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HYDROLOGIC RECONNAISSANCE OF THE FISH SPRINGS FLAT AREA, TOOELE, JUAB, AND MILLARD COUNTIES, UTAH

by

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in cooperation with
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[Plate is in pocket]

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Most values are given in this report in U.S. customary units followed by metric units. The conversion factors used 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 U.S. customary units.

U. S. customary			Metric	
Units (Multiply)	Abbreviation	(by)	Units (to obtain)	Abbreviation
Acre		0.4047	Square hectometer	hm^2
		.004047	Square kilometer	km^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 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 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 U.S. customary 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 U.S. customary unit, equivalents per million.

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

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ABSTRACT

The Fish Springs Flat area includes about 590 square miles (1,530 square kilometers) in western Utah. Total annual precipitation on the area averages about 7 inches (180 millimeters) and totals about 232,000 acre-feet (286 cubic hectometers). Fish Springs Wash is the major drainage in the area; and, along with numerous smaller washes, it flows only in direct response to precipitation. Runoff from the area is estimated to be about 2,000 acre-feet (2.5 cubic hectometers) per year.

Ground-water recharge from precipitation is about 4,000 acre-feet (5 cubic hectometers) annually. Ground-water discharge is chiefly by springs and evapotranspiration. The largest springs in the Fish Springs group discharge about 26,000 acre-feet (32 cubic hectometers) annually. All other springs discharge about 600 acre-feet (0.74 cubic hectometer) per year, or only about 2 percent of the total spring discharge. Discharge by evapotranspiration is about 8,000 acre-feet (10 cubic hectometers) per year. Discharge by wells and by subsurface outflow is negligible. The difference between discharge and local recharge--approximately 31,000 acre-feet (38 cubic hectometers)--is assumed to enter the Fish Springs Flat area by interbasin flow.

The estimated amount of water recoverable from storage in the upper 100 feet (30 meters) of saturated valley fill is about 550,000 acre-feet (680 cubic hectometers); and most of this water is slightly to moderately saline.

The water in the Fish Springs Flat area ranges from slightly saline to briny; and the predominant ions in the water are sodium and chloride. The water that underlies the mudflats in the northwest part of the area is briny. Water that issues from Fish Springs is slightly saline.

The water in the Fish Springs Flat area is not suitable for drinking. The water that issues from Fish Springs is used for wildlife management, which includes ponding and irrigation of vegetation (chiefly saltgrass) in the Fish Springs National Wildlife Refuge. The water from the wells in the area is used for livestock and mining operations.

INTRODUCTION

This report was prepared by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. It is the eighteenth report in a series that describes the water resources of the western basins of Utah (fig. 1). The purpose of the report is to present hydrologic data for the Fish Springs Flat area, to provide an evaluation of present and potential water-resources development, and to indicate future studies that would provide better understanding of the hydrology of the area.

The report is based on available file information of the Geological Survey and of the Utah State Engineer. Discharge records of Fish Spring were provided by the U.S. Fish and Wildlife Service. Data collected during brief field reconnaissance in August 1976 and April 1977 were used to supplement available file data. Additional information was obtained from published reports listed in the references-cited section of this report.

The data and general information about the area provided by personnel of the Fish Springs National Wildlife Refuge and Brush Wellman, Inc., are gratefully acknowledged.

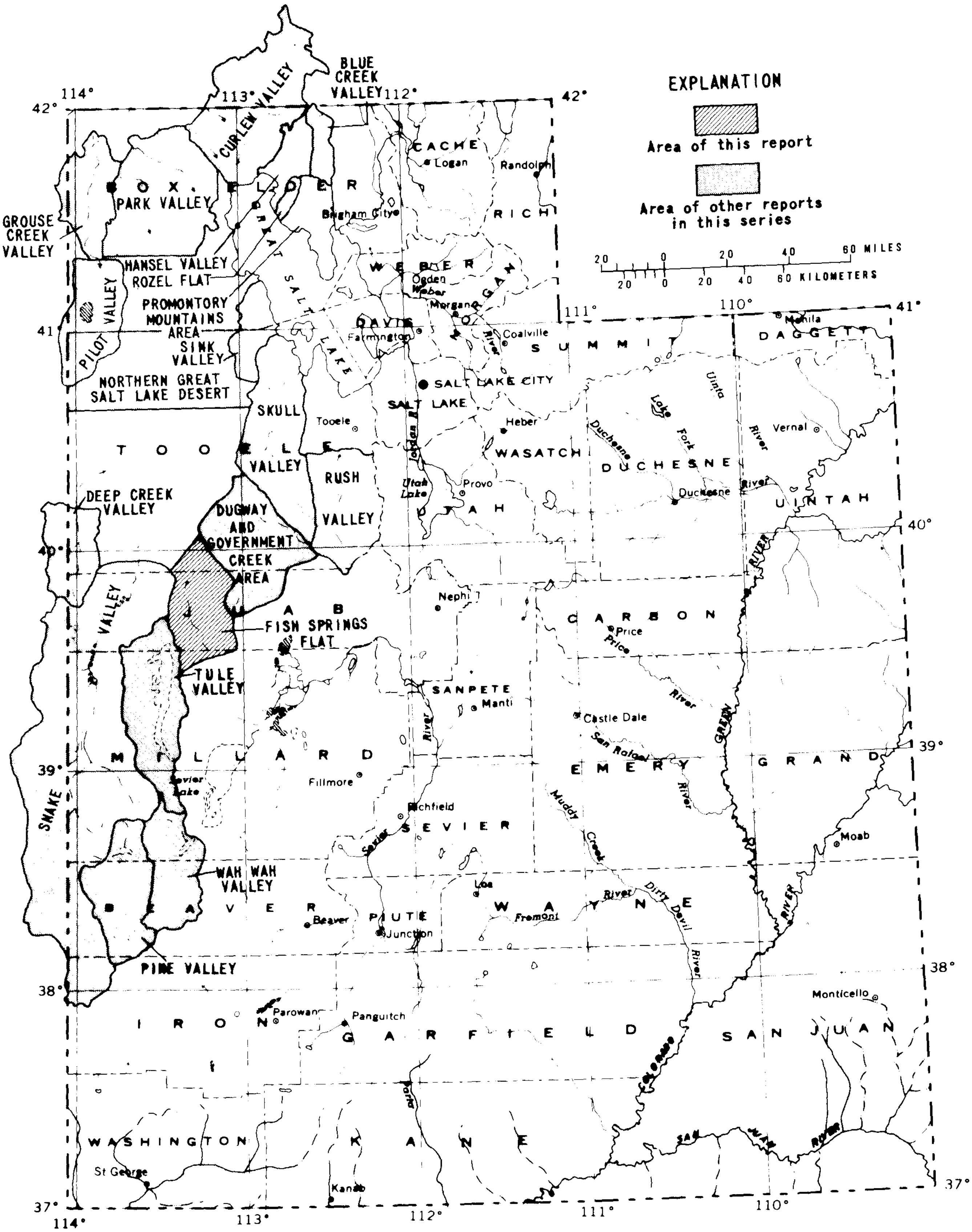

Figure 1.—Location of the Fish Springs Flat area and areas described in other reports in this series.

