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HYDROLOGIC RECONNAISSANCE OF THE SEVIER LAKE AREA, WEST-CENTRAL UTAH

By

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Prepared by the
United States Geological Survey
in cooperation with the
Utah Department of Natural Resources
Division of Water Rights

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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
foot squared per day[1]	0.0929	meter squared per day
foot	0.3048	meter
foot per day	0.3048	meter per day
foot per mile	0.1894	meter per kilometer
foot per foot	0.3048	meter per meter
foot per year	0.3048	meter per year
gallon per minute	0.06308	liter per second
inch	25.4	millimeter
	0.0254	meter
mile	1.609	kilometer
square mile	2.59	square kilometer

Water temperature is given in degrees Celsius (°C) and air temperature is given in degrees Fahrenheit (°F). The conversion formulas are:

$$°C = 0.56\ (°F - 32)$$

$$°F = 1.8\ (°C) + 32.$$

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter (μS/cm) at 25 degrees Celsius.

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[1]An alternative way of expressing transmissivity is cubic foot per day per square foot, per foot of aquifer thickness.

Classification of Natural Water

[After Feltis, 1966, p. 8; from Robinove and others, 1958, p. 3]

Class	Dissolved-solids concentrations (milligrams per liter)	Specific conductance (microsiemens per centimeter at 25 °Celsius)
Fresh	0 to 1,000	0 to 1,400
Slightly saline	1,000 to 3,000	1,400 to 4,000
Moderately saline	3,000 to 10,000	4,000 to 14,000
Very saline	10,000 to 35,000	14,000 to 50,000
Briny	Greater than 35,000	Greater than 50,000

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The hydrologic system of the Sevier Lake area, at the terminus of the Sevier Lake drainage basin in west-central Utah, was studied during 1987-88 to determine baseline hydrologic conditions prior to anticipated development. Sevier Lake was reestablished during 1983-87 on the normally dry playa as a result of record volumes of surface-water runoff, but the lake was receding during the study. In June 1985, the lake reached a maximum depth of about 13 feet, with a water-surface altitude of 4,527 feet above sea level.

The basin-fill aquifer includes a coarse-grained facies at higher altitudes of the alluvial slopes and a fine-grained facies at lower altitudes around Sevier Lake. Water levels indicate a potential for lateral ground-water movement away from the lake and toward the northwest, west, and south.

Transmissivity of the coarse-grained facies, determined from one well, was 4,120 feet squared per day. Transmissivity values for the fine-grained facies ranged from 1×10^{-3} to 5×10^{-2} foot squared per day, determined from slug tests of shallow wells near the shoreline of the lake, and 5.2 feet squared per day determined from a well in the lakebed.

The predominant constituents of water sampled in the Sevier Lake area are sodium, sulfate, and chloride. The concentration of dissolved solids ranges from 480 to 120,000 milligrams per liter. Smaller concentrations of dissolved solids were determined for water from wells completed in the coarse-grained facies, and larger concentrations were determined for water from wells completed in the fine-grained facies.

INTRODUCTION

Sevier Lake is about 35 miles southwest of Delta and about 25 miles northwest of Milford, in west-central Utah (fig. 1). The water resources of the Sevier Lake area, which is defined by the local drainage basin in the immediate vicinity of ephemeral Sevier Lake, were assessed by the U.S. Geological Survey (USGS), in cooperation with the Utah Department of Natural Resources, Division of Water Rights, as part of a continuing program to describe the availability and quality of water within the State. The need for a water-resources assessment to establish baseline hydrologic conditions prior to potential mineral or industrial development is apparent from the lack of previous hydrologic studies for the area. The information provided in this study will allow land, water, mineral, and industrial managers to better understand the water resources of the area.

Purpose, Scope, and Method of Study

The purpose of this report is to describe baseline hydrologic conditions in the Sevier Lake area (fig. 1). The report includes information about surface-water inflow and historic lake levels; ground-water occurrence, recharge, movement, and discharge; aquifer characteristics of consolidated rocks and transmissivity of basin-fill deposits; chemical composition of surface water and ground water; and an approximate ground-water budget.

Data collection for this study included a computer and manual search of U.S. Geological Survey files for previously measured water-level data, water-quality analyses, and drillers' logs; measurement of ground-water levels; and collection of water samples. Data collected from May 1987 through March 1988 included: static water levels; water chemistry (including specific conductance, alkalinity, and pH); water samples for chemical analysis from 21 wells, 2 springs, and 1 surface-water site on the Sevier River; and 2 aquifer tests and 15 slug tests. Selected data collected prior to May 1987 are included in this report. Data from aquifer tests and slug tests were used to calculate point-specific values of transmissivity and hydraulic conductivity.

Slug-test data were collected from 15 shallow wells that were drilled by the U.S. Geological Survey during the Great Basin Regional Aquifer Systems Analysis study (1980-85) and by the Department of Defense during the MX-missile siting program (1978-80). The well casings were cleaned by flushing each well with fresh water several times. An air compressor and air line were used to completely evacuate the casing of residual water and water used for flushing before a water sample was collected. The previously described procedure ensured that water samples from the well were not contaminated by residual drilling mud and that water in the well was water from the surrounding aquifer. Slug-test recovery data were collected after evacuation to estimate local transmissivity and hydraulic conductivity of the aquifer. Water samples were collected from the flushed wells after the water levels had recovered to near static levels. The water samples were sent to the U.S. Geological Survey laboratory in Denver, Colorado, for chemical analysis.

Acknowledgments

Appreciation is extended to Larry Sower, Project Manager for the Crystal Peak Minerals Corporation, for his willingness to share information gained through years of experience associated with the harvesting of mineral brines and particularly his knowledge of Sevier Lake and vicinity, and to Murray C. Godbe III, consulting geologist, who enthusiastically shared his geologic knowledge of Sevier Lake and data gained during an extensive private drilling project during the late 1970's and early 1980's.

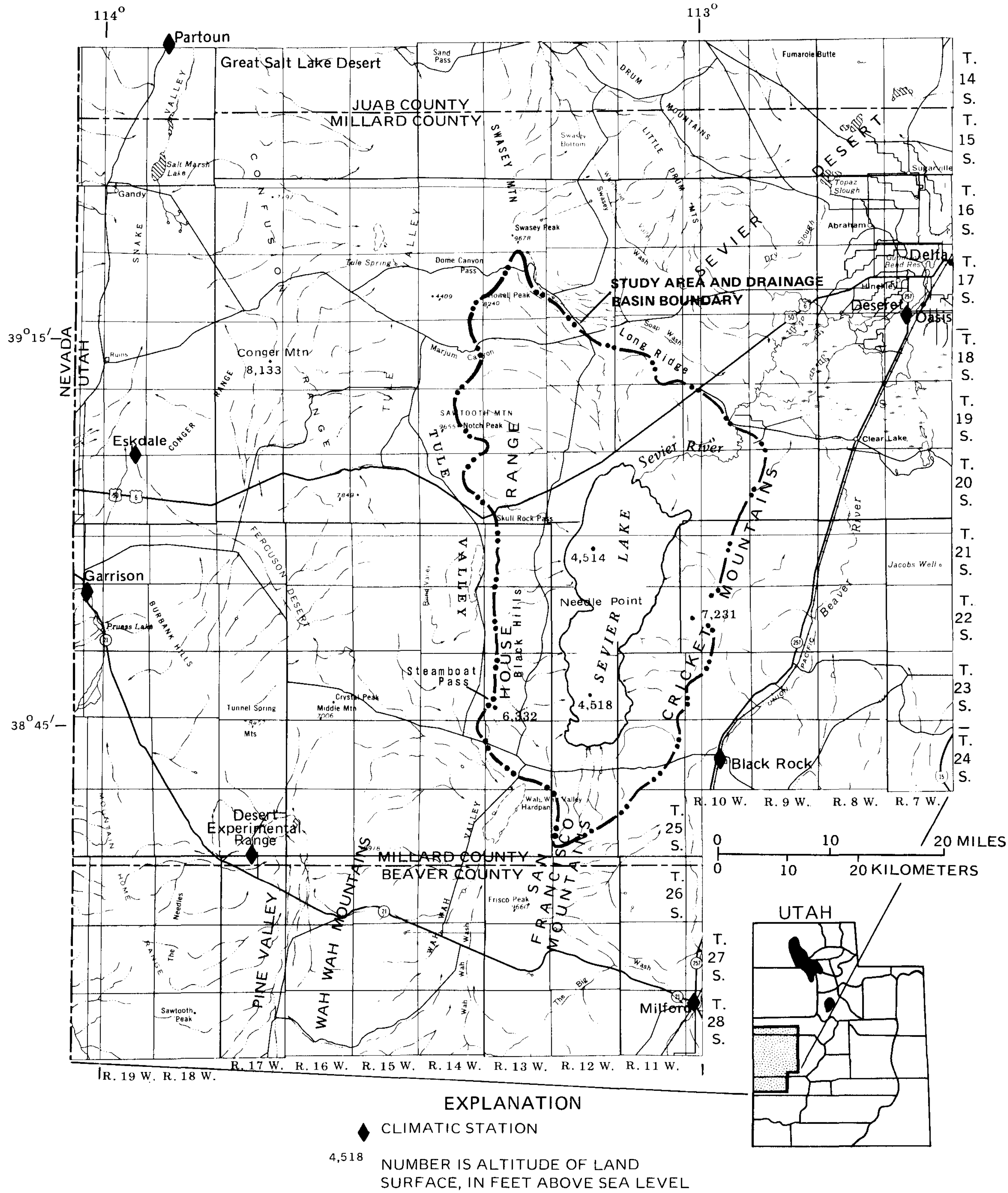

Figure 1.--Geographic features of west-central Utah, location of the Sevier Lake area, location of climatic stations, and selected land-surface altitudes.

Numbering System for Hydrologic-Data Sites

The system of numbering hydrologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the data site, describes its position in the land net. The land-survey system divides the State into four quadrants separated by the Salt Lake Base Line and the Salt Lake Meridian. These quadrants, designated by the uppercase letters A, B, C, and D, indicate the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range, in that order, follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section, which generally is 10 acres[1] for regular sections. The lowercase letters a, b, c, and d indicate the northeast, northwest, southwest, and southeast quarters of each subdivision, respectively. The number after the letters is the serial number of the hydrologic-data site within the 10-acre tract. The letter 'S' preceding the serial number designates a spring. Thus (C-19-11)34dcc-1 designates the first well constructed or visited in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, SE$\frac{1}{4}$, section 34, T. 19 S., R. 11 W., and (C-25-12)30ddb-S1 designates a spring in the NW$\frac{1}{4}$, SE$\frac{1}{4}$, SE$\frac{1}{4}$, section 30, T. 25 S., R. 12 W. The numbering system is shown in figure 2.

Geographic Setting

The Sevier Lake area of about 850 square miles in west-central Utah is in the interior-draining Great Basin (fig. 3). The Sevier Lake area is defined by the local Sevier Lake drainage basin in the immediate vicinity of ephemeral Sevier Lake (fig. 1) and is not to be confused with the larger Sevier Lake basin (fig. 3). The Sevier Lake area is characterized by north-trending, block-faulted ranges and alluvial slopes that encircle the down-dropped, sediment-filled Sevier Lake graben, which forms the lowest part of the basin. The Sevier River enters the undrained basin from the northeast at a topographic low point between the Cricket Mountains and Long Ridge (fig. 1). Ephemeral streams drain to Sevier Lake from the surrounding ranges. The ranges that surround the lake include the Black Hills, Sawtooth, and Swasey Mountains part of the House Range to the west and northwest; the low-lying Long Ridge to the north, the Cricket Mountains to the east; and the northern part of the San Francisco Mountains to the south. The slightly elevated Wah Wah Valley and Wah Wah Valley Hardpan are southwest of Sevier Lake and are separated from the lake by a low topographic divide. The geographic features of west-central Utah, the location of the Sevier Lake area, the location of climatic stations, and selected land-surface altitudes are shown in figure 1.

Altitudes within the study area range from about 4,514 feet above sea level on the bed of Sevier Lake to 9,655 feet above sea level atop Notch Peak

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[1]Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

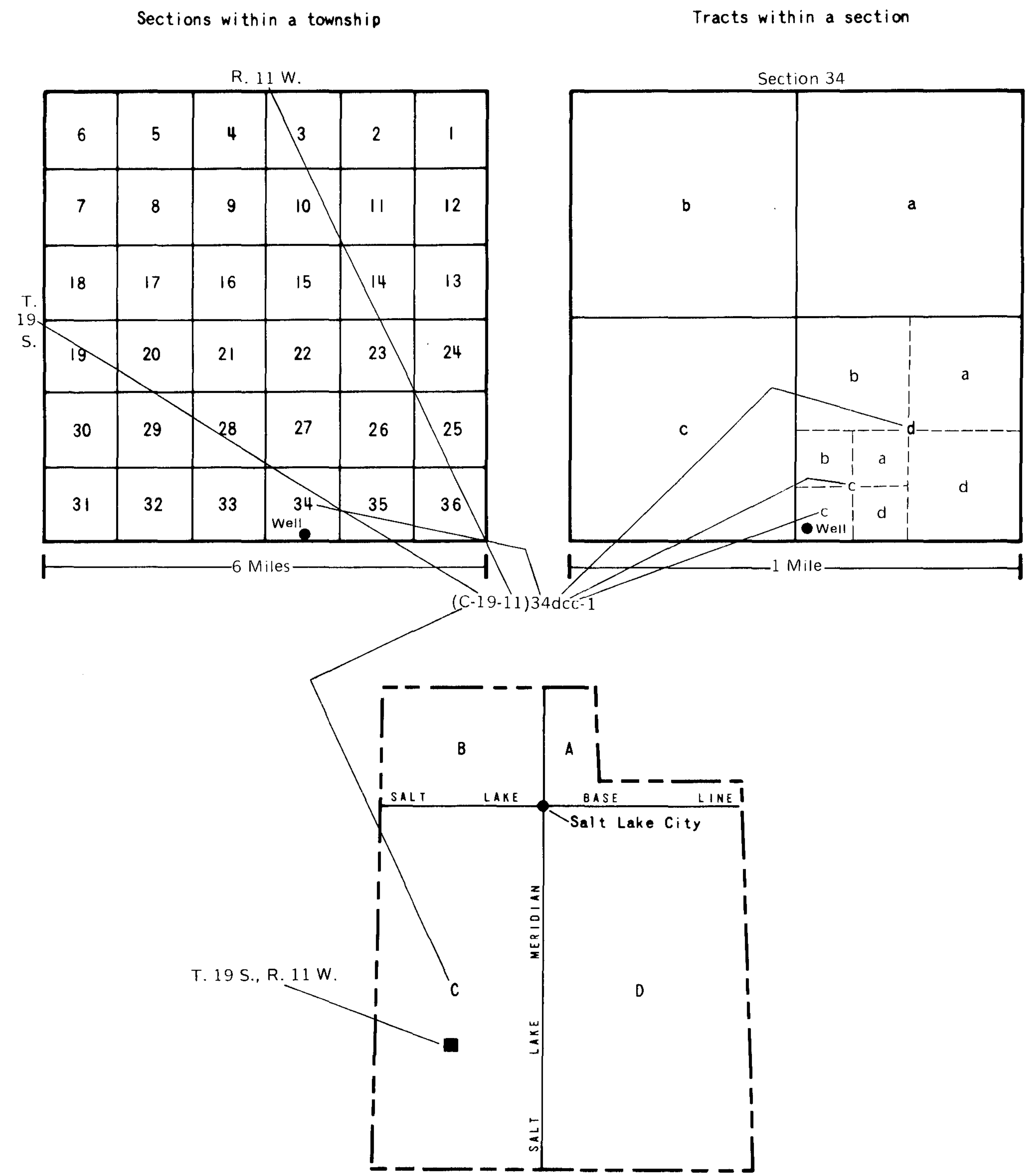


Figure 2.--Numbering system for hydrologic-data sites in Utah.

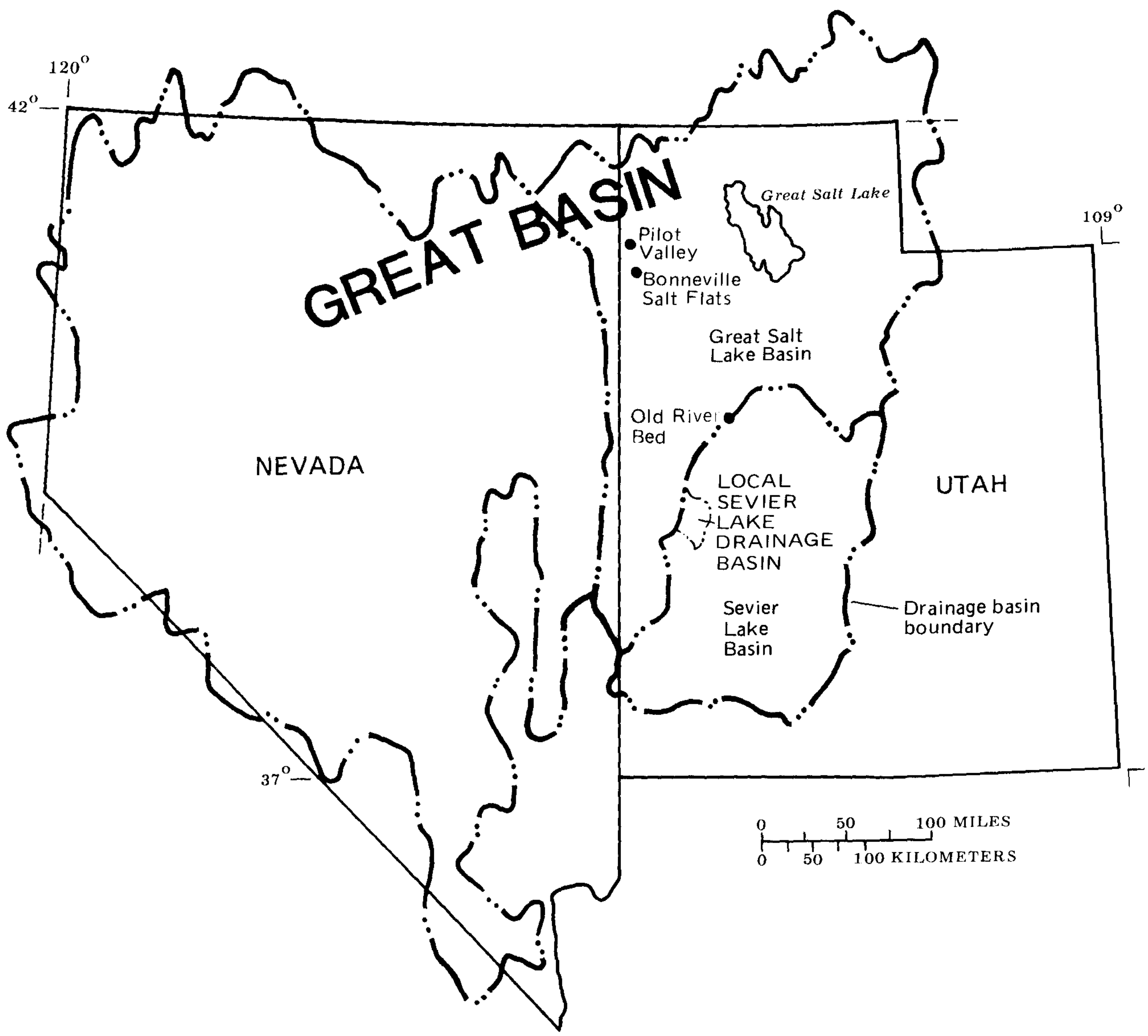


Figure 3.--Location of the local Sevier Lake drainage basin and other selected features within the interior drainage of the Great Basin.

in the Sawtooth Mountain part of the House Range. Intermediate high points are 7,231 feet above sea level in the Cricket Mountains and 6,332 feet above sea level in the Black Hills part of the House Range near Steamboat Pass.

