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HYDROLOGIC RECONNAISSANCE OF THE SOUTHERN GREAT SALT LAKE DESERT AND SUMMARY OF THE HYDROLOGY OF 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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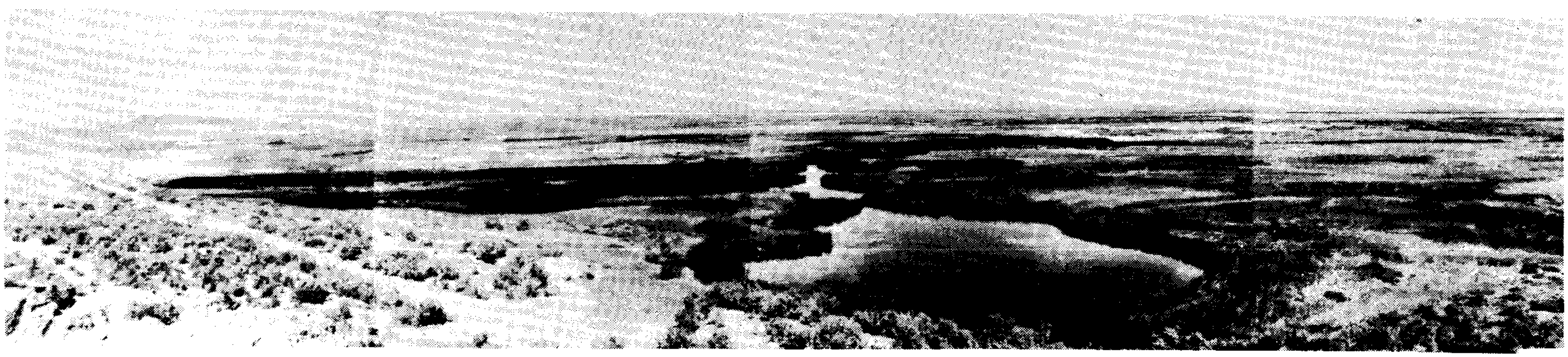

Frontispiece.—View northeastward from Blue Lake Springs with the Great Salt Lake Desert in the background

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CONVERSION FACTORS

Most values in this report are given in inch-pound units followed by metric units. The conversion factors are shown to four significant figures. In the text, however, the metric equivalents are shown only to the number of significant figures consistent with the accuracy of the value in inch-pound units.

Inch-pound Unit (Multiply)	Inch-pound Abbreviation	(by)	Metric Unit (to obtain)	Metric Abbreviation
Acre		0.4047	Square hectometer	hm^2
Acre-foot	acre-ft	.001233	Cubic hectometer	hm^3
Cubic foot per second	ft^3/s	.02832	Cubic meter per second	m^3/s
Foot	ft	.3048	Meter	m
Gallon	gal	3.785	Liter	L
		.003785	Cubic meter	m^3
Gallon per minute	gal/min	.06309	Liter per second	L/s
Inch	in.	25.40	Millimeter	mm
		2.540	Centimeter	cm
Mile	mi	1.609	Kilometer	km
Square foot	ft^2	.0929	Square meter	m^2
Square mile	mi^2	2.590	Square kilometer	km^2

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 concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in the inch-pound unit, parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter (meq/L). Meq/L is numerically equal to the inch-pound unit, equivalents per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation: $°F=1.8(°C)+32$.

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ABSTRACT

This report is the last of 19 hydrologic reconnaissances of the basins in western Utah. The purposes of this series of studies are (1) to analyze available hydrologic data and describe the hydrologic system, (2) to evaluate existing and potential water-resources development, and (3) to identify additional studies that might be needed. Part 1 of this report gives an estimate of recharge and discharge, an estimate of the potential for water-resources development, and a statement on the quality of water in the southern Great Salt Lake Desert part of west-central Utah. Part 2 deals with the same aspects of west-central Utah as a whole. Part 2 also summarizes the evidence of interbasin ground-water flow in west-central Utah and presents a theory for the origin of the water discharged from Fish Springs.

The southern Great Salt Lake Desert covers about 2,600 square miles (6,700 square kilometers) in the northern part of west-central Utah. Average annual precipitation ranges from less than 5 inches (130 millimeters) in the lowest part of the desert to more than 20 inches (510 millimeters) in the mountains on the southwest edge of the desert. The total annual precipitation is estimated to average about 880,000 acre-feet (1,085 hm^3 [cubic hectometers]). No perennial streams originate in this area of internal drainage and runoff reaches the desert floor only during or after intense summer thunderstorms or during periods of rapid snowmelt. About 2,000 acre-feet (2.6 hm^3) per year of surface flow moves into the southern desert from Deep Creek Valley.

Ground water occurs in both consolidated and unconsolidated rocks in the southern desert area. The largest quantities, ranging in quality from fresh to briny, are in the unconsolidated to partly consolidated basin-fill aquifer and the unconsolidated alluvial-fan aquifer. Large quantities of brine also occur in the shallow-brine aquifer under the Bonneville Salt Flats near Wendover and may occur under much of the 1,900 square miles (4,900 kilometers) of saline mudflats, which make up most of the desert.

Many of the items in the ground-water budget are poorly known, but annual recharge to and discharge from the aquifers of the southern desert is about 84,000 acre-ft (104 hm^3).

In general, water in the shallow-brine aquifer of the southern desert contains more than 100,000 milligrams per liter of dissolved solids. Much of the water in the basin-fill aquifer under the mudflats likely is also briny. Ground water in other parts of the basin-fill aquifer and in the alluvial-fan aquifer ranges from fresh to very saline.

West-central Utah includes about 10,300 square miles (26,700 square kilometers) of basin lowlands and mountains, including part of the eastern edge of Nevada. Annual precipitation ranges from less than 5 inches (130 millimeters) in the Great Salt Lake Desert to more than 30 inches (760 millimeters) in the Deep Creek Range, and total annual precipitation is about 4.88 million acre-feet (6,020 hm^3). No significant amounts of surface water flow into or out of the area.

Ground water occurs in consolidated and unconsolidated rocks, with the largest supplies in the unconsolidated basin fill. Reevaluation of data given in the other reports in this series indicates that net annual recharge to ground-water reservoirs averages about 241,000 acre-feet (297 hm^3), of which on the order of 28,000 acre-feet (35 hm^3) moves into the area from outside its drainage, mostly through consolidated rock.

The total net discharge of ground water from individual basins in west-central Utah in 1977 was about 259,000 acre-feet (319 hm^3). Of this amount, about 186,000 acre-feet (229 hm^3) is discharged by evapotranspiration and about 73,000 acre-feet (90 hm^3) is discharged by wells and springs.

An estimated 17.4 million acre-feet (21,400 hm^3) of ground water, of which possibly as much as two-thirds is fresh, could be withdrawn from the upper 100 feet (30 meters) of saturated material in the basins of west-central Utah, excluding the area under the saline mudflats of the southern Great Salt Lake Desert. Most of this water is in Snake Valley.

Dissolved-solids concentrations in samples of water from west-central Utah range from 38 to 258,800 milligrams per liter. The lowest concentrations are in surface water and ground water in and near the higher mountain ranges, and the highest concentrations are found in water at shallow depths below the playas in the lowest parts of the basins.

Ground water flows into west-central Utah and between basins in the area through consolidated rock. Most of the water discharged by Fish Springs, 26,000 acre-feet (32 hm^3) per year, probably was recharged along the margins of the Deep Creek Range and moved through Snake Valley either directly to Fish Springs or to Fish Springs via Tule Valley.

INTRODUCTION

This report is the nineteenth and last in a series prepared by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights, that describes the water resources of the basins in western Utah. The purposes of this series of reconnaissances and of this report are (1) to analyze available hydrologic data and describe the hydrologic system, including estimation of ground-water budgets for each basin, (2) to evaluate existing and potential water-resource development, and (3) to identify additional studies that might be needed in the future to provide a more complete understanding of the hydrologic system.

This report has two main parts. Part 1 is a report of the hydrologic reconnaissance of the southern Great Salt Lake Desert and tributary areas not included in other studies in this series, and it completes the studies of the basins of western Utah. Part 1 gives an estimate of the recharge to and discharge from the ground-water system, an estimate of the potential for water-resources development, and a statement on the quality of water in the southern Great Salt Lake Desert.

Part 2 is a summary of the hydrology of west-central Utah, including the southern Great Salt Lake Desert. This section includes revised ground-water budgets for each basin, a statement on water quality, an estimate of the potential for water-resources development, the evidence for interbasin ground-water flow, and a theory for the origin of the water that discharges from Fish Springs.

The data on which this report is based were obtained from previous reports in this series, from field reconnaissance in the southern Great Salt Lake Desert during the period October 1977 to July 1978, and from an earth-resistivity survey of Fish Springs Flat (see fig. 1) done in cooperation with the U.S. Bureau of Land Management. The resistivity survey, made mostly in the western part of Fish Springs National Wildlife Refuge during May and June 1978, was to obtain data on the lithology of and quality of water in the subsurface material of Fish Springs Flat, and to help determine the relation between faults and the discharge of water from Fish Springs.

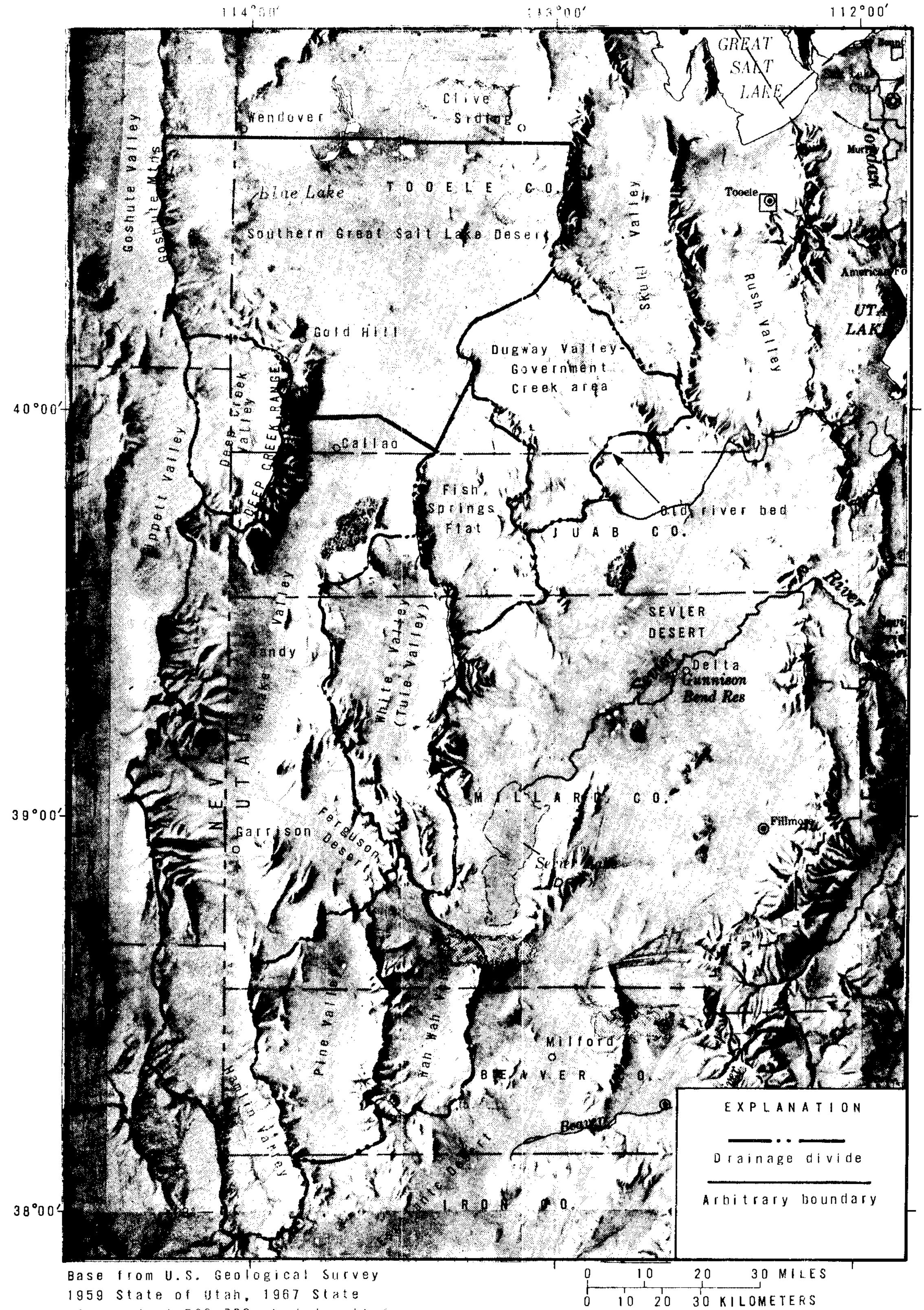
Data for most water-budget items are incomplete, but estimates have been made using available information. The methods used to make these estimates are explained in the text.

Previous studies

The first hydrologic reconnaissance in west-central Utah was by Meinzer (1911); and Snyder (1963) summarized stock-water development in western Utah. Stephens (1974a) described the hydrology of the northern Great Salt Lake Desert and summarized the hydrology of northwestern Utah using eight other reports in the reconnaissance series and part of a ninth. The present report includes an area that extends south of the area covered by Stephens and includes the areas covered by seven reports in the reconnaissance series.

Below is a list of the publications of the hydrologic reconnaissances in this series that cover west-central Utah. Figure 1 shows the areas covered by these individual reports, plus the location, physiography, and boundaries of the hydrologic areas of west-central Utah. Table 1 is a general description of the geologic and hydrologic characteristics of the rocks of west-central Utah, and plate 1 is a generalized geologic map of the area. The units in the table and on the plate are composed of rocks that have approximately similar hydrogeologic characteristics.

Area	Reference
Snake Valley, Utah and Nevada	Hood and Rush (1965)
Deep Creek Valley, Utah and Nevada	Hood and Waddell (1969)
Wah Wah Valley, Utah	Stephens (1974b)
Pine Valley, Utah	Stephens (1976)
Tule Valley, Utah	Stephens (1977)
Dugway Valley-Government Creek area, Utah	Stephens and Sumsion (1978)
Fish Springs Flat, Utah	Bolke and Sumsion (1978)



Base from U.S. Geological Survey 1959 State of Utah, 1967 State of Nevada 1:500,000 shaded relief

Figure 1.—Location, physiography, and boundaries of hydrologic areas of west-central Utah.

