population of 1,500.
Nevada Medium Security Prison[1/]	2 wells at Medium Security Prison	50	Estimated population of 380.
Subtotal (rounded)		590	
	Eagle Valley		
Stewart	1 active well	100	Estimated population 1,000, about ½ of which reside only ¾ of each year.
	Diversions from Clear Creek to water lawns and grounds	50	Worts and Malmberg, 1966, p. 23.
Carson Water Co.	5 wells in Eagle Valley; 2 wells in Jack's Valley; Eagle Valley spring and stream flow; imported water from Marlette water system	[a] 2,920	Records of Carson Water Co. and Nevada Division of Buildings and Grounds (see table 23).
Rural	Individual wells	400	Estimated population of 3,000+

Table 21.--Estimates of public, domestic, and industrial water use during 1971 water year--Continued

Population group or facility served	Source of supply	Estimated 1971 use (acre-feet)	Basis of estimate
State system	Eagle Valley spring and streamflow	a 150	Records of State Division of Buildings and Grounds (table 19), and Worts and Malmberg (1966, table 6).
	Imported water from Marlette water system	a 253	
Subtotal (rounded)		3,870	
	Dayton Valley		
Virginia City (includes Gold Hill and Silver City)	Imports from Washoe Valley and Tahoe basin via Marlette water system.	a 220	Records of State Division of Buildings and Grounds (table 19).
Residences in Mound House area	Springs in the Virginia Range	12	Estimated population of 100.
Area near Junction of U.S. Highway 50 and Nevada Highway 17	Individual wells	5	Estimated population of 25-50.
Dayton	Individual wells	30	Estimated population of 250 and several commercial establishments.
Rural	Individual wells	30	Estimated population of 250.
Subtotal (rounded)		300	
	Churchill Valley		
Silver Springs	2 community wells	30	Estimated population of 225 and 8 commercial establishments.
Rural	Individual wells	25	Estimated population of 200.
Subtotal (rounded)		55	

Table 21.--Estimates of public, domestic, and industrial water use during 1971 water year--Continued

Population group or facility served	Source of supply	Estimated 1971 use (acre-feet)	Basis of estimate
	Carson Desert		
Hazen	Diversions from Truckee Canal	10	Estimated population of 50-100.
Fallon	2 wells	a 1,030	City pumpage records.
U.S. Naval Air Station	3 wells	a 438	Navy pumpage records.
Rural	Individual wells	1,000	Estimated population of 8,000+.
Kennametal, Inc.[1/]	1 well	50	Information from J. D. Frank, Manager
Subtotal (rounded)		2,530	
Total (rounded)		7,300	

1. Location not shown on plate 1.

a. Estimate of water delivered to consumers, but not adjusted to reflect true consumptive use.

Table 22.--Summary of estimated ground-water pumpage for public supply, domestic, and industrial purposes, 1971 water year

Hydrographic area	Pumpage estimates (acre-feet)
Carson Valley	580
Eagle Valley	1,360
Dayton Valley	65
Churchill Valley	55
Carson Desert	2,500
Packard Valley	minor
White Plains	none
Total (rounded)	4,600

Table 23.--Water input to the Carson Water Company distribution system during the 1970 and 1971 calendar years

Source	INPUT 1970 Acre-feet	1970 Percentage of annual subtotal	1971 Acre-feet	1971 Percentage of annual subtotal
Pumpage from Eagle Valley wells1/	1,264	45	1,357	47
Stream and springflow from Eagle Valley drainages1/	1,340	48	1,363	47
Imports from the State distribution system2/	212	7	174	6
Eagle Valley system subtotal	2,816	100	2,894	100
Jack's Valley system1/	23	--	25	--
Water Company combined system total (rounded)	2,840	--	2,920	--

1. Data from Carson Water Co. records.

2. Data from Nevada Division of Buildings and Grounds.

Table 24.--Pumpage of Fallon city wells and Fallon Naval Air Station wells during the 1966-71 water years

Water year	Pumpage (acre-feet per year)		
	Fallon wells[1]	Navy wells[2]	Total
1967	784	457	1,241
1968	853	486	1,339
1969	911	438	1,349
1970	874	438	1,312
1971	1,029	438	1,467

1. Data furnished by Milton Lakey, Assistant City Engineer of Fallon.

2. Data furnished by Lt. P. A. Faletti, Public Works Officer, U.S. Naval Air Station, Fallon.

Water is used for power generation at Lahontan Dam by Sierra Pacific Power Co., and at a small powerplant on the V-canal by the Truckee-Carson Irrigation District. However, since 1967, no water has been used for power generation alone, because the plants use water only when it is being released for irrigation purposes.

Irrigation Pumpage

Cropland within the report area is irrigated primarily with surface water. Most ground-water pumpage for irrigation in areas upstream from Lahontan Reservoir, particularly in Carson and Dayton Valleys, is supplemental to surface-water irrigation. In other words, most irrigators supply their crops with ground water only when surface-water supplies are inadequate. As a result, pumpage is largest during years of deficient surface-water supply, and smallest during years of abundant runoff. Table 25 shows the estimated maximum, minimum, and average irrigation pumpage under current (1971) conditions of agricultural development.

Pumpage estimates for Carson Valley were made during a recent ground-water investigation (Walters, Ball, Hibdon, & Shaw, 1970, p. 42). The estimate for 1968 was 10,000 acre-feet, when the combined river flow was about 70 percent of the 1905-69 average. The estimate for 1969 was 3,000 acre-feet, when combined river flow was about 176 percent of the 64-year average. This suggests that the average annual pumpage rate during years of normal river flow is about 5,000 acre-feet.

Irrigation pumpage in Eagle Valley is estimated at less than 100 acre-feet per year, because the only known pumpage not accounted for as domestic and municipal use is that for the local golf course and cemetery.

Table 25.--Estimated annual irrigation pumpage

Hydrographic area	Pumpage estimates (acre-feet)		
	Small runoff years	Average runoff years	Large runoff years
Carson Valley[1]	10,000	5,000	3,000
Eagle Valley	less than 100	less than 100	less than 100
Dayton Valley[2]	7,000	3,500	1,200
Churchill Valley[3]	50	50	50
Carson Desert[4]	minor	minor	minor
Packard Valley[3]	none	none	none
White Plains[3]	none	none	none
Total (rounded)	about 17,000	about 9,000	about 4,000

1. Modified from data of Walters, Ball, Hibdon, & Shaw, 1970, p. 42.

2. Based on field data collected during this study and water-rights data of Nevada State Engineer's office.

3. Based on field data collected during this study.

4. Oral communication with Truckee-Carson Irrigation District staff, 1971.

Irrigation pumpage in Dayton Valley is also mainly supplemental to surface-water irrigation. The exceptions are in the Stagecoach area (17/23-10) and the area southeast of the Carson River a few miles downstream from Dayton (16/22-4 and 9), where farmers cumulatively irrigated about 400 acres exclusively by ground-water pumpage in 1971-72.

The only known irrigation pumpage in Churchill Valley during 1971-72 was for an alfalfa field of about 15 acres at the west edge of Silver Springs. The annual pumpage is estimated at about 50 acre-feet, and is supplied by well 18/24-25bda (pl. 1 and table 39).

The Carson Desert probably has only a minor amount of irrigation pumpage because the Truckee-Carson Irrigation District does not permit ground-water irrigation of areas greater than one acre by any individual farm. Therefore, each farm does not irrigate more than a small garden or lawn with ground water, and the total cumulative pumpage for this purpose probably is accounted for in estimates of rural domestic water use (table 21).

A comparison of tables 21 and 25 shows: (1) irrigation pumpage is somewhat more than all other pumpage in Carson and Dayton Valleys, (2) irrigation pumpage is about equal to other pumpage in Churchill Valley, (3) public, domestic, and industrial pumpage is much greater than irrigation pumpage in Eagle Valley and Carson Desert, and (4) combined pumpage for all purposes in Packard Valley and White Plains is negligible.

Surface-Water Diversions

Irrigation by surface-water diversions was not determined directly because this reconnaissance did not include detailed mapping of irrigated lands according to crop type; in fact, irrigated lands and phreatophyte areas have been field-mapped as a single unit (pl. 1). Estimates of irrigated acreages for the various hydrographic areas shown in table 28 were generally obtained from other sources, as credited in the table. Total evapotranspiration of crops and phreatophytes is approximated by difference in the water budget (table 30).

Livestock Use

Water for livestock comes from wells, springs, streams, and irrigation ditches. The amounts consumed are small compared to other types of water use. Table 26 lists the estimated average annual consumption by livestock from all water sources as of 1971. Total use of water by livestock throughout the study area in 1971 was about 700 acre-feet.

Recreation Use

Recreation is one of the fastest growing water uses in the Carson River basin. This reconnaissance does not allow an analysis of the present use or future potential of the river system for recreation purposes, because the use is generally nonconsumptive. Two principal areas of recreation use are Lahontan Reservoir, for boating and fishing, and Stillwater Wildlife Management Area, for wildfowl.