The central feature of the study area, Sevier Lake, is a flat, vegetation-free, playa (fig. 1) at the terminus of the Sevier Lake basin. Since the late 19th century, surface-water inflow from the Sevier River to Sevier Lake has progressively diminished because of the expansion of irrigation in the area upstream. Presently (1988), surface-water flows rarely exceed upstream demands and provide inflow to the lake. This inflow occurs only during periods of excessive precipitation or upstream reservoir spillage. Since the early 1900's, substantial inflow from the Sevier River to Sevier Lake has occurred only in 1914, 1923, and in the early 1980's. For most of the 20th century, Sevier Lake probably has been dry.

Sevier Lake, which has been referred to as a lake, a dry lake, or a playa, is often dry except for ephemeral inflow. The term Sevier Lake is used in this report because that term is widely used in Utah and in previously published reports.

Climate

The climatic zones in the study area include desert (arid) on the playa floor and steppe (semiarid), possibly on the alluvial slopes and at the higher altitudes of the mountains. Stands of conifers indicate that limited areas of undifferentiated highland climate (subhumid to humid) might occur above an altitude of 7,000 feet. Desert climatic zones occur in areas where the average annual precipitation, usually about 5 to 8 inches, is less than one-half of the annual potential evapotranspiration. Most of the area receives less than 8 inches of annual precipitation. Steppe climatic zones are at higher altitudes peripheral to the margins of the desert zone where average annual precipitation, which generally ranges from 8 to 14 inches (Murphy, 1981, p. 55), is greater than one-half of the annual potential evapotranspiration. The undifferentiated highland climatic zone occurs where average annual precipitation generally exceeds potential evapotranspiration. The annual potential evapotranspiration varies from about 30 inches at the lower altitudes of the study area to about 18 inches at the higher altitudes (Richardson and others, 1981, p. 65).

During the summer, the study area primarily is affected by a warm, relatively dry Pacific air mass. Beginning in mid-July and continuing through August, warm masses of moist, tropical air circulate clockwise around the Bermuda High, intrude into the Pacific air mass, and bring infrequent but intense thundershowers to the study area.

The annual distribution and magnitude of precipitation directly affects the water budget of the area. Normal monthly precipitation for 1951-80 at seven stations near the study area is shown in figure 4. Selected climatic data for 1951-80 for the same stations are listed in table 1.

Vegetation

Within the study area, there are five vegetation zones, in order of greater altitude: salt flats, salt desert scrub, sagebrush-grassland, desert

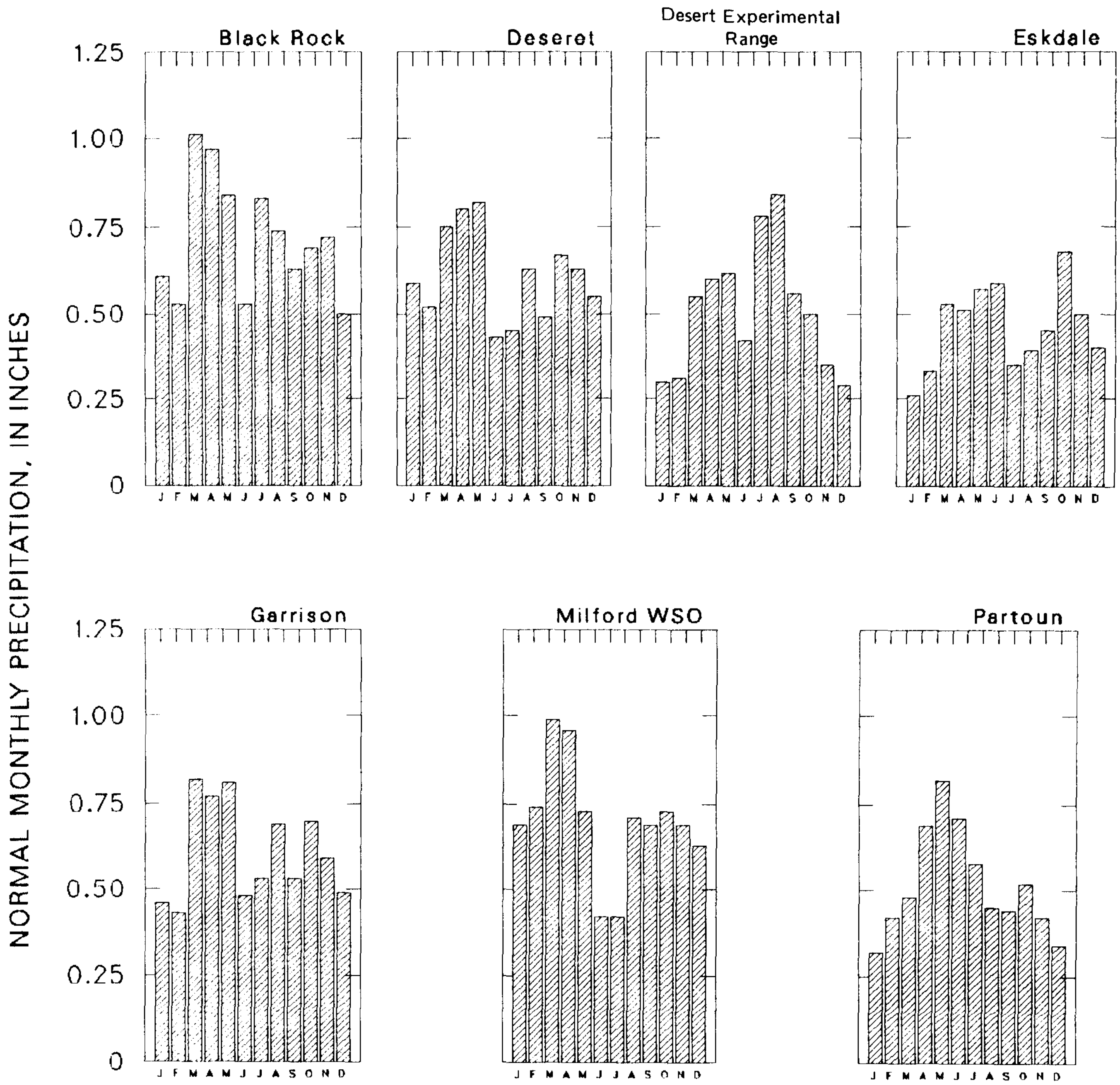


Figure 4.--Normal monthly precipitation for seven climatic stations near the Sevier Lake area, 1951-80.

Table 1.--Selected climatic data for seven climatic stations near the study area, 1951-80

[Data are from U.S. Department of Commerce, 1982; Stevens and others, 1983]

Climatic station	Altitude (feet above sea level)	Normal annual temperatures (degrees Fahrenheit)			Normal annual precipitation (inches)	Estimated annual pan evaporation (inches)	Annual freeze-free period (days)
		Maximum	Minimum	Mean			
Black Rock	4,895	66.9	31.8	49.4	8.60	80.00	108
Deseret	4,585	65.6	32.7	49.2	7.33	72.04	128
Desert Experimental Range	5,252	65.7	32.4	49.0	6.12	75.41	123
Eskdale	4,980	67.6	33.4	50.5	5.51	78.54	138
Garrison	5,275	66.2	34.7	50.4	7.30	73.36	135
Milford WSO	5,028	65.2	32.9	49.1	8.59	87.41	131
Partoun	4,750	66.7	33.1	49.9	6.19	76.84	123

woodland, and montane forest (Shultz and Shultz, 1984, p. 262). The salt-flats zone, which includes pickleweed, iodine bush, salt grass, and other halophyte associations, is next to the mudflats and playa and is characterized by highly saline soils and abundant soil moisture. Tamarisk and other phreatophytes are limited to the river bottoms along the downstream part of the Sevier River and to local sites on the shoreline of Sevier Lake where the zone of saturation is near the land surface. The salt-desert scrub zone, which includes greasewood, shadscale, and kochia plant associations, is on slightly higher ground and is characterized by well-drained soils that have large salt and alkali content and small organic-matter content. The annual precipitation for this zone is between 6 and 10 inches per year (Shultz and Shultz, 1984, p. 263). The sagebrush-grassland zone, which includes the grassland association and numerous sagebrush associations as well as rabbitbrush, is at higher altitudes where annual precipitation ranges from 10 to 16 inches per year, winters are cold, and soils generally are moderately deep, moderately alkaline, and well drained (Shultz and Shultz, 1984, p. 264). The desert-woodland zone, dominated by the pinyon-juniper association, typically is found where average annual precipitation is greater than 12 inches and altitudes range from 5,000 to 8,000 feet (Shultz and Shultz, 1984, p. 265). The montane-forest zone, which primarily consists of pine and fir conifer trees, is limited to the highest parts of the San Francisco Mountains that have north-facing slopes.

Geologic Setting

Metamorphic, sedimentary, and igneous rocks that range in age from Precambrian to Quaternary crop out in the Sevier Lake area. These rocks represent complex tectonic events and depositional environments that span nearly 1 billion

years. Low-grade metamorphic assemblages, principally quartzite, crop out in the San Francisco Mountains and are late Precambrian to Early Cambrian in age (Woodward, 1970, p. 1580). Early Paleozoic sedimentary clastic and carbonate rocks, deposited in a miogeocline, are exposed in the Cricket Mountains and the House Range (Hintze, 1984). The granitic intrusion exposed near Notch Peak is of Late Jurassic age (Hintze, 1973, p. 60). Limited outcrops of welded ash-flow tuffs in the Black Hills generally are Oligocene in age (Steven and Morris, 1983). Though not exposed within the study area, consolidated Tertiary shales, carbonate rocks, and halite deposits mixed with volcanic detritus have been detected in seven wells drilled in the nearby Sevier Desert area (Mitchell and McDonald, 1987, p. 547). Similar deposits are assumed to be in the subsurface of the Sevier Lake graben. Quaternary surficial materials, deposited in lacustrine, deltaic, playa, and eolian environments, are composed of thinly bedded clay, silt, and sand-sized clasts. Coarser-grained sediment, found at beach sites that mark the level of former lakes and on alluvial slopes, forms a veneer covering the consolidated-rock contacts within the study area. A block diagram of the generalized geomorphic setting, structural framework, and the relation between consolidated rocks and basin-fill deposits in the Sevier Lake area is shown in figure 5.

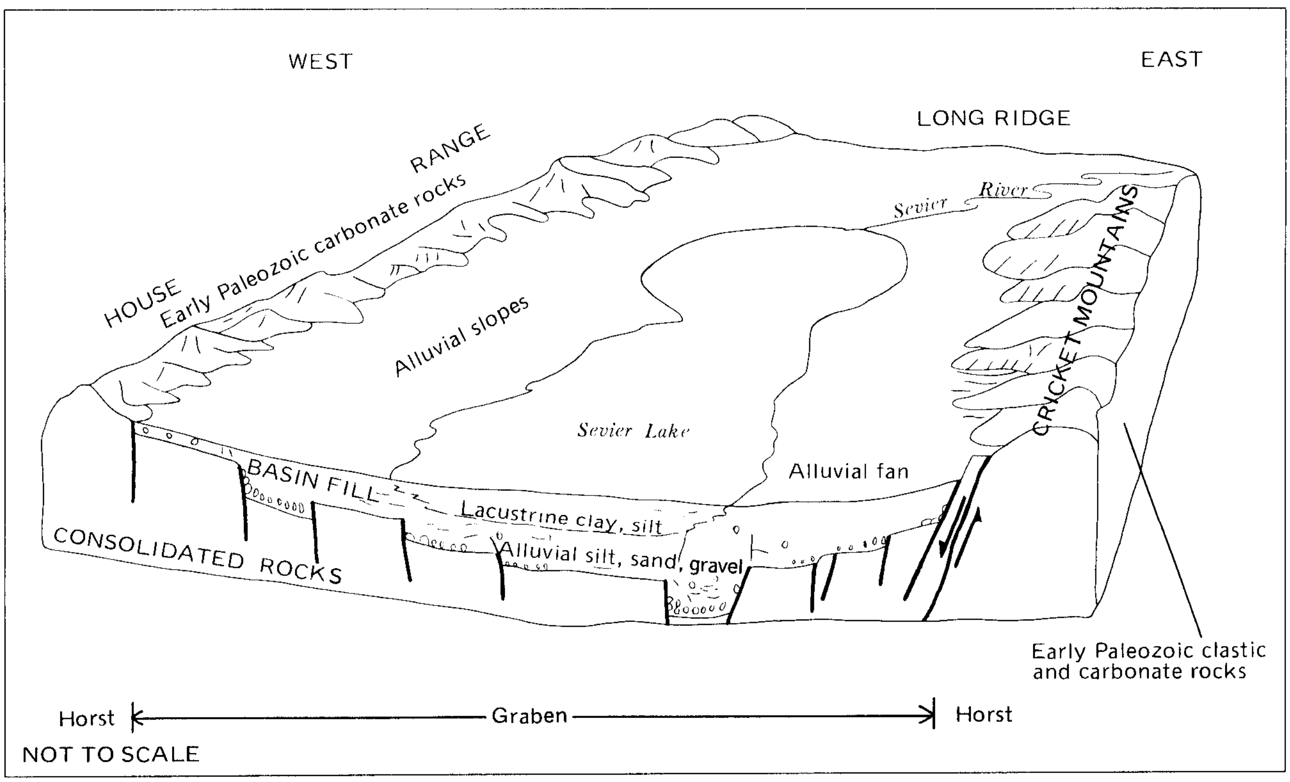


Figure 5.--Generalized block diagram showing geomophic setting, structural framework, and relation between consolidated rocks and basin-fill deposits in the Sevier Lake area.

Basin-fill deposits of Tertiary and younger age consist of unconsolidated alluvium on the alluvial slopes and consolidated, semiconsolidated, and unconsolidated sediments (possibly interbedded with volcanic rocks) as much as 4,600 feet thick in the Sevier Lake graben. During the Quaternary Period, the Sevier Lake graben was the catchment for all sediments and dissolved constituents transported by the Sevier River. Periodic evaporation of the lake water has concentrated and precipitated the dissolved constituents and has deposited potentially marketable quantities of brines and soluble salts in the basin-fill deposits.

Within the study area, structural features include the fault-bounded Sevier Lake graben, the Cricket Mountains and House Range horsts (fig. 5), and east-west-oriented lineaments and offsets. The eastward-tilted, asymmetric graben is bounded by two north-trending, en echelon fault zones having a maximum vertical displacement of approximately 4,000 feet on the east and about 2,300 feet on the west (Case and Cook, 1979, p. 55, 63). Southward, the graben is bounded by a proposed east-trending offset (Crosby, 1973), indicated by the right-lateral topographic offset between the northern part of the San Francisco Mountains and the southern part of the Cricket Mountains, and the geophysical changes in lines of equal gravity in the area (Case and Cook, 1979, p. 57, 63).

Gravity data indicate that the Sevier Lake graben contains a maximum of nearly 4,600 feet of basin-fill deposits along its deeper eastern margin (Case and Cook, 1979, p. 64). Faults of late Pleistocene to Holocene age form the eastern boundary of the graben (Oviatt, 1987, p. 40). To the west, the graben is bounded by relatively small, normal faults that displace the eastward dipping back slope of the Black Hills. Depths to consolidated rock are more shallow west of the lake. Information from drillers' logs indicates that the Bureau of Land Management (BLM) Black Hills Well (site 37, fig. 6) penetrated consolidated rock at a depth of about 560 feet (table 7 at back of report). No other wells in the area are known to penetrate the basin-fill deposits to consolidated rock.

HYDROLOGY

Surface-Water Resources

Sources of surface-water inflow to the study area are the Sevier River and local, ephemeral streams that flow in response to snowmelt or rainfall. Unusually wet climatic conditions during the early to mid-1980's resulted in record runoff of 2.27 million acre-feet from 1983-87 in the Sevier River and reestablished Sevier Lake, which reached a maximum lake level of 4,527 feet above sea level in June 1985.

Sevier River

Sevier River is the principal source of surface-water inflow to Sevier Lake. Headwaters of the Sevier River are in the plateaus of south-central Utah. The Sevier Lake basin (fig. 3) encompasses 16,184 square miles and has nearly 485,000 acre-feet of reservoir storage capacity. The nearly complete utilization of available surface-water supplies by upstream water users or in storage-retention facilities effectively limits the volume of water that flows into Sevier Lake.

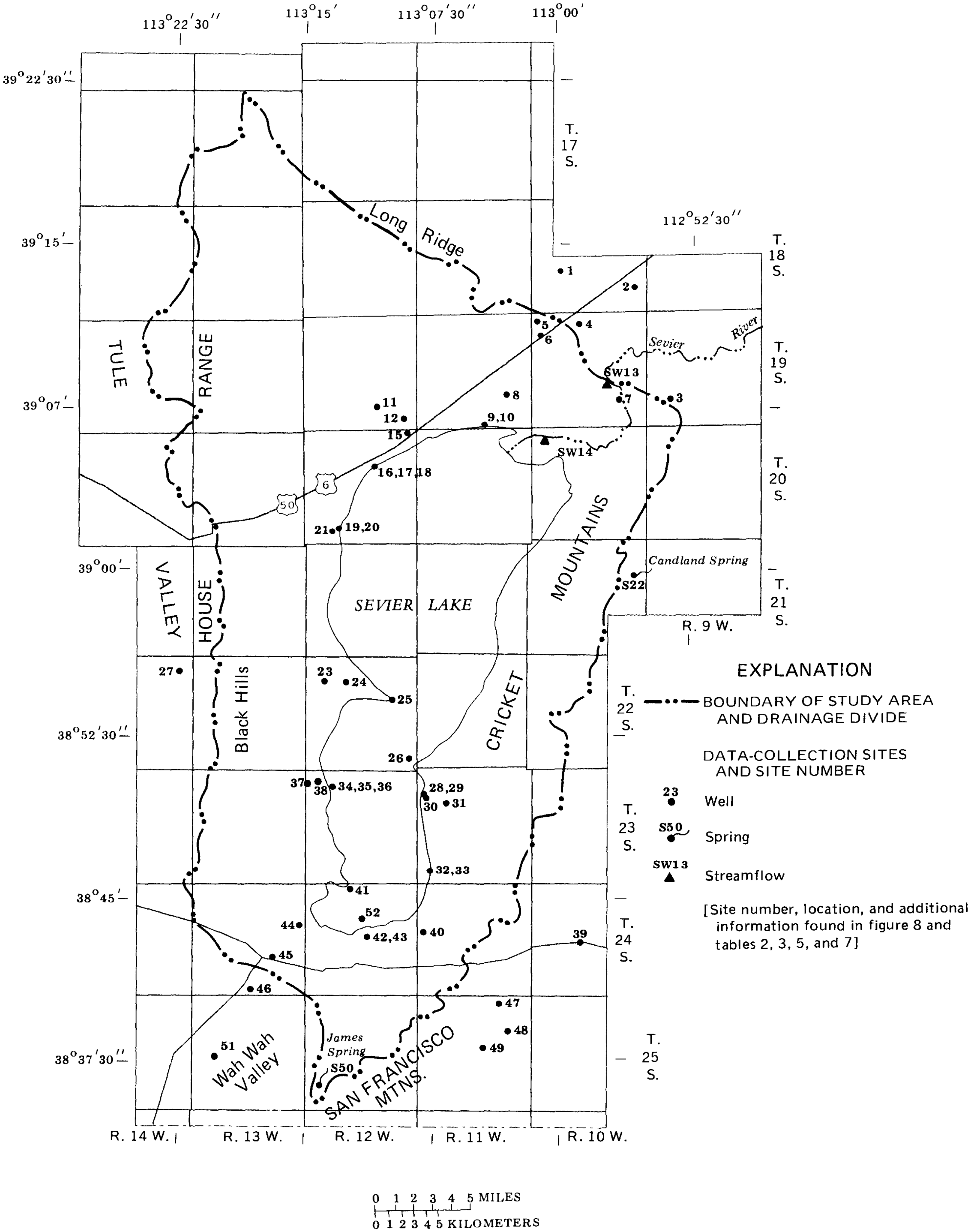


Figure 6.--Location of hydrologic-data sites in and adjacent to the Sevier Lake area.