Table 1.--General description of water-bearing characteristics of hydrologic units in west-central Utah

Age: Era	Age: System	Hydrogeologic unit and symbol on plate 1	Occurrence and lithology	Water-bearing characteristics
CENOZOIC	Quaternary	Alluvium and colluvium (Qa)	Mainly sand and gravel but includes some intermixed and interbedded clay and silt; forms sloping alluvial apron at base of mountains and grades laterally into fine-grained alluvium and thins toward centers of valleys where it is present as a veneer overlying and adjacent to fine-grained lakebed deposits. Includes coarse-grained colluvial deposits adjacent to bedrock outcrops, sand and gravel in stream channels in and near mountain areas, and glacial-outwash deposits in Deep Creek Valley.	Slightly to highly permeable, but shallower parts of this material are generally above the zone of saturation; water from surface runoff and direct precipitation infiltrates these deposits and moves downward and laterally into underlying aquifers. Stream-channel alluvium generally is moderately permeable; and glacial-outwash deposits probably are highly permeable.
CENOZOIC	Quaternary	Lacustrine deposits (Ql)	Mainly lakebed clays and silts deposited in the valley flats; locally includes surficial playa deposits, including crystalline salt; deposits of windblown sand; and deposits of lacustrine beaches, baymouth bars, and near-shore bars, composed mainly of sand but including considerable fine gravel, silt, and clay.	Lakebed clays and silts and playa deposits generally have low permeability; windblown sand and beach and bar deposits are slightly to highly permeable. Precipitation on or surface runoff to the lower valley flats and playas remains ponded until it evaporates; at such times the playa deposits are saturated to the land surface. In basins that have no subsurface outflow, the water table in playa areas commonly is near the land surface, and these areas are a locus of ground-water discharge. Most precipitation on or run off across the windblown sand and beach and bar deposits is absorbed and subsequently transpired by vegetation (commonly dense on these deposits) or moves downward and laterally into underlying aquifers. The wind and beach and bar deposits commonly are above the zone of saturation.
CENOZOIC	Tertiary and Quaternary	Older alluvium and sedimentary rocks undifferentiated, and interbedded pyroclastics (QTu)	Ranges in size from clay to boulders with clay, silt, sand, and gravel intermixed and interbedded; unconsolidated to well-cemented. Includes some lacustrine deposits and colluvium, locally includes beds of limestone and conglomerate of uncertain age, locally includes tuffaceous sedimentary beds and interbedded pyroclastic deposits, and reportedly is interbedded with extrusive igneous rocks in its deeper parts. Underlies younger deposits in the valleys in most of the area; maximum thickness unknown but on the order of thousands of feet.	Slightly to highly permeable, depending on grain size, sorting of grains, and degree of cementation. Shallow deposits of sand and gravel probably are more permeable than deeper deposits which include consolidated and volcanic rocks; probably contains most of the ground water of usable quality in storage in west-central Utah; crops out at scattered locations along the mountain fronts, in Deep Creek Valley, and in upper Government Creek Valley.
MESOZOIC and CENOZOIC	Jurassic and Tertiary	Extrusive igneous rocks (TMZe)	Includes ignimbrites, tuffs, lava flows, and breccias, ranging in composition from mafic to felsic; also includes small outcrops of associated intrusive rocks. Crops out extensively between Fish Springs Flat and Dugway Valley and in the uplands flanking southern Snake Valley, Pine Valley, and Wah Wah Valley; reportedly occurs at depth in the valley areas interbedded with older alluvium; maximum thickness unknown.	Primary permeability generally low except locally in breccias and in zones between lava flows; secondary permeability locally high where rocks are faulted and (or) fractured or jointed.
PRECAMBRIAN, MESOZOIC, and CENOZOIC	Precambrian(?), Jurassic, Cretaceous, and Tertiary	Intrusive igneous rocks (TMZpCi)	Mainly porphyritic quartz monzonite and granitoid rocks; crops out at scattered locations in the mountain areas and extensively in the Deep Creek Mountains; thickness and subsurface extent unknown.	Primary permeability low; secondary permeability may be moderate to high in surficial weathered zones and in zones of faulting and fracturing and jointing.
PALEOZOIC and MESOZOIC	Middle Cambrian to Triassic	Sedimentary and metasedimentary carbonate rocks (MZPZc)	Mainly limestone and dolomite with some beds of shale, siltstone, sandstone, and conglomerate. Locally altered by contact metamorphism where adjacent to intrusive rocks, and locally overlain by extrusive igneous rocks. Crops out extensively in most of the mountain ranges of west-central Utah and probably underlies younger rocks in most of the valley areas.	Primary permeability generally low; secondary permeability moderate to high where solution openings are present, especially where solution has been enhanced by bedding-plane weaknesses in the rocks, faults, and fractures. Probably serve as the major conduits for subsurface movement of water between individual basins.
PRECAMBRIAN and PALEOZOIC	Precambrian to (?)	Sedimentary and metasedimentary quartzitic rocks (PZpCq)	Mainly quartzites but includes phyllites, phyllitic shales, and argillites. Crops out in most of the mountain areas, generally as resistant cliff-forming strata; thickness and subsurface extent unknown but likely underlies younger rocks at depth in most of the area.	Primary permeability low; secondary permeability locally moderate where faulted and (or) fractured or jointed. Because these rocks are mostly of low permeability, little infiltration occurs from precipitation or surface runoff over their outcrops.

These reports are based on available data on geology, streams, wells, springs, climate, and water use. These data were supplemented with field data on wells, springs, water quality, and phreatophytic vegetation that were collected during a brief reconnaissance of each area. Basic hydrologic data for the southern Great Salt Lake Desert and supplemental data for other areas in west-central Utah are at the back of this report (tables 8, 9, and 10). The remainder of the basic data for the other areas in west-central Utah are included in the report for each area.

In addition to the studies cited above, others of or related to the hydrology of west-central Utah have been made and are included in the list of references. Of special importance to this investigation are the study of the Bonneville Salt Flats and Pilot Valley playa (Lines, 1978 and 1979), the study of the brines of the Great Salt Lake Desert by Nolan (1928), and the study of the Nevada part of the southern Great Salt Lake Desert by Harrill (1971).

Acknowledgments

As a part of this study, R. J. Bisdorf supervised the earth-resistivity survey in Fish Springs Flat. D. W. Finn collected samples of water from Fish Springs for age-dating by carbon-14 analysis and computed the age of the water.

The cooperation of land and well owners in supplying information on wells and springs and allowing the collection of water samples for chemical analysis is gratefully acknowledged. Rolf Kraft, Refuge Manager, Fish Springs National Wildlife Refuge, and his staff were very helpful during the earth-resistivity survey at the refuge.

Well- and spring-numbering system

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating 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--generally 10 acrea (4 hm^2);[1] the letters a, b, c, and d indicated, respectively the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within

[1] Although the basic land unit, the section, is theoretically 1 mi^2 (2.6 km^2), many sections are irregular. Such sections are subdivided into 10-acre 4-hm^2) 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.

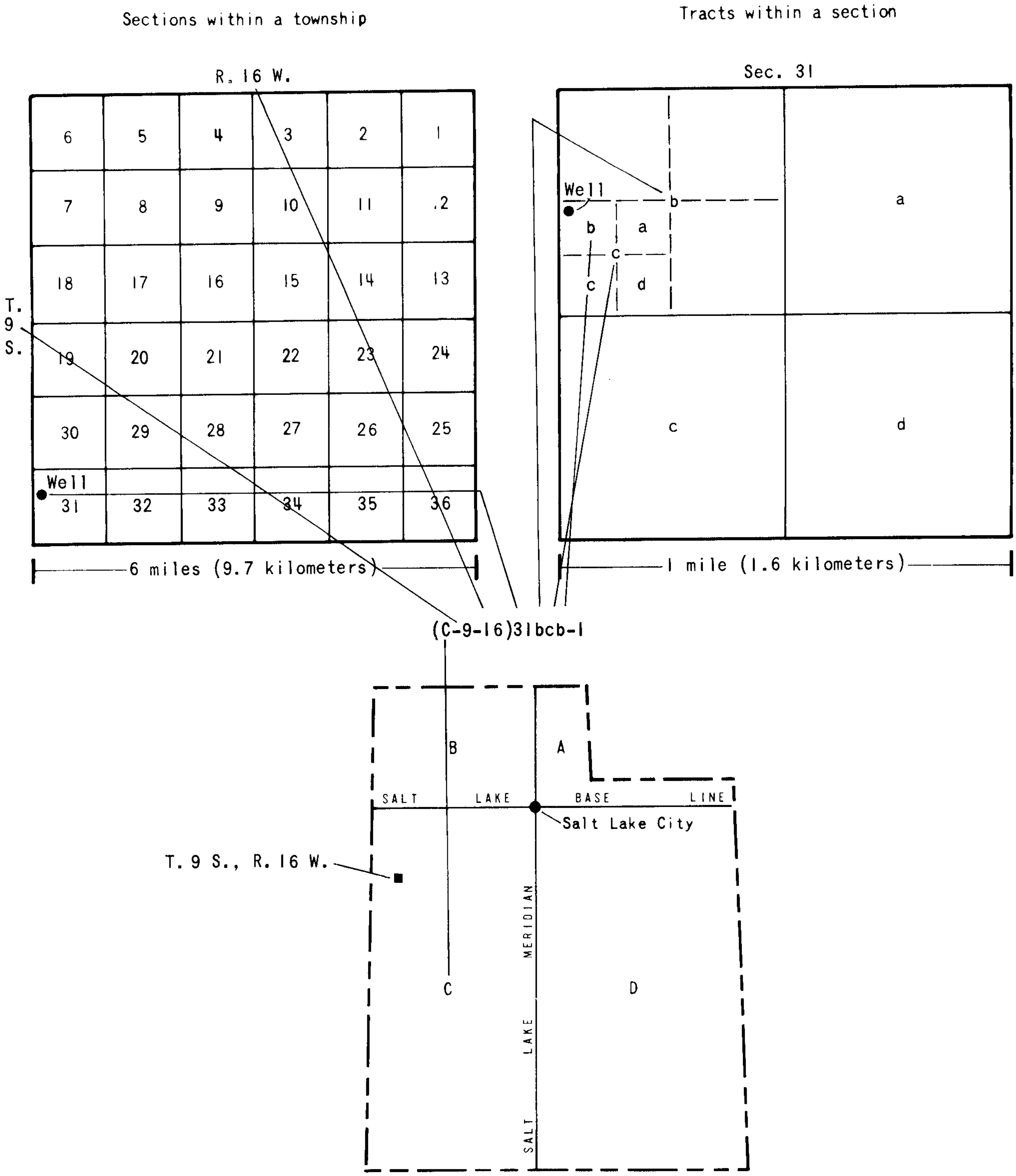


Figure 2.— Well- and spring-numbering system used in Utah.

the 10-acre (4-hm^2) tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used and the serial number is omitted. Thus (C-9-16)31bcb-1 designates the first well constructed or visited in the NW¼SW¼NW¼ sec. 31, T. 9 S., R. 16 W., and (C-9-16)31a-S1 designates a spring known only to be in the NE¼ of the same section. Other sites where hydrologic data were collected are numbered in the same manner, but three letters are used after the section number and no serial number is used. The numbering system is illustrated in figure 2.

In Nevada, the well and spring numbers are referenced to the Mount Diablo base line and meridian. A typical Nevada number consists of three elements. The first is the township north of the Mount Diablo base line; and the second element, separated from the first by a slant line, is the range east of the Mount Diablo meridian. The third element, separated from the second by a dash, is the section in the township, and the section number is followed by lowercase letters that indicate the quarter section and the quarter-quarter section.

Finally, the letters are followed by the serial number of the well within the quarter-quarter section. The letters a, b, c, and d, respectively, designate the northeast, northwest, southwest, and southeast quarters and quarter-quarters of the section.

PART 1

HYDROLOGIC RECONNAISSANCE OF THE SOUTHERN GREAT SALT LAKE DESERT

Location and general features

The southern Great Salt Lake Desert (fig. 1) includes an area of about 2,600 mi^2 (6,700 km^2), more than 70 percent of which is barren, saline mudflats or salt flats. Great Salt Lake is the remnant of Lake Bonneville of Pleistocene age, which covered much of western Utah, including the Great Salt Lake Desert (fig. 3). The drying up of this extensive freshwater lake left the mud and salt flats--the salt on the salt flats and in the saline mud is both a residue from the evaporation of the lake and salt left by evaporation of ground water, as the mudflats are the locus of discharge of much ground water in the Great Salt Lake Desert area.

The mountains around the southern Great Salt Lake Desert--the Cedar Mountains, Dugway Range, Fish Springs Range, Deep Creek Range, and Goshute Mountains-Toana Range (fig. 1)--are relatively upraised blocks of mostly Paleozoic and Tertiary rocks (pl. 1). Isolated mountains and hills within the desert, such as Wildcat Mountain, are geologically similar, although Granite Peak is a block mostly of intrusive igneous rock. The basin areas are relatively downdropped blocks covered with thick unconsolidated sediments derived from the mountain blocks.

Hydrology

Climate and precipitation

The climate of the southern Great Salt Lake Desert is temperate, arid to semiarid, with generally hot and dry summers and cold and moderately moist

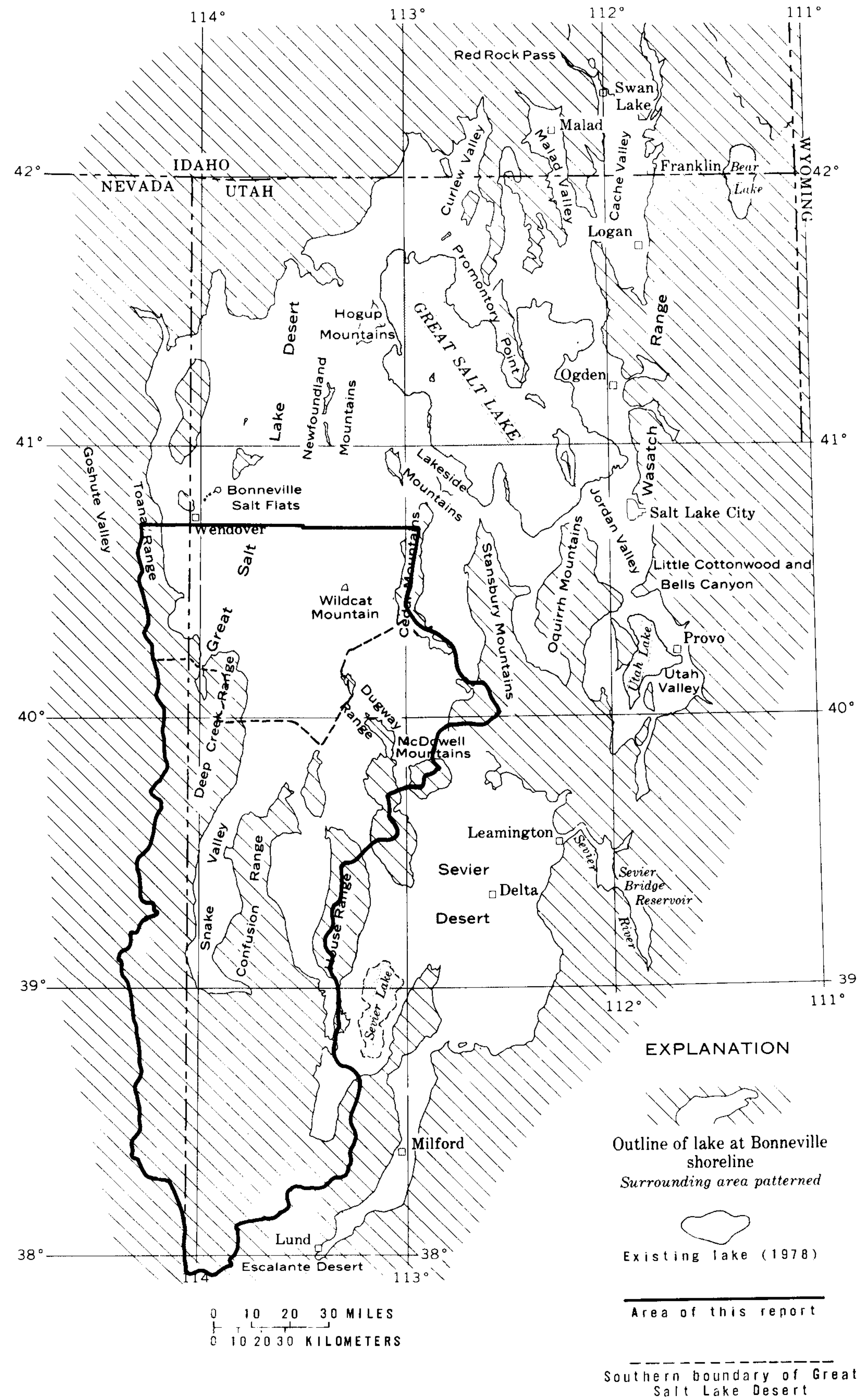


Figure 3.—Map of Lake Bonneville (after Crittenden, 1963, fig. 1).

winters. Wendover (fig. 1) is the site of the only long-term weather station (at an altitude of 4,237 ft or 1,291 m above mean sea level), in the Great Salt Lake Desert--just north of the area of this investigation. The 1941-70 normal annual precipitation at Wendover is 4.88 in. (124 mm) and normal average annual temperature is 52.2°F (11.2°C).

Gold Hill (fig. 1) has the only active weather station in the southern Great Salt Lake Desert, at an altitude of 5,320 ft (1,620 m). For the period of record (1967-77), annual precipitation averaged 9.45 in. (240 mm) and annual temperature averaged 50.7°F (10.4°C).

