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# HYDROLOGIC RECONNAISSANCE OF THE WAH WAH VALLEY DRAINAGE BASIN, MILLARD AND BEAVER COUNTIES, UTAH

by

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bу

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#### ABSTRACT

The Wah Wah Valley drainage basin is an area of about 600 square miles  $(1,550~{\rm km}^2)$  in Millard and Beaver Counties in southwestern Utah. Surface-water supplies of the area are negligible--total runoff averages about 7,800 acre-feet  $(9.62~{\rm km}^3)$  annually, all streams are ephemeral or intermittent, and surface storage is negligible. Evaporation and transpiration within the basin consume more than 97 percent of total annual precpitation. There is no surface outflow.

Ground water is present in most of the rock units in the drainage basin, but they are tapped by few wells and springs because the top of the saturated zone for the most part is deep below the land surface. Total annual recharge to the ground-water system is estimated to average about 10,000 acre-feet (12.3 hm³)--7,000 acre-feet (8.63 hm³) from precipitation in the basin and 3,000 acre-feet (3.70 hm³) from subsurface inflow. Estimates and measurements of discharge from the ground-water system total about 1,500 acre-feet (1.85 hm³). A few springs, wells, mine drains, and prospect pits, most of which yield less than 10 gallons per minute (0.63 1/s), discharge about 100 acre-feet (0.123 hm³) of ground water annually from stream-channel alluvium, igneous rocks, and quartzite. The older alluvium in the valley fill discharges 1 to 2 acrefeet (1,230-2,470 m³) annually to a single well.

Wah Wah Springs discharge about 800 acre-feet (0.987 hm $^3$ ) annually from at least 10 individual spring openings, and an additional 600 acre-feet (0.740 hm $^3$ ) of ground water is discharged annually by evapotranspiration in the immediate vicinity of the springs. The springs is sue from fractures and solution channels in Paleozoic carbonate rocks and from tufa deposits in an area where the land surface transects a structurally controlled fracture zone with relatively high permeability.

Recharge to and discharge from the ground-water system are assumed to be equal over a long period of time because there are no known changes of storage in the system. Thus, the difference between the totals for recharge and discharge represents subsurface outflow from the drainage basin.

Most known ground-water sources in the basin yield fresh, very hard water. In general, the highest concentrations of dissolved solids (maximum 4,550 milligrams per litre) are found in ground water from igneous rocks, and the lowest (minimum 99 milligrams per litre) are found in water from quartzite and carbonate rocks.

#### INTRODUCTION

This report is the fourteenth in a series by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights, which describes the water resources of the western basins of Utah (fig. 1). The purpose of the report is to present hydrologic data for the Wah Wah Valley drainage basin, to provide an evaluation of present and potential water-resources development in the area, and to identify needed studies that would improve understanding of the area's water supply.

The investigation on which the report is based consisted largely of a study of available data for geology, streams, wells, springs, climate, water quality, and water use. These data were supplemented with data on landforms, vegetation, geology, and water sources collected during brief field reconnaissances in September and October 1972 and June 1973.

Several published reports listed in the selected references contain information on the geology and water resources of the Wah Wah Valley area. Principal sources of basic hydrologic data are the files of the U.S. Geological Survey and of the Utah State Engineer. The geologic map of Utah (Stokes, 1964) is the main source for the geology shown on plate 1.

Most of the numbers given in this report are in English units followed by metric units in parentheses. Chemical concentrations are given only in metric units. A list of metric units, abbreviations, and conversion factors is included in the appendix.

Hydrologic-data sites referred to in the report are assigned a number that serves both to identify and to specifically locate the site. This numbering system is described in detail in the appendix.

#### GENERAL HYDROLOGIC ENVIRONMENT

The area described in this report includes Wah Wah Valley and its tributary drainage area, a total of about 600 square miles (1,550  $\rm km^2$ ) in Millard and Beaver Counties in southwestern Utah (fig. 1). Plate 1 shows the topographic and geologic setting of the area, and figure 2 shows representative views of the area.

Except for a small tract of irrigated land at Wah Wah Ranch, the land in the drainage basin is used mainly for livestock grazing. More than 87 percent—about 332,000 acres (1,340 km $^2$ )—of the land is in Federal ownership, about 11 percent—43,000 acres (174 km $^2$ )—is owned by the State of Utah, and the remainder—about 9,000 acres (36 km $^2$ )—is privately owned.

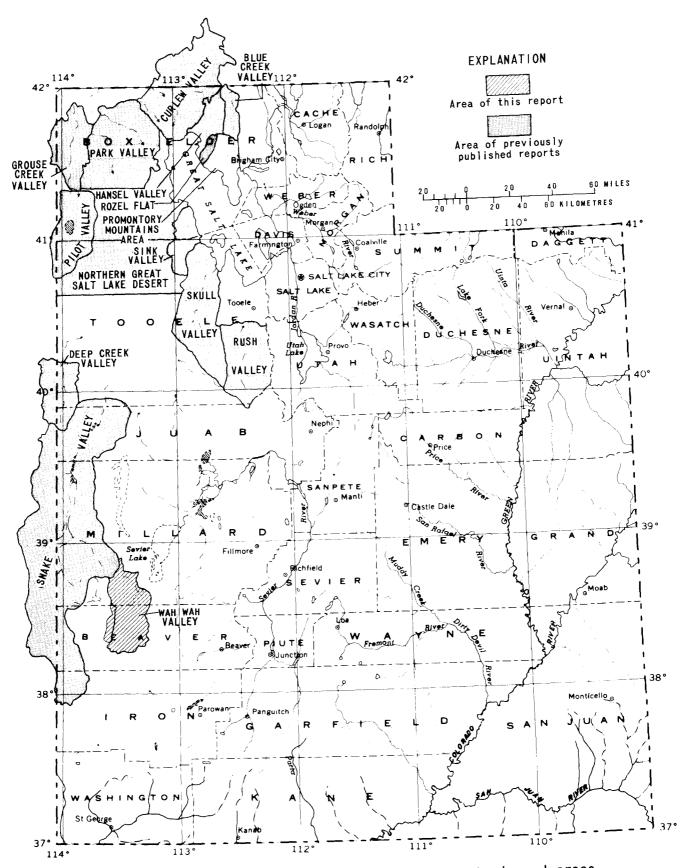


Figure 1.—Location of the Wah Wah Valley drainage basin and areas described in previously published reports in this series.



A. Southern end of Wah Wah Valley Hardpan; looking northwestward from near Crystal Springs.



B. Central part of valley, Frisco Peak, and Wah Wah Ranch; looking eastward from near Wah Wah Springs.

Figure 2. - Wah Wah Valley.

## Physiography

The Wah Wah Valley drainage basin is a closed basin bounded by drainage divides in the Wah Wah Mountains on the west and southwest, the Confusion and House Ranges on the north, and the San Francisco Mountains on the east. The northeastern boundary of the basin is a broad, low ridge, which connects the northern end of the San Francisco Mountains with the southern end of the House Range. The ridge rises about 25 feet (7.6 m) above the floor of the Wah Wah Valley Hardpan and divides the surface drainage of the Wah Wah Valley basin from that of the Sevier Lake basin.

## Climate

The climate of Wah Wah Valley is arid--annual precipitation over the entire basin is estimated to average about 9 inches (229 mm). Figure 3 shows the general distribution of precipitation over the area, and table 1 lists selected climatologic data for Wah Wah Ranch. As indicated in table 1, about one-half of the annual precipitation at Wah Wah Ranch falls during May-September. Precipitation (mostly snowfall) during December-March accounts for less than one-fourth of the annual precipitation on the lowlands and probably not more than one-third of the annual precipitation on the uplands.

## Vegetation

Because of the general aridity, native vegetation in Wah Wah Valley consists primarily of "salt-desert" shrubs that are typical of millions of acres in the Great Basin. Vegetation is absent on the playa (Wah Wah Valley Hardpan, pl. 1 and fig. 2). On the gravelly soils surrounding the playa and covering most of the remaining valley floor, a mixed association of shadscale (Atriplex confertifolia) and bunchgrasses predominates. This vegetative cover is sparse, generally covering less than 10 percent of the ground.

On the alluvial slopes adjacent to the valley floor, sagebrush (Artemisia sp.) is the dominant plant below an altitude of about 6,000 feet (1,830 m) above mean sea level. Above that altitude, juniper (Juniperus sp.) and pinyon (Pinus sp.) woodlands predominate on both alluvial and residual soils. Several types of deciduous shrubs grow in the uplands, especially on north-facing slopes.

Rabbitbrush (Chrysothamnus sp.) and greasewood (Sarcobatus vermiculatus) grow locally in and along stream channels in the alluvium and in places on the valley floor. These shrubs are limited primarily to areas of sandy soils that absorb precipitation and runoff readily and temporarily store it as soil moisture for subsequent plant use. Where moisture is perennially available, as in the vicinity of Wah Wah Springs (figs. 4 and 5) saltgrass (Distichlis spicata var. stricta), greasewood, rabbitbrush, and other phreatophytes are common. Cattail (Typha sp.), watercress (Rorippa nasturtium-aquaticum), and other hydrophytes grow locally in areas of spring discharge.

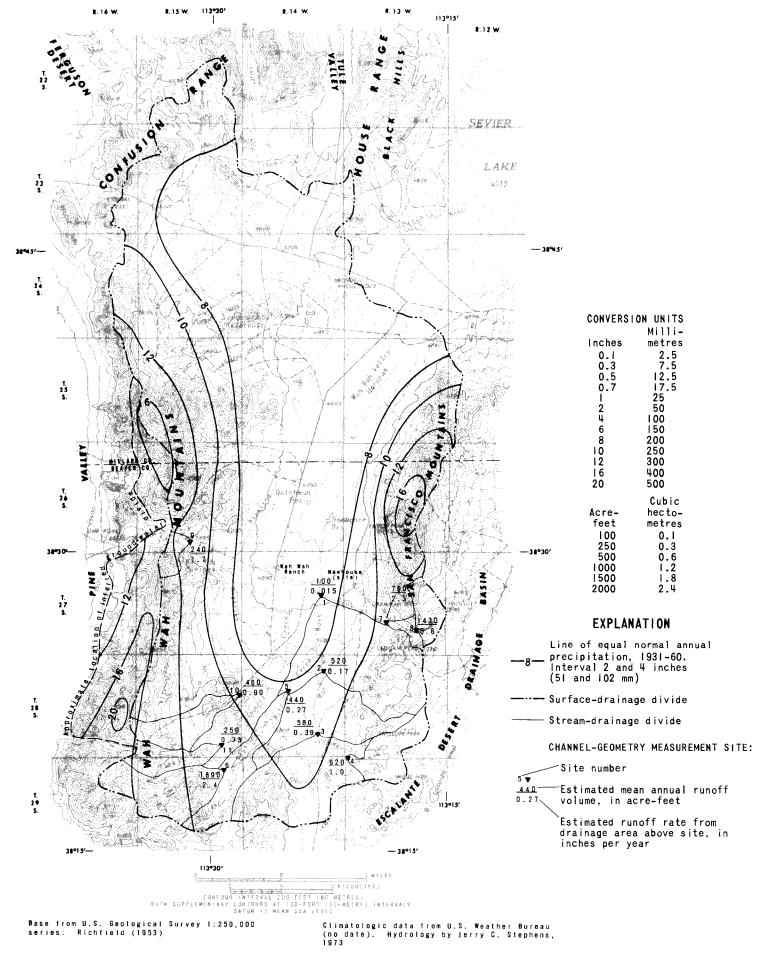


Figure 3.— Normal annual precipitation and location of sites for which runoff was estimated.

# Table 1.--Selected climatologic data for Wah Wah Ranch

(Based on U.S. National Oceanographic and Atmospheric Administration, U.S. Environmental Science Services Administration, and U.S. Weather Bureau publications listed in selected references)

Altitude: 4,960 feet above mean sea level. Period of record: September 1955-December 1972

Average monthly:	Temperature (°F)	Precipitation (in.)
o ,		
January	28.7	0.26
February	34.6	.40
March	40.5	<b>.</b> 52
April	47.8	.65
May	58.0	<b>.</b> 58
June	67.7	•48
July	76.2	.60
August	74.0	1.08
September	63.7	.61
October	51.8	.67
November	38.3	<b>.</b> 50
December	29.6	.34
Average annual	50.9	6.69 <sup>1</sup>
Maximum/minimum:		
Period of record	106/-27	<del>-</del>
Annual	_	10.11/3.55
Monthly	-	2.31/0.00

<sup>&</sup>lt;sup>1</sup>Sum of monthly averages. Average annual precipitation for 17 complete years of record (January 1956-December 1972) is 6.80 inches.

## Geology

Rocks ranging in age from Precambrian to Holocene crop out in the Wah Wah Valley drainage basin. On the basis of lithologic and hydrologic similarities, these rocks are grouped into generalized hydrogeologic units, each of which has a significant effect on the hydrologic system of the basin. Table 2 gives a generalized description of the lithology and water-bearing characteristics of these units, and plate 1 shows their distribution.

Wah Wah Valley is part of an eastward-tilted fault block that is bounded on the west by a fault along the western side of the Wah Wah Mountains and on the east by a series of faults along the western side of the San Francisco Mountains (pl. 1). In addition to the major structural features, minor folding and extensive faulting, fracturing, and brecciation have accompanied the emplacement of igneous intrusives, especially in the San Francisco Mountains (Butler, 1913, p. 70-74). The

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

Er Sys Ser	tem	Hydrogeologic unit and symbol on plate 1	Lithology, thickness, and extent	Mater-bearing characteristics	
		Stream-channel alluvium (Qay)	Mainly sand and gravel, but includes some clay and silt. Present as channel fill along larger streams at south end of valley. Maximum thickness probably less than 20 feet (6.1 m).	Generally moderately permosable. Most deposits are saturated to or within a few inches of land surface during and for short periods following runoff, but water levels may be several feet below land surface and thinner sections may be dry during much of the summer.	
Tertiary Tertiary and Quaternary Quaternary	Alluvium: (Qas)	Mainly sandy, gravelly clay. Occurs as thin veneer overlying and adjacent to lakehed clays near center of valley; thickens laterally and grades into coarser alluvium on gently sloping land along valley margin. Maximum thickness unknown.	Permeability generally low. Deposits generally above satu- rated zone.		
	(Qag)	Mainly sand, gravel, and boulders, but includes some intermixed and interbedded clay and silt. Forms steeply sloping alluvial apron at base of mountains; grades laterally into finer grained alluvium toward valley axis. Includes colluvial materials adjacent to bedrock outcrops. Maximum thickness unknown.	Slightly to highly permeable. Direct precipitation and run- off from higher altitudes infiltrates these deposits and moves downward and laterally into underlying aquifers. De- posits are generally above the saturated zone.		
	Lacustrine deposits: (Q1c)	Lakebed clay and silt, including surficial playa deposits on Wah Wah Valley hardpan. Probably underlie most of gently sloping alluvial deposits (Qas). Maximum known thickness about 230 feet (70 m) at wells (C-24-13)33daa-1 and 34ccb-1 (table 7); thin laterally from axis of valley and toward south end of valley.	Permeability generally low. Most precipitation and runoff reaching the Wah Wah Valley Hardpan remains ponded until it evaporates. At such time, the thin plays deposits may be saturated for short periods. Locally may confine water in underlying aquifer.		
			(Qlt)	Lacustrine beach ridges, bay-mouth bars, or near-shore bars, mainly sand but containing considerable amounts of fine gravel, silt, and clay. Present as broad, low ridges on valley floor, oriented approximately at right angles to axis of valley. Maximum thickness probably less than 20 feet (6.1 m).	Slightly to moderately permeable. Deposits absorb much of the precipitation falling on them and retain it as soil moisture, thus supporting a denser vegetative cover than adjacent areas. Deposits are generally unsaturated.
		Spring deposits (QTs)	Calcareous tufa deposited by precipitation from spring discharge; generally contain some clay and silt. Form prominent terraces at several levels downslope from Wah Wah Springs, and occur locally in and near other spring areas. Maximum thickness probably about 120 feet (37 m) at Wah Wah Springs; elsewhere deposits are small and only a few feet thick.	Slightly to highly permeable, depending on degree to which clay and silt have plugged primary openings. Contains abundant cavities and tabular openings resulting from resolution and from decomposition of vegetative material incorporated during deposition. Generally saturated to or within a few feet of land surface by discharging springflow upslope.	
	Terriary and Qua	Older alluvium (QTa)	Materials ranging in size from clay through boulders, intermixed and interbedded, unconsolidated to well cemented. Probably include some lacustrine deposits and colluvium, but consist primarily of alluvium. Well-cemented gravel beds crop out locally along valley margins, but exposures are too small to show at scale of map (pl. 1). Underlie younger deposits throughout most of area; grades upward into younger alluvium and lacustrine deposits along valley margins. Reportedly interbedded with extrusive igneous rocks at well (C-28-14)llabb-1. Maximum thickness unknown; probable thickness at well (C-24-13)33daa-1 is 1,252 fect (382 m) (table 7).	Slightly to highly permeable, depending on size and degree of sorting of materials and degree of cementation in individual strata. Well (C-24-13)34ccb-1 is reported to yield water from sand and gravel heds in this unit from 230 to 290 feet (70-88 m) below land surface. This unit forms the bulk of the valley fill, which is the major ground-water reservoir in Wah Wah Valley.	
	Extrusive igneous rocks (Te)	Primarily ignimbrites and lava flows ranging in composition from mafic to felsic. May include some tuffs, breccias, and other volcanic rocks. Crop out extensively in the southern part of the area and in isolated patches in the northern part. Maximum thickness unknown. Reportedly occur in subsurface, interbedded with older alluvium, at well (C-28-14)llabb-1 below 1,193 feet (364 m).	Primary permeability generally low except locally in some breccias and interflow zones. Where fractured and broken by faulting, secondary permeability may be high. A few springs, seeps, and abandoned mine workings discharge water from these rocks in the southern part of the area. Sufficial weathered zones, especially on the ignimbrite sheets at the southern end of the area, may readily absorb precipitation and runoff and transmit water downgradient to aquifers beneath the valley floor.		
		Intrusive igneous rocks (Ti)	Mainly porphyritic quartz monzonite. The outcrop in the San Fran- cisco Mountains is an eroded stock; the small outcrop in the cen- tral Wah Wah Mountains may be part of a similar, but less ex- posed, intrusive. Thickness and subsurface extent unknown.	Primary permeability low. Surficial weathered zones and fractured zones may be moderately to highly permeable. Sev- eral mine workings that penetrate these rocks yield small quantities of water.	
E ro		Sedimentary and meta- sedimentary carbonate rocks (Pzc)	Mainly limestone and dolomite, with some beds of shale, siltstone, and sandstone. Altered by contact metamorphism adjacent to intrusive rocks in San Francisco Mountains; some parts of the contact zone are highly mineralized and have been mined extensively. Form bulk of mountain ranges bordering valley. Locally overlain by extrusive igneous rocks on mountain flanks. Prohably underlie most of area at depth. Thickness and subsurface extent unknown.	Primary permeability generally low; secondary permeability moderate to high where solution openings are present, especially along bedding planes, fractures, and faults. Most ground-water recharge in the area is absorbed by these rocks where they crop out in the mountains and moves downgradient along bedding planes and fractures to discharge areas. Wah Wah Springs discharge an estimated 800 acrefect (0.987 hm²) annually from these rocks. The carbonate rocks probably serve as the principal conduit for groