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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES OF THE WALKER RIVER INDIAN RESERVATION, WEST-CENTRAL NEVADA

By Donald H. Schaefer

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

Except for water-quality units of measure, only the "inch-pound" system is used in this report. Abbreviations and conversion factors from inch-pound to International (metric) units are listed below.

Multiply	By	To obtain
Acres	0.4047	Hectares (ha)
Acre-feet (acre-ft)	0.001233	Cubic hectameters (hm^3)
Cubic feet per second (ft^3/s)	28.32	Cubic meters per second (m^3/s)
Feet (ft)	0.3048	Meters (m)
Feet per second (ft/s)	0.3048	Meters per second (m/s)
Feet per day (ft/d)	0.3048	Meters per day (m/d)
Gallons per minute (gal/min)	0.06308	Liters per second (L/s)
Gallons per minute per foot [(gal/min)/ft]	0.2070	Liters per second per meter [(L/s)/m]
Inches (in.)	25.40	Millimeters (mm)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.590	Square kilometers (km^2)

Water-quality units of measure used in this report are as follows:

For concentration, milligrams per liter (mg/L) and micrograms per liter (ug/L), which are equivalent to parts per million and parts per billion for dissolved-solids concentrations less than about 7,000 mg/L.

For temperature, degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by using the formula °F=[(1.8)(°C)]+32.

For specific conductance, micromhos per centimeter at 25°C (micromhos).

NATIONAL GEODETIC VERTICAL DATUM OF 1929

In this report, the term "National Geodetic Vertical Datum of 1929" (or its abbreviation, "NGVD of 1929") replaces the formerly used term "mean sea level." The datum is derived from a general adjustment of the first-order leveling networks of both the United States and Canada.

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SUMMARY

Increasing interest in expanding the livestock and agricultural operations on the Walker River Indian Reservation has prompted the Walker River Paiute Tribe to have the water resources of the reservation appraised and proposed sites for new wells evaluated.

Flow of the Walker River into the reservation averages about 114,000 acre-feet a year. Of this amount, about 42,000 acre-feet is used on the reservation, recharging the ground-water system and supplying irrigation water for alfalfa and pasture crops. The quality of the river water is well suited for these purposes, and the possibility of expanding surface-water use exists.

A mathematical model of the ground-water system was constructed to test various assumptions about recharge and discharge rates. The model generated water-level contours that agreed reasonably well with measured water levels; median deviation was 12 feet. With additional data the model could be used in the future to test the feasibility of evapotranspiration salvage at the seven proposed sites for new stock and irrigation wells.

The primary consumption of ground water on the reservation occurs with phreatophytes and playa surfaces. They allow ground water to be lost to evaporation. About 19,000 acre-feet per year is lost through this mechanism. Domestic and livestock use account for only 250 acre-feet per year. Total recharge to the ground-water system amounts to about 30,000 acre-feet per year, and the possibility of more extensive use of ground water on the reservation exists. Among sampled domestic well waters, excessive hardness and dissolved-solids concentrations are the principal water-quality problems. The suitability of ground water for irrigation in some currently unirrigated areas may be diminished by high or very high sodium hazards. With a few exceptions, sampled ground water is suitable for livestock use.

INTRODUCTION

This study was conducted in cooperation with the Economic Development Administration, U.S. Department of Commerce, to appraise the ground- and surface-water resources of the Walker River Indian Reservation. The suitability of drilling new stock and irrigation wells on sites selected by the Walker River Paiute Tribe was determined.

Location and Development

The Walker River Indian Reservation encompasses an area of about 500 mi^2 along the Walker River north of Hawthorne and Walker Lake and east of Yerington in Mineral County (fig. 1).

The town of Schurz is the major population center on the reservation and has a population of about 680 people. The major economic endeavors are raising cattle and cultivating of alfalfa. Most of the land on the reservation supports the grazing of approximately 2,500 head of cattle. Water for the cattle comes from 12 stock wells scattered throughout the reservation. Alfalfa is cultivated on about 2,800 acres of land along the Walker River north and south of Schurz (fig. 1). About 2,000 acres of irrigated pastureland lies to the north of Walker Lake and is used for grazing cattle during the summer.

Water for irrigation is obtained from two canals that divert water from the river 2 mi downstream from Weber Dam (fig. 1). These diversion canals, which are lined with concrete for approximately half their length, branch out into many unlined canals and laterals throughout the irrigated area. The fields are flood irrigated.

Purpose and Approach

The principal objectives of this study were: (1) To develop sufficient understanding of the hydrology of the Walker River Indian Reservation to make an evaluation of the nature and magnitude of the supply potentially available from ground-water and surface-water sources; (2) to describe and document conditions in the hydrologic system as they existed in 1977-78; and (3) to evaluate the feasibility of constructing wells at selected sites for stock water or irrigation.

The study involved: (1) Measuring and sampling wells and springs on the reservation to determine ground-water flow patterns and quality; (2) determining depth to bedrock and detailing subsurface geology through a series of seismic reflection measurements; (3) measuring discharge at a number of sites along the Walker River and diversion canals to document seepage losses; (4) mapping the distribution of phreatophytes, agricultural areas, and free-water surfaces to determine evapotranspiration losses; (5) constructing a simple mathematical model of the ground-water system to test various assumptions about ground-water recharge and discharge rates; and (6) evaluating the selected sites for new irrigation and stock wells on the basis of existing data and data gathered during this study.

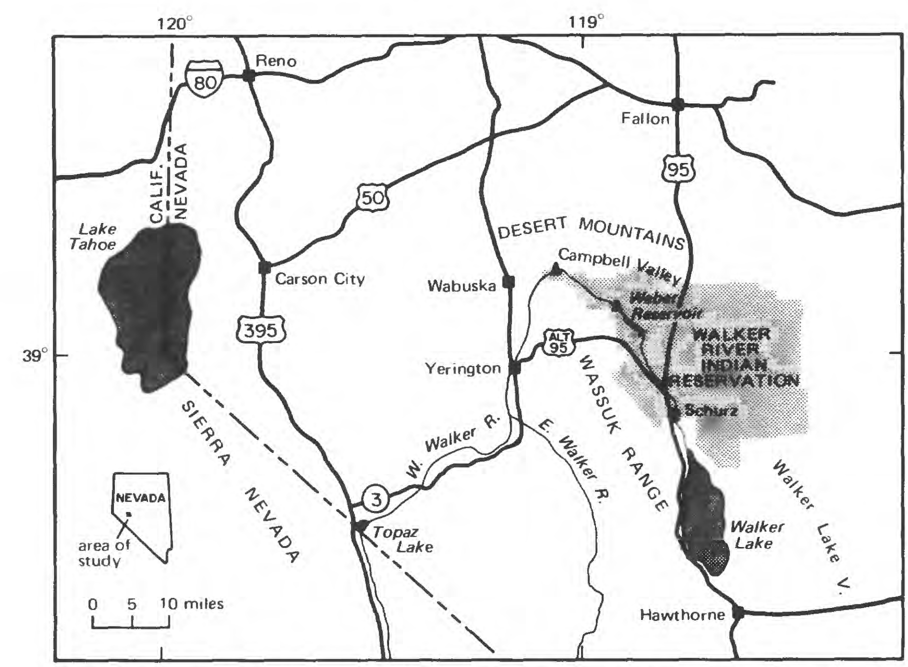

FIGURE 1. - - Location of Walker River Indian Reservation. Triangle indicates stream-gaging station.

Previous Investigations

The hydrology of the reservation was first reported in a reconnaissance study of the Walker Lake area by Everett and Rush (1967). Although that report presented only a reconnaissance-level evaluation of the area's hydrology, the report provided a basis for the present study. Other aspects of the hydrologic system of the reservation were covered in reports on Walker Lake (Rush, 1970) and Weber Reservoir (Katzer and Harmsen, 1973).

Geologic features of the reservation have been discussed by Ross (1961), Moore and Archibald (1969), and Willden and Speed (1974).

Well and Spring Numbering System

The numbering system for wells and springs 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 (for example 13N/29E-7AA) consists of three units: The first is the township north of the base line; the second unit, separated from the first by a slash, 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 can be 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. A number following the letters indicates, relatively, when that well was drilled in the quarter section. If no number appears, age is unknown. For example, well 14N/31E-21B1, is the first well recorded in the NW¼ sec. 21, T. 14 N., R. 31 E., referenced to the Mount Diablo base line and meridian.

Wells or springs with numbers containing only section numbers and no letters indicates a well or spring that could be located only within that section.

Descriptions of wells and springs can be found in the Data Section.

Acknowledgments

The author wishes to thank the many well owners and ranchers that cooperated in this study. Special appreciation is given to Randall Emm and the Walker River Paiute Tribal Council for their assistance in obtaining information on wells on the reservation and background data.

GEOLOGY AND HYDROGRAPHIC AREAS

Geologic Units and Water-Bearing Characteristics

For the purposes of this study, the rather complex geology as mapped by Ross (1961), Moore and Archibald (1969), and Willden and Speed (1974) has been simplified into consolidated rocks, valley-fill deposits, and playa deposits (fig. 2).

The consolidated rocks range in age from Triassic to Quaternary and consist mainly of volcanics (basalt, rhyolite, and andesite), quartz monzonite, and granodiorite. They underlie the alluvial and playa deposits on the reservation and compose the surrounding hills and mountains. The rocks are nearly impermeable except where fractured or weathered and are generally not an important source of ground water. For this study, the consolidated rocks are not considered to be water-bearing.

The valley-fill sedimentary deposits, of Quaternary age, average about 1,000 ft in thickness and consist mainly of alluvial and lacustrine material dominated by sand, silt, and clay. Most of the reservation was once covered by ancient Lake Lahontan (Everett and Rush, 1967). Because the resulting lacustrine deposits and their reworked alluvial counterparts are predominantly fine-grained, much of the valley fill is also distinctly fine-grained. Where saturated, however, the valley fill generally yields water freely to wells: For example, several newly constructed irrigation wells south of Schurz yield as much as 2,500 gal/min.

The playa deposits, of Quaternary age, underlie the several dry lakes on the reservation. The deposits are composed generally of clay with some minor content of sand and silt. Few wells are drilled in these dry lakes, owing to low yields and poor water quality. The log of well 13N/29E-25BA (fig. 2), which was drilled on the edge of the large unnamed playa east of Schurz, indicates that the playa deposits there are about 50 ft thick. A thickening of the deposits toward the center of the playa could be expected, although no data exist to substantiate this.

Numerous faults transect the reservation, but they are not shown in figure 2 because they demonstrate no effect on the movement of ground water. Faulting tends to be associated with uplift and deformation of the mountain blocks.

Seismic Investigations

To obtain a better understanding of the hydrologic system of the Walker River Indian Reservation, a seismic refraction/reflection survey was conducted in most of the valley areas on the reservation (fig. 2). The purpose of the survey was to determine the thickness of the alluvial deposits so that a more accurate determination of the quantity of ground water in storage could be made. The refraction method did not prove successful during this study, due to equipment limitations, but the reflection method gave some depth data.

Seismic reflection is a technique whereby the travel time of seismic waves from an explosive source indicates the depth to a reflecting surface, in this case, bedrock. If the seismic velocity, the velocity at which compressional waves travel through a medium, is known for the material overlying the reflecting surface, the depth to this surface can be calculated. The wave fronts travel downward and outward from the explosion, bounce off the reflecting surface, and travel upwards. Their arrival is detected by a seismograph that measures the travel time. The velocities for compressional waves in the alluvial deposits on the reservation were found to average about 6,250 ft/s. Arrival times were usually less than half a second.

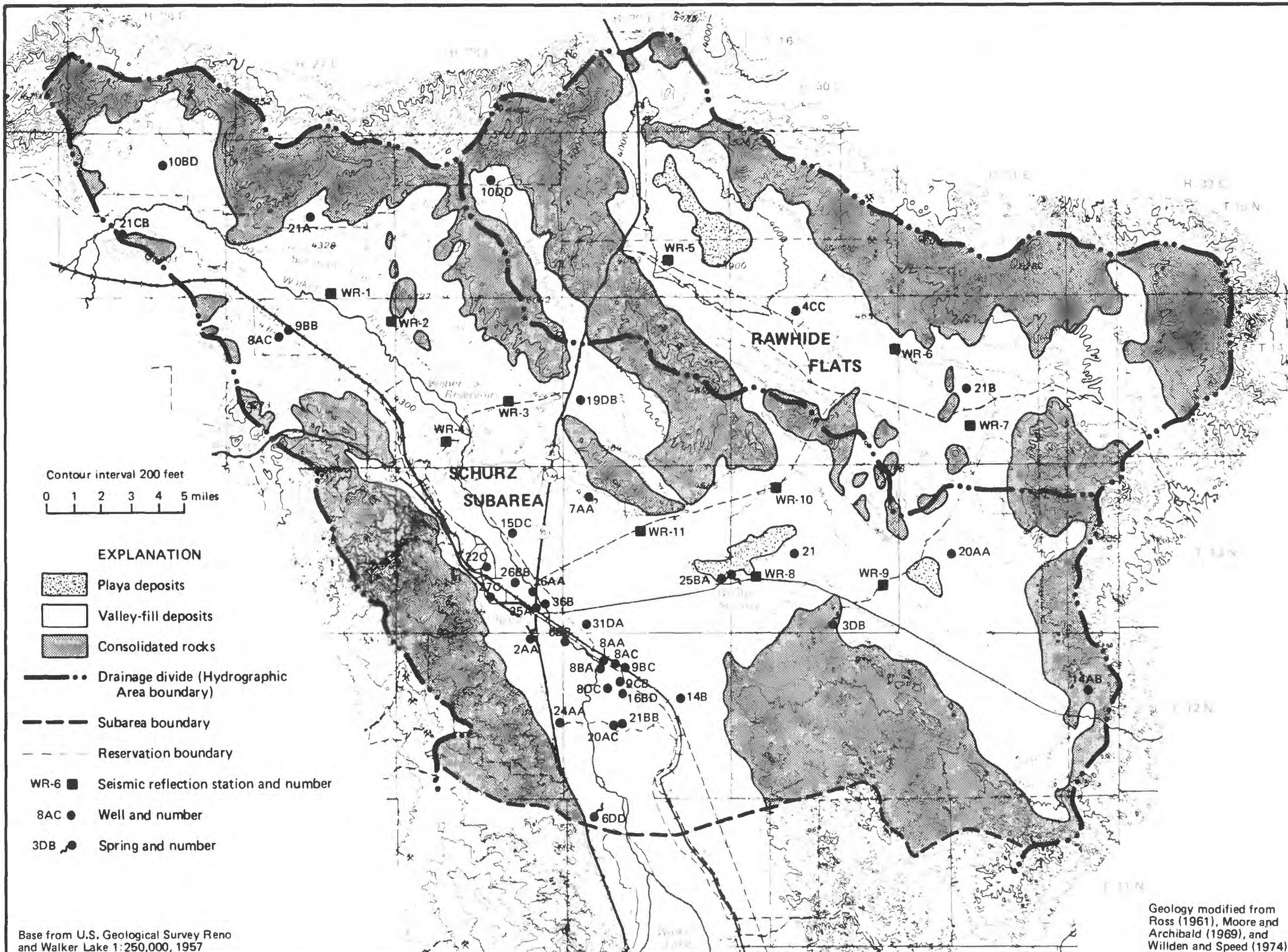

FIGURE 2. - - Geology, wells, and seismic stations.

For this study, 11 seismic reflection stations were located in various areas of the reservation (fig. 2). The seismic reflection data showed that depths to bedrock in various areas of the reservation range from 600 ft to over 1,400 ft. The thickest section of alluvium is found in the Sunshine Flat area (fig. 2). The alluvium gradually thins to the west. The alluvium in the vicinity of Double Springs is fairly thin, 600 ft. In Rawhide Flats the alluvium is again rather thick, being at least 1,300 ft thick in most areas.

Table 1 lists the reflection stations shown in figure 2, with their locations and the calculated depth to bedrock at each station.

TABLE 1.--*Seismic reflection stations*

Station (fig. 2)	Location	Calculated depth to bedrock (feet)	Relative quality of results
1	15N/27E-34	1,150	poor
2	14N/27E-1	1,420	good
3	14N/28E-23	1,300	good
4	14N/28E-32	830	fair
5	15N/28E-27	1,260	fair
6	14N/30E-12	1,300	fair
7	14N/31E-28	1,060	fair
8	13N/30E-17	600	fair
9	13N/30E-25	1,150	good
10	13N/30E-5	900	fair
11	13N/29E-16	1,020	poor

Hydrographic Areas

The reservation is divided hydrographically into two areas, based on the hydrographic boundaries as designated by the Nevada State Engineer (Rush, 1968). The largest of the two, the Schurz subarea (fig. 2), is a subdivision of the Walker Lake Valley hydrographic area. The Schurz subarea covers the bulk of the reservation, about 390 mi^2. The Rawhide Flats hydrographic area in the northeast corner of the reservation covers about 110 mi^2.

SURFACE-WATER RESOURCES

The Walker River, the dominant surface-water feature on the reservation, serves as a source of both irrigation water and ground-water recharge. Figure 3 shows the course of the river through the reservation.