During the period when data are available for both stations, the station at Wendover averaged 110 percent of normal precipitation and 98 percent of normal temperature. (U.S. Environmental Science Services Administration, 1968-70; and U.S. National Oceanic and Atmospheric Administration, 1971-78).

Annual precipitation averages less than 6 in. (150 mm) over most of the southern Great Salt Lake Desert area, and less than 5 in. (130 mm) over its lowest north-central part (pl. 2). In the higher parts of the Cedar Mountains and Goshute Mountains-Toana Range and the parts of the Deep Creek Range tributary to the study area, annual precipitation is estimated to exceed 16 in. (410 mm), and probably exceeds 20 in. (510 mm) in a small tributary area in the Deep Creek Range.

Table 2, which uses data on plates 1 and 2, shows the estimated precipitation and ground-water recharge in the southern Great Salt Lake Desert. Total annual precipitation is estimated at about 880,000 acre-ft (1,085 hm^3) and total annual recharge at about 47,000 acre-ft (58 hm^3).

Surface water

No perennial streams originate in the southern Great Salt Lake Desert--only just below perennial springs is there any flow in stream channels, and this flow generally infiltrates within a short distance. Estimated surface runoff is negligible over most of the basin lowlands, and even in the highest parts of the tributary area in Utah in the Deep Creek Range, runoff is estimated to be less than 8 in. (202 mm) (Bagley and others, 1964, p. 55). In the Nevada part of the area, Katzer (in Harrill, 1971, p.16) estimated an average runoff from areas above 7,000 ft (2,100 m) in the Goshute Mountains-Toana Range to be about 0.6 in. (15 mm). Most of the approximately 880,000 acre-ft (1,085 hm^3) of precipitation that falls on the area annually is quickly discharged by evapotransipration or is stored temporarily as soil moisture to be discharged ultimately by evapotranspiration.

During and immediately after intense summer thunderstorms and during periods of rapid snowmelt, some water runs off the steep consolidated-rock slopes of the mountains. Very little of this runoff reaches the basin lowland areas, however, because it infiltrates the alluvial stream channels in and below the consolidated rock areas. Locally, at times, ephemeral streamflow reaches the basin areas where it spreads out on the flats and either evaporates quickly or is stored as ice or soil moisture and evaporates at a later time.

Table 2.--Estimated average annual volumes of precipitation and ground-water recharge in the southern Great Salt Lake Desert

[Areas of precipitation zones measured from isohyetal and geologic maps, plates 1 and 2]

Precipitation zone (inches)	Area (acres)	Precipitation		Recharge	
		Feet	Acre-feet	Percent of precipitation	Acre-feet
		Consolidated rocks			
Less than 5	1,900	0.375	700	0	0
5-6	14,200	.46	6,500	0	0
6-8	50,800	.58	29,500	1	300
8-10	44,800	.75	33,600	2	700
10-12	52,500	.92	48,300	6	2,900
12-16	55,700	1.17	65,200	10	6,500
16-20	10,200	1.5	15,300	20	3,100
More than 20	600	1.83	1,100	25	300
Subtotal	230,700		200,200		13,800
		Unconsolidated rocks			
Less than 5					
Lacustrine and other unconsolidated deposits	509,800	0.375	191,200	-	32,000[1]
Salt flats	31,200	.375	11,700	-	-
5-6	496,600	.46	228,400	0	0
6-8	328,200	.58	190,400	0	0
8-10					
Lacustrine deposits	4,300	.75	3,200	0	0
Other unconsolidated deposits	42,800	.75	32,100	1	300
10-12	16,400	.92	15,100	2	300
12-16	10,000	1.17	11,700	5	600
Subtotal	1,439,300		683,800		33,200
Totals (rounded)	1,670,000		880,000		47,000

[1]See pages 14-15 for discussion of recharge estimate for the crust and mudflats.

All drainage in the southern Great Salt Lake Desert, except for a small area in the northeast corner that drains to the northern part of the desert, is internal. The lowest part of the area is the Bonneville Salt Flats near Wendover (pl. 1).

Annual runoff in the southern Great Salt Lake Desert probably is on the order of 1 percent of precipitation, or somewhat less than 10,000 acre-ft (12 hm^3). Some surface flow reaches the southern Great Salt Lake Desert from tributary basins--an average of 2,000 acre-ft (2.5 hm^3) per year from Deep Creek Valley (Hood and Waddell, 1969, p. 18), and in some years small amounts from Snake Valley, Fish Springs Flat, and the Dugway Valley-Government Creek area.

Ground water

Ground water occurs in both consolidated and unconsolidated rocks in the southern Great Salt Lake Desert. The major ground-water reservoir, however, is the unconsolidated to partly consolidated basin fill.[1] The thickness of this material is not known in most parts of the area--only in the Wendover area have wells been drilled deep enough to penetrate a significant thickness of this unit. The Shell Oil Co. Salduro No. 1 oil test (in sec. 4, T. 2 S., R. 18 W.) reportedly penetrated unconsolidated rocks (probably lacustrine and alluvial deposits) to a depth of 1,375 ft (419 m) and volcanic rocks to a depth of 2,742 ft (836 m) (Turk, 1969, p. 26). Several deep brine wells drilled in T. 2 S., R. 19 W., by Kaiser Aluminum and Chemical Corp. and its predecessor companies have penetrated up to 2,068 ft (630 m) of unconsolidated and partly consolidated material--commonly lacustrine clays and gypsum to depths of about 700 to 1,100 ft (200 to 340 m) and unconsolidated and semiconsolidated sand and gravel and conglomerate below. Drillers' logs of two brine wells are given in table 9.

Stephens (1974a, fig. 4) illustrated the relations between the three aquifers--the shallow-brine, alluvial-fan, and basin-fill aquifers--in the Wendover area. His sketch, as modified by Lines (1979, fig. 30) is included in this report as figure 4. This illustration probably is most relevant in the Wendover-Bonneville Salt Flats area. In the rest of the lowlands of the southern Great Salt Lake Desert, the shallow-brine aquifer may not be present because of the lack of crystalline salt and possibly a lack of jointed, shallow carbonate muds. In addition, the lacustrine clays and gypsum beds between the shallow-brine aquifer and the basin-fill aquifer are likely thickest in the Bonneville Salt Flats area because this area probably has been the lowest part of the basin for a long time.

Test hole 33/69-34d, drilled 7 mi (11 km) southwest of Wendover to a depth of 838 ft (255 m), penetrated mostly alluvial-fan and basin-fill sands and gravels with almost no lacustrine deposits (Harrill, 1971, table 11).

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[1]In table 1 and on plate 1 of this report, the water-bearing basin fill is primarily material classified as older alluvium and sedimentary rocks, undifferentiated, and interbedded pyroclastics; although locally the ground-water reservoir may include part of the alluvium or colluvium of Quaternary age.

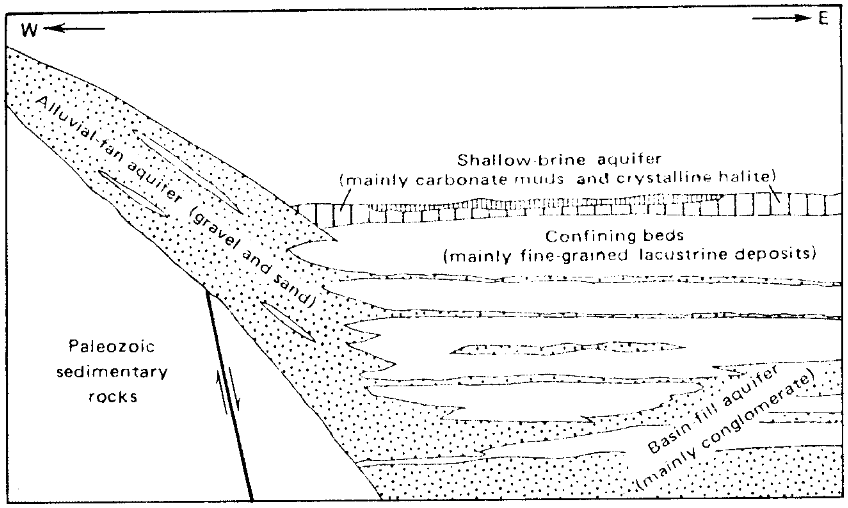

Figure 4.— Diagrammatic sketch showing inferred hydrogeology near Wendover (from Lines, 1979, fig. 30, as modified from Stephens, 1974a, fig. 4).

Another test hole, 33/70-21b, drilled 2 mi (3 km) southwest of Wendover to a depth of 750 ft (230 m), penetrated mostly sand and gravel to a depth of 446 ft (136 m), where it probably encountered consolidated rocks (Harrill, 1971, table 11). No other wells or test holes are known to have been drilled deeper than 535 ft (163 m) in the southern Great Salt Lake Desert.

The following information on aquifers in the southern Great Salt Lake Desert is compiled from data collected during this study and from data summarized by Turk (1969, p. 64-159), Stephens (1974a, p. 11-22), and Lines (1979, p. 56-96), mostly from the Bonneville Salt Flats-Wendover area. Very few general data and no data on hydraulic properties of aquifers are available outside of the Bonneville Salt Flats area.

Shallow-brine aquifer (saline mudflats)

The surficial lakebed clay and silt and crystalline salt comprise an aquifer that yields brines used for potash production near Wendover. This aquifer, which is included in material classified as lacustrine deposits in table 1, underlies the Bonneville Salt Flats, and possibly similar beds underlie about 1,900 square miles (4,900 km^2) of the saline mudflats of the southern Great Salt Lake Desert.

Nolan (1928) sampled brine in these beds over the entire Great Salt Lake Desert, and selected data from his study were used to construct the map of chemical quality of ground water in this report (pl. 3). However, whether these beds are permeable enough to yield brines to wells over the entire area is not known. Permeability at the Bonneville Salt Flats in the upper 15-25 ft (5-8 m) of these beds is due to the presence of crystalline salt and joints in the carbonate muds. The salt beds exist only in the salt-flats area and the extent of the permeable, jointed carbonate muds is not known. However, Nolan (1928, p. 34) did note the existence of several moist areas, some linear in shape, on the west side of the salt flats, and he speculated that they might be caused by a rise of brine along joints in the compact clays beneath the surface muds.

Aquifer properties.--Turk (1969, p. 115) gave a range, derived from aquifer tests, in the coefficient of storage of the shallow-brine aquifer of 1.2×10^{-1} to 5×10^{-5}. Lines (1979, p. 69-70) made four aquifer tests and obtained storage-coefficient values of 3.8×10^{-3} to 4.1×10^{-4}. These data indicate both unconfined and confined conditions--probably unconfined where vertical joints penetrate the entire unit, confined where they do not or where they are not present.

Lines (1979, fig. 33) constructed a map of transmissivity of the shallow-brine aquifer, using both his and Turk's data. The map shows that over most of the Bonneville Salt Flats, transmissivities are between 500 and 6,000 ft^2/d (46-560 m^2/d). The higher values of transmissivity are found where the crystalline salt is thickest.

Recharge.--Recharge and inflow to the shallow-brine aquifer are by infiltration of precipitation and by lateral subsurface inflow, largely from tributary basins. Brine-evaporation ponds may also contribute some recharge, but the amount from this source was not estimated. The exact amount of recharge to the shallow-brine aquifer is not known, but over a period of several years it is equal to the average discharge, most of which is made up of evaporation from the mudflats, or about 50,000 acre-ft (62 hm^3) per year (p. 34). Most of the recharge to the shallow-brine aquifer is from precipitation, much of which discharges by evaporation within the same year and within a short distance of where it is recharged.

Stephens (1974a, p. 13-14) estimated, using data presented by Turk (1969), that recharge by precipitation to the 96,000 acres (390 km^2) of salt crust at the Bonneville Salt Flats in the northern Great Salt Lake Desert is about 20,000 acre-ft (25 hm^3) per year. A proportional amount of recharge to the 31,200 acres (126 km^2) historically occupied by salt crust (as shown on topographic maps) in the southern Great Salt Lake Desert is about 6,500 acre-ft (8 hm^3) per year.

However, Lines (1979, figs. 10 and 11) indicated that there currently is no salt crust thicker than one-eighth of an inch (0.3 cm) in the southern Great Salt Lake Desert part of the Bonneville Salt Flats--most of the area now has gypsum and mud at the surface and is bordered by areas of carbonate muds. He (p. 85-86) estimated that recharge to these surfaces is about 10 percent of that to the salt-crust area, so perhaps this area receives 700 acre-ft (0.9 hm^3) per year of recharge. Whether this lesser rate of recharge can be applied to the entire 1,900 mi^2 (4,900 km^2) of saline mudflats in the southern desert is not known. If this were the case, however, recharge to the entire mudflat area would be about 25,000 acre-ft (31 hm^3) per year, about half of the amount estimated to discharge from the mudflats by evaporation.

The lateral subsurface inflow from the alluvial-fan aquifer to the shallow-brine aquifer probably is negligible, because recharge from precipitation that falls in the mountains bordering the southern Great Salt Lake Desert about equals the sum of evapotranspiration in a strip of land that borders the desert and the discharge from wells and springs between the uplands and the flats. However, about 18,000 acre-ft (22 hm^3) per year of ground water has been estimated to flow in the subsurface to the mudflats from tributary basins, and most of this water eventually moves into the shallow-brine aquifer or its equivalent.

Stephens and Sumsion (1978, p. 16) estimated that about 8,000 acre-ft (10 hm^3) per year of ground water moves from the Dugway Valley-Government Creek area to the southern Great Salt Lake Desert. Most of this water probably discharges by evaporation from the mudflats just northwest of where the area drains to the desert. In addition, Hood and Rush (1965, p. 24) estimated that about 10,000 acre-ft (12 hm^3) of ground water flows annually to the southern desert from Snake Valley, and this water also discharges by evapotranspiration on the mudflats just northeast of Snake Valley.

If total annual recharge to the shallow-brine aquifer is on the order of 50,000 acre-ft (62 hm^3), and annual subsurface inflow is 18,000 acre-ft (22 hm^3), then the approximate recharge by precipitation is the difference between these quantities, or on the order of 32,000 acre-ft (39 hm^3) per year.

Ground-water movement.--Except on the Bonneville Salt Flats, where withdrawals of brine have distorted the potentiometric and water-table contours, water-level data to determine directions of movement are lacking. Ground water probably moves from recharge areas on alluvial fans bordering the mountain ranges toward the saline mudflats, where it discharges by evaporation. Water that is recharged locally on the saline mudflats where the surface is permeable, may also discharge locally by evaporation, although some ground water probably moves toward lower areas on the flats. Whether most of the ground water under the entire mudflat area discharges at the Bonneville Salt Flats or discharges locally is not known.

Lines (1979, figs. 34, 35, 37, and 38) prepared maps of the potentiometric surface on the Salt Flats which indicate that ground-water movement is now from the salt crust toward manmade points of discharge--the brine-collection ditches and wells along the western edge of the Salt Flats. However, before brine was withdrawn by man, ground water in the shallow-brine aquifer probably moved to the salt-crust area, where it discharged by evaporation (Lines, 1979, p. 77).

Discharge.--The shallow-brine aquifer discharges ground water by evaporation and by flow into brine-collection ditches. No wells or springs are known to discharge water from this aquifer.

Lines (1979, p. 89) determined the rate of evaporation from the carbonate muds on the Bonneville Salt Flats to be about 3.0×10^{-3} in./d (7.6×10^{-3} cm/d). If evaporation occurs at this rate over the entire southern desert mudflat area, the annual ground-water discharge would be about 100,000 acre-ft (123 hm^3). But because the average water-table depth probably is greater than the depth at the salt flats, a better estimate may be half of this figure, or 50,000 acre-ft (62 hm^3) per year. This figure was used as the total discharge from the shallow-brine aquifer. Ground water discharged by the brine-collection ditches was not added to this amount because the ditches divert water normally discharged by evaporation.