Discharge data from streamflow gaging stations (Woolley, 1947, p. 71-72) and information provided by the Sevier River Water Commissioner (Roger Walker, oral commun., 1988) for Sevier River discharge at Deseret or Oasis are plotted in figure 7. Mean annual discharge for the Sevier River at Oasis was 104,000 acre-feet in 1913; 170,000 acre-feet in 1914; 70,000 acre-feet in 1915; 125,000 acre-feet in 1922; and 175,000 acre-feet in 1923 (Woolley, 1947, p. 71). Some part of the flow during these years is assumed to have reached Sevier Lake. Mean annual discharge of the Sevier River at Oasis or Deseret from the 1920's to the 1980's rarely exceeded 10,000 acre-feet per year and generally was zero. The 1983-87 runoff, which totaled about 2.27 million acre-feet (Roger Walker, Sevier River Water Commissioner, oral commun., 1988), clearly was the largest for the period of record (fig. 7), and attests to the infrequent recurrence. Records are sketchy or nonexistent before about 1910, but surface-water inflow to Sevier Lake purportedly was common (Roger Walker, Sevier River Water Commissioner, oral commun., 1988).

Ephemeral Streams

Estimates of runoff from ephemeral streams in the Sevier Lake area range from 18 acre-feet per year, using a runoff-altitude relation developed by Moore (1968) for areas in Nevada, to 3,500 acre-feet per year, using a runoff rate of about 0.1 inch per year estimated for the low-altitude area of the Uinta Basin in eastern Utah (Lindskov and Kimball, 1984, p. 10). The runoff rate for the Sevier Lake area could be less than 0.1 inch per year, but additional data are needed in order to make an informed estimate. The estimates are assumed to be the maximum and minimum limits for runoff values, and the actual value probably is between the two values given. An undetermined part of the ephemeral runoff infiltrates into the basin-fill deposits and contributes variable quantities of water to the ground-water system.

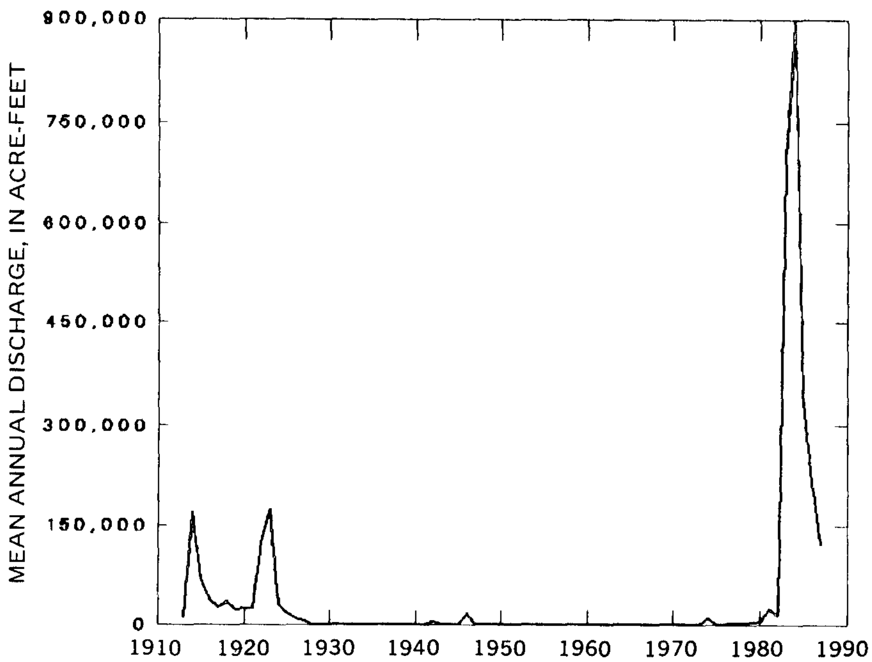


Figure 7.--Mean annual discharge of Sevier River at Deseret or Oasis, 1913-87.

Sevier Lake

Sevier Lake is a remnant of one or several pluvial lakes that formed during the Pleistocene Epoch and culminated with the final highstand of Lake Bonneville about 15,000 years ago (Currey and Oviatt, 1985, p. 13). Following the catastrophic lowering of Lake Bonneville during the geologically instantaneous Bonneville Flood, the remnant Lake Bonneville receded to Great Salt Lake basin as a result of increasing aridity (fig. 3). Drainage from the Sevier Lake basin was northward to the Great Salt Lake basin via the low point at the Old River Bed, which is north of the Sevier Lake area (fig. 3). Oviatt (1987, p. 56), has called the lake that existed in the Sevier Lake area after Lake Bonneville and before Sevier Lake, Lake Gunnison, in memory of the U.S. Army Topographic Engineer who was killed near the shores of Sevier Lake in October 1853 while exploring the region. Radiocarbon-dated wood and stratigraphic and geomorphic analysis of a persistent beach deposit found at levels above the present-day lake indicate that Lake Gunnison existed from about 10,000 to 12,000 years ago as a shallow, freshwater lake at an altitude of about 4,560 feet above sea level (Oviatt, 1987, p. 57).

The late Holocene lacustrine chronology is more complete for Great Salt Lake basin, but the general details are assumed to be applicable to the Sevier Lake basin (fig. 3). The Sevier Lake chronology during the Holocene Epoch (roughly 10,000 years ago to the present) has been detailed by Oviatt (1987). Radiocarbon dates from gastropods and alluvial deposits indicate that from about 10,000 years ago to the present, the lake(s) in the Sevier Lake basin did not exceed the Lake Gunnison level (Oviatt, 1987, p. 59). The fluctuating wet-dry cycles typical of the Holocene Epoch undoubtedly have created a complex record of alternation between playa and lake conditions, but the number and duration of playa-lake oscillations is not yet known.

Historic information about Sevier Lake was acquired from early explorers' journals, government reports, and observations by local water officials. In 1776, the Dominguez-Escalante expedition recorded information furnished by the indigenous people of the Sevier Desert area about a body of water into which the Sevier River flowed. Gilbert (1890, p. 224) suggested that government explorers of the region, including Fremont in 1845, Gunnison in 1853, and Beckwith and Simpson in 1853 and 1859, knew of the existence of the lake. Wheeler, in 1869, approached the lake from the west and determined its true geographic position (Gilbert, 1890, p. 224).

The first hydrologic details of Sevier Lake and surroundings were provided by Gilbert during the Wheeler Survey of 1871-74 and the Powell Survey of 1875-79. In 1872, Sevier Lake had an area of 188 square miles, a salinity weight percent of 8.64 consisting chiefly of sodium chloride and sodium sulfate, and a maximum depth of about 15 feet, with the northern part being deeper than the southern part (Gilbert, 1890, p. 225). Gilbert reported the lake was nearly dry in January 1880 and had been for the previous one or two years. By August 1880, the surface of the lakebed was a mixture of salt crystals and mud, and snowshoes were required to cross the mud to reach the water's edge (Hunt, 1981, p. 186). Coincidentally, during the summer of 1987, the lake was similar in physical characteristics and chemical composition to the lake that Gilbert described in 1872.

Lake-level data for Sevier Lake were not collected until the wet period of the early to mid-1980's because of the intermittent occurrence of water on the lakebed. Water probably was present in 1913-15 and 1922-23, the only years of substantial runoff in the Sevier River at Deseret or Oasis until 1983-87 (fig. 7). Water undoubtedly was present on the lakebed in other years, but the quantity of inflow was small and the duration limited to a season or less. The level of Sevier Lake reached a maximum of 4,527 feet above sea level in June 1985 (fig. 8) and resulted in a maximum depth of about 13 feet. The location of the lake-level measurement site varied as the level rose; the measurements were collected by Larry Sower (Crystal Peak Minerals Corporation). Since January 1987, the lake levels have been measured at a surveyed site near the southern shore (site 52, fig. 6).

The annual evaporation for a free-water surface at the latitude of Sevier Lake is about 50 to 55 inches per year (Farnsworth and others, 1982, map 3), and approximates the 45 inches of lake-level decline measured in 1987 (Larry Sower, Crystal Peak Minerals Corporation, oral commun., 1988). The total free-water-surface evaporation from the lake in 1987 was about 460,000 acre-feet. Assuming that no more surface water were to flow to the lake, it would take about 4 years to evaporate the volume of water that entered the lake from 1983 to 1987 but the evaporation rate would diminish as the concentration of the brine increased.

An unknown quantity of the surface water that flows onto the lakebed probably recharges the local shallow ground-water system, but the infiltration rate could be small because of the small permeability of the lakebed and the contrast in density between the surface water in the lake and the shallow ground water. In addition, the depth to the ground water is shallow, which limits the space available for accepting and storing recharge.

Chemical quality

Chemical analysis of a water sample from the Sevier River collected at the inflow to Sevier Lake is listed in table 2 (site SW14, fig. 6). The sample, collected on December 4, 1987, when the measured discharge of the river was 17.9 cubic feet per second, was assumed to represent the water quality of baseflow. At the time of collection, water was not being released from the upstream reservoirs (Roger Walker, Sevier River Water Commissioner, oral commun., 1987), and the combined discharge of the Sevier River near Deseret and the only drain west of Hinckley that was flowing was estimated to be less than 5 cubic feet per second.

The chemical composition of water in Sevier Lake varies in response to surface-water inflow, evaporation rates, and composition of the lakebed material, which affect the equilibrium concentration (solubility) of compounds common to the lake. When large inflows of surface water entered the lake from 1983 to 1987, the water quality of the lake initially was fresh to slightly saline but became increasingly briny as the constituents were concentrated by evaporation and dissolution of the lakebed material. Eventually, the compounds in the brine reached a point of supersaturation, depending on temperature, salinity, and interference by other solutes, and the minerals precipitated sequentially. For most saline lakes, the progressive concentration of brines causes a decrease in solubility and classically leads to sequential precipitation of carbonate constituents followed by sulfate and

Table 2.—*Chemical analyses of water from selected*

Site number: Refers to hydrologic-data site number in figure 6.
Location: See text for explanation of numbering system for hydrologic-data sites.
Units: µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius; ft^3/s, cubic feet per second; g/ml, grams per
Additional data: F, value for specific conductance determined onsite; < indicates less than value shown; -- indicates no

Site number	Location	Date of sample	Altitude of land surface (feet)	Specific conductance, lab (µS/cm)	pH (units)	Temperature, water (°C)	Discharge (ft^3/s)	Density (g/ml at 20 °C)	Hardness (mg/L as $CaCO_3$)	Alkalinity, field (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)
					Wells						
2	(C-18-10)25cad- 1	07-16-81	4,558	34,900	7.40	14.0	--	--	6,300	--	190
3	(C-19- 9)29cbc- 1	08-14-86	4,553	1,040	7.90	20.0	0.006	--	210	--	157
6	(C-19-10) 7bda- 1	09-22-87	4,692	3,260	7.50	14.5	--	--	90	125	127
9	(C-19-11)34dcc- 1	09-22-87	4,523	118,000	7.70	19.5	--	1.088	10,000	120	115
10	(C-19-11)34dcc- 2	09-22-87	4,525	80,000	7.20	15.0	--	1.046	9,000	135	134
12	(C-19-12)36bca- 1	09-22-87	4,607	9,460	7.90	16.0	--	--	300	238	215
15	(C-20-12) 1aac- 1	07-15-81	4,544	51,400	7.50	15.0	--	--	11,000	--	110
16	(C-20-12)10dcd- 1	09-23-87	4,523	127,000	7.20	17.5	--	1.048	10,000	729	581
17	(C-20-12)10dcd- 2	09-23-87	4,524	126,000	7.40	18.0	--	1.087	8,400	175	174
18	(C-20-12)10dcd- 3	09-23-87	4,525	88,400	7.20	17.5	--	1.051	6,100	163	161
19	(C-20-12)32aaa- 1	09-23-87	4,525	65,700	7.30	13.5	--	1.036	5,500	80	82
21	(C-20-12)32abd- 1	09-23-87	4,550	39,600	7.40	15.5	--	1.024	3,300	123	121
27	(C-22-14) 1cba- 1	01-14-76	4,779	1,000F	--	--	--	--	250	244	--
	do.	12-02-87	--	1,010	7.70	19.5	--	--	190	--	193
28	(C-23-11) 7bbc- 1	10-06-87	4,525	105,000	7.70	18.5	--	1.075	15,000	206	206
29	(C-23-11) 7bbc- 2	10-06-87	4,530	99,900	7.30	15.0	--	1.060	9,700	58	59
30	(C-23-11) 7bdb- 1	10-06-87	4,550	91,000	7.60	13.0	--	1.054	12,000	86	87
35	(C-23-12) 5cdd- 2	09-24-87	4,525	66,800	7.80	16.0	--	1.039	5,600	125	127
36	(C-23-12) 5cdd- 3	09-24-87	4,525	76,800	7.40	16.0	--	1.044	6,300	74	74
37	(C-23-12) 6ccd- 1	12-02-87	4,632	960	8.40	19.0	--	--	90	--	82
38	(C-23-12) 6dac- 1	09-24-87	4,560	56,500	7.60	16.5	--	1.071	4,300	102	102
39	(C-24-10)21aba- 1	12-02-87	4,850	6,320	7.60	12.0	--	--	740	--	150
43	(C-24-12)15cdc- 1	11-11-87	4,568	860	7.90	23.5	--	--	190	108	110
44	(C-24-13)13aac- 1	09-24-87	4,555	35,000	7.70	16.0	--	1.020	2,500	65	65
45	(C-24-13)23ccd- 1	09-24-87	4,615	5,540	7.60	16.0	--	--	720	110	107
46	(C-24-13)34ccb- 1	01-14-76	4,645	2,800F	--	--	--	--	350	153	--
					Springs						
S22	(C-21-10)13baa-S1 Candland Spring	09-21-87	5,790	1,360	7.80	19.5	<0.01	--	410	334	271
S50	(C-25-12)30ddb-S1 James Spring	10-05-87	6,630	780	7.60	13.0	<0.002	--	230	--	204
					Surface water						
SW13	(C-19-10)22ddb- 1 Sevier River near culverts on county road	12-04-87	4,535	4,660F	--	3.0	15.7	--	--	--	--
SW14	(C-20-10) 6dd- 1 Sevier River at mouth	12-04-87	4,533	4,950	8.30	5.0	17.9	--	980	--	275

wells, springs, and surface-water sites

milliliter; mg/L, milligrams per liter; µg/L, micrograms per liter.
data.

Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Percent sodium	Sodium ad-sorp-tion ratio	Potas-sium, dis-solved (mg/L as K)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Solids, sum of consti-tuents, dis-solved (mg/L)	Nitro-gen, NO_2+NO_3, dis-solved (mg/L as N)	Boron, dis-solved (µg/L as B)	Sele-nium, dis-solved (µg/L as Se)
							Wells						
970	950	5,200	64	29	83	2,500	11,000	0.80	28	21,000	0.00	2,800	--
41	26	130	56	4	9.9	87	200	0.40	27	620	<0.100	390	<1
21	9.0	600	93	28	3.2	200	780	2.1	1.0	1,700	<0.100	3,000	<1
700	2,000	38,000	88	170	1,100	15,000	66,000	0.10	6.1	120,000	100	14,000	25
950	1,600	25,000	85	120	250	7,700	33,000	0.20	23	69,000	8.00	--	--
46	45	1,700	90	44	72	630	2,600	1.3	28	5,300	1.80	3,600	13
1,600	1,700	13,000	71	55	320	4,600	28,000	0.20	26	49,000	1.50	7,000	--
610	2,100	19,000	79	83	750	17,000	65,000	<0.10	50	100,000	<0.100	13,000	3
240	1,900	35,000	90	170	260	16,000	65,000	0.30	11	120,000	4.20	--	--
610	1,100	28,000	90	160	320	7,700	37,000	0.30	15	75,000	1.20	--	--
790	860	14,000	84	84	150	6,900	25,000	0.60	12	48,000	0.460	4,000	20
570	460	12,000	89	93	58	9,000	13,000	0.50	15	35,000	<0.100	--	--
47	33	180	59	5	19	200	170	1.1	22	820	0.530	340	--
34	26	130	58	4	13	120	130	1.0	19	590	0.340	--	--
730	3,100	43,000	86	160	20	20,000	48,000	0.10	5.8	120,000	8.00	25,000	30
580	2,000	36,000	89	160	2.7	7,300	51,000	0.40	6.3	97,000	<0.100	--	--
1,300	2,200	21,000	79	84	5.1	8,900	37,000	0.30	8.3	70,000	<0.100	--	--
750	910	20,000	88	120	91	7,300	24,000	0.40	15	53,000	<0.100	3,700	<1
870	1,000	24,000	89	130	77	7,000	31,000	0.60	8.1	64,000	<0.100	--	--
18	11	160	77	8	11	120	230	0.80	5.3	610	<0.100	--	--
690	630	16,000	89	110	75	8,300	20,000	0.60	13	46,000	<0.100	--	--
140	96	930	72	15	48	230	2,000	1.2	40	3,600	<0.100	2,000	<1
38	24	86	48	3	9.3	70	150	0.50	41	480	2.40	--	--
350	390	6,700	85	60	65	6,300	10,000	1.4	6.8	24,000	<0.100	--	--
75	130	910	72	15	25	620	1,400	0.70	37	3,300	0.200	--	--
63	47	460	73	11	21	200	700	0.60	41	1,600	3.20	230	--
							Springs						
110	33	140	42	3	2.8	80	200	0.40	19	790	1.20	--	--
64	17	64	37	2	7.9	39	86	0.40	15	420	1.40	--	--
							Surface water						
--	--	--	--	--	--	--	--	--	--	--	--	--	--
130	160	630	58	9	9.0	880	1,000	0.50	18	3,000	0.120	770	1

Figure 8.--Altitude of Sevier Lake level, 1982-88. (Data from Larry Sower, Crystal Peak Minerals Corporation, 1988.)

chloride constituents. Sevier Lake, like the more concentrated Great Salt Lake, does not follow the classical precipitation sequence closely because it lacks excess carbonate constituents and precipitates and has a surplus of sulfate and chloride constituents and precipitates. When sulfate and chloride are the principal anions, sodium carbonates are no longer precipitated (Sonnenfeld, 1984, p. 142).