Table 26.--Estimated annual consumption of water by livestock, 1971 calendar year

Hydrographic area	Population estimates[1/] Range cattle	Milk cows	Hogs	Sheep	Horses	Total consumption (acre-feet, rounded)
Carson Valley	23,000	1,500	500	7,000	1,000	220
Eagle Valley	1,100	100	minor	1,300	700	20
Dayton and Churchill Valleys	2,000	minor	minor	1,000	200	18
Carson Desert	50,000	3,200	1,000	15,000	3,500	480
White Plains[2/]	minor	none	none	minor	minor	minor
Packard Valley[2/]	200	none	none	minor	minor	2
Total (rounded)	76,000	4,800	1,500	24,000	5,400	700

1. Population estimates based on U.S. Dept. of Commerce (1971) and modified with assistance of County Extension Agent's staffs, except as noted. Animal per-capita use rates as follows (Nevada State Engineer, 1971, p. 16):

Range cattle - 6 gal/d (gallons per day)
Milk cows - 20 gal/d
Hogs - 2 gal/d
Sheep - 2 gal/d
Horses - 10 gal/d

2. Population estimates by P. A. Glancy.

Springs

Numerous small springs occur in the consolidated rocks of the mountains. Some springs also discharge from the valley fill (pl. 1). Although these springs furnish water for stock and wildlife, the cumulative water quantities involved are minimal compared to pumpage and streamflow in the area. The springflow typically supports growth of meadowgrass, saltgrass, rabbitbrush, greasewood, willow, and aspen over very limited areas. Some of the flow probably seeps back into the ground. Doud Spring (11/21-20cd) and Saratoga Spring (14/20-21cdd) in Carson Valley have much higher discharges than most springs visited during this investigation (table 27). The table indicates that several of the springs are thermal. Worts and Malmberg (1966, p. 30) discussed springs in Eagle Valley, and Morrison (1964, p. 117) discussed springs in the Carson Desert.

Natural Evapotranspiration

In areas of shallow ground water, natural discharge occurs by evaporation from surface-water bodies and bare-soil areas, and by transpiration from naturally growing plants called phreatophytes, whose roots tap the ground-water reservoir. Large amounts of water are naturally discharged to the atmosphere by these evapotranspiration processes in the Carson River basin. However, as mentioned in the section on "Irrigation pumpage," no estimates of crop or natural losses are made in this report. They are shown by difference in table 30. Evapotranspiration areas are listed in table 28 and are shown in combination with irrigated areas on plate 1.

Table 27.--Spring data

Location	Name	Approximate land-surface altitude (feet)	Date	Estimated flow (gal/min)	Temperature °F	Temperature °C
11/21-20cd	Doud Spring	5,750	5- 7-70	180	70	21.0
-26ba	Double Spring	5,930	5- 6-70	<10	52	11.0
13/19-22abc	Walleys Hot Spring	4,670	11-10-59	10-15	146	63.0
14/19-23dd	Hobo Hot Spring	4,760	5- 3-60	10-15	114	45.5
14/20-21cdd	Saratoga Hot Springs	4,700	5-14-70	350	122	50.0
16/21-2daa	Sutro Tunnel	4,480	6- 1-70	25-50	83	28.5
-22cb	Dove Spring	4,620	6- 1-70	5	59	15.0
16/24-15bcd	--	4,275	6- 8-70	3	61	16.0
16/29-34bc	Lee Hot Springs	4,020	8-18-70	10	boiling	boiling
17/22-8cad	Sutro Springs	5,590	7-23-72	10	69	20.5
17/31-31ab	Rock Spring	3,915	8-19-70	1	68	20.0
-31ba	--	3,920	8-19-70	1	66	19.0
18/22-25da	Cooney Spring	5,330	6- 3-70	<1	69	20.5
18/23-33ccb	Corral Spring	4,395	12- 7-71	1	58	14.5
28/34-31db	--	5,035	10- 8-70	5	62	16.5

Table 28.--Estimated acreage of irrigated lands, phreatophytes, surface-water bodies, and discharging playas[1]

(All figures rounded)

	Carson Valley (Nevada)	Eagle Valley	Dayton Valley	Churchill Valley	Carson Desert	Packard Valley	White Plains	Total
Irrigated lands	a 48,000	b 700	a 6,300	a 1,300	c 56,000	(d)	(d)	112,000
Phreatophytes[2]	6,000	b 5,100	6,700	22,000	e 300,000	1,700	13,000	e 350,000
Surface-water bodies (lakes, ponds, and streams)	1,100	minor	300	>7,000	65,000	minor	500	74,000
Discharging playa	none	none	none	none	276,000	none	12,000	290,000
Playa of uncertain ground-water discharge	none	none	none	none	5,500	none	(d)	5,500
Mixed marsh grass, greasewood, bare soil, and surface water	(d)	(d)	(d)	(d)	4,200	(d)	(d)	4,200
Mixed bare soil and a few phreatophytes	(d)	(d)	(d)	(d)	32,000	(d)	(d)	32,000
Mainly surface water with some pasture, marsh grass, and phreatophytes	(d)	(d)	(d)	(d)	4,200	(d)	(d)	4,200
Total (rounded)	55,000	5,800	13,000	30,000	740,000	1,700	25,000	870,000

1. Values determined during period of study. Some areas may vary substantially during periods of varying wetness.
2. Numerical difference between combined reconnaissance-field-mapped acreage of phreatophytes and irrigation, and reported irrigated acreage.
a. Acreage from U.S. Soil Conservation Service (Joe VanMullem, oral and written commun., 1974).
b. From Worts and Malmberg (1966, p. 24 and table 8).
c. From U.S. Bureau of Reclamation (Nathan Geering, oral commun., 1971).
d. No acreage determined in given category.
e. Includes about 250,000 acres where phreatophytes may be spotty or in some places absent.

Estimates of average net evaporation from surface-water bodies in individual hydrographic areas of the Carson River basin are shown in table 29. Acreage estimates were based on the following assumptions and criteria: Carson Valley acreage includes ponds, lakes, and major stream channels; Dayton Valley acreage is almost all river-surface area; Churchill Valley acreage is largely Lahontan Reservoir and a small amount of river surface; Carson Desert acreage includes a reasonably firm estimate of about 35,000 acres of lakes, ponds, and reservoirs; a somewhat less confident estimate of about 10,000 acres in Carson Lake; and a very crude estimate of about 20,000 acres of flooded playa in the Carson Sink and Fourmile Flat areas.

Evaporative discharge from bare soil (table 28) involves water losses from the ground-water reservoir, but not losses associated with playa-surface flooding, which are accounted for in estimates of evaporation from surface-water bodies. Significant areas of bare-soil ground-water discharge exist only in Carson Desert and White Plains. The probability of ground-water discharge from the playa areas of Turupah Flat, southeast of the Fallon Naval Air Station, and Bass Flats, at the southern edge of Carson Lake, is very uncertain. Recently drilled shallow wells in these playas suggest static water levels in Turupah Flat and Bass Flats are about 11 feet and 14 to 25 feet below land surface, respectively (table 39); the amount of ground-water discharge under these conditions is considered minor.

Table 29.--Estimated average annual evaporation from surface-water bodies for mainstem hydrographic areas, 1919-69

Hydrographic area	Estimated average area (acres)	Net evaporation rate[1]/ (feet per year)		Average annual discharge (acre-feet per year)
Carson Valley	1,100	2½		2,800
Dayton Valley	300	3		900
Churchill Valley	>7,000	>3½		30,000
Carson Desert	a 45,000 b 20,000	4 a 2	180,000 40,000	220,000

1. Average annual lake evaporation (Kohler and others, 1959, pl. 2) minus average annual precipitation (table 4).

a. Perennial lakes and ponds as determined by 1971 field studies. During periods of deficient water supply, such as 1920-35 and 1958-61, many of these areas reportedly decrease markedly (Harold Soule, Truckee-Carson Irrigation District, and George Luke, Stillwater resident, oral commun., 1974).

b. Mainly playa areas that are partly flooded on a very irregular basis. Therefore evaporation rate assumes water coverage only half of each year on the average.

Water losses from large areas in the Carson Lake and Stillwater Wildlife Management segment of Carson Desert are dominated from time to time by either water-surface evaporation, bare-soil ground-water discharge, phreatophyte discharge, or various combinations of these three types of discharge, depending on prevailing water supplies and water-management practices. These areas of variable discharge, therefore, are listed in several special discharge categories in table 28.

Packard Valley has practically no water-surface evaporation. Transpiration from about 1,700 acres of phreatophytes is estimated to be about 340 acre-feet per year.

Part of White Plains is flooded about twice per decade, on the average, during years of large runoff in the Humboldt River basin. The ponded flood water generally evaporates and (or) drains to Carson Desert, and the flooded areas become dry within a few months. Water-surface evaporation probably averages less than 500 acre-feet per year. Phreatophytes (mainly greasewood) occupy about 13,000 acres in a generally sparse pattern, and consume an estimated 1,300 acre-feet per year. Ground-water discharge from bare soil is an estimated 1,200 acre-feet per year from about 12,000 acres of playa surface. Total evapotranspiration, then, may be about 3,000 acre-feet per year for White Plains.

WATER BUDGETS

Water budgets for the mainstem hydrographic areas are dominated by the Carson River, because river-flow quantities generally are much larger than other budget elements. Water budgets for hydrographic areas are shown in table 30. The various budget elements are determined for the 51-year base period 1919-69, and therefore, the recent sharp increases in water imports as well as domestic and muncipal use have little effect on the long-term budget averages.

Mainstem Areas

Carson Valley (Nevada)

In Carson Valley, most mountain-front runoff (table 14) and most of the ground water recharged through consolidated rocks reach the river or the valley-fill ground-water reservoir. The net average quantity annually entering the system by these two processes is assumed to be about 30,000 acre-feet (table 30).

The annual net depletion, or consumptive use, within the valley is computed by difference to be about 80,000 acre-feet. This estimate compares favorably with the 77,000 acre-feet of Piper (1969, p. F7), although Piper relied on a different period of record (1909-60) and also included the area in California below the Woodfords gage.

Dayton Valley

Most of the mountain-front runoff in Dayton Valley (averaging 1,400 acre-feet annually, table 14) is assumed to be either dissipated by evapotranspiration or infiltrated to the ground-water reservoir before reaching the river. As a result, potential ground-water recharge (7,900 acre-feet annually, table 17) is considered the local input to the Dayton Valley hydrographic area.