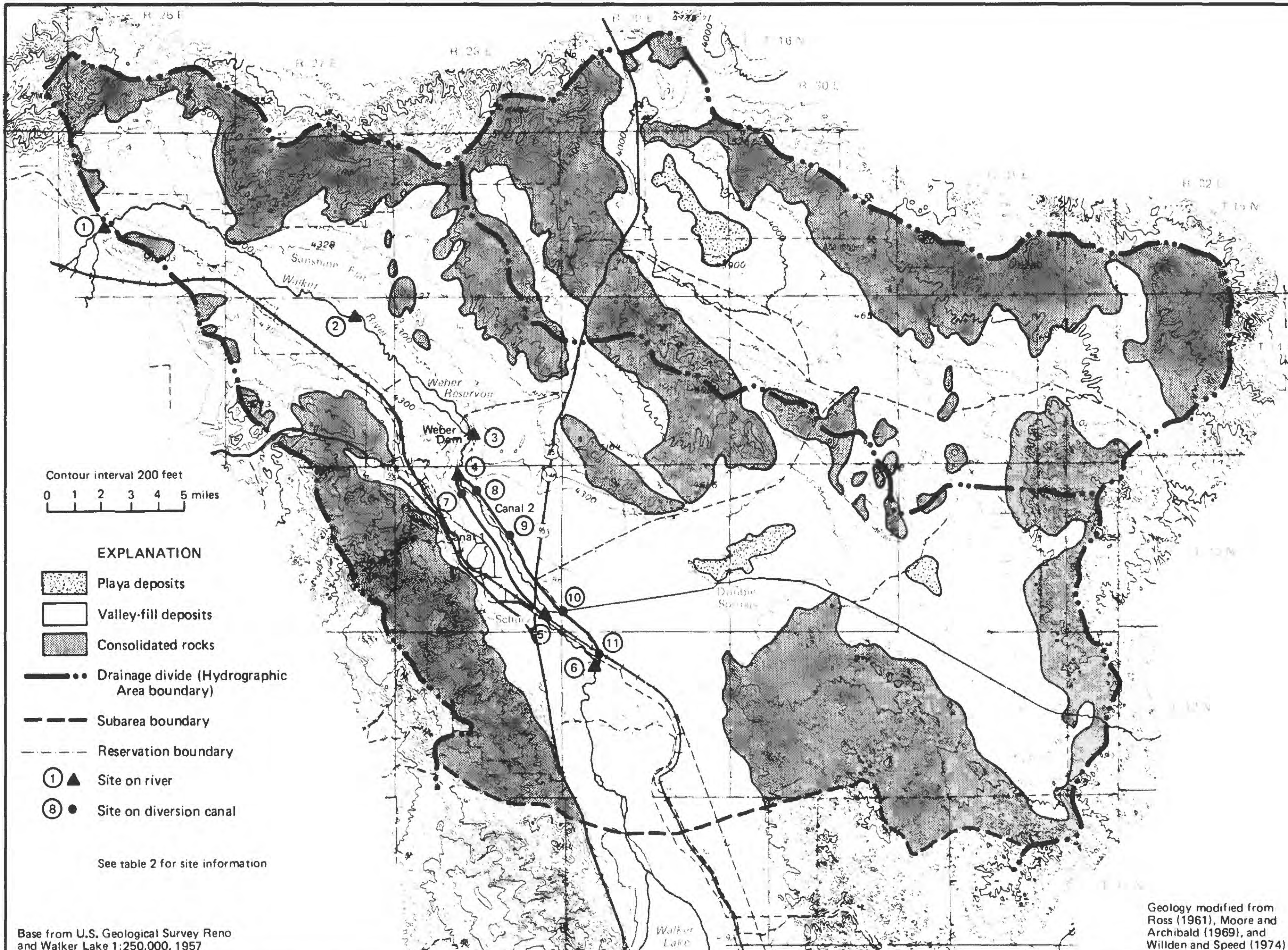

FIGURE 3. - - Surface-water measurement and sampling sites.

One long-term streamflow gaging station (Walker River near Wabuska) is just west of the reservation boundary (fig. 3, site 1). Additional stations have been maintained, at various times, downstream. Table 2 lists the stations, the type of data collected, and their record lengths.

Flow past the Wabuska gage has averaged 113,800 acre-ft/yr for the period of full-year record (table 3). Flow for the period June 1977 through May 1978 was 22,400 acre-ft, well below average due to the recent drought.

Weber Dam, which impounds Weber Reservoir, is about 8 miles upstream from Schurz. The dam was constructed in 1935 by the U.S. Indian Service, now the Bureau of Indian Affairs.

Flow into Weber Reservoir is gaged and amounted to 15,400 acre-ft for the period June 1977 through May 1978. Flow into Walker Lake is not gaged, and only a few measurements are available. Rush (1970) estimated the average annual flow into Walker Lake to be 85,000 acre-ft. With the few measurements available, this figure cannot be verified. However, an average annual flow of 69,600 acre-ft into the lake was estimated from the mathematical model developed for the study. The lower estimated value, if valid, could be the result of increased use of water upstream on the reservation since 1970.

The major uses for Weber Reservoir are the storage of irrigation water and flood control, with minor recreation use. A bathymetric reconnaissance of Weber Reservoir (Katzer and Harmsen, 1973) concluded that the flood control ability of the reservoir is poor because of its low storage capacity. The maximum operating storage capacity of the reservoir is 10,700 acre-ft (Katzer and Harmsen, 1973).

Streamflow Characteristics

The Walker River flows perennially through most of the reservation. The main source of water for the Walker River is the winter snowpack in the Sierra Nevada, but minor amounts of flow are contributed locally by rainstorms. Flow is regulated upstream by Bridgeport and Topaz Reservoirs.

Figure 4 shows the average monthly discharge and the quartiles for flows at the Wabuska gage for the period of record. The major part of the runoff occurs from snowmelt in the spring, with streamflow beginning to increase in late April, reaching a peak in June, and decreasing until August. For the remainder of the year the streamflow is fairly constant. About 50 percent of the annual runoff occurs during the 3-month snowmelt period of May to July.

Irrigation and Diversion

Two canals divert water from the river about 2 mi below Weber Dam (fig. 3). These canals run parallel to the river channel south towards Schurz. Canal No. 1, west of the river, is concrete lined for half its length. Canal No. 2, east of the river, is lined for approximately 40 percent of its length. Numerous laterals and diversions branch off the main canals and distribute water throughout the irrigated area. The average flow into the main canals is about 50 ft^3/s (Jim Long, Bureau of Indian Affairs, oral commun., 1978) during the irrigation season (approximately May to October).

TABLE 2.--*Gaging stations and surface-water sampling sites*

Site no.	Station name and number	Type of station	Period of record	Type of data[1]	Discharge: Cubic feet per second	Discharge: Date
1	Walker River near Wabuska -----	Long term	1902-8, 1920-35, 1939-present	SW, QW	(2,3)	--
2	Walker River above Weber Reservoir ------------------	Long term	1977-present	SW, QW	(3)	--
3	Walker River below Weber Dam ------------------------	MSM[4]	do.	SW, QW	(5)	--
4	Walker River at diversions ----	MSM	do.	SW, QW	[a] 8	5/12/78
					(2,3)	--
5	Walker River at Schurz --------	MSM, long term	1913-33	SW	No flow	11/02/78
					17.9	5/12/78
					.18	6/29/78
6	Walker River below Schurz -----	MSM	--	SW	No flow	11/02/77
					34.2	5/12/78
					6.2	6/29/78
7	Canal No. 1 at diversion ------	MSM	--	SW	No flow	11/02/77
					39.6	5/12/78
					19.9	6/29/78
8	Canal No. 2 at diversion ------	MSM	--	SW	No flow	11/02/77
					35.2	5/12/78
9	Canal No. 2, 3 mi north of Schurz ---------------------	MSM	--	SW	54.6	5/12/78
10	Canal No. 2, near Schurz ------	MSM	--	SW	28.5	5/12/78
11	Canal No. 2, 2-1/2 mi southeast of Schurz ---------	MSM	--	SW	11.7	5/12/78

[1] SW, surface-water discharge; QW, surface-water quality.
[2] Historical data available.
[3] Data for water years 1977 and 1978 published by U.S. Geological Survey (1978, 1979).
[4] MSM, miscellaneous surface-water discharge measurements.
[5] Measured once-monthly.
[a] Estimated.

TABLE 3.--*Annual flow of Walker River near Wabuska*[1]

Water[2] year	Annual flow (acre-feet)	Water year	Annual flow (acre-feet)	Water year	Annual flow (acre-feet)
1903	127,000	1941	179,900	1961	23,780
1904	251,000	1942	Partial record	1962	37,260
1905-20	Partial record	1943	240,100	1963	169,200
1921	76,800	1944	Partial record	1964	51,450
1922	248,000	1945	331,900	1965	123,200
1923	131,000	1946	170,900	1966	107,600
1924	52,600	1947	84,410	1967	237,100
1925	Partial record	1948	31,070	1968	90,710
1926	29,200	1949	36,520	1969	403,200
1927	100,000	1950	30,330	1970	134,900
1928	46,900	1951	158,600	1971	93,720
1929	18,300	1952	379,000	1972	63,970
1930	14,500	1953	121,800	1973	104,400
1931	9,340	1954	43,340	1974	121,600
1932	59,800	1955	34,620	1975	165,200
1933	35,900	1956	277,000	1976	46,030
1934	21,000	1957	88,350	1977	17,970
1935	46,410	1958	227,300		
1936-39	Partial record	1959	70,590		
1940	62,960	1960	26,260		

Average for period of full-year record --------------------- 113,800
Standard deviation[3] -- 13,600

[1] Data from published records of U.S. Geological Survey.
[2] A water year is a 12-month period, October 1 through September 30, designated by the calendar year in which it ends.
[3] Standard deviation is the square root of the average of the squares of a set of deviations about an arithmetic mean.

By court decree the Walker River Indians are guaranteed 26.25 ft^3/s, or 19,000 acre-ft, per year at the point of diversion on the river approximately 9,450 acre-ft/yr were diverted for irrigation of crops on the reservation. Upon completion of Weber Dam in 1935, about 31,900 acre-ft/yr were diverted. In 1977, an estimated 18,000 acre-ft was diverted from the river for irrigation.

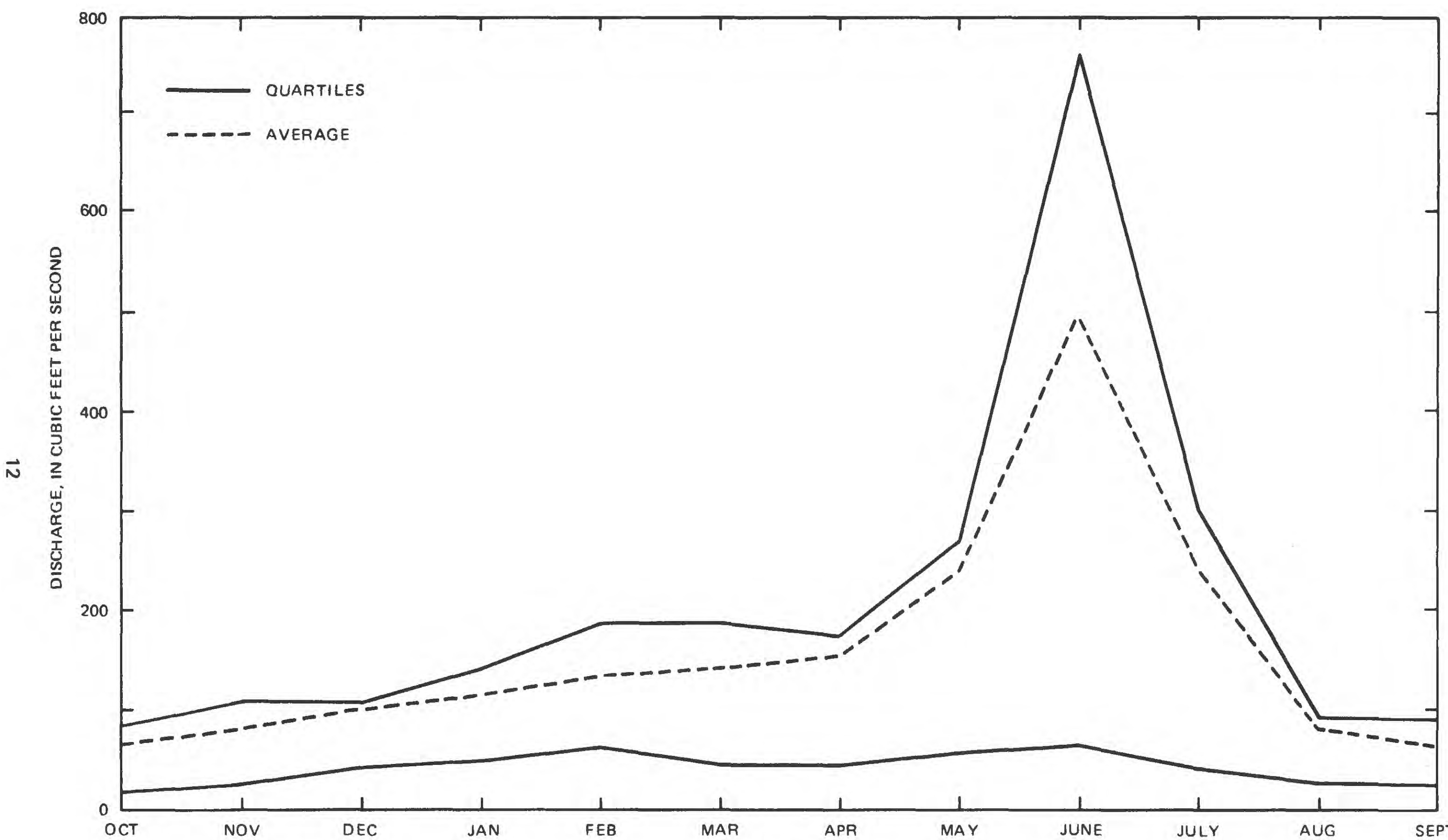

FIGURE 4. -- Average monthly flow distribution, Walker River near Wabuska, for period of full-year record (table 3). Quartiles indicate discharge values that were exceeded 25 percent of the time (upper quartile) and 75 percent of the time (lower quartile).

Irrigation of alfalfa and pastureland is the major use of surface water on the reservation. Houston (1950, p. 21) used a consumptive-use rate of 2 ft per acre per year for alfalfa. However, Tovey (1963) used a rate of about 3 ft per acre for alfalfa. On the basis of available evidence, the latter rate seems more reasonable. Therefore, an estimated 8,400 acre-ft of the 16,800 acre-ft used for irrigation of the 2,800 acres of alfalfa on the reservation is consumed annually. The pastureland probably has a consumptive-use rate of about 2 ft per acre per year. At this rate, 4,000 acre-ft/yr was used to irrigate the pastureland.

Precipitation on Water Surfaces

Precipitation on the surface of the Walker River and Weber Reservoir acts as a source of recharge to the surface-water supply. The average surface area of the river on the reservation is about 140 acres. With an average rainfall of 5.33 in., this adds about 60 acre-ft/yr to the river.

The surface area of Weber Reservoir varies with the reservoir's stage (Katzer and Harmsen, 1973). The average stage for the study period, 4,195 ft above the National Geodetic Vertical Datum of 1929 (mean sea level), was quite low due to the drought conditions. This yields about 350 acres of surface area and 155 acre-ft/yr of recharge from precipitation. The average storage of the reservoir is usually larger, however, and a more representative figure under normal hydrologic conditions was used for budget calculations. The reservoir is usually filled close to capacity, with a stage of 4,207 ft above sea level, a surface area of about 800 acres gains 350 acre-ft/yr from precipitation.

Losses to the Ground-Water System

Because the river is everywhere underlain by permeable alluvium, seepage can occur along its entire 45-mi length. The amount of seepage loss depends on the stage and flow of the river. Calculation of losses was based on discharge measurements during the period June 1977 to June 1978 at the gages near Wabuska and above Weber Reservoir (fig. 3) and results from the ground-water model. The losses in the 45-mi reach between Wabuska and Weber, in addition to evapotranspiration losses, amounted to about 3,600 acre-ft.

Miscellaneous streamflow measurements made during the study indicate that the Walker River loses water to the ground-water system in certain reaches during some river stages and gains water from the ground-water system during other river stages. One reach of the river that gains from ground water during the winter months, when releases from Weber Reservoir are cut back, is downstream from Schurz.

Overall, the river tends to lose to the ground-water systems, and on the basis of data available, losses from the entire river are estimated at 13,800 acre-ft/yr.

Evaporation Losses

Owing to the arid climate at the reservation, evaporation losses are high. Kohler and others (1959) gave an evaporation rate of 4 ft/yr for this area. The Walker River on the reservation has an average surface area of 140 acres. Evaporation from the river is about 560 acre-ft/yr. Evaporation from the reservoir is about 3,200 acre-ft/yr when it is filled to capacity.

Water Quality

The water quality of the Walker River is monitored at the Wabuska gaging station, which has been designated as a part of the Geological Survey's National Stream Quality Accounting Network. Monthly samples are analyzed for common mineral constituents and quarterly samples are analyzed for trace metals and pesticides. Additional data are available for the river above Weber Reservoir and at the diversions near Schurz. Water-quality data for water year 1978 (Oct. 1, 1977-Sept. 30, 1978) are listed in table 13. Numerous previous analyses are available in the annual reports of the U.S. Geological Survey (Water Resources Data for Nevada).

The river water is of generally good quality, and suitable for irrigation. Some of the important considerations for suitability are: (1) Concentration of dissolved solids, (2) proportion of sodium relative to calcium and magnesium, and (3) presence of specific constituents in amounts that can be toxic to plants. One such constituent is boron.

Alfalfa, the major crop grown on the reservation, is tolerant of relatively poor-quality irrigation water, but can be affected by excessive concentrations of dissolved solids and boron. A maximum boron content of 2,000 ug/L is recommended by the National Academies of Sciences and Engineering (1973, p. 341). Additional information they present (p. 335) suggests that dissolved-solids concentrations considerably in excess of 2,000 mg/L can be detrimental under all but ideal circumstances of climate, soil type, drainage efficiency, and amount of irrigation water applied. Boron and dissolved solids in water from the Walker River are well below these concentration limits (table 13).

Another index of irrigation-water suitability is the proportion of sodium relative to calcium and magnesium, which can be expressed as the sodium-adsorption ratio (SAR; Richards, 1954, p. 72). The sensitivity to excessive sodium increases with increasing dissolved-solids concentration. Table 4 summarizes a general relationship between SAR and dissolved solids for irrigation water, expressed as "sodium hazard." Data for the Walker River (table 13) indicate a consistently low sodium hazard.

The National Academies of Sciences and Engineering (1973, p. 308-312) have recommended the following concentration limits for water consumed by livestock: Boron (B), 5,000 ug/L; fluoride (F), 2.0 mg/L; and dissolved solids, 3,000 mg/L. Concentrations in the river water are well below these limits (table 13).

TABLE 4.--*Sodium hazard for irrigation water of differing dissolved-solids concentrations and SAR values*[1]

Sodium hazard	Range of SAR values for the following dissolved-solids concentrations: 500 mg/L	1,000 mg/L	2,000 mg/L
Low	0-6	0-5	0-4
Medium	6-12	5-10	4-8
High	12-18	10-16	8-13
Very high	>18	>16	>13

[1] Data from Richards, 1954, figure 25 (assumes that dissolved-solids concentration is two-thirds of specific-conductance value). The actual sodium hazard of a particular water also depends on crop type and soil characteristics (National Academies of Sciences and Engineering, 1973, p. 329-330).

GROUND-WATER RESOURCES

Occurrence and Movement of Ground Water

Ground-water use (250 acre-ft/yr) accounts for less than 2 percent of the total water use on the Walker River Indian Reservation. Ground-water use is generally restricted to domestic and stock requirements.

Ground water on the reservation occurs primarily in unconfined (water-table) aquifers. In the area of the dry lake east of Schurz (fig. 5), the ground water is confined by a clay layer, and well 13N/29E-25BA flows. On February 2, 1978, the well was flowing at a rate of 16 gal/min. Double Springs, about 500 ft to the east, also flows, but in a lesser amount. The extent of this clay layer is not known, but it is probably only a very localized feature. A well (13N/30E-21) about 3 mi to the east did not encounter the confining clay layer and hence does not flow.

Figure 5 shows the depth to ground water on the reservation. Depth to water ranges from 0 to 600 ft and is less than 100 ft over about 50 percent of the ground-water basin. The depth decreases near the river to less than 50 ft and greatly increases in the more remote areas.

Ground water enters the Schurz subarea through the Walker and Parker Gaps (fig. 6) and flows in a southeasterly direction parallel to the river. Flow continues in this direction to about the area of Schurz where the flow splits, with part moving almost due east towards the area of Double Springs and well 13N/31E-20AA (fig. 6). The remainder of the flow continues southward towards Walker Lake.