The brine density and concentrations of major constituents vary with lake levels and indicate an inverse relation between lake volume and salinity. The brine density at various lake levels and the dissolved concentration of major constituents for January 1987 to July 1988 are given in table 3 and indicate that the major constituents are sodium, sulfate, and chloride.

Ground-Water Resources

Ground water in the study area is in fractures and solution openings of consolidated rocks or in interstices and pore space of unconsolidated basin-fill deposits. On the basis of geographic extent and location, length of ground-water flow path, water-level data, and chemical quality, three types of flow systems (fig. 9) might be present in or near the Sevier Lake area. As defined by Gates (1987, p. 83), these are: (1) Local flow systems that have shallow flow paths less than about 25 miles in length, are limited to one topographic basin, and discharge to a river or terminal lake; (2) an intermediate flow system that has relatively deeper and longer flow paths, is not necessarily limited to one topographic basin, and discharges to a river or terminal lake; and (3) a regional flow system that can include one or more intermediate flow systems, extends beneath many topographic basins, and discharges at a regional sink in a topographic low point, such as the southern part of Great Salt Lake Desert or, perhaps, the Sevier Lake area (fig. 1).

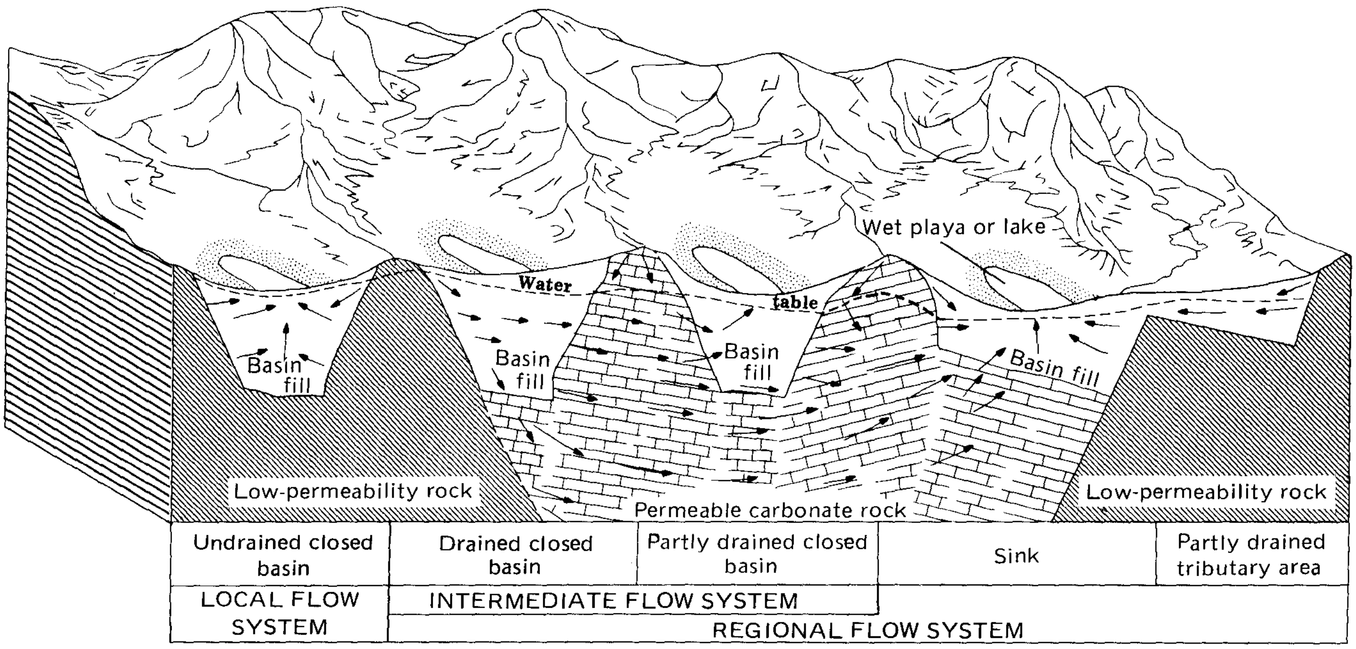


Figure 9.--Block diagram showing local, intermediate, and regional flow systems. (Modified from Eakin and others, 1976, fig. 3.)

Table 3.—*Lake levels, brine density, dissolved concentration of major constituents, and salinity of Sevier Lake from January 1987 to July 1988; Great Salt Lake during June 1987; and the average composition of seawater*

[g/mL, grams per milliliter at 20 degrees Celsius; mg/L, milligrams per liter; --, no data]

Date	Lake level (feet above sea level)	Brine density (g/mL at 20 °C)	Dissolved concentration of major constituents[1] Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Salinity (weight percent)
			Sevier Lake[2]					
01-01-87	4,518.90	1.050	--	--	--	--	--	--
02-01-87	4,519.50	1.050	1,365	21,420	735	12,810	28,245	6.15
03-01-87	4,520.00	1.050	1,365	22,470	735	15,960	27,615	6.49
04-01-87	4,521.00	1.050	1,365	21,840	945	16,065	26,565	6.35
05-01-87	4,520.40	1.050	1,365	20,685	945	14,595	25,830	6.04
06-01-87	4,519.75	1.060	1,485	24,485	740	18,230	29,360	7.01
07-01-87	4,518.70	1.060	1,590	25,120	850	18,870	30,000	7.20
08-01-87	4,518.10	1.080	1,945	35,315	970	26,135	41,905	9.84
09-01-87	4,517.60	1.090	2,290	39,565	1,200	29,430	46,870	10.95
10-01-87	4,517.35	1.110	2,775	50,060	1,445	36,740	59,610	13.56
11-01-87	4,517.35	1.090	2,510	34,555	1,310	14,715	50,685	9.50
12-01-87	4,517.35	1.070	2,570	31,670	1,285	8,990	51,040	8.92
01-01-88	4,517.50	1.080	3,130	38,990	1,510	7,885	64,690	10.77
02-01-88	4,517.60	1.060	1,800	24,590	1,165	10,920	36,250	7.04
03-01-88	4,517.60	1.080	2,485	34,235	1,190	15,120	49,895	9.50
04-01-88	4,517.60	1.090	2,615	41,420	1,415	20,165	57,880	11.33
05-01-88	4,517.35	1.100	2,640	46,860	1,430	28,380	60,500	12.72
07-01-88	4,516.00	--	--	--	--	--	--	--
			Great Salt Lake, South Arm (average of 5 sites with 44 separate sample depths)[3]					
06-10-87	4,211.60	1.069	3,620	32,600	2,080	6,550	57,500	9.57
			Great Salt Lake, North Arm (average of 4 sites with 30 separate sample depths)[3]					
06-09-87	4,210.70	1.159	6,210	62,800	3,560	11,500	109,000	16.66
			Seawater[4]					
--	--	1.035	1,350	10,500	390	2,700	19,000	3.28

[1] Brine saturation commonly is reported in salinity (weight percent) of solute. To convert the value given to weight percent, divide concentration (mg/L) by density (g/ml) and 1×10^4 (conversion factor to change g/ml to mg/L = 1×10^6; percent = 1×10^{-2}; therefore 1×10^4). To determine the weight percent of water, subtract the salinity weight percent from 100.

[2] Data from Larry Sower, Project Manager, Crystal Peak Minerals Corp., written commun., 1988.

[3] Data from Gwynn, 1988.

[4] Data from Hem, 1985.

Within the Sevier Lake area, the basin-fill aquifer has been divided into two informal units; the coarse-grained facies and the fine-grained facies. The coarse-grained facies is at the higher altitudes of the alluvial slopes and is composed of relatively coarse material. The fine-grained facies is near Sevier Lake at altitudes generally less than 4,530 feet.

The local flow system in the Sevier Lake area includes the shallow part of the basin-fill aquifer that is recharged in the adjacent mountains and upper parts of the alluvial slopes. Discharge from the local flow system is at the lower parts of the alluvial slopes near the edge of the lake and the downstream part of Sevier River (fig. 10).

The regional flow system includes ground-water flow in the carbonate and clastic consolidated rocks. Recharge to the system is by subsurface inflow from adjoining areas, such as the Milford area to the east and southeast. Gates (1987, p. 85) described the Sevier Lake regional flow system, and concluded that the Sevier Desert-Sevier Lake area was the ultimate discharge area for all topographic basins tributary to Sevier Desert or Sevier Lake. Limited hydraulic-head data for the Black Hills Well completed in bedrock just below the basin-fill boundary (site 37, fig. 6, table 8 at back of report), west of Sevier Lake, and the Ibex Well completed in basin-fill deposits (site 27, fig. 6, table 8) in the southern part of Tule Valley indicate that the potential exists for regional ground-water movement toward the topographically lower Tule Valley through carbonate and clastic consolidated rocks.

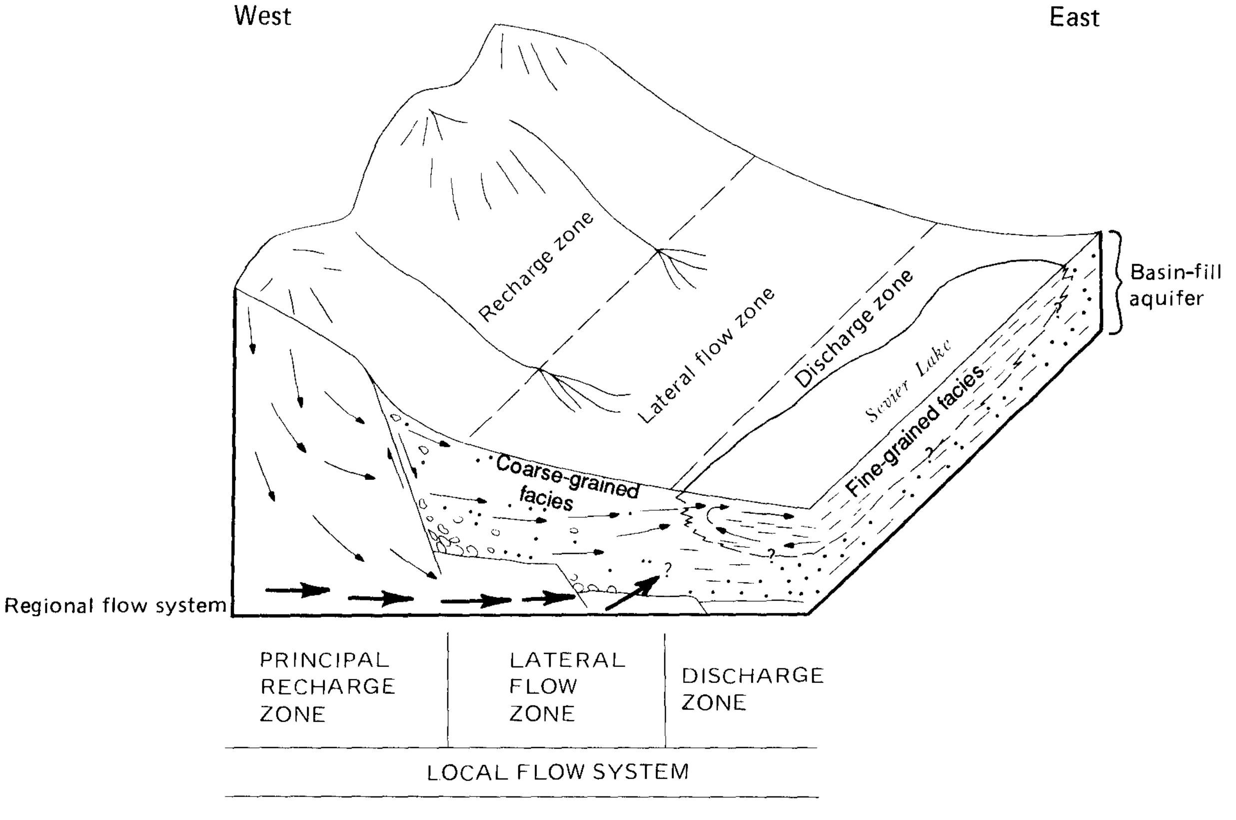


Figure 10.--Generalized local and regional flow system of the Sevier Lake area, (Modified from Duffy and Al-Hassan, 1988.)

If the quantity of ground-water outflow from the Sevier Lake area were determined to be a substantial part of the total water budget of the area, then the Sevier Lake regional flow system could be redefined as an intermediate system in an enlarged Great Salt Lake Desert regional flow system. Data collected during the present study do not warrant redefinition of the Sevier Lake regional flow system.

Consolidated Rocks

The consolidated rocks in the study area primarily consist of carbonate rocks but include some clastic and igneous rocks. Carbonate rocks can be more permeable than other consolidated rocks if dissolution has occurred along bedding planes, fractures, joints, and faults. The carbonate rocks of western Utah and adjoining parts of Nevada are believed to form an aquifer system of regional extent on the basis of water levels measured in wells and imbalances in the water budgets for individual basins (Gates and Kruer, 1981, p. 31-38). As previously discussed, the potential exists for ground-water movement in the carbonate rocks from the Milford area to the Sevier Lake area and from the Sevier Lake area to southern Tule Valley, but the existence of movement and the rate of movement are uncertain.

Occurrence

Ground-water occurrence in the consolidated, primarily carbonate, rocks of the Sevier Lake area is poorly known. Only the Black Hills Well (site 37, fig. 6, table 7) is thought to be completed in consolidated rocks, though it penetrates only 1 foot below the basin-fill deposits (mostly clay at this location). In 1987, the water in this well stood at an altitude of about 4,428 feet above sea level.

Recharge

Ground-water recharge to the Sevier Lake area in the local flow system is derived from precipitation and ephemeral stream runoff that infiltrates into the consolidated rock outcrops of the adjacent mountains. Ground-water recharge as subsurface inflow from the regional flow system moves through fractures, faults, and solution cavities in the consolidated carbonate rocks from adjoining areas to the east and southeast, such as the Milford area.

Estimates of the quantity of recharge to consolidated rocks are discussed later in the report in the basin-fill recharge section. Estimates of the quantity of ground-water inflow from adjoining areas are derived from a calibrated digital ground-water model and depend on the values for hydraulic characteristics assigned in the model. Estimates of subsurface inflow to the area through consolidated rocks are about 11,400 acre-feet per year from the Milford area (J.L. Mason, U.S. Geological Survey, written commun., 1988). This estimate was derived from a calibrated local-scale digital ground-water model of the Milford area.

Movement

The direction of ground-water movement in the local flow system is from areas of recharge, generally in the mountains, to areas of discharge at topographic low points (fig. 10). The direction of ground-water movement in

consolidated rocks in the regional flow system is east to west, or from the Milford area and the Sevier Desert and perhaps toward Tule Valley. Ground-water movement in the regional system is estimated from measured water levels in wells that are completed in basin-fill deposits. It is assumed that hydraulic connection exists between the consolidated rocks and the basin-fill deposits. Evidence for inflow from the Milford area is based on water-level data from wells, which show a hydraulic-head gradient toward Sevier Lake, and water-budget analyses, which do not balance without subsurface outflow to the Sevier Lake area.

Discharge

Ground-water discharge from the local flow system occurs at the lower parts of the alluvial slopes near the edge of Sevier Lake and the downstream parts of the Sevier River. Ground-water discharge from consolidated rocks in the regional flow system occurs by upward leakage into the overlying basin-fill deposits, and subsequently discharges to the lower part of the Sevier Lake area, or possibly by subsurface outflow to adjacent areas in southern Tule Valley. Few data are available and estimates of ground-water outflow through consolidated rocks to adjacent areas are speculative. Stephen Carlton (U.S. Geological Survey, written commun., 1989) suggested that the best results from the model of the Fish Springs multi-basin flow system were obtained when Sevier Lake was simulated as an area of discharge.

Ground water is pumped from consolidated rocks within the study area from one well, the Black Hills Well (site 37, fig. 6), for livestock watering during part of the year. The quantity pumped is estimated to be less than 10 acre-feet per year. Because this well penetrates only 1 foot of consolidated rock (table 7), some of the water pumped might be from the overlying basin-fill deposits. Relative contributions of water from the basin-fill deposits and consolidated rocks are unknown.

Aquifer Characteristics

No aquifer tests are known to have been made at wells completed in the consolidated rocks in the Sevier Lake area. Bedinger and others (1986) compiled values of hydraulic conductivity and effective porosity from the literature for the types of consolidated rocks common in the Basin and Range province of the southwestern United States and plotted the values on log-normal plots. The mean or 50th percentile value presented in table 4 indicates that fractured and cavernous carbonate rocks have the greatest potential for transmitting fluid.

Basin Fill

Basin-fill deposits, present throughout the Great Basin, include large ground-water reservoirs that store and transmit vast quantities of water and contain many potential aquifers (Thomas and others, 1986). The basin-fill aquifer in the Sevier Lake area has been divided into two informal units; the coarse-grained facies, which is located at the higher altitudes of the alluvial slopes, and the fine-grained facies, which is located at the lower altitudes around Sevier Lake. The drillers' lithologic logs (table 7) indicate that the deposits are coarser toward the mountains than they are at

Table 4.--*Aquifer characteristics of consolidated rocks in the Basin and Range province, southwestern United States*

(Modified from Bedinger and others, 1986)
[Asterisk (*), indicates words were mistakenly reversed in original reference; the correct wording is cited here (M.S. Bedinger, U.S. Geological Survey, retired, oral commun., 1989)]

Rock type	Description	Mean hydraulic conductivity (feet per day)	Mean effective porosity
Metamorphic and felsic and mafic intrusive rocks	Weathered	1×10^{-1}	0.05
	Fracture permeability; depth less* than 1,000 feet	2×10^{-3}	.003
	Fracture permeability; depth greater* than 1,000 feet	1×10^{-6}	.0001
Lava flows; includes basalt, rhyolite, and trachyte	Fractured and cavernous	$2 \times 10^{+0}$	.15
	Moderately dense to dense	1×10^{-3}	.01
Tuff	Welded and fractured	$3 \times 10^{+0}$	.03
	Welded and moderately fractured to dense	1×10^{-3}	.001
	Nonwelded, partially welded, friable, pumiceous, zeolitized, and bedded friable	1×10^{-4}	.35
Clastic sedimentary rocks (consolidated)	Coarse-grained (sandstone and conglomerate)	1×10^{-1}	.18
	Fine-grained (argillite and shale)	2×10^{-6}	.22
Carbonate rocks; includes limestone, dolomite, and marble	Fractured, karstic, and cavernous	$2 \times 10^{+2}$	.12
	Dense to moderately dense	1×10^{-2}	.01

lower altitudes. A block diagram conceptualizing the general hydrology of the local and regional flow systems of the Sevier Lake area is presented in figure 10.

Occurrence

The occurrence of ground water in the basin-fill aquifer is known from water levels measured in wells that are finished in these deposits. Water levels in shallow wells near Sevier Lake to the northwest, west, and south are higher than water levels in wells a short distance away from the lake and indicate a potential for ground-water movement away from the lake (sites 12 and 15; 21; 23 and 24; 38; 43; 44 and 45)(fig. 11, table 5). Associated with the differences in hydraulic-head values is a decrease in the sum of constituents in water sampled from wells that are located at increasing distances from the lake (tables 2 and 5).

