STATE OF NEVADA
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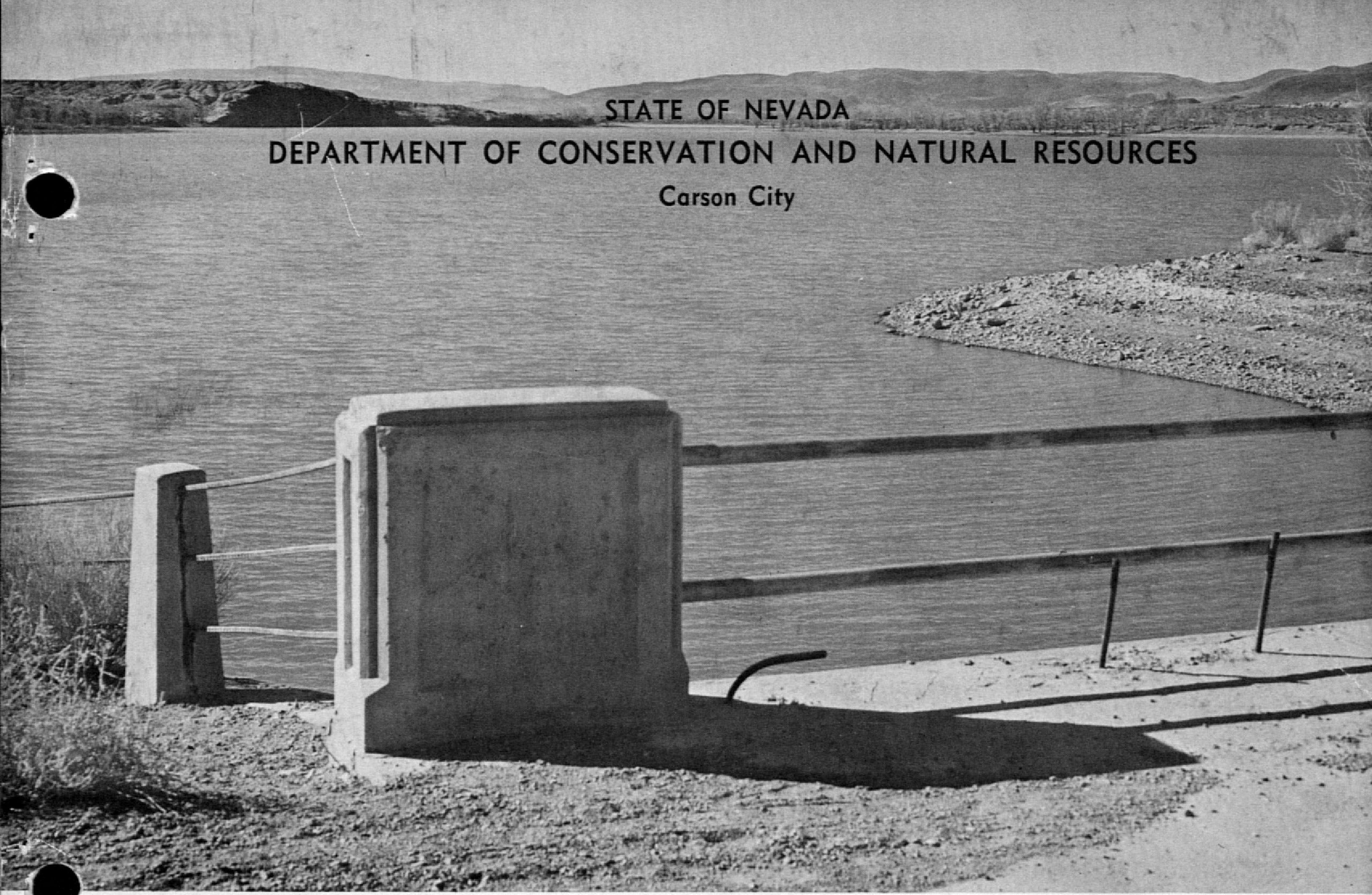

View of Weber Reservoir looking northwest from the dam.

WATER RESOURCES – RECONNAISSANCE SERIES
REPORT 40

A BRIEF APPRAISAL OF THE WATER RESOURCES OF THE WALKER LAKE AREA, MINERAL, LYON, AND CHURCHILL COUNTIES, NEVADA

By
D. E. Everett, Chemist
and
F. Eugene Rush, Geologist

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

FEBRUARY 1967

Water Resources - Reconnaissance Series

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A BRIEF APPRAISAL OF THE WATER RESOURCES OF THE WALKER LAKE AREA, MINERAL, LYON AND CHURCHILL COUNTIES, NEVADA

by D. E. Everett and F. E. Rush

SUMMARY

The Walker Lake area, which includes Walker Lake Valley and Rawhide Flats, is in west-central Nevada at the downstream end of the Walker River. Walker Lake Valley in turn is subdivided into the Schurz, the Lake, and Whisky Flat-Hawthorne subareas.

For the period 1908-65 the estimated average annual gross inflow of water to Walker Lake Valley was about 169,000 acre-feet, of which about 140,000 acre-feet was supplied by the Walker River. During the same period, the estimated total discharge from Walker Lake Valley was about 256,000 acre-feet per year, of which 220,000 acre-feet was discharged by evaporation from Walker Lake, 4,000 acre-feet by evaporation from Weber Reservoir, 21,000 acre-feet by evapotranspiration of phreatophytes and bare soil, 10,000 acre-feet by crop use, and about 1,400 acre-feet by pumpage and by surface-water diversions for municipal use.

Water levels in Walker Lake have declined an average of 1.84 feet per year for the period 1908-65. The average area of the lake for this period was about 54,000 acres. Accordingly, the average annual depletion of storage in Walker Lake was about 100,000 acre-feet. As the lake levels declined, the water table around the lake also declined. Since 1908, an estimated 3,000 acre-feet of ground water has been lost annually from ground water in storage.

Recharge from local sources to the Schurz, Whisky Flat-Hawthorne, and Lake subareas is about 500 acre-feet, 5,400 acre-feet, and 600 acre-feet, respectively. Any substantial drawdown of water levels caused by pumping near the river in the Schurz subarea would cause water to be diverted from the river to the ground-water system. The annual discharge by wells near Hawthorne in the Whisky Flat-Hawthorne subarea since 1908 was estimated to be about 200 acre-feet, and in large part was used by the town of Hawthorne and the Naval Ammunition Depot for municipal supplies.

Most of the ground water in Walker Lake Valley is suitable for agricultural and domestic uses. However, a few wells in the Schurz subarea yield water which is unsuitable for irrigation, and municipal wells near Hawthorne yield water with a high sulfate content.

The preliminary estimates of perennial yield are: Whisky Flat-Hawthorne subarea, probably not in excess of 5,000 acre-feet;

Lake subarea, probably not in excess of 700 acre-feet; and Rawhide Flats, about 500 acre-feet. The perennial yield of the Schurz subarea is largely indeterminate at this time. However, the estimated average annual water inflow was somewhat more than 140,000 acre-feet, for the years 1908-65 and more than 110,000 acre-feet for the years 1948-65, most of which discharges into Walker Lake.

INTRODUCTION

Purpose and Scope of the Study

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

Recognizing this need, the State Legislature enacted special legislation (Chapt. 181, Stats., 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U. S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the fortieth report prepared as part of the reconnaissance studies (fig. 1). Because of the need for information on the surface-water resources, this reconnaissance series has been broadened to include preliminary evaluations of the surface-water resources in the valleys studied.

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

The period 1908-65 is used in this report because (1) the earliest stage of Walker Lake was measured in 1908, (2) nearly continuous stream-flow records at Wabuska and Schurz are available since 1914, and (3) the period is believed to approach closely a period of average wetness.

Field work was done during February and March 1966. The investigation was made under the general supervision of G. F. Worts, Jr., District Chief in charge of hydrologic studies by the Geological Survey in Nevada.

Location and General Features

The Walker Lake area, which includes Walker Lake Valley and Rawhide Flats, is in west-central Nevada and is approximately enclosed by lat 38°05' and 39°15' N., long 116°30' and 117°00' W. (fig. 1). It is almost entirely in Mineral County; however, the extreme northern and northwestern parts are in Churchill and Lyon Counties, respectively (pl. 1). It is about 75 miles long, 25 miles wide, and covers an area of about 1,560 square miles.

For the purposes of this report, Walker Lake Valley has been

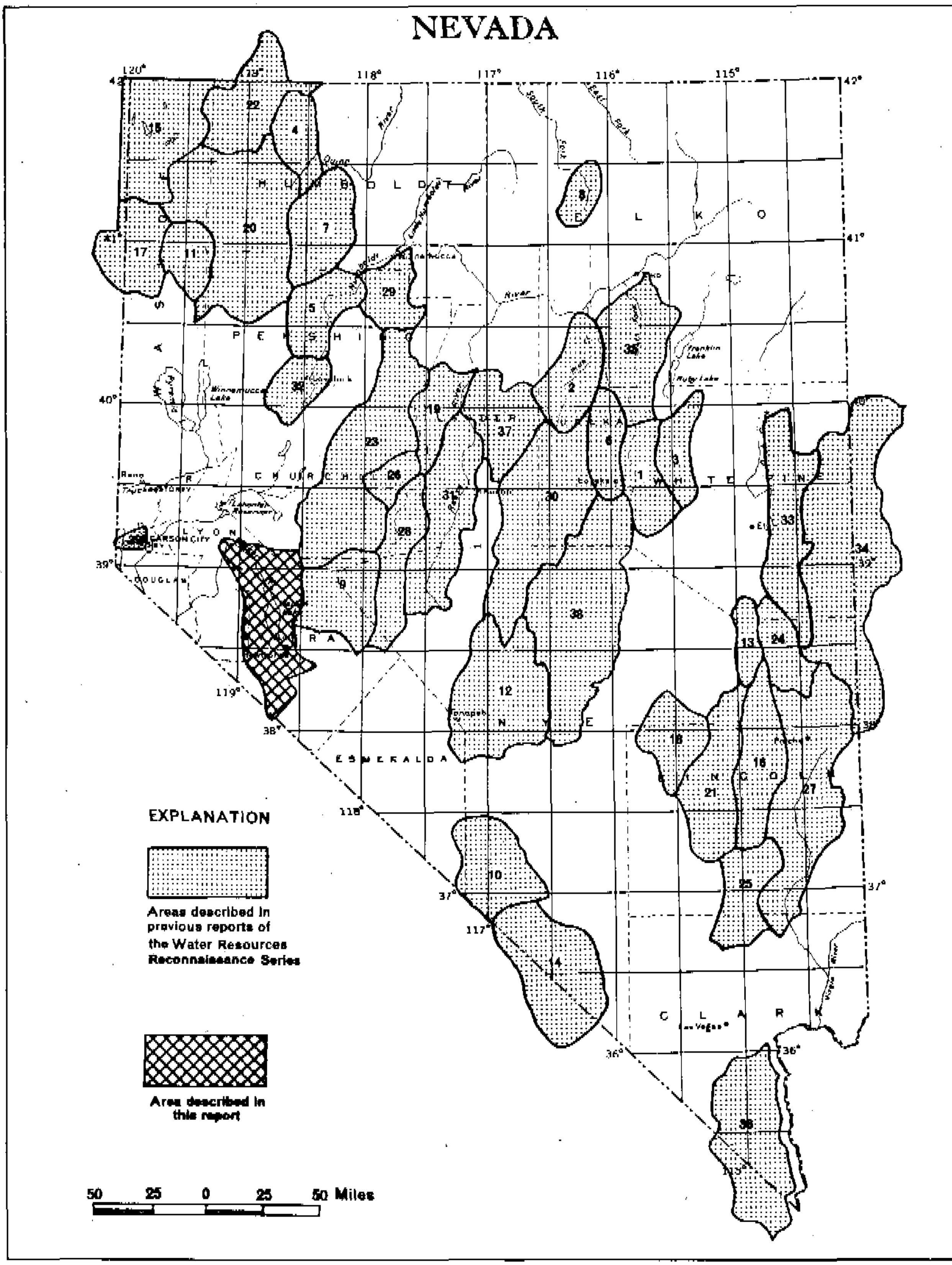

Figure 1.—Areas in Nevada described in previous reports of the Water Resources Reconnaissance Series and the area described in this report