Table 30.—Reconnaissance water budgets, in acre-feet per year, for mainstem hydrographic areas, 1919-69

	Carson Valley (Nev.)	Dayton Valley	Churchill Valley	Carson Desert	Total (rounded)
INFLOW					
Mainstem inflow:					
Streamflow (table 12)	315,000	272,000	a 268,000	b 380,000	315,000
Ground water (table 18)	7,200	15	70	unknown	7,200
Imported water (tables 19 and 20)	c minor	d 150	e 170,000	e 10,000	180,000
Inflow from nonmainstem (adjacent) hydrographic areas:					
Streamflow	f 1,100	g 3,500	h 1,000	i 1,400	8,500
Ground water (table 17)	g 600	g 1,600	h 150	j 1,200	3,600
Input to system from within mainstem hydrographic area	k 30,000	ℓ 7,900	ℓ 1,300	ℓ 1,300	40,000
TOTAL INFLOW (rounded)	355,000	285,000	440,000	390,000	550,000
OUTFLOW					
Mainstem outflow:					
Streamflow (table 12)	272,000	a 268,000	b 380,000	0	0
Ground water (table 18 and p. 77)	minor	70	minor	<1,000	<1,000
Evaporation from surface-water bodies (table 29)	2,800	900	30,000	220,000	250,000
Other outflow quantities[1]	m 80,000	n 16,000	o 30,000	p 170,000	300,000
TOTAL OUTFLOW (rounded)	355,000	285,000	440,000	390,000	550,000

1. Computed by difference: total inflow minus all other outflow elements. Includes water consumptively used for municipal, industrial, domestic, and agricultural purposes, plus evapotranspiration from phreatophytes and playas.

a. Carson River, 252,000 acre-feet (table 12) plus Buckland Ditch, 16,000 acre-feet.

b. U.S. Bureau of Reclamation records.

c. Average import from Lake Tahoe basin minor for period 1919-69.

d. For Virginia City area; estimated long-term average on basis of data in table 19).

e. Truckee Canal (quantity for Carson Desert is net import).

f. Clear Creek (Worts and Malmberg, 1966, p. 19, plus 100 acre-feet diversion from Clear Creek to Jacks Valley).

g. From Eagle Valley (Worts and Malmberg, 1966, p. 19 and 29).

h. Inflow from Adrian Valley (Huxel, 1969, p. 22).

i. Inflow from White Plains (1,000 acre-ft per yr) and Packard Valley (400 acre-ft per yr).

j. Inflow from White Plains (20 acre-ft per yr), Packard Valley (400 acre-ft per yr), and Fernley area (800 acre-ft per yr, Van Denburgh and others, 1973, p. 47).

k. Net annual average input of 30,000 acre-feet assumed on the basis of 15,000 acre-feet estimated mountain-front runoff (table 14) and 25,000 acre-feet estimated potential ground-water recharge (table 17).

ℓ. Assumed equal to estimated potential ground-water recharge (table 17).

m. Agrees reasonably well with 77,000 acre-feet of Piper (1969, p. F7). Includes water consumed by about 54,000 acres of crops and phreatophytes.

n. Includes minor pumpage for stock and domestic use, plus water for 13,000 acres of crops and phreatophytes.

o. Includes pumpage for stock and domestic and water for about 20,000 acres of crops and phreatophytes; may include substantial ground-water outflow to Carson Desert (see text).

p. Includes water consumed by 56,000 acres of crops and up to about 620,000 acres of phreatophytes and discharging playas.

Churchill Valley

The hydrologic budget of Churchill Valley is dominated not only by natural river flow, as are upstream valleys, but also by inflow of the Truckee Canal, evaporation from Lahontan Reservoir, and man-controlled releases from Lahontan Reservoir. Therefore, man-controlled activities dominate the outflow elements and also strongly influence inflow totals. Natural local input (mountain-front runoff, 900 acre-feet, plus potential ground-water recharge, 1,300 acre-feet) is insignificant when compared to most other budget elements. The budget of table 30 shows 30,000 acre-feet per year of "other outflow quantities" (by difference), which includes crop, phreatophyte, municipal, and domestic consumptive use. However, the total seems to be about 10,000 acre-feet more than the apparent water requirements indicated according to crop and phreatophyte acreages. Therefore, the apparent excess of 10,000 acre-feet presumably is either the product of errors in the estimation of inflow and outflow elements, or it represents a quantity of water escaping the valley via some undefined route.

Carson Desert

Carson Desert hydrology is dominated by man-controlled releases from Lahontan Reservoir. The "other outflow quantities" determined by difference suggest that only 170,000 acre-feet of water is consumed annually by domestic, municipal, and agricultural consumptive use and natural evapotranspiration. The crops, phreatophytes, and naturally discharging bare playas (table 28) alone probably would consume or discharge considerably more than 170,000 acre-feet annually. Therefore, the outflow of water from Carson Desert seems greater than is accountable through the combined inflow elements. Reconciliation of this critical problem, unfortunately, was beyond the scope of this reconnaissance.

Another budget element not considered in this reconnaissance is the amount of irrigation water that went into ground-water storage from canals, distribution ditches, and fields following the start of the Newlands Project in about 1905. Water levels locally rose as much as 50 to 60 feet during the period 1905-30 (Rush, 1972). This additional water loss, if known, would increase the losses under the "outflow" section of the budget (table 30).

Nonmainstem Areas

Eagle Valley

The water budget of Eagle Valley used in this study is that of Worts and Malmberg for conditions as of 1965 (1966, p. 33 and table 11). Their budget indicates a near balance between inflow and outflow of about 14,500 acre-feet annually; of that quantity, about 8,300 acre-feet ultimately reaches the mainstem Carson River (table 30), and the residual, 6,200 acre-feet is assumed dissipated within Eagle Valley.

Packard Valley

Packard Valley is tributary to Carson Desert (though it is not tributary to the Carson River). Subsurface leakage to Carson Desert from Packard Valley is considered as the arithmetic difference between estimates of recharge and natural discharge in Packard Valley. Estimated recharge (table 17) is 710 acre-feet and natural discharge from about 1,700 acres of phreatophytes (table 28) is estimated at about 340 acre-feet. Subsurface leakage is therefore assumed to be about 400 acre-feet. Average annual surface-water runoff to Carson Desert from Packard Valley probably is less than 100 acre-feet per year.

White Plains

Average annual outflow from the White Plains hydrographic area is estimated at about 6,000 acre-feet, and consists of about 1,000 acre-feet of surface-water flow (p. 53); an estimate of 20 acre-feet of ground-water underflow to Carson Desert (table 18); about 2,600 acre-feet of natural discharge by 13,000 acres of phreatophytes (table 28); 1,200 acre-feet of bare-soil evaporation from 12,000 acres (table 28); and roughly 1,000 acre-feet of estimated water-surface evaporation from about 500 acres (table 28).

Average annual inflow estimates are as follows: a minor amount of ground-water recharge within the hydrographic area (table 17); and ground-water inflow from the Humboldt Sink of about 60 acre-feet (table 18). Surface inflow from the Humboldt Sink is assumed to equal the difference between the other elements of inflow and outflow, or about 6,000 acre-feet per year, on the average (p. 53).

Entire Carson River Basin

For the entire report area, including mainstem and nonmainstem hydrographic areas, the estimated total water supply has averaged about 560,000 acre-feet per year during the base period 1919-69. The total includes 550,000 acre-feet in mainstem areas (table 30), 6,200 acre-feet in Eagle Valley (p. 101), 710 acre-feet in Packard Valley (p. 101), and 6,000 acre-feet in White Plains (p. 102). Of this approximate 560,000 acre-feet total supply, 322,000 acre-feet enter the report area from the Carson River drainage in California (table 30), 180,000 acre-feet are imported from the Truckee River via the Truckee Canal (table 30), 6,000 acre-feet are supplied from the Humboldt River drainage via White Plains (p. 102), and 1,000 acre-feet enter from the Walker River basin via Adrian Gap (table 30). Thus, the combined total inflow from outside the report area is roughly 510,000 acre-feet. Therefore, only about 50,000 acre-feet, or slightly less than 10 percent, of the total area supply is generated within the confines of the report area in Nevada.

The estimated total outflow also has averaged about 560,000 acre-feet per year, including 250,000 acre-feet of evaporation from surface-water bodies (table 29) and 310,000 acre-feet (calculated by difference) of evapotranspiration from phreatophytes, bare playas, and agricultural lands plus water consumed for municipal, industrial, and domestic purposes.

WATER QUALITY

The water quality of the Carson River basin is best in the headwater areas and tends to deteriorate in a downstream direction as a result of both natural processes and man-caused effects. The quality involves, and is determined by, a complex interrelationship of at least four general components: (1) physical characteristics of the water, such as temperature and rate and path of movement, (2) dissolved chemical constituents in the water, (3) particulate matter carried by, or in contact with, the water, and (4) the biologic community of plants and animals, including man, that live partly or wholly in this hydrologic environment. The complex interrelationship of the above components requires detailed knowledge of Carson River basin hydrology both to understand present water-quality characteristics and to predict successfully specific future changes in water quality. This required knowledge is presently inadequate, mainly because of a shortage of hydrologic data. Therefore, this study is concerned mainly with a summary presentation of some of the available data and preliminary interpretations of these data, where feasible.

General Chemical Character

Table 31 shows chemical analyses of representative water samples collected within the report area. Although the interpretations of chemical quality in the study area rely largely on the data of table 31, they are also based in part on data of Miller and others (1953), University of Nevada (1944), Walters, Ball, Hibdon, & Shaw (1970), Guyton & Associates (1967), and Worts and Malmberg (1966). Data from these reports generally are not repeated in table 31. Many unpublished analyses from the files of the Nevada Division of Health were also utilized in the interpretations. Some of these data are included in table 31.

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The specific conductances in table 31 can be used as a preliminary indication of general chemical character, because the concentration of dissolved solids in a water, expressed in milligrams per litre (mg/l), is generally 55 to 70 percent of the specific conductance, in micromhos per centimetre at 25°C (hereafter abbreviated "micromhos"). Milligrams per litre are equivalent to parts per million in most waters; see footnote 1, table 31.