Stephens (1974a, p. 14-15) summarized data that indicate that the brine-collection ditches north of U.S. Highway 40 (now Interstate 80) in the northern Great Salt Lake Desert receive about 960 acre-ft (1.2 hm^3) per year of ground water from the shallow-brine aquifer. No data are available on discharge to the more extensive ditch system south of the highway in the southern Great Salt Lake Desert, but it probably is on the order of 1,000-10,000 acre-ft (1.2 to 12 hm^3) per year.

Storage.--No estimate was made of water in storage in the shallow-brine aquifer. Not enough data are available on aquifer properties over the entire mudflat area, and other than for mineral production, the brine has no uses.

Alluvial-fan and basin-fill aquifers

Unconsolidated alluvium, much of it sand and gravel, occurs between the mountain areas and the mudflats in the southern Great Salt Lake Desert, and underlies the mudflats at depth. This material, where it is saturated, is part of either the alluvial-fan or basin-fill aquifers--because these aquifers merge (fig. 4), it generally is not possible or particularly useful to determine which aquifer is tapped by a given well.

Shallow wells close to the mountains probably tap the alluvial-fan aquifer, and deep wells close to the mudflats probably tap the basin-fill aquifer. The deep wells drilled to produce brine on the Bonneville Salt Flats tap unconsolidated to semiconsolidated sand, gravel, and conglomerate in the basin-fill aquifer. The basin-fill aquifer and deeper parts of the alluvial-fan aquifer correspond to the upper or non-volcanic part of the unit "older alluvium and sedimentary rocks, undifferentiated, and interbedded pyroclastics" of Tertiary and Quaternary age in table 1. The shallower parts of the alluvial-fan aquifer correspond to the unit "alluvium or colluvium" of Quaternary age in table 1.

Water in the basin-fill aquifer and in the deeper and downslope parts of the alluvial-fan aquifer probably is under semiartesian or artesian conditions. The clay beds and lenses that occur in these aquifers impede the vertical movement of water and cause it to be under artesian pressure. Six wells that were drilled to depths of from 45 to 77 ft (14 to 23 m) in T. 9 S., R. 16 W. (see table 8 and pl. 2) flow at land surface, at the toe of alluvial fans east of the Deep Creek Range, proving that water occurs under artesian conditions locally at shallow depths. Values of the coefficient of storage obtained from aquifer tests near Wendover indicate that the water in the basin-fill aquifer is under artesian conditions (Stephens, 1974a, p. 21), although the wells do not flow. Wells drilled on the higher parts of alluvial fans in the southern Great Salt Lake Desert probably tap water under water-table conditions.

Aquifer properties.--Little is known about the hydraulic properties of the alluvial-fan and basin-fill aquifers other than under and adjacent to the Bonneville Salt Flats. Aquifer-test data from that area indicate that the alluvial-fan aquifer has a transmissivity in the range of 20,000-70,000 ft^2/d (1,900-6,500 m^2/d) and a storage coefficient of 1 to 5 x 10^{-4} (Turk, 1969, p. 70). The basin-fill aquifer, in the vicinity of Wendover, has a transmissivity of about 13,000 ft^2/d (1,200 m^2/d) and a storage coefficient of about 4 x 10^{-4} (Stephens, 1974a, p. 21).

Recharge.--Recharge to the alluvial-fan and basin-fill aquifers of the southern Great Salt Lake Desert originates from precipitation on the mountain areas around the desert and on the upper parts of the alluvial fans. Recharge probably occurs mainly as infiltration of surface water as it flows out of the mountain areas onto the fans, either as a result of snowmelt or summer thunderstorms. This water moves down to the water table in the alluvial-fan aquifer and then laterally into the basin-fill aquifer.

The annual amount of recharge to these aquifers is about 15,000 acre-ft (18 hm^3), which includes recharge derived from all areas above the saline mudflats and salt flats--47,000 acre-ft (58 hm^3) for the entire southern desert less 32,000 acre-ft (39 hm^3) to the salt and mudflats, (see table 2).

Ground-water movement.--Water infiltrates into the upper parts of the alluvial fans along the mountains, moves down to the water table, and then moves laterally in the alluvial-fan and basin-fill aquifers toward the saline mudflats, and mostly discharges by evapotranspiration in areas of phreatophytes along the margin of the flats.

Plate 2 shows contours of ground-water levels for west-central Utah. The areas where data are available and contours are drawn are few in the southern Great Salt Lake Desert, but they show the general movement from the mountain areas toward the mudflats. Water-level data near Clive Siding in the northeastern part of the southern Great Salt Lake Desert, near Wendover in the northwestern part, at the north end of the Deep Creek Range, and along the southern edge of the desert from Callao to Dugway Valley, all show that ground water moves from the upland areas toward the mudflats.

Discharge.--Most of the water moving toward the mudflats in the alluvial-fan and basin-fill aquifers discharges by evapotranspiration along the margin of the flats. A band of phreatophytes averaging about 0.5 mi (0.8 km) wide borders the mudflats east of the Goshute Mountains-Toana Range and the Deep Creek Range and west of the Cedar Mountains. Species of phreatophytes present include greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), and iodinebush (*Allenrolfea occidentalis*), with some saltgrass (*Distichlis spicata*, var. stricta), sagebrush (*Artemisia tridentata*), seepweed (*Suaeda torreyana*), rabbitbrush (*Chrysothamnus nauseosus*), and saltbush (*Atriplex truncata* and *Atriplex* cf. *tridentata* (?)).

Mower and Nace (1957, table 6) list annual consumption of water by phreatophytes in Malad Valley, Idaho, about 150 mi (240 km) northeast of the southern Great Salt Lake Desert. They include four phreatophytes common around the margin of the southern desert--greasewood, iodinebush (pickleweed), saltgrass, and rabbitbrush--with an average annual water consumption for 100-percent density of 2.6 acre-ft/acre (0.79 m^3/m^2). The area of the band of phreatophytes around the southern desert is about 35 mi^2 (90 km^2), and the plant density is about 20 percent. If the water used annually around the southern desert is about 3 acre-ft/acre (0.9 m^3/m^2) for 100-percent density, then the discharge from this zone by evapotranspiration is on the order of 13,000 acre-ft (16 hm^3).

In addition to discharge by evapotranspiration, ground water in the alluvial-fan and basin-fill aquifers is discharged by springs and wells. The discharge from Redden Springs, (C-9-16)31ccd-S1, is about 800 acre-ft (1 hm^3) per year, and the flowing wells around the springs (also in sec. 31) discharge about 700 acre-ft (0.9 hm^3) per year. Irrigation well (C-6-18)5ddb-1 and the few stock and domestic wells in the area probably discharged about 800 acre-ft (1 hm^3) in 1978. The total annual discharge from wells and springs in the alluvial-fan and valley-fill aquifers is estimated to be about 2,300 acre-ft (2.8 hm^3).

Storage.--No estimates were made of the amounts of water stored in the alluvial-fan and basin-fill aquifers because little is known of their thickness, extent, and specific yield. A large quantity of water probably is stored in the basin-fill aquifer, but much of the aquifer probably is fine grained or partly cemented and has a low specific yield, which would result in a smaller amount of recoverable water. In addition, much of the water probably is of poor quality and is unsuitable for most uses.

Only in the area north of Callao is there a known occurrence of fresh ground water that could be tapped by wells. In the part of this area in the southern Great Salt Lake Desert (around the southwest corner of T. 9 S., R. 16 W.), freshwater occurs in a section that probably is at least 100 ft (30 m) thick under an area of about 4 mi^2 (10 km^2). If the specific yield of the saturated material is 10 percent, then on the order of 26,000 acre-ft (32 hm^3) of recoverable fresh ground water is in storage.

Other aquifers

Other aquifers in the southern Great Salt Lake Desert area include unconsolidated alluvial deposits in stream channels in the mountains and consolidated rocks. Little is known of aquifer properties and recharge, movement, and storage of ground water in these aquifers, although some data are available on ground-water discharge.

On the west side of the Cedar Mountains, five springs (three are shown in pl. 2) with small flow discharge about 10 acre-ft (0.012 hm^3) per year from quartzitic and carbonate rocks. On the east side of the Goshute Mountains in Nevada, about 16 springs (five are shown on pl. 2) with small to moderate flows discharge about 80 acre-ft (0.098 hm^3) per year from volcanic or carbonate rocks. At the northeast end of the Deep Creek Range, about 12 springs (three are shown in pl. 2), most with small flows, discharge about 70 acre-ft (0.086 hm^3) per year from carbonates and igneous rocks.

All these springs discharge water that has been recharged locally into fractured and jointed carbonates, quartzites, volcanics, and igneous rocks, and possibly into carbonates that contain solution openings. The total amount discharged from springs of this type in the southern Great Salt Lake Desert is about 160 acre-ft (0.20 hm^3) per year.

In addition, two spring areas are east of the Goshute Mountains at the edge of the saline mudflats--Blue Lake Springs (also called Big Salt Springs), (C-4-19)7abc-S1, and a smaller spring area 2 mi (3 km) to the south (sometimes called Little Salt Springs), (C-4-19)20abb-S1. Blue Lake Springs discharge about 17,000 acre-ft (21 hm^3) per year, and the springs 2 mi (3 km) south discharge about 1,700 acre-ft (2.1 hm^3) per year.

Both spring areas are just east of outcrops of brecciated limestone of Paleozoic age and probably represent discharge of water from the limestone along fault zones. Water discharged from these springs likely is recharged outside the drainage of the southern Great Salt Lake Desert (probably in Nevada west of the Goshute Mountains) and moves into the basin by subsurface flow through carbonate rocks.

Harrill (1971, p. 17 and 23, table 7) prepared water budgets for the basins in Nevada to the west and southwest of the southern Great Salt Lake Desert. He estimated that annual amounts of 1,000 acre-ft (1.2 hm^3) from Goshute Valley and 5,000 acre-ft (6.2 hm^3) each from Antelope and Tippett Valleys flow in the subsurface through consolidated rock to the Utah part of the southern Great Salt Lake Desert. Most of this 11,000 acre-ft (14 hm^3) per year likely discharges from the springs at and south of Blue Lake. The entire 19,000 acre-ft (23 hm^3) that is discharged by the springs probably enters the southern desert from basins to the west in Nevada, although studies conducted along the eastern border of Nevada do not indicate this amount of water moving to Utah (Harrill, 1971, table 7; Nevada Division of Water Resources, 1971).

Summary of estimates of recharge and discharge

In this type of hydrologic reconnaissance, a precise hydrologic budget is not possible; but a usable estimate can be made for most items.

The total discharge from wells, springs, and phreatophytes above the mudflats, about 15,500 acre-ft (19 hm^3), is approximately equal to the 15,000 acre-ft (18 hm^3) of recharge. Therefore, most of the ground water recharged in the uplands apparently is discharged before it reaches the mudflats.

If much of the mudflat area has low surface permeability, recharge to the flats could be much less than the 50,000 acre-ft (62 hm^3) per year estimated.

The total annual recharge and inflow to the southern Great Salt Lake Desert, as given above, is about 84,000 acre-ft (104 hm^3), of which 19,000 acre-ft (23 hm^3) flows into the area through consolidated rock and 18,000 acre-ft (22 hm^3) through unconsolidated basin fill. Recharge and discharge estimates, in acre-feet per year, for the southern Great Salt Lake Desert are summarized below:

Water recharged to or entering the southern Great Salt Lake Desert		Water discharged from the southern Great Salt Lake Desert	
Recharge to alluvium or basin fill above the mudflats--	15,000	Discharge from springs in the uplands--------------	160
Recharge to the mudflats by precipitation------------	32,000	Discharge from wells and springs between the uplands and the mudflats---------	2,300
Subsurface inflow to the mudflats through basin fill from the Dugway Valley-Government Creek area--------------------	8,000	Discharge by evapotranspiration in a band of phreatophytes around the upper margin of the mudflats---	13,000
From Snake Valley---------	10,000	Discharge by evaporation from the mudflats--------	50,000
Subsurface inflow through consolidated rock from basins to the west in Nevada-------------------	19,000	Discharge from the springs at and south of Blue Lake--------------------	19,000
Totals (rounded)	84,000		84,000

Water quality

Ground water in the southern Great Salt Lake Desert ranges in quality from fresh to briny, according to a classification commonly used by the U.S. Geological Survey (Hem, 1970, p. 219):

Classification	Dissolved-solids concentration, in milligrams per liter
Fresh	Less than 1,000
Slightly saline	1,000- 3,000
Moderately saline	3,000-10,000
Very saline	10,000-35,000
Briny	More than 35,000

Plate 3 shows the locations where ground water was sampled in the southern desert and shows the dissolved-solids content of the water. Complete analyses for the samples are given in table 10. Where data are sufficient, colors are used to show where the basin fill contains fresh, slightly saline, moderately saline, very saline, and briny ground water.

Data collected by Nolan (1928) were used to indicate the quality of shallow brine under the mudflats. The dissolved-solids content of selected brine samples collected by Nolan from boreholes 3-10 ft (0.9-3 m) deep is shown at the location of each hole. Contours are used to indicate the general dissolved-solids content of the brine under the mudflats.

No samples of surface water were collected for chemical analysis in the southern desert.

Plate 3 shows that most of the ground water in the southern Great Salt Lake Desert is slightly saline to briny. Ground water in the shallow-brine aquifer or its equivalent under the mudflats is briny, commonly containing more than 100,000 mg/L dissolved solids, and samples from the basin-fill aquifer under the Bonneville Salt Flats in the Wendover area show that the deeper ground water there is also briny. The highest dissolved-solids content in the brine, more than 200,000 mg/L, occurs in an elongate area on the west side of the mudflats extending from Wendover southeast toward Fish Springs. This is the last local area of ancient Lake Bonneville to dry up. It is the lowest area of the flats, where surface water collects at times and where a large proportion of the ground-water discharge from the flats occurs.

Ground water in the other parts of the basin-fill aquifer and in the alluvial-fan aquifer ranges from fresh to very saline. The only area where a large amount of fresh ground water occurs in the southern Great Salt Lake Desert is just north of Snake Valley. This water is outflow from Snake Valley and recharge from the east slopes of the Deep Creek Range. Slightly saline ground water occurs at the north end of the Deep Creek Range where Deep Creek recharges the alluvial-fan aquifer. Small volumes of fresh ground water probably occur locally along the east margin of the Goshute Mountains, although no data are available in this area to indicate such occurrences.

Springs in the upland areas yield freshwater on the east side of the Goshute Mountains and the east side of the Deep Creek Range. Springs at the north end of the Deep Creek Range yield fresh to moderately saline water, probably because some of the rocks have been hydrothermally altered and include significant amounts of soluble material. Springs in the Cedar Mountains yield slightly to moderately saline water. This water probably is salty because salt and saline particles of sediment are deposited in the mountains by the predominantly westerly winds and dissolved by precipitation that ultimately recharges permeable zones in consolidated rocks.

Water from the large-yield springs discharging from consolidated rock at and south of Blue Lake is moderately saline. This water likely has moved into the southern Great Salt Lake Desert from outside the drainage basin. It probably has traveled distances of up to several tens of miles at depths of up to several thousands of feet and has dissolved soluble material in transit.

Potential for additional water-resources development

Large amounts of ground water occur in the southern Great Salt Lake Desert, but most of it is of poor quality and much of it is in fine-grained unconsolidated deposits that will not yield more than a few gallons per minute of water to wells. Only in the area north of Snake Valley and in the area where Deep Creek enters the southern desert are there large quantities of fresh to slightly saline ground water that could be developed for irrigation or stock supply. In addition, small volumes of fresh to slightly saline ground water possibly occur locally along the east side of the Goshute Mountains. These could be developed for stock supplies. Much of the mudflat area may be underlain by deposits permeable enough to yield brine to wells for mineral extraction.

Ground water presently discharged by evapotranspiration from areas of phreatophytes and from the mudflats can be intercepted by wells between the flats and the uplands, but because this discharge is at a small rate along the entire margin of the mudflats, large-scale salvage in any one area is not practical. The only possible exception is at the north end of Snake Valley where Hood and Rush (1965, p. 24) estimated that 10,000 acre-ft (12 hm^3) per year of ground water flowed to the southern desert, and where additional fresh ground water moves toward the mudflats from the east slopes of the Deep Creek Range north of the area studied by Hood and Rush.