divided into the Whisky Flat-Hawthorne, the Lake, and the Schurz subareas. The Whisky Flat-Hawthorne subarea extends from the southern boundary of the drainage area to the southern end of Walker Lake. The Lake subarea extends from the southern to the northern end of Walker Lake. All the area north of Walker Lake, except for Rawhide Flats, is included in the Schurz subarea which includes Weber Reservoir. Rawhide Flats is a separate valley northeast of the Schurz subarea.

Principal access to the area is by U. S. Highway 95 which passes through the area from north to southeast. Alternate U. S. Highway 95, State Highway 30, and unimproved roads provide access to most other points in the area.

The principal towns in the area are Hawthorne and Babbitt, which are on U. S. Highway 95 and are about 5 miles west of the Southern Pacific Railroad. The population of Hawthorne in 1960 was 5,277.

Previous Work

An unpublished report was written by D. G. Metzger, C. H. Carstens, and W. P. Somers in 1953 on the water resources in the vicinity of Hawthorne. S. T. Harding (1965) described the historical lake levels of Walker Lake. The domestic water supply of the Hawthorne Naval Ammunition Depot has been reported on by H. E. Wilbert (1947). The geology and mineral deposits of Mineral County were mapped by D. C. Ross (1961). A preliminary geologic map of Lyon, Douglas, Ormsby, and part of Washoe Counties has been prepared by Moore (1961).

Acknowledgments

The cooperation and assistance of various Federal, State, and local agencies are gratefully acknowledged. The Hawthorne Naval Ammunition Depot provided pumpage figures from municipal wells, data on streamflow, and figures on streamflow use. The Bureau of Indian Affairs, Nevada Indian Agency, provided figures on streamflow diversion and irrigated acreage. The Hawthorne Municipal Water Works provided pumpage figures from municipal wells and figures on streamflow use. Many of the well data and logs were provided by the office of the State Engineer.

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

Special acknowledgment is given Fred Ruward, Public Works Office, Hawthorne Naval Ammunition Depot, R. Kuntze, superintendent of the Hawthorne Municipal Water Works, and Everett Randall, Nevada Indian Agency, who supplied much of the information on water distribution and use.

HYDROLOGIC ENVIRONMENT

Climate

The climate in the project area generally is semiarid in the valleys and subhumid in the higher mountains. Precipitation and humidity generally are low, and summer temperatures and evaporation rates are high. Precipitation varies widely in amount but generally is least on the valley floor and greatest in the mountains. Snow is common during the winter months, and localized thundershowers provide much of the summer precipitation. A further discussion of precipitation is included in the hydrology section of this report. The daily temperature range is commonly about 50°F. The length of the growing season varies from year to year; however, Houston (1950, p. 18) stated that the average growing season for the Walker Lake area is about 136 days (May 15 to September 28).

Physiography and Drainage

The area covered in this report is in the Great Basin section of the Basin and Range physiographic province (Fenneman, 1931). Walker Lake Valley is a north-trending valley bordered on the west by the Wassuk Range, on the north by the Desert and Terrill Mountains, on the east by the Garfield Hills, Gillis Range, and Sand Springs Range, and on the south by the Excelsior Mountains and Anchorite Hills.

Mt. Grant, altitude 11,239 feet, in the Wassuk Range is the highest peak in the area. However, several other peaks have altitudes greater than 10,000 feet. The lowest point in the valley, 3,973 feet in 1965, is the surface of Walker Lake. Accordingly, the maximum relief is about 7,300 feet.

The principal surface drainage in Walker Lake Valley is toward Walker Lake. The flood plain of the Walker River in the report area has an average gradient of about 4 feet per mile. Gradients on the alluvial aprons, which lie between the mountains and the lowlands, commonly range from 100 to 300 feet per mile. In the mountains, erosion has produced steep-sided canyons, and stream-channel gradients generally are in excess of 300 feet per mile; locally they are as much as 1,000 feet per mile.

Rawhide Flats is a northwest-trending valley bordered on the south and west by the Terrill Mountains, on the north by the Blow Sand Mountains, on the west by the Desert Mountains, and on the east by the Sand Springs Range. An unnamed peak, altitude 7,170 feet, in the Sand Springs Range is the highest peak in the area. The lowest point in the valley, 3,880 feet, is on the playa. The maximum relief is about 3,300 feet. The principal surface drainage is northwestward toward the playa. In the valley lowland, southeast of the playa, the gradient is about 35 feet per mile.

Lithologic and Hydrologic Features of the Rocks

The hydrogeologic units shown on plate 1 are consolidated rocks and alluvium. A further division of the consolidated rocks was made by Ross (1961, pl. 2) and Moore (1961), but for the purposes of this reconnaissance, it is assumed that the hydrologic properties of the various consolidated-rock types generally are similar.

The consolidated rocks range in age from Precambrian to Tertiary. The dominant rock types in all the mountains, except the Wassuk Range, are volcanic flows, tuff, and breccia. The Wassuk Range is principally quartz monzonite, but volcanic tuff and flows are common. All the consolidated rocks are assumed to have low permeability except for fracture zones. Springs occur locally in the consolidated rocks and are used as a municipal supply by the Naval Ammunition Depot.

The alluvium is of late Tertiary and Quaternary age and consists of gravel, sand, silt, and clay. This material is not only derived from the adjacent mountains but also transported into the area by the Walker River. The alluvial deposits are poorly consolidated to unconsolidated, well to poorly sorted, and in some areas are faulted and folded. Several well logs listed in table 10 show the types of material penetrated.

Lake Lahontan, a Pleistocene lake, occupied much of the valley floor in Walker Lake Valley and Rawhide Flats. The highest recognized lake level, altitude 4,380 feet, is shown on plate 1 (Russell, 1885). Walker Lake is a desiccating remnant of Lake Lahontan. In the area once occupied by the lake, fine-grained material was deposited from the standing water. Logs of wells 8/30-3d1 and 8/30-8d1 (table 10) in the Whisky Flat-Hawthorne subarea show the dominant lithology to be clay from land surface to a depth of at least 500 feet. To the southwest beyond the lake area, well logs 8/30-18a1 and 8/31-32b1 list less, about one-third clay. These fine-grained lenses have low permeability but are interbedded with lenses of sand and gravel. They supply large amounts of water to wells with small drawdowns in the vicinity of Hawthorne and Babbitt.

PRECIPITATION

Precipitation has been recorded at many locations in and near the project area. However, for the purposes of this report, records from five stations are used. Three of the stations, Schurz, Thorne, and Hawthorne-Babbitt are in the area. Only 23 years of data are available for Wellington, 30 miles west of the project area in an adjacent valley, but long-term data are available for the other four stations. The average monthly and annual precipitation for these five stations is listed in table 1.

The precipitation pattern in Nevada is related principally to the topography; the stations at higher altitudes generally receive more precipitation than those at lower altitudes. However, this relation may be considerably modified by local conditions. For example, Schurz (altitude 4,124 feet) receives nearly twice as much precipitation as Thorne, which is about at the same altitude. The stations other than Schurz conform reasonably well to a precipitation-altitude relation.

Precipitation on Walker Lake

Precipitation data from Thorne and Schurz suggest that precipitation on Walker Lake ranges from about 3 inches at the south end to 5 inches at the north end. Because data are not available for different locations on the lake, it is estimated that the average annual precipitation on the lake is an average of these two, or about 4 inches. The estimated area of Walker Lake for the period 1908-65 was about 54,000 acres. These estimates suggest that on the average about 18,000 acre-feet of precipitation directly entered lake storage each year.

Precipitation data from Schurz and Yerington suggest that precipitation on Weber Reservoir averages about 5 inches a year. The average area of the reservoir is approximately 1,000 acres. Accordingly, an estimated 400 acre-feet of precipitation directly enters reservoir storage each year.

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Precipitation data from Schurz and Yerington suggest that precipitation on Weber Reservoir averages about 5 inches a year. The average area of the reservoir is approximately 1,000 acres. Accordingly, an estimated 400 acre-feet of precipitation directly enters reservoir storage each year.

Table 1.--Average monthly and annual precipitation, in inches, at four stations in and near the Walker Lake area

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

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Schurz[1/]	0.49	0.52	0.45	0.52	0.59	0.40	0.33	0.31	0.32	0.41	0.39	0.60	5.33
Thorne[2/]	.25	.41	.31	.45	.45	.28	.12	.16	.20	.31	.23	.23	3.32
Wellington[3/]	1.07	1.18	.76	.48	.98	.67	.40	.34	.32	.48	.38	.98	8.73
Yerington[4/]	.58	.58	.38	.39	.58	.45	.20	.22	.30	.31	.50	.50	4.92
Hawthorne-Babbit[5/]	.36	.41	.41	.47	.67	.44	.26	.17	.22	.41	.28	.28	4.53

	Altitude (in feet)	Section	Location Township	Range	Remarks
1.	4,124	26	13 N.	28 E.	Average for period 1920-56
2.	4,200	36	9 N.	30 E.	Average for period 1884-1949.
3.	4,800	2	10 N.	23 E.	30 miles west of project area. Average for period 1943-65; continuing record.
4.	4,375	15	13 N.	25 E.	15 miles west of project area. Average for period 1892-95, 1902-65; continuing record.

5. Altitude about 4,200 feet. Location not given because of repeated movement of station between Hawthorne and Babbit. Average for period 1937-65; continuing record.

SURFACE WATER

By Donald O. Moore

Walker River

The principal source of surface water in Walker Lake Valley is the Walker River which flows into the valley from the northwest and discharges into Walker Lake. In 57 water years (1909-65) the discharge of the Walker River at Wabuska, just upstream from Walker Lake Valley, has ranged from 9,340 acre-feet in 1931 to 540,000 acre-feet in 1914 and has averaged 140,000 acre-feet per year (table 2). However, the flow during the period 1948-65 probably reflects more accurately the long-term average under present conditions of upstream development. The flow during this 18-year period averaged about 107,000 acre-feet per year.