Criteria for Suitability

Suitability for Domestic Use and Public Supply

The U.S. Public Health Service (1962, p. 7-8) has formulated standards that are generally accepted as a guideline for drinking-water supplies; these standards have been adopted by the Nevada Bureau of Environmental Health for public supplies in the State. The standards, as they apply to data listed in table 31, are as follows:

Constituent	Recommended maximum concentration (milligrams per litre)
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	a/ About 1.2
Nitrate (NO_3)	45
Dissolved solids	b/ 500

a/ Based on an annual average maximum daily air temperature of about 68°F. The optimum fluoride concentration is about 0.9 mg/l. Water containing more than about 1.8 mg/l should not be consumed regularly, especially by children.

b/ Equivalent to a specific conductance of about 750 micromhos.

Most of these are only recommended limits, and water therefore may be acceptable to many users despite concentrations exceeding the given values. Excessive iron causes staining of porcelain fixtures and clothing. Large concentrations of chloride and dissolved solids impart an unpleasant taste, and sulfate can have a laxative effect on persons who are drinking a particular water for the first time. Excessive fluoride tends to stain teeth and to cause bone changes, especially those of children, and a large amount of nitrate is dangerous during pregnancy and infancy because it may increase the susceptibility to "blue-baby" disease.

The arsenic concentration of drinking water is particularly important because of the possibility of long-term poisoning. The U.S. Public Health Service standards (1962, p. 8), state that arsenic should not exceed 0.05 mg/l in drinking water.

The bacteriological quality of drinking water also is important, but is outside the scope of this report.

The hardness of a water is of concern to many users. The U.S. Geological Survey has adopted the following rating:

Hardness, as $CaCO_3$ (milligrams per litre)	Rating and remarks
0-60	Soft (suitable for most uses without artificial softening)
61-120	Moderately hard (usable except in some industrial applications; softening profitable for laundries)
121-180	Hard (softening required by laundries and some other industries)
More than 180	Very hard (softening desirable for most purposes)

The data in table 31 show that suitable water is available in all of the valleys, but that problem areas do exist. The individual problems are discussed in later sections dealing with the specific hydrographic areas.

Suitability for Agricultural Use

In evaluating the suitability of a water for irrigation, the most critical considerations include dissolved-solids concentration, the relative proportion of sodium to calcium plus magnesium, and the abundance of constituents such as boron that can be toxic to plants. Four factors used by the U.S. Salinity Laboratory Staff (1954, p. 69-82) to evaluate the suitability of irrigation water are listed in table 31, and are discussed briefly in footnote 2 of that table. Minor amounts of boron (as much as 0.5 mg/l) are essential to plant nutrition, but larger concentrations can be highly toxic. The approximate upper limits recommended for boron in water irrigating sensitive, semitolerant, and tolerant crops are, respectively, 0.5-1.0, 1.0-2.0, and 2.0-4.0 mg/l (National Technical Advisory Committee, 1968, p. 153).

Most animals are more tolerant of poor water than man. Although available data are somewhat conflicting, a dissolved-solids concentration less than 4,000-7,000 mg/l (equivalent to a specific conductance of about 6,000-10,000 micromhos) apparently is safe and acceptable (McKee and Wolf, 1963, p. 112-113), provided that specific undesirable constituents are not present in excessive concentrations.

Specific problems relating to suitability of water for agricultural use are discussed later by hydrographic areas.

Suitability for Industrial Use

Water-quality requirements for industrial use vary greatly, depending on the particular use. A use-by-use discussion is outside the scope of this reconnaissance, but McKee and Wolf (1963, p. 92-106) and the National Advisory Committee (1968, p. 185-215) discuss the subject in detail. Much of the water of the Carson River basin is acceptable for most industrial uses, but other waters probably are not, on the basis of particular water-quality problems discussed below.

Sewage

Sewage effluent is rapidly becoming a significant part of the hydrologic environment of the Carson River basin. Recent accelerated urbanization within the basin with its accompanying increases in sewage wastes (table 32), as well as recent dramatic increases in sewage effluent imports from the Lake Tahoe basin (table 20) emphasize the increasing importance of sewage to this study area, particularly regarding its effects on water quality.

Sewage is generally collected for treatment and disposal in the major municipalities. In some small communities, some suburban areas, and all rural areas, individual dwellings and establishments dispose of their own individual sewage. In a minority of the individual disposal systems, untreated sewage is directly discharged to the Carson River or its major tributaries. In most places, individual discharge involves injection of untreated sewage into septic tanks, the effluent from which then percolates to ground water and, depending on a variety of circumstances, may ultimately discharge to streams. The degree to which contaminants are removed from ground water prior to its discharge to streams depends on the type of contaminants, the specific nature of the ground-water reservoir materials, the hydraulics of the flow system, the quantity of contaminants, and the rate and duration of injection.

Table 32.--Estimated quantities of sewage processed by treatment plants within the Carson River basin

Treatment system	Disposition of treated effluent[1]	Quantity of water processed (acre-feet)				
		1967	1968	1969	1970	1971
Gardnerville-Minden[2]	Evaporation plus seepage, and discharge to Carson River	--	--	--	--	560
Stewart[3]	Evaporation plus seepage, and discharge to Clear Creek	70	70	70	70	70
Nevada Medium Security Prison[4]	Evaporation plus seepage, and discharge to Clear Creek	--	--	--	--	32
Carson City[5]	Evaporation plus seepage, and discharge to Carson River	1,570	1,480	1,870	2,010	2,100
Virginia City[6]	Evaporation plus seepage, and discharge to Sixmile Canyon	--	--	--	--	56
Fallon[7]	Evaporation plus seepage, and discharge to Carson Desert alluvium	--	--	--	420	480
U.S. Naval Air Station, Fallon[8]	Evaporation plus seepage, and discharge to Carson Desert alluvium	320	340	300	300	300
Total (rounded)		--	--	--	--	3,600

1. Some unknown quantity probably enters ground-water system in all systems.

2. C. A. Altemueller (Minden-Gardnerville Sanitation Dist. Engineer, oral commun., 1971) estimates that an average of 500,000 gallons per day is processed; he also estimates that about 30 percent of this is ground water that leaks into sewer mains.

3. Quantity from Worts and Malmberg (1966, p. 26) because population and water use apparently have not changed appreciably since that time.

4. Quantity based on an average population of 375 (Walter Mandeville, Prison employee, oral commun., 1971) and 70 percent of water supplied.

5. Flow into plant is metered. James Dunn (City employee, oral commun., 1971) stated that these metered quantities are conservative estimates because during peak-load periods the maximum inflow meter rate is exceeded. Quantities include an unknown amount of ground water that leaks into sewer mains.

6. Estimated quantity based on estimated average resident and tourist populations of 450 and 200. Collection system does not include communities of Gold Hill or Silver City.

7. Quantities are metered inflow to treatment plant.

8. Quantities based on Public Works office estimate that an average of 70 percent of utilized water supply is processed as sewage.

The collected sewage is generally delivered to a treatment plant where, prior to final discharge, it receives different degrees of treatment depending on each plant's designed capability. The several treatment plants in the Carson River basin utilize at least primary and in many facilities secondary treatment techniques.

Data necessary but generally unavailable to evaluate the short- and long-term effects of sewage discharge on the environment throughout the basin are (1) continuous records of quantities of discharge from municipal plants, (2) continuous records of discharge of sewage imports to the river and to other sources, (3) continuous records of detailed chemical and biological makeup of sewage discharge, and (4) various types of hydrologic data on the components of the hydrologic system that are involved in the disposal of sewage.

Estimated sewage totals for 1971 in tables 20 and 32 show that the volume processed by seven treatment plants in the Carson basin was about equal to the amount of treated effluent imported from the Lake Tahoe basin.

Table 32 suggests that during 1971 nearly 2,800 acre-feet of varyingly treated sewage was discharged into the Carson River from treatment plants within the basin. The greatest quantity of imported sewage effluent reaching the river during 1971 from any single source probably was that from the Douglas County Water Reclamation Project plant which discharged about 520 acre-feet to Daggett Creek. However, a substantial amount of that 520 acre-feet may have been consumed by evapotranspiration before reaching the river, because an unknown amount of Daggett Creek flow is used for irrigation during the growing season. According to Cliff Girbon, Jr., an employee at the Incline Village General Improvement District treatment plant (oral commun., Dec. 1971), more than 97 percent of the treated effluent transported through that system was utilized by the U.S. Bureau of Land Management for stockwatering, and by the Harry Schneider ranch for irrigation in Jacks Valley. The South Tahoe Public Utility District delivers its tertiary treated effluent to Indian Creek reservoir (table 11) and some is used for irrigation of nearby agricultural lands (Record-Courier, 1972).

An unknown amount of the sewage effluent generated within and imported to the basin percolates into the ground-water reservoir from storage facilities and irrigation systems.

Specific effects of sewage effluent on surface-water quality within the report area are discussed below.

Carson River

Mainstem

Table 33 is a summary of selected chemical data collected at five locations along the Carson River from 1966 through 1971 by the Nevada Bureau of Environmental Health. The tabulation is based on about 55 monthly samples from each station.

Several trends suggested by the data are (1) average water temperatures gradually increase downstream, and temperature maxima are roughly equal at the three mainstem sites but are appreciably higher than the maxima at the two tributary sites; (2) average nitrate concentrations at the three mainstem sites are similar, and at least twice as great as those of the two tributary sites; (3) average orthophosphate concentrations at the mainstem sites far exceed those of the upstream tributary sites; (4) average dissolved-solids concentrations progressively increase downstream; (5) pH values vary little from site to site; and (6) minimum dissolved-oxygen concentrations generally decrease downstream to New Empire.