PART 2

SUMMARY OF THE HYDROLOGY OF WEST-CENTRAL UTAH

Part 2 of this report is a summary of the hydrology of the entire west-central Utah area. This section briefly discusses surface water, ground water, and water quality; makes an estimate of the potential for water-resources development; summarizes the evidence of interbasin ground-water flow; and presents a theory for the source of the water that discharges from Fish Springs.

For the purpose of this report, west-central Utah (fig. 1) includes that part of the State commonly termed the "Western Desert" south of T. 1 S. and tributary areas on the eastern edge of Nevada. It includes the southern half of the Great Salt Lake Desert, Dugway Valley, the Government Creek area, Fish Springs Flat, and Tule, Wah Wah, Pine, and Snake Valleys (Snake Valley includes Hamlin Valley and the Ferguson Desert). Parts of Snake Valley (including much of Hamlin Valley) and the southern Great Salt Lake Desert are in Nevada. Major mountain ranges within the area are the Dugway Range, Fish Springs Range, Wah Wah Mountains, Confusion Range, House Range, and Deep Creek Range; and major ranges bounding the area include the Cedar Mountains, Snake Range, and White Rock Mountains.

Figure 1 shows the general physiography, plate 1 shows hydrogeologic units, plate 2 shows annual precipitation and water-level contours, and plate 3 shows water quality. Table 1 is a general description of the lithology and water-bearing characteristics of hydrogeologic units. These units are not based on the standard stratigraphic classification, but consist of standard units grouped together mostly because of similar hydrologic characteristics and, to a lesser degree, because of age and lithology.

Faults are not shown on plate 1 because no general relation between major faults and ground water is known for west-central Utah. Faults and fractures likely affect ground-water occurrence and movement in the area, but the relations probably are local and complex. More detailed descriptions of the hydrology of individual basins are given in the publications listed on page 3 and in the preceding part of this report.

Precipitation

Average annual precipitation over west-central Utah, an area of about 10,300 mi^2 (26,700 km^2), ranges from less than 5 in. (130 mm) in the Great Salt Lake Desert to more than 30 in. (760 mm) in the Deep Creek Range. Total average annual precipitation is about 4.88 million acre-ft (6,020 hm^3) (table 3). Of this precipitation, an average of about 4 percent (211,000 acre-ft or 260 hm^3) recharges the ground-water reservoir. Most of the remainder of the precipitation is returned to the atmosphere by evapotranspiration before it reaches the water table. A small percentage of the water runs off in streams and also is eventually returned to the atmosphere by evapotranspiration because west-central Utah is part of the Great Basin, which has no outlet to the ocean. Ultimately, all the precipitation on west-central Utah, except for minor amounts that may be lost by subsurface outflow from the area, returns to the atmosphere by evapotranspiration--including precipitation that recharges the ground-water reservoir.

Table 3.--Summary of estimated average annual volumes of precipitation and ground-water recharge in hydrologic areas of west-central Utah

Hydrologic area	Area (1,000s of acres)	Precipitation (1,000s of acre-ft/yr) (rounded)	Recharge	
			Percent of precipitation	1,000s of acre-ft/yr
Dugway Valley-Government Creek area	570	380	1.8	7
Fish Springs Flat	379	230	1.7	4
Deep Creek Valley	281	290	5.9	17
Wah Wah Valley	380	290	2.4	7
Pine Valley	466	410	5.1	21
Tule Valley	600	400	1.9	7.6
Snake Valley	2,230	2,000	5.0	100
Southern Great Salt Lake Desert (table 2)	1,670	880	5.3[1]	47[1]
Totals (rounded)	6,600	4,880	4.3	211

[1]Includes 32,000 acre-ft of local recharge on the mudflats of the Great Salt Lake Desert (if this quantity is left out and only precipitation and recharge above the mudflats are considered, the recharge and percentage of precipitation for the southern Great Salt Lake Desert are 15,000 acre-ft/yr and 3.4 percent, respectively).

Surface water

In addition to direct precipitation, one basin in west-central Utah receives surface inflow from an adjacent basin. Surface flow of 2,000 acre-ft (2.5 hm^3) per year moves from Deep Creek Valley to the southern Great Salt Lake Desert. (p.12). However, no surface flow moves to west-central Utah from outside its drainage, and none moves out of west-central Utah.

Few perennial streams are in the area and very little streamflow reaches the basin lowlands from the mountains. Only near the Deep Creek Range and near the Snake Range in Nevada are there streams that have perennial reaches in the basin lowlands areas. The only long-term record of flow in the area is for Trout Creek near Callao (see pl. 2), where the average annual discharge from October 1958 to October 1977 was about 3,800 acre-ft (4.7 hm^3) (U.S. Geological Survey, 1978). Other runoff occurs only as a direct result of thunderstorms or during brief periods of spring snowmelt. Estimates of as much as 2,590 ft^3/s (73.3 m^3/s) of peak flow due to thunderstorms have been made for ephemeral streams in the area (Stephens, 1977, p. 11). Total annual runoff in west-central Utah is about 110,000 acre-ft (140 hm^3)--of which more than three-quarters is in the Snake Valley and Deep Creek Valley drainages.

This figure was obtained by summing estimates of runoff from the reports listed on page 3. Much of this runoff infiltrates unconsolidated deposits just below the mountain fronts.

Ground water

Ground water occurs in consolidated and unconsolidated rocks, with the largest supplies in the unconsolidated fill underlying the basins. Estimated ground-water budgets for each of the basin areas of west-central Utah, based on the reports in this series, are given in table 4. The average annual recharge to and discharge from the ground-water reservoirs of individual basins are approximately in balance. In this and other reports in this series, the budgets for individual basins have been balanced by assuming that subsurface inflow or outflow exists equal to the difference between estimates of recharge and discharge for each basin.

Only in Snake Valley is ground-water discharge greater than recharge, and this is because of withdrawals of water from wells. In 1964 about 7,000 acre-ft (8.6 hm^3) was pumped in the valley (Hood and Rush, 1965, p. 23), but by 1977 the pumpage had increased to about 18,000 acre-ft (22 hm^3) (Herbert in Gates and others, 1978, p. 13), much of which probably was withdrawn from storage.

The sums of average long-term annual pre-development recharge and discharge to all the basins of west-central Utah, as based on this and previous reports (including subsurface inflow and outflow), probably are about equal at 324,000 acre-ft (399 hm^3). However, if the flow from springs at and near Blue Lake represents underflow from outside west-central Utah, total recharge from precipitation and subsurface inflow from outside the basins is about 240,000 acre-feet (296 hm^3) per year, as shown below.

	Acre-feet
Annual recharge from precipitation within west-central Utah	211,000
Annual inflow to the Dugway Valley-Government Creek area from the Sevier Desert	5,000
Annual inflow to Snake Valley from Spring Valley, Nevada	4,000
Annual inflow to the southern Great Salt Lake Desert from areas to the west in Nevada	19,000
Total (rounded)	240,000

The difference between 324,000 acre-ft (399 hm^3) and 240,000 acre-ft (296 hm^3), or 84,000 acre-ft (104 hm^3), results from subsurface flow between the basins of west-central Utah. Part of the recharge to some basins discharges to other basins and is included more than once in computations of recharge and discharge.

The generalized water-level contours in plate 2 show the approximate altitude and configuration of the potentiometric surface where the data are available in the basin areas. Most of the water levels used to construct the map were measured during 1964-78, although some water levels in stock wells were measured prior to this. However, with the exception of parts of Snake

Valley, where ground water is being withdrawn from storage, water levels probably have changed little in west-central Utah since measurements began; and the contours fairly well portray the current potentiometric surface.

The contours show that the general direction of ground-water movement is toward the southern Great Salt Lake Desert, indicating that the desert, except for any relatively small volumes of water that may be moving out of the area by subsurface flow through consolidated rock, is the eventual discharge point for much of the ground water in west-central Utah. Although data under the mudflats are lacking, the potentiometric surface there probably is relatively flat.

Table 5 gives estimates of volumes of ground water in storage that can be withdrawn by wells from the upper 100 feet (30 m) of saturated unconsolidated aquifer material in six of the eight basins in west-central Utah. The total volume of recoverable water is about 17.4 million acre-ft (21,450 hm^3), of which possibly two-thirds is fresh. The total volume of ground water in these six basins undoubtedly is several times this amount because much ground water occurs below the upper 100 ft (30 m) of saturated material. However, a significant amount of the deeper water likely is slightly saline or of poorer quality. Insufficient data were available to make estimates of water in storage in Wah Wah and Pine Valleys, although large amounts very likely exist--even if they are partly of poor quality and in low-permeability material.

Estimates of ground water in storage in the upper 100 ft (30 m) of saturated material were made for six of the basins. In Fish Springs Flat, the Dugway-Government Creek area, and Tule Valley, about 550,000 acre-ft (680 hm^3), 3.8 million acre-ft (4,700 hm^3), and 680,000 acre-ft (840 hm^3), respectively, is in storage; but much of this water is slightly to moderately saline and much may occur in deposits of low permeability and specific yield. In these basins, the amount of water of good quality that is easily recoverable by wells probably is considerably less than the figures given.

In the southern Great Salt Lake Desert, large volumes of ground water exist, but much of it is brine and may occur in material of low permeability. The 26,000 acre-ft (32 hm^3) of water estimated to be in storage is that which is fresh and in relatively permeable material. Deep Creek Valley contains 320,000 acre-ft (395 hm^3) in storage, most of which is fresh and in permeable material. Snake Valley has the largest volume of ground water that is mostly fresh and mostly in permeable material--12 million acre-ft (14,800 hm^3). Details of the estimation of the volumes of ground water are given in the reports listed on page 3.

Water quality

Dissolved-solids concentrations in samples of ground and surface water from west-contral Utah range from 38 to 136,000 mg/L. This does not include samples of shallow brine collected from just below the surface of the southern Great Salt Lake Desert by Nolan (1928), which contained as much as 258,000 mg/L dissolved solids. Concentrations in ground-water samples range from 94 to 136,000 mg/L (table 6). The 147 analyses summarized in table 6 are given in reports listed on page 3, in table 10, and by the U.S. Geological Survey (1977, 1978). The samples were collected from 72 wells (127 to 136,000 mg/L), 70 springs (94 to 22,000 mg/L), and five mines (130 to 3,240 mg/L). In

Table 4.—Summary of ground-water budgets for hydrologic areas in west-central Utah

[All volumes are in thousands of acre-feet per year]

Area	Recharge				Discharge					Remarks
	From precipitation	Subsurface inflow	Origin	Subtotal (rounded)	Evapotranspiration	Wells, springs, and seeps	Subsurface outflow	Destination	Subtotal (rounded)	
Dugway Valley-Government Creek area	7	<5[1]	Sevier Desert	12	<1	2.8	8[1]	Great Salt Lake Desert	12	Subsurface outflow to the Great Salt Lake Desert estimated to balance the difference between recharge and discharge.
Fish Springs Flat	4	31[2]	?	35	8	27	<.1[1]	do.	35	Subsurface inflow estimated to balance the difference between discharge and recharge.
Deep Creek Valley	17	0	—	17	15	1.6	0	—	17	
Wah Wah Valley	7	3[2]	Pine Valley	10	.6	.9	8.5[2]	?	10	Subsurface outflow estimated to balance the difference between recharge and discharge.
Pine Valley	21	0	—	21	5.5	1.6	14[2]	3 to Wah Wah Valley, 11 to ?	21	Do.
Tule Valley	7.6	32[2]	?	40	40	.13	0	—	40	Subsurface inflow estimated to balance the difference between discharge and recharge.
Snake Valley	100[3]	4[2]	Spring Valley, Nev.	105±[3]	80	7	10[1]	Great Salt Lake Desert	112	Subsurface outflow (through consolidated rock) estimated to balance the difference between recharge and discharge; discharge greater than recharge because (1) much of the water discharged by wells is taken from ground-water storage, and (2) some of the water discharged by wells is intercepted discharge by evapotranspiration not accounted for in estimates of discharge by evapotranspiration.
							15[2]	Fish Springs Flat(?)		

Table 4.—Summary of ground-water budgets for hydrologic areas in west-central Utah—Continued

Area	Recharge				Discharge					Remarks
	From precipitation	Subsurface inflow	Origin	Subtotal (rounded)	Evapotranspiration	Wells, springs, and seeps	Subsurface outflow	Destination	Subtotal (rounded)	
Southern Great Salt Lake Desert	47[4]	19[2]	11 from Goshute, Antelope, and Tippitt Valleys in Nevada; 8 probably from these same valleys.	84	63[5]	21	0	—	84	8,000 of 19,000 acre-ft/yr subsurface inflow estimated to balance the difference between discharge and recharge.
		18[1]	10 from Snake Valley and 8 from Dugway Valley-Government Creek area.							
Totals (rounded)	211	112		324	213	62	56		331	

[1] Flow through unconsolidated basin fill.
[2] Flow through consolidated rock.
[3] Hood and Rush (1965, table 5) estimated 100,000 acre-ft/yr recharge from precipitation, and then estimated total recharge to be about 105,000 acre-ft/yr (4,000 acre-ft/yr subsurface inflow + 100,000 acre-ft/yr = 105,000 ± acre-ft/yr). Although the figures do not balance, they are used in this report as they were given.
[4] Includes 32,000 acre-ft of local precipitation on the mudflats.
[5] Includes 50,000 acre-ft of evaporation from the mudflats.

Table 5.--Estimated volumes of recoverable ground water in storage in hydrologic areas of west-central Utah[1]

Area	Assumed specific yield or storage coefficient	Volume in storage (1,000s of acre-ft)	Remarks
Dugway Valley-Government Creek area	0.10	3,800	Fresh to moderately saline.
Fish Springs Flat	.025	550	Mostly slightly to moderately saline.
Wah Wah Valley	-	([2])	Fresh to moderately saline(?).
Pine Valley	-	([2])	Mostly fresh(?).
Tule Valley	.10	680	Fresh to slightly saline.
Deep Creek Valley	.10	320	Mostly fresh.
Snake Valley	.10	12,000	Do.
Southern Great Salt Lake Desert	.10	26	Freshwater only, north of Callao.
Total (rounded)		17,400	

[1]Based on dewatering of the upper 100 ft (30 m) of saturated material.

[2]Insufficient data to use in estimating.

addition, samples from nine streams in the area had a range of 38 to 407 mg/L in dissolved-solids concentration.

Plate 3 shows the generalized occurrence of ground water classified by salinity in unconsolidated deposits of west-central Utah. All the basins (with the exception of Fish Springs Flat) have some known areas with fresh ground water, and most of Snake and Deep Creek Valleys is underlain by freshwater. The Dugway Valley-Government Creek area and Fish Springs Flat have large areas with slightly saline and poorer quality water, and most of the southern Great Salt Lake Desert is underlain by brine. The water in the southern desert is the poorest quality because it contained the last, and most saline, local remnant of ancient Lake Bonneville, and the surficial sediments are saline. In addition, the desert is the discharge area for much of the

Table 6.—Summary of chemical analyses of ground-water samples from west-central Utah[1]

Area	Dissolved-solids concentration[2]										Minimum	Maximum
	< 1,000 mg/L		1,000-3,000 mg/L		3,000-10,000 mg/L		10,000-35,000 mg/L		> 35,000 mg/L			
	No. of samples	Percent of samples	No. of samples	Percent of samples	No. of samples	Percent of samples	No. of samples	Percent of samples	No. of samples	Percent of samples		
Dugway Valley-Government Creek area	23	62	11	30	2	5	1	3	—	—	186	10,200
Fish Springs Flat	—	—	5	50	3	30	2	20	—	—	1,740	22,900
Wah Wah Valley	10	3	4	25	2	12	—	—	—	—	99	4,550
Pine Valley	11	100	—	—	—	—	—	—	—	—	94	732
Tule Valley	4	67	2	33	—	—	—	—	—	—	516	1,580
Deep Creek Valley	19	100	—	—	—	—	—	—	—	—	118	562
Snake Valley	24	92	1	4	—	—	1	4	—	—	152	10,100
Southern Great Salt Lake Desert	10	45	6	27	4	18	1	5	1	5	232	136,000
Totals	101	69	29	20	11	7	5	3	1	1		

[1] Generally includes the most recent sample from each source.