Approximately 600 shallow wells were drilled less than 20 feet deep on the dry lakebed in the early 1980's. Some flowed for a limited time, and indicated the existence of shallow, noncontinuous artesian conditions. The shallow artesian wells were drilled in slight topographic depressions (on the lakebed) south of Needle Point and near the Sevier River inflow, with a few isolated wells both east and north of Needle Point (Murray C. Godbe III, consultant, written commun., 1987).

Four open holes (sites 25, 26, 32, and 33, fig. 11) were drilled to depths ranging from 705 to 975 feet on the dry lakebed in 1978-79. Reported water levels (table 8) and altitudes of hydraulic heads (table 5) were below the land surface. The chemical analyses of brine sampled at various depths in the four open holes were highly variable (Murray C. Godbe III, consultant, written commun., 1987) and indicated that the fine-grained facies of the basin-fill aquifer might be heterogeneous and anisotropic.

In Pilot Valley, Utah (fig. 3), Duffy and Al-Hassan (1988) have demonstrated the existence of a free-convection cell that recirculates brines under the lakebed towards a zone of ground-water discharge near the playa margin. A similar phenomenon might occur in the study area. Because of a lack of water-level data over time and at various locations on and near the lakebed, however, it is not known how such a convection cell relates to the water levels measured at Sevier Lake.

Recharge

The basin-fill aquifer is recharged near the mountain fronts from infiltration of ephemeral surface-water runoff, which is derived from snowmelt and thundershowers, and from direct infiltration of precipitation. Locally derived subsurface inflow from the consolidated rocks of the adjacent mountain areas also recharges the basin-fill aquifer. In addition, inflow from adjacent areas, such as the Sevier Desert, and surface-water runoff that flows into Sevier Lake from outside the study area contribute to the recharge of the basin-fill aquifer.

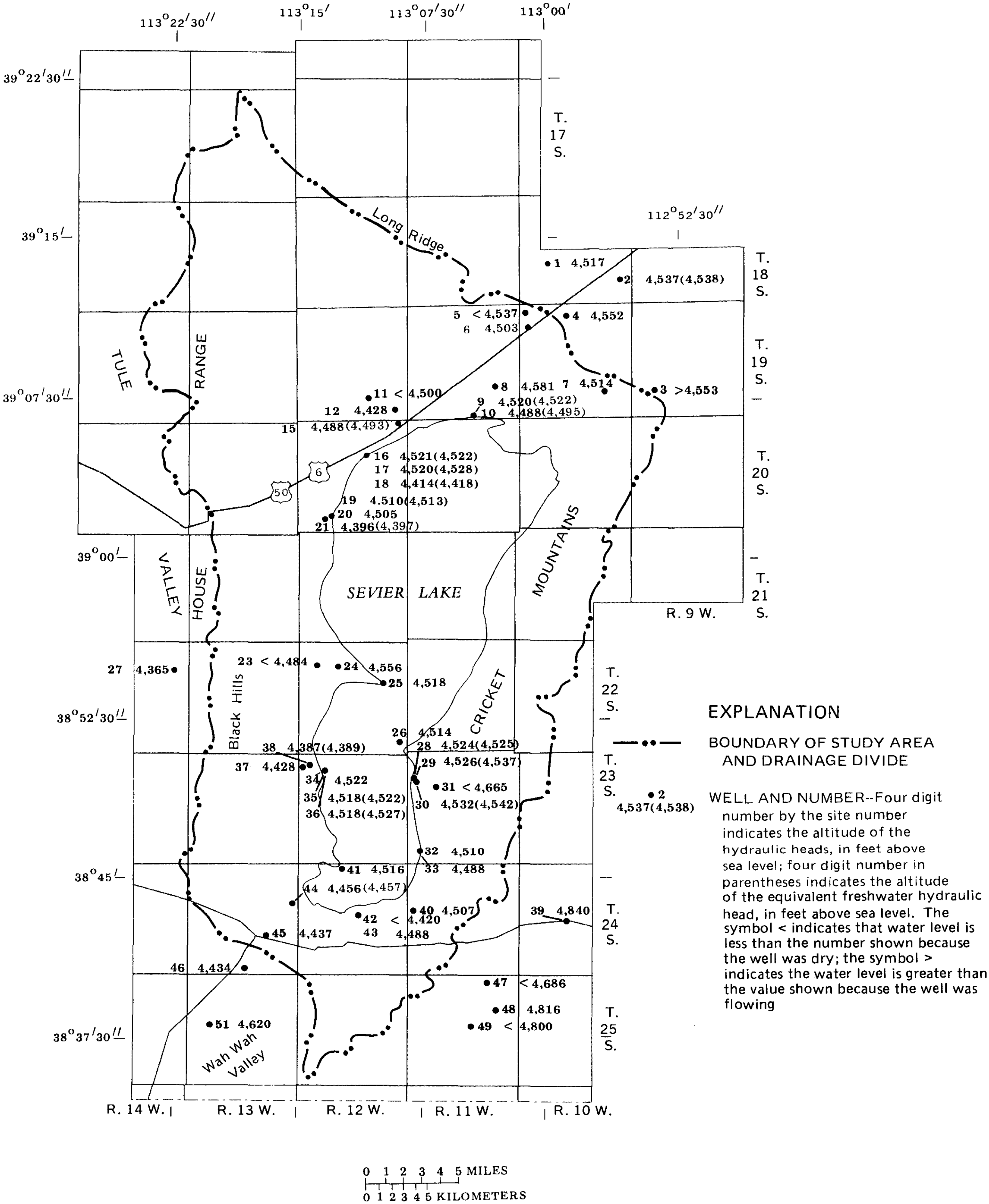


Figure 11.--Location of wells in the Sevier Lake area and altitude of hydraulic heads.

Table 5.--*Water levels, density, sum of constituents, altitude of hydraulic head, and altitude of equivalent freshwater hydraulic head for wells in the Sevier Lake area*

Site number: Refers to hydrologic-data site number in figures 6 and 11.
Location: See text for explanation of numbering system for hydrologic-data sites.
Casing: 0, depth of open hole; see table 7 for additional well information.
Water level below land surface: Measured by the U.S. Geological Survey except when followed by an R, reported by driller or owner; F, flowing well. Asterisk (*) indicates nonstatic water level due to evacuation of water column during cleansing, slug-test, or sampling operations. Additional water-level information in table 8.
Density: g/ml, grams per milliliter at 20 °Celsius; e, estimated value based on regression of lab-reported values of density versus dissolved solids, yielded an r^2 = 89.5 percent when the lab-determined density value for site 38 was deleted; L, lab-determined value reported in table 2.
Sum of constituents: mg/L, milligrams per liter.
Altitude of hydraulic head: Defined as the level to which water will rise in a well, and determined by subtracting the water level from the altitude of land surface. The symbol (<) indicates that water level is less than the number shown because the well was dry; the symbol (>) indicates the water level is greater than the value shown because the well was flowing.
Altitude of equivalent freshwater hydraulic head: Hydraulic heads that have been corrected to equivalent freshwater heads for wells that yield briny water and that have density values.
Dashes (--) indicate no data.

Site number	Location	Altitude of land surface (feet)	Depth of casing or open hole (feet)	Water level below land surface (feet)	Date measured	Density (g/ml at 20 °C)	Sum of constituents (mg/L)	Altitude of hydraulic head (feet above sea level, rounded)	Altitude of equivalent freshwater hydraulic head (feet above sea level, rounded)
1	(C-18-10)20cbd-1	4,689	198.0	171.66	03-03-81	--	--	4,517	--
2	25cad-1	4,558	76.0	21.40	03-27-88	1.021e	21,000	4,537	4,538
3	(C-19- 9)29cbc-1	4,553	674.0	F	12-04-87	--	620	> 4,553	--
4	(C-19-10) 4cad-1	4,624	152.0	72.35	03-03-81	--	--	4,552	--
5	6bcd-1	4,742	205.0	Dry R	07- -80	--	--	< 4,537	--
6	(C-19-10) 7bda-1	4,692	778.0	188.58	03-27-88	--	1,700	4,503	--
7	26db -1	4,545	147.0	31.0 R	07- -80	--	--	4,514	--
8	(C-19-11)26aab-1	4,615	150.0	34.05	03-03-81	--	--	4,581	--
9	34dcc-1	4,523	16.0	2.94	03-27-88	1.088	120,000	4,520	4,522
10	34dcc-2	4,525	203.0	37.39	03-27-88	1.046	69,000	4,488	4,495
11	(C-19-12)27ddb-1	4,695	195.0	Dry R	02-03-82	--	--	< 4,500	--
12	36bca-1	4,608	195.0	180.28	03-26-88	--	--	4,428	--
15	(C-20-12) 1aac-1	4,544	145.0	55.82	03-26-88	1.049e	--	4,488	4,493
16	10dcd-1	4,523	13.0	1.99	03-26-88	1.048	100,000	4,521	4,522
17	10dcd-2	4,524	101.5	4.29	03-26-88	1.087	120,000	4,520	4,528
18	10dcd-3	4,525	203.0	111.40*	03-26-88	1.051	75,000	4,414*	4,418*
19	32aaa-1	4,525	101.0	15.35	03-26-88	1.036	48,000	4,510	4,513
20	32aaa-2	4,525	201.0	19.71	02-06-84	--	--	4,505	--
21	32abd-1	4,550	200.0	154.36	03-26-88	1.024	35,000	4,396	4,397
23	(C-22-12) 8bcb-1	4,680	196.3	Dry	02-04-82	--	--	< 4,484	--
24	9bcb-1	4,615	145.0	58.71	08-05-81	--	--	4,556	--
25	14a -1	4,528	975.0 0	10 R	09-02-78	--	--	4,518	--
26	36acc-1	4,517	840.0 0	3 R	08-24-78	--	--	4,514	--
27	(C-22-14) 1cba-1	4,779	493.0	414 R	- -35	--	--	4,365	--
28	(C-23-11) 7bbc-1	4,525	22.6	1.20	03-26-88	1.075	120,000	4,524	4,525
29	7bbc-2	4,530	203.0	4.43	03-26-88	1.060	97,000	4,526	4,537
30	7bdb-1	4,550	207.0	18.06	03-26-88	1.054	70,000	4,532	4,542
31	8cda-1	4,685	20.0	Dry R	07-07-84	--	--	< 4,665	--
32	31a -1	4,520	705.0 0	10 R	08-27-78	--	--	4,510	--
33	31a -2	4,520	920.0 0	32 R	08-28-78	--	--	4,488	--
34	(C-23-12) 5cdd-1	4,524	17.0	1.53	08-19-83	--	--	4,522	--
35	5cdd-2	4,525	102.0	7.15	03-26-88	1.039	53,000	4,518	4,522
36	5cdd-3	4,525	203.0	6.60	03-26-88	1.044	64,000	4,518	4,527
37	6ccd-1	4,632	560.0	204.25	12-02-87	--	610	4,428	--
38	6dac-1	4,560	200.0	173.35*	03-26-88	1.071L	46,000	4,387*	4,389*
38	6dac-1	4,560	200.0	173.35*	--	1.032e	46,000	4,387*	4,388*
39	(C-24-10)21aba-1	4,850	91.0	9.96	12-02-87	--	3,600	4,840	--
40	(C-24-11)18cac-1	4,650	147.0	143.05	07-29-83	--	--	4,507	--
41	(C-24-12) 4aca-1	4,525	226.5	9.42	11-12-87	--	--	4,516	--
42	15cc -1	4,570	150.0	Dry	02-03-82	--	--	< 4,420	--
43	15cdc-1	4,568	532.0	80.05	03-26-88	--	480	4,488	--
44	(C-24-13)13aac-1	4,555	145.0	98.55*	03-26-88	1.020	24,000	4,456*	4,457*
45	23ccd-1	4,615	195.5	178.29*	03-26-88	--	3,300	4,437*	--
46	34ccb-1	4,645	236.0	211	12-02-87	--	1,600	4,434	--
47	(C-25-11) 2bdb-1	4,885	199.0	Dry	08-16-83	--	--	< 4,686	--
48	11dcd-1	4,875	197.0	59.40	08-01-83	--	--	4,816	--
49	15cda-1	4,950	150.0	Dry	08-02-83	--	--	< 4,800	--
51	(C-25-13)20bbb-1	4,637	720.0 0	17 R	09-17-78	--	--	4,620	--

The quantity of precipitation that falls on the study area averages about 333,000 acre-feet per year and was estimated from maps showing lines of equal precipitation based on the 30-year average from 1931-60. Most of the precipitation infiltrates only a few inches and is consumed by evapotranspiration.

The volume of ground-water recharge derived from precipitation was estimated using a method adapted from Stephens and Sumsion (1978, p. 10) for basin-fill deposits and consolidated rocks and is summarized in table 6. Less than 1 percent of the precipitation, or about 2,300 acre-feet per year, contributes to ground-water recharge in the study area. This recharge includes the local sources listed above: infiltration of ephemeral surface-water runoff, direct infiltration of precipitation, and locally derived subsurface inflow from consolidated rocks.

Table 6.--*Estimated average annual precipitation and ground-water recharge to basin-fill deposits and consolidated rocks in the Sevier Lake area*
(Modified from Stephens and Sumsion, 1978, p. 10)

Precipitation zone (inches per year)	Average precipitation (inches/feet per year)	Area (square miles /acres)	Annual volume of precipitation (acre-feet)	Recharge: Percentage of precipitation (percent)	Recharge: Total (acre-feet)
6-8	7 / 0.58	723/462,720	268,380	0	0
8-10	9 / 0.75	96/ 61,440	46,080	1	460
10-12	11 / 0.92	15/ 9,600	8,830	5	440
12-16	14 / 1.17	8/ 5,120	5,990	12	720
16-20	18 / 1.50	4/ 2,560	3,840	17	650
Total		846/541,440	333,120		2,300 (rounded)

Based on the difference between upstream (SW13) and downstream (SW14) discharge measurements (fig. 6, table 2), it is assumed that 1,600 acre-feet per year of ground water flows into the basin-fill deposits in the Sevier Lake area from the Sevier Desert. The inflow represents a minimum quantity of ground-water inflow from adjacent areas because there were insufficient data to calculate total inflow across the boundary that separates the Sevier Lake area from adjacent areas of Sevier Desert (fig. 1).

Movement

Horizontal and vertical ground-water flow directions are approximated from water-levels or hydraulic heads measured in wells completed in the basin-fill aquifer. The direction of potential horizontal ground-water flow is perpendicular to the hydraulic-head contours and downgradient. Vertical ground-water flow direction is determined from hydraulic heads measured in closely spaced wells completed at different depths and is based on the potential for ground water to flow toward lower hydraulic heads. For example, if the hydraulic head in two contiguous wells of differing depths is equal, then there is no head difference and, therefore, no potential for vertical flow. If a deeper well has a hydraulic head higher than an adjacent shallower well, then the head difference indicates an upward vertical component.

For hydraulic heads in wells with high density water, located on the shoreline of Sevier Lake, the estimate of the potential for vertical flow was upward when the hydraulic heads were corrected to equivalent freshwater hydraulic heads for comparison from a common datum. In several wells, the equivalent freshwater hydraulic heads were above land surface datum (table 5). Equivalent freshwater hydraulic heads were calculated for wells with high density water using the following relation:

$$\text{Correction} = [(TD - WL)SG]$$

where TD = total depth of open hole or casing, in feet;

WL = measured water level or hydraulic head, in feet; and

$SG = \dfrac{\text{density of brine}}{\text{density of water}}$, unitless.

Hydraulic heads measured in wells completed in the basin-fill deposits of the study area, in general, indicate a potential for water to move from areas of higher hydraulic head in the east to areas of lower hydraulic head in the west (fig 11; table 5). The hydraulic-head values for wells near the northwestern, western, and southern shorelines of the lake indicate a potential for ground water to move laterally away from the lake. These hydraulic-head differences are difficult to reconcile with the hydraulic-head differences between closely spaced wells such as sites 35 and 36 (fig. 11) on the western shoreline of the lake.

Discharge

Ground-water discharge from the basin-fill aquifer in the Sevier Lake area is by seepage to Sevier River along its downstream reaches between the study-area boundary and Sevier Lake, by discharge from flowing wells and springs, by evaporation from the lakebed, by evapotranspiration from areas of phreatophytes on the margins of the lakebed, and perhaps by subsurface outflow to adjacent areas. Ground-water discharge from the basin-fill aquifer is determined from measured seepage to the Sevier River, estimated flowing-well and spring discharge, and estimated evaporation and evapotranspiration. Subsurface outflow is speculative and estimates could not be made.

Base flow, the sustained flow of a stream maintained primarily by ground-water discharge to the stream, was estimated as the difference in streamflow

measurements at two sites on the Sevier River near the inflow to Sevier Lake (sites SW13 and SW14, fig. 6, table 2). The measurements indicate that the reach is gaining 2.2 cubic feet per second, or about 1,600 acre-feet per year, which is the estimated recharge to the Sevier Lake area from the Sevier Desert (see section on recharge to basin fill). Seepage to the river is representative of base-flow conditions only during early December 1987. The annual ground-water discharge projection, based on a single base-flow estimate and representative of conditions at one point in time, is an approximation.

Flowing-well and spring discharge, estimated to be less than 10 acre-feet per year based on discharge measurements from one well and one spring, is relatively minor. Currently (1988), no ground water is pumped from wells in the basin-fill aquifer in the study area.

Estimates of evaporation from the lakebed, which used rates of salt accumulation determined by Lines (1979, p. 89) for the Bonneville Salt Flats (fig. 3), 140 miles to the north, and by Feth and Brown (1962, p. 100) for the eastern shore of the Great Salt Lake (fig. 3), 160 miles to the northeast, produced evaporation rates that ranged from about 3,800 to 4,100 acre-feet per year for an assumed freeze-free period of 125 days.

Estimates of total evapotranspiration for the Sevier Lake area were made using data gathered from Smith Creek Valley of west-central Nevada (R.L. Carman, U.S. Geological Survey, written commun., 1988), which has a geographic setting similar to Sevier Lake with presumably similar phreatophyte densities and types. The average evapotranspiration rate of 0.0043 foot per day for Smith Creek Valley was determined for predominantly greasewood and rabbitbrush plant communities. The eddy-correlation method was used to estimate actual evapotranspiration.

Application of the Smith Creek Valley average evapotranspiration rate produced an estimate of about 11,300 acre-feet per year for the Sevier Lake area. For the estimate, it was assumed that about 5 percent of the nonlakebed area, or 21,000 acres, were occupied by phreatophytes and that the freeze-free period was 125 days (table 1). The evapotranspiration estimate included direct evaporation of precipitation and soil moisture, and runoff derived from precipitation. Evapotranspiration withdrawn directly from ground water, however, may be only one-third to one-half of the total estimated using rates established by Carman, or using adjustments from Mower and Nace (1957, p. 30) and J.R. Harrill (U.S. Geological Survey, written commun., 1988), about 3,700 to 5,600 acre-feet per year.

Currently (1988), no water is pumped from wells in the basin-fill aquifer. As stated previously, Black Hills Well is thought to be completed in consolidated rocks, though it penetrates only 1 foot below the basin-fill deposits. With the anticipated completion of the Crystal Peak Minerals Corporation brine-processing facility, pumpage could range from about 3,000 to 4,000 acre-feet per year from the coarse-grained facies and about 30,000 acre-feet per year from the fine-grained facies (Larry Sower, Crystal Peak Minerals Corp., oral commun., 1988).