Location and physiography

The Fish Springs Flat area includes about 590 mi^2 (1,530 km^2) in the southern part of the Great Salt Lake Desert drainage basin, within the Great Basin section of the Basin and Range physiographic province in western Utah. The drainage area of Fish Springs Flat includes parts of Tooele, Juab, and Millard Counties (pl. 1). The area averages about 35 mi (56 km) in length and about 17 mi (27 km) in width.

The Fish Springs Flat area is bounded on the west by the Fish Springs Range and Swasey Mountain, on the east by the Dugway Range, the Thomas Range, and the Drum Mountains. The Little Drum Mountains border the southeast part of the area. The southern boundary is a broad, low divide connecting Swasey Mountain and the Little Drum Mountains. The area opens northwestward to the Great Salt Lake Desert. Total relief in the area is about 4,260 ft (1,298 m), ranging from a high point of 8,523 ft (2,598 m) in the Fish Springs Range to a low of about 4,260 ft (1,298 m) in the Great Salt Lake Desert. Drainage generally is from the mountainous areas toward the flat and then north into the Great Salt Lake Desert.

Land-status maps of the U.S. Bureau of Land Management (1970a, b) indicate that about 90 percent of the land in the Fish Springs Flat area is Federally owned, about 9 percent is owned by the State of Utah, and less than 1 percent is privately owned. The land is used for seasonal livestock grazing, beryllium mining in the Spor Mountain area, and wildlife management in the Fish Springs National Wildlife Refuge. The only residents are the personnel of the wildlife refuge.

Climate and vegetation

The climate of the Fish Springs Flat area is arid. Average annual precipitation ranges from somewhat more than 6 in. (150 mm) on the flats to about 16 in. (410 mm) in the highest mountains (pl. 1). The average annual precipitation over the entire area is about 7 in. (180 mm).

Climatologic data collected at the Fish Springs National Wildlife Refuge (pl. 1) from 1960 to 1976 (table 1) show that average monthly precipitation at the station varied from 0.28 in. (7 mm) in January to 1.04 in. (26 mm) in April. The average monthly temperatures at the wildlife refuge varied from about 29°F (-1.5°C) in January to about 80°F (26.5°C) in July.

Vegetation is sparse on most of the valley flat and is nearly nonexistent on the mudflats north of the wildlife refuge. Greasewood (*Sarcobatus vermiculatus*) is scattered in the lowland areas where the depth to chemically tolerable water is not greater than about 40 ft (12 m) or where ample soil moisture is present, as on alluvial slopes, along stream channels, along roadways, or on sand dunes. Pickleweed (*Allenrolfea occidentalis*) and saltgrass (*Distichlis spicata* var. *stricta*) are the predominant phreatophytes on the low-lying mudflats. Saltgrass is well-established within the wildlife refuge, and scattered saltcedar (*Tamarix* sp.) and locally dense stands of hydrophytes grow near the spring ponds of the refuge. Upland vegetation consists chiefly of sagebrush (*Artemesia* sp.), horsebrush (*Tetradymia glabrata*),[1] and Mormon tea (*Ephedra nevadensis*)[1] with some widely scattered juniper (*Juniperus* sp.).

Geology

Rocks of Paleozoic and Cenozoic age are exposed in the Fish Springs Flat area. These rocks are grouped into generalized hydrogeologic units on the basis of lithologic and hydrologic similarities, and each unit has a significant effect on the hydrologic system in the area. Table 2 gives a generalized description of the lithology and water-bearing characteristics of these units, and plate 1 shows their distribution.

[1] Identification by Lois A. Arnow, Curator, Garrett Herbarium, University of Utah.

Table 1.--Average monthly climatologic data for Fish Springs National Wildlife Refuge for the period July 1960-December 1976

(Data from U.S. Weather Bureau, 1962-66, 1965; U.S. Environmental Science Services Administration, 1967-70; and U.S. National Oceanographic and Atomospheric Administration, 1971-77)

Altitude 4,335 feet above mean sea level

	Precipitation (inches)	Temperature (°F)	Evaporation[1] (inches)
January	0.28	28.9	—
Febraury	.48	36.3	—
March	.61	42.2	—
April	1.04	49.7	6.30 (2)
May	.76	61.4	11.44 (7)
June	.97	70.0	13.01 (13)
July	.55	80.0	16.13 (13)
August	.43	77.4	13.71 (13)
September	.58	66.2	9.91 (13)
October	.74	53.4	5.95 (6)
November	.50	40.7	—
December	.43	29.4	—
Annual			
Total	7.37		76.45
Mean		53.0	

[1] Freshwater pan evaporation. Number of years of record in parentheses.

Table 2.--Lithology and water-bearing characteristics of hydrogeologic units

Age		Hydrologic unit and symbol on plate 1	Lithology, thickness, and extent	Water-bearing characteristics
CENOZOIC	Quaternary	Eolian dune sand (Qds)	Linear dunes and barchans along the margin of the Great Salt Lake Desert and in discontinuous patches throughout the area. Some dunes are stabilized by vegetation. Composed mainly of fine to medium quartzose sand. Maximum thickness about 20 ft (6 m).	Permeable, retaining sufficient moisture to support vegetation. Generally unsaturated but locally may contain fresh perched ground water during the spring or early summer; may transmit water to underlying hydrogeologic units; not an important aquifer in this area.
		Alluvium and colluvium (Qag)	Fluvial deposits of sand, gravel, and boulders with intermixed clay and silt in major stream channels and near mountains, with coalescing alluvial-fan deposits along lower mountain slopes; maximum thickness probably less than 200 ft (60 m). Colluvial deposits of angular rock fragments locally on higher mountain slopes; maximum thickness probably less than 100 ft (30 m).	Moderately to highly permeable but too thin to store significant quantities of water; mostly unsaturated, only thickest deposits may be saturated in lower areas; accepts recharge from snowmelt, transmitting water to underlying hydrogeologic units; this and the underlying older alluvium (QTu) comprise an aquifer along the mountain fronts and in the southern part of the valley.
		Alluvial and lacustrine deposits (Qlc)	Fluvial and lacustrine marl, clay, silt, sand, and gravel in the valley areas, with alluvium confined mostly to stream channels. Lacustrine deposits in relatively flat areas. Include the lower parts of some alluvial fans, fans near low parts of mountain ranges, and slope wash. Bars, spits, terraces, and deltas, which were deposited in Pleistocene Lake Bonneville, are composed chiefly of sand and fine gravel. Maximum thickness probably less than 100 ft (30 m).	May be slightly to highly permeable, but generally unsaturated except in the lower (northern) part of Fish Springs Flat, where fairly permeable. May accept recharge from snowmelt, transmitting water to underlying hydrogeologic units.
	Tertiary and Quaternary	Older alluvial and lacustrine deposits (QTu)	Fluvial and lacustrine clay, sand, and gravel; unconsolidated to well-cemented with calcium carbonate. Exposed in a small area at the west side of the Drum Mountains but underlie most of the Quaternary alluvial and lacustrine deposits of the area. Maximum thickness in Fish Springs Flat not known, but probably more than 450 ft (137 m).	Slightly to highly permeable, although five stock wells in the area have yields ranging only from 12 to 40 gal/min (0.8 to 2.5 L/s). Wells having greater yields are prabably feasible but may contain brackish or saline water in the lower northern part of the area.
	Tertiary	Igneous rocks (Te)	Rhyolitic to basaltic lava flows, ignimbrites, and pyroclastic deposits mainly in the mountain ranges in the eastern part of the area, but interlayered locally with older alluvium in the subsurface. Include a few small isolated exposures of intrusive porphyritic rhyolite-rhyodacite breccia.	Permeability very low except where fractured or where clastic interlayers may be permeable; yield water to a few small springs in the mountains where fractured. Accept recharge where fractured and transmit water to adjacent or underlying hydrogeologic units.
PALEOZOIC	Cambrian to Pennsylvanian	Consolidated carbonate rocks, undifferentiated (Pzc)	(Pzc) Limestone and dolomite with subordinate shale and sandstone ranging in age from Cambrian to Pennsylvanian; complexly folded and faulted.	(Pzc) Slightly permeable but local fractures and solution channels impart zones of high permeability; the apparent source of water discharging from most springs in the Fish Springs group; accept local recharge where fractured.
		Consolidated quartzitic rocks, undifferentiated (Pzq)	(Pzq) Quartzite and sandstone with subordinate shale, of Cambrian and Ordovician ages; complexly folded and faulted.	(Pzq) Permeability very low except where fractured; accept recharge where fractured.