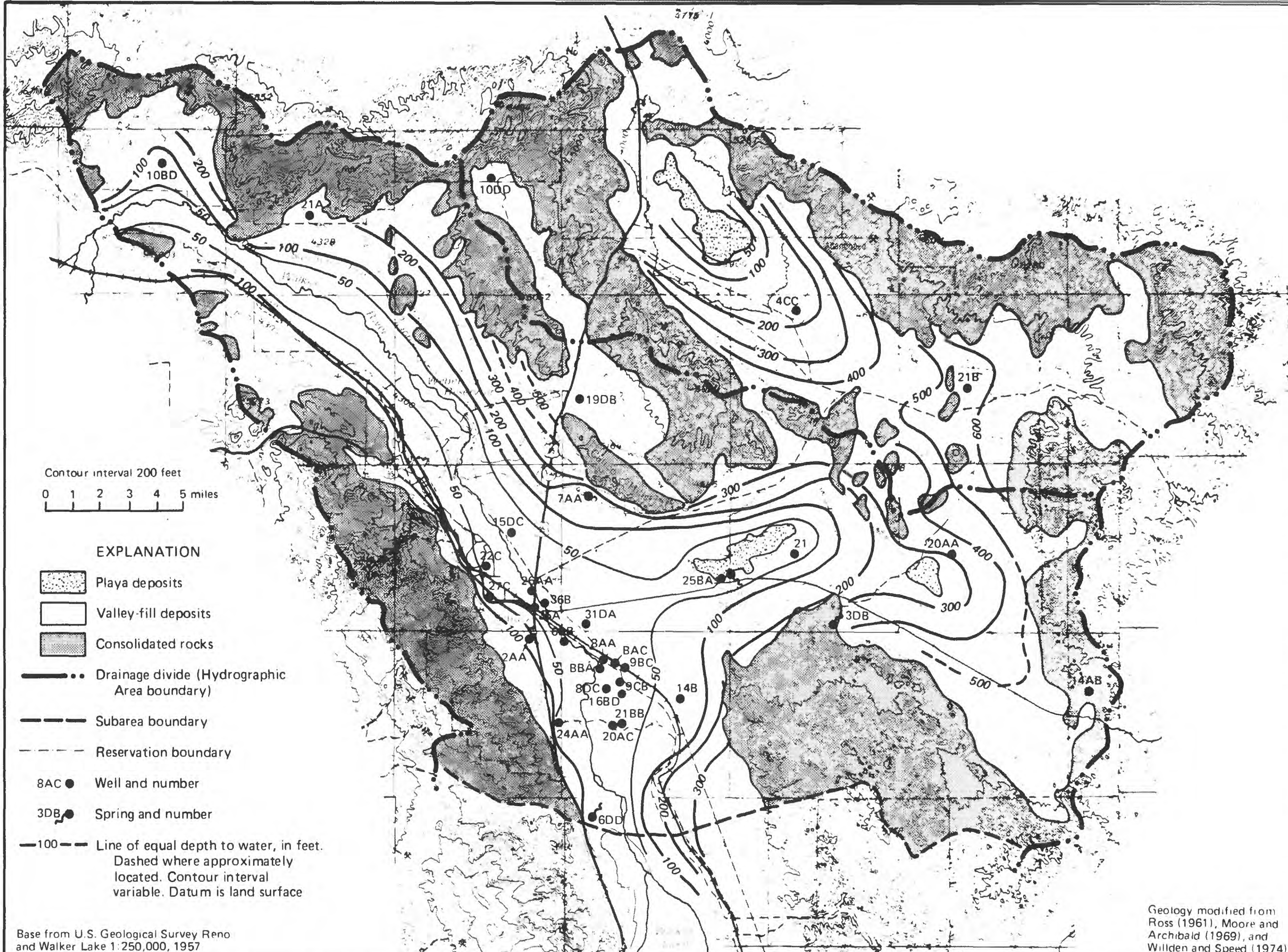

FIGURE 5. - - Depth to ground water, winter 1977-78.

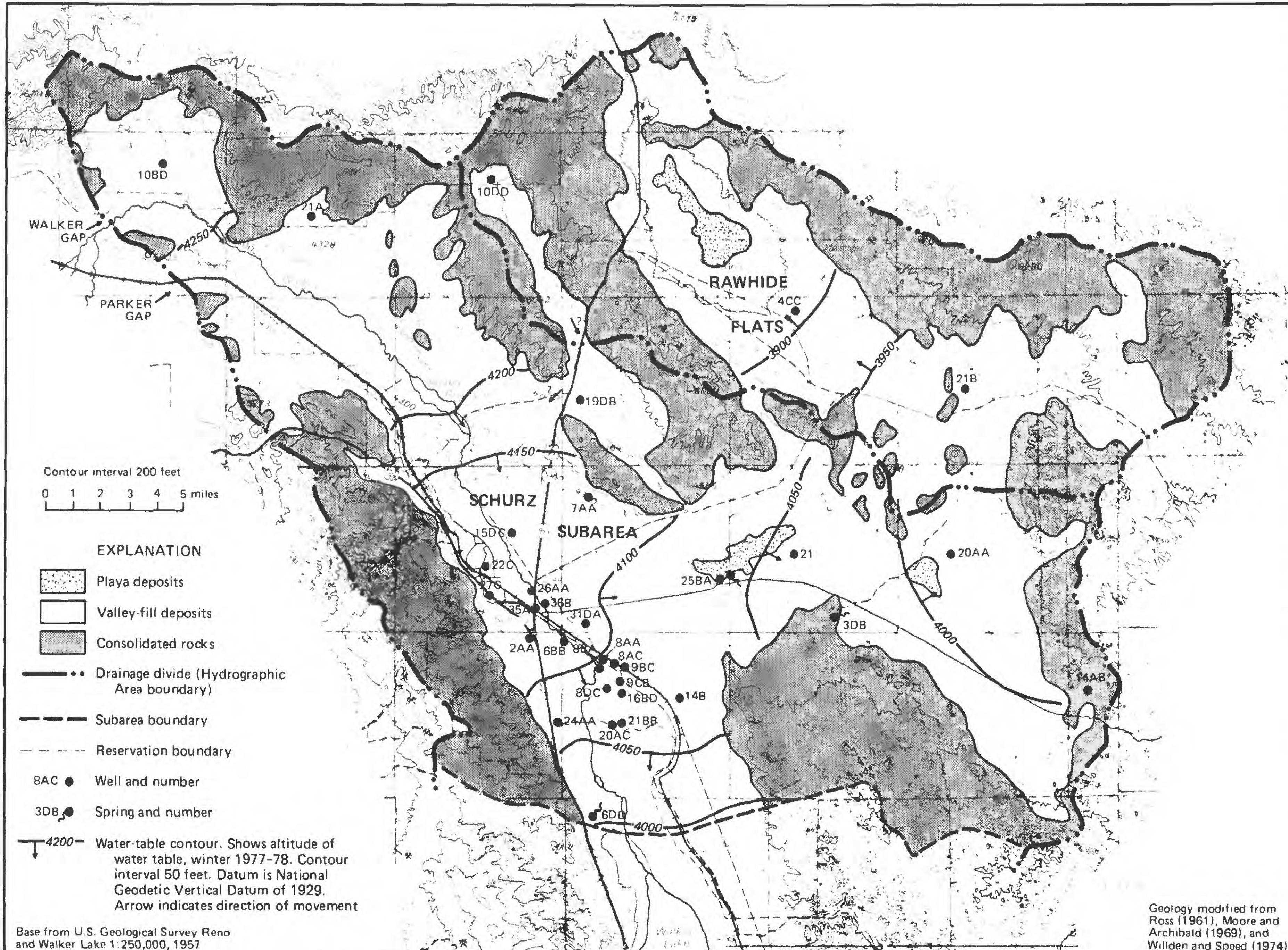

FIGURE 6. - - Water-table contours, winter 1977-78.

Flow in Long Valley, about 12 mi north of Schurz (fig. 6), probably moves in a southeasterly direction and enters the main part of the Schurz subarea west of the Calico Hills.

In the vicinity of well 13N/31E-20AA, ground water moves toward the northeast and then north into the Rawhide Flats hydrographic area. Flow within this hydrographic area is toward the northwest, ultimately into the alkali flat just north of the reservation.

Recharge

Recharge to the ground-water system on the reservation occurs as: (1) precipitation and runoff from the mountainous areas surrounding the reservation, (2) seepage losses from the Walker River, (3) subsurface inflow from adjacent ground-water basins, and (4) irrigation return flow.

Precipitation and Runoff

Recharge to the ground-water system occurs as precipitation and as runoff from the surrounding highland areas. Everett and Rush (1967) estimated the average annual recharge in the Schurz subarea and Rawhide Flats area as 500 and 150 acre-ft/yr, respectively.

Table 5 lists the long-term average monthly and annual precipitation at Schurz. The average precipitation for the period 1920-56 is 5.33 in./yr. The rain gage at Schurz was discontinued in 1956, but the period of record probably reflects a long-term average. Because of the high evaporation rate in this area, precipitation most likely contributes little, if any, recharge to the ground water.

Seepage Losses from Walker River

The major source of recharge to the ground water is seepage from the river. Based on calculations from seepage measurements, records from the two streamflow gaging stations, and results from the ground-water model mentioned previously, the river loses, on the average, about 13,800 acre-ft/yr.

Subsurface Inflow

The ground water that enters the reservation at the Walker and Parker Gaps (fig. 6) is subsurface outflow from Mason Valley (not shown) on the west. Huxel (1969) estimated the outflow from Mason Valley at each of these two gaps at 700 acre-ft/yr.

Ground-water inflow to the Rawhide Flats area from the Schurz subarea is estimated to be about 4,500 acre-ft/yr.

TABLE 5.--*Average monthly and annual precipitation at Schurz, 1920-56*[a]

Month	Precipitation (inches)
January	0.49
February	.52
March	.45
April	.52
May	.59
June	.40
July	.33
August	.31
September	.32
October	.41
November	.39
December	.60
Annual	5.33
Standard deviation	2.0

[a] Location of gage: sec. 26, T. 13 N., R. 28 E. Altitude: 4,124 ft above National Geodetic Vertical Datum of 1929. Data from published records of National Weather Service.

Recharge from Excess Irrigation

Approximately 4,800 acres of land on the reservation are irrigated for the production of some type of crop. Of this acreage, the 2,000 acres of pastureland north of Walker Lake probably contribute little in the way of irrigation return flow to the major part of the ground-water system. The return flow enters just north of the lake. The model yielded a figure of about 6,000 acre-ft/yr of recharge from this pastureland.

Irrigation return flow from the 2,800 acres of farmland along the river near Schurz recharges the ground-water supply. The computer model yielded a figure of about 8,400 acre-ft/yr for recharge from the irrigated cropland. The total amount of recharge from excess irrigation was computed as 14,400 acre-ft.

Discharge

Discharge from the ground-water system on the reservation occurs as: (1) Subsurface outflow from the system, (2) evapotranspiration of ground water by phreatophytes and discharging playas where the water table is near surface, (3) pumpage of ground water for domestic, irrigation, and stock uses, and (4) discharge in some reaches at the Walker River.

Subsurface Outflow

Outflow from the reservation enters Walker Lake south of Schurz. On the basis of data gathered during this study and results obtained from the computer model, flow from the Schurz Subarea into Walker Lake is judged to be about 10,850 acre-ft/yr.

Evapotranspiration Losses

Evapotranspiration losses occur through phreatophytes and the evaporation of ground water from playas.

Phreatophytes are plants that send their roots down to the water table and can be responsible for large amounts of ground-water use. On the reservation they are concentrated along the river and the borders of the discharging playas. The principal phreatophytes are rabbitbrush, willow, greasewood, grasses, cottonwood, and saltcedar.

Figure 7 shows the distribution of the phreatophytes and discharging playas. Table 6 lists the transpiration rate, the estimated amount discharged annually, and the standard deviation for the annual discharge for each calculated phreatophyte group as identified in figure 7. The method for obtaining standard deviation is discussed in the section on Variability Analysis.

Discharging playas are dry lakes in which the depth to water is generally less than 20 ft. The water table is close enough to land surface that capillary action in the playa deposits is able to bring the ground water to the surface to be evaporated. The rate of discharge may seem high due to limitations in the model used to calculate the figure. Table 6 lists the surface area of the discharging playas and the annual use.

Pumpage

Pumpage is another source of ground-water discharge. The main area of pumpage is the town of Schurz, where water is used mainly for domestic purposes and, to some extent, minor irrigation of small plots of land. Pumpage is estimated on the basis of population figures and a per capita use rate of 110 gal/d. Pumpage for domestic purposes is estimated to be about 80 acre-ft/yr.

Estimates of pumpage from stock wells throughout the reservation is based upon water consumption of 6 gal/d per head for range cattle (Nevada State Engineer, 1971, p. 16) and a cattle population of 2,500. Also included is miscellaneous pumpage for domesticated farm animals. A figure of about 170 acre-ft/yr for stock use of ground water has been estimated.

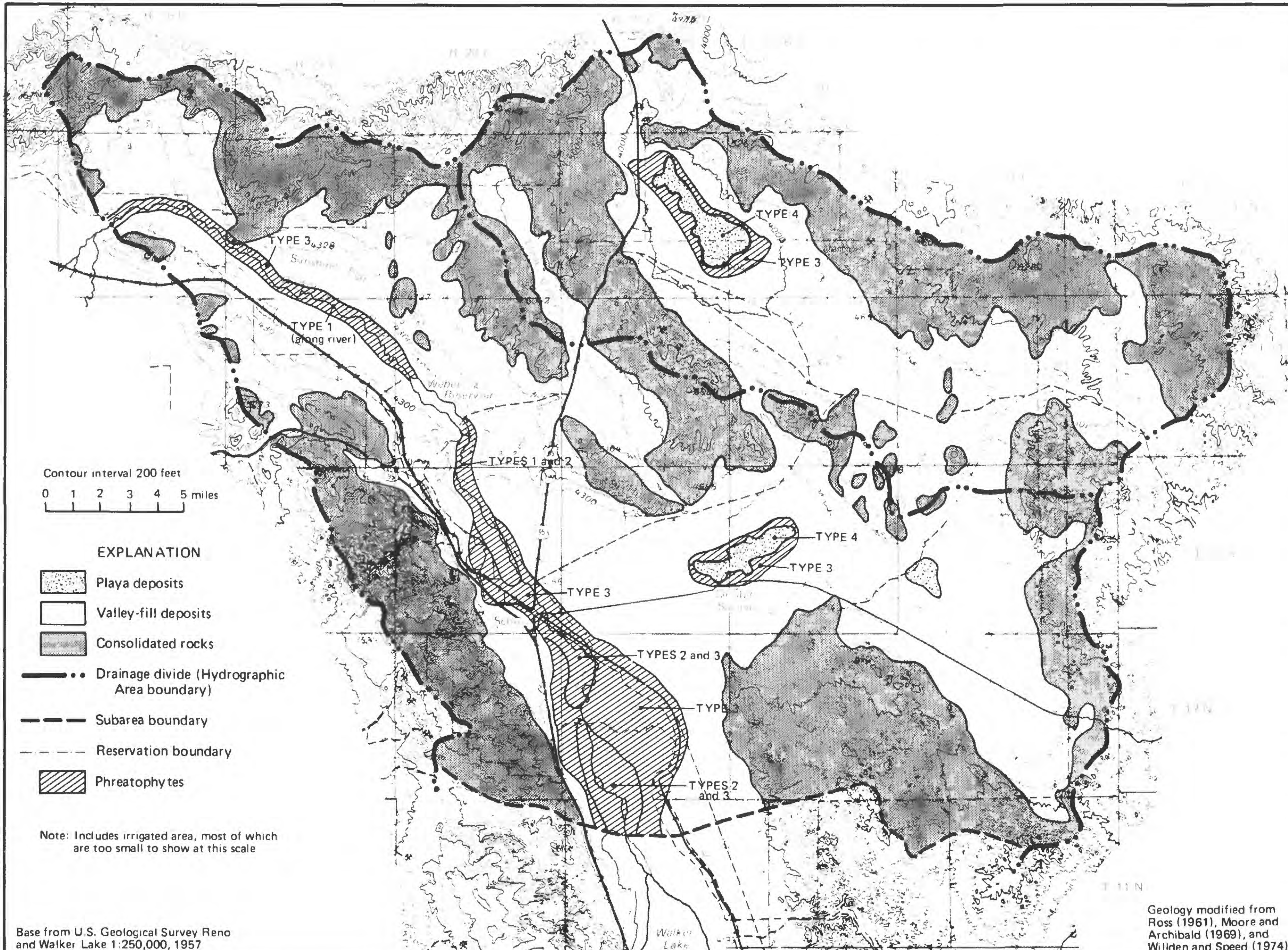

FIGURE 7. - - Phreatophyte distribution. See table 6 for explanation.

TABLE 6.--*Estimated average annual evapotranspiration by phreatophytes and discharging playas*

Type	Source of evapotranspiration	Area (acres)[1]	Evapotranspiration: Feet per year[2]	Evapotranspiration: Acre-feet per year	Calculated standard deviation of estimate (acre-feet per year)
		Schurz subarea			
1	Grasses, rabbitbrush, greasewood, and some cottonwood and willow	1,800	2.0	3,600	700
2	Grasses and willows	4,070	1.5	6,100	600
3	Greasewood	10,000	.2	2,000	400
4	Discharging playa	1,500	1.8	2,700	300
			Total (rounded)	14,000	
		Rawhide Flats area			
3	Greasewood	3,000	0.2	600	200
4	Discharging playa	2,300	1.8	4,100	700
			Total	4,700	

[1] Area within reservation boundary as shown on U.S. Geological Survey Walker Lake 1:250,000 quadrangle.

[2] Rates are from Everett and Rush (1967), except those for discharging playas, which were model-generated.

Discharge into Walker River

As was mentioned previously, the river is primarily a source of recharge to the ground-water system. Some reaches of the river, however, do gain water from the ground-water reservoir. No attempt was made to determine the amount of loss to the river, but it is probably minor and was not considered as part of the budget discussed later.

Water Levels

Because the river is hydraulically connected with the ground-water system, water levels in the immediate area of the river show little, if any, decline. Depth to water in wells near the river that was measured for the study by Everett and Rush (1967) averaged less than 40 ft and were found to be generally the same during the winter of 1977-78.

Water levels in the interior valleys, usually many miles from the river, have generally remained at the same level for the past 10 years. In well 15N/26E-10BD, near the northwest corner of the reservation about 1-1/2 mi from the river, water levels have declined about 2 ft in the past 10 years. This decline may reflect the below-average streamflow for the 1977 water year more than excessive ground-water usage.

Declines in water levels denote a change in storage for the ground-water system. The very slight change in water levels throughout the reservation is probably due to the recent drought. This suggests that the ground-water withdrawals are so small in relation to the recharge that no appreciable change in storage has resulted.