Little surface water is contributed to the Walker River where it flows through the north end of the valley to Walker Lake.

Estimated Local Runoff

A method has been devised by Riggs and Moore (1965) to estimate runoff from ungaged basins in mountainous areas. The method still is in the development stage and is subject to further field checking and adjustment. It is a reconnaissance method only, and in no way should it be construed that the method necessarily produces results of equivalent reliability to those based on extensive data. This method is explained briefly, as follows: Using the drainage areas supplying the natural flow to streams where gaging stations have been or are operated, recorded runoff is prorated by altitude zones (1,000-foot intervals) with due regard to the proportional areas of the several zones and with increasing unit values of runoff for increasing altitude. The adjustment of the runoff coefficients for local conditions are based on streamflow measurements. The measurements are adjusted first to the average for the year then to a long-term average annual discharge. Also considered are the different physical characteristics, such as vegetation, amounts of precipitation, geology, and types of soil.

Walker Lake Valley was found to have three different sets of runoff values with the highest intensity of runoff in the Wassuk Range north of Cat Creek and the lowest intensity in the southern subarea. The largest source of locally derived surface-water runoff in Walker Lake Valley is generated on the east flank of the Wassuk Range between Cat Creek and Cottonwood Creek. The remaining surface-water runoff in Walker Lake Valley is generated from the remainder of the Wassuk Range, Anchorite Hills, and the Excelsior Mountains. Runoff rates from the mountains generally decrease in a southerly direction.

The estimated average annual runoff is about 10,000 acre-feet in the Whisky Flat-Hawthorne subarea and 4,700 acre-feet in the

Lake and Schurz subareas, or a total of roughly 15,000 acre-feet (table 3). In the Lake and Whisky Flat-Hawthorne subareas much of the runoff is detained in reservoirs where water is diverted to the Naval Ammunition Depot for municipal use and where some evaporates. It is estimated that on the average not more than 2,000 acre-feet per year flows directly into Walker Lake. In the Whisky Flat-Hawthorne subarea most of the 10,000 acre-feet of estimated average annual runoff percolates downward to ground water or is retained as soil moisture. An average of probably not more than 1,000 acre-feet per year reaches Walker Lake as surface-water runoff. Accordingly, the estimated average annual surface-water runoff to Walker Lake from local sources is about 3,000 acre-feet, or about one-fifth of the total runoff from the mountains surrounding the lake.

Streamflow Characteristics

Streamflow in Walker Lake Valley varies considerably from year to year and also for different periods throughout the year. Figure 2 shows the discharge hydrograph for water years 1961 and 1962 for Rose Creek. The graphs show that snowmelt occurs during the period April to June and that this period has a much higher discharge than other periods of the year. Also flow during 1962 was much larger than during 1961. Years with the largest snow packs in the mountains generally have the highest runoff.

Available Records

The Hawthorne Naval Ammunition Depot has kept records on Cottonwood, Rose, House, Squaw, and Cat Creeks for many years. These records have not been published. As part of this study measurements were made on most of the streams on the west side of the valley between Reese River Canyon and Powell Canyon.

Table 2.--Streamflow of the Walker River at the Wabuska gaging station (site 1, pl. 1) for water years 1909-65

Water year	Discharge (acre-feet)	Water year	Discharge (acre-feet)	Water year	Discharge (acre-feet)
1909-11	a 300,000	1929	18,300	1947	84,410
1912	b 160,000	1930	14,500	1948	31,070
1913	c 170,000	1931	9,340	1949	36,520
1914	d 540,000	1932	59,800	1950	30,330
1915	d 210,000	1933	35,900	1951	158,600
1916	d 310,000	1934	21,000	1952	379,000
1917	d 320,000	1935	46,410	1953	121,800
1918	d 160,000	1936	c 110,000	1954	43,340
1919	d 200,000	1937	c 114,000	1955	34,620
1920	d 60,000	1938	c 470,000	1956	277,000
1921	76,800	1939	c 80,000	1957	88,350
1922	248,000	1940	62,960	1958	227,300
1923	131,000	1941	179,900	1959	70,590
1924	52,600	1942	c 280,000	1960	26,260
1925	c 20,000	1943	240,100	1961	23,780
1926	29,200	1944	c 70,000	1962	37,260
1927	100,000	1945	331,900	1963	169,200
1928	46,900	1946	170,900	1964	51,460
				1965	123,200
Average annual (rounded)					140,000

a. Estimated average annual discharge based on streamflow records on the Carson River near Empire, Nevada.
b. Estimated discharge based on streamflow records on the Walker River near Mason, Nevada.
c. Estimated discharge based on streamflow records on the East Walker River near Mason and the West Walker River near Hudson.
d. Estimated discharge based on streamflow records on the Walker River near Schurz, Nevada. (site 2, pl. 1).

Table 3.--Estimated average annual runoff in Walker Lake Valley

Mountain Segment	Location	Area		Estimated runoff	
		Acres	(percent of runoff area)	(Acre-feet per year)	(percent of total runoff)
Wassuk Range	East flank of mountains north of Cat Creek above 7,000 ft in the Lake and Schurz subareas.	29,000	24	4,700	32
Wassuk Range	East flank of mountains south of Cat Creek to Powell Canyon above 7,000 ft in the Whisky Flat-Hawthorne subarea.	46,700	39	6,300	43
Anchorite Hills and Excelsior Mountains	East flank of Anchorite Hills south of Powell Canyon and northwest flank of Excelsior Mountains above 7,000 ft in the Whisky Flat-Hawthorne subarea.	44,700	37	3,700	25
Total (rounded)		120,000	100	15,000	100

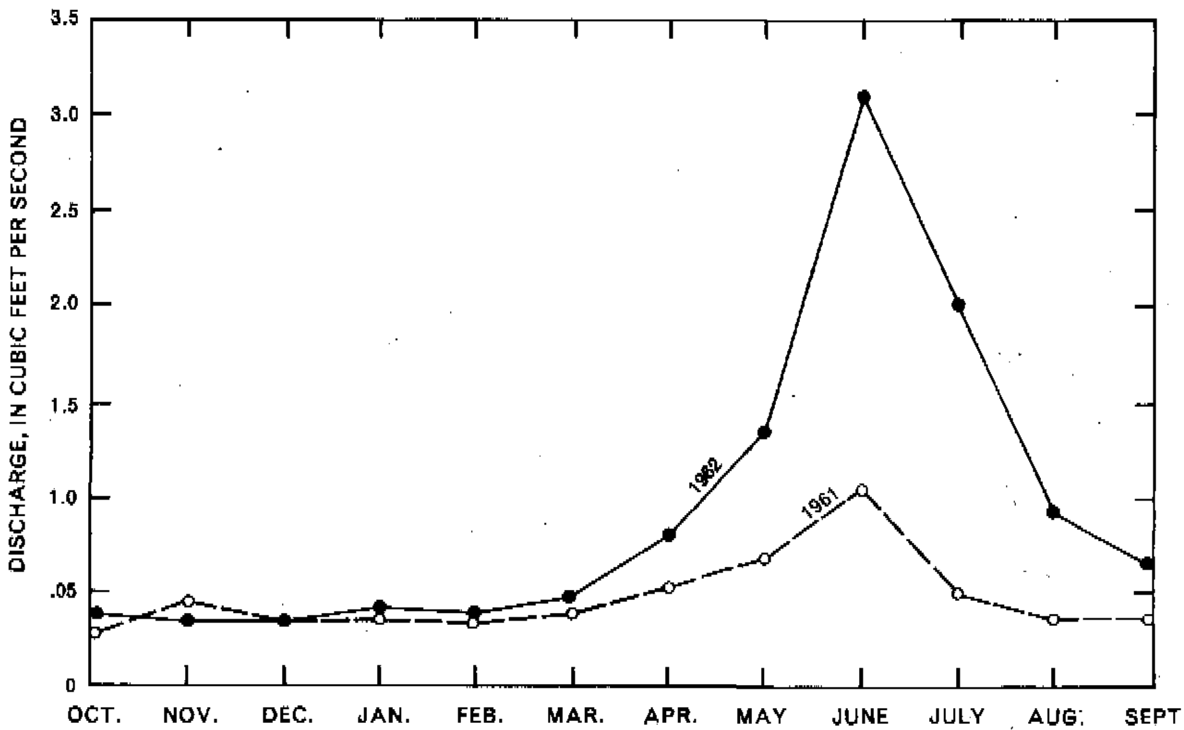

Figure 2.—Discharge of Rose Creek for 1961 and 1962 water years. Records by Hawthorne Naval Ammunition Deport, Hawthorne, Nevada

STREAMFLOW DISPOSITION AND ROUTING

Irrigation Use

Water from the Walker River is diverted near Schurz by the Walker River Indians for the irrigation of native grass and hay. The Nevada Indian Agency at Stewart, Nevada, reports the following diversions and use: (1) For the years prior to 1935 approximately 9,450 acre-feet of water per year was diverted to irrigate 2,100 acres of farmland and native grass; and (2) starting with the completion of Weber Dam in 1935, approximately 31,900 acre-feet of water per year was diverted to irrigate 6,280 acres of farmland and native grass.

According to Houston (1950, p. 21), the annual consumptive use of water by alfalfa and native grass in the Walker Lake area is about 2 acre-feet per acre per year. Water applied in excess of this amount is to leach the soil; it eventually returns to the Walker River or is consumed by evapotranspiration outside the irrigated areas.

The above reports and estimates suggest that the consumptive use during the period 1908-34 averaged about 4,000 acre-feet per year, and during the period 1935-65 averaged 12,000 to 13,000 acre-feet per year. The weighted average for the two periods is nearly 10,000 acre-feet per year.

Municipal and other Uses

Runoff from the Wassuk Range is diverted by the Hawthorne Municipal Water Works, the Hawthorne Naval Ammunition Depot, and local ranchers for municipal, domestic, and agricultural uses. It is estimated that in recent years approximately 2,000 acre-feet is diverted annually from Cory, Cottonwood, House, Rose, Squaw, Cat, and a few unnamed creeks. For the period 1908-65, the use may have averaged about 1,000 acre-feet per year.

EVAPORATION FROM WATER SURFACES

Walker Lake

All water entering Walker Lake Valley that is not otherwise discharged ultimately reaches Walker Lake. The fluctuation of lake level is dependent upon the relation between inflow to and evaporation from the lake. When evaporation exceeds inflow, the lake level declines, and of course the converse is true. Figure 3 shows that the level of Walker Lake has declined from an altitude of 4,078 feet in 1908 to 3,973 feet in 1965--105 feet of decline in 57 years, or an average decline of 1.84 feet per year.

The areas of the lake in 1908 and 1965 were approximately 66,000 and 38,000 acres, respectively. The average area during this period was about 54,000 acres, based on the configuration of the lake shore as now expressed. According to Harding (1965, p. 147), the average annual evaporation from Walker Lake is 4.1 feet.