The rocks in the Fish Springs Flat area are greatly faulted. Fish Springs Flat is bounded on the west and southwest by major inferred and concealed faults at the base of the Fish Springs Range and Swasey Mountain (pl.1). In addition to the major faults, the rocks of Paleozoic age in the mountain ranges are complexly folded and faulted. The complex structure of the Thomas and Dugway Ranges, for example, is described in some detail by Staatz and Carr (1964, p. 120-129). Futhermore, the Tertiary igneous rocks that overlie the Paleozoic units contain many small faults and numerous joints. The numerous faults in the Fish Springs Flat area may have a profound affect on the hydrology by acting as conduits for the transmission of water.

Numbering system for hydrologic-data sites

The system of numbering hydrologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating a site as a well, spring, or miscellaneous site, 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 acres (4 hm^2);[1] the letters a, b, c, and d indicate, 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 the 10-acre (4-hm^2) tract; the letter S preceding the serial number denotes a spring. Thus (C-11-14)23dcc-1 designates the first well constructed or visited in the SW¼SW¼SE¼ sec. 23, T. 11 S., R. 14 W. Other sites where hydrologic data were collected are numbered in the same manner, but no serial number is used. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used. The numbering system is illustrated in figure 2.

WATER-RESOURCES APPRAISAL

The total amount of precipitation that falls on the Fish Springs Flat area is about 232,000 acre-ft (286 hm^3) per year (table 3). Most of the precipitation falls sporadically and is largely consumed by evapotranspiration before sustained runoff occurs or before any large amount of it recharges the ground-water reservoir. Thus, streamflow is ephemeral; and less than 2 percent of the total precipitation within the area is estimated to reach the ground-water reservoir.

Surface water

Fish Springs Wash is the major drainage in the Fish Springs Flat area. Fish Springs Wash and numerous smaller drainages flow only in direct response to thunderstorms or snowmelt, and in many years they may not flow at all. This is demonstrated by the following record of peak discharges obtained during 1961-77 at a tributary to Fish Springs Wash about 1.5 mi (2.4 km) west of Dugway Pass (pl. 1).

Date	Peak discharge (ft^3/s)	Peak discharge (m^3/s)
1961	No evidence of flow	
2- 9-62	2	0.06
1963	No evidence of flow	
1964	No evidence of flow	
9- 6-65	215	6.1
1966	No evidence of flow	
6-12-67	17.5	.50
8-21-68	253	7.2
1969	No evidence of flow	
7-22-70	197	5.6
1971	Flow not determined	
1972	Flow not determined	
7-14-73	1,720	48.7
7-16-74	15	.42
1975	Flow not determined	
1976	Flow not determined	
4-26-77	No evidence of flow	

[1] Although the basic land unit, the section, theoretically is 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.

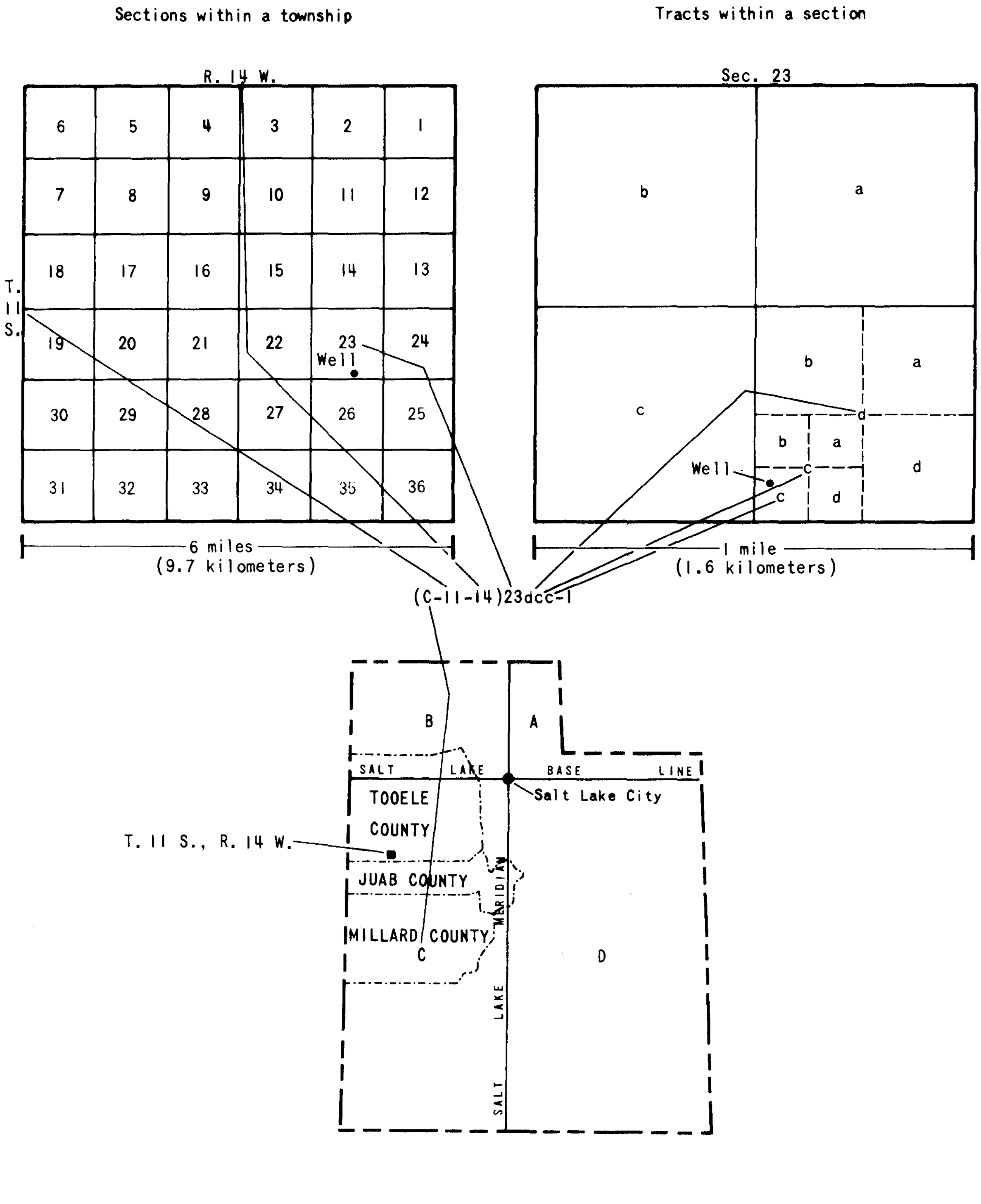

Figure 2.—Numbering system for hydrologic-data sites.