Ground-Water Storage

Ground water in storage is the volume of water in the pore voids of the saturated alluvial deposits that can be withdrawn. Storage was determined by multiplying the surface area of the basin by the average saturated thickness and then multiplying the result by the specific yield.

The saturated thickness was calculated on the basis of the water levels and thickness of alluvial deposits as indicated by the seismic surveys.

Specific yield is the ratio of the volume of water the rock or soil will yield by gravity from the saturated volume of the deposit to its own volume; it is expressed as a percentage. Determination of the specific yield is based on the lithology reported in the drillers' logs of wells drilled on the reservation. About 30 drillers' logs were qualitatively appraised, using the method devised by Davis, Green, Olmsted, and Brown (1959). From this appraisal, the specific yield in the valleys was estimated to range from 6 to 25 percent and average about 14 percent.

The two hydrographic areas (Schurz subarea and Rawhide Flat) were divided into five storage units (fig. 8), and storage estimates were computed for each unit. Table 7 presents the surface area, average saturated thickness, specific yield, and storage figures for each unit.

The total storage calculated is not necessarily water that can be entirely recovered. To recover all ground water in storage would require very deep wells and pumping costs would probably be prohibitive. For this reason, a usable storage figure has also been calculated. This figure uses a 200-ft saturated thickness but employs the same surface area and specific yield figures.

Neither storage figure takes into account areas of poor-quality water which may exist on the reservation.

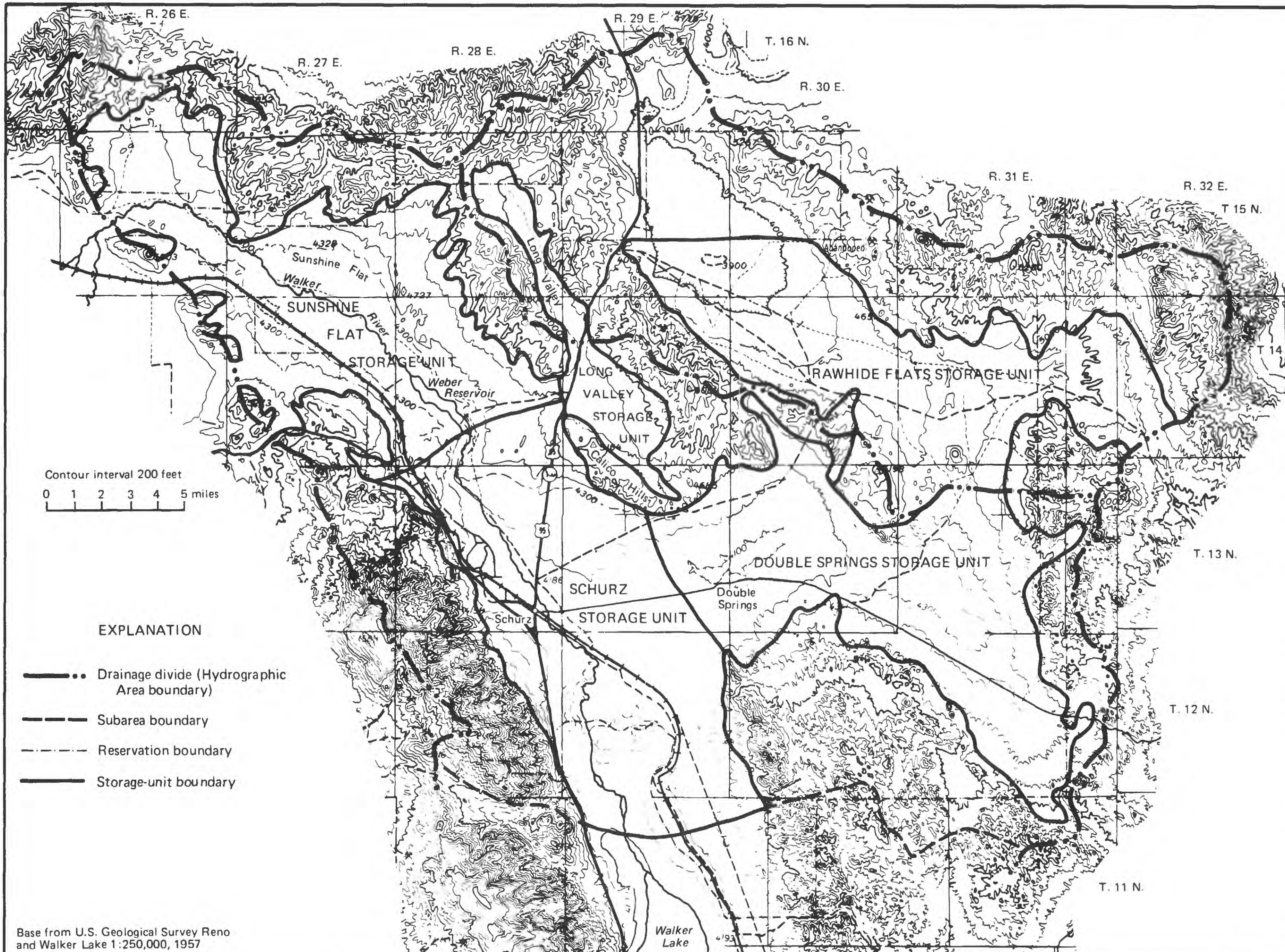

FIGURE 8. - - Ground-water storage units.

Water Quality

Ground-water quality on the reservation (table 14) tends to be similar to the quality of the Walker River. The major constituents of the ground water are characteristically sodium and bicarbonate. Wells 12N/29E-6BB and 8BA2, near the river, yield sulfate-rich water (200 and 290 mg/L, respectively). These higher-than-normal concentrations appear to be due to the influences of irrigation return flows. Analyses for the Walker River (table 13) show a downstream increase in sulfate, which tends to confirm this.

TABLE 7.--*Ground water in storage*

Storage unit	Surface area (acres)	Average saturated thickness (feet)	Specific yield (percent)	Storage (millions of acre-feet)	Usable storage[1] (millions of acre-feet)
Sunshine Flat	61,000	1,000	17	10	2.1
Schurz	65,000	1,000	14	9.1	1.8
Long Valley	12,800	Insufficient data	14	Unknown	[a] .36
Double Springs	60,000	900	10	5.4	1.2
Rawhide Flats	45,000	800	17	6.1	1.5

[1] Usable storage is based on a 200-ft saturated thickness.
[a] Estimated.

A very high sulfate concentration (2,700 mg/L) and fairly high chloride concentration (1,400 mg/L) were found in the water of stock well 13N/29E-7AA. This may reflect the influence of evaporites from the lacustrine deposits of ancient Lake Lahontan.

The U.S. Environmental Protection Agency (EPA) has recommended several guideline standards for drinking water (1977, p. 17146). The standards that apply to data listed in table 14 are as follows:

Constituent	Recommended maximum concentration
Chloride (Cl)	250 mg/L
Dissolved solids	500 mg/L
Iron (Fe)	300 ug/L
Sulfate (SO_4)	250 mg/L

EPA also has established values for the maximum permissible concentrations of several constituents in public drinking-water supplies (1975, p. 59570). The values that apply to table 14 are as follows:

Constituent	Maximum permissible concentration (milligrams per liter)
Fluoride (F)	[a] 1.8
Nitrate (as N)	10

[a] For an average maximum daily air temperature of about 21°C.

Regarding the constituents listed above, large concentrations of chloride and iron impart an unpleasant taste, and the iron can stain porcelain fixtures and clothing. Excessive sulfate can have a laxative effect on persons who are drinking a sulfate-rich water for the first time; and excessive fluoride tends to mottle teeth, especially those of children. A large amount of nitrate is dangerous during pregnancy and infancy because it may increase the possibility of "blue-baby" disease; excessive nitrate may also be a sign of contamination by percolating sewage.

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. Therefore, the U.S. Geological Survey has adopted the following rating:

Hardness, as $CaCO_3$ (milligrams per liter)	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)

On the basis of the guidelines described above and the data in table 14, the suitability of ground water in the study area for domestic use differs considerably from place to place. Most of the sampled waters contained more than 500 mg/L of dissolved solids, and many were very hard. Several of the well waters contained more than the recommended maximum concentrations of chloride, sulfate, or iron, and three contained more than 1.8 mg/L of fluoride. Among the wells listed in table 14 that were used for domestic purposes at the time of sampling, the principal water-quality problems were excessive hardness and dissolved-solids concentrations. Because ground-water quality does differ from place to place, the Consumer Health Protection Services, Nevada Department of Human Resources, in Carson City, can be contacted for advise if any doubt exists in the future concerning the acceptability of a specific water supply on the reservation for domestic use.

The suitability of ground water for irrigation differs areally. Using the guidelines for dissolved solids, boron, and sodium hazard discussed on page 14 and in table 4, and the analytical data in table 14, only sodium hazard appears to be a widespread problem:

Dissolved solids greater than 2,000 mg/L: 2 out of 24 sites.
Boron greater than 2,000 ug/L: 1 out of 14 sites.
Sodium hazard high or very high: 9 out of 24 sites.

Although none of the wells or the spring listed in table 14 was used for irrigation at the time of sampling, the data do indicate that water quality could affect the success of future ground-water irrigation in some parts of the reservation.

Three of the stock wells listed in table 14 yield water that is less than suitable for consumption by livestock, on the basis of recommendations listed on page 14: wells 13N/29E-7AA (excessive dissolved solids), 13N/29E-25BA (excessive boron, fluoride), and 15N/26E-10BD (excessive fluoride).

HYDROLOGIC SUMMARY

Hydrologic Budget

The hydrologic budget of a ground- or surface-water system can be expressed as a balance of the water entering the system to the amount of water leaving the system and any accompanying change in storage. The hydrologic budget can be expressed as the equation:

$$I = O \pm \Delta S \qquad (1)$$

where I is the inflow into the system, O is the outflow leaving the system, and ΔS is the change in storage. The change in storage can be either an addition or depletion of water. The budgets are assumed to be for steady-state conditions; therefore, the change-in-storage term is neglected.

Because there are two types of hydrologic systems (surface and ground water), they will be treated individually. But because of the interactive nature of the two systems, a combined budget is also computed.

Variability Analysis

As with any numerical analysis, errors can be incorporated within the calculation of parameter values for a hydrologic budget. These errors are then passed on through other calculations until the final answer has a considerable range of values. The square root of the averages of the squares of a set of deviations about an arithmetic mean is termed the standard deviation (σ). In calculating the value of the standard deviation for any individual term, the overall standard deviation can be expressed in an equation. For example, the equation for the calculation of the inflow term of precipitation on a free water surface is:

$$P_{RF} = A \times R \qquad (2)$$

where P_{RF} is the inflow term (acre-ft)
A is the surface area (acres)
R is the rainfall (ft).

The deviation for the terms in this equation is:

$$\left(\frac{\sigma P}{P}\right)^2 = \left(\frac{\sigma A}{A}\right)^2 + \left(\frac{\sigma R}{R}\right)^2 \qquad (3)$$

If the value for the surface area is 940 acres with an estimated standard deviation of 100 acres and the rainfall equals 0.44 ft with a standard deviation of 0.17 ft, the error propagation becomes:

$$\left(\frac{\sigma P}{410}\right)^2 = \left(\frac{100}{940}\right)^2 + \left(\frac{0.17}{0.44}\right)^2 \qquad (4)$$

$$\sigma P_{RF} = 165 \text{ acre-ft}$$

This means the value for inflow precipitation on water surfaces may deviate 165 acre-ft from the 410 acre-ft calculated.

Some of the terms used in computing the ground-water budget were from other sources if the original data used in computing the values were not available. In these cases, a standard deviation value has been assigned on the basis of what would be a reasonable deviation.

Once the standard deviations for each term in the equation are calculated (listed in table 8), the variance for each of the terms can be calculated. The variance (Var) is the square of the standard deviation. The calculation of the variance for the total inflow term is the sum of the variances of the individual inflow terms:

$$\text{Var (Inflow)} = \text{Var}(I_{AB}) + \text{Var}(R_{WR}) + \text{Var}(R_{SS}) + \text{Var}(R_{IR}) \qquad (5)$$

which becomes

$$\sigma(\text{Inflow}) = \sqrt{\text{Var (Inflow)}}$$

In general, the standard deviation of the individual terms gives some indication of the reliability of these figures. The larger the standard deviation, the greater the variability of the figures.

The standard deviation of the inflow and outflow terms reflect the general confidence in these figures.

TABLE 8.--*Inflow and outflow terms for surface-water budget*

Term	Source	Estimated acre-feet per year	Standard deviation of estimate (acre-feet per year)
	INFLOW		
I_{SW}	Walker River	[a]113,800	13,600
P_{RF}	Precipitation on river and reservoir	410	165
F_{IR}	Return from irrigated area (left over from consumptive use and ground-water recharge)	5,200	500
	Total inflow (rounded)	119,000	13,600
	OUTFLOW		
O_{WR}	Walker River flow into Walker Lake	69,600	[b]5,000
E	Evaporation from river and reservoir	3,800	200
O_{GW}	Recharge to ground-water system from river	14,000	[b]2,100
D_{IR}	Diversions for irrigation	32,000	[b]1,000
	Total outflow (rounded)	119,000	5,500

[a] Mean annual flow measured at Wabuska gage (table 3).
[b] Estimated.

Surface-Water Budget

The surface-water budget of the reservation is expressed as an expanded form of equation 1. Inflow into the surface-water system includes: (1) Walker River streamflow at Wabuska (I_{SW}), (2) precipitation on the river and Weber Reservoir (P_{RF}), and (3) return flow from irrigated area (F_{IR}).

The outflow terms include: (1) Walker River flow into Walker Lake (O_{WR}), (2) evaporation from Walker River and Weber Reservoir (E), (3) recharge to ground-water system from river (O_{GW}), and (4) diversions for irrigation (D_{IR}). Equation 1 is expanded to include all terms and yields:

$$I_{SW} + P_{RF} + F_{IR} = O_{WR} + E + O_{GW} + D_{IR} \quad (6)$$

The values for the various parameters and their standard deviation are listed in table 8.

Ground-Water Budget

The terms in equation 1 can be expanded to represent the ground-water system. Inflow into the system or recharge to the basin includes: (1) inflow from adjacent basins (I_{AB}), (2) recharge from Walker River (R_{WR}), (3) recharge from runoff of small streams (R_{SS}), and (4) recharge from irrigation return flows (R_{IR}).

The outflow terms include: (1) discharge from playa surfaces (including discharge by greasewood (type 3, table 6)) (D_{DP}), (2) discharge by phreatophytes along the river (discharge by type 1 and 2 phreatophytes in table 6) (D_{RP}), (3) underflow into Walker Lake (U_{WL}), and (4) domestic and stock pumpage (P_{DS}).

The expanded equation becomes:

$$I_{AB} + R_{WR} + R_{SS} + R_{IR} = D_{DP} + D_{RP} + U_{WL} + P_{DS} \quad (7)$$

The values for the various parameters and their standard deviations are listed in table 9.

Overall Hydrologic Budget

An overall hydrologic budget combines terms from both the surface-water and ground-water budgets and takes into account only those terms that represent water actually entering or leaving the system. Terms like recharge to the ground-water system resulting from seepage out of the river are neglected because the water is still part of the overall system. However, the underflow into Walker Lake is a term in the combined hydrologic budget because it represents a quantity of water that has physically left the system.

The equation for the overall hydrologic budget is similar to the preceding discussions, and equation 1 is expanded into its component parts:

$$I_{AB} + I_{SW} + P_{RF} + R_{SS} = O_{WR} + E + D_{DP} + D_{RP} + U_{WL} + P_{DS} + C_{IR} \quad (8)$$

where the inflow terms include: (1) Inflow from Mason Valley (I_{AB}), (2) Walker River streamflow at Wabuska (I_{SW}), (3) precipitation on Walker River and Weber Reservoir (P_{RF}), and (4) recharge from runoff of small streams (R_{SS}).

The outflow terms include: (1) Walker River flow into Walker Lake (O_{WR}), (2) evaporation from the river and reservoir (E), (3) discharge from playa surfaces (includes surrounding phreatophytes) (D_{DP}), (4) discharge by phreatophytes along the river (D_{RP}), (5) underflow into Walker Lake (U_{WL}), (6) domestic and stock pumpage (P_{DS}), and (7) consumptive use by crops (C_{IR}).

Table 10 lists the parameters, the values, and the standard deviations.

TABLE 9.--*Inflow and outflow terms for ground-water budget*

Term	Source	Estimated acre-feet per year	Standard deviation of estimate (acre-feet per year)
	INFLOW		
I_{AB}	Inflow from Mason Valley	1,400	[a]200
R_{WR}	Recharge from Walker River	14,000	[a]2,100
R_{SS}	Recharge from runoff of small streams	650	[a]200
R_{IR}	Recharge from excess irrigation	14,000	[a]3,000
	Total inflow (rounded)	30,000	[b]3,600
	OUTFLOW		
D_{DP}	Discharge from playas and surrounding phreatophytes	9,400	900
D_{RP}	Discharge by riparian phreatophytes	9,700	900
U_{WL}	Underflow into Walker Lake	11,000	[a]2,000
P_{DS}	Domestic and stock pumpage	250	[a]50
	Total outflow (rounded)	30,000	[c]2,400

[a] Estimated.
[b] Estimated as $[(I_{AB})^2 + (R_{WR})^2 + (R_{SS})^2 + (R_{IR})^2]^{\frac{1}{2}}$.
[c] Estimated as $[(D_{DP})^2 + (D_{RP})^2 + (U_{WL})^2 + (P_{DS})^2]^{\frac{1}{2}}$.

DEVELOPMENT OF A GROUND-WATER MODEL

Considerable uncertainty exists as to the actual rates of ground-water recharge from the Walker River and ground-water discharge from the Double Springs and Rawhide Flats playas. A mathematical model of the ground-water system, however, provides a tool for testing assumptions about these rates of recharge and discharge. Furthermore, a sensitivity analysis can be used to evaluate the effect of uncertainty in knowledge of the actual system on estimates of those rates.

Description of the Model

Governing Equation

The model of the Walker River Indian Reservation ground-water system treats the prototype as a single-aquifer system. An equation that describes ground-water flow for this assumption is (Bear, 1972, p. 215):

$$\frac{\partial}{\partial x}\left(T\,\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\,\frac{\partial h}{\partial y}\right) - W = 0$$

TABLE 10.--*Inflow and outflow terms for overall hydrologic budget*

Term	Source	Estimated acre-feet per year	Standard deviation of estimate (acre-feet per year)
	INFLOW		
I_{AB}	Ground-water inflow from Mason Valley	1,400	[a]200
I_{SW}	Walker River	[b]113,800	13,600
P_{RF}	Precipitation on river and reservoir	410	165
R_{SS}	Runoff of small streams	650	[a]200
	Total inflow (rounded)	116,000	13,600
	OUTFLOW		
O_{WR}	Walker River flow into Walker Lake	69,600	[a]5,000
E	Evaporation from river and reservoir	3,800	200
D_{DP}	Discharge from playas and surrounding phreatophytes	9,400	900
D_{RP}	Discharge by riparian phreatophytes	9,700	900
U_{WL}	Underflow into Walker Lake	11,000	[a]2,000
P_{DS}	Domestic and stock pumpage	250	50
C_{IR}	Consumptive use in irrigated areas	12,000	[a]1,000
	Total outflow (rounded)	116,000	5,600

[a] Estimated.
[b] Mean annual flow measured at Wabuska gage (table 3).

where T is transmissivity, h is water level, and W is the discharge of a source or sink. The source-sink function was discharge, irrigation return, recharge from small streams, and recharge from the Walker River. In the model these distributed quantities are treated as point sources and sinks (Pinder and Frind, 1972).