For the period 1908-65 the average annual evaporation is the product of the average area times the evaporation rate (54,000 acres x 4.1 feet), or an estimated 220,000 acre-feet per year. For the same period, the average annual depletion of lake storage is the product of the average area times the average annual rate of decline of lake level (54,000 acres x 1.84 feet), or an estimated 100,000 acre-feet per year.

Weber Reservoir

Weber Reservoir was constructed in 1935 by the U. S. Indian Service, now the Bureau of Indian Affairs. It is about 8 miles upstream from Schurz and is used to store irrigation water and for flood control. The average area of the reservoir is approximately 1,000 acres and the evaporation rate is about 4 feet per year (Kohler and others, 1959, p. 13). Accordingly, the estimated average annual evaporation from Weber Reservoir is about 4,000 acre-feet.

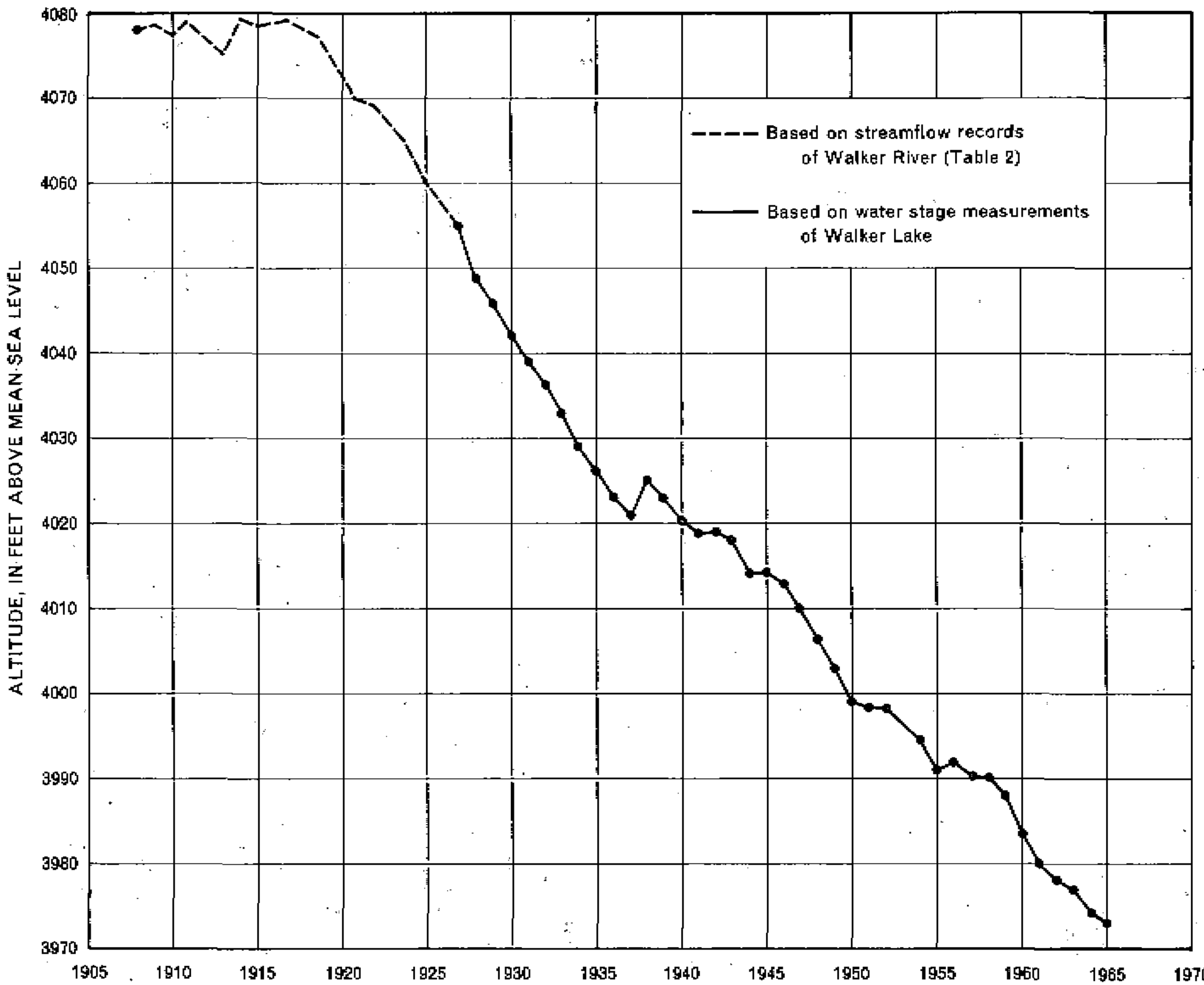

Figure 3.—Variations in stage of Walker Lake, 1908-65

GROUND WATER

Source and Occurrence

The source of all ground water in the project area is from precipitation within the area, from seepage loss from the Walker River as it crosses the area, from recharge resulting from the downward percolation of irrigation water, and from subsurface flow from Mason Valley. It is assumed that little if any ground-water inflow from the Fallen area to the north occurs. Most of the water is contained in the younger and older alluvium and occurs under both artesian and water-table conditions. Well 13/28-25b1, the only known flowing well in the Schurz subarea, had an estimated flow of 2 gpm (gallons per minute) on February 17, 1966 (table 9).

The thickness of the ground-water reservoir is not known, because wells near the center of the valley do not penetrate its full thickness. Well 8/30-8d1, in the Whisky Flat-Hawthorne subarea, was drilled to a depth of 542 feet and did not encounter bedrock (table 10).

Although ground water occurs in large quantities in Walker Lake Valley, the water between Schurz and the northern end of Walker Lake in places is too highly mineralized for agricultural or domestic uses. However, ground water northwest of Schurz and in the Whisky Flat-Hawthorne subarea probably is suitable for both uses. Part of the water supply for Hawthorne is obtained from two wells in the city and from one well in Cory Canyon. The Naval Ammunition Depot obtains part of its water supply from nine wells in the vicinity of Hawthorne. These wells yield 250 to 1,050 gpm. Well 8/30-18a1 reportedly yielded approximately 1,050 gpm with a 10-foot drawdown.

Some ground water occurs in the consolidated rocks as is evidenced by springs discharging from them. Yields from wells tapping these rocks probably would be small.

Movement

Ground water, like surface water, moves from areas of higher head to areas of lower head. Unlike surface water, however, it moves very slowly, 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 Walker Lake Valley, ground water moves from recharge areas along the valley margins to discharge areas in the valley lowlands. The principal lateral direction of movement is toward Walker Lake in the central part of the valley. Flow in Rawhide Flats generally is toward the playa, which is in the northwestern part of the valley.

Recharge

Recharge from Precipitation within the Area

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

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

The precipitation map of Nevada (Hardman and Mason, 1949, p. 10) has been adjusted to the improved topographic base maps (scale 1:250,000) now available for the whole State. Hardman showed that average annual precipitation is closely related to altitude. This map was used to estimate the precipitation within selected altitude zones.

Table 4 lists the altitude zones, the estimated average annual precipitation, and the estimated percentage of the precipitation in each zone that ultimately recharges the ground-water reservoir. The estimated average annual precipitation for Walker Lake Valley and the hydrologically separate Rawhide Flats is 410,000 and 75,000 acre-feet, respectively, and the estimated average annual recharge is 6,500 and 150 acre-feet, respectively. In the project area estimated recharge is only 1 to 2 percent of the total precipitation. Very little ground-water recharge occurs in the Lake subarea west of Walker Lake, because of the land gradients are steep and the consolidated rocks in many places extend to the lake. Accordingly, most runoff that might become ground-water recharge flows over the consolidated rocks to the lake.

Seepage Loss from Walker River

Seepage loss from Walker River recharges the ground-water reservoir, and most probably occurs in the spring and early summer when the stage of the river is highest. No seepage measurements were made during the course of this investigation and the time and place of losses were not determined. Most of the seepage goes to replenish the water consumed by evapotranspiration and part is discharged downstream by underflow to the lake.

Subsurface Inflow

Subsurface inflow, or ground-water underflow, enters the Schurz subarea from Mason Valley, which is upstream along the Walker River. Huxel (oral communication, 1966) estimated this underflow to be about 600 acre-feet per year in the area where Walker River flows into the project area, and 700 acre-feet per year at the alluvial divide approximately 3 miles southeast of the river. Accordingly, the subsurface inflow from Mason Valley is estimated to be about 1,300 acre-feet per year. Subsurface inflow from the north (the Fallon area) to Rawhide Flat may occur, but data is lacking to support such a conclusion.

Recharge Resulting from Irrigation

As previously mentioned, Walker River water is diverted for irrigation in the Schurz subarea. Some of the water percolates downward beneath the ditches to the ground-water reservoir, and some percolates downward beneath the irrigated fields. However, all the water diverted in excess of crop needs does not percolate downward to the ground-water reservoir; some flows off the fields into drainage ditches with discharge water back into the river. The amount of ground-water recharge and return flow in the drainage ditches were not estimated in this study.

Discharge

In the Walker Lake area, ground water is discharged by evapotranspiration and pumping.

Evapotranspiration

Ground water discharged by evapotranspiration is consumed by phreatophytes and evaporates from areas of bare soil. The area of evapotranspiration is shown on plate 1. The principal phreatophytes are cottonwood, meadowgrass, greasewood, rabbitbrush, and willow bushes. Cottonwood grows principally along the banks of the Walker River.

Table 5 lists the estimated average annual evapotranspiration for each area and subarea. These estimates are based on rates of evapotranspiration in other areas, as determined by Lee (1912), White (1932), Young and Blaney (1942), and Houston (1950). The estimated weighted average annual evapotranspiration of ground water in the Schurz subarea for the period 1908-65 was about 17,000 acre-feet; excluding Walker Lake, it is about 800 acre-feet in the Lake subarea; and in the Whisky Flat-Hawthorne subarea about 3,000 acre-feet--a total of about 21,000 acre-feet. In the Rawhide Flats area the estimated evapotranspiration of ground water is about 800 acre-feet per year.

Pumpage

Pumpage in the report area is from 12 large-diameter wells near Hawthorne, a few irrigation wells in Whisky Flats, domestic wells in the Schurz subarea, and stock wells scattered throughout the area.

The annual discharge by municipal wells of Hawthorne, Naval Ammunition Depot wells, and local domestic wells near Hawthorne for the period 1962-65 is listed in the following tabulation:

Year	Annual discharge (acre-feet)
1962	390
1963	340
1964	620
1965	410

For this period the average annual discharge by wells was about 440 acre-feet per year and was used mainly to supplement the supply from streams in the Wassuk Range. Prior to the construction of the Naval Ammunition Depot in 1930, little ground water was pumped.