The proposed pumping would alter the approximate steady-state conditions that exist at present (1988) in the basin-fill aquifer. The specific effects of pumping depend on the quantity of water pumped from the aquifer, the

duration and frequency of pumping, and the distribution of the pumped wells. As water is removed from storage in the basin-fill aquifer, hydraulic heads for water in wells can be expected to decline until a new equilibrium is established between discharge and recharge. A condition of disequilibrium would occur if the rate of discharge by pumped withdrawals exceeds the rate of recharge.

Horizontal brine intrusion could occur if the cone of depression around a pumped well in the coarse-grained facies intercepts the brine in the fine-grained facies of the basin-fill aquifer. The presumably small transmissivity of the material near the shoreline, however, could effectively limit the quantity of water that could move from the fine-grained facies to the adjacent coarse-grained facies.

Transmissivity

Transmissivity of the basin-fill aquifer describes the capacity to transmit water. Transmissivity of the coarse-grained facies was determined from data collected during a short-term aquifer test performed on a 532-foot deep well. Transmissivity values of the fine-grained facies were determined from data from a single-well aquifer test and from 8 slug tests of shallow wells.

A short-term, single-well aquifer test of the coarse-grained facies of the basin-fill aquifer, used a 532-foot deep well (site 43, figs. 6 and 11), drilled by Crystal Peak Minerals Corporation (table 8). The well, perforated from 420 to 500 feet (table 8), was pumped continuously for nearly 3 hours at a constant discharge of 30 gallons per minute; water levels were measured during drawdown and recovery. Transmissivity was determined using a relation developed by Theis (1935) between residual drawdown and the ratio of time since pumping started to time after pumping stopped (t/t'). Residual drawdown data resulted in a transmissivity estimate of 4,120 feet squared per day. Hydraulic conductivity (i.e., transmissivity divided by the thickness of the perforated interval) was 51.5 feet per day. The aquifer-test analysis was constrained by the limited duration of the test and small discharge. A longer aquifer test, using at least one observation well and a discharge well with sufficient yield to adequately stress the coarse-grained facies of the basin-fill aquifer, might have provided a more representative value of transmissivity.

A short-term single-well aquifer test of the fine-grained facies of the basin-fill aquifer used a 226.5-foot deep well (site 41, figs. 6 and 11) drilled by the Crystal Peak Minerals Corporation on the lake bed. The well, perforated from 160 to 200 feet (table 8), was pumped at a gradually decreasing discharge, which ranged from 32.6 to 27.0 gallons per minute for 131 minutes. Water levels were measured during drawdown and recovery. Transmissivity, determined using the Theis (1935) residual drawdown method, was 5.2 feet squared per day; hydraulic conductivity was 0.13 foot per day. These values are typical of material that varies from clay and silt to mixtures of clay, silt, and sand (Todd, 1980, p. 72). Like the aquifer test of the coarse-grained facies, this aquifer test also was constrained by limited duration and small discharge.

Fifteen slug-tests were conducted by evacuating most of the fluid in the casing by air-lifting, using an air compressor and submerging an air line below the water level. The water level in the well was measured as it recovered to the initial, pretest level. Aquifer transmissivity was determined from slug-test data by matching curves showing water-level recovery as a function of time, plotted on semilogarithmic graph paper, with a set of computed type curves (Cooper and others, 1967). Not all of the recovery curves for the slug tests could be readily matched with type curves. The usable data from eight wells yielded transmissivity values that ranged from 1×10^{-3} to 5×10^{-2} foot squared per day and hydraulic conductivity values that ranged from 3.3×10^{-4} to 5.0×10^{-3} foot per day.

Chemical quality

Suitability of water for domestic, agricultural, or industrial uses is determined by its chemical quality. Water in wells near Sevier Lake has a large dissolved-solids concentration that makes it suitable for brine harvesting. At increasing distances from the lake, the dissolved-solids concentration decreases, and the water is suitable for most domestic and agricultural uses.

Temperature

Temperature of ground water generally is an indication of the depth to which the water has circulated. Elevated ground-water temperatures can be caused by subsurface heat sources that generate increased geothermal gradients. Adaptation of a thermal-spring classification developed by Mundorff (1970) to ground-water systems is useful to point out anomalous ground-water temperatures. This classification compares temperature of sampled ground water with mean annual air temperature. Thermal ground water has a temperature 5.6 °C (10 °F) greater than the mean annual air temperature, which is about 10 °C (50 °F) for the study area (table 1). Assuming a uniform geothermal gradient (rate of temperature increase in the earth with increasing depth) for the study area of 1 °C per 131 feet of depth (1 °F per 43 feet), the ground-water temperatures of five sampled sources in the Sevier Lake area are anomalously high and could indicate either deep ground-water circulation or undetected subsurface heat sources. The four wells and one spring that have thermal water are at the north end of the Cricket Mountains (site 3), the Ibex Well (site 27), the Black Hills Well (site 37), the Crystal Peak Minerals Corporation test well (site 43), and Candland Spring (site S22)(fig. 6, table 2).

Dissolved solids

The term dissolved solids defines the quantity of dissolved material in a sample of water. The quantity of dissolved solids is determined by the residue on evaporation, dried at 180 °C; or, for many waters that contain more than about 1,000 parts per million or 1,000 milligrams per liter, the sum of determined constituents (U.S. Geological Survey, 1958, p. 50).

Specific conductance or electrical conductivity of aqueous solutions is a function of temperature, valence of dissolved ionic species, and concentration of dissolved constituents. At small dissolved-solids concentrations, conductivity of an electrolyte is directly proportional to concentration. At

larger concentrations, complex ions form and cause nearly constant conductivity for increasing concentration; this precludes using conductivity for measuring concentrations of strong brines (Whelan and Petersen, 1977, p. 10). Concentrations of dissolved solids and comparable values of specific conductance for natural waters are shown at the front of the report with conversion factors and related information.

Concentration of dissolved solids in water from wells in and near the study area ranges from 480 to 120,000 milligrams per liter (table 2). Generally, smaller concentrations of dissolved solids are in water samples from wells completed in the coarse-grained facies of the basin-fill aquifer, and larger concentrations of dissolved solids are in water from wells completed in the fine-grained facies of the basin-fill aquifer near the shoreline of Sevier Lake.

The large contrast of density and dissolved-solids concentration in ground water in the adjacent coarse- and fine-grained facies of the basin-fill aquifer could indicate limited ground-water movement within the aquifer. Dissolved-solids concentrations are as much as 75 times greater within distances of less than 1 mile from Black Hills Well (e.g., sites 37 and 38, table 2). Smaller variations of dissolved-solids concentration exist between the paired sites 12 and 15, 19 and 21, 29 and 30, and 44 and 45 (fig. 6, table 2).

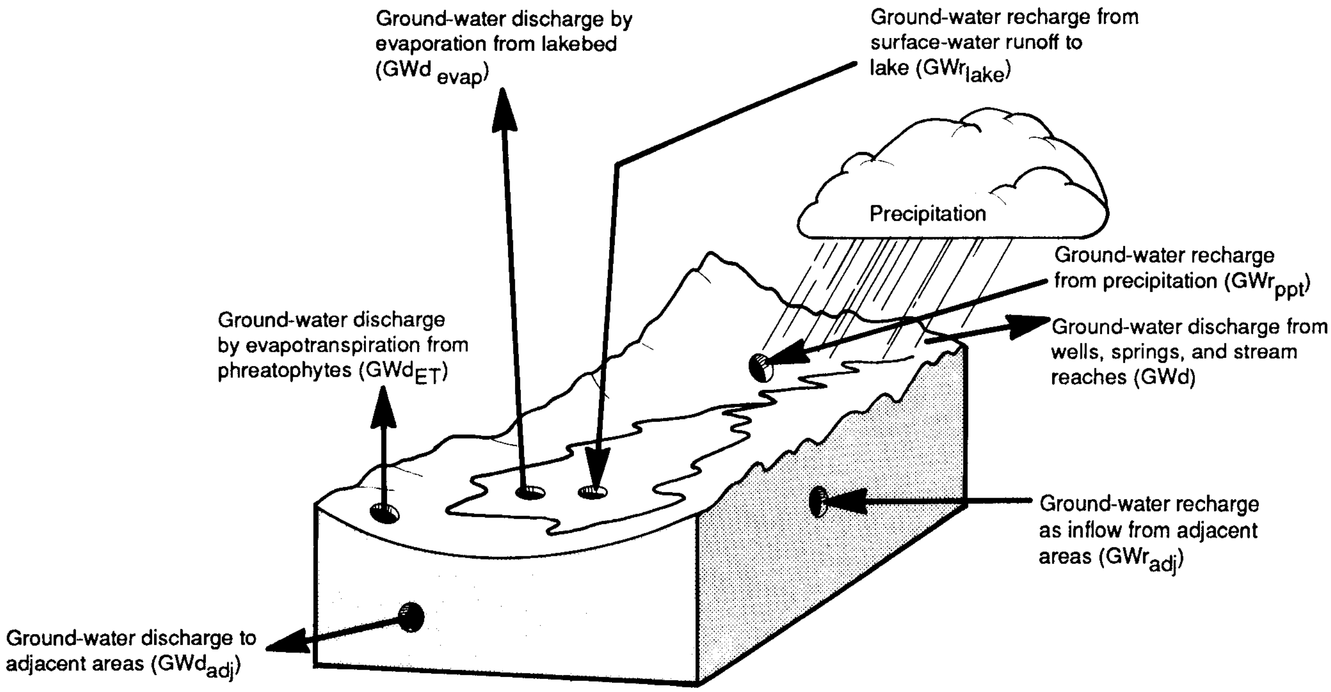
Water composition

Water samples collected from wells that are completed in the fine-grained facies of the basin-fill aquifer near the shoreline of Sevier Lake contain large concentrations of sodium, sulfate, and chloride (table 2). At increasing distances from the shoreline, concentrations of these ions decrease.

The effect of mixing, longer flow paths, and increased residence times is illustrated by composition differences between a water sample from James Spring (site S50)(fig. 6), which is in a recharge area of the San Francisco Mountains, and a water sample from a well at site 43, which is topographically and hydrologically downgradient from James Spring. Water from the well contains a slightly greater concentration of sulfate and chloride and a slightly smaller concentration of calcium than does the upgradient James Spring.

APPROXIMATION OF GROUND-WATER BUDGET COMPONENTS

A water budget is a hydrologic accounting of inflow to, outflow from, and change in storage of water in a hydrologic system (Langbein and Iseri, 1960). The annual ground-water budget for the Sevier Lake area includes the following recharge components: ground-water inflow from adjacent areas, precipitation, and surface-water runoff to the lake. Discharge components of the budget include: evapotranspiration, evaporation, discharge from springs, wells, and seepage to streams, and ground-water discharge to adjacent areas. Values for each water-budget component are given to provide insight into the nature of the Sevier Lake ground-water flow system (fig. 12).



FOR EQUILIBRIUM SYSTEM: RECHARGE = DISCHARGE

Recharge (acre-feet per year)			Discharge (acre-feet per year)		
GWr_{adj}	=	13,000	GWd_{ET}	=	3,700 to 5,600
GWr_{ppt}	=	About 2,300	GWd_{evap}	=	3,800 to 4,100
GWr_{lake}	=	Not estimated	GWd	=	1,600
			GWd_{adj}	=	Not estimated
		15,300	does not equal		9,100 to 11,300

Figure 12.--Approximated water-budget components of the ground-water system.

Inflow to the Sevier Lake area includes ground-water recharge from adjacent areas, precipitation that recharges the ground-water system, and recharge from surface-water runoff to Sevier Lake. Ground-water inflow from adjacent areas is at least 13,000 acre-feet per year: 11,400 in consolidated rock and 1,600 in basin fill. The quantity of precipitation that falls on the study area is about 333,000 acre-feet per year, of which probably less than 1 percent, or about 2,300 acre-feet per year, recharges the ground-water system (table 6). The balance of the precipitation is consumed by evaporation or evapotranspiration of soil moisture in the unsaturated zone. The total discharge of the Sevier River at Deseret or Oasis is assumed to flow into Sevier Lake, and in most years, the discharge is negligible. Most of the surface water that enters the lake probably evaporates before it affects the underlying aquifers and thus, does not affect the water budget. The total of all inflow components of the ground-water budget is about 15,300 acre-feet, not including an unknown quantity of recharge from Sevier River and Sevier Lake.

Outflow from the Sevier Lake area includes evapotranspiration from phreatophytes; evaporation at the surface of the lakebed; discharge from wells and springs, and seepage to streams; and ground-water discharge to adjacent areas. Evapotranspiration in the Sevier Lake area, which assumes that about 5 percent of the nonlakebed is occupied by phreatophytes and that the freeze-free period is 125 days, is estimated to be about 11,300 acre-feet per year. Direct evapotranspiration from ground water is perhaps one-third to one-half of the estimate, or approximately 3,700 to 5,600 acre-feet per year. For the lakebed, which measures 190 square miles, the annual ground-water discharge from evaporation was estimated to range from about 3,800 to 4,100 acre-feet per year, using the rate of evaporation determined from salt accumulation at other playas. Discharge from wells and springs and seepage to streams is about 1,600 acre-feet (about 10 acre-feet from flowing wells and springs and 1,600 acre-feet from seepage to streams). Subsurface ground-water outflow is unknown and indeterminate from available data. The total annual outflow from the ground-water system is estimated to be 9,100 to 11,300 acre-feet.

An exact balance of the ground-water budget was not possible because of the uncertainty of the assumptions and the range of values for each component. The objective was to approximate the various components of the water budget, which serves to point out the assumptions and the limitations of the data and areas where they could be improved. Better estimates of ground-water recharge from Sevier River, Sevier Lake, and inflow from adjacent areas; evaporation and evapotranspiration; and ground-water discharge to adjacent areas are needed to more closely define the water budget. The problem of balancing the water budget and final determination of whether Sevier Lake is a hydrologic source, sink area, or has characteristics of both that could vary with climatic conditions, cannot be resolved with available data.

SUMMARY

The Sevier Lake area of about 850 square miles in west-central Utah is in the interior draining Great Basin. The area is defined by the local Sevier Lake drainage basin in the immediate vicinity of ephemeral Sevier Lake. The purpose of the report is to describe the baseline hydrologic conditions of the previously unstudied Sevier Lake area for future evaluation of potential ground-water development and for assessment of the effects of development.

Sources of surface-water inflow to the study area are the Sevier River and local, ephemeral streams that flow in response to snowmelt or rainfall. For most of the 20th century, Sevier Lake probably has been dry. The nearly complete utilization of available surface-water supplies by upstream water users or in storage-retention facilities effectively limits the volume of water that flows into Sevier Lake. Unusually wet climatic conditions during the early to mid-1980's, however, resulted in record runoff of about 2.27 million acre-feet from 1983-87 in the Sevier River and reestablished Sevier Lake, which reached a maximum lake level of 4,527 feet above sea level in June 1985.

The water quality of the lake initially was fresh to slightly saline but became increasingly briny as the constituents were concentrated by evaporation and dissolution of the lakebed material. The major constituents are sodium, sulfate, and chloride.

Ground-water occurrence in the consolidated, primarily carbonate, rocks of the Sevier Lake area is poorly known. Only the Black Hills Well (site 37) is thought to be completed in consolidated rocks, though it penetrates only 1 foot below the basin-fill deposits. Ground-water recharge as subsurface inflow from the regional flow system moves through fractures, faults, and solution cavities in the consolidated carbonate rocks. Regional ground-water movement in the consolidated rocks generally is from east to west, or from the Milford area and the Sevier Desert and perhaps towards Tule Valley. Ground-water discharge might occur by upward leakage into the overlying basin-fill deposits of the Sevier Lake area or possibly by subsurface outflow to adjacent areas in southern Tule Valley.

The occurrence of ground water in the basin-fill aquifer is known from water levels measured in wells that are completed in the basin-fill deposits. The basin-fill aquifer has been divided into two informal units: the coarse-grained facies, which is at the higher altitudes of alluvial slopes, and the fine-grained facies, which is at the lower altitudes around Sevier Lake. Water levels in shallow wells completed in the basin-fill aquifer near Sevier Lake on the northwest, west, and south are higher than water levels in wells that are a short distance from the lake.

The basin-fill aquifer is recharged near the mountain fronts by infiltration of ephemeral surface-water runoff and from direct infiltration of precipitation. Locally derived subsurface inflow from the consolidated rocks of adjacent mountain areas and from adjacent areas of basin-fill deposits also recharges the basin-fill aquifer.

Hydraulic heads, in wells on the shoreline of Sevier Lake with high density water, were corrected to equivalent freshwater heads for comparison from a common datum. In several wells, the equivalent freshwater hydraulic heads were above the land-surface datum. The hydraulic heads in wells near the northwestern, western, and southern shorelines of the lake, however, indicate a potential for ground water to move laterally away from the lake. These hydraulic-head differences are difficult to reconcile with the hydraulic head differences between closely spaced wells, such as at sites 35 and 36 (fig. 11), on the western shoreline of the lake.

Ground-water discharge from the basin-fill aquifer in the Sevier Lake area is by seepage to the Sevier River along its downstream reaches between

the study-area boundary and Sevier Lake, by discharge from flowing wells and springs, by evaporation from the lakebed, and by evapotranspiration from areas of phreatophytes on the margins of the lakebed, and perhaps by subsurface outflow to adjacent areas. Currently (1988), no water is pumped from wells in the basin-fill aquifer, but with the anticipated completion of a brine-processing facility, pumpage from the basin-fill aquifer could range from about 3,000 to 4,000 acre-feet per year from the coarse-grained facies and about 30,000 acre-feet per year from the fine-grained facies of the basin-fill aquifer. The proposed pumping would alter the approximate steady-state conditions that exist at present (1988) in the basin-fill aquifer. As water is removed from storage in the basin-fill aquifer, hydraulic heads can be expected to decline until a new equilibrium is established between discharge and recharge. A condition of disequilibrium would occur if the rate of discharge by pumped withdrawals exceeds the rate of recharge.

Transmissivity of the coarse-grained facies of the basin-fill aquifer was determined from data collected during a short-term aquifer test on a 532-foot deep well. Residual drawdown data indicated a transmissivity of 4,120 feet squared per day and a hydraulic conductivity of 51.5 feet per day.

Transmissivity values for the fine-grained facies were determined from single-well aquifer test and from slug tests of shallow wells near the shoreline of the lake. Transmissivity for the single-well test was 5.2 feet squared per day, and the hydraulic conductivity was 0.13 feet per day. The slug-test data yielded transmissivity values that ranged from 1×10^{-3} to 5×10^{-2} foot squared per day and hydraulic conductivity values that ranged from 3.3×10^{-4} to 5.0×10^{-3} foot per day.

The concentration of dissolved solids in water from wells in and near the study area ranges from 480 to 120,000 milligrams per liter. Generally, water from wells completed in the coarse-grained facies of the basin-fill aquifer contains smaller concentrations of dissolved solids than does water from wells completed in the fine-grained facies of the basin-fill aquifer near the shoreline of Sevier Lake. Dissolved-solids concentrations are as much as 75 times greater within distances less than 1 mile from the Black Hills Well. Water samples collected from wells near the shoreline of Sevier Lake contain large concentrations of sodium, sulfate, and chloride.