Table 3.--Estimated average annual volumes of precipitation and ground-water recharge

(Areas of precipitation zones calculated from pl. 1; all estimates are rounded.)

Precipitation zone (inches)	Area (acres)	Precipitation (acre-feet)	Recharge	
			Percentage of precipitation	Acre-ft
		Consolidated and unconsolidated rocks		
6- 8	326,000	190,000	1	1,900
		Unconsolidated rocks		
8-10	16,000	12,000	1	120
		Consolidated rocks		
8-10	30,000	22,000	3	660
10-12	4,000	3,700	8	300
12-16	2,400	2,800	10	280
16-20	800	1,200	25	300
Subtotal	37,200	29,700		1,540
Totals (rounded)	379,000	232,000		4,000

Surface runoff in the Fish Springs Flat area was estimated using information from previous reports in this series. Stephens (1974, 1976, 1977) estimated runoff for Wah Wah, Pine, and Tule Valleys, and Stephens and Sumsion (1978) estimated runoff in the Dugway Valley-Government Creek area. The estimates of runoff in these previous studies were based on channel-geometry measurements. In all the areas except the Dugway Valley-Government Creek area, where runoff was negligible, estimated runoff was about 1 percent of the total precipitation. Using that percentage, therefore, the runoff for the Fish Springs Flat area would be about 2,000 acre-ft (2.5 hm^3) annually. Some additional water leaves the area as runoff, but this is the result of overflow water from the spring ponds at the wildlife refuge and is classified as ground-water discharge. The amount of overflow is unknown, but it is probably small and occurs during periods of low evaporation. The overflow eventually drains northward into the Great Salt Lake Desert.

Some runoff is periodically stored in reservoirs for livestock. These reservoirs are few in number and are dry most of the time, so that their importance as dependable water sources is minimal.

Ground water

Recharge

The amount of recharge from infiltration of precipitation was estimated using a method developed by Eakin and others (1951, p. 79-81) and modified by Hood and Waddell (1968, p. 22-23). Using this method, the average annual amount of recharge derived from infiltration of precipitation for the Fish Springs Flat area was estimated to be about 4,000 acre-ft (5 hm^3) (table 3).

Another source of water to the Fish Springs Flat area may be interbasin flow through fault zones, fractures, and solution channels in the rocks of the mountain masses that otherwise are considered boundaries of the ground-water reservoir in the unconsolidated deposits in Fish Springs Flat. Also, some subsurface inflow may occur through unconsolidated deposits that underlie passes, such as Sand Pass near the southwestern part of the area. Total inflow from outside the drainage area is unknown but significant, as indicated by the ground-water balance discussed later in this report.

Occurrence and movement

The data available for the Fish Springs Flat area, although scant, indicate that ground water occurs under both artesian and water-table conditions. The springs that comprise the Fish Springs group and most of the other springs in the area rise under artesian pressure (supported in some cases by hydrothermal convection, such as at Wilson Hot Springs) along fracture zones associated with concealed faults. Water-level data for wells (C-11-12)15bba-1 and (C-14-12)4cbc-1 (table 5) and lithologic information from drillers' logs for these wells (table 6) indicate that ground water occurs under artesian conditions on the higher valley slopes. The water-bearing material in these areas is principally coarse sand and gravel (QTu in table 2); and when penetrated by wells, the water rises above the bed in which it was encountered. In the lowland areas, particularly the salty mudflats in the northern part of Fish Springs Flat, shallow auger holes show that the potentiometric surface is within a few feet of the land surface. Locally, such as in recharge areas on alluvial fans or sand dunes, ground water occurs under water-table conditions or sometimes as perched water.

Ground water moves generally from areas of recharge toward the unconsolidated valley fill and then along the axis of the valley northward toward the Great Salt Lake Desert (pl. 1). The water moves at a relatively slow rate through the ground-water system primarily due to the small amount of recharge and probably also due to the low permeability of the unconsolidated materials in the central part of the valley. The amount of water leaving the study area as subsurface flow is estimated to be less than 100 acre-ft (0.12 hm^3) per year.

Some ground water may move into the Fish Springs Flat area from other basins such as Tule Valley (Stephens, 1977, p. 16 and 21) through pathways provided by fractures and solution channels in the consolidated rocks forming the boundaries of the area. This water either moves into the unconsolidated fill or into fractures which give rise to springs that discharge at the land surface. These fractures have a higher permeability than the adjacent or overlying valley fill. Some of the springs along fracture zones, such as the Fish Springs group, discharge large quantities of water. Additionally, some ground water may enter the area through the unconsolidated material that comprises low divides, such as Sand Pass.

Storage

Because of the scant data available, the amount of water in storage can only be estimated. The quantity of water recoverable from the upper 100 ft (30 m) of the saturated valley fill (unconsolidated alluvial and lacustrine deposits) is the product of the volume of saturated fill and the specific yield of that material.[1] In the Fish Springs Flat area, the volume of the upper 100 ft (30 m) of saturated valley fill is about 22 million acre-ft (27,000 hm^3). Because of the abundance of fine-grained sediment in the fill, the specific yield is estimated to range from less than 1 to about 5 percent. Assuming the average specific yield of the fill to be about 2.5 percent, the total recoverable storage in the upper 100 ft (30 m) of saturated valley fill is about 550,000 acre-ft (680 hm^3). Most of this water is slightly to moderately saline.

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[1] Specific yield of a rock or soil is the ratio of the volume of water it will yield by gravity after being saturated to the volume of the rock or soil.

Discharge

Ground water in the Fish Springs Flat area is discharged principally by springs and evapotranspiration. The amount of ground water discharged by subsurface flow that leaves the area and by wells in the area is unknown but is not a significant part of the total discharge.

Springs.--The Fish Springs Flat area contains several areas of spring discharge, data for which are given in table 7. The Fish Springs group includes all the springs at the northeastern edge of the Fish Springs Range (Mundorff, 1970, p. 37). The group includes Wilson Hot Springs, at the northern tip of the range: North Springs (called Big Spring by Mundorff), about 1.6 mi (2.6 km) southeast of Wilson Hot Springs; Fish Springs, a series of springs in the wildlife refuge headquarters area; and other springs south of Wilson Hot Springs and north of Fish Springs (pl. 1). The eight largest springs in the Fish Springs group are North Springs, Walter Spring (between North Springs and Fish Springs), and the following springs located at Fish Springs: House Springs (combined with Mirror Spring), Thomas Springs, Middle Spring, Lost Spring (combined with Crater Spring), South Springs, and Percy Spring. These springs collectively discharge a total of about 26,000 acre-ft (32 hm^3) of water annually, according to monthly measurements made by personnel of the wildlife refuge. All other springs within the study area discharge an estimated 600 acre-ft (0.74 hm^3) annually, or only about 2 percent of the total spring discharge.