Approximate solutions to the ground-water-flow equation were obtained by using the Galerkin-finite-element method. Pinder and Frind (1972) gave a mathematical description of this method. Briefly, it involves subdividing the ground-water system into elements having quadrilateral shape and assuming that the solution to the ground-water-flow equation can be written as a linear combination of relatively simple trial functions. Associated with the trial functions are adjustable coefficients, which the Galerkin computational scheme adjusts to give some best approximation to the ground-water-flow equation. The computer program used for these computations is a Galerkin-finite-element program developed by G. F. Pinder (written commun., 1975).

Figure 9 shows the element configuration used for the analysis of the Walker River Indian Reservation ground-water system. The geometry of the ground-water system is specified in the model through the configuration of elements. Water-bearing properties of the prototype are specified in the model by assigning transmissivity values to the elements. The model uses these transmissivity values to compute water levels that mathematically satisfy the ground-water-flow equation for the sources and sinks applied and the boundary conditions imposed.

River-Aquifer Interactions

The most important source of ground-water recharge to the Walker River Indian Reservation ground-water system is percolation from the channel of the Walker River. The river is hydraulically connected with the ground-water system, and exchanges of water occur between the two systems. The rate of exchange depends on the ground-water level adjacent to the river, the permeability of the channel bed, and the stage and width of flow in the channel.

To express mathematically the dependence on these variables, Muskat (1937, p. 350) gave an approximate relation for the seepage discharge from canals and ditches that merge with a shallow water table. By this relation the seepage discharge is approximately linear for small head differentials between the river stage and water table. Concomitantly, in the ground-water model the seepage discharge from or to a channel reach was assumed to be proportional to the head differential between the river stage and ground-water level at the midpoint of the reach and proportional to the flow width of the river. Symbolically, the seepage rate, Q_R, is given by

$$Q_R = C_R\ (h_R - h)\ W_R L$$

where C_R is a constant of proportionality, h_R is the river stage, h is the ground-water level, W_R is the flow width, and L is the reach length.

The stage and width of flow were expressed as power functions of the upstream discharge in the reach. The river stage was represented by the relation (Leopold, Wolman, and Miller, 1964, p. 215)

$$h_R = H_R + a_d\ Q^{b_d}$$

where H_R is the channel-bed altitude, Q is the river discharge, and a_d and b_d are numerical coefficients. The flow width was represented by the relation (Leopold, Wolman, and Miller, 1964, p. 215)

$$W_R = a_w\ Q^{b_w}$$

where a_w and b_w are numerical coefficients.

FIGURE 9. - - Element configuration of ground-water model.

Source and Sink Discharges

The source and sink discharges include agricultural and domestic pumpage, recharge from irrigation return water, discharge from riparian phreatophytes and playas, recharge from small streams, and recharge from the Walker River. While the ground-water model computed recharge from the river and discharge from playas, the other quantities are inputs to the model. Development of estimates for these inputs was discussed in earlier parts of the report. The geographic distribution of these inputs that was used in the ground-water model is shown in figures 10 and 11.

Boundary Conditions

The ground-water-flow equation has an infinite number of solutions. The question naturally arises as to how one may choose among the infinite number of solutions applying to any particular problem. Without any detailed analysis, differences in the solutions are related, in part, to differences in the boundaries defining the ground-water basin and to the conditions that are imposed at these boundaries. In this regard, the boundary conditions used on the ground-water model are of two types, specification of water level on the boundary and specification of discharge across the boundary.

The boundary at Walker Lake was represented in the model by the specification of the ground-water level, which was assumed to equal the stage in Walker Lake.

Boundaries with specified discharge are used in other parts of the model. Except at Walker and Parker Gaps, the discharge is specified to be zero (an impermeable boundary) along these boundaries. Minor quantities of water may enter the ground-water system as underflow through the alluvial deposits that typically underlie the stream channels debouching from the highlands adjacent to the ground-water system. Tongues of alluvium generally extend along the stream channels far up into their canyons. This source of underflow was ignored, however, in the ground-water model, because it is small in comparison with other recharge.

At Walker and Parker Gaps, ground-water underflow from Mason Valley enters the Walker River Indian Reservation ground-water system. At these locations nonzero values of discharge were specified for boundary segments. Discharges of 700 acre-ft/yr were used at Walker and Parker Gaps.

System Parameters

The system parameters are the transmissivity of the ground-water-flow equation (T) and the coefficients of the river-seepage equation (C_R, a_d, b_d, a_w, and b_w). Values of these parameters were selected so that the model would be a reasonable approximation of the actual ground-water system.

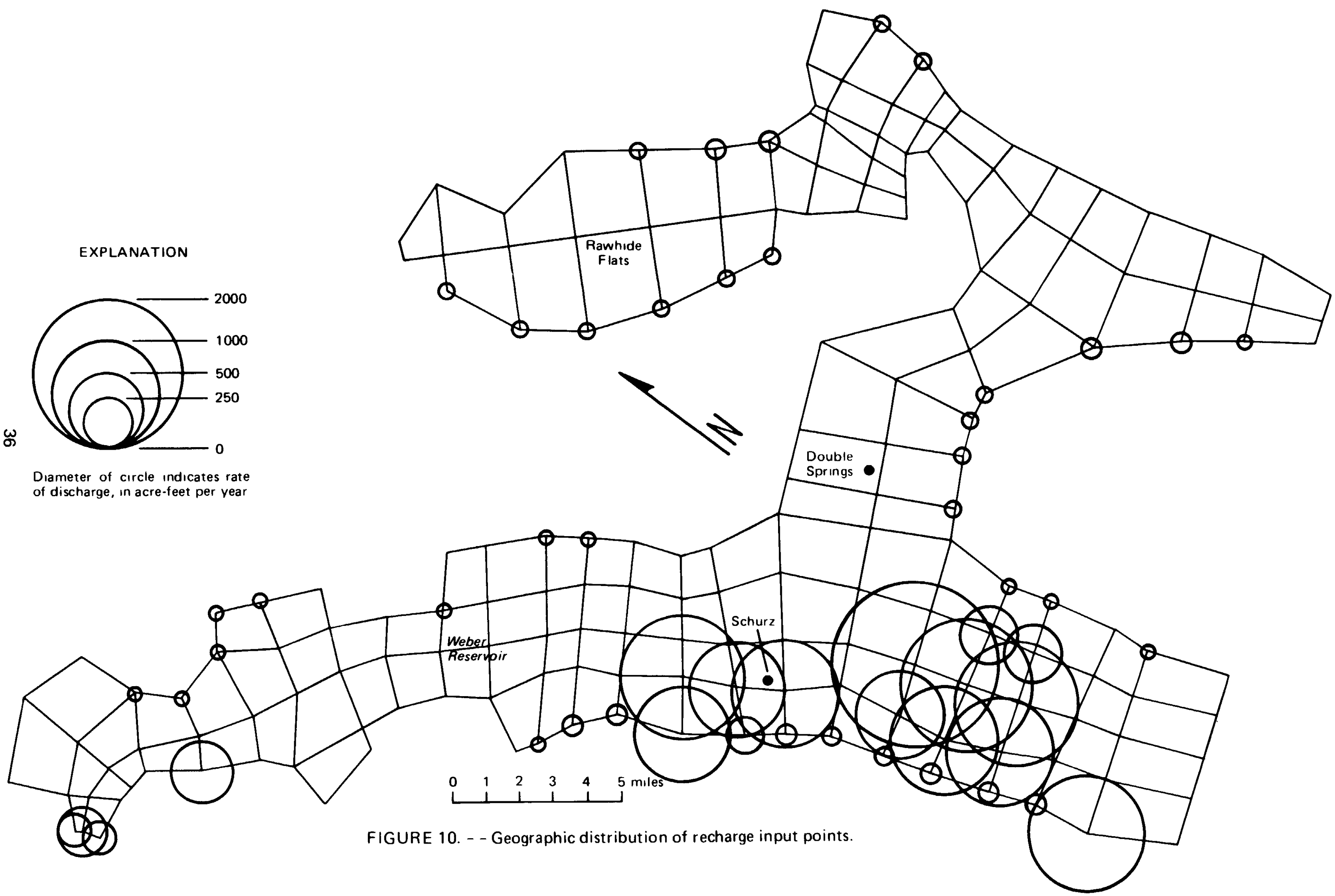

FIGURE 10. - - Geographic distribution of recharge input points.

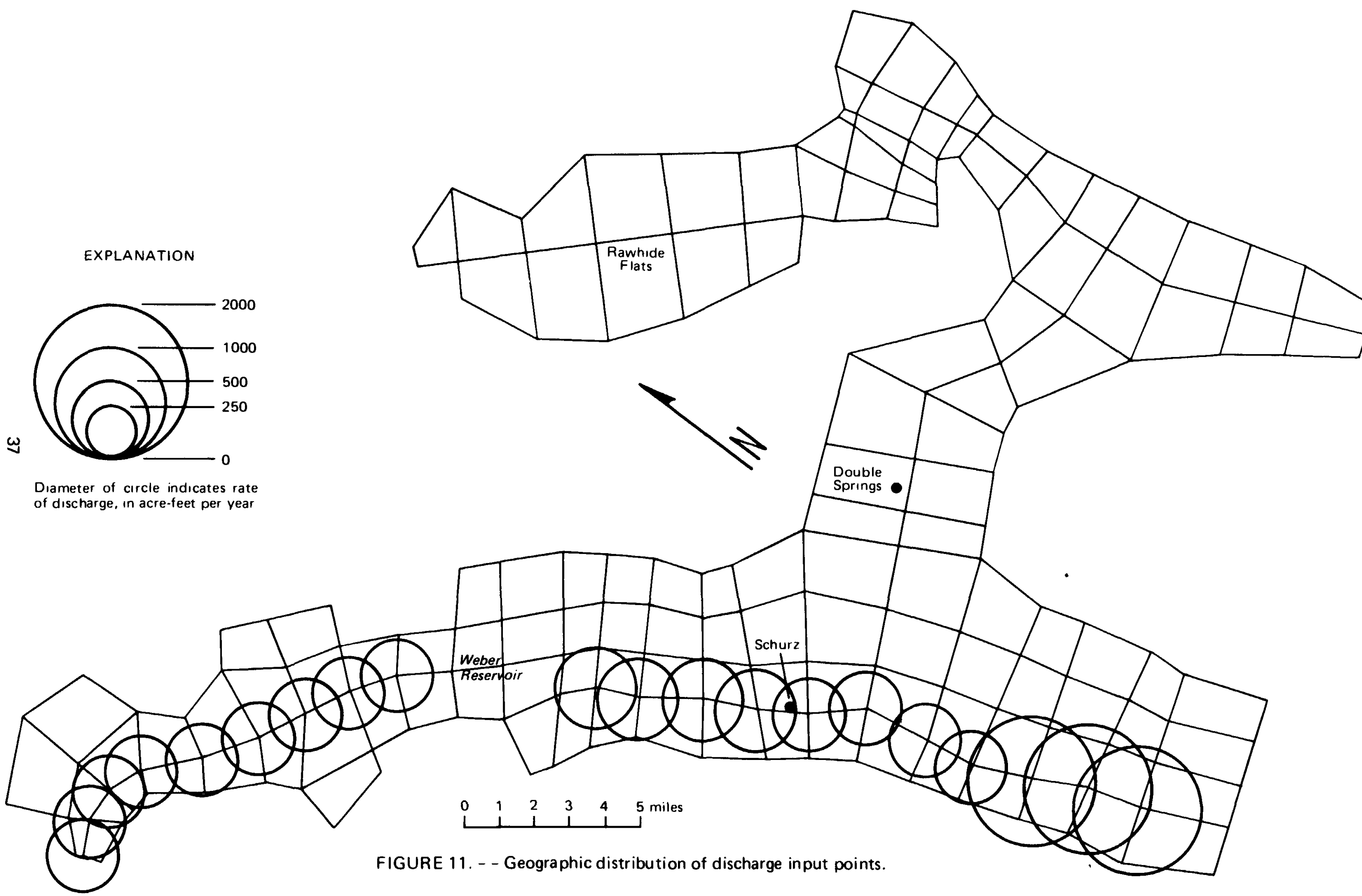

FIGURE 11. - - Geographic distribution of discharge input points.

Ground-Water-Flow Equation

Limited aquifer test data are available for the Walker River Indian Reservation ground-water system to define the geographic distribution of transmissivity. If some assumptions regarding the general nature of the distribution of transmissivity are accepted, however, the available data provide a basis for a quantitative estimate of the transmissivity distribution that is hydrologically reasonable. The assumptions were designed to reduce unexplained geographic variability of transmissivity by explaining the variability, to the extent possible, through indirect data sources.

The local transmissivity is a function of the local thickness of the ground-water system and the local average hydraulic conductivity of the lithologic units that compose the system. However, the local average hydraulic conductivity is assumed to be constant throughout the ground-water system. The previously described seismic-reflection data provide estimates of the variability of system thickness. Available aquifer test data represent specific capacity tests from 24 wells in the Schurz area. Hydraulic conductivity was computed by using a specific capacity-transmissivity relationship developed by Theis (1963). This relationship is influenced by well diameter, aquifer storage coefficient, and well efficiency. The hydraulic conductivity estimates obtained from these data ranged from 1 to 92 ft/d and averaged 34 ft/d. This average hydraulic conductivity was used with thickness estimates to obtain final transmissivity values for use in the model. The transmissivity values obtained in this manner primarily reflect properties of the zone penetrated by the well.

River-Seepage Equation

Values for the coefficients of the power functions relating flow width to discharge and flow depth to discharge were estimated from streamflow data. Measurements of flow width and discharge are plotted logarithmically in figure 12, and flow depth and discharge in figure 13. On a logarithmic graph a power curve is a straight line. The coefficients a_d and a_w are the log-intercept of the straight line representing the data, and the coefficients b_d and b_w are the slope of the line.

The constant of proportionality (C_R) in the river-seepage equation depends in part on the vertical permeability of the channel bed and on the ability of ground water to move laterally in the immediate vicinity of the river. Direct measurements are not available to estimate a value for this parameter. Instead, a value was selected by adjustment so that the model seemed to reproduce the behavior of the actual system. The selected value was 0.01 per second.

Model Results

Figure 14 shows the distribution, computed by the ground-water model, of water levels in the ground-water system. The shape of the computed solution compares reasonably well with the measured water levels also shown in figure

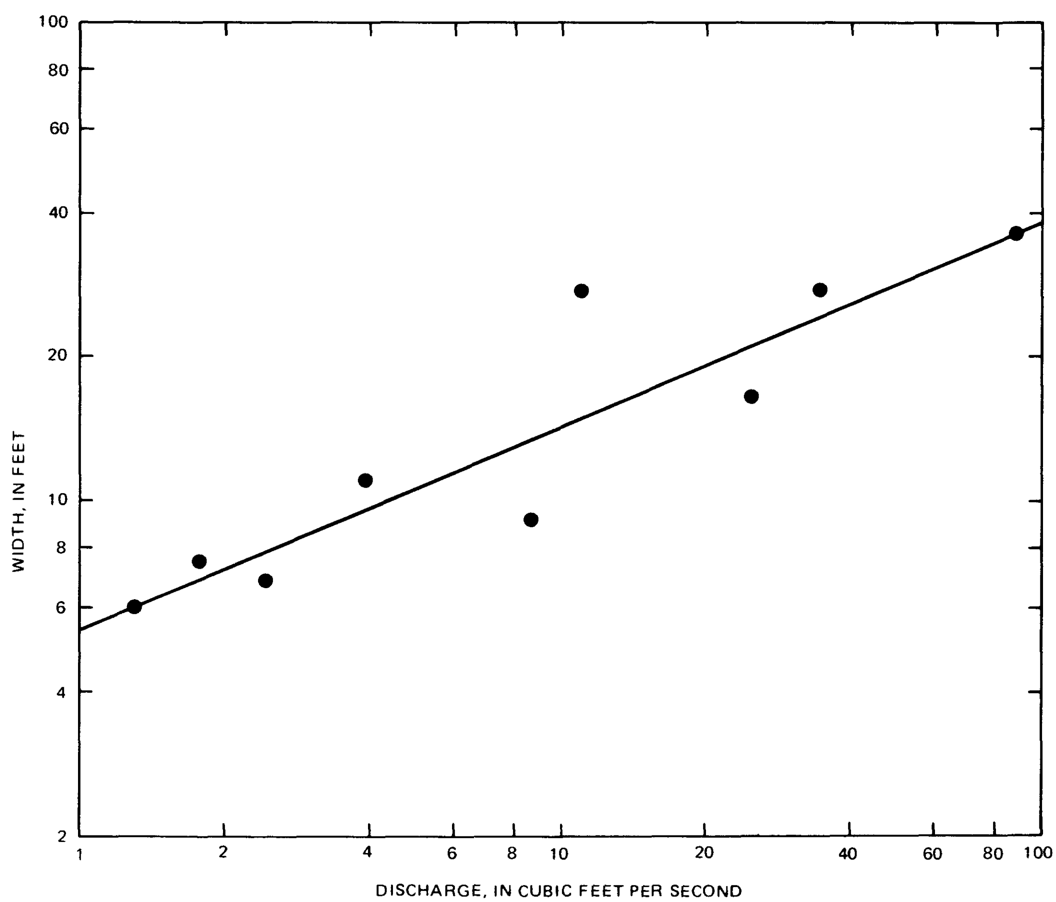

FIGURE 12. - - Relationship between flow width and discharge.