At present about 100 acres in Whisky Flats are being irrigated from wells. The estimated discharge in 1965 was about 300 acre-feet. Domestic and stock wells are numerous in the Schurz subarea and Rawhide Flats. However, the average annual pumpage is estimated to be not more than 200 and 100 acre-feet, respectively. For the period 1908-65 the average annual pumpage for all uses probably has not exceeded 400 acre-feet per year.

Storage

Estimated Storage Capacity

The amount of ground water in storage in the Walker Lake area is equal to the volume of saturated material multiplied by the specific yield of the material. Specific yield is the ratio of (1) the volume of water that will drain by gravity from the zone of saturation to (2) the volume of the saturated material drained, commonly expressed as a percentage (Meinzer, 1923).

In the Walker Lake area, the specific yield of the uppermost 100 feet of saturated material is assumed to average about 10 percent. However, in the area near Hawthorne, the coarse material reported on well logs suggest that it may be as high as 15 percent (table 10). The area mapped as alluvium having 100 feet or more of saturated thickness is estimated to be about 75 percent in the Whisky Flat-Hawthorne subarea, the Schurz subarea, and Rawhide Flats, and about 50 percent in the Lake subarea. This is based on topography, the subsurface distribution of the alluvium, and the shape of the areas. For example, a long narrow valley would have a larger percentage of alluvium near bedrock where the thickness of the alluvium may not be 100 feet. The areas mapped as alluvium on plate 1, the areas used to compute storage, and the estimated amount of stored water are summarized in table 6.

Although the estimates of ground water in storage are large, the amount where the depth to water is less than 100 feet and where suitable land is available for cultivation is appreciably less. Also, in the Schurz subarea some of this water is highly mineralized and is unsuitable for irrigation or domestic uses. The amount of usable ground water in storage that is economically available depends in part on the distribution of water-storing deposits, the distribution and range in chemical quality of the ground water, and the number and distribution of pumped wells.

Table 4.--Estimated average annual precipitation and ground-water recharge in the Walker Lake area

Altitude zone (feet)	Area (acres)	Estimated annual precipitation: Range (in inches)	Estimated annual precipitation: Average (in feet)	Estimated annual precipitation: Average (in acre-feet)	Estimated recharge: Assumed percentage of precipitation	Estimated recharge: (ac.-ft. per year)
WALKER LAKE VALLEY						
Whisky Flat - Hawthorne subarea						
Above 10,000	920	more than 20	1.75	1,600	25	400
9,000 - 10,000	7,300	15-20	1.46	11,000	15	1,600
8,000 - 9,000	25,000	12-15	1.12	28,000	7	2,000
7,000 - 8,000	57,000	8-12	.83	47,000	3	1,400
Below 7,000	235,000	less than 8	.50	120,000	--	--
Subtotal (rounded)	325,000			210,000	--	a 5,400
Lake subarea (east side)						
7,000 - 8,000	2,400	8-12	.83	2,000	3	600
Below 7,000	79,000	less than 8	.50	40,000	--	--
Subtotal (rounded)	81,400	--	--	42,000	--	600
Schurz subarea						
7,000 - 8,000	3,000	12-15	1.12	3,400	7	240
6,000 - 7,000	9,600	8-12	.83	8,000	3	240
Below 6,000	298,000	less than 8	.50	150,000	--	--
Subtotal (rounded)	311,000	--	--	160,000	--	500
Total (rounded)	717,000	--	--	410,000	--	6,500
RAWHIDE FLATS						
6,000 - 7,000	6,000	8-12	.83	5,000	3	150
Below 6,000	139,000	less than 8	.50	70,000	--	--
Total (rounded)	145,000	--	--	75,000	--	150

a. Of this total, about 2,000 acre-feet is generated in Whisky Flat.

Table 5.--Estimated average annual evapotranspiration of ground water by phreatophytes and bare soil for the period 1908-65

Phreatophyte	Area (acres)	Depth to water (feet)	Evapotranspiration acre-feet per acre	Evapotranspiration acre-feet (rounded)
WALKER LAKE VALLEY				
Schurz subarea (1908-34)				
Meadowgrass and willow bushes	a 3,500	0-10	1.5	5,200
Meadowgrass, rabbitbrush, greasewood, and some cottonwood and willow bushes[1/]	4,500	0-10	2.0	9,000
Greasewood	10,000	10-50	0.2	2,000
Bare soil	1,500	--	0.1	150
Subtotal (rounded)	20,000			16,000
Schurz subarea (1935-65)				
Meadowgrass and willow bushes	b 6,200	0-10	1.5	9,300
Meadowgrass, rabbitbrush, greasewood, and some cottonwood and willow bushes[1/]	3,000	5-10	2.0	6,000
Greasewood	10,000	10-50	0.2	2,000
Bare soil	1,500	--	0.1	150
Subtotal (rounded)	21,000			17,000
Subtotal 1908-65 (rounded)	21,000			c 17,000

Table 5.--Continued

Phreatophyte	Area (acres)	Depth to water (feet)	Evapotranspiration acre-feet per acre	Evapotranspiration acre-feet (rounded)
	Whisky Flat-Hawthorne subarea			
Meadowgrass	1,400	0-10	2.0	2,800
Greasewood and rabbitbrush	9,000	10-50	0.2	1,800
Subtotal (rounded)	10,000			d 4,600
	Lake subarea			
Meadowgrass	Trace	0-10	1.0	--
Greasewood	4,000	10-50	0.2	800
Subtotal (rounded)	4,000			800
Total (rounded)	35,000			21,000
	RAWHIDE FLATS			
Greasewood	2,000	10-40	0.2	400
Bare soil	3,800	--	0.1	380
Total (rounded)	6,000			e 800

1. Includes evaporation from Walker River.

a. Average area for the period 1908-34. With the recession of Walker Lake, the area increased from a few hundred acres to approximately 7,000 acres in 1934.

b. Average area for the period 1935-65. With the continued recession of Walker Lake, the area increased from 7,000 acres to approximately 11,700 acres in 1965; the Nevada Indian Agency reports that about 3,100 acres of this increase is being irrigated by surface water, as discussed previously.

c. Weighted average for the period 1908-65.

d. Of this total, about 300 acre-feet occurs in Whisky Flat from about 1,700 acres of greasewood, rabbitbrush, and a small amount of meadowgrass.

e. Probably includes the discharge derived by inflow from areas outside Rawhide Flat, where higher water levels occur.

Table 6.--Estimated stored water in the upper 100 feet of saturated alluvium

Alluvial area (acres)	Area having 100 feet or more of saturated thickness (percentage)	Area having 100 feet or more of saturated thickness (acres)		Estimated stored water[1] (acre-feet)
WALKER LAKE VALLEY				
Whisky Flat-Hawthorne subarea				
120,000	75	90,000	a	900,000
Lake subarea (east side)				
20,000	50	10,000	a	100,000
Schurz subarea				
200,000	75	150,000	a	1,500,000
Total (rounded) 340,000		250,000		2,500,000
RAWHIDE FLATS				
72,000	75	54,000	a	540,000

1. Based on an assumed specific yield of 10 percent.

a. May include some water of poor or marginal quality.

Natural Depletion of Ground Water in Storage

As previously stated, water levels in Walker Lake have declined 105 feet between 1908 and 1965. As the lake levels declined the water table also declined, because the lake and the ground-water reservoir are hydraulically connected. Thus, there has been a loss of ground water in storage largely by evapotranspiration and drainage to the lake. For the period 1908-65 ground water has been lost from storage over an area about 8 miles long and 5 miles wide south of Walker Lake. The average lowering of the water table over this area was roughly 40 feet. Assuming a specific yield of about 15 percent, based on types of materials reported in the logs of a few wells, about 100,000 acre-feet of ground water has been lost from storage, or about 1,800 acre-feet per year. Data are not available on the decline of ground-water levels north and east of Walker Lake. However, it is estimated that the loss in ground-water storage in these two areas since 1908 has amounted to about 50,000 acre-feet, or about 1,000 acre-feet per year. Accordingly, the estimated average annual loss in ground-water storage in Walker Lake Valley since 1908 has been roughly 3,000 acre-feet per year.

WATER BUDGET

The water budget is a quantitative evaluation of the flow system in which all items of inflow, outflow, and changes in the amount of water in storage are listed. In Walker Lake Valley, the water budget for the period 1908-65 can be expressed by the following equation: Inflow minus outflow equals the net loss of water in storage. The 1908-65 period was chosen because of the availability of Walker River Streamflow data and Walker Lake stage measurements.

Table 7 shows the water budget as computed by two independent methods: first, the depletion shown by the difference between inflow and outflow; and second, the depletion shown by direct estimates of the decrease in storage of the lake and ground water. If all elements of inflow, outflow, and storage depletion were accurate, the difference (3) between total inflow (1) and total outflow (2) would be equal to the direct estimate of decrease in storage (4). The imbalance of 16,000 acre-feet is a result of the limited available data, errors in the estimates of all components of the water budget, or unresolved hydrologic problems.

In Rawhide Flats the average annual recharge and discharge are 150 acre-feet and 800 acre-feet, respectively. The large imbalance may be due to ground-water inflow from adjacent areas which are topographically higher and which have higher water levels, possibly the Fallon area to the north.

Table 7.--Water budget for Walker Lake Valley

Budget element	57-year average (acre-feet per year)
Inflow:	
Walker River discharge at Wabuska (table 2)	140,000
Local runoff into Walker Lake (p. 9)	3,000
Ground-water recharge (table 4)	6,500
Subsurface inflow (p. 17)	1,300
Precipitation on Walker Lake (p. 7)	18,000
Precipitation on Weber Reservoir (p. 7)	400
Total (rounded) (1)	169,000
Outflow:	
Evaporation from Walker Lake (p. 14)	220,000
Evaporation from Weber Reservoir (p. 14)	4,000
Evapotranspiration in areas of phreatophytes (table 5)	21,000
Consumptive use of water by irrigated crops (p. 13)	10,000
Municipal and other uses (p. 13)	a 1,000
Pumpage (p. 18)	a 400
Total (rounded) (2)	256,000
Difference: (3) = (1) - (2)	-87,000
Net decrease in storage:	
Walker Lake (p. 14)	-100,000
Ground water (p. 24)	-3,000
	-103,000
Imbalance between methods: (5) = (3) - (4)	16,000

a. Possibly a total of 500 acre-feet per year or more percolates ground water from lawn watering, sewage effluent, and irrigation water in the Hawthorne area.

PERENNIAL YIELD

The perennial yield of a ground-water reservoir may be defined as the maximum amount of water of usable chemical quality that can be withdrawn economically each year for an indefinite period of time. If the perennial yield is continually exceeded, water levels will decline until the ground-water reservoir is depleted of water of usable quality, or the pumping lifts become uneconomical to maintain. The perennial yield, therefore, cannot exceed the natural recharge to or discharge from an area. Under conditions of actual development, however, the yield may be limited to the amount of natural discharge that can be economically salvaged for beneficial use.