The annual ground-water budget for the study area includes the following recharge components: ground-water inflow from adjacent areas, precipitation, and surface-water runoff to the lake. Discharge components of the budget include: evapotranspiration, evaporation, discharge from springs, wells, seepage to streams, and ground-water discharge to adjacent areas. An exact balance of the ground-water budget was not possible because of the uncertainty of the assumptions and the range of values for each component. Better estimates of ground-water recharge from Sevier River, Sevier Lake, and inflow from adjacent areas; evaporation and evapotranspiration; and ground-water discharge to adjacent areas are needed to more closely define the water budget.

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Table 7.—*Drillers' lithologic logs of selected wells*

Site number: Refer to data-collection site number in figure 6.
Location and material: See text for explanation of numbering system for hydrologic-data sites. Well logs compiled by U.S. Geological Survey personnel unless specified. Altitudes (Alt.) are in feet above sea level and are interpolated from U.S. Geological Survey topographic maps or surveyed. Surveyed altitudes are given in feet and decimal fractions.
Thickness: Material thickness, in feet.
Depth: Depth to base of unit, in feet below land surface datum.

Site number	Location and material	Thickness	Depth
2	(C-18-10)25cad- 1. Log by Fugro National, Inc. Alt. 4,558 feet		
	Sand, fine, poorly graded, subrounded, silt, slightly plastic, strong effervescence	1	1
	Clay, sandy, slight plasticity	8	9
	Silt, medium plasticity, sand, subrounded, strong effervescence	8	17
	Sand, fine to coarse, poorly graded, silt, clay, gravel, rounded, strong effervescence	4	21
	Clay, medium plasticity, sand fine to coarse, subrounded, strong effervescence	28	49
	Clay, medium plasticity, sand fine to coarse, subrounded	39	88
	Sand, fine, poorly graded, silt, clay, slightly plastic strong effervescence	6	94
	Soil, loose and soft, drill fell almost instantly	2	96
	Sand, fine to coarse, poorly graded, subrounded to rounded, weak effervescence.	16	112
3	(C-19-9)29cbc- 1. Log by Tom L. Jones. Alt. 4,533 feet		
	Sand	10	10
	Sand, fine	5	15
	Clay	15	30
	Sand, fine	5	35
	Clay	15	50
	Sand, fine	20	70
	Clay	2	72
	Sand, fine	6	78
	Clay	9	87
	Sand, fine	8	95
	Clay	20	115
	Sand, fine	20	135
	Clay	15	150
	Sand, fine	5	155
	Clay	10	165
	Sand, fine	5	170
	Clay	9	179
	Sand, fine	9	188
	Clay	12	200
	Sand, fine	15	215
	Clay	40	255
	Sand, fine	10	265
	Clay	15	280
	(C-19-9)29cbc- 1.--Continued		
	Sand, fine	5	285
	Clay	30	315
	Sand, fine	5	320
	Clay	5	325
	Sand, fine	3	328
	Clay	2	330
	Sand, medium, some water	22	352
	Clay	12	364
	Sand, medium, some water	3	367
	Clay	8	375
	Sand, medium, some water	40	415
	Clay	5	420
	Sand, fine, some water	14	434
	Clay	15	449
	Sand, fine, some water	11	460
	Clay	3	463
	Sand, fine, some water	12	475
	Clay	20	495
	Sand, fine, some water	7	502
	Clay	18	520
	Sand, fine, some water	5	525
	Clay	45	570
	Sand, fine, some water	23	593
	Clay	4	597
	Sand, fine, some water	10	607
	Clay	23	630
	Sand, fine, some water	15	645
	Clay	30	675
	Sand, fine, some water	24	699
10	(C-19-11)34dcc- 2 Alt. 4,525 feet		
	Sand, and gravel, small, unsorted	4	4
	Clay, red-brown, gypsum	51	55
	Clay, sandy	23	78
	Clay, red-brown, thin layer of gray-green clay at 130 feet	125	203
12	(C-19-12)36bca- 1. Log by Fugro National, Inc. Alt. 4,607 feet		
	Sand, fine to coarse, poorly graded, some gravel, strong effervescence	3	3
	Clay and silt, interbedded, weak effervescence	3	6
	Clay, slight to medium plasticity, silt trace, weak effervescence	50	56
	Silt, nonplastic, sand, fine, subangular to subrounded, weak effervescence	144	200

Table 7.--*Drillers' lithologic logs of selected wells*--Continued

Site number	Location and material	Thickness	Depth
15	(C-20-12) 1aac- 1. Log by Fugro National, Inc.		
	Alt. 4,543.8 feet		
	Sand, silty, poorly sorted...	2	2
	Gravel, silty, poorly graded, strong effervescence	7	9
	Clay, silty, weak effervescence....................	10	19
	Clay, strong effervescence...	10	29
	Clay, medium plasticity, weak effervescence..........	30	59
	Clay, high plasticity, strong effervescence........	10	69
	Clay, medium plasticity, weak effervescence..........	27	96
	Silt, nonplastic, gravel, fine, angular, weak effervescence..............	4	100
	Clay, slight to medium plasticity, silt interbeds..	50	150
17	(C-20-12)10dcd- 2		
	Alt. 4,524.5 feet		
	Clay, tan, and gravel, unsorted...................	5	5
	Clay, tan....................	25	30
	Clay, reddish-brown	71.5	101.5
18	(C-20-12)10dcd- 3		
	Alt. 4,525 feet		
	Clay, tan, and gravel, unsorted...................	5	5
	Clay, tan....................	30	35
	Clay, gray-green............	2	37
	Clay, red-brown, some gypsum crystals present...........	53	90
	Clay, gray-green, with some interbedded red-brown clay containing some gypsum......	40	130
	Clay, red-brown, sand, coarse	73	203
19	(C-20-12)32aaa- 1		
	Alt. 4,525 feet		
	Sand, gravel, clay, unsorted....................	1	1
	Clay, tan....................	4	5
	Clay, red-brown..............	40	45
	Clay, red-brown, high plasticity..................	5	50
	Clay, red, tan, intermittent gray-green clay layers......	10	60
	Clay, red....................	2	62
	Clay, red-brown..............	39	101
20	(C-20-12)32aaa- 2		
	Alt. 4,525 feet		
	Sand, gravel clay, unsorted....................	1	1
	Clay, tan, gypsum present....	7	8
	Clay, red, with intermittent gray-green clay layers......	195.5	203.5
21	(C-20-12)32abd- 1		
	Alt. 4,550 feet		
	Sand, thin soil layer on top.	8	8
	Clay, red, low plasticity ...	17	25
	Clay, red-brown, thin layer of gray-green clay at 40 feet........................	125	150
	Clay, alternating red-brown and gray-green.............	52	202
25	(C-22-12)14a - 1. Log by M. C. Godbe, III		
	Alt. 4,528 feet		
	Limestone, dark gray to black, minor quartzite pebble gravel, quartz sand and grit, tan and light brown, grades downward with silt and clay, gray, interbedded with sand, salty taste...?..................	30	30
	Clay, silty, dark, carbonaceous.....................	10	40
	Clay, silty, green-gray, silt and sand, fine, silty clay zone partially cemented with gypsum and selenite crystals....................	20	60
	Sand, dark brown to gray, thin beds, grading to clay, salty......................	20	80
	Clay, gray-green, sandy zones, slight salt taste....	20	100
	Clay, gray-green, and silty clay, brown, mottled, silty-sand zones, some carbon, salty......................	100	200
	Clay, brown, mottled, silt and sand, gray-green, slightly salty..............	20	220
	Clay, gray-green and brown, mottled, hard, dense, slightly salty.............	20	240
	Clay, gray-green and brown, alternating, mottled, moderately hard, dense.........	80	320
	Clay, sandy-silty, green-gray and brown, some gypsum cementing...................	40	360
	Clay, silty, gray-green and brown, occasionally mottled, slightly salty, dense, hard, zones of carbonaceous material from 430-490............	158	518
	Sand, fine, dark gray-brown, clay bits, gray............	7	525
	Sand and silt, brown and red-brown, scattered gypsum in clay........................	50	575
	Silt, gray-brown.............	5	580

Table 7.--*Drillers' lithologic logs of selected wells*--Continued

Site number	Location and material	Thickness	Depth
	(C-22-12)14a - 1.--Continued		
	Clay, silty, gray-green and brown, occasional carbon, little salty taste..........	140	720
	Clay, gray-green and brown, not salty...................	60	780
	Silt and silty clay, gray-brown.......................	60	840
	Sand, fine-grained, dark gray brown, lime and quartz grains......................	10	850
	Sand, silt, and clay interbeds, gray-green and gray-brown, occasional carbonaceous clay.................	125	975
26	(C-22-12)36acc- 1. Log by M. C. Godbe III Alt. 4,517 feet		
	Clay, cream-colored, pebble gravel with limestone and quartzite clasts, sand, medium coarse, salt encrustation at top inch...........	21	21
	Clay, blue-gray..............	7	28
	Clay, blue to green-gray, scattered salt seams........	10	38
	Sand, medium grain, gray.....	2	40
	Clay, light gray, scattered salt seams..................	16	56
	Sand, medium grain, gray.....	2	58
	Clay, sandy, light gray......	30	88
	Clay, light gray to green-gray with brown-black seams.	52	140
	Clay, dense, light gray, euhedral salt (gypsum?) crystals....................	30	170
	Clay, dense, light green-gray	25	195
	Clay, dense, light brown.....	5	200
	Clay, light green-gray.......	15	215
	Clay, silty, light green-gray, with sand, fine- to medium-grained lenses, some carbonaceous pieces and streaks...	27	242
	Clay, dense, gray............	8	250
	Clay, dense, gray-green, abundant carbonaceous streaks...	20	270
	Clay, silty, dry, green-gray.	10	280
	Clay, moderately compact, gray-green..................	40	320
	Clay, brown..................	5	325
	Clay, moderately compact, gray to light gray..........	35	360
	Clay, moderately hard, alternating gray-green and brown.	28	388
	Clay, green-gray.............	8	396
	Clay, moderately dry, alternating gray-green and brown.	34	430
	Clay, wet, slightly salty taste, green-gray...........	20	450
	Clay with silt and sand interbeds, dry, salty taste, alternating gray-green and red-brown..................	78	528
	(C-22-12)36acc- 1.--Continued		
	Unit similar to above but wetter and less salty taste....	27	555
	Unit similar to above but with decreasing sand content.....	5	560
	Clay, silty, dry, hard, carbonaceous, gray and gray-green, occasional sand grains......	36	596
	Clay, wet, gray to green, sand, medium- to coarse-grained, scattered, salty taste.......................	54	650
	Clay, brown..................	5	655
	Clay, sandy-silty, alternating wet and dry, gray-green and gray....................	121	776
	Clay, silty-sandy, gray to gray-green with some brown, slightly salty taste........	64	840
29	(C-23-11) 7bbc- 2 Alt. 4,530 feet		
	Clay, sandy..................	3	3
	Sand, gravel, clay, unsorted, wet.........................	2	5
	Clay, tan, sandy.............	2	7
	Clay, tan....................	11	18
	Clay, gray...................	22	40
	Clay, black..................	5	45
	Clay, gray-green.............	80	125
	Clay, gray-green, high plasticity..................	78	203
30	(C-23-11) 7bdb- 1 Alt. 4,550 feet		
	Sand, fine with clay.........	1	1
	Sand, angular, and gravel, rounded, unsorted...........	12	13
	Clay, tan, gypsum crystals present.....................	12	25
	Clay, gray-green, gypsum crystals present, high plasticity..................	30	55
	Clay, gray-green, high plasticity..................	105	160
	Clay, gray-green alternating with brown.................	18	178
	Clay, gray-green alternating with dark gray to black, high plasticity.............	7	185
	Clay, gray-green alternating with brown, high plasticity..................	9	194
	Clay, gray-green, high plasticity..................	13	207
31	(C-23-11) 8cda- 1. Log by Stephenson Drilling Inc. Alt. 4,685 feet		
	Top soil....................	2	2
	Clay, blue..................	538	540

Table 7.--*Drillers' lithologic logs of selected wells*--Continued

Site number	Location and material	Thickness	Depth
32	(C-23-11)31a -1. Log by M. C. Godbe III Alt. 4,520 feet		
	Pebble gravel, quartzite	3	3
	Sand, coarse, quartz, with clay beds, light green to gray, salty	7	10
	Clay, light green to gray, moderately dense	12	22
	Clay, brown, scattered with sand, medium coarse, quartz.	8	30
	Clay, gray-green, dense, some salt crystals	8	38
	Clay, dark gray-green, dry, carbonaceous, salty, sand seams	22	60
	Clay, gray-green, wet, some brown zones, salty taste	40	100
	Clay, light to dark gray-green, silty, some vegetal remains	20	120
	Clay, gray-green, some brown, wet, dense	12	132
	Clay, gray-green, silt, some brown streaks, wet	103	235
	Clay, dark gray-green, slightly silty, carbonaceous	20	255
	Clay, interbedded brown and gray-green, some salt and gypsum, silty in places	235	490
	Silt, brown and gray, with abundant sand	8	498
	Gypsum crystals and clay, gray	10	508
	Clay, mottled gray-green and brown, dense, some silt, salty	172	680
	Gypsum, some silt	5	685
	Clay, green-gray, mottled with brown, hard, dense	20	705
33	(C-23-11)31a -2. Log by M. C. Godbe III Alt. 4,520 feet		
	No samples	35	35
	Clay, green-gray to gray-green, occasional silty zones vegetal material, salt and gypsum in vugs	39	74
	Clay, dark gray-blue to gray, carbonaceous zones, silty	41	115
	Silty	45	160
	Clay, gray-green mottled with brown, hard, silty, little salt	55	215
	Clay, gray-green, moderately hard, wet, silty, gypsum crystals in vugs	50	265
	Clay, brown and gray-green, mottled	25	290
	Clay, gray-green, wet, scattered sand grains	5	295
	Clay, brown and gray-green, mottled	30	325
	(C-23-11)31a -2.--Continued		
	Clay, gray-green, hard, dense, silty zones, carbonaceous specks	35	360
	Clay, brown and gray-green, mottled, silty zones	130	390
	Gypsum, euhedral crystals	5	395
	Clay, gray-green, occasional brown mottling, slightly silty, moderately dense	45	540
	Clay, gray-green, some mottling, silty, some wet areas, slightly salty taste	30	570
	Silt, moderate	10	580
	Clay, gray-green, some mottling, silt	25	605
	Silt	5	610
	Clay, gray-green	70	680
	Silt, moderate, slight salt	5	685
	Clay, alternating gray-green and brown, hard, dense, carbonaceous spots	102	787
	Silt	3	790
	Carbonaceous and vegetal material	5	795
	Clay, gray-green and brown mottled, silt zones, hard, dense, slightly salty	75	870
	Clay, blue-gray to dark gray, carboneceous in spots	50	920
35	(C-23-12) 5cdd- 2 Alt. 4,525 feet		
	Sand	2	2
	Clay, gray-green	6	8
	Clay, gray-green, darker than above	27	35
	Clay, reddish-tan, with intermittent gray-green layers	67	102
36	(C-23-12) 5cdd- 3 Alt. 4,525.4 feet		
	Sand	2	2
	Clay, light gray-green	10	12
	Clay, red-brown	3	15
	Clay, dark gray-green	15	30
	Clay, brown	2	32
	Clay, dark gray-green with alternating brown layers	40	72
	Clay, gray-green, low plasticity, alternating thin-layered, clay, red-brown, higher plasticity	101	173
	Clay, gray-green, high plasticity	30	203
37	(C-23-12) 6ccd- 1. Log by Gerald Cazier, Driller Alt. 4,632 feet		
	Clay, white, greasy, heavy	559	559
	Bedrock with water	1	560

Table 7.--*Drillers' lithologic logs of selected wells*—Continued

Site number	Location and material	Thickness	Depth
38	(C-23-12) 6dac- 1 Alt. 4,560 feet		
	Soil, sandy.................	5	5
	Clay, light brown............	3	8
	Clay, light gray-green.......	7	15
	Clay, gray-green, with intermittent thin brown clay layers................	50	65
	Clay, blue-green, high plasticity.................	10	75
	Clay, alternating brown and gray-green, layers 2 to 3 feet thick, high plasticity.	38	113
	Clay, gray-green, high plasticity.................	17	130
	Clay, brown.................	8	138
	Clay, gray-green............	6	144
	Clay, gray-green, with intermittent brown layers...	48	192
	Clay, gray-green, white crystals present...........	2	194
	Clay, gray-green............	7	201
39	(C-24-10)21aba- 1. Log by Stephenson Drilling Inc. Alt. 4,850 feet		
	Top soil....................	6	6
	Clay, gray, water at 12 ft...	6	12
	Sand, fine grained, black, with clay interbeds.........	43	55
	Sand, coarse grained.........	13	68
	Sand, fine-grained, and clay interbedded................	23	91
	Clay, gray..................	159	250
41	(C-24-12) 4aca- 1 Log by B & B Drilling Co. Alt. 4,525.0		
	Top soil....................	12	12
	Clay, blue..................	3	15
	Clay, white.................	157	172
	Clay with hard and soft gravel streak..............	54.5	226.5
43	(C-24-12)15cdc- 1. Log by B and B Drilling Co. Alt. 4,568 feet		
	Clay and rock...............	8	8
	Clay, white.................	392	400
	Clay, blue, with white streaks	75	475
	Lava, decomposed, water bearing.....................	57	532
44	(C-24-13)13aac- 1. Log by Fugro National, Inc. Alt. 4,555.4 feet		
	Silt, high plasticity, some clay and sand, weak effervescence..............	6	6
	Gravel, sandy, poorly graded, fine to coarse sand, silt...	10	16
	Sand, silty, poorly graded...	5	21
	Clay, medium to high plasticity, some sand.......	80	101
	(C-24-13)13aac- 1.--Continued		
	Silt, non plastic, clay, sand weak effervescence, some gypsum clasts..............	49	150
45	(C-24-13)23ccd- 1. Log by Fugro National, Inc. Alt. 4,615 feet		
	Silt, high plasticity, clay, carbonate and evaporite clasts......................	2.5	2.5
	Clay, medium plasticity, sub-angular to subrounded sand clasts, dessication cracks..	2.5	5
	Sand, fine, poorly sorted....	4.5	9.5
	Silt and sand, caliche (Stage II)........................	2	11.5
	Clay, medium plasticity, sand, fine, subangular to subrounded..................	169	180.5
	Sand, fine to medium grained, weak effervescence..........	20	200.5
46	(C-24-13)34ccb- 1. Log by H.L. Hall and H.M. Robison Alt. 4,645 feet		
	Clay, light-colored..........	35	35
	Clay, light brown............	65	100
	Clay, brown.................	41	141
	Clay, gray, with gypsum......	9	150
	Clay, brown.................	80	230
	Sand, fine, water bearing....	4	234
	Gravel, hard, porphyritic (conglomerate?)............	36	270
	Gravel, water bearing........	20	290
	Unreported..................	4	294
47	(C-25-11) 2bdb- 1 Alt. 4,885 feet		
	Silt, sandy, tan............	2	2
	Sand and gravel.............	2	4
	Sand, coarse, angular........	2	6
	Clay, brown to reddish-brown with intermittent thin layers......................	38	44
	Clay, alternating between gray-green to reddish brown.......................	19	63
	Sand, medium to coarse.......	10	73
	Sand, medium, some gravel....	17	90
	Clay, sandy, gray-green......	5	95
	Clay, gray-green............	7	102
	Sand, gray..................	5	107
	Sand, coarse, some gravel....	3	110
	Gravel, some sand...........	3	113
	Clay, gray-green, intermittent gravel.........	13	126
	Clay, gray-green............	14	140
	Gravel......................	4	144
	Sand, coarse, gray...........	6	150
	Clay, sandy, gray-green......	10	160
	Clay, gray-green............	32	192
	Clay, some gravel...........	4	196
	Sand........................	4	200