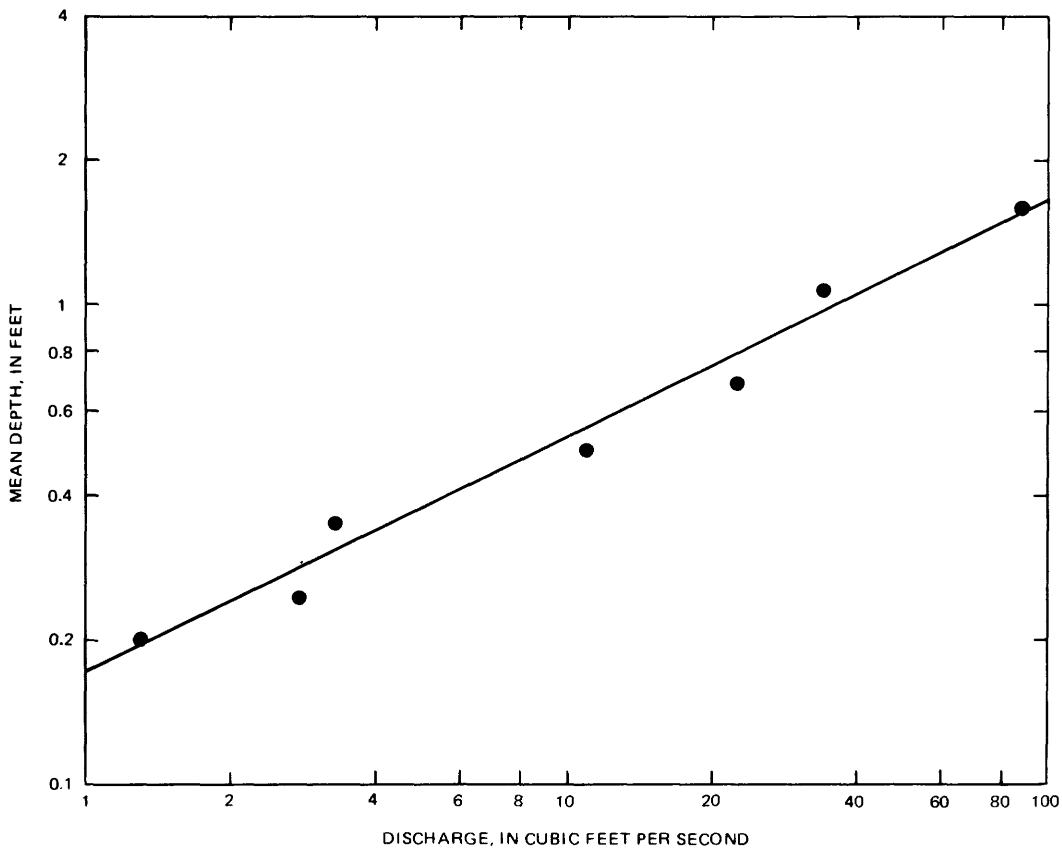

FIGURE 13. - - Relationship between flow depth and discharge.

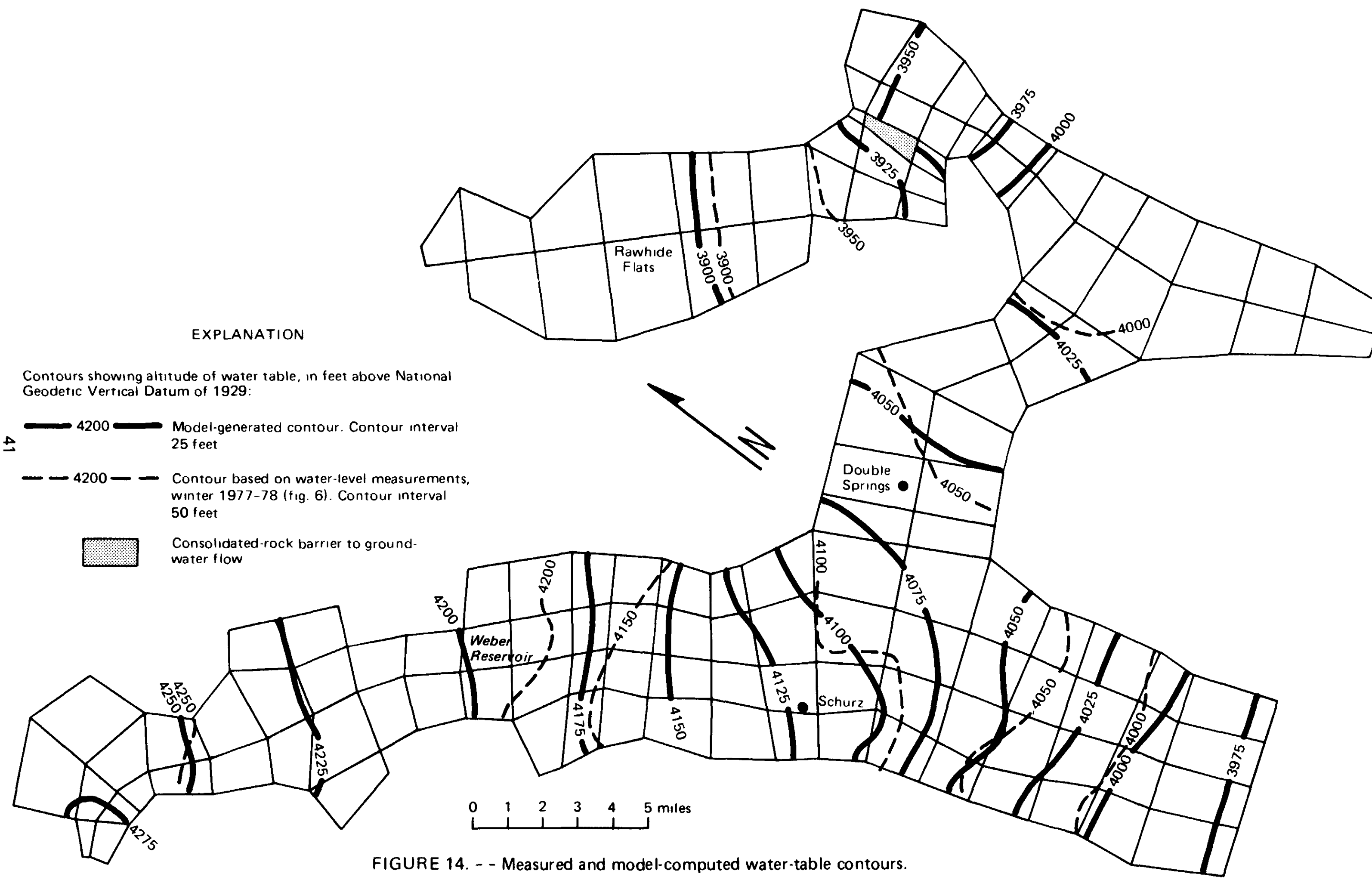

FIGURE 14. - - Measured and model-computed water-table contours.

14. The cumulative distribution of the deviation of model-generated water levels from measured water levels is shown in figure 15. The median deviation is 12 ft, and the maximum deviation is 70 ft.

In addition to simulating ground-water levels, the model also simulates recharge from the river and discharge from the playas. The simulated rates of recharge and discharge are directly related to the value of mean hydraulic conductivity used to estimate the geographic distribution of transmissivity. If a larger value were used, the simulated recharge and discharge would be larger. Similarly, if a smaller value of hydraulic conductivity were used, the recharge and discharge would be smaller. Figure 16 shows how the simulated recharge varies with the hydraulic conductivity used in the model, and figure 17 shows how the simulated discharge varies with hydraulic conductivity. The general linear trend of the graphs coupled with the random samples of wells to compute transmissivity indicate the values for recharge and discharge to be reasonable. But the lack of independent estimates of recharge and discharge makes it difficult to confirm. Because the model only takes into account horizontal transmissivity, the discharge at the playas may seem large. With vertical transmissivity acting against discharge at the playas, the figure would probably be smaller.

Possible Future Uses of the Model

Although the model of the Walker River Indian Reservation ground-water system was developed specifically as a tool for estimating ground-water recharge from the Walker River and ground-water discharge to the Double Springs and Rawhide Flat playas, it could be used for other purposes if more data were available to verify the estimates. One use is the evaluation of different plans for managing the water resources of the reservation. For example, it might be possible to use the ground-water system to store water from the Walker River. During the periods of high river flow, water might be stored in the ground-water system. Then, in periods of low river flow the stored water could be pumped back for use. The model might be used to test the feasibility of such a plan.

Additionally, large quantities of water are apparently discharged by the playas on the reservation. It may be possible to "capture" this water by lowering the water table under the playas. If the need arose to make use of this water, the model could be used to test the general feasibility of this plan. Furthermore, if the plan appeared feasible, the model could be used to design a layout of wells for its implementation.

FUTURE DEVELOPMENTS

The Walker River Paiute Indian Tribe is interested in making the most efficient use of the available surface- and ground-water supplies. Future developments planned by the tribe include expanding the network of stock-watering wells throughout the reservation and possibly extending the farming areas away from the immediate vicinity of the Walker River. If the farming areas are expanded away from the relatively easy availability of river water, large capacity irrigation wells will be necessary.

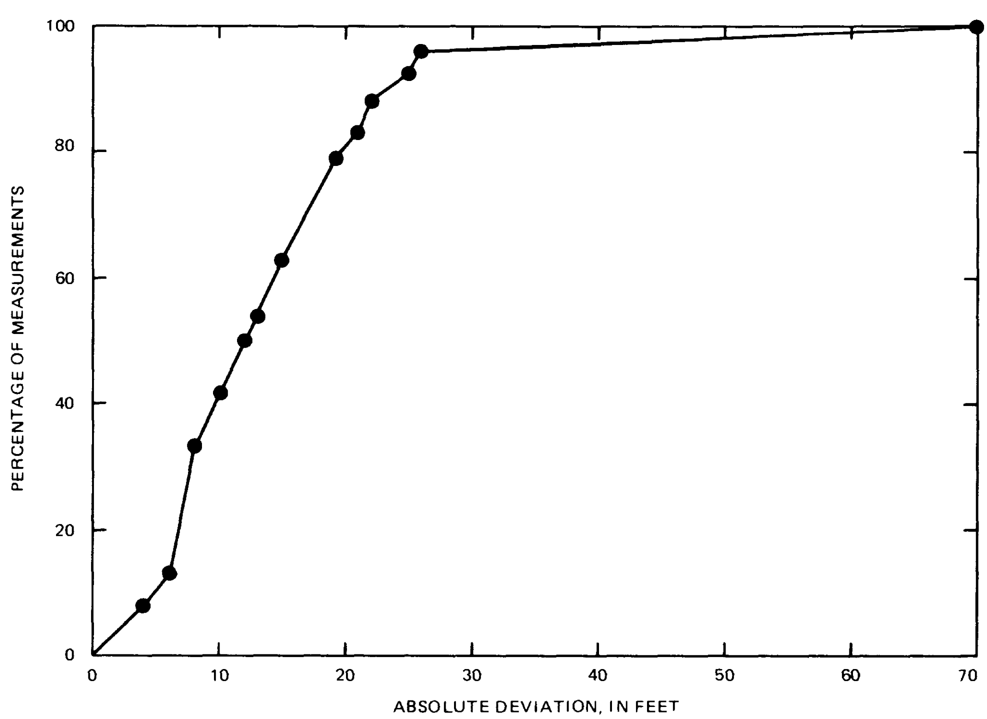

FIGURE 15. - - Cumulative distribution of deviation of model-generated water levels.

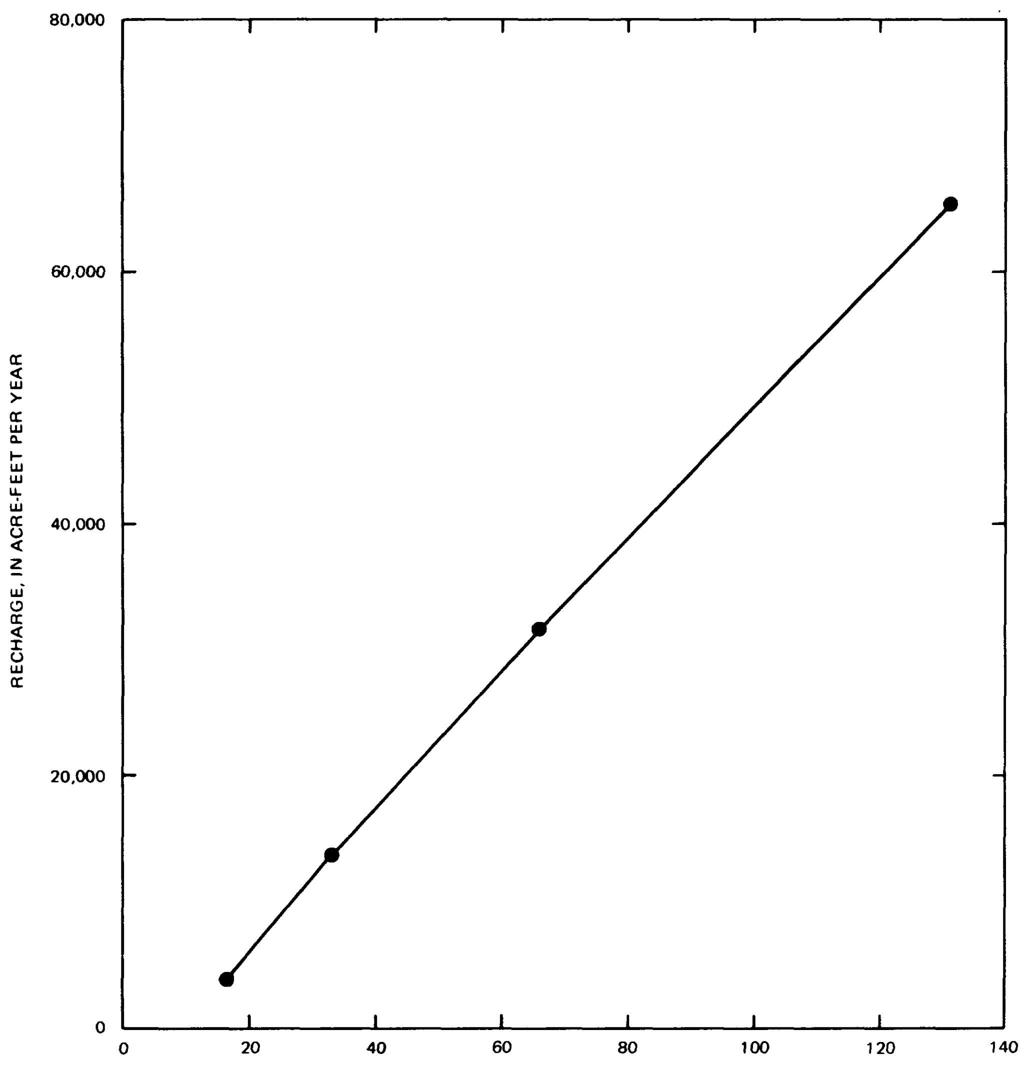

FIGURE 16. - - Relationship of recharge to hydraulic conductivity.

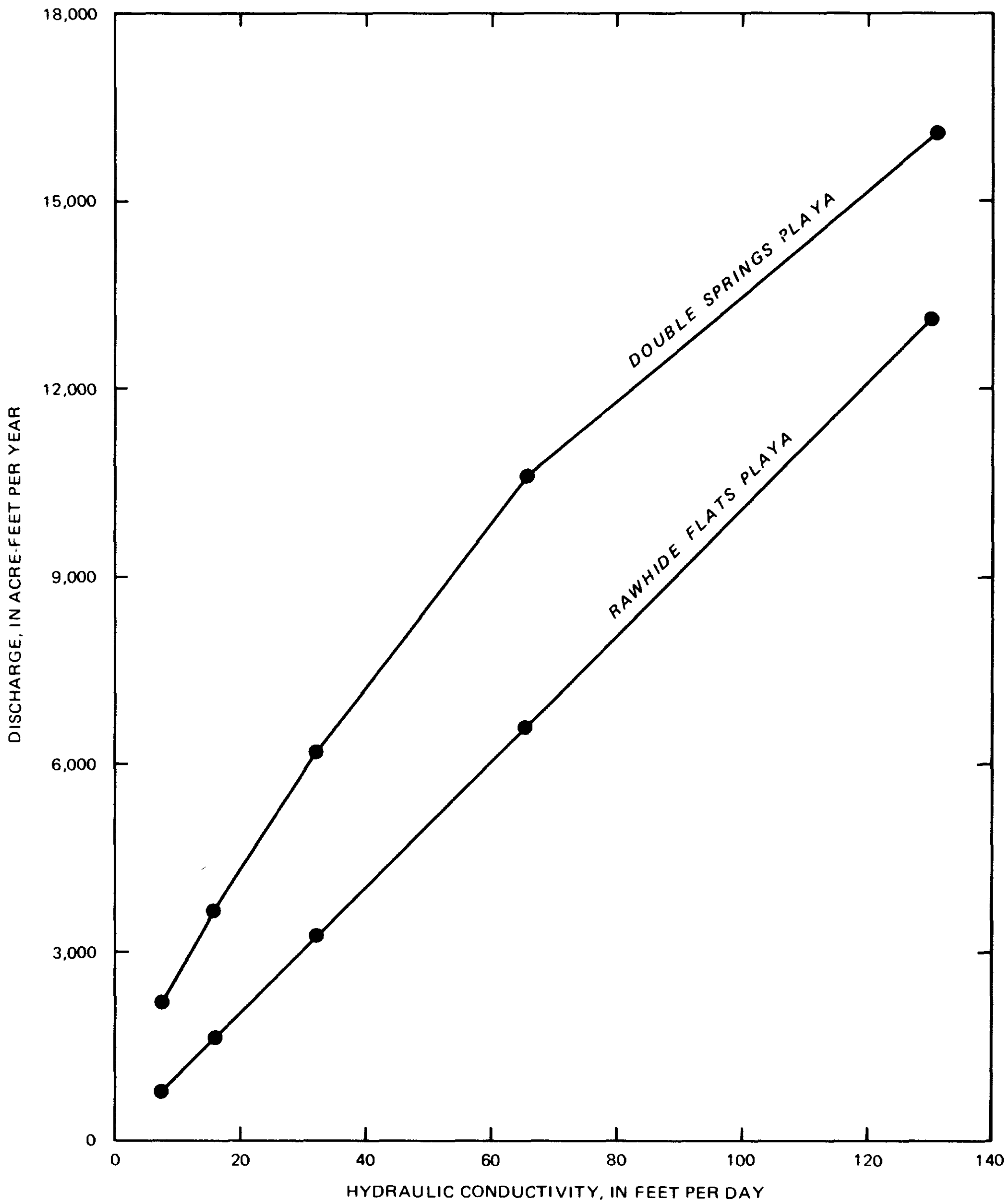

FIGURE 17. - - Relationship of discharge at playas to hydraulic conductivity.

Well-Site Evaluations

Representatives of the tribe are interested in seven areas for the construction of new stock and irrigation wells (Randall Emm, written commun., 1978). The suitability of any area for the drilling of a well depends on three basic factors:

(1) Depth to ground water in the area is one important factor. This dictates the expense of drilling the well initially plus the operation cost once the well is put into production.

(2) Expected chemical quality of the ground water is another important factor. The important point to consider is what the intended use of the water will be. Water from a well intended for irrigation use must be of better quality, in many cases, than water intended for stock use.

(3) Expected yield from a well is also an important consideration. Although this is a very subjective determination, often depending on how well the well is constructed, an approximation can be based on expected lithology.

On the basis of the above criteria, the seven well sites shown in figure 18 were evaluated.