The marked increases in nutrient (nitrate and orthophosphate) concentrations between the tributary forks and New Empire are probably the result of (1) agriculture-related input (fertilizers and animal wastes) mainly in Carson Valley, and (2) the inflow of sewage effluent in Carson Valley and from the Carson City sewage treatment plant. The marked decrease in orthophosphate concentrations between New Empire and Weeks may be the result of biologic and nonbiologic assimilation. The general downstream decrease in dissolved-oxygen minima to New Empire probably is a rough indication of increased biochemical oxygen demand caused by agricultural and sewage inflows.

Table 33.—Summarized water-quality data for sites on Carson River, July 1966 to December 1971[1]

[Data from Nevada Bureau of Environmental Health]

Site (approximate location in downstream order; not shown on plate 1)	Maximum, minimum, and average values for samples collected about monthly (in milligrams per litre, except for temperature and pH)							
	Temperature °F	°C	Chloride (Cl)	Nitrate (NO_3)	Ortho-phosphate (PO_4)	Dissolved solids (residue at 105°C)	pH	Dissolved oxygen
West Fork	66	19.0	8	3.7	0.21	120	8.2	12.1
Carson River	32	0.0	1	.0	.00	25	7.4	7.5
near Highway 88	47	8.5	2	.3	.06	59		9.8
(11/20-19ab)								
East Fork	71	21.5	12	12	0.33	173	8.9	12.9
Carson River at	32	0.0	1	.0	.00	54	7.4	7.6
Lahontan Fish	50	10.0	5	.6	.09	112		10.4
Hatchery (12/20-23dd)								
Carson River at	85	29.5	19	9.6	1.1	275	8.1	11.4
Cradlebaugh	32	0.0	1	.0	.15	67	7.2	5.8
Bridge	52	11.0	7	1.2	.43	164		8.7
(14/20-30db)								
Carson River	85	29.5	28	7.7	9.2	582	8.6	17.5
near New	32	0.0	1	.0	.27	82	7.4	4.1
Empire	54	12.5	11	1.5	1.3	228		9.7
(15/20-12bc)								
Carson River	81	27.0	18	14	1.7	416	8.3	11.9
at Weeks	32	0.0	1	.0	.10	92	7.4	6.5
(17/24-35da)	56	13.5	10	1.4	.45	237		9.7

1. Samples collected on a once-a-month basis with frequency distribution of sampling generally as follows: July-October 1966; July-December 1967; 1968, monthly; 1969, monthly; January-October 1970; and 1971, monthly.

The U.S. Geological Survey has analyzed numerous samples of Carson River water collected near Fort Churchill (17/24-32dc) as part of its irrigation network sampling program. These data have been collected for about 10 years and are published annually in the Geological Survey's publication titled "Water Resources Data for Nevada."

Some early (1906-7) chemical data on Carson River water were obtained just downstream from the confluence of the Truckee Canal and the river, near the present site of Lahontan Dam (Stabler, 1911, p. 23-25). These data represent the combined flow of the Truckee Canal and the Carson River, and provide some insight to the quality of Newlands Irrigation Project water supply at an early period of the project's history.

Carson River water is temporarily stored in Lahontan Reservoir. Its dissolved chemical load may be slightly concentrated during storage, according to Rollins (1965, p. 10) and Clyde-Criddle-Woodward, Inc. (1971, p. 26). However, summary data of table 34 suggest a decrease in dissolved-solids concentration of reservoir water compared to that of the inflow at Weeks (table 33). This apparent decrease may exist because sampling of reservoir water was restricted to spring and summer months when the effects of fresh seasonal inflow would most likely dominate near the reservoir surface, whereas summary data for the inflow more nearly reflects the average of varying conditions throughout the year. The increased chemical concentration of water within the main body of the reservoir, if such is indeed the case, is at least partly offset near Lahontan Dam by the inflow of characteristically more dilute water from the Truckee Canal (Rollins, 1965, p. 10).

Table 34.--Summarized water-quality data for Lahontan Reservoir, July 1966 to July 1971[1/]

[Data from Nevada Bureau of Environmental Health]

Site (approximate location in downstream order; not shown on plate 1)	Maximum, minimum, and average values for samples collected occasionally during spring and summer months[2/] (in milligrams per litre, except for temperature and pH)							
	Temperature °F	°C	Chloride (Cl)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids (residue at 105°C)	pH	Dissolved oxygen
17/25-22	82	28.0	12	1.7	0.76	200	8.8	16.0
	50	10.0	1	.0	.28	118	7.5	5.4
	70	21.0	6	.7	.44	165		9.2
18/25-20	77	25.0	12	4.8	0.85	223	8.6	9.6
	54	12.5	1	.0	.20	118	7.6	6.1
	65	18.5	6	1.4	.48	164		7.8
18/25-24	77	25.0	16	4.8	1.0	238	8.9	10.6
	50	10.0	1	.0	.13	116	7.6	6.4
	66	19.0	8	1.6	.47	163		7.9
19/26-33	74	23.5	17	10	1.6	183	8.7	9.2
	52	11.0	1	.0	.30	119	7.5	5.0
	66	19.0	10	2.2	.79	151		7.5

1. This summary updates the tabulation of Katzer (1972) with the addition of 1970 and 1971 data.

2. Data based on about 14 samples collected only during spring and summer months as follows: 2 in 1966; 2 in 1967; 4 in 1968; 4 in 1969; 1 in 1970; and 1 in 1971. Samples collected from boat; sample depth 0-1 foot.

Below Lahontan Dam, the dissolved-solids concentration of the Carson River increases markedly downstream mainly because of inflowing irrigation drainage (Rollins, 1965, p. 16, and Clyde-Criddle-Woodward, Inc., 1971, App. A, table 6). However, some of the increase during periods of low river stage may also be from inflow of shallow saline ground water, plentiful in the Carson Desert area.

Mercury, normally a trace constituent of stream waters, is of special concern in the Carson River. Before 1900, about a dozen mills along the river used mercury in the so-called "Washoe Process" for the milling of silver and gold ore from the Comstock Lode. During that time, almost 15 million pounds of the mercury escaped recovery (Smith, 1943, p. 257), much of it being incorporated in the mill tailings. Today, downstream from the millsites, measured concentrations of mercury are as much as 200 times the normal "background" level in shallow, fine-grained sediment from the bottom of streams, canals, and Lahontan Reservoir (Van Denburgh, 1973, p. 3). The greatest concentrations have been encountered in sediments of the Carson River, within and immediately upstream from the reservoir. Data for the river near Fort Churchill suggest that most of the shallow mercury may be present as mercuric sulfide or as a component of non-methyl organic compounds.

Among stream waters sampled in 1971-72, about 70 percent contained less than 1 µg/l (microgram per litre) of total mercury (Van Denburgh, 1973, table 2). The maximum measured quantity was 6.3 µg/l, for the Carson River near Fort Churchill during the spring snowmelt runoff. (The interim limit for drinking water, established by the U.S. Environmental Protection Agency, is 5 µg/l of mercury.) At the highest concentrations, most of the mercury was associated with suspended sediment in the stream, rather than being dissolved. In areas of mercury-rich stream-bottom sediment, peak discharges in May 1973 that were greater than the relatively low flows of 1971-72 produced greater total-mercury concentrations in the streamflow (A. S. Van Denburgh, U.S. Geol. Survey, oral commun., 1973). A recent investigation by the College of Agriculture, University of Nevada, shows no evidence of mercury accumulation ("magnification") in terrestrial plants or animals from the Carson River basin (Dr. H. G. Smith, written commun., 1972). In contrast, a similar study by the Nevada Department of Fish and Game has shown that fish in the mercury-affected lakes and streams contain greater-than-background concentrations (R. C. Sumner, oral commun., 1972).

In the future, increased nutrient contributions to the river from sewage treatment plants may in turn increase the "accessibility" of the mercury now present in the bottom sediments, through chemical transformations associated with biologic activity. The presence of mercury in the river-bottom sediments raises the question of whether toxic amounts might thus enter the food chain of high-order organisms.

Tributaries

Table 31 includes data from several small tributary streams in Carson Valley. The dissolved-solids concentrations of 7 streams draining the Sierra Nevada on the west side of the valley range from 36 to 110 mg/l, whereas samples from two streams draining the Pine Nut Mountains on the east side have concentrations of 234 and 253 mg/l.

The Bryant Creek basin, mainly in California but tributary to the East Fork Carson River in the upstream part of Carson Valley in Nevada, has been a source of concern regarding pollution. Bryant Creek and some of its tributaries are reportedly polluted by acid mine drainage from the Leviathan Sulfur Mine (California Water Resources Control Board, written commun., 1970). As a Carson River tributary, any localized pollution problems of Bryant Creek are subsequently transmitted in some degree to the Carson River. Bryant Creek normally furnishes only a minor part of the total flow of East Fork Carson River; therefore pollutants transported by Bryant Creek are generally subject to substantial dilution by river flow. Localized flooding of Bryant Creek at a time of low river flow might pose a downriver pollution hazard because of insufficient dilution of Bryant Creek runoff.

Tables 35 and 36 summarize available data on the quality of tributary inflow to the Carson River where treated sewage effluent is a component of the inflow. Table 35 shows the changes in the quality of Daggett Creek when treated sewage effluent from the Douglas County Water Reclamation Project was added in the 1969 water year (table 20). The concentrations of chloride, nitrate, orthophosphate, and dissolved solids all increased after sewage effluent was introduced. However, the lack of great change in the minimum concentrations of some of these constituents reflects the intermittent manner in which the treated effluent is introduced into the creek. The general chemical character of Daggett Creek about a decade before introduction of treated sewage effluent is shown in table 31.