Analysis of monthly discharge measurements of the eight large springs for 1970-76 shows that the variability[1] of the discharge ranged from 64 percent for Percy Spring, (C-11-14)26daa-S1, to 275 percent for Walter Spring, (C-11-14)11cdb-S1, the largest spring with the lowest average discharge. The variability of the sum of all the individual monthly discharges was about 58 percent, which is less than the variability of any individual spring. This suggests that discharge of individual springs fluctuates independently, or that errors in discharge measurements are compensated by summing all spring discharge. Data from North Springs, (C-11-14)3dbd-S1, suggest the latter. The variability of North Springs was about 118 percent, as determined from monthly measurements for the 1970-76 period. However, during the period from November 1965 to July 1968, a continuous gage-height recorder was in operation at North Springs. The variability as determined from this record was only 15 percent. This difference in determinations of variability at North Springs indicates that the instantaneous monthly determinations of discharge may be affected by such factors as wind, errors in gage readings, or muskrats making holes in banks around ponded areas and diverting water above points of measurement.

Analysis of the sum of the discharges of the eight large springs of the Fish Springs group shows a gradual increase in the total discharge for the 1970-76 period. (See fig. 3.) Assuming that the discharge of the Fish Springs group is the outflow point for subsurface flow from Fish Springs Flat and one or more of the surrounding basins, then recharge from precipitation that falls on those basins should affect the discharge of the springs. However, attempts to correlate the variations of the spring discharge to variations in precipitation that falls locally and at surrounding weather stations have proved unsuccessful, perhaps due to scant data, the short record of spring discharge, or a time lag of unknown length.

An attempt was made, therefore, to correlate the discharge of Fish Springs with the fluctuations of Great Salt Lake, which reflects precipitation in a drainage basin of about 53,000 mi^2 (137,270 km^2) centered about 110 mi (177 km) northeast of Fish Springs. Hydrographs for the springs and the lake both show an upward trend for the 1970-76 period (fig. 3). The rise in lake level reflects above-average precipitation during 1970-76 in Great Salt Lake drainage basin. By contrast, precipitation during 1970-76 was below average at the Fish Springs National Wildlife Refuge. During the 1974-77 period, the yearly highs and lows in the springs hydrograph lag behind the highs and lows in the Great Salt Lake hydrograph by 3-6 months, but no such correlation is evident for the 1970-73 period. These factors suggest, in a general way, that the discharge of the Fish Springs group is affected by regional precipitation and flow systems rather than by local effects.

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[1] Variability is defined as the maximum discharge minus the minimum discharge divided by the average discharge, all multiplied by 100.

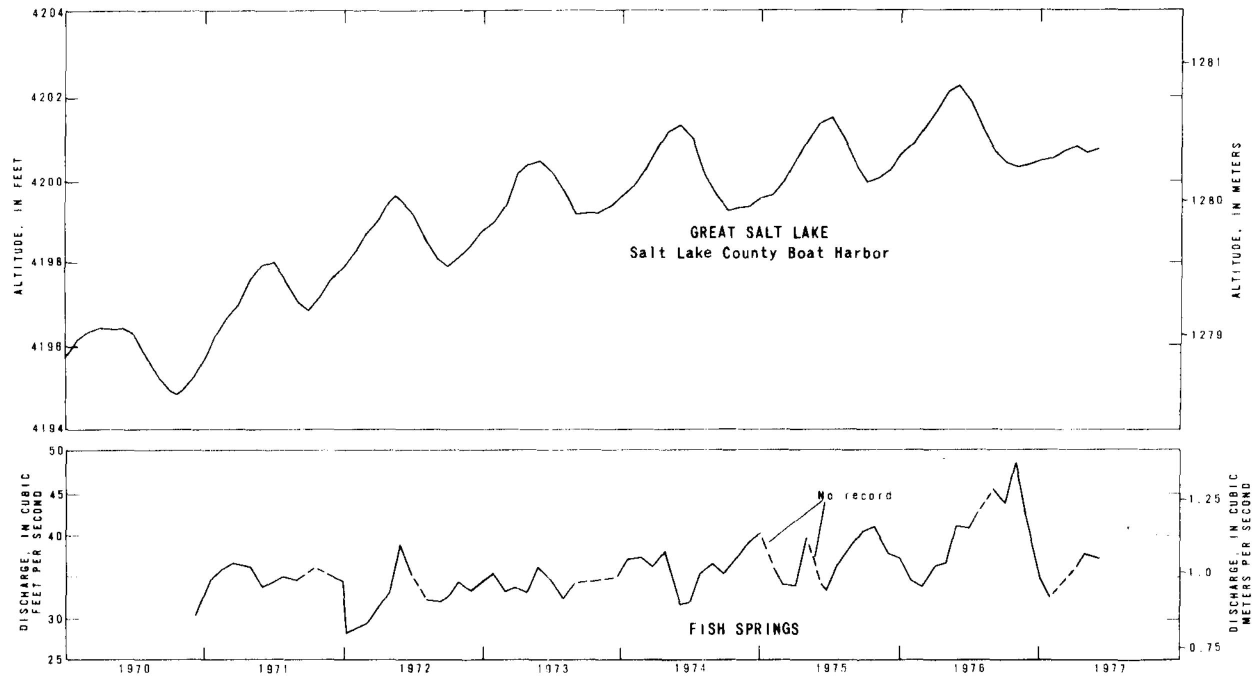

Figure 3.— Discharge of the eight largest springs in the Fish Springs group and fluctuation of Great Salt Lake, 1970-77.

Evapotranspiration.--The amount of water lost to evapotranspiration from the Fish Springs Flat area is about 8,000 acre-ft (10 hm^3) per year. This does not include evapotranspiration that is directly related to spring discharge.

The most important phreatophytes in the Fish Springs Flat area, from the standpoint of water use, are greasewood and pickleweed.

Greasewood is scattered throughout the area where the depth to water is not greater than about 40 ft (12 m), such as on sand dunes and on lower alluvial slopes of the adjacent mountains and hills. The most concentrated growth of greasewood is on the lower alluvial slopes of the Fish Springs Range near sec. 3, T. 12 S., R. 14 W. The lower limit of greasewood growth is about 4,310 ft (1,314 m), which is the altitude below which the ground-water salinity is greater than greasewood can tolerate. The upper altitude limit of greasewood growth is variable, depending on the depth to water and soil conditions. Pickleweed grows near some spring areas but particularly in the salty mudflats in the northern part of the area below an altitude of about 4,310 ft (1,314 m). Saltgrass is well established in an near most of the spring areas, particularly near Fish Springs, but it is only scattered elsewhere. Table 4 summarizes the discharge of water by evapotranspiration in the Fish Springs Flat area.

Table 4.--Estimated average annual ground-water discharge by evapotranspiration in the Fish Springs Flat area

Phreatophyte	Area (acres)	Depth to water (feet)	Areal density of growth (percent)	Rate of evapo-transpiration (ft/yr)	Discharge (acre-ft/yr, rounded)
Scattered pickleweed (salty mud-flats)	50,800	0-10	0- 5	0.1[1]	5,100
Pickleweed, scattered greasewood	12,800	5-20	0- 5	.1[2]	1,300
Greasewood	14,100	Unknown[3]	0- 5	.1[4]	1,400
Greasewood	640	10-20	20-30	.2[4]	100
Total (rounded)					8,000

[1] From Feth, Barker, Moore, Brown, and Veirs (1966, p. 69-70).
[2] From Mower and Nace (1957, p. 21).
[3] Assumed to be less than 40 ft.
[4] From Robinson (1958, p. 69).