Site 1

Location. Northwest corner of section 32, T. 14 N., R. 28 E.
Altitude. 4,320 ft (estimated from topographic map)
Intended use. Stock supply
Estimated depth to water. 50-100 ft
Suggested depth of well. 150-200 ft
Estimated yield. 50-100 gal/min
Estimated water quality. Good for livestock (specific conductance 500-700 micromhos)
Evaluation. The site is in a relatively flat area a little more than 1 mi west of Weber Dam and 0.6 mi northwest of access road to Weber Reservoir. Alluvial deposits in this area are fairly coarse sand and gravel with possibly some finer-grained material.

Site 2

Location. Sunshine Flat, section 16, T. 14 N., R. 28 E.
Altitude. 4,277 ft (estimated from topographic map)
Intended use. Stock supply
Estimated depth to water. 100 ft or less
Suggested depth of well. 200 ft
Estimated yield. 100 gal/min
Estimated water quality. Good for livestock (specific conductance less than 1,000 micromhos)
Evaluation. The site is in Sunshine Flat about 1 1/2 mi north of the river. The area is fairly flat, but there are no access roads. Alluvial deposits are probably fairly coarse grained.

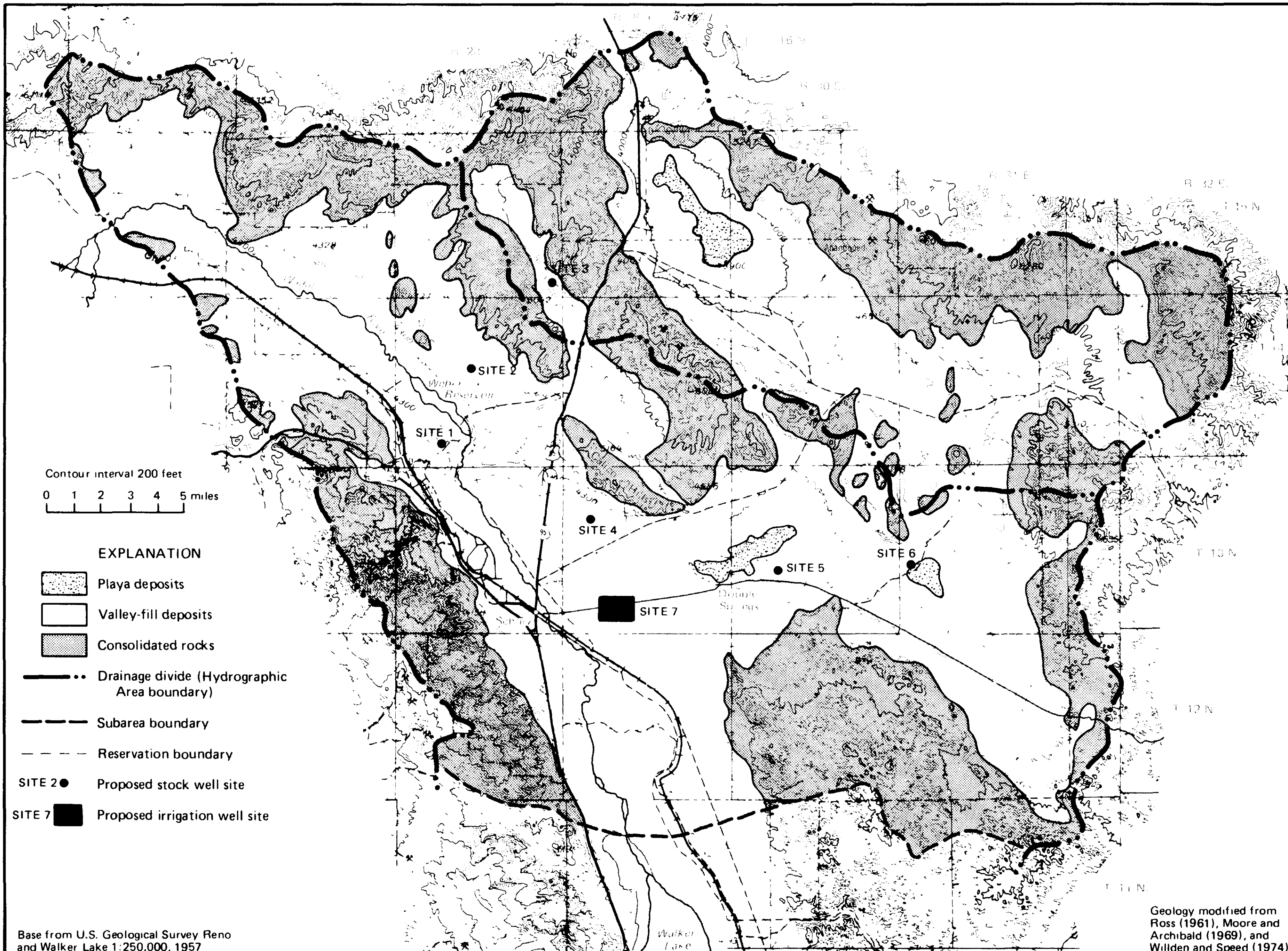

FIGURE 18. - - Proposed well sites.

Site 3

Location. Long Valley, section 25, T. 15 N., R. 28 E.
Altitude. Averages about 4,840 ft (estimated from topographic map)
Intended use. Stock supply
Estimated depth to water. Less than 300 ft
Suggested depth of well. Maximum of 400 ft
Estimated yield. Not enough data to judge
Estimated water quality. No data
Evaluation. The site is in Long Valley, about 3 mi northwest of road to Fallon. Not much data exists about the hydrologic nature of the valley. There is one dry well (15N/28E-10DD) at the north end of the valley, just off the reservation (Data section).

Minor stands of greasewood in the vicinity of the well site suggests that depth to water may be less than 100 ft. A test well drilled in the area of the site would provide needed data. Site warrants further study.

Site 4

Location. Section 18, T. 13 N., R. 29 E.
Altitude. 4,200 ft (from topographic map)
Intended use. Stock supply
Estimated depth to water. 100-150 ft
Suggested depth of well. 200-250 ft
Estimated yield. Not enough data to judge
Estimated water quality. Not enough data to judge
Evaluation. The site is about 1 mi south of an existing stock well (13N/29E-7AA). The present well has serious water-quality problems with high dissolved solids (Data section). A new well to the south may have better water. The reason for the poor quality of the water in the existing well is not known, and limited water-quality data exist for the surrounding area; a test well should probably be drilled first. Site warrants further study.

Site 5

Location. Northwest corner of section 20, T. 13 N., R. 30 E.
Altitude. Averages about 4,100 ft (estimated from topographic map)
Intended use. Stock supply
Estimated depth to water. Less than 100 ft
Suggested depth of well. 200 ft
Estimated yield. 25-50 gal/min
Estimated water quality. Fair (specific conductance probably less than 3,000 micromhos)
Evaluation. The reason for drilling a well in this area is to take advantage of the confining layer that causes Double Spring and well 13N/29E-25BA to flow. The extent of this clay layer is not known and may be locally discontinuous. Even if a well drilled in this area did not penetrate a confined aquifer, the well might be suitable for stock supply. The water in this area, based on an analysis for well 13N/29E-25BA, may be of fair quality.

Site 6

Location. Section 19, T. 13 N., R. 31 E.
Altitude. 4,280 ft (estimated from topographic map)
Intended use. Stock supply
Estimated depth to water. 250-300 ft
Suggested depth of well. 350-400 ft
Estimated yield. 25 gal/min
Estimated water quality. Fair (specific conductance 1,000-4,000 micromhos)
Evaluation. Again, in an effort to take advantage of the confining layer that exists to the west, a stock well was considered for this location. However, the probability of the clay layer being present in this area is remote. Additional problems are the great depth to water and the chance of poor water quality due to the proximity of the playa. For these reasons this area does not warrant further study unless the need is great for a stock well.

Site 7

Location. Sections 28, 29, 32, 33, T. 13 N., R. 29 E.
Altitude. 4,150 ft (estimated from topographic map)
Intended use. Irrigation supply
Estimated depth to water. 50 to 75 ft
Suggested depth of well. 150 to 175 ft
Estimated yield. 50-100 gal/min (minimum)
Estimated water quality. Good for livestock (specific conductance 500-750 micromhos)
Evaluation. This site is on rolling terrain about 3 mi east of Schurz. The tribe is interested in expanding agricultural operations on the reservation, and the possibility exists of drilling many irrigation wells. The site appears to be well suited for the intended purpose. Water quality is probably suitable for irrigation use. Water is shallow enough for pumping.

Available and Future Water Supplies

Ground Water

The possibility exists of making more use of the available ground-water supply. As of 1978, 5.5 million acre-ft of usable ground water (200 ft of saturated thickness) existed in the Schurz subarea, with another 1.5 million acre-ft in the Rawhide Flats area. Continued pumping at the 1978 rate, or even a tenfold increase, will not appreciably lower ground-water levels. The situation along the river is such that the more ground water is pumped, the more water enters the system from the river. For this reason no estimate of a sustained-yield rate for the Schurz subarea is made.

The Rawhide Flats hydrographic area also seems to have an adequate ground-water supply for current ground-water uses as well as any planned expansion. If pumpagebegins to lower water levels, a program of evapotranspiration salvage at the playa could be activated. This would involve destroying the phreatophytes that use ground water.

In many areas of the reservation, ground water is close to the surface, is of good quality, and exists in large quantities. More use of ground water for supplying water requirements for the reservation is possible in the future.

Surface Water

The present use of surface water for irrigation on the reservation accounts for only 28 percent of the streamflow of water entering the reservation in an average year. However, it should be noted that the Walker River is the major source of water for Walker Lake. Any substantial increase of water usage from the river means less water flowing into the lake and declining lake levels. Careful management practices will be necessary for responsible resource utilization.

BASIC DATA

TABLE 11.--*Description of selected wells*

Use: D, destroyed; H, domestic; I, irrigation; S, stock; U, unused.
Yield, drawdown, and depth to water: R, reported; F, flow; E, estimated.
Data: C, chemical analysis in table 14; L, log available; W, other water levels available.

Well location	Owner	Use of well	Year drilled	Depth of well (feet)	Diameter (inches)	Land-surface altitude (feet above sea level)	Yield (gal/min) and drawdown (feet)	Date measured	Depth to water: Feet below land surface	Depth to water: Date measured	Data
12N/28E-2AA	Jack Manhire	H	--	--	6	4,180	--	--	80.39	4-17-78	C
-24AA	Walker River Tribe	I	1977	375	16	4,070	2,500/96R	10- -77	35.5R	10- -77	L
12N/29E-6BB	Sam Clyde	H	1974	56	6	4,113	10/1R	9- -77	18R	9- -77	C,L
-8AA	Randy Emm	H	1975	103	6	4,100	--	--	28.17	1-12-78	C
-8AC	Louie Williams	H,S	--	--	8	4,100	--	--	--	--	C
-8BA1	Rodger Williams	H,S	1978	110	6-1/2	4,100	--	--	26.04	1-12-78	C
-8BA2	Rodger Williams	H,S	--	55	8	4,100	--	--	--	--	C
-8DC	Warren Emm	S	1977	77	6-5/8	4,095	40/3R	11- -77	23.35	1-12-78	L,W
-9BC	John Berry	H,S	--	--	6	4,100	--	--	4.60	1-12-78	C,W
-9CB	John Olesnowich	H	--	--	6	4,095	--	--	28.75	1-12-78	C
-14B	Walker River Tribe	S	--	47	8	4,115	--	--	41.02	1-12-78	--
-16BD	Walker River Tribe	I	1977	350	16	4,082	2,500/56R	8- -77	13R	8- -77	L
-20AC	Walker River Tribe	I	1977	460	16	4,060	2,500/113R	4- -77	33R	9- -77	L
-21BB	Walker River Tribe	I	1977	470	16	4,079	2,500/66R	9- -77	32R	9- -77	L
12N/31E-14AB	Walker River Tribe	S	1966	502	8-5/8	4,398	15/0R	1- -66	455R	2-17-66	L,W
13N/28E-15DC	John Hoffman	S	--	--	--	4,135	--	--	--	--	C
-22C	Reynold Sammarip	H	1972	133	6-5/8	4,140	--	--	20.12	4-17-78	--
-26AA	Walker River Tribe	S	1977	124	8-5/8	4,170	40/4R	8- -77	55R	8- -77	L
-26BB	Betty Rodgers	H	--	--	--	4,135	--	--	--	--	C
-27C	Jonathan Hicks	H	1974	56	6	4,145	10/2R	3- -74	22.0	3- -74	L
-35A	Walker River Tribe	H	1932	24.7	87	4,120	--	--	18.35	8- 8-50	C
-36B1	Southern Pacific Transp. Co.	D	1945	190	12	4,120	266/34R	4- -45	16.4	4- -45	C,L
-36B2	Southern Pacific Transp. Co.	D	--	16.3	84	4,120	--	--	11.34	8- 8-50	C
13N/29E-7AA	Walker River Tribe	S	1966	212	8	4,278	15/?R	1- -66	144.15	4- 4-78	C,L,W
-25BA	Walker River Tribe	S	1948	102	7	4,060	16F	2- 6-78	Flows	2- 6-78	C,L
-31DA	Walker River Tribe	S	1977	114	8-5/8	4,140	50/2R	11- -77	58.35	1-12-78	C,L
13N/30E-21	Walker River Tribe	U	--	87	6	4,130	--	--	--	--	--
13N/31E-20AA	Walker River Tribe	S	--	380	8	4,315	--	--	348.20	1-10-78	--
14N/27E-8AC	U.S. Geol. Survey	U	1964	52	1-1/2	4,318	--	--	43.20	3-16-66	C
-9BB	U.S. Geol. Survey	U	1964	62	1-1/2	4,280	--	--	52.26	3-16-66	C
14N/29E-19DB	Walker River Tribe	S	1978	--	6	4,645	--	--	300R	1- -78	C
14N/30E-4CC	Walker River Tribe	S	1965	162	8-5/8	4,041	10/?R	1- -65	145R	1- -65	L
14N/31E-21B1	Walker River Tribe	S	1934	615	6	4,520	--	--	Dry	6-22-78	--
-21B2	Walker River Tribe	S	1978	--	6	4,520	--	--	546.80	6-22-78	--
15N/26E-10BD	Bur. Land Mgmt.	S	1955	98	6	4,330	5/?R	12- -55	68.5	2- 6-78	C,L,W
-21CB	U.S. Geol. Survey	U	1964	32	1-1/2	4,312	--	--	25.07	3-16-66	C
15N/27E-21A	Bur. Land Mgmt.	S	--	--	6	4,450	--	--	158.94	2-16-66	--
15N/28E-10DD	Bur. Land Mgmt.	U	1967	241	6	5,005	--	--	Dry	4-25-78	--

TABLE 12.--*Description of selected springs*

Spring location	Owner	Use of water[1]	Land-surface altitude	Flow (gal/min)[1]	Date measured	Name	Data[1]
11N/29E-6DD	Walker River Tribe	U	4,020	100R	--	--	C
12N/30E-3DB	Walker River Tribe	U	4,610	0	2-06-78	Greasewood Spring	--
13N/29E-25BA	Walker River Tribe	U	4,060	10E	2-06-78	Double Spring	--

1. C, chemical analysis in table 14; E, estimated; R, reported; U, unused.

TABLE 13.--*Water-quality data for Walker River, water year 1978, and summary for period of record*[1]

WALKER RIVER NEAR WABUSKA (STA. NO. 10301500)

PERIOD OF RECORD.--February 1960 to current year.
CHEMICAL ANALYSES: October 1968 to September 1969, daily (composited) and monthly; October 1969 to current year, monthly.
SPECIFIC CONDUCTANCES: October 1968 to September 1976, once-daily; October 1976 to current year, monthly.
BIOLOGICAL DATA: October 1974 to September 1977, monthly; October 1977 to current year, monthly (seasonal).
MICROBIOLOGICAL DATA: October 1974 to current year, monthly.
WATER TEMPERATURES: February 1960 to September 1963, occasional; October 1963 to September 1968, monthly; October 1968 to September 1976, once-daily; October 1976 to current year, monthly.
SEDIMENT DATA: October 1973 to current year, monthly.

REMARKS.--Inflow from two drainage ditches enters stream less than a mile (1.6 km) above sampling site. Because inflow and stream-flow differ in quality, and because the waters do not mix thoroughly above sampling site, flow at site is not homogenous either chemically or thermally. This doubtless was responsible for some of the variation shown by daily specific-conductance and temperature data during water years 1969-76. Detailed sampling information is available from U.S. Geol. Survey office, Carson City, NV.

COOPERATION.--Pesticide analyses by U.S. Environmental Protection Agency.

EXTREMES MEASURED FOR PERIOD OF RECORD.--
SPECIFIC CONDUCTANCES: Maximum, 792 micromhos Dec. 12, 1972; minimum, 183 micromhos June 26, 1969.
PHYTOPLANKTON: Maximum, 120,000 cells/mL Mar. 27, 1975; minimum, 590 cells/mL Nov. 17, 1977.
FECAL STREPTOCOCCI: Maximum, 1,600 colonies/100 mL (non-ideal colony count) Dec. 23, 1977; minimum, 16 colonies/100 mL Mar. 9, 1976.
WATER TEMPERATURES: Maximum, 36.5°C July 28, 1961; minimum, freezing point on several days during winter months of most years.
SUSPENDED-SEDIMENT CONCENTRATIONS: Maximum, 1,720 mg/L Mar. 27, 1975; minimum, 10 mg/L Nov. 17, 1977.

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	FIELD PH (UNITS)	WATER TEMPER-ATURE (DEG C)	TUR-BID-ITY (JTU)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	COLI-FORM, FECAL, 0.45 UM-MF (COLS./100 ML)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./100 ML)
OCT										
04...	1000	12	687	--	10.0	--	--	--	--	--
17...	0955	.93	576	--	10.5	15	--	--	<2	--
NOV										
17...	1040	1.0	673	8.2	7.5	8	--	--	47	--
DEC										
02...	1020	1.2	711	--	5.0	--	--	--	--	--
23...	1000	13	611	8.4	2.0	90	--	--	110	--
JAN										
30...	1045	12	673	8.0	4.5	25	--	11.2	3	--
MAR										
02...	1010	20	648	8.2	8.5	40	--	--	150	--
31...	1040	8.2	673	8.4	12.0	30	--	9.8	62	--
APR										
25...	1010	85	634	8.1	12.0	95	--	10.0	--	290
MAY										
31...	1040	63	383	8.2	16.0	45	--	8.7	--	150
JUN										
28...	1015	35	449	7.9	19.0	--	6.9	8.1	--	72
AUG										
04...	1305	52	308	8.1	27.0	--	17	7.0	--	60
SEP										
12...	1320	111	396	8.4	17.5	--	3.2	8.9	--	19

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[1]Data from U.S. Geological Survey, 1979, p. 134-137, 142, 143. Pesticide analyses by U.S. Environmental Protection Agency.