Table 35.--Summarized water-quality data for Daggett Creek, August 1966 to December 1971[1]

Sampling period	Temperature °F	Temperature °C	Chloride (Cl)	Nitrate (NO_3)	Ortho-phosphate (PO_4)	Dissolved solids (residue at 105°C)	pH	Dissolved oxygen
	Maximum, minimum, and average values for samples collected about monthly (in milligrams per litre, except for temperature and pH)							
August 1966 -	60	15.5	12	8.7	0.10	100	8.2	11.8
September 1968[2]	34	1.0	3	.0	.00	63	7.5	7.3
	49	9.5	5	.9	.04	87		9.1
October 1968 -	64	17.5	77	27	24	283	8.2	11.9
December 1971[3]	32	.0	1	.0	.46	67	7.5	8.1
	47	9.0	15	5.5	6.0	126		9.6

1. Sampling site not shown on plate 1 (13/19-27bbd). Data furnished by Nevada Bureau of Environmental Health.
2. Data based on 18 samples collected as follows: 2 in 1966, in August and October; 7 in 1967, monthly from June to December; 9 in 1968, monthly.
3. Data based on 37 samples collected as follows: 3 in 1968, monthly; 12 in 1969, monthly; 10 in 1970, monthly from January to October; 12 in 1971, monthly.

Table 36.—Summarized water-quality data for some Carson River tributaries that convey treated sewage[1]

Tributary and sampling site (location not shown on pl. 1)	Temperature °F	Temperature °C	Chloride (Cl)	Nitrate (NO_3)	Ortho-phosphate (PO_4)	Dissolved solids (residue at 105°C)	pH	Dissolved oxygen
	Maximum, minimum, and average values for samples collected about monthly (in milligrams per litre, except for temperature and pH)							
Ditch to East Fork Carson River from Gardnerville-Minden sewage treatment plant (13/19-24cdd)[2]	83	28.5	18	5.1	8.5	316	8.5	13.7
	45	7.0	2	.2	.88	127	7.4	2.9
	61	16.0	9	1.7	2.0	233		8.8
Clear Creek at mouth (14/20-10bbb)[3]	81	27.0	17	0.8	1.7	339	8.2	10.3
	36	2.0	1	.0	.35	86	7.6	5.6
	56	13.5	10	.3	.72	155		8.8
Sewage effluent ditch below Carson City sewage treatment plant (15/20-15cbb)[4]	60	15.5	31	2.6	25	398	8.0	7.5
	38	3.5	24	1.1	12	321	7.6	5.4
	48	9.0	27	1.7	18	361		6.7
Mexican Ditch, including Carson City effluent, at confluence with Carson River (15/20-11bdc)[5]	79	26.0	26	1.6	13	343	8.0	12.8
	45	7.0	8	.7	.40	186	7.4	5.1
	59	15.0	16	1.2	5.5	251		8.3

1. Data furnished by Nevada Bureau of Environmental Health.
2. Data based on 11 samples collected as follows: 1 in November 1970: 10 on a monthly basis from January to October 1971.
3. Data based on 11 samples collected monthly from January to November 1971.
4. Data based on 3 samples collected in October, November, and December 1971.
5. Data based on 10 samples collected as follows: 1 in November 1970; 9 on a monthly basis from January to September 1971.

A few data, not included in table 31, collected on streamflow of Gold Canyon and Sixmile Canyon Creeks in Dayton Valley during brief periods of rainfall and snowmelt runoff, suggest that the dissolved-solids concentration of these streams is frequently greater than the average of those in the Carson River basin. The data show that the water is very hard and occasionally contains appreciable quantities of sulfate. In these respects, the streamflow is chemically similar to ground water in Dayton Valley, as discussed in a later section of this report.

The final vestiges of Humboldt River flow dominate surface drainage in White Plains. Sample data of this water are included in table 31. However, the two samples may not be representative of average water quality. Humboldt River water that survives evaporation during its transit through White Plains flows into the Carson Sink and merges with any residual of Carson River flow. It then becomes more chemically concentrated through solution of playa salts in the Carson Desert and by evaporation.

The Packard Valley area has no perennial streams that reach the valley fill. No known data are available to characterize the chemical quality of ephemeral runoff in the area.

Newlands Reclamation Project Irrigation Water

Rollins (1965) described the water quality of the Newlands Reclamation Project as of 1960. Although the study was done in a restricted time period (1959-61) during which the river flows were below average (Rollins, 1965, p. 6), the results and conclusions of the study also may be valid for years of average or above average water-supply conditions. A brief summary of Rollins' conclusions are as follows (1965, p. 17 and 18): (1) The irrigation water is of good chemical quality, having a medium salinity hazard and practically no sodium hazard; (2) the drainage waters are higher in dissolved solids and percent sodium than the irrigation water; (3) drainage waters further increase in salt concentration as they flow downstream; (4) drains in the center of the project, particularly south of the Carson River, are free from excessive salt but pick up salt rapidly as they approach the Carson Lake and Carson Sink areas; (5) conversely, drains immediately north of the Carson River carry high salt concentrations; (6) seasonal water-quality changes are more pronounced in the drainage water than in the irrigation supply; (7) some drainage is of an acceptable quality for further use as an irrigation supply, whereas other drainage is unacceptable; (8) reduction in the quantity of the irrigation supply would be expected to increase the concentrations of dissolved solids and sodium in drainage waters; (9) irrigation waters now being used in the project area probably would not harm most canal liners being used, although some of the drainage waters with highest dissolved-solids concentrations could shorten the life of some liners; (10) soil salinity and alkalinity are nearly stabilized under the existing (1960) irrigation and drainage systems; (11) over-irrigation should be prevented to avoid excessive rises in static ground-water levels; and (12) chemical quality of the irrigation water supply probably has not changed since the project began (1905), but the quality of drainage water has probably improved overall.

A considerable amount of data on chemical quality of Newlands Project irrigation water and drainage has also been collected during the last several decades by the U.S. Bureau of Reclamation (J. Gallagher, oral commun., 1971), and is available in the files of the Bureau of Reclamation office in Carson City. A salt-balance study of irrigation water and lands by the U.S. Bureau of Reclamation (unpublished report, 1967) suggests that more salts left the irrigated area by drainage return flow than entered the area in the irrigation supply. Therefore, irrigation practice was leaching salts from the soils.

Ground Water

Carson Valley

The valley-fill deposits of Carson Valley form the major storage reservoir of high-quality ground water in the Carson River basin (table 31). The water stored in these deposits may well be the major future source of supply for a large urban populace in this part of western Nevada. Walters, Ball, Hibdon, & Shaw (1970) discussed the quality of ground water in Carson Valley as part of their study for the Carson Water Company. Their report indicates (p. 10) that the ground water is generally excellent. They also concluded (p. 34) that the central and western parts of the valley apparently contain the best quality ground water. Wells in the Hot Springs Mountain area, 8 miles north of Minden (pl. 1), particularly deep wells, generally produce the poorest-quality water known in the valley. This localized area of poor-quality water may be related to deeply circulating, high temperature, mineralized water from sources associated with Saratoga Hot Springs (14/20-21cdd, pl. 1).

The Stewart area historically has had problems with excess iron in the ground-water supply. The problem is spotty, though, and not all wells encounter the iron problems.

Eagle Valley

Worts and Malmberg (1966, p. 35) categorized Eagle Valley water as "generally satisfactory for irrigation, domestic, and most common uses." Guyton & Associates (1967, p. ii) rated Eagle Valley water quality as "generally good." However, Carson Water Co. well 15/20-17dd, drilled in 1969, yields water that apparently contains a small amount of hydrogen sulfide, which imparts an objectionable taste and smell.

Analyses of water from well 15/20-9da in Worts and Malmberg (1966, table 12) and well 15/20-9acba1 (table 31, this report) suggest that poor quality ground water occurs in the New Empire area of northeast Carson City.

Dayton Valley

Ground-water quality in Dayton Valley varies greatly from place to place (table 31). Miller and others (1953, p. 34) published a small amount of Dayton Valley water-quality data.

Several acute water-quality problem areas exist in Dayton Valley. Ground water in the Pinion Hills suburban area just east of the Carson River near Carson City is of very poor quality. A January 7, 1971, memorandum from the Nevada Bureau of Environmental Health to Pinion Hills residents categorized most of the ground water in the area as "hot mineralized water in a cemented gravel strata," and having the following general chemical composition:

Constituent	mg/l
Iron	0.4
Calcium	280
Sodium	200
Sulfate	900
Fluoride	4.2
Total dissolved solids	1,500
Total hardness	600

The mineralized and thermal character of this water suggests that it is associated with a deeply circulating ground-water system. The surface venting of this hot water probably is related to geologic structure. However, several wells in the southwest part of the subdivision produce cool water with a dissolved-solids concentration of only about 300 mg/l. This cool water is of generally acceptable quality for most uses on the basis of presently available information. These wells probably produce from aquifers more closely associated with the Carson River flow system than with the deep-circulation system described above.

Poor-quality ground water also occurs north of the Carson River from the Mound House area eastward to the junction of Nevada State Route 17 and U.S. Highway 50 (pl. 1). This water is characterized mainly by high concentrations of calcium (100 to >600 mg/l), sulfate (500 to >2,000 mg/l), and dissolved solids (1,000 to >3,000 mg/l), which apparently are related to gypsum-rich rocks and alluvial deposits in the immediate area. Geology of these gypsum deposits was discussed by Lincoln (1923, p. 129) and Archbold in Moore (1969, p. 34). Many of the residents in the Mound House area are supplied by a community water system fed by springs of better-quality water from the Virginia Range to the north (Mrs. Julius Bunkowski, oral commun., 1971).

Much of the water used for domestic purposes in the community of Dayton comes from shallow wells in town. The chemical character of water from one well serving several homes and the community center building is shown by analysis 16/21-23acd in table 31. These and other data show that the water is high in dissolved solids (400 to >500 mg/l) and sulfate (150 to >250 mg/l), and is hard (200 to 300 mg/l).

Ground waters within Dayton Valley east of Dayton and north-northwest of the Carson River, although locally variable in quality, are also commonly characterized by moderately high dissolved solids (as much as 600 mg/l), sulfate (more than 300 mg/l), and hardness (as much as 300 mg/l). This condition is prevalent not only near Sixmile Canyon but also in the Stagecoach subarea about 15 miles northeast of Dayton. The character of this ground water strongly suggests that mineralization in the Virginia Range is a dominant chemical influence. The Virginia Range probably is the main recharge area for most of the ground water.