[2] Includes values determined both by sum of determined constituents and residue of evaporation at 180°C; if both are available the residue value is used.

ground water in west-central Utah. The ground water discharges by evapotranspiration, leaving its dissolved salts on or adjacent to the mudflats.

Most of the surface water in upland areas and most water from springs in the higher mountains is fresh because it has not been in contact with soluble material for long periods of time.

Potential for additional water-resources development

The main source of water for additional development in the area is the ground-water reservoir. The only surface-water flow that is reliable enough for development occurs in the Deep Creek and Snake Ranges. Most of this water is currently used for irrigation in the bordering Deep Creek and Snake Valleys. Other current uses of the water resources of west-central Utah are for stock, domestic, mine, and mill supplies, and as a source of minerals.

As in northwestern Utah (Stephens, 1974a, p. 34), the major constraint to the development of additional ground water in west-central Utah is chemical quality. The water under most of the southern Great Salt Lake Desert and under a large part of the Dugway Valley-Government Creek area is moderately saline to briny, and much of the water in basin lowlands where data are lacking probably is of poor quality. Another constraint to the development of ground water is that large quantities probably occur in fine-grained material of low permeability, resulting in low yields to wells in much of the southern Great Salt Lake Desert and under many of the playas or lowest parts of the basins. A third constraint is that along the margins of the upland areas, where fresh ground water can occur, water levels commonly are deep, and pumping for irrigation may not be economical.

In Deep Creek and Snake Valleys, however, most of the ground water is fresh and much of it occurs in material of moderate to high permeability. In Snake Valley, about 80,000 acre-ft (100 hm^3) of ground water is discharged annually by evapotranspiration from phreatophyte areas, and 10,000 acre-ft (12 hm^3) is discharged annually by subsurface flow to the southern Great Salt Lake Desert (Hood and Rush, 1965, p. 24). A part of this water could be salvaged on a sustained basis by pumping from wells. In fact, the annual pumping of ground water in Snake Valley increased from 7,000 acre-ft (9 hm^3) in 1964 to 18,000 acre-ft (22 hm^3) in 1977 (see p. 24). In Deep Creek Valley, about 15,000 acre-ft (18 hm^3) per year is discharged by evapotranspiration, some beneficially by pastureland. Hood and Waddell (1969, p. 25) estimated that a quantity somewhat less than the 4,000 acre-ft (5 hm^3) per year of nonbeneficial discharge could be salvaged on a sustained basis by pumping from wells. Some potential also exists for pumping fresh to slightly saline ground water to salvage the 40,000 acre-ft (49 hm^3) of ground water per year lost by evapotranspiration in Tule Valley (Stephens, 1977, p. 21).

In addition to salvaging water discharged by evapotranspiration and subsurface outflow to the southern desert, fresh ground water could be withdrawn from storage with resulting declines in water levels in Snake and Deep Creek Valleys. Although few data are available in the other basins, fresh ground water occurs and also could be withdrawn in Tule, Pine, and Wah Wah Valleys and in the Government Creek area.

Small supplies of ground water for stock and domestic use are available in most of the basins of west-central Utah, although freshwater occurs only locally in Dugway Valley, in the southern Great Salt Lake Desert, and possibly in Fish Springs Flat.

Interbasin flow and the source of water discharged from Fish Springs

One of the objectives of this study was to determine how the water discharged from Fish Springs moves to Fish Springs Flat and, if possible, its area of origin. Evidence of interbasin flow was evaluated and samples of water from the springs were "age-dated" to determine the time since the water was recharged. In addition, an earth-resistivity survey was made in the Fish Springs area to locate faults along the east side of the Fish Springs Range which may be related to the springs, and to determine the thickness and lithology of, and the quality of water in, the basin fill under Fish Springs Flat.

Evidence for interbasin flow

Several of the studies in west-central Utah have indicated that subsurface flow occurs into and(or) out of individual basins. If the estimated water budget of a basin has an excess of discharge over recharge, subsurface inflow to the basin is assumed to balance the budget; if there is an excess of recharge over discharge, subsurface outflow is assumed to occur.

The best example is the Fish Springs Flat drainage, which has about 31,000 acre-ft (38 hm^3) of discharge in excess of estimated recharge annually (Bolke and Sumsion, 1978, p. 13), most of which is the 26,000 acre-ft (32 hm^3) per year discharged by Fish Springs. This water is assumed to be furnished by subsurface inflow to the basin, but the source of this water is not known.

The imbalances in the budgets of individual basins in west-central Utah, not accounted for in terms of disposition (excess recharge) or source (excess discharge), are as follows:

	Excess annual recharge (acre-feet)	Excess annual discharge (acre-feet)
Tule Valley	--	32,000
Fish Springs Flat	--	31,000
Snake Valley	15,000[1]	--
Pine Valley	11,000	--
Wah Wah Valley	8,500	--
Totals (rounded)	35,000	63,000

[1]From Hood and Rush (1965, p. 24). However, exact calculation of this amount is 14,000 acre-ft (17 hm^3) (see footnote 3, table 4).

These data indicate that over the entire drainage area of west-central Utah, there is an annual excess of internal discharge over internal recharge for individual basins of about 28,000 acre-ft (35 hm^3). This quantity of water either results from overestimates or underestimates in water budgets for individual basins, or this water enters west-central Utah by subsurface inflow from outside. Even if estimation errors in individual basin water budgets account for the overall recharge-discharge imbalance, subsurface flow between basins must occur to account for the large discharge from Fish and Blue Lake Springs.

A variety of other data suggest subsurface flow in consolidated rock in west-central Utah. Hood and Rush (1965, p. 20) noted that water levels east of Garrison in and near the Ferguson Desert of Snake Valley indicate ground water moves from the basin fill eastward into consolidated rock toward the southern end of Tule Valley. They also reported (p. 12) that permeable zones in carbonate rocks were encountered in two oil-test wells east of Gandy and in one oil test east of Garrison in Snake Valley.

In addition, fresh to slightly saline water and water with a low chloride content were reported from depths as great as 5,777 ft (1,761 m) in the three oil tests (Hood and Rush, 1965, p. 12). If water from these depths is fresh or slightly saline, it probably is not stagnant, which suggests movement of water in consolidated rock. A water sample from a depth of 6,060-6,070 ft (1,847-1,850 m) in another oil test south of Garrison was also fresh (table 10 and J. W. Hood, written commun., March 27, 1969), indicating movement of ground water in consolidated rock.

The age of ground water discharging from the Fish Springs group of springs, as calculated from carbon-14 analyses using the approach of Pearson and Hanshaw (1970), indicates that this water is not recharged locally but has moved a considerable distance, suggesting it has entered the Fish Springs Flat drainage by subsurface flow. The age of water discharging from Cold Spring, (C-11-14)4aab-S1 (pl. 4), is 8,300 (if from a temperate recharge area) to 11,400 (if from a semiarid to arid recharge area) years, and the age of water from Percy Spring, (C-11-14)26daa-S1 (pl. 4), is 12,500 (temperate recharge area) to 15,600 (semiarid to arid recharge area) years. Because much of this water likely was recharged to carbonate rocks in mountain areas, the climate in the recharge area would have been more temperate than arid, and the water probably was recharged 9,000 to 14,000 years ago.

Winograd and Thordarson (1975, p. C114-C115) estimated interbasin ground-water flow velocities in carbonate rocks in Nevada to be 6 to 600 ft (2 to 200 m) per year in one area and 600-60,000 ft (200-20,000 m) per year in another area. If the average velocity of ground-water flow in the consolidated rocks in west-central Utah is as low as 10 ft (3 m) per year, then the water has moved distances on the order of 17-27 miles (27-43 km) since it was recharged. Water discharged from Fish Springs could thus have been recharged in the Deep Creek Range, 25 miles (40 km) to the west. The range is a likely source of water because it is a major source of recharge to Snake Valley, which has the largest estimated recharge of the basins of west-central Utah (table 4). If the average velocities were assumed to be larger, the distances of flow would be longer.

In summary, water budgets of individual basins, local hydraulic gradients, data from oil tests, and the age of water from Fish Springs all indicate that ground water moves into west-central Utah and moves between the basins of the area. The water probably moves principally through solution-enhanced fracture openings in carbonate rocks of Paleozoic age. These rocks crop out in large areas of west-central Utah (pl. 1) and probably occur extensively in the subsurface.

Earth-resistivity survey in the Fish Springs area

An earth-resistivity survey (Bisdorf and Zohdy, 1980) was conducted in the Fish Springs area to help determine if the springs are associated with faults and to obtain data on the thickness and lithology of, and the quality of water in, the basin fill of Fish Springs Flat. This survey was made in cooperation with the U.S. Bureau of Land Management to help that agency classify Federal land between the Fish Springs National Wildlife Refuge and the Fish Springs Range and to collect data to help the Geological Survey evaluate the hydrology of Fish Springs Flat, including potential interbasin flow discharging from Fish Springs.

The ease with which earth material transmits electrical current is a function of its resistivity, and resistivity in turn can be related to hydrogeologic properties, including lithology, porosity, permeability, water salinity, and water temperature. The resistivity survey consisted of 43 vertical electrical soundings--41 along six east-west profiles mostly in the northwest part of the flat in the Wildlife Refuge, one near the Refuge Headquarters, and one in the Fish Springs Range. The location of the soundings and computer-drawn sections of resistivity are shown on plate 4.

The Schlumberger electrode array (Zohdy, Eaton, and Mabey, 1974, p. 11), which consists of a four-electrode array to measure voltage distribution for a known input current, was used for the soundings. A sounding consists of (1) applying a voltage to a pair of electrodes (current electrodes), which induces direct-current flow and an electrical field in the earth; and (2) measuring the resulting voltage at a second pair of electrodes (potential electrodes). A succession of measurements are made with the current-electrode spacing increased for each measurement, from a minimum of about 20 ft (6 m) to as much as 24,000 ft (7,300 m). Resistivities for each spacing are computed from formulas derived for the electrode geometry.

Earth resistivities as a function of depth are derived from a sounding curve with the aid of digital-computer programs (Zohdy, 1975). Maximum electrode half-spacings for the Fish Springs surveys commonly ranged from 4,000 to 8,000 ft (1,200 to 2,400 m), with two half-spacings to 12,000 ft (3,700 m). The depth of investigation was from about 1,500 ft (450 m) to more than 10,000 ft (3,000 m). Sounding curves for each vertical sounding, and 13 computer-drawn sections showing vertical variations in resistivity along each of the six east-west sounding profiles and along seven north-south profiles constructed using points on the east-west profiles, were given by Bisdorf and Zohdy (1980). Nine sections are shown on plate 4;they were prepared by R. J. Bisdorf but are interpreted to greater depths than the sections given in the report by Bisdorf and Zohdy (1980).

Plate 4 shows, both on the map and in the sections, approximate positions of faults along both sides of Fish Springs Flat. The data indicate that the west side has more than one zone of faulting. The resistivity data also show that the basin fill of the northern end of Fish Springs Flat is predominately fine-grained material, probably containing water poorer in quality than slightly saline. These data suggest that beds in the basin fill do not transmit the large quantities of mostly slightly saline water discharged by the springs. The large flow of Fish Springs--six springs of the Fish Springs group yield from 1,100 to 5,400 gal/min (70 to 340 L/s) each (Bolke and Sumsion, 1979, p. 20)--suggests the springs discharge from carbonate rocks correlative with these exposed in the Fish Springs Range rather than from basin fill.

Because faulting occurs along the west side of Fish Springs Flat, the water likely rises in high permeability zones along faults or fault zones. The faults shown on the map and resistivity sections do not coincide exactly with the locations of the springs, probably because the resistivity data do not locate the faults as precisely as do the springs. In addition, the faults dip eastward, and the surface locations of the springs and fault traces are not directly above the average subsurface position of the faults as indicated by resistivitity data.

Resistivity and age-of-water data from the Fish Springs Flat area indicate that the water discharged by Fish Springs is not recharged locally along the east flank of the Fish Springs Range, but is recharged outside the drainage basin of the flat. Data on the water budget of the flat, on spring-water temperatures, and on variations in spring discharge (Bolke and Sumsion, 1978, p. 15, 10, and 14) also indicate that the water discharged by Fish Springs is not recharged locally. Therefore, surface uses of land between the Fish Springs Range and the Fish Springs National Wildlife Refuge probably will not affect the springs. However, mining or drilling in exploration for petroleum, natural gas, or geothermal resources between the Fish Springs Range and the springs possibly could affect the springs if carried out at depths more than 1,000 ft (300 m) below the elevation of the springs. Such effects probably would be limited to minor changes in water quality, although if water were pumped from mines or wells, the discharge of the springs could be diminished.

Source of water discharging from Fish Springs and of other interbasin flow

Although available evidence indicates that interbasin flow occurs to and within west-central Utah and that it likely occurs through solution-enhanced fracture openings in carbonate rocks of Paleozoic age, the exact source area of all this water is not known. Water budgets of Fish Springs Flat, Tule Valley, and the southern Great Salt Lake Desert require that large quantities of water move to these basins by subsurface flow; and water levels in west-central Utah (pl. 2) show that ground water potentially could move eastward from Snake Valley and northward from Pine and Wah Wah Valleys to Tule Valley and Fish Springs Flat. As shown on page 31, there is an annual imbalance of about 28,000 acre-ft (35 hm^3) in the water budget of west-central Utah--estimated discharge exceeds estimated recharge by that amount.

Possible explanations for the budget imbalance in west-central Utah include (1) overestimation of discharge, and especially discharge by evapotranspiration, from individual basins; (2) underestimation of recharge to individual basins; and (3) unknown subsurface inflow from outside west-central Utah or underestimation of known flows.

Discharge of ground water by evapotranspiration is a large part of the water budget of many of the basins in west-central Utah, and estimates of evapotranspiration are approximate at best. Annual ground-water discharge by evapotranspiration (other than evaporation from the mudflats of the Great Salt Lake Desert) is 15,000 acre-ft (22 hm^3) or more in Snake Valley (80,000 acre-ft or 100 hm^3), Tule Valley (40,000 acre-ft or 49 hm^3), and Deep Creek Valley (15,000 acre-ft or 22 hm^3). If discharge by evapotranspiration from these three basins has been overestimated, the overall annual excess of discharge over recharge in west-central Utah would be much less.

Similarly, recharge from precipitation is an estimated quantity and is only approximate. If annual recharge to the basin where this quantity is largest--Snake Valley with 100,000 acre-ft (123 hm^3)--has been underestimated then the excess of discharge over recharge would be much less.

It is likely that the water-budget imbalance in west-central Utah results mostly from an overestimation of discharge of ground water by evapotranspiration in Snake, Tule, and Deep Creek Valleys; possibly from some underestimation of recharge by precipitation in the Snake Valley drainage basin; and from underestimation of the subsurface flow to the southern Great Salt Lake Desert from Nevada. If evapotranspiration from Snake, Tule, and Deep Creek Valleys were 20 percent lower than previously estimated, if recharge to the Snake Valley drainage basin were increased by 2 percent, and if the entire flow from springs at and near Blue Lake were assumed to flow to the southern desert from Nevada, then the overall ground-water budget of west-central Utah would balance. This would result in accounted-for imbalances in budgets of individual basins as follows:

	Excess annual recharge (acre-feet)	Excess annual discharge (acre-feet)
Tule Valley	--	24,000
Fish Springs Flat	--	31,000
Southern Great Salt Lake Desert	--	--
Snake Valley	32,000	--
Deep Creek Valley	3,000	--
Pine Valley	11,000	--
Wah Wah Valley	8,500	
Totals (rounded)	55,000	55,000

The resulting changes in the ground-water budgets for the valleys of west-central Utah, considered to be better estimates than the corresponding figures in table 4, are shown in table 7.