Whisky Flat-Hawthorne Subarea

In the Whisky Flat-Hawthorne subarea the estimated average annual recharge and discharge are 5,400 and 4,600 acre-feet, respectively (tables 4 and 5). With proper well location most of the natural supply probably could be salvaged. However, any substantial drawdown of water levels near Walker Lake would induce inflow of highly mineralized water from the lake. Thus, with proper well location the preliminary estimate of the perennial yield is considered to be the average of the estimated recharge and discharge, or probably not in excess of 5,000 acre-feet.

Lake Subarea

In the Lake subarea the estimated average annual recharge and discharge are 600 and 800 acre-feet, respectively (tables 4 and 5). Because the discharge area occurs in a narrow strip along the east side of Walker Lake, any substantial pumping would induce inflow of highly mineralized water from the lake. Nevertheless, probably with proper well location the preliminary estimate of the perennial yield is considered to be the average of the estimated recharge and discharge, or not in excess of 700 acre-feet.

Schurz Subarea

The perennial yield of the ground-water reservoir in the Schurz subarea is largely indeterminate at this time because of the existing hydraulic relation between the Walker River and the ground-water system. Any substantial drawdown of water levels caused by pumping near the river would induce recharge from the river as long as any flow existed. Even if the 17,000 acre-feet of natural discharge (table 5) could be salvaged, it is a relatively small part of the total water inflow to the Schurz subarea, which on the average was somewhat more than 140,000 acre-feet per year for the period 1908-65 and more than 110,000 acre-feet for the period 1948-65 (from inflow data shown in tables 2 and 4, and p. 7,9, and 16).

Rawhide Flats

With proper well location most of the natural discharge in Rawhide Flats probably could be salvaged. The estimated average annual recharge and discharge are 150 and 800 acre-feet, respectively (tables 4 and 5). These quantities are not equal, because of the likelihood of subsurface inflow from an adjacent area--probably the Fallon area to the north. Nevertheless, the preliminary estimate of the perennial yield is taken as the average of the two, or roughly 500 acre-feet.

DEVELOPMENT

The development of surface water in the Schurz subarea prior to the construction of Weber Reservoir in 1935, according to the Nevada Indian Agency, consisted of irrigation of about 2,100 acres of alfalfa and pasture with Walker River water. However, since the construction of Weber Reservoir a more consistent and dependable supply of water has been available for irrigation, especially in late summer. According to the Nevada Indian Agency, present development consists of the irrigation of 6,280 acres of mainly alfalfa and pasture.

An estimated 2,000 acre-feet of runoff from the Wassuk Range is diverted by the town of Hawthorne, the Hawthorne Naval Ammunition Depot, and local ranchers for municipal, domestic, and agricultural uses. The only significant ground-water development is in the Whisky Flat-Hawthorne subarea. The town of Hawthorne and the Naval Ammunition Depot obtain part of their water supplies from 12 wells near Hawthorne. Some ground water in this area is also used for irrigation. In 1965 it was reported by the Sweetwater Cattle Company in Whisky Flat that 100 acres were being irrigated with approximately 300 acre-feet of water.

The ground-water levels along the south and east shores of Walker Lake have been declining about 1 foot per year since 1908, because of the lowering of lake stage. Therefore, any new wells drilled in this area should penetrate a sufficient thickness of saturated material to allow for about a 1-foot per year drop in water level for the expected life of the wells.

CHEMICAL QUALITY

Water samples were analyzed as part of the present study to make a generalized appraisal of the suitability of the water for agricultural and domestic uses and to help define potential water-quality problems. Samples were collected from wells, springs, and from three locations on the Walker River. The analyses are listed in table 8.

Suitability for Agricultural Use

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

Sampling sites were chosen in the Walker Lake area to achieve the widest possible areal coverage. Most of the wells and springs sampled yield water with a medium to high salinity hazard and a low to medium alkali hazard (fig. 4). The boron content of two of the seven samples analyzed exceeds 2 ppm (parts per million). Water from wells 12/31-14a1, 13/28-27c1, and 13/29-7a1, and spring 13/29-25b1 in the Schurz subarea has a very high salinity and alkali hazard. Accordingly, this water at best is marginal and probably is unsuitable for irrigation.

The Walker River, which supplies virtually all the water used for irrigation in the project area, was sampled in April 1966 at three locations below Weber Reservoir. The salinity hazard was low (fig. 4, points a, b, and c). Based on these three samples, the water is suitable for irrigation.

Table 8.--Chemical analyses, in parts per million, of water from the Walker River, wells, and springs in the Walker Lake area

[Analyses by the U.S. Geological Survey]

Location (Stream, well no., or spring no.)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	RSC	SAR	Specific conductance (micromhos at 25°C)	pH
Walker River below Weber Reservoir																						
Site A[1]	4-13-66	--	--	--	49	6.7	59		238	0	69	25	--	--	--	--	150	0	0.41	2.1	518	8.1
Site B[1]	4-13-66	--	--	--	42	12	62		215	0	70	28	--	--	--	--	154	0	.44	2.2	531	8.2
Site C[1]	4-13-66	--	--	--	45	15	79		230	0	107	33	--	--	--	--	174	0	.29	2.6	644	7.9
Wells and springs																						
5/31-19a1	12- 8-52	110	37	--	6.0	.9	116		47	9	109	64	4.8	0.1	--	a 370	19	0	.71	12	575	--
6/31-33b2[1]	2-18-66	51	--	--	33	13	44		90	0	93	38	--	--	--	--	128	54	.00	1.7	450	8.1
7/30-2c1	12-11-52	--	30	0.12	111	26	101	5.0	112	0	376	90	.2	.3	1.1	796	384	292	.00	2.2	1,090	7.7
8/30-18a1	12-11-52	--	32	.04	51	3.8	176	5.5	52	0	383	60	1.6	.2	.84	742	149	105	.00	6.3	1,110	8.0
8/30-26d1	12-11-52	--	59	.07	88	11	214	3.8	134	0	455	98	1.5	.1	2.1	1,000	264	154	.00	5.7	1,430	7.7
Do.[1]	2-15-66	75	--	--	78	14	205		129	0	436	98	--	--	--	--	252	146	.00	5.6	1,380	8.0
8/30-27d1	5- 1-57	80	25	.01	82	14	148	6.4	92	0	403	79	.7	.2	--	810	262	195	.00	4.0	1,180	7.4
8/31-32b1	12-11-52	--	54	.05	32	6.1	245	10	118	0	374	102	6.8	.2	2.3	891	105	8	.00	10	1,320	8.0
Do.[1]	2-15-66	100	--	--	33	10	224		100	0	372	101	--	--	--	--	125	43	.00	8.7	1,340	7.9
11/29-6d1[1]	3- 8-66	--	--	--	3.5	12	175		265	23	92	60	--	--	--	--	56	0	3.99	10	905	8.3
12/29-8a1[1]	3- 8-66	53	--	--	45	27	112		372	0	104	37	--	--	--	--	222	0	1.66	3.3	905	8.2
12/31-14a1[1]	2-18-66	64	--	--	2.4	4.4	305		484	28	129	78	--	--	--	--	24	0	8.38	27	1,300	8.7
13/28-15d1[1]	3-29-66	--	--	--	90	32	35		306	0	126	42	--	--	--	--	356	105	.00	.9	778	7.5
13/28-26b1[1]	3-29-66	--	--	--	69	27	69		294	0	127	43	--	--	--	--	283	42	.00	1.8	809	7.4
13/28-27c1[1]	3- 8-66	--	--	--	70	16	536		503	0	836	241	--	--	--	--	240	0	3.44	18	3,380	8.0
13/28-35a1	8- 8-50	62	49	.02	18	3.2	79		130	0	84	22	2.0	.4	.40	a 322	58	0	.97	4.5	469	7.6
13/28-36b1	8- 8-50	59	58	.02	9.2	2.3	35		94	0	20	5.8	.5	.2	.20	a 177	32	0	.90	2.7	203	7.5
13/28-36b2	8- 8-50	62	42	.02	74	20	102		308	0	166	44	.4	.7	.40	a 601	266	14	.00	2.7	913	7.5
13/29-7a1[1]	3- 8-66	--	--	--	324	46	1,820		128	0	2,700	1,440	--	--	--	--	998	893	.00	25	9,530	7.8
13/29-23b1[1]	2-18-66	--	--	--	1.8	1.6	654		528	147	343	293	--	--	--	--	11	0	13.3	86	2,750	9.5
14/31-21b1[1]	2-18-66	64	--	--	9.0	8.1	73		129	0	52	39	--	--	--	--	56	0	.98	4.2	432	8.1
15/26-10b1[1]	2-16-66	63	--	--	6.2	5.7	161		219	13	127	40	--	--	--	--	39	0	3.24	11	740	8.6

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

a. Calculated from sum of determined constituents.

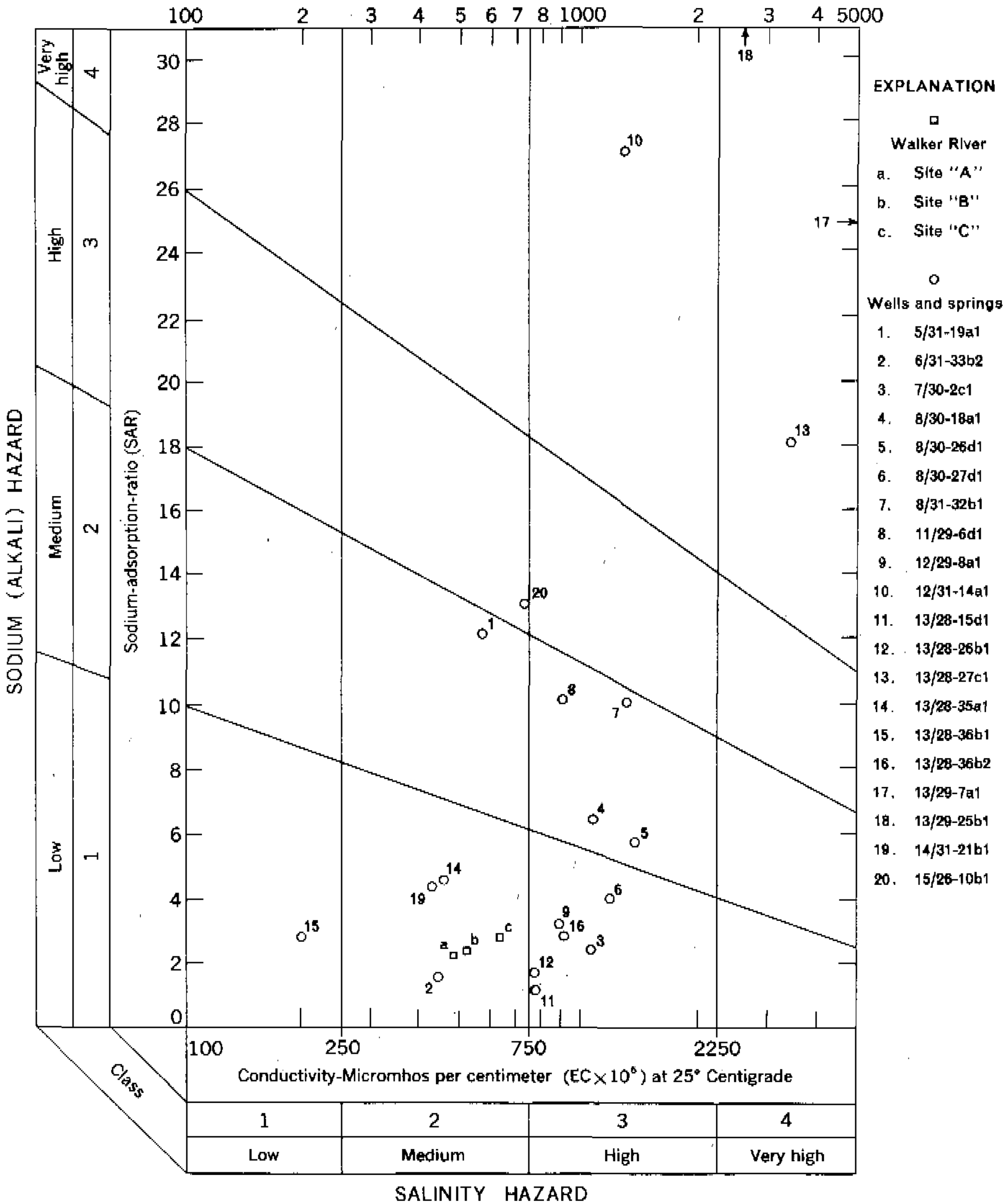

Figure 4.—Classification of irrigation water in the Walker Lake area, based on conductivity and sodium-adsorption ratio. (After U.S. Department of Agriculture, 1954)