Chemical data are scanty south and southwest of the Carson River in Dayton Valley. The few available analyses are restricted to wells east of Dayton in T. 16 N., Rs. 21 and 22 E., and suggest that ground water may generally be somewhat more dilute than that across the river. If so, the difference may reflect a contrast in geochemical control of ground water in the Pine Nut Mountain recharge province compared to that of the Virginia Range.

A somewhat anomalous situation exists with regard to nitrate concentrations in the ground water of Dayton Valley. About one-third of Dayton Valley ground-water analyses examined (most of which are by the Nevada Bureau of Environmental Health) show nitrate concentrations in excess of 10 mg/l, with a maximum (analysis 17/23-36baa, table 31) of 62 mg/l. Although nitrate concentrations locally exceed 10 mg/l in Carson Desert, the normal concentrations for ground water in most of the Carson River basin are somewhat less than 10 mg/l. The above-average nitrate concentrations encountered in Dayton Valley also apparently extend to the Silver Springs area of Churchill Valley (table 31).

Churchill Valley

Ground water from community wells supplying Silver Springs is generally of good chemical quality (table 31). Although the water is hard, the dissolved-solids and sulfate concentrations are not excessive. The numerous domestic wells in the area may not have the same chemical characteristics as the Silver Springs community wells.

Water from the only known well in White Sage Flat (not labeled on pl. 1) of northern Churchill Valley (18/23-4a) is of much poorer quality than the Silver Springs community wells (table 31). It is extremely hard and has excessive amounts of iron, calcium, and bicarbonate.

Carson Desert

Ground water in the Carson Desert is abundant, but much of it is of poor to very poor chemical quality for most uses. The Carson Desert is the terminus of the Carson River hydrologic system. It is therefore the final discharge area for water that has moved downbasin and, as such, becomes the final receiving area for soluble chemicals transported by the water. As water evaporates from the desert, it leaves behind its dissolved chemical load. A substantial part of this load remains highly soluble and therefore tends to progressively enrich the remaining and incoming water supply. The residual waters therefore are considerably more saline than the composite inflow. Available data suggest that the ground water can be grouped into five general categories according to chemical characteristics, as follows: (1) large quantities of moderately saline to very saline water fill most of the valley-fill deposits from relatively shallow to great depths; (2) an unknown quantity of moderately dilute water occurs within a basalt aquifer of apparently local areal extent generally about 500 feet below land surface in the Fallon area; (3) unknown quantities of dilute to moderately dilute water are found within, or associated with, recent fluvial sediments generally near present or relatively contemporary Carson River channels, from shallow to unknown maximum depths; (4) dilute to moderately dilute water occurs within shallow valley-fill deposits, probably resulting from infiltration of irrigation water beneath or near lands of the Newlands Reclamation Project; and (5) unknown amounts of water of variable chemical quality lie within consolidated rocks.

Domestic water demands are supplied mainly by (1) public-supply systems for the city of Fallon and the Naval Air Station, which tap water from the basalt aquifer, and (2) individual domestic wells that tap the shallow and generally thin lens of relatively dilute water overlying the vast saline reservoir that occupies most of the valley-fill deposits. Water from the basalt aquifer has been utilized as a public supply for more than two decades. The water is soft and generally suitable for most uses. Thus far, only the arsenic concentration (characteristically 0.05-0.10 mg/l) has caused any concern regarding suitability for human consumption. Arsenic concentrations slightly exceed the limit for drinking water (p. 111). Public-supply systems continue to rely on the basalt aquifer, owing to (1) the lack of any evidence of long-term adverse effect attributable to the arsenic, and (2) the probably great expense involved in developing an alternate source of supply.

The shallow ground water tapped by most individual domestic wells in the Carson Desert area has an uncertain future as an acceptable supply because of the risk of contamination. This risk is further increased by the fact that most of the people extracting the water from shallow domestic wells also use septic tanks that discharge at shallow depths within, or very close to, the water-supply zone. Future replenishment of this domestic supply is also uncertain because the amount and quality of replenishment depends on irrigation practices and conditions. Current emphasis on increasingly frugal use of water for irrigation suggests that future replenishment may differ somewhat from past replenishment. Lawrence Wolf, Churchill County Health Department (oral commun., 1972), stated that water quality of the shallow aquifer apparently deteriorates during periods of nonirrigation and no canal flow.

Salinity of Carson Desert ground water and the water's mineral precipitates have from time to time been exploited commercially. The salt deposits associated with Soda Lakes were mined extensively during the latter half of the 19th and early 20th centuries. However, rising lake levels associated with infiltration of irrigation water after the establishment of the Newlands Reclamation Project (Lee and Clark, 1916, p. 679 and 680) flooded the salt works and diluted the saline lake water. The unique hydrologic and chemical character of Soda Lakes was discussed by Rush (1972), Breese (1968), Lincoln (1923), Lee and Clark (1916), Stabler (1904), Russell (1885), and others. The geologic origin of Soda Lakes has been most recently discussed by Morrison (1964, p. 71-72).

The U.S. Geological Survey prospected for salt deposits associated with the valley fill during the early part of the 20th century (Gale, 1913, p. 303-311). Other explorations probably were made from time to time throughout the Carson Desert. Sodium chloride is presently harvested on the Fourmile Flat playa (pl. 1) by the Huck Salt Company of Fallon. This company, since 1938, has been producing salt that becomes concentrated on the playa surface through the interaction of the ground- and surface-water flow systems (Elmer Huckaby, oral commun., 1971). Earlier exploitation of saline playa deposits in the study area was described by Russell (1885, p. 234 and 235) and Lincoln (1923, p. 7-9 and 14).

White Plains and Packard Valley

Very few water-chemistry data are available for the White Plains and Packard Valley areas (table 31). One sample (well 23/28-29dc) suggests that the valley-fill deposits of White Plains are saturated with saline, sodium chloride-rich water similar to much of the very saline ground water of Carson Desert. This similarity is to be expected because both areas are the sinks of their respective large drainage systems. Salt has been harvested along the west edge of White Plains playa in the past, as evidenced by the remains of abandoned salt evaporation pans visible from U.S. Interstate Highway 80. Salt harvesting was described by Lincoln (1923, p. 7 and 14).

Two chemical analyses (27/33-24ccd and 28/34-31db; table 31) suggest that ground water of the Packard Valley area is of the calcium sodium chloride type, and varies in dissolved-solids concentration from place to place. The chemical quality doubtless deteriorates as the ground water moves downgradient toward the Carson Sink. The end product is the highly saline water that saturates the valley-fill deposits of the sink.

Thermal Water

Thermal water, for purposes of this discussion, is arbitrarily defined as ground water obviously warmer than the mean annual air temperature at the site.

Data in tables 27 and 31 suggest that several localized areas of deep-seated ground-water circulation exist. The flows of Walleys, Hobo, and Saratoga Hot Springs in Carson Valley (table 27) are thermal. Worts and Malmberg (1966, p. 30, and table 12) described Carson Hot Springs in Eagle Valley. The urbanizing area east of the Carson River at the base of Pinion Hills between Mexican Dam and New Empire (location about 15/20-35c; locally referred to as the Pinion Hills subdivision) has a number of wells with thermal water. Sutro Tunnel in Dayton Valley discharges warm water from the consolidated rocks.

The major known thermal ground-water area of Carson Desert is a generalized zone extending from Soda Lakes to Stillwater that recently was classified by the U.S. Geological Survey (Godwin and others, 1971, p. 2 and 4) as a "known geothermal resource area." Morrison (1964, p. 117) briefly discussed the thermal ground water in this area. This possibly extensive geothermal system is widely recognized, but published information regarding its ground-water flow system is scanty. The basic nature of such an extensive geothermal system inherently guarantees some influence on the quality of the involved ground water, but the extent of influence in this case is virtually unknown.

Principal Water-Quality Problems

Table 37 summarizes the presently recognized problems in the Carson River basin. It also summarizes some possible future problems that might be anticipated on the basis of present developments, limited knowledge of water quality, and the hydrologic flow system of the basin.

Table 37.--Summary of presently recognized and possible future water-quality problems

Area	Present problem	Possible future problem
Bryant Creek, East Fork Carson, and Carson River below confluence with Bryant Creek	Chemically contaminated streamflow originating in vicinity of Leviathan sulfur mine may adversely affect Carson River water under certain hydrologic conditions.	Pollution threat could continue, subside, or possibly worsen, depending on hydrologic and other circumstances.
Do.	Massive landslide in area of Leviathan sulfur mine tightly encroaching on tributary to Bryant Creek. Hydrologic circumstances could result in serious sediment-pollution problem downstream, and (or) potential downstream flash-flood danger.	Same potential for future as at present. Threat depends on future movement of slide and flow conditions in streams tributary to slide area.
Carson River and tributaries	Periods of highly turbid streamflow caused by both natural and man-accelerated influences. Results in problems to surface-water irrigation systems. Also causes unknown amount of damage to fish habitat. Diminishes esthetic value of streamflow to unknown degree. Magnitude of problem not presently known because of lack of data.	Same as present, with possible additional problems also to future municipal and industrial use of river water, and reduced capacity of present and future streamflow-storage reservoirs. Could also seriously hamper attempts to utilize streamflow for artificial recharge of diminishing ground-water supplies.
Do.	Discharge of sewage effluent of a quality poorer than natural streamflow causes several problems to river environment that vary in intensity depending on hydrologic circumstances at time of discharge.	Same as present problems: severity will increase if quantity of effluent increases without counterbalance by upgrading of effluent quality.