Ground water probably moves northward in the subsurface from Pine and Wah Wah Valleys to Tule Valley and eastward from the Deep Creek Range to Snake

Table 7.—Revision of ground-water budgets for hydrologic areas in west-central Utah (all volumes are in thousands of acre-feet per year) (see table 4 for remarks)

Area	Recharge			Discharge			
	Subsurface inflow	From precipitation	Subtotal (rounded)	Subsurface outflow	Evapotranspiration	Wells, springs, and seeps	Subtotal (rounded)
Dugway Valley - Government Creek area	<5[1,2]	7	12	8[1]	<1	2.8	12
Fish Springs Flat	31[3]	4	35	<.1[1]	8	27	35
Deep Creek Valley	0	17	17	3[3,4]	12	1.6	17
Wah Wah Valley	3[3]	7	10	8.5[3]	.6	.9	10
Pine Valley	0	21	21	14[3]	5.5	1.6	21
Tule Valley	24[3]	7.6	32	0	32	.13	32
Snake Valley	4[2,3]	102	106	10[1] 32[3]	64	18[5]	124
Southern Great Salt Lake Desert	19[2,3] 18[1]	47[6]	84	0	63[7]	21	84
Totals (rounded)	104	213	317	76	186	73	335

[1] Flow through unconsolidated basin fill.
[2] Originates outside the area defined as west-central Utah.
[3] Flow through consolidated rock.
[4] Subsurface outflow estimated as the difference between recharge and discharge.
[5] 1977 discharge from wells, remarks on this item in table 4 apply to this figure as well.
[6] Includes 32,000 acre-ft of local precipitation on the mudflats.
[7] Includes 50,000 acre-ft of evaporation from the mudflats.

Valley and then directly east to Tule Valley and Fish Springs Flat, and possibly to Fish Springs Flat via Tule Valley. It also is possible that some water moves north and northwest from the Deep Creek Range to furnish part of the water discharged in the Blue Lake Springs area. However, it is more likely that the discharge from the Blue Lake Springs area has only one source, and this source is most likely to be the basins to the west in Nevada.

A less likely possibility is that the entire 28,000 acre-ft (35 hm^3) per year of excess discharge in west-central Utah is derived from subsurface flow from outside its drainage basin. Current estimates of subsurface flow to west-central Utah include: (1) 19,000 acre-ft (23 hm^3) per year (p. 19, 24) that moves to the southern Great Salt Lake Desert from basins to the west in Nevada; (2) 4,000 acre-ft (5 hm^3) per year (p. 24) that moves to Snake Valley from Spring Valley, Nev.; and (3) 5,000 acre-ft (6 hm^3) that enters the Dugway Valley-Government Creek area from the Sevier Desert through basin fill (Hood and Rush, 1965; Harrill, 1971; and Mower and Feltis, 1968) (p. 24). No available data indicate that any more water moves as subsurface flow to west-central Utah.

Other areas that also could be sources for subsurface flow to west-central Utah include the Escalante Desert (Beryl-Enterprise and Milford areas) and the Sevier Desert to the southeast and east. Water levels in these basins are higher than levels in adjacent parts of Wah Wah and Tule Valleys (typical water-level elevations are plotted on plate 2 east and southeast of the drainage divide for west-central Utah) so there is potential for movement. However, water-level contour maps prepared for the Beryl-Enterprise and Milford areas (Sandberg, 1966, fig. 6; Mower and Cordova, 1974, pl. 4) do not indicate any movement toward west-central Utah.

Mower and Feltis (1968, p.49) stated that less than 5,000 acre-ft (6 hm^3) per year of ground water flows to the Dugway Valley-Government Creek area from the northern part of the Sevier Desert at the "Old River Bed" (fig. 1), and this amount is included in the water budget of west-central Utah (Stephens and Sumsion, 1978, p. 15). Water-level contours in the central Sevier Desert indicate that ground water flows west from the Delta area, but data are not available to show direction of movement on the western side of the Sevier Desert. However, data compiled by Mower and Feltis (1968, p. 48-59) indicate that most of the ground water in the Sevier Desert is discharged by evapotranspiration and by wells before it reaches the western side of the area, so movement of large quantities of water from the Sevier Desert westward to Tule Valley is not likely.

Ground water could also move from the Sevier Lake playa westward to the southern tip of Tule Valley or southwest to Wah Wah Valley. A well 1 mi (1.6 km) west of the playa (table 8; pl. 2) has a reported water level about 90 ft (30 m) below the water levels under the playa reported by Whelan (1969, table 2). The level in the well is in turn above the water level in a well in the southern tip of Tule Valley. However, the existence of the saline Sevier Lake playa suggests that all the ground water in the southwestern Sevier Desert discharges at Sevier Lake.

At some locations, ground-water flow out of west-central Utah is possible, such as in the southern parts of Hamlin Valley and Pine Valley, where water levels are higher than in the adjacent Escalante Desert. However, no available data indicate any movement of water out of these areas in west-central Utah to the Escalante Desert.

Summary

Although conclusive evidence does not exist to identify the source of ground-water budget imbalances in west-central Utah, the most probable source is overestimation of discharge by evapotranspiration in the water budgets of individual basins; and to a lesser extent, underestimation of subsurface flow from Nevada and underestimation of recharge from precipitation. The water discharging from Fish Springs, which makes up a significant part of the apparent excess water, probably moves eastward from Snake Valley by subsurface flow through consolidated rock.

Revised ground-water budget for west-central Utah

Table 7 gives revised estimates of total ground-water recharge and discharge for individual basins of west-central Utah. Although the total annual recharge is 317,000 acre-ft (391 hm^3), some of this water is included under recharge to more than one basin because of interbasin flow through consolidated rock. The net recharge to west-central Utah is 241,000 acre-ft (297 hm^3), of which 213,000 acre-ft (263 hm^3) originates as precipitation within the area and 28,000 acre-ft (35 hm^3) moves into the area from outside its drainage basin, mostly through consolidated rock.

Total estimated discharge in 1977 from individual basins was about 335,000 acre-ft (413 hm^3). However, because part of this water is included in discharge from more than one basin, the net total annual discharge is about 259,000 acre-ft (319 hm^3). Of this amount, about 186,000 acre-ft (229 hm^3) is discharged by evapotranspiration and about 73,000 acre-ft (90 hm^3) is discharged by wells and springs, including the estimated 18,000 acre-ft (22 hm^3) withdrawn in 1977 from wells in Snake Valley. The imbalance between the estimated values of recharge and discharge from wells in Snake Valley is due to the assumption that water discharged from wells in Snake Valley is withdrawn from storage. It is likely, however, the part of this is water that would have discharged naturally by evapotranspiration, but was intercepted.

Future studies

The only source of water in west-central Utah for large-scale future development is the ground-water reservoir; and the most readily available ground water is in the basin fill. Considerable data are already available on the occurrence of water in the basin fill, and relatively inexpensive, properly located wells will yield several hundred gallons per minute or more of freshwater in several of the basin areas.

However, any attempt to develop large supplies of ground water for irrigation or industry should begin with detailed hydrologic studies, including test drilling, aquifer tests, and chemical analyses of ground water. In some areas, pumping large volumes of ground water could induce the flow of saline water toward wells and contamination of the water supply. Detailed hydrologic studies should evaluate this possibility and propose well-spacing and well-design that would minimize contamination by saline ground water.

In addition to water in the basin fill, water also occurs in consolidated rock and moves between the basins of west-central Utah through this rock. Little information is available on this water--other than near springs in consolidated rock, the areas and geologic units through which the water moves and the depth to and hydraulic characteristics of permeable zones are not known. At the two identified points of concentrated discharge of this water in west-central Utah, at Blue Lake Springs and Fish Springs, the water is mostly slightly to moderately saline, but few other data are available on its quality. Before the water in consolidated rock can be developed, more information on this resource will be needed.

Exploration for and extensive development of water in consolidated rock, however, could be costly because many test holes likely would have to be drilled to depths of several thousand feet. Even so, because ground water in the consolidated rock is hydraulically connected with water in basin fill, points of recharge to and discharge from consolidated rock under the fill should be identified in the near future in order to efficiently plan development of water in the basin fill.

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Table 8.--Records of selected wells and springs in the southern Great Salt Lake Desert and supplemental data for other areas in and near west-central Utah

Location: See section on numbering systems for hydrologic-data sites.
Altitude of land surface: Above mean sea level as interpolated from U.S. Geological Survey topographic maps.
Water level: Reported except m, measured.
Geologic source of water: See table 1 for explanation of symbols.
Yield: Rate - Estimated except m, measured, r, reported.
Method of lift: F, flows; N, none; P, piston pump; S, submersible pump; T, turbine pump.
Use of water: H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; U, unused.
Remarks and other data available: C, chemical-quality data in table 10; D, driller's log in table 9.

Location	Owner, user, and (or) local name	Year constructed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet below land surface)	Depth of perforated interval (feet)	Altitude of land surface (feet)	Water level: Feet above(+) or below land-surface datum	Water level: Date	Geologic source of water	Yield: Rate (gal/min)	Yield: Date	Method of lift	Use of water	Water temperature (°C)	Remarks and other data available
							SOUTHERN GREAT SALT LAKE DESERT									
							Utah									
(C-2-10)16bbb-1	Skull Valley Co. (Deseret Livestock)	1966	535	-	-	-	5,235	-	-	-	-	-	N	U	-	Drilled for stock supply; insufficient water (?), plugged, and abandoned. D.
(C-2-19)2ccb-1	Kaiser Aluminum and Chemical Corp.	1951	1,508	12	1,030	-	4,215	44	9- 8-67	QTu	-	-	-	U	-	Abandoned brine-production well No. 12.
2ccb-2	do.	1978	1,365	14	1,365	965-1,365	4,215	64	2-17-78	QTu	1,750r	2-18-78	N	U	-	Brine-production well No. 14; drilled to 1,520 ft and completed to 1,365 ft; put in production in 1978; yield from test; reported specific capacity 37 (gal/min)/ft; brine contains 157,000 mg/L dissolved solids estimated from specific gravity. D.
3bcd-1	do.	1950	1,126	12	930	-	4,216	30	9- -50	QTu	1,000r	9-16-50	-	U	28.0	Abandoned brine-production well No. 8; brine-bearing zone reported at 1,040 ft; reported specific capacity 25 (gal/min)/ft. C,D.
10cdd-1	do.	1951	1,370	16	1,015	-	4,216	-	-	QTu	-	-	-	U	-	Abandoned brine-production well No. 11; 372 ft of perforated 12-in. casing reported at bottom of hole.
11cdc-1	do.	1950	1,540	16	1,118	-	4,216	40	1950	QTu	1,000r	4-30-50	-	U	-	Abandoned brine-production well No. 5; brine-bearing zone reported at 1,277 ft; reported specific capacity 30 (gal/min)/ft.
14ada-1	do.	1939	1,200	8	1,175	-	4,215	26	1- -48	QTu	662r	4-15-48	-	U	43.0	Abandoned brine-production well No. 1; drilled to 660 ft and cased to 447 ft with 10-in. casing in 1939, completed in 1942-43; reported specific capacity 11 (gal/min)/ft.
(C-3-10)16abb-S1	Quincy Spring	-	-	-	-	-	6,110	-	-	MZPZc	2.3m	11-15-77	-	S	13.5	Piped to mountain front. C.
(C-4-10)18dbd-S1	Browns Spring	-	-	-	-	-	5,335	-	-	PZpCq	.7m	10- 4-77	-	S	16.0	C.
(C-4-11)35ddd-S1	Cedar Spring	-	-	-	-	-	4,950	-	-	PZpCq	.5m	10- 4-77	-	S	16.0	Two seepage areas, part of discharge from upper area issues from pipe; yield is discharge from pipe. C.
(C-4-19)7abc-S1	Blue Lake Springs	-	-	-	-	-	4,260	-	-	MZPZc	10,200	7-11-78	-	S	29.0	Several springs and Blue Lake (a large spring) located at and east of an outcrop of brecciated limestone; yield is discharge of all springs estimated using flow measurements with a current meter and flow estimates; temperature is of water from south spring at outcrop; also called Big Salt Springs. C.
20abb-S1	Little Salt Springs	-	-	-	-	-	4,275	-	-	MZPZc	1,000	5-31-78	-	S	27.0	Springs at an outcrop of brecciated limestone; yield is discharge of all springs estimated using flow measurements with a current meter; temperature is of water from north spring. C.
(C-5-18)35dda-1	-	-	-	-	-	-	4,262	8.63m	11-16-77	Qa?	-	-	N	U	-	Unused stock well.
(C-5-19)33cba-1	U.S. Bureau of Land Management ("Jerry" well)	1961	305	6	270	10-270	4,495	220	12-25-61	QTu	-	-	T	S	-	Intermittently used stock well; reportedly bailed 30 gal/min from well. D.
(C-6-18)5ddb-1	Lyle Bunker	1976	210	12	210	76-82 180-210	4,356	95.4m	11-16-77	QTu	1,300r	11-16-77	T	I	18.0	Data on yield reported by owner. C.
5ddb-2	do.	1976	182	6	182	170-180	4,356	93.0m	11-16-77	QTu?	-	-	S	H	-	Ranch-house supply well. C,D.
(C-7-17)17dcd-1	U.S. Bureau of Land Management	1969	240	6	240	154-158	4,405	146.9m	5-26-78	QTu?	-	-	N	U	-	Drilled for stock supply and abandoned because water was too saline; reportedly bailed 22 gal/min from well. D.
(C-7-18)[illegible]		-	-	-	-	-	5,270	-	-	MZPZc	1.8m	11-16-77	N	S	11.5	Drainage from mine tunnel (locally called Berg Spring) piped to tank and trough about 0.6 mi down the canyon. C.
(C-8-18)2abb-S1	U.S. Bureau of Land Management (Cane Spring)	-	-	-	-	-	5,400	-	-	MZPZc	5r	-	-	S	-	Flow piped to storage tank. C.
11bcc-S1	ASARCO Inc. (Ochre Springs)	-	-	-	-	-	5,835	-	-	MZPZc	3	6-19-73	-	U	12.0	Formerly used for public supply at Gold Hill; tunnel driven at springs to increase flow; reported discharge for all springs 25 gal/min. C.
11cca-1	UV Industries	1958	50	6	50	-	5,832	5	8- -58	MZPZc	1.5r	-	F	P	-	Public supply for Gold Hill; flow combined with flow from spring (C-8-18)11cca-S1 in concrete tank below land surface.
11cca-S1	UV Industries (Youngs Spring)	-	-	-	-	-	5,832	-	-	MZPZc	5r	-	-	P	-	Public supply for Gold Hill; yield includes an estimated 1.5 gal/min from well (C-8-18) 11cca-1. C.
(C-9-16)31bcb-1	Gail Parker	1940	55	4	55	-	4,293	-	-	Qa?	100	5-24-78	F	I	17.0	
31bcb-2	do.	1976	72	8	72	45-70	4,293	-	-	Qa?	150	5-24-78	F	I	17.0	C,D.
31bcc-2	do.	1947	50	6	50	-	4,293	-	-	Qa?	-	-	F	S	16.0	Yields on the order of 50 gal/min.
31ccc-2	do.	1976	62	8	62	45-60	4,297	+5	10-10-76	Qa?	90	5-24-78	F	I	17.5	C.