WATER-QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	STREP-TOCOCCI FECAL, (COLS. PER 100 ML)	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)
OCT										
04...	--	--	--	--	--	--	--	--	--	--
17...	74	--	140	42	9.6	69	2.5	--	--	--
NOV										
17...	90	--	160	47	10	90	3.1	--	--	--
DEC										
02...	--	--	--	--	--	--	--	--	--	--
23...	K1600	--	150	45	11	74	2.6	5.7	170	100
JAN										
30...	160	--	170	46	12	81	2.7	5.5	190	110
MAR										
02...	130	--	160	46	12	77	2.6	5.8	160	100
31...	120	--	170	48	12	85	2.8	6.1	190	120
APR										
25...	--	420	100	28	7.4	36	1.6	4.8	120	40
MAY										
31...	--	200	110	30	7.6	39	1.6	5.5	130	42
JUN										
28...	--	170	130	36	9.6	50	1.9	6.2	140	55
AUG										
04...	--	160	100	30	6.7	36	1.5	5.6	130	37
SEP										
12...	--	98	120	34	7.4	38	1.5	4.6	140	44

DATE	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N)
OCT										
04...	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	.01	.01	.02	.01
NOV										
17...	--	--	--	--	--	--	.01	.01	.02	.01
DEC										
02...	--	--	--	--	--	--	--	--	--	--
23...	29	1.0	26	373	394	14.1	.27	.03	.30	.04
JAN										
30...	28	1.1	30	430	430	14.4	--	--	.06	.02
MAR										
02...	27	.8	28	408	406	22.0	--	--	.04	.01
31...	34	.9	25	412	441	9.12	--	--	.05	.03
APR										
25...	12	.8	16	217	219	49.3	--	--	.09	.11
MAY										
31...	16	.7	20	246	240	42.2	.02	.01	.03	.09
JUN										
28...	18	.8	20	291	280	27.5	.02	.00	.02	.00
AUG										
04...	12	.5	21	--	--	--	.04	.00	.04	.05
SEP										
12...	13	.6	21	247	247	74.0	.06	.01	.09	.11

K: NON-IDEAL COLONY COUNT.

WATER-QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, ORGANIC TOTAL (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, TOTAL (MG/L AS P)	PHOSPHORUS, DISSOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DISSOLVED (MG/L AS C)	CARBON, ORGANIC SUSPENDED TOTAL (MG/L AS C)
OCT										
04...	--	--	--	--	--	--	--	--	--	--
17...	--	.24	--	--	.27	.12	--	--	--	--
NOV										
17...	--	.24	--	--	.27	.14	--	--	--	--
DEC										
02...	--	--	--	--	--	--	--	--	--	--
23...	.09	.50	.44	.53	.84	.26	.10	5.4	--	--
JAN										
30...	--	.35	--	.63	.43	.16	.05	3.0	--	--
MAR										
02...	--	.40	--	.29	.45	.07	.05	--	3.9	--
31...	--	.56	--	.39	.64	.09	.08	--	3.5	1.4
APR										
25...	--	.81	--	.49	1.0	.37	.08	--	--	--
MAY										
31...	--	.77	--	.54	.89	.19	.08	6.0	--	--
JUN										
28...	--	.52	--	.51	.54	.14	.09	--	7.0	.5
AUG										
04...	--	.49	--	--	.58	.18	.12	5.4	--	--
SEP										
12...	.00	.64	.36	.36	.84	.13	.09	--	12	.2

DATE	TIME	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DISSOLVED (UG/L AS AS)	BARIUM, TOTAL RECOVERABLE (UG/L AS BA)	BARIUM, DISSOLVED (UG/L AS BA)	BORON, DISSOLVED (UG/L AS B)	CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	CADMIUM DISSOLVED (UG/L AS CD)	CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR)	CHROMIUM, DISSOLVED (UG/L AS CR)
DEC										
23...	1000	14	13	--	--	--	<10	1	0	0
MAR										
31...	1040	20	15	100	0	610	<10	5	0	0
JUN										
28...	1015	19	17	300	200	430	--	--	10	0
SEP										
12...	1320	14	14	200	200	270	--	--	10	0

DATE	COBALT, TOTAL RECOVERABLE (UG/L AS CO)	COBALT, DISSOLVED (UG/L AS CO)	COPPER, TOTAL RECOVERABLE (UG/L AS CU)	COPPER, DISSOLVED (UG/L AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	IRON, DISSOLVED (UG/L AS FE)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	LEAD, DISSOLVED (UG/L AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)
DEC									
23...	<10	0	30	2	4700	20	60	13	210
MAR									
31...	<10	2	<10	2	1500	10	30	10	260
JUN									
28...	3	2	12	4	1200	30	--	--	130
SEP									
12...	0	0	7	2	650	30	--	--	60

DATE	MANGANESE, DISSOLVED (UG/L AS MN)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)	MERCURY DISSOLVED (UG/L AS HG)	SELENIUM, TOTAL (UG/L AS SE)	SELENIUM, DISSOLVED (UG/L AS SE)	SILVER, TOTAL RECOVERABLE (UG/L AS AG)	SILVER, DISSOLVED (UG/L AS AG)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	ZINC, DISSOLVED (UG/L AS ZN)
DEC									
23...	70	.2	.0	0	0	--	--	40	0
MAR									
31...	140	.0	.0	0	0	<10	0	20	0
JUN									
28...	20	.0	.0	0	0	1	0	20	0
SEP									
12...	0	.0	.2	0	0	0	0	10	10

WATER-QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	TIME	PCB, TOTAL (UG/L)	PCB, TOTAL IN BOTTOM MATERIAL (UG/KG)	ALDRIN, TOTAL (UG/L)	ALDRIN, TOTAL IN BOTTOM MATERIAL (UG/KG)	ATRAZINE, TOTAL (UG/L)	ATRAZINE, TOTAL IN BOTTOM MATERIAL (UG/KG)	CHLORDANE, TOTAL (UG/L)	CHLORDANE, TOTAL IN BOTTOM MATERIAL (UG/KG)	DDD, TOTAL (UG/L)
NOV 17...	1040	ND	ND	ND	ND	--	ND	ND	ND	ND
MAR 31...	1040	ND	--	ND	--	ND	--	ND	--	ND
MAY 31...	1040	ND	ND	ND	ND	ND	--	ND	ND	ND
SEP 12...	1520	ND	--	ND	--	--	--	ND	--	ND

DATE	DDD, TOTAL IN BOTTOM MATERIAL (UG/KG)	DDE, TOTAL (UG/L)	DDE, TOTAL IN BOTTOM MATERIAL (UG/KG)	DDT, TOTAL (UG/L)	DDT, TOTAL IN BOTTOM MATERIAL (UG/KG)	DIAZINON, TOTAL (UG/L)	DIAZINON, TOTAL IN BOTTOM MATERIAL (UG/KG)	DIELDRIN TOTAL (UG/L)	DIELDRIN, TOTAL IN BOTTOM MATERIAL (UG/KG)	ENDRIN, TOTAL (UG/L)
NOV 17...	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MAR 31...	--	ND	--	ND	--	ND	--	ND	--	ND
MAY 31...	ND	ND	ND	ND	ND	--	ND	ND	ND	ND
SEP 12...	--	ND	--	ND	--	ND	--	ND	--	ND

DATE	ENDRIN, TOTAL IN BOTTOM MATERIAL (UG/KG)	ETHION, TOTAL (UG/L)	ETHION, TOTAL IN BOTTOM MATERIAL (UG/KG)	HEPTACHLOR, TOTAL (UG/L)	HEPTACHLOR, TOTAL IN BOTTOM MATERIAL (UG/KG)	HEPTACHLOR EPOXIDE TOTAL (UG/L)	LINDANE TOTAL (UG/L)	LINDANE TOTAL IN BOTTOM MATERIAL (UG/KG)	MALATHION, TOTAL (UG/L)	MALATHION, TOTAL IN BOTTOM MATERIAL (UG/KG)
NOV 17...	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MAR 31...	--	ND	--	ND	--	ND	ND	--	ND	--
MAY 31...	ND	--	ND	ND	ND	ND	ND	ND	--	ND
SEP 12...	--	ND	--	ND	--	ND	ND	--	ND	--

DATE	METHOXYCHLOR, TOTAL (UG/L)	METHOXYCHLOR, TOT. IN BOTTOM MATL. (UG/KG)	METHYL PARATHION, TOTAL (UG/L)	METHYL PARATHION, TOT. IN BOTTOM MATL. (UG/KG)	METHYL TRITHION, TOTAL (UG/L)	METHYL TRITHION, TOT. IN BOTTOM MATL. (UG/KG)	PARATHION, TOTAL (UG/L)	PARATHION, TOTAL IN BOTTOM MATERIAL (UG/KG)	TOXAPHENE, TOTAL (UG/L)	TOXAPHENE, TOTAL IN BOTTOM MATERIAL (UG/KG)
NOV 17...	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MAR 31...	ND	--	ND	--	ND	--	ND	--	ND	--
MAY 31...	ND	ND	--	ND	--	ND	--	ND	ND	ND
SEP 12...	ND	--	ND	--	ND	--	ND	--	ND	--

DATE	TOTAL TRITHION (UG/L)	TRITHION, TOTAL IN BOTTOM MATERIAL (UG/KG)	2,4-D, TOTAL (UG/L)	2,4-D, TOTAL IN BOTTOM MATERIAL (UG/KG)	2,4,5-T TOTAL (UG/L)	2,4,5-T TOTAL IN BOTTOM MATERIAL (UG/KG)	SILVEX, TOTAL (UG/L)	SILVEX, TOTAL IN BOTTOM MATERIAL (UG/KG)	SIMAZINE TOTAL COULSON COND. (UG/L)	SIMAZINE IN BOTTOM MATERIAL (UG/KG DRY SOLIDS)
NOV 17...	ND	ND	ND	ND	ND	ND	ND	ND	--	ND
MAR 31...	ND	--	ND	--	ND	--	ND	--	ND	--
MAY 31...	--	ND	--	--	--	--	--	--	ND	--
SEP 12...	ND	--	--	--	--	--	--	--	--	--

ND: NONE DETECTED.

TABLE 13.--*Water-quality data for Walker River*--Continued

WALKER RIVER ABOVE WEBER RESERVOIR NEAR SCHURZ (STA. NO. 10301600)

PERIOD OF RECORD.--June 1977 to current year.
CHEMICAL ANALYSES: June 1977 to current year, monthly.
SPECIFIC CONDUCTANCES AND WATER TEMPERATURES: June to October 1977, twice-monthly; November 1977 to current year, monthly.

EXTREMES MEASURED FOR PERIOD OF RECORD.--
SPECIFIC CONDUCTANCES: Maximum, 705 micromhos Jan. 30, 1978; minimum, 365 micromhos April 25, 1978.
WATER TEMPERATURES: Maximum, 26.0°C July 22, Aug. 11, 1977; minimum, 4.0°C Dec. 23, 1977.

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	WATER TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	SODIUM AD-SORP-TION RATIO	BORON, DIS-SOLVED (UG/L AS B)
OCT										
04...	1145	11	591	13.5	--	--	--	--	--	--
17...	1120	.06	400	15.0	130	37	9.8	53	2.0	430
NOV										
17...	1220	.03	423	10.5	120	34	8.9	43	1.7	320
DEC										
02...	1105	.05	435	8.0	--	--	--	--	--	--
23...	1140	14	607	4.0	150	42	10	72	2.6	530
JAN										
30...	1310	7.2	705	5.0	170	48	12	85	2.8	590
MAR										
02...	1215	17	648	8.5	160	45	12	77	2.6	570
31...	1320	7.9	650	12.5	170	48	12	79	2.6	580
APR										
25...	1250	89	365	13.5	100	30	7.0	35	1.5	320
MAY										
31...	1250	60	414	18.0	120	33	8.1	44	1.8	350
JUN										
28...	0855	21	490	15.5	140	40	9.2	53	2.0	430
AUG										
04...	1100	41	420	24.0	120	34	7.9	43	1.7	350
SEP										
12...	1145	110	400	15.0	120	37	7.5	41	1.6	270

WALKER RIVER AT DIVERSIONS ABOVE SCHURZ (STA. NO. 10301750)

PERIOD OF RECORD.--May 1977 to current year.
CHEMICAL ANALYSES: June 1977 to current year, monthly.
SPECIFIC CONDUCTANCES: May 1977 to October 1977, twice-monthly; November 1977 to current year, monthly.
WATER TEMPERATURES: June to October 1977, twice-monthly; November 1977 to current year, monthly.

EXTREMES MEASURED FOR PERIOD OF RECORD.--
SPECIFIC CONDUCTANCES: Maximum, 743 micromhos Sept. 8, 1977; minimum, 473 micromhos, Sept. 12, 1978.
WATER TEMPERATURES: Maximum, 27.0°C Aug. 1, 1977; minimum, 4.0°C Dec. 23, 1977, Jan. 30, 1978.

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	WATER TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	SODIUM AD-SORP-TION RATIO	BORON, DIS-SOLVED (UG/L AS B)
OCT										
04...	1315	.06	603	17.0	--	--	--	--	--	--
17...	1245	10	609	14.0	150	42	11	74	2.6	620
NOV										
17...	1330	E.50	668	6.5	160	45	12	88	3.0	630
DEC										
02...	1250	E.50	671	6.0	--	--	--	--	--	--
23...	1330	.90	664	4.0	160	46	11	86	3.0	560
JAN										
30...	1425	.70	664	4.0	160	46	10	87	3.0	540
MAR										
02...	1320	.70	662	10.0	160	45	11	85	2.9	540
31...	1420	1.0	698	14.0	150	43	11	100	3.5	580
APR										
25...	1400	45	647	12.0	150	40	12	78	2.8	580
MAY										
31...	1425	72	582	19.5	150	42	11	70	2.5	490
JUN										
28...	0650	26	571	16.0	150	42	11	65	2.3	490
AUG										
04...	0915	70	509	23.0	140	39	9.3	57	2.1	450
SEP										
12...	0925	39	473	14.5	130	38	8.6	49	1.9	380

E: ESTIMATED.

TABLE 14.--*Water-quality data for wells and springs*

(Analyses by U.S. Geological Survey; results in milligrams per liter, except as noted)

Location	Date of collection	Use[1]	Temperature (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (as N)	Boron (B) (ug/L)	Iron (Fe) (ug/L)	Hardness as $CaCO_3$	Dissolved solids[2]	Sodium adsorption ratio	Specific conductance (micromhos)	Sodium hazard[3]
11N/29E-6DD[a]	3-08-66[b]	U	--	--	3.5	12	175[c]	--	265	23	92	60	--	--	--	--	56	640E	10	905	M
12N/28E-2AA	4-17-78	H	13	46	21	1.4	48	3.3	110	0	49	8.7	1.1	--	270	40	58	233	2.7	279	L
12N/29E-6BB	1-12-78	H	12	43	97	27	81	10	310	0	200	59	.3	--	1,100	90	350	671	1.9	1,020	L
-8AA	1-12-78	H	11	54	15	3.1	35	7.1	110	0	23	6.6	.4	--	250	30	50	199	2.2	261	L
-8AC	3-08-66	H,S	11.5	--	45	27	112[c]	--	372	0	104	37	--	--	--	--	222	640E	3.3	905	L
Do.	1-12-78	H	7	52	56	17	120	7.5	410	0	82	38	.8	--	720	530	210	577	3.6	873	L
-8BA2	1-12-78	H,S	8.5	44	91	27	160	12	230	0	290	160	.5	--	730	50	340	899	3.8	1,450	L
-9BC	1-12-78	H,S	6	43	5.9	.5	290	7.1	550	21	100	43	1.5	--	1,100	60	17	784	31	1,310	V
-9CB	1-12-78	H	12	50	1.7	.3	200	4.3	280	28	99	55	.7	--	1,000	270	5	578	37	931	V
12N/31E-14AB	2-18-66[b]	S	18	--	2.4	4.4	305[c]	--	484	28	129	78	--	--	--	--	24	920E	27	1,300	V
13N/28E-15DC	3-29-66[b]	S	--	--	90	32	39[c]	--	306	0	126	42	--	--	--	--	356	550E	.9	778	L
-26BB	3-29-66[b]	H	--	--	69	27	69[c]	--	294	0	127	43	--	--	--	--	283	570E	1.8	809	L
-27C1	3-08-66	H	--	--	70	16	636[b]	--	503	0	836	241	--	--	--	--	240	2,400E	18	3,380	V
-35A1	8-08-50	H	15.5	49	18	3.2	79[c]	--	130	0	84	22	2.0	0.1	400	20	58	322	4.5	469	L
-36B1	8-08-50	U	15	58	9.2	2.3	35[c]	--	94	0	20	5.8	.5	.2	200	20	32	177	2.7	203	L
-36B1	2-07-55	U	15	--	9.6	1.9	--	--	92	0	--	5.5	--	--	--	--	150E	--	206	--	L
-36B2	8-08-50	U	16.5	42	74	20	102[c]	--	308	0	166	44	0.4	.2	400	20	266	601	2.7	913	L
13N/29E-7AA	3-08-66[b]	S	--	--	324	46	1,820[c]	--	128	0	2,700	1,400	--	--	--	--	998	6,840E	25	9,630	V
-25BA	10-21-63	S	12.0	40	0	.4	685	14	534	166	347	295	8.8	.5	3,300	--	2	2,100E	240	2,950	V
-25BA	2-18-66[b]	S	--	--	1.8	1.6	654[c]	--	528	147	343	283	--	--	--	--	11	1,960E	86	2,760	V
Do.	2-06-78	S	13.5	37	1.5	1.0	670	12	860[d]	--	330	300	9.3	--	7,300	20	8	1,790	100	2,950	V
-31DA	1-12-78	S	12	56	17	3.5	25	4.8	100	0	21	5.8	.4	--	200	30	57	183	1.4	222	L
14N/27E-8AC	3-30-66	U	16	--	3.0	1.1	156[c]	--	26	98	93	49	--	--	--	--	12	630E	20	881	V
-9BB	3-30-66	U	--	--	14	2.4	83[c]	--	104	14	51	46	--	--	--	--	45	350E	5.4	489	L
14N/29E-19DB	3-13-78	S	13	140	10	.9	160	4.8	280	0	81	42	1.6	--	1,600	90	29	580	13	742	H
14N/31E-21B1	2-18-66[b]	S	18	--	9.0	8.1	73[c]	--	128	0	52	39	--	--	--	--	56	310E	4.2	432	L
15N/26E-10BD	2-16-66[b]	S	17	--	6.2	5.7	161[c]	--	219	13	127	40	--	--	--	--	39	520E	11	740	M
Do.	2-06-78	S	12	54	6.7	1.5	180	4.7	250	0	150	40	5.2	--	1,200	610	23	567	16	808	H
-21CB	3-30-66	U	18.5	--	9.5	.9	210[c]	--	0	78	176	104	--	--	--	--	29	920E	18	1,300	U

1. H, domestic; S, stock; U, unused.
2. "E" indicates dissolved-solids concentration estimated from specific conductance.
3. L, low; M, medium; H, high, V, very high. Based on relationships given by Richards (1954, fig. 25).

a. Spring; all other analyses are for well water.
b. Field-office analysis.
c. Calculated sodium plus potassium, expressed as sodium.
d. Bicarbonate plus carbonate, expressed as bicarbonate.

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