Suitability for Domestic Uses

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

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

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

The city of Hawthorne and the Naval Ammunition Depot obtain their municipal water supplies from 12 wells near Hawthorne. Wells 7/30-2cl, 8/30-18al, 8/30-26dl, 8/30-27dl, and 8/31-32bl were sampled and all contained sulfate in amounts significantly larger than those recommended (table 8). Also, water from well 8/31-32bl contained 6.8 ppm fluoride. Stock well 5/31-19al and domestic well 13/28-35al contain 2 ppm or more of fluoride. Excessive fluoride in drinking water may be harmful to teeth, especially those of children, and excessive sulfate may have a laxative effect. Ground water in parts of the Schurz subarea also is unsuitable for domestic use because of the high sulfate, chloride, and dissolved-solids content. For example, water from well 13/29-7al contains 2,700 ppm sulfate, 1,440 ppm chloride, and an estimated dissolved-solids content greater than 6,000 ppm.

Variations in Water Quality of the Walker River

Chemical analyses of water at three locations on the Walker River below Weber Reservoir, designated A, B, and C on plate 1 and a, b, and c on figure 4, show that the water becomes more highly mineralized as it moves downstream. The specific conductance increased from 518 micromhos per centimeter at station A to 644 micromhos per centimeter at station C (table 8). Sodium and sulfate account for most of the increase. The small increase in specific conductance is expected because the samples were collected in April before the start of the irrigation season. However, during the irrigation season the specific conductance of the water as it moves downstream probably increases due to the return flow from irrigation.

Water Quality and its Relation to the Ground-Water System

Quality of ground water in the project area varies from place to place. However, in general, the dissolved-solids content is low in recharge areas in the mountains and increases as it moves toward areas of discharge in the lower parts of the valley. For example, in the Whisky Flat-Hawthorne subarea water from well 6/31-33b2 has a specific-conductance value of 450 micromhos per centimeter. The source of much of this water probably is precipitation on the Excelsior Mountains and Anchorite Hills. As the ground water moves northward, it dissolves additional mineral matter, and the specific conductance of water from wells 8/30-26d1 and 8/31-32b1 increased to 1,430 and 1,340 micromhos per centimeter, respectively. Although some chemical constituents in the water in this area are derived from ground-water underflow from the south, the large increase in specific conductance suggests that at least some chemical constituents are derived from lacustrine deposits which the wells penetrate.

Most of the ground water in the Whisky Flat-Hawthorne subarea is a sodium sulfate type. However, water from wells 6/31-33b2 and 7/30-2c1 is a mixed calcium-sodium bicarbonate type. In the Schurz subarea most of the ground water is a sodium bicarbonate type. However, water from well 13/28-15d1 is a calcium bicarbonate type, and water from well 13/28-26b1 is a mixed calcium-sodium bicarbonate type. Water from well 13/29-7a1 is a sodium sulfate type but also has a high concentration of chloride.

NUMBERING SYSTEM FOR WELLS AND SPRINGS

The numbering system for wells and springs in this report is based on the rectangular subdivision of the public lands, referenced to the Mount Diablo base line and meridian. It consists of three units: the first is the township north of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; the third unit, separated from the second by a dash, designates the section number. The section number is followed by a letter that indicates the quarter section; the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. Following the letter, a number indicates the order in which the well or spring was recorded within the 160-acre tract. For example, well 7/29-10a1 is the first well recorded in the NE¼ sec. 10, T. 7 N., R. 29 E., Mount Diablo base line and meridian.

Because of the limitation of space, wells and springs are identified on plate 1 only by the section number, quarter section letter, and number. Township and range numbers are shown along the margins of the area on plate 1.

Table 9.--Records of selected wells in the Walker Lake area

Use: D, domestic; I, Irrigation; S, stock; PS, public supply;
RR, railroad; U, unused
Yield: In gallons per minute (gpm)
Water-level measurement: Depth, in feet below land-surface datum:
M, measured; R, reported
Log number: Number is log number in the files of the State Engineer

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm)/ drawdown (feet)	Water-level measurement Date	Depth		Log number
5/31-1c1	--	--	--	8	S	--	2-15-66	86.85	M	--
3c1	Sweetwater Cattle Co.	1958	395	12	I,D	--	9-12-58	63	R	4828
19a1	Bureau of Land Management	1941	345	6	S	--	2-15-66	304.65	M	--
6/31-33b1	Sweetwater Cattle Co.	1956	162	10	U	--	2-15-66	36.43	M	3348
33b2	Sweetwater Cattle Co.	1953	132	10	U	--	2-15-66	45.92	M	3347
33c1	Sweetwater Cattle Co.	1960	285	12	I	--	2-15-66	44.19	M	5828
7/29-10a1	City of Hawthorne	1965	250	12	PS	--	9-29-65	33	R	8704
7/30-2c1	Naval Ammunition Depot Well no. 4	1943	610	16	PS	--	11-21-52	478	R	--
8/30-3d1	Naval Ammunition Depot Well no. 7	1954	514	18	PS	220/55	2-17-66	51.79	M	3561
8d1	Naval Ammunition Depot Well no. 8	1955	500	16	PS	400/6	11-19-56	70	R	3562
18a1	Naval Ammunition Depost Well no. 1	1942	345	18	PS	1050/10	9-27-65	102.45	M	2193
8/30-18d1	Naval Ammunition Depot Well no. 5	1942	312	18	PS	850/16	2-16-66	207.61	M	2189
21c1	Naval Ammunition Depot Well no. 9	--	423	12-16	PS	400/155	--	194	R	--
21d1	Naval Ammunition Depot Well no. 6	1944	394	18	PS	540/11	9-27-65	214.12	M	3560
26d1	Naval Ammunition Depot Well no. 2	1942	423	18	PS	250/5	2-16-66	252.44	M	2192
27c1	City of Hawthorne	1942	482	16	PS	--	--	350	R	1712

Table 9.--Continued.

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) : drawdown (feet)	Water-level measurement Date	Water-level measurement Depth		Log number
27d1	City of Hawthorne	--	[illegible]602	16	PS	--	--	350	R	--
8/31-32b1	Naval Ammunition Depot Well no. 3	1942	452	18	PS	250/35	2-16-66	245.50	M	2191
12/28-2a1	Curtice Cline	1963	252	10	D	--	4-10-63	105	R	7113
4d1	James Willie	1964	74	6	D	--	7- 1-64	17	R	8012
12/29-8a1	Louis Williams	--	45	6	D	--	--	40	R	--
14b1	Indian Reservation	--	66	8	S	--	--	42	R	--
12/31-14a1	Indian Reservation	--	502	8	S	--	--	455	R	--
13/28-22c1	Indian Reservation	1954	295	8	D	--	8-18-54	41	R	--
27c1	Clarence Williams	1962	140	6	D,S	--	3-8-66	10.64	M	--
13/28-35a1	Indian Reservation	1932	25	84	D	--	8-8-50	18.35	M	--
35a2	Indian Reservation	--	25	78	D	--	8-8-50	20.10	M	--
36b1	Southern Pacific Railroad	1945	190	12	RR	--	8-8-50	16	R	1433
36b2	Southern Pacific Railroad	--	16	84	RR	--	8-8-50	11.34	M	--
13/29-7a1	Indian Reservation	--	212	8	S	--	--	100	R	--
25b1	Indian Reservation	1948	102	6	S	--	2-17-66	F. 2	gpm	--
14/30-4c1	Indian Reservation	--	162	6	S	--	--	145	R	--
14/31-21b1	--	1934	615	6	S	--	--	542	R	--
15/26-10b1	Bureau of Land Management	--	--	6	S	--	2-16-66	67.28	M	--
15/27-21a1	Bureau of Land Management	--	--	6	S	--	2-16-66	158.94	M	--

Table 10.--Drillers' logs of selected wells

Material	Thickness (feet)	Depth (feet)
5/31-3c1		
Clay, sandy	10	10
Clay, brown	2	12
Gravel, loose	3	15
Rock	5	20
Gravel and clay	30	50
Rock	1	51
Gravel, loose and clay	9	60
Clay	10	70
Gravel, loose	30	100
Clay	10	110
Clay, sandy	12	122
Sand, loose	14	136
Rock	1	137
Gravel, loose	33	170
Gravel and clay	10	180
Sand, loose	30	210
Sand	10	220
Sand, loose	17	237
Rock	3	240
Sand, loose	30	270
Clay, sandy	20	290
Sand, loose	105	395
6/31-33b1		
Boulders	5	5
Clay and sand	53	58
Rock, volcanic	1	59
Clay and sand, coarse	51	110
Rock	2	112
Clay and sand	21	133
Clay, bentonite	6	139
Gravel, coarse	2	141
Clay	3	144
Sand and stone layers	3	147
Gravel, coarse	3	150
Sand and stone layers	1	151
Clay and gravel	8	159
Sand and stone layers	3	162
6/31-33b2		
Surface wash	60	60
Sand	37	97
Clay, gray	2	99