Ground-water balance

In the Fish Springs Flat area, the long-term recharge to the ground-water reservoir is the same as the long-term discharge because there is little interference by man. Thus, the system is in equilibrium, and there is no apparent change in storage in the ground-water reservoir.

About 4,000 acre-ft (5 hm^3) of water recharges the ground-water reservoir by infiltration of local precipitation. An unknown amount of water moves into the area as underflow from other basins. This unknown amount of interbasin flow can be estimated as the residual after summing the total discharge from all sources and subtracting the estimated amount of local recharge. About 27,000 acre-ft (33 hm^3) is discharged annually from springs, and about 8,000 acre-ft (10 hm^3) is discharged annually by evapotranspiration. Discharge by wells and by subsurface outflow is negligible. Thus, about 35,000 acre-ft (43 hm^3) leaves the area as discharge. The difference between discharge and local recharge--approximately 31,000 acre-ft (38 hm^3)--is assumed to enter the Fish Springs Flat area by interbasin flow.

Previous reports in this series noted the occurrence of interbasin ground-water flow in Snake Valley (Hood and Rush, 1965, p. 24), in Wah Wah Valley (Stephens, 1974, p. 26-27), in Pine Valley (Stephens, 1976, p. 17), and in Tule Valley (Stephens, 1977, p. 16 and 21). These valleys are south and west of the Fish Springs Flat area. The scant data available indicate that the ground water from these areas moves in the general direction of the Fish Springs Flat area.

Chemical quality of ground water

Water-quality data in the Fish Springs Flat area are scant, and no data are available for surface water. The data available for the few wells and springs in the area are given in table 8.

The ground water in the Fish Springs Flat area ranges from slightly saline to briny according to a classification used by the U.S. Geological Survey (Robinove and others, 1958, p. 3).

Classification	Dissolved-solids concentration (mg/L)
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

Sodium and chloride are the predominant ions in the water from all wells and springs sampled in the study area.

Variations in quality

The most highly mineralized water in the Fish Springs Flat area is under the salty mudflats in the northwest part of the study area. The specific conductance of water from a shallow auger hole in sec. 17, T. 10 S., R. 14 W. (about 2 mi (3.2 km) northwest of the study area), was 150,000 micromhos/cm at 25°C in September 1975. Water from another shallow auger hole just south of Fish Springs in sec. 36 T. 11 S., R. 14 W., had a specific conductance of 54,000 micromhos/cm (R.K. Glanzman, U.S. Geol. Survey, written commun., 1977). Based on the relationship between specific conductance and dissolved-solids concentration, these waters would probably be classified as very saline or briny.

Other than the shallow water cited above, the most highly mineralized water in the area is that from Wilson Hot Springs, which discharges in the mudflats at the north end of the Fish Springs Range. The concentration of dissolved solids in water discharging from one of the orifices of the springs, (C-10-14)33cdc-S1, was 22,400 mg/L. In contrast, Middle Spring, (C-11-14)23ddc-S1, of Fish Springs discharged better quality water with a concentration of dissolved solids of 1,910 mg/L. Well (C-11-14)23dcc-1, which is about 0.25 mi (0.4 km) west of Middle Spring, is only about 35 ft (11 m) deep. The water from the well had about the same specific conductance as the water from the spring, thus indicating that their sources may be the same.

Quality relative to use

The water in the Fish Springs Flat area is not suitable for drinking, according to the following recommended standards of the U.S. Public Health Service (1962):

Dissolved constituent	Recommended maximum concentration (mg/L)
Chloride (Cl)	250
Sulfate (SO_4)	250
Dissolved solids	500

All water sources sampled exceed all the standards given above.

The U.S. Salinity Laboratory Staff (1954, p. 79-81) developed a classification to show the suitability of water for irrigation based on the sodium and salinity hazards of the water. In that classification, it is assumed that an average quantity of water will be used under average conditions of the following: soil texture, salt tolerance of crops, climate, drainage, and infiltration. According to that classification, all water sampled in the study area has a high sodium hazard and much of the water has a very high salinity hazard. However, the water that issues from Fish Springs is used for wildlife management (particularly waterfowl), which includes ponding and irrigation of vegetation (chiefly saltgrass) in the wildlife refuge.

The concentration of boron is also a principal factor determining the suitability of water for irrigation. Of the 10 water samples in the study area that were analyzed for boron, only 2 would be classed as unsuitable for use on crops that were semitolerant or tolerant to boron (Hem, 1970, p. 329).

The water from many of the wells in the area is used for livestock. Water from well (C-14-12)4cbc-1 has the lowest concentration of dissolved solids, 2,370 mg/L, of any stock well in the area. Water from well (C-13-12)5cbd-1, which is used for mining purposes, had a dissolved-solids concentration of 1,740 mg/L on June 15, 1977.

Temperature of ground water

The temperature of most ground water sampled in the Fish Springs Flat area is 20.0°C (68°F) or higher, which is considerably higher than the expected temperature of nonthermal ground water in the area. The latter temperature would be expected to be about the same as the average annual air temperature at Fish Springs Refuge, or about 11.5°C (53°F). The warm temperatures may be due to several factors, one of which is heat flow from either shallow or deep volcanic rocks of late Tertiary age, some of which crop out in the area (pl 1). For example, the water from well (C-14-12)4cbc-1 has a temperature of 23.0°C (73°F). The well penetrates 509 ft (155 m) of valley fill; but volcanic rocks crop out in nearly all directions from the well site, and these rocks may be a shallow heat source for the water.

The warm temperatures also could be due to deep circulation of atmospheric water. If a geothermal temperature gradient of 1.8°C/100 m (1°F/100 ft) is assumed, then water from Cold Spring, (C-11-14)4aab-S1, that has a temperature of 17.5°C (63°F), indicates possible circulation to a depth of 1,100 ft (335 m). The water that issues from Middle Spring, (C-11-14)23ddc-S1, with a temperature of 27.0°C (81°F), would have circulated to a depth of about 2,800 ft (850 m), assuming the same geothermal gradient. The temperature of 75.5°C (168°F) reported by Mundorff (1970, p. 37) for water at the center of a spring pool at Wilson Hot Springs would indicate circulation to about 11,500 ft (3,500 m).

Although an extensive heat-flow analysis is not within the scope of this study and the depths of circulation are only estimates, they do, along with differences in concentration of dissolved solids, indicate that the water from these springs does not issue from the same fault. For instance, water from Cold Spring has a lower temperature and a higher dissolved-solids concentration than water from Middle Spring.

SUMMARY AND NEEDS FOR FURTHER STUDIES

Total annual precipitation on the Fish Springs Flat area averages about 232,000 acre-ft (286 hm^3), of which only about 4,000 acre-ft (5 hm^3) recharges the ground-water reservoir and about 2,000 acre-ft (2.5 hm^3) is estimated to be runoff.