Table 8.--Records of selected wells and springs in the southern Great Salt Lake Desert and supplemental data for other areas in and near west-central Utah--Continued

Location	Owner, user, and (or) local name	Year constructed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet below land surface)	Depth of perforated interval (feet)	Altitude of land surface (feet)	Water level: Feet above(+) or below land-surface datum	Water level: Date	Geologic source of water	Yield: Rate (gal/min)	Yield: Date	Method of lift	Use of water	Water temperature (°C)	Remarks and other data available
SOUTHERN GREAT SALT LAKE DESERT--Continued																
Utah--Continued																
(C-9-16)31ccc-1	Gail Parker	1949	45	8	45	-	4,297	-	-	Qa?	80m	5-31-78	F	I	17.5	
31ccd-S1	Gail Parker (Redden Springs)	-	-	-	-	-	4,289	-	-	Qa?	320m	5-31-78	-	I	-	Yield measured from two main pools; total discharge from all springs probably about 500 gal/min; little variation reported in flow of springs. C.
31cdd-1	Gail Parker	1940	77	3	77	-	4,288	+5m	5-24-78	Qa?	5m	5-24-78	F	S	14.0	
(C-9-17)25dbd-1	Eugene Timm	-	40	8	40	-	4,303	-	-	Qa?	-	-	S	N,H	-	Used at tungsten-ore mill and for domestic supply; depth and casing data reported by owner. C.
(C-10-16)6bcc-1	-	-	-	8	-	-	4,306	1.7m	5-24-78	-	-	-	N	U	-	
Nevada																
29/69-5ab1	Dead Cedar Spring	-	-	-	-	-	6,095	-	-	MZPZc	.09m	11-17-77	-	S	10.0	Piped to trough. Water temperature may be affected by air temperature. C.
30/69-33ad1	Ferguson Springs	-	-	-	-	-	6,100	-	-	MZPZc	21m	11-17-77	-	I,H,S	-	Used by nearby highway maintenance station as well as for stock. C.
32/68-22ca1	Summit Spring	-	-	-	-	-	6,990	-	-	MZPZc	1.5m	6- 2-78	-	S	10.0	Piped to trough. C.
32/68-24bb1	Mud Spring	-	-	-	-	-	6,350	-	-	TMZe	-	-	-	S	11.0	Total discharge in seepage area around spring about 5 gal/min. C.
32/68-26ad1	Spring Gulch Spring	-	-	-	-	-	6,255	-	-	TMZe	2	6- 2-78	-	S	9.5	Piped to small pond. C.
32/69-2ba1	U.S. Bureau of Land Management (Wendover well)	1940	346	6	-	-	4,575	326	-	QTu?	25r	-	N	U	-	Data on date constructed, depth, diameter, water level, and yield from Harrill (1971).
33/69-34d	U.S. Army	1942	800	-	-	-	4,630	367	-	QTu?	-	-	N	U	-	Abandoned test hole; data from Harrill (1971); actual location may be 33/69-35d. C.
SUPPLEMENTAL DATA FOR OTHER AREAS IN AND NEAR WEST-CENTRAL UTAH																
Northern Great Salt Lake Desert																
(C-1-10)5cab-1	Utah State Road Commission	1969	420	8	390	-	4,596	360.6m	11- 9-71	QTu	50	9-10-69	N	U	-	In Stephens (1974a, table 10); altitude corrected from recent topographic map; drawdown 50 ft after 6 hours pumping 50 gal/min.
(C-1-11)36bba-2	Skull Valley Co. (Deseret Livestock Co.)	1946	293	6	265	-	4,509	263	11-10-46	QTu	-	-	P	S	-	Located just north of boundary of southern Great Salt Lake Desert. In Stephens (1974a, table 10); altitude corrected from recent topographic map. C.
Pine Valley																
(C-28-17)11cca-1	Phelps Dodge Corp.	1978	970	12	970	270-970	5,680	367	1978	QTu	-	-	-	-	-	Drilled to 1,305 ft and completed to 970 ft.
22dda-1	do.	1978	2,006	8	2,006	500-2,006	5,780	386	1978	QTu	-	-	-	-	-	Bailed 25 gal/min with 75 ft of drawdown in a test.
Sevier Desert																
(C-23-12)6ccd-1	U.S. Bureau of Land Management (Black Hills well)	1945	560	6	-	-	4,632	204	1946	Qa?	-	-	P	S	-	Stock well just east of the divide between Tule and Wah Wah Valleys; dissolved solids 571 mg/L in 1963.
Snake Valley																
(C-10-17)5add-S1	Eight-Mile Spring	-	-	-	-	-	4,886	-	-	Qa?	5	5-26-78	-	S	-	Actual spring location may be upslope with water piped to the tank at (C-10-17)5add. C.
(C-24-19)32dbd-1	State of Utah (W. J. Gould No. 3 State)	1969	7,025	8	-	-	6,362±	-	-	MZPZc	-	-	N	U	-	Oil-test well, sampled when drilling at and cased to 6,590 ft, perforated 6,060-6,070 ft; reportedly in Guilmette Formation of Devonian age; estimated water level 750 ft below land surface; estimated yield 50 gal/min. C.
Wah Wah Valley																
(C-28-14)3bd-1	Earth Sciences Inc. (well No. 29)	1975	1,500	16, 12	1,500	700-1,480	5,180±	690	2-20-75	QTu	1,400r	2-16-75	T	N	21.5	Location approximate; yield reported during test. C.
27aa-1	Earth Sciences Inc. (well No. 2)	1974	-	-	-	-	5,405±	535	3-21-74	QTu	-	-	N	U	-	Location approximate; test hole, drilled to 750(?) ft and abandoned; water level measured while drilling at 563 ft; specific conductance 560 micromhos/cm (measured by owner).

Table 9.--Drillers' logs of selected wells in the southern Great Salt Lake Desert

Altitudes are of land surface at well, in feet above mean sea level.
Thickness, in feet.
Depth to bottom of unit, in feet below land surface.

Material	Thickness	Depth
(C-2-10)16bbb-1. Log by J. C. Petersen. Alt. 5,235.		
Sand and topsoil	4	4
Clay, light blow sand, and gravel	12	16
Sand and loose, small gravel	14	30
Blow sand	5	35
Clay, thin layered, and silt	36	71
Clay and sand, brown	16	87
Gravel, small and loose	1	88
Blow sand and small gravel	13	101
Blow sand with small gravel layer	75	176
Gravel, limestone, small, with sand layer	60	236
Cobbles, limestone	4	240
Gravel, quartzite, and cobbles	6	246
Clay and fine brown blow sand	5	251
Clay, sand, and gravel, mixed thin layers	15	266
Sand and gravel, medium to large	15	281
Clay, sand, and gravel, layered	2	283
Clay, white	2	285
Clay, gravel, and cobbles, mixed and layered	7	292
Clay and sand, mixed	4	296
Clay, silt, and sand, brown	20	316
Sand and gravel, layered, brown, and clay	10	326
Clay and sand, mixed	3	329
Clay, sand, and gravel, thin layers	7	336
Limestone, quartzite gravel, and clay	8	344
Sand and gravel, small	12	356
Sand and gravel, large and coarse	8	364
Sand, and one thin layer of medium to large gravel	7	371
Sand, medium; some gravel	15	386
Clay, sand, and medium to small gravel, brown	15	401
Sand, gravel, and cobbles	23	424
Cobbles, quartzite	1	425
Gravel, large, layered, with seams of sand and clay	51	476
Limestone and quartzite cobbles in clay	11	487
Clay and medium gravel	6	493
Gravel, large	3	496
Limestone, quartzite cobbles, and clay	5	501
Clay and large gravel	32	533
Cobbles, large	2	535
(C-2-19)2ccb-2. Log compiled by S. A. Kruer from notes and drilling report of the Thompson Drilling Co. Alt. 4,215.		
Clay	63	63
Clay, gray	35	98
Clay	74	172
(C-2-19)2ccb-2--Continued		
Clay, gray	23	195
Clay with streaks of gypsum	21	216
Clay	89	305
Clay, gray, with streaks of gypsum	23	328
Clay	89	417
Clay, gray, with streaks of gypsum	22	439
Clay	133	572
Clay, gray, with streaks of gypsum	23	595
Clay	455	1,050
Gravel	110	1,160
Conglomerate (hard, cemented gravel)	180	1,340
Gravel	14	1,354
Gravel, hard	22	1,376
No log	22	1,398
Gravel	22	1,420
Gravel, hard	22	1,442
No log	23	1,465
Sand and clay	17	1,482
No log	38	1,520
(C-2-19)3bcd-1. Compiled by L. J. Turk. Alt. 4,216.		
Clay	268	268
Gypsum	4	272
Clay	48	320
Gypsum	3	323
Clay	57	380
Gypsum	1	381
Clay	9	390
Gypsum	1	391
Clay	9	400
Clay and gypsum	16	416
Clay	44	460
Gypsum	3	463
Clay, sticky	12	475
Clay	10	485
Gypsum	2	487
Clay, sticky	9	496
Gypsum	11	507
Clay	6	513
Gypsum	2	515
Clay	50	565
Gypsum	6	571
Clay	37	608
Gypsum	2	610
Clay	18	628
Gypsum, hard	6	634
Clay	4	638
Gypsum	7	645
Clay	55	700
Gypsum	4	704
No log	41	745
Clay	9	754
Gypsum	3	757
Clay	115	872
Gypsum	22	894
Clay	24	918
(C-2-19)3bcd-1--Continued		
Clay; gravel showing in sample	12	930
Gravel	14	944
Conglomerate	95	1,039
Gravel	7	1,046
Conglomerate, hard, brown	14	1,060
Conglomerate	66	1,126
(C-5-19)33cba-1. Log by J. D. Hill and U.S. Bureau of Land Management. Alt. 4,495.		
Silt, gray	15	15
Gravel, cemented	45	60
Hardpan, red	10	70
Gravel, cemented, gray	165	235
Sand, hard; water	5	240
Gravel, cemented, gray	10	250
Clay and water gravel	5	255
Gravel, cemented	20	275
Gravel, water, and streaks of clay	5	280
Clay and gravel	25	305
(C-6-18)5ddb-2. Log by Herald S. Petersen. Alt. 4,356.		
Conglomerate	122	122
Gravel	5	127
Conglomerate	33	160
Gravel	22	182
(C-7-17)17dcd-1. Log by E. W. Hales. Alt. 4,405.		
Sand, fine, gray	10	10
Sand, fine, gray, and clay	5	15
Sand, fine, gray	15	30
Sand, fine, light-brown	5	35
Sand, fine, gray, and clay	5	40
Sand, fine, brown, and clay	5	45
Boulders	13	58
Sand, fine, brown	5	63
Boulders	5	68
Sand, fine, brown	2	70
Sand, fine, gray, and clay	26	96
Sand, fine, brown	8	104
Sand, fine, brown, and clay	17	121
Sand and clay	33	154
Gravel; salty water	4	158
Sand, hard, brown	2	160
Sand, fine, gray, and clay	15	175
Sand, fine, brown, and clay	8	183
Sand and gravel; salty water	12	195
Sand, fine, gray	38	233
Gravel; salty water	7	240
(C-9-16)31bcb-1. Log by Glen Mosely. Alt. 4,293.		
Silt	20	20
Clay and gravel	25	45
Sand and gravel; water	15	60
Hardpan and conglomerate	12	72

Table 10.--Chemical analyses of ground-water samples from the southern Great Salt Lake Desert and supplemental analyses for other areas in and near west-central Utah

Location: See section on numbering systems for hydrologic-data sites.
Specific conductance: Laboratory determinations except f, field measurement.
pH: Laboratory determinations except f, field measurement.

Location	Date of collection	Water temperature (°C)	Milligrams per liter: Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Sum of determined constituents	Specific conductance (micromhos per centimeter at 25°C) (rounded)	pH	Percent sodium	Sodium-adsorption ratio
								SOUTHERN GREAT SALT LAKE DESERT											
								Utah											
(C-2-19)3bcd-1	11-12-76	28.0	-	1,600	1,500	47,000	2,100	135	-	5,600	77,000	10,000	10,000	136,000	-	-	-	-	-
(C-3-10)16abb-S1	11-15-77	13.5	15	110	47	630	5.9	190	-	190	1,100	470	310	-	2,190	3,960	7.8	74	13
(C-4-10)18dbd-S1	10- 4-77	16.0	18	350	200	860	13	230	-	390	2,100	1,700	1,500	-	4,040	7,200	7.6	52	9.1
(C-4-11)35ddd-S1	10- 4-77	16.0	36	250	60	230	6.0	230	-	110	800	870	680	-	1,610	2,940	7.8	36	3.4
(C-4-19)7abc-S1[1]	10- 5-77	29.0	28	130	56	1,600	110	290	-	250	2,500	560	320	-	4,820	8,470	7.5	83	30
20abb-S1[2]	10- 5-77	27.0	28	140	60	1,400	110	300	-	240	2,300	600	350	-	4,430	7,920	7.7	81	25
(C-6-18)5ddb-1	6- 2-78	18.0	49	130	68	720	53	330	0	910	690	600	330	-	2,780	4,160	6.8f	70	13
5ddb-2[3]	11-16-77	-	49	210	110	390	49	340	-	840	460	980	700	-	2,280	3,330	7.7	45	5.4
(C-7-18)2cdb[4]	11-16-77	11.5	11	60	39	150	2.5	220	-	72	260	310	130	-	703	1,300	8.4	51	3.7
(C-8-18)2abb-S1[5]	5-25-78	-	30	480	310	280	8.6	100	0	340	1,900	2,500	2,400	-	3,400	6,000	6.1f	20	2.5
11bcc-S1[6]	6-19-73	12.0	15	160	57	190	3.7	155	0	210	500	630	510	-	1,210	2,030	7.3	39	3.3
11cca-S1[7]	5-26-78	-	15	170	57	190	3.6	220	0	130	550	660	480	-	1,220	2,030	6.1f	38	3.2
(C-9-16)31bcb-2	5-25-78	17.0	21	39	24	110	5.5	180	0	38	170	200	49	-	496	840	6.7f	54	3.4
31ccc-2	5-25-78	17.5	19	32	20	100	5.4	170	0	35	140	160	23	-	435	800	6.9f	56	3.4
31ccd-S1[8]	5-25-78	-	18	23	14	82	4.2	150	0	25	100	120	0	-	340	600	6.7f	60	3.3
(C-9-17)25dbd-1[3]	5-26-78	-	29	23	10	190	9.5	150	0	59	240	99	0	-	634	1,010	7.1f	79	8.3
								Nevada											
29/69-5ab1	11-17-77	10.0[9]	17	88	42	99	2.3	280	-	120	170	390	160	-	676	1,170	7.9	35	2.2
30/69-33ad1	11-17-77	-	15	52	22	28	2.0	150	-	55	60	220	97	-	308	550	8.1	21	.8
32/68-22ca1	6- 2-78	10.0	17	65	22	12	.8	280	0	22	9.7	250	23	-	287	480	7.0f	9	.3
24bb1	10- 5-77	11.0	28	47	11	16	2.0	190	-	16	18	160	7	-	232	370	8.3	17	.5
26ad1	6- 2-78	9.5	30	59	15	23	1.1	240	0	24	20	210	12	-	290	460	6.8f	19	.7
33/69-34d[10]	2-10-43	-	49	2,090	434	8,200		98	-	1,000	16,800	7,010	-	31,500[11]	-	-	7.3	-	43
								SUPPLEMENTAL ANALYSES FOR OTHER AREAS IN AND NEAR WEST-CENTRAL UTAH											
								Northern Great Salt Lake Desert											
(C-1-11)36bba-2[12]	11-15-77	-	25	350	320	1,900	52	99	-	230	4,100	2,200	2,100	-	7,030	12,300	7.8	65	18
								Snake Valley											
(C-10-17)5add-S1[5]	5-26-78	-	16	60	24	38	0.9	250	0	22	63	250	44	-	347	520	6.6f	25	1.0
(C-24-19)32dbd-1[13]	3-21-69	-	14	38	23	7.9	2.5	217	0	22	10	191	13	220	225	381	8.0	-	.2
								Wah Wah Valley											
(C-28-14)3bd1	2-16-75	21.5	9.9	47	17	37	9.1	141	-	74	63	190	72	-	337	565f	8.1f	29	1.2

1 Sampled from south spring at limestone outcrop.
2 Sampled from north spring.
3 Sampled from pressure tank.
4 Drainage from mine tunnel.
5 Sampled overflow from tank.
6 Sampled second spring from north.
7 Sampled from concrete collecting box; sample includes water from well (C-8-18)11cca-1.
8 Sampled outflow from the two main pools.
9 May be affected by air temperature.
10 Sampled from test hole when drilling below 655 ft. This and other analyses at other depths reported in Harrill (1971).
11 Residue on evaporation at 105°C.
12 Sampled from recently filled tank.
13 Sampled from 6,060 to 6,070 feet.

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