Table 7.--*Drillers' lithologic logs of selected wells*--Continued

Site number	Location and material	Thickness	Depth
48	(C-25-11)11dcd- 1		
	Alt. 4,875 feet		
	Topsoil, dark brown..........	7	7
	Sand, medium to coarse, dark brown..................	3	10
	Clay, sandy, reddish-brown...	10	20
	Clay, light gray............	3	23
	Clay, sandy, reddish-brown...	14	37
	Clay, alternating gray-green and reddish-brown...........	23	60
	Clay, reddish-brown with intermittent thin layers of medium sand.................	10	70
	Clay, alternating gray-green and reddish-brown...........	20	90
	Clay, gray to gray-green, intermittent black, organic streaks.....................	13	103
	Clay, alternating gray-green and reddish-brown...........	42	145
	Clay, gray-green.............	48	193
	Clay, gray-green, some light gray to white selenite crystals, intermittent black organic streaks and black sand..................	7	200
49	(C-25-11)15cda- 1		
	Alt. 4,950 feet		
	Topsoil, sandy, tan..........	1	1
	Sand, fine, reddish-brown....	3	4
	Sand, fine, some gravel, unsorted....................	24	28
	Clay, dry, powdery, fine to coarse sand, unsorted.......	23	51
	Clay, reddish-brown, with variable amounts of fine sand, angular, unsorted.....	24	75
	Clay, silty, reddish-brown...	8	83
	Clay, light tan.............	4	87
	Clay, silty, reddish-brown, dry, crumbles easily........	29	116
	Clay, sandy, reddish-brown...	9	125
	Clay, alternating with layers of fine sand, some gravel, reddish-brown.......	8	133
	Silt, with fine sand, some clay, reddish-brown.........	5	138
	Sand, fine, appears cemented, some gravel.................	10	148
51	(C-25-13)20bbb- 1. Log by M. C. Godbe III		
	Alt. 4,637 feet		
	Silt, reddish, gray-brown, damp........................	10	10
	Silt, clayey, gray, slightly damp, water table(?)........	10	20
	(C-25-13)20bbb- 1--Continued		
	Clay, slightly silty, gray, wet.........................	2	22
	Silt, light gray to red-brown, clay, gray, quartzite fragments.............	8	30
	Clay, slightly silty, light gray........................	28	58
	Clay, slightly silty, green-gray, mottled with light red clay....................	40	98
	Clay, reddish-brown, mottled with gray-green clay, slightly silty, slightly salty.......................	22	120
	Clay, greenish-gray, occasional reddish-brown mottling, slightly salty........	50	170
	Clay, brown, mottled.........	5	175
	Clay, greenish-gray, occasional reddish-brown mottling, slightly salty........	75	250
	Clay, gray-green, lenses of silt and fine sand, non-salty, streaks of carbon....	5	255
	Clay, greenish-gray, occasional reddish-brown mottling, slightly salty........	60	315
	Clay, dark gray-green, carbonaceous................	10	325
	Clay, greenish-gray, occasional reddish-brown mottling, slightly salty........	35	360
	Sand, fine, and silt, dark gray and gray-green, beds of silt, yellow, and clay, gray, little or no salt taste.......................	50	410
	Sand, fine- to medium-grained, dark gray..........	26	436
	Quartzite and limestone pebble and cobble fragments, dark gray to black, sand, fine to coarse, and silt beds, minor clay seams, possible alluvial fan encroachment from east, non-salty.......................	129	565
	Quartzite pebbles, dark red-brown to white, glassy, sand, fine to coarse, subangular to subrounded, non-salty to slightly salty, more sandy at 580-590, 620-655, sparse clay seams at 660-695.....................	155	720

Table 8.—*Records of selected wells, springs, and surface-water sites*

Site number: Refer to data-collection site number in figure 6; SW, surface-water data-collection site; S, spring data-collection site; all others, data were collected from wells.
Location: See text for explanation of numbering system for hydrologic-data sites.
Owner or user: Last known owner or user; USAF, U.S. Air Force; USGS, U.S. Geological Survey; BLM, U.S. Bureau of Land Management; UDOT, Utah Department of Transportation; CPMC, Crystal Peak Minerals Corp.
Casing: Total depth, NA indicates not applicable because there was an open hole and had no casing. Finish, letter indicates type of finish: P, perforated-casing interval; S, screened-casing interval; O, open hole.
Water level: Below or above (-) land surface. F, flowing well. Measured by the U.S. Geological Survey except when followed by an R, reported by driller or owner. Asterisk (*) indicates nonstatic water level due to evacuation of water column during cleansing, slug-test, or sampling operations. See table 5 for water levels corrected to equivalent freshwater hydraulic heads.
Altitude of land surface: Surveyed altitudes given in feet and decimal fractions. Altitudes interpolated from U.S. Geological Survey 7.5- and 15-minute topographic maps are given in feet above sea level.
Use of water: Z, plugged by the State of Utah; N, not used except for periodic water-level measurements and water sampling by U.S. Geological Survey as part of a statewide observation-well network; L, livestock; D, could not locate during field inventory, probably destroyed; T, test; A, abandoned.
Remarks and other available data: D, driller's log in files of the U.S. Geological Survey; C, chemical analysis (table 2); L, drillers' log (table 7); X, well destroyed by shore ice or by other natural phenomenon between date of last measurement and January 21, 1986.
Dashes (--) indicate no data.

Site number	Location	Owner or user	Date completed	Depth of hole (feet)	Casing: Diameter (inches)	Casing: Total depth (feet)	Casing: Finish (feet)	Water level: Below land surface datum (feet)	Water level: Date measured	Altitude of land surface (feet above sea level)	Use of water	Remarks and other available data
1	(C-18-10)20cbd- 1	USAF	1979	200.0	2.0	198.0	P 178.0-198.0	171.78	08-07-80	4,689	Z	D
								171.66	03-03-81			
2	25cad- 1	USGS	1980	112.0	2.0	76.0	P 56.0-76.0	23.13	08-07-80	4,558	N	CL
								22.88	03-03-81			
								22.34	03-29-84			
								22.25	09-06-84			
								21.95	09-09-85			
								21.73	03-01-86			
								21.73	08-12-86			
								21.50	09-10-87			
								21.42	12-04-87			
								21.40	03-27-88			
3	(C-19- 9)29cbc- 1	BLM	1940	699.0	1.25	674.0	-- --	3.24	03-03-81	4,553	L	CL
								F	12-04-87			
4	(C-19-10) 4cad- 1	USAF	1979	156.0	2.0	152.0	P 132.0-152.0	68.85	08-07-80	4,624	Z	D
								72.35	03-03-81			
5	6bcd- 1	USAF	1980	205.0	2.0	205.0	P 182.0-202.0	DRY R	07----80	4,742	D	D
6	7bda- 1	UDOT	1951	778.0	8.0	778.0	P 523.0-778.0	188.96	03-04-75	4,692	T	C
								188.97	08-26-75			
								188.83	03-02-76			
								188.90	09-22-76			
								188.77	03-02-77			
								188.75	08-30-77			
								188.75	02-28-78			
								188.81	09-07-78			
								189.00	03-06-79			
								189.08	08-24-79			
								188.90	03-11-80			
								188.93	03-03-81			
								189.71	09-03-81			
								188.89	03-16-82			
								189.05	09-07-82			
								188.91	03-08-83			
								188.90	09-08-83			
								188.77	03-14-84			

Table 8.--*Records of selected wells, springs, and surface-water sites*—Continued

Site number	Location	Owner or user	Date completed	Depth of hole (feet)	Casing: Diameter (inches)	Casing: Total depth (feet)	Casing: Finish (feet)	Water level: Below land surface datum (feet)	Water level: Date measured	Altitude of land surface (feet above sea level)	Use of water	Remarks and other available data
6	(C-19-10) 7bda- 1-Continued							188.97	09-06-84			
								188.78	09-05-85			
								188.73	03-01-86			
								188.58	03-10-86			
								188.81	08-12-86			
								188.78	08-25-86			
								188.74	06-29-87			
								188.80	08-17-87			
								188.78	09-10-87			
								188.85	09-22-87			
								188.79	12-01-87			
								188.58	03-27-88			
7	26db - 1	USAF	1980	150.0	2.0	147.0	P 127.0-147.0	31.0R	07----80	4,545	D	D
8	(C-19-11)26aab- 1	USAF	1979	150.0	2.0	150.0	P 130.0-150.0	30.28	08-07-80	4,615	Z	D
								34.05	03-03-81			
9	34dcc- 1	USGS	1982	16.4	2.0	16.0	-- --	2.86	06-29-87	4,523	N	C
								2.95*	07-02-87			
								2.76	08-20-87			
								2.74	09-22-87			
								2.98	12-01-87			
								2.94	03-27-88			
10	34dcc- 2	USGS	1983	203.0	2.0	203.0	S 200.0-203.0	37.13	02-12-84	4,525	N	CL
								37.34	01-21-86			
								37.56	05-18-87			
								37.63	06-29-87			
								37.24*	09-22-87			
								37.43	12-01-87			
								37.39	03-27-88			
11	(C-19-12)27ddb- 1	USAF	1980	200.0	2.0	195.0	P 177.0-195.0	DRY R	02-03-82	4,695	Z	D
12	36bca- 1	USGS	1979	200.0	2.0	195.0	P 177.0-195.0	180.42	08-07-80	4,608	N	CL
								180.29	03-03-81			
								175.32	03-27-84			
								180.43	09-06-84			
								180.37	09-09-85			
								180.32	03-01-86			
								180.33	08-12-86			
								180.29	07-01-87			
								180.28	08-18-87			
								180.19*	09-22-87			
								180.28	12-01-87			
								180.28	03-26-88			
SW13	(C-19-10)22ddb- 1	--	--	--	--	--	-- --	--	--	4,535	N	C; Sevier River near culverts on county road
SW14	(C-20-10) 6dd - 1	--	--	--	--	--	-- --	--	--	4,533	N	C; Sevier River at mouth
15	(C-20-12) 1aac- 1	USGS	1979	150.0	2.0	145.0	P 127.0-145.0	56.67	08-07-80	4,544	N	CL
								56.64	03-03-81			
								56.79	07-22-82			
								55.38	03-27-84			
								55.64	08-12-86			

Site number	Location	Owner or user	Date completed	Depth of hole (feet)	Casing: Diameter (inches)	Casing: Total depth (feet)	Casing: Finish (feet)	Water level: Below land surface datum (feet)	Water level: Date measured	Altitude of land surface (feet above sea level)	Use of water	Remarks and other available data
15	(C-20-12) 1aac- 1--Continued							56.08	07-01-87			
								56.00	08-18-87			
								56.04	09-22-87			
								55.99	12-01-87			
								55.82	03-26-88			
16	(C-20-12)10dcd- 1	USGS	1982	13.0	2.0	13.0	-- --	2.01	02-12-84	4,523	N	C
								3.87*	12-01-87			
								1.99	03-26-88			
17	10dcd- 2	USGS	1983	101.5	2.0	101.5	S 98.5-101.5	1.43	02-12-84	4,524	N	CL
								1.27	01-21-86			
								3.71	08-18-87			
								4.30	09-23-87			
								4.27	12-01-87			
								4.29	03-26-88			
18	10dcd- 3	USGS	1983	203.0	2.0	203.0	S 200.0-203.0	24.32	02-12-84	4,525	N	CL
								14.35	01-12-86			
								102.15*	07-01-87			
								142.21*	09-23-87			
								111.40*	03-26-88			
19	32aaa- 1	USGS	1983	101.0	2.0	101.0	S 98.0-101.0	13.84	02-06-84	4,525	N	CL
								9.14	01-21-86			
								13.49	05-18-87			
								14.55	07-01-87			
								15.85	12-03-87			
								15.35	03-26-88			
20	32aaa- 2	USGS	1983	203.5	2.0	201.0	S 198.0-201.0	19.71	02-06-84	4,525	N	XL
21	32abd- 1	USGS	1983	202.0	2.0	200.0	S 197.0-200.0	152.68	02-06-84	4,550	N	CL
								153.46	01-21-86			
								153.52	05-18-87			
								154.49	07-01-87			
								155.03	08-19-87			
								156.43*	09-23-87			
								154.84	12-03-87			
								154.36	03-26-88			
S22	(C-21-10)13baa-S1	BLM	--	--	--	--	--	--	09-21-87	5,790	L	C; Candland Spring
23	(C-22-12) 8bcb- 1	USAF	1979	201.3	2.0	196.3	P 178.3-196.3	DRY	02-04-82	4,680	Z	D
24	9bcb- 1	USAF	1979	150.0	2.0	145.0	P 127.0-145.0	58.71	08-05-81	4,615	Z	D
25	14a - 1	CPMC	1978	975.0	5.0	NA	0 NA	10R	09-02-78	4,528	AT	L
26	36acc- 1	CPMC	1978	840.0	5.0	NA	0 NA	3R	08-24-78	4,517	AT	L
27	(C-22-14) 1cba- 1	BLM	1935	515.0	6.25	493.0	-- --	414R	-- -- 35	4,779	N	C; Ibex Well
28	(C-23-11) 7bbc- 1	USGS	1982	22.6	2.0	22.6	S 21.2-22.6	0.70	02-05-84	4,525	N	C
								-1.34	01-21-86			
								1.16	05-19-87			
								1.78	06-30-87			
								2.44*	08-21-87			
								2.58*	10-06-87			
								1.79	12-03-87			
								1.20	03-26-88			

Table 8.--*Records of selected wells, springs, and surface-water sites*--Continued

Site number	Location	Owner or user	Date completed	Depth of hole (feet)	Casing: Diameter (inches)	Casing: Total depth (feet)	Casing: Finish (feet)	Water level: Below land surface datum (feet)	Water level: Date measured	Altitude of land surface (feet above sea level)	Use of water	Remarks and other available data
29	(C-23-11) 7bbc- 2	USGS	1983	203.0	2.0	203.0	S 200.0-203.0	5.70	08-21-86	4,530	N	CL
								5.74	10-06-87			
								5.13	12-03-87			
								4.43	03-26-88			
30	7bdb- 1	USGS	1983	207.0	2.0	207.0	S 204.0-207.0	17.53	02-05-84	4,550	N	CL
								15.95	01-21-86			
								15.47	05-19-87			
								15.48	06-30-87			
								18.05*	08-21-87			
								18.53*	10-06-87			
								18.33*	12-03-87			
								18.06*	03-26-88			
31	8cda- 1	BLM	1984	540.0	6.6	20.0	O 20.0	DRY R	07-07-84	4,685	T	L
32	31a - 1	CPMC	1978	705.0	5.0	NA	O NA	10R	08-27-78	4,520	AT	L
33	31a - 2	CPMC	1978	920.0	5.0	NA	O NA	32R	08-28-78	4,520	AT	L
34	(C-23-12) 5cdd- 1	USGS	1982	17.0	2.0	17.0	S 14.0-17.0	1.53	08-19-83	4,524	N	X
35	5cdd- 2	USGS	1983	102.0	2.0	102.0	S 99.0-102.0	10.69	02-06-84	4,525	N	CL
								7.40	01-21-86			
								9.34	05-18-87			
								10.10	07-01-87			
								10.77*	08-20-87			
								11.07*	09-24-87			
								10.85	12-03-87			
								7.15	03-26-88			
36	5cdd- 3	USGS	1983	203.0	2.0	203.0	S 200.0-203.0	5.01	02-06-84	4,525	N	CL
								5.87	01-21-86			
								4.85	05-18-87			
								5.31	07-01-87			
								8.63	08-20-87			
								9.81	09-24-87			
								10.56	12-03-87			
								6.60	03-26-88			
37	6ccd- 1	BLM	1945	560.0	6.0	560.0	-- --	204R	02-04-46	4,632	L	CL; Black Hills Well
								204.00	05-18-87			
								204.07	07-01-87			
								204.06	08-19-87			
								204.20	09-24-87			
								204.25	12-02-87			
38	6dac- 1	USGS	1983	200.0	2.0	200.0	S 197.0-200.0	157.00	02-06-84	4,560	N	CL
								167.67	01-21-86			
								168.59	05-18-87			
								168.78	07-01-87			
								172.79*	08-19-87			
								179.93*	09-24-87			
								177.75*	12-03-87			
								173.35*	03-26-88			
39	(C-24-10)21aba- 1	BLM	1959	250.0	6.0	91.0	P 50.0- 84.0	9.96	12-02-87	4,850	L	CL; Black Rock Well

Table 8.--*Records of selected wells, springs, and surface-water sites*--Continued

Site number	Location	Owner or user	Date completed	Depth of hole (feet)	Casing: Diameter (inches)	Casing: Total depth (feet)	Casing: Finish (feet)	Water level: Below land surface datum (feet)	Water level: Date measured	Altitude of land surface (feet above sea level)	Use of water	Remarks and other available data
40	(C-24-11)18cac- 1	USAF	1980	150.0	2.0	147.0	P 127.0-147.0	142.39 143.59 143.05	08-05-81 02-10-83 07-29-83	4,650	Z	D
41	(C-24-12) 4aca- 1	CPMC	1988	226.5	12.0	226.5	P 160.0-200.0	9.42	11-12-87	4,525	T	L
42	15cc - 1	USAF	1980	150.0	2.0	150.0	P 130.0-150.0	DRY DRY	08-05-81 02-03-82	4,570	Z	D
43	15cdc- 1	CPMC	1987	532	6.0	532	P 420.0-500.0	80.41 80.05	11-13-87 03-26-88	4,568	T	CL
44	(C-24-13)13aac- 1	USGS	1979	150.0	2.0	145.0	P 127.0-145.0	96.79 96.96 96.99 97.11 96.99 97.05* 100.12* 98.55*	08-05-81 02-04-82 09-05-84 09-04-85 05-19-87 06-30-87 12-03-87 03-26-88	4,555	N	CL
45	23ccd- 1	USGS	1979	200.5	2.0	195.5	P 177.5-195.5	177.94 178.02 177.68 177.51 177.75 177.39 177.58 178.53* 178.35* 178.29*	08-04-81 02-03-82 09-05-84 09-04-85 08-27-86 05-19-87 06-30-87 11-11-87 12-03-87 03-26-88	4,615	N	CL
46	34ccb- 1	BLM	1934	294.0	8.0,6.0	236.0	O 236.0	212.1 211	10-13-72 12-02-87	4,645	L	CL; Wah Wah Well
47	(C-25-11) 2bdb- 1	USGS	1983	199.0	2.0	199.0	S 196.0-199.0	DRY	08-16-83	4,885	N	L
48	11dcd- 1	USGS	1983	197.0	2.0	197.0	S 194.0-197.0	59.40	08-01-83	4,875	N	L
49	15cda- 1	USGS	1983	150.0	1.25	150.0	P 140.0-150.0	DRY	08-02-83	4,950	N	L
S50	(C-25-12)30ddb-S1	--	--	--	--	--	-- --	--	10-05-87	6,630	L	C; James Spring
51	(C-25-13)20bbb- 1	CPMC	1978	720.0	5.0	--	O -- --	17R	09-17-78	4,637	AT	L