Ground-water discharge is chiefly by springs and evapotranspiration. Springs discharge about 27,000 acre-ft (33 hm^3) per year, and discharge by evapotranspiration is about 8,000 acre-ft (10 hm^3) per year. Annual discharge by wells and by subsurface flow is negligible. The difference between total discharge and local recharge--31,000 acre-ft (38 hm^3)--is assumed to enter the Fish Springs Flat area by interbasin flow.

Ground water in the Fish Springs Flat area ranges from slightly saline to briny. The predominant ions in the water from all the sources sampled are sodium and chloride. The water in the area is not suitable for drinking. Some water is used for mining purposes and for irrigation of vegetation in connection with wildlife management.

In order to obtain a better understanding of the water resources in the Fish Springs Flat area, test drilling and possibly surface geophysical surveys would be required to (1) determine the subsurface geology and delineate major aquifers; (2) better define the potentiometric surface within the drainage basin as well as near low divides, such as Sand Pass; (3) determine water-bearing properties of the aquifers; and (4) delineate patterns of water quality that can be useful for determining ground-water movement. In addition, the installation of a continuous gage-height recorder on at least one of the Fish Springs would provide a better definition of the seasonal and annual variations in the spring discharge as well as a more accurate determination of the long-term average discharge of the springs.

A regional appraisal of water resources would be needed to determine the source of water that issues from the Fish Springs group. The amount of recharge to the ground-water reservoir from precipitation that falls within the Fish Springs Flat drainage area is not sufficient to account for spring discharge and evapotranspiration. Water lost by evapotranspiration alone is greater than the amount of recharge. A major part of the water discharged enters the area by subsurface flow; and a regional study would be needed to determine the source and exact quantity of the subsurface flow.

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Table 5.--Records of selected wells

Location: See section on numbering system for hydrologic-data sites.
Finish: P, perforated; X, open hole.
Altitude of land-surface datum: Above mean sea level as interpolated from U.S. Geological Survey topographic maps.
Geologic source of water: Pzc, sedimentary carbonate rocks, undifferentiated; QTu, older alluvium; Te, igneous rocks.
Water level: Reported, unless indicated by M, measured.
Method of lift: P, piston pump; T, turbine pump.
Use of water: H, domestic; N, industrial; S, livestock; U, unused.
Other data available: C, chemical analysis in table 8; D, driller's log in table 6.

Location	Owner	Year constructed	Depth of well (ft)	Casing diameter (in.)	Depth to first opening (ft)	Finish	Altitude of land-surface datum (ft)	Geologic source of water	Water level: Below land-surface datum (ft)	Water level: Date	Method of lift	Discharge: Rate (gal/min)	Discharge: Date	Use of water	Temperature (°C)	Specific conductance (micromhos per centimeter at 25°C)	Date[1]	Other data available
(C-11-12)4ccd-1	U.S. Bureau of Land Management	1935	538	6	532	X	4,471	QTu	154.02M	8-23-76	P	20	8- 5-35	S	-	-	-	D
15bba-1	do	1962	330	6	305	P	4,580	QTu	255	10-31-62	T	30	10-31-62	S	-	5,200[2]	4-27-77	D
(C-11-14)23dcc-1	U.S. Fish and Wildlife Service	1964	35	12	0	X	4,330	Pzc	20	6- -64	T	228	6- -64	H	27.0	3,500	8-24-76	
(C-12-12)31cca-1	-	-	-	-	-	-	4,565	-	226.76M	4-27-77	P	-	-	U	-	-	-	
31ccb-1	U.S. Bureau of Land Management	1946	232	6	223	P	4,540	-	203	2-19-46	P	5	2-19-46	U	-	-	-	
(C-12-13)12caa-1	do	1956	210	6	200	P	4,510	Te	183	7-10-56	T	40	2- 6-72	U	-	-	-	C,D
(C-12-14)23bcc-1[3]	do	-	-	-	-	-	4,345	QTu	10	8-24-76	-	-	-	U	20.0	16,000	8-24-76	
(C-13-12)5cbd-1	Brush Wellman, Inc.	1961	615[4]	5	-	-	4,756	Te	427	3-26-62	P	([5])	-	N	-	-	-	C,D
(C-14-12)4cbc-1	U.S. Bureau of Land Management	1935	509	6	403	P	4,811	QTu	370	3-17-35	P	40	3-17-35	S	-	-	-	D
(C-14-13)9cba-1	do	1966	266	6	246	P	4,673	QTu	226	4-26-66	P	12	10- 9-68	S	-	-	-	D

[1] Date refers to measurements of specific conductance and temperature.
[2] Specific conductance measured in nearby storage tank.
[3] Apparent sinkhole.
[4] Originally drilled to 745 ft, caved back to 615 ft.
[5] Well reportedly flowed 5-10 gal/min during drilling at about 405 ft.

Table 6.--Drillers' logs of selected wells

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-11-12)4ccd-1. Log by Coxe and Clarkson. Alt. 4,471		
Clay	12	12
Clay, gravel, and boulders	68	80
Gravel; dry	90	170
Sand, gray; little water	30	200
Clay, yellow, sand and gravel	150	350
Gravel; dry	10	360
Sand, gray, cemented	100	460
Clay and sand; alternating layers	40	500
Sand, coarse; ample water	38	538
(C-11-12)15bba-1. Log by C. M. Stephenson. Alt. 4,580.		
Top soil	6	6
Clay and gravel, brown	149	155
Sandstone, dark-brown, decomposed	42	197
Lava, gray	28	225
Lava, red	25	250
Lava, gray	25	275
Clay and gravel, gray	12	287
Clay, sand, and gravel, brown; good water from 305 to 330 ft	43	330
(C-12-13)12caa-1. Log by D. Smith. Alt. 4,510		
Sand, fine	3	3
Clay, gravel, and boulders	13	16
Sand and gravel, cemented	126	142
Cinders, volcanic	48	190
Cinders, red; water	4	194
Clay and cinders	6	200
Cinders, red; water	8	208
Clay and cinders	2	210
(C-13-12)5cbd-1. Geologist's log from Brush Wellman, Inc. Alt. 4,756.		
Alluvium	10	10
Rhyolite	735	745
(C-14-12)4cbc-1. Log by E. C. Staffa. Alt. 4,811.		
Soil, clay, and gravel, black, and boulders	135	135
Clay, sandy, gray	17	152
Clay and gravel, gray; alternating layers	246	398
Gravel, coarse, loose; water	3	401
Sand, weakly cemented	59	460
Sand, coarse; water	5	465
Clay, gray	44	509

Table 6.--Drillers' logs of selected wells - Continued

Material	Thickness	Depth
(C-14-13)9cba-1. Log by D. L. Campbell. Alt. 4,623.		
Clay, gravel, and boulders, black	20	20
Clay and gravel	60	80
Clay and sand, gray	5	85
Sand, brown	20	105
Sand and gravel, gray	8	113
Boulders, hard	5	118
Clay and gravel, white	7	125
Gravel and boulders, brown	30	155
Sand and gravel, gray	45	200
Sand, brown	10	210
Sand and gravel; water at 230 ft	56	266

Table 7.--Records of selected springs

Location: See section on numbering system for hydrologic-data sites.
Altitude of land-surface datum: Above mean sea level as interpolated from U.S. Geological Survey topographic maps.
Geologic source of water: Pzc, sedimentary carbonate rocks, undifferentiated; Te, igneous rocks.
Use of water: S, livestock; U, unused; W, wildlife.
Other data available: C, chemical analysis in table 8.