Table 37.--Summary of presently recognized and possible future water-quality problems--Continued

Area	Present problem	Possible future problem
Carson River and tributaries	--	Ground water contaminated by septic-tank effluent and sewage-effluent spreading; could also seep to river and degrade streamflow quality.
Do.	--	Improperly located or unprotected landfill deposits could furnish leachate pollutant that would degrade stream quality and ground water.
Carson Valley: Saratoga Hot Springs area	High dissolved-solids and sulfate concentrations in ground water.	Same as present.
Carson Valley-Eagle Valley: Stewart area	Excessive iron concentrations in water.	Same as present.
Eagle Valley	Foul-smelling water from one municipal supply well.	Unknown.
Carson River below Carson City	Mercury in shallow fine-grained bottom sediments of river, canals, and Lahontan Reservoir. Excessive mercury in river water near Fort Churchill during periods of high flow. Above-normal mercury in fish associated with the mercury-affected surface waters and bottom sediments.	Increased nutrient contributions from sewage treatment plants may in turn increase the "accessibility" of the mercury through chemical transformations associated with biologic activity.
Dayton Valley: Pinion Hills area	Poor-quality ground water: high concentrations of dissolved solids, sulfate, fluoride, iron, calcium, and sodium, and excessive hardness.	Same as present.

Table 37.--Summary of presently recognized and possible future water-quality problems--Continued

Area	Present problem	Possible future problem
Dayton Valley: Mound House area	Poor-quality ground water: high concentrations of dissolved solids, calcium, and sulfate, and excessive hardness.	Same as present.
Dayton Valley: north of river downstream from Dayton.	Ground water commonly hard to very hard with high concentrations of dissolved solids and sulfate.	Same as present.
Dayton Valley-Churchill Valley	Ground waters in a substantial number of wells in the valley downstream from Dayton may have nitrate concentrations somewhat above average, compared to the total river basin.	Increasing disposal of sewage through septic tanks and incompletely treated sewage may foul the ground-water reservoir; risk is increased because nitrate concentrations appear to be above average at present.
Churchill Valley: Silver Springs area	Ground water very hard.	Same as present.
Churchill Valley: White Sage Flat	Ground water is apparently extremely hard and has excessive concentrations of iron, calcium, and bicarbonate.	Same as present
Lahontan Reservoir and possible future large storage reservoirs	--	Increased sewage effluent may result in nutrient enrichment of reservoir water, causing problems of excessive algae.
Carson Desert	Saline water throughout most of the valley-fill reservoir.	Same as present.

Table 37.--Summary of presently recognized and possible future water-quality problems--Continued

Area	Present problem	Possible future problem
Carson Desert: Fallon area	Large quantities of saline water throughout most of the ground-water system.	Excessive pumping of the basalt aquifer supplying Fallon and Naval municipal supplies may promote saline-water intrusion into this aquifer system.
Carson Desert	Same as above.	Increasing septic disposal of sewage may degrade the quality of the shallow, fresh ground-water supply to a point of unacceptability. Decrease in amount of irrigation infiltration, related to probable reduction in application of water, may accelerate deterioration of water quality of shallow ground-water system.

AVAILABLE WATER SUPPLY

Ground-Water Storage in the Valley-Fill Reservoirs

The amount of ground water stored in the valley fill to any selected depth below the ground-water surface is the product of the area, the selected saturated thickness (in this study, 100 ft), and the specific yield of the deposits (assumed to average 10 percent for the study area). The estimates are listed in table 38.

Although the estimates of stored ground water are large, the amount available in areas where the depth to water is within economic pumping lift and where land is suitable for cultivation is appreciably less. The amount of usable ground water in storage that is economically available depends in part on the distribution of the water-bearing deposits, the permeability of the deposits, the distribution and range in chemical quality of the ground water, the number and distribution of pumped wells, and the intended water use. Also, large withdrawals of ground water along the flood plains of perennial streams can affect the flow of surface water and therefore might legally infringe on previously decreed surface-water rights.

Table 38.--Estimated quantity of ground water stored in the upper 100 feet of saturated valley fill[1]

Hydrographic area (in downstream order)	Area probably underlain by 100 feet or more of saturated valley fill[2] (acres, rounded)	Estimated quantity of stored ground water (acre-feet, rounded)
Carson Valley (Nev.)	70,000	700,000
Eagle Valley[3]	13,000	200,000
Dayton Valley	44,000	440,000
Churchill Valley	a 74,000	a 740,000
Carson Desert	b 800,000	c 8,000,000
Entire Carson River basin in Nevada	b 1,000,000	c 10,000,000
Packard Valley	50,000	500,000
White Plains	b 42,000	c 420,000

1. Data developed mainly by A. S. Van Denburgh, U.S. Geological Survey.
2. Assumed to be about 80 percent of the alluvial areas listed in table 2, because of inward-sloping contact between valley fill and consolidated rocks. (Does not apply to Eagle Valley.)
3. Data from Worts and Malmberg (1966, p. 11).

a. Includes ground water underlying Lahontan Reservoir.

b. Includes areas where ground water is too saline for most common uses.

c. Much of this water is probably of an unacceptable quality for most common uses.

Available Supply, Mainstem Areas

The available water supply in mainstem areas of the Carson River basin in Nevada during the base period 1919-69 consisted principally of about 320,000 acre-feet per year of combined river flow and ground-water underflow at the California State line; 50,000 acre-feet per year of local surface- and ground-water inflow to the system, for a total of 370,000 acre-feet between the State line and the Carson Sink; and about 180,000 acre-feet of water imported from the Truckee River basin through the Truckee Canal; for a grand total of about 550,000 acre-feet per year (table 30). In addition, more than 10 million acre-feet of ground water is presently stored in the upper 100 feet of saturated valley-fill deposits of the study area (table 38). Most of the surface water but little of the ground water has been developed, as described in this report. However, much of the stored ground water, particularly in the Carson Desert, may be of unacceptable chemical quality for most uses.

Activities are underway to determine the most efficient legal, economic, and physical solutions to the problems of the combined Truckee and Carson River basins. One principal problem relates to use and diversion of the water supply of the two river basins, which has contributed to the declining stage of Pyramid Lake, the terminal sink of the Truckee River basin. Traditionally, the Carson River basin has been geared to a mining and agricultural economy and its needs. However, if the present trends of population growth and urbanization continue, many new hydrologic problems should be expected.

Available Supply, Nonmainstem Areas

The available supply of Eagle Valley was described by Worts and Malmberg (1966, p. 39) as the system yield, and was estimated at 10,000 acre-feet per year.

Packard Valley and White Plains are tributary to the sink area of Carson Desert but are not tributary to the river mainstem. White Plains receives surface inflow on a generally irregular basis from the Humboldt River, and discharges part of that flow to the Carson Sink. Very little ground-water underflow enters or leaves White Plains (table 18) and only a minor amount of ground-water recharge originates within the White Plains hydrographic area (table 17). Most stored ground water may be of very poor quality, and surface inflow from the Humboldt Sink is of variable and possibly poor quality much of the time. Therefore, the amount of water reaching White Plains depends on the degree of upstream utilization of Humboldt River, which is subject to changing practices of man, and consequently, the residual is of undependable quantity and quality. Thus, the dependable, usable, and therefore available water supply, including the largely saline stored water (table 38), of White Plains can be considered small at best.

Packard Valley does not receive inflow from other hydrographic areas but precipitation within its own area generates a potential for significant recharge. Packard Valley discharges water to the Carson Sink by intermittent streamflow and ground-water underflow. Because of intermittent flow characteristics, the average annual streamflow is too unpredictable to be considered a dependable water supply. Proper development of a well field might allow salvage of the phreatophyte discharge (about 300 acre-feet) and salvage of some of the ground-water underflow to Carson Desert. Assuming effective salvage of about half the underflow (about 200 acre-feet), the available supply of the valley would be about 500 acre-feet per year, plus a substantial part of the 500,000 acre-feet of stored water (table 38).

GEOHYDROLOGIC HAZARDS

Geohydrologic hazards are as critical in the Carson River basin as they are in almost any area of the world. Among these hazards, flooding on the Carson River itself may be the most noticeable, because of its widespread effect. Other water-related hazards of a generally more localized nature include flash floods in small-drainage basins, snow avalanches, and landslides. Earthquakes also must be considered because, though generally not hydrologic in origin, they nonetheless could be direct forerunners of hydrologic hazards.

None of these hazards should be considered independently. For example: (1) landslides can become more active during earthquakes and during times of intense, flood-causing rains; (2) collapse of flood-control dams, with subsequent major flooding, might well occur during an intense earthquake; (3) snow avalanches could well be triggered by heavy rains or earthquakes; and (4) landslides might cause major floods on relatively small tributary streams by ponding large quantities of water that could then suddenly be released as the impounding landslide is overtopped and quickly eroded.

NUMBERING SYSTEM FOR HYDROLOGIC SITES

The numbering system for hydrologic sites in this report indicates location on the basis of the rectangular subdivision of public lands, referenced to the Mount Diablo base line and meridian. Each number consists of three units: the first is the township north of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; the third unit, separated from the second by a dash, designates the square-mile section. The section number is followed by letters that indicate the quarter section, quarter-quarter section, and so on; the letters a, b, c, and d designate the northeast, northwest, southwest and southeast quarters, respectively. For example, well 14/19-15bcc is in SW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 15, T. 14 N., R. 19 E. In this report, most sites identified with three and occasionally four letters are in areas where detailed U.S. Geological Survey topographic maps (scale, 1:62,500 and 1:24,000) are available. In other areas, sites have been located using aerial photographs and a less detailed 1:250,000-scale map. An index to Geological Survey topographic maps in Nevada can be obtained free of charge from the Distribution Section, Geological Survey, Federal Center, Lakewood, Colo. 80225.

Because of space limitation, wells are shown on plate 1 by a map number which is referenced to a location number in table 39. Springs and other hydrologic sites are identified on plate 1 only by the above described site numbering system. Township and range numbers are shown along the margins of the plate.

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1938	860	1939
1943	980	1945
1951	1214	1953
1956	1444	1958
1961-65	1927	1970

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