Material	Thickness (feet)	Depth (feet)
6/31-33b2--continued		
Sand, coarse	9	108
Clay, gray	9	117
Sand, fine	6	123
Clay, gray	2	125
Sand, coarse	7	132
6/31-33cl		
Sand and clay	135	135
Sand	25	160
Clay, sandy	20	180
Boulders, clay, and sand	102	282
Sand and boulders	3	285
7/29-10al		
Silt, gravel, and boulders	20	20
Clay, yellow, and gravel	33	53
Gravel, loose	17	70
Clay, brown, hard	6	76
Gravel	19	95
Granite	35	130
Gravel	2	132
Granite	38	170
Boulders, large	20	190
Rock	60	250
8/30-3dl		
Soil	8	8
Sand and gravel	7	15
Sand	15	30
Clay, sandy	14	44
Sand and gravel	6	50
Clay, sand, and gravel	20	70
Clay, blue	22	92
Sand, blue	1	93
Clay, brown, sandy	32	125
Clay, blue	67	192
Clay, brown	22	214
Sand and gravel	2	216
Clay, brown, sandy	6	222
Sand and gravel	4	226
Clay, brown, sandy	12	238
Clay, blue	58	296
Sand and gravel	10	306
Clay, blue	2	308
Sand and gravel	8	316

Material	Thickness (feet)	Depth (feet)
8/30-3d1--continued		
Clay, blue	126	442
Sand and gravel	10	452
Clay, blue, and sand, fine	8	460
Clay, blue	58	518
Sand, gravel, and clay, blue	10	528
Clay, blue	14	542
8/30-8d1		
Topsoil	5	5
Clay, sand, and gravel	27	32
Gravel and clay, brown	11	43
Clay and gravel	27	70
Clay and sand, water	8	78
Clay, green	24	102
Clay, red	30	132
Clay, sand, and gravel	6	138
Clay and sand	16	154
Clay, sand, and gravel	14	168
Clay and sand	10	178
Clay, sand, and gravel	34	212
Sand and gravel, water	2	214
Clay, green	32	246
Clay, yellow	102	348
Clay, blue, and sandstone	152	500
8/30-18a1		
Topsoil	18	18
Sand and gravel	8	26
Gravel and boulders	62	88
Clay, yellow and gravel	8	96
Sand and gravel	65	161
Gravel	21	182
Clay, yellow, and gravel	8	190
Sand and gravel	12	202
Clay, yellow, and gravel	44	246
Sand and gravel	1	247
Clay, gravel, and boulders	6	253
Gravel	21	274
Sand, fine	5	279
Clay, gravel, and boulders	49	328
Gravel, cemented	8	336
Clay, gravel, and boulders	9	345
8/30-18d1		
Sand, gravel, and boulders	190	190
Boulders and sand, cemented	43	233

Material	Thickness (feet)	Depth (feet)
8/30-18d1--continued		
Gravel	7	240
Boulders	20	260
Gravel, water	38	298
Sand, cemented	9	307
Boulders	5	312
8/30-21d1		
Topsoil	22	22
Sand, coarse, and gravel	23	45
Sand, gravel, and boulders	4	49
Conglomerate	9	58
Sand, conglomerate, and gravel	17	75
Sand, gravel, and boulders	8	83
Sand, hard, silt	6	89
Sand, coarse, and boulders	9	98
Sand, hard, silt	8	106
Gravel, coarse	6	112
Clay and gravel	30	142
Sand and gravel, water	40	182
Gravel and sand, coarse	40	222
Clay, brown, and sand	51	273
Sand and gravel	82	355
Clay, sand, and gravel	39	394
8/30-26d1		
Sand	35	35
Clay, yellow	4	39
Sand, packed	14	53
Sand and gravel, cemented	66	119
Sand and gravel	28	147
Sand, cemented	50	197
Clay, yellow	5	202
Sand and gravel, dry	40	242
Clay, yellow	14	256
Sand, packed	20	276
Sand and gravel	27	303
Sand, fine	27	330
Clay, yellow, sandy	32	362
Sand, packed	38	400
Gravel	8	408
Sand, fine	4	412
Clay, yellow	11	423

Material	Thickness (feet)	Depth (feet)
8/30-27c1		
Sand and gravel	28	28
Gravel and boulders	119	147
Clay, sandy	5	152
Gravel and rocks	42	194
Sand	9	203
Rocks, large	27	230
Gravel and clay	18	248
Boulders	2	250
Gravel and rocks	9	259
Gravel and clay	10	269
Rocks and clay	8	277
Clay, gravelly	55	332
Sand and gravel, water	46	378
Gravel and clay	27	405
Gravel and rocks	9	414
Gravel and clay	23	437
Gravel, water	22	459
Clay, yellow	23	482
8/31-32b1		
Topsoil	10	10
Sand	17	27
Gravel	57	84
Clay, yellow	42	126
Clay, yellow, sandy	21	147
Sand, packed	109	256
Clay, yellow, sandy	8	264
Sand and gravel, fine	4	268
Clay, yellow, sandy	50	318
Clay, gravel, and boulders	37	355
Gravel	11	366
Clay, yellow	5	371
Gravel, cemented	33	404
Clay and gravel	8	412
Gravel, cemented	40	452
12/28-2a1		
Topsoil	5	5
Gravel, cemented	100	105
Sand, water	7	112
Clay and gravel	118	230
Sand and gravel	22	252

Material	Thickness (feet)	Depth (feet)
12/28-4d1		
Topsoil	2	2
Sand	2	4
Clay and gravel, cemented	4	8
Sand	4	12
Clay and gravel, cemented	16	28
Gravel, loose	4	32
Clay, gray	16	48
Sand and gravel	26	74
13/28-36b1		
Sand	5	5
Gravel	5	10
Sand, fine	4	14
Quicksand	6	20
Sand	45	65
Sand and gravel	5	70
Clay and sand	10	80
Clay, sandy	25	105
Sand and clay	1	106
Clay, yellow	6	112
Clay, blue, and sand	8	120
Sand, tight	4	124
Clay, blue, and sand	1	125
Sand, coarse	15	140
Sand, coarse, tight	15	155
Clay, blue	6	161
Sand, loose	4	165
Sand, coarse	3	168
Sand, hard	8	176
Clay, hard, and sand	14	190

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Report No.	Valley
1	Newark (out of print)
2	Pine (out of print)
3	Long (out of print)
4	Pine Forest
5	Imlay area (out of print)
6	Diamond (out of print)
7	Desert
8	Independence
9	Gabbs
10	Sarcobatus and Oasis
11	Hualapai Flat
12	Ralston and Stonecabin
13	Cave
14	Amargosa
15	Long Surprise Massacre Lake Coleman Mosquito Guano Boulder
16	Dry Lake and Delamar
17	Duck Lake
18	Garden and Coal
19	Middle Reese and Antelope
20	Black Rock Desert Granite Basin High Rock Lake Summit Lake
21	Pahranagat and Pahroc
22	Pueblo Continental Lake Virgin Gridley Lake
23	Dixie Stingaree Fairview Pleasant Eastgate Jersey Cowkick
24	Lake
25	Coyote Spring Kane Spring Muddy River Springs
26	Edwards Creek
27	Lower Meadow Patterson Spring (near Panaca) Panaca Eagle Clover Dry
28	Smith Creek and Ione
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34	Snake Hamlin Antelope Pleasant Ferguson Desert (out of print)
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36	Eldorado - Piute Valley (Nevada and California)
37	Grass and Carico Lake (Lander and Eureka Co.)
38	Hot Creek Little Smoky Little Fish Lake
39	Eagle Valley (Ormsby County)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

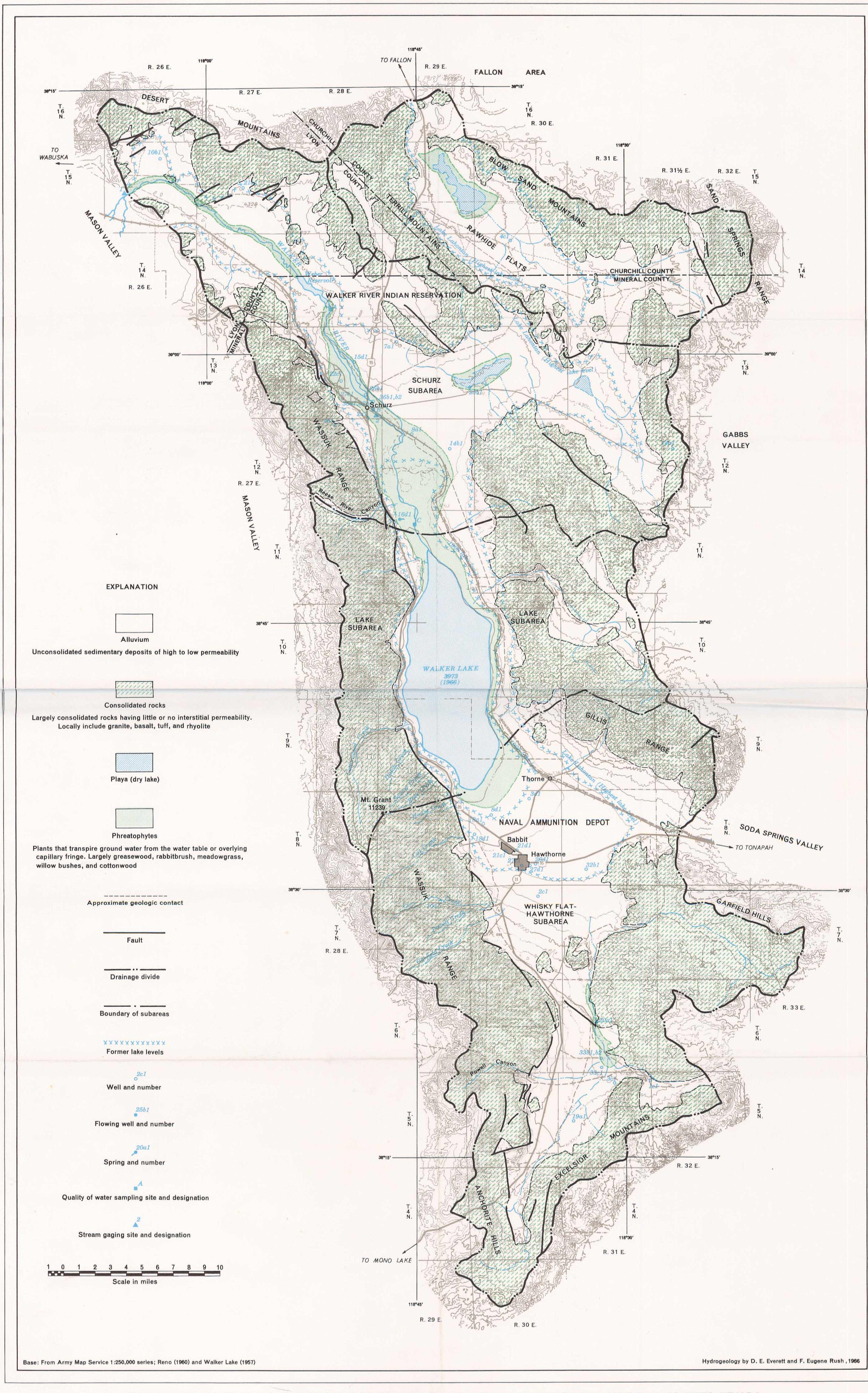

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE WALKER LAKE AREA, MINERAL, LYON AND CHURCHILL COUNTIES, NEVADA