Location	Owner	Name	Altitude of land-surface datum (ft)	Geologic source of water	Discharge: Rate (gal/min)	Discharge: Date	Temperature (°C)	Specific conductance (micromhos/cm at 25°C)	Date[1]	Use of water	Other data available
(C-10-14)33c-S	U.S. Army, Dugway	Wilson Hot[2]	4,293	Pzc	-	-	60.5	31,200	7-12-67	U	C
33cdc-S1	do	do	4,293	Pzc	<1	-	55.6	34,700	8-24-76	U	C
33cdd-S1	do	do	4,293	Pzc	10	8-24-76	58.9	15,000	8-24-76	U	
33dba-S1	do	do	4,298	Pzc	60	8-24-76	60.6	23,000	8-24-76	U	
33dcb-S1	do	do	4,298	Pzc	30	8-24-76	60.0	17,000	8-24-76	U	
(C-11-14)3dbd-S1	U.S. Fish and Wildlife Service	North[2]	4,303	Pzc	3,140	8-24-76	23.5	5,000	8-24-76	W	C
4aab-S1	U.S. Bureau of Land Management	Cold[2]	4,303	Pzc	-	-	-	11,700	6- 7-74	U	C
4bbb-S1	do	-	4,298	Pzc	20	8-24-76	18.0	9,000	8-24-76	U	
11bcb-S1	U.S. Fish and Wildlife Service	Deadman[2]	4,310	Pzc	100	8-24-76	23.0	4,000	8-24-76	W	
11cdb-S1	do	Walter[2]	4,308	Pzc	150	7-22-76	20.5	3,900	8-23-76	W	
23aca-S1	do	House[2,3,4]	4,315	Pzc	-	-	24.0	3,070	3-26-56	W	C
					850	7-22-76	20.0	3,200	8-24-76		
23dbd-S1	do	Thomas[2,3]	4,315	Pzc	-	-	25.0	3,160	3-26-56	W	C
					2,400	7-22-76	27.0	3,200	8-24-76		
23ddc-S1	do	Middle[2,3]	4,315	Pzc	- -	-	22.0	3,100	3-26-56	W	C
					5,400	8-24-76	27.0	3,120	8-24-76		
26aaa-S1	do	Lost[2,3,5]	4,310	Pzc	-	-	25.5	3,160	3-26-56	W	C
					1,100	7-22-76	26.0	3,200	8-24-76		
26add-S1	do	South[2,3]	4,310	Pzc	-	-	21.0	3,170	3-26-56	W	C
					3,600	7-22-76	27.5	3,200	8-24-76		
26daa-S1	do	Percy[2,3]	4,315	Pzc	1,700	7-22-76	26.0	3,200	8-24-76	W	
(C-12-12)10cbc-S1	U.S. Bureau of Land Management	Wildhorse	5,300	Te	<1	8-23-76	22.0	8,400	8-23-76	S	C
(C-12-14)23dcc-S1	do	Cane	4,333	-	([6])	-	20.0	10,000	8-24-76	U	C
(C-15-13)29ddc-S1	-	Lost	6,800	Pzc	-	-	-	-	-	-	
33cbc-S1	-	North	6,700	Pzc	-	-	-	-	-	-	

[1]Date refers to measurements of specific conductance and temperature.
[2]One of Fish Springs group.
[3]One of Fish Springs.
[4]Includes Mirror Spring.
[5]Includes Crater Spring.
[6]Discharge diffuse over large area.

Table 8.--Chemical analyses of ground water

Location: See section on numbering system for hydrologic-data sites.

Location	Date of collection	Temperature (°C)	Dissolved iron (Fe) (Micrograms per liter)	Dissolved manganese (Mn) (Micrograms per liter)	Dissolved boron (B) (Micrograms per liter)	Dissolved silica (Milligrams per liter)	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)	Dissolved fluoride (F)	Dissolved nitrite plus nitrate (N)	Dissolved ortho-phorphorus (P)	Dissolved solids: Residue at 180°C	Dissolved solids: Sum	Hardness (Ca,Mg)	Noncarbonate hardness	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH
(C-10-14)33c-S	7-12-67	60.5	-	-	2,600	33	741	224	7,090	18	178	0	1,560	11,900	4.0	-	-	22,900	21,800	2,770	2,620	-	59	31,200	7.4
33cdc-S1	8-24-76	55.6	40	80	3,100	33	740	220	7,600	250	187	0	1,500	12,000	1.8	0.09	0.07	-	22,400	2,800	2,600	84	63	34,700	7.2
(C-11-14)3dbd-S1	8-24-76	23.5	20	0	930	20	120	69	800	53	297	0	400	1,200	1.1	.15	.01	-	2,810	580	340	73	14	5,000	7.3
4aab-S1	6- 7-74	-	90	0	-	-	180	98	2,100	70	246	0	480	3,500	1.0	-	-	-	6,550	850	650	83	31	11,700	7.5
	8-24-76	17.5	40	10	1,200	18	190	100	2,200	73	250	0	540	3,700	1.0	.34	.01	-	6,950	890	680	83	32	11,400	7.4
23aca-S1	3-26-56	24.0	-	-	-	-	-	-	-	-	316	-	-	-	-	-	-	-	-	500	241	-	-	3,070	7.2
23dbd-S1	3-26-56	25.0	-	-	-	-	-	-	-	-	321	-	-	-	-	-	-	-	-	508	245	-	-	3,160	7.2
23ddc-S1	3-26-56	22.0	-	-	-	-	-	-	-	-	316	-	-	-	-	-	-	-	-	500	241	-	-	3,100	7.3
	8-24-76	27.0	20	10	860	19	100	54	480	45	311	0	390	670	1.2	.14	.01	-	1,910	470	220	66	9.6	3,120	7.3
26aaa-S1	3-26-56	25.5	-	-	-	-	-	-	-	-	320	-	-	-	-	-	-	-	-	512	250	-	-	3,160	7.4
26add-S1	3-26-56	21.0	-	-	460	22	100	58	485	42	311	0	386	648	1.2	-	-	1,900	1,900	488	233	66	9.5	3,170	7.3
(C-12-12)10cbc-S1	8-23-76	22.0	120	100	490	31	690	170	870	18	227	0	380	2,500	2.9	1.9	.03	-	4,780	2,400	2,200	44	7.7	8,400	7.3
(C-12-13)12caa-1	9- 1-56	-	-	-	-	-	-	-	871	-	570	0	360	1,080	-	-	-	-	-	370	0	-	20	4,600	8.0
(C-12-14)23dcc-S1	8-24-76	20.0	60	240	1,500	21	300	120	1,700	100	493	0	540	3,100	.9	.06	.03	-	6,130	1,200	840	73	21	10,000	7.3
(C-13-12)5cbd-1	6-15-77	16.5	150	20	320	3.2	130	53	410	5.1	180	-	340	610	.6	23	.04	-	1,740	540	390	62	7.7	2,890	-
(C-14-12)4cbc-1	4-26-77	23.0	20	10	1,100	52	110	72	650	23	360	-	300	980	.4	.63	.11	-	2,370	570	280	70	12	4,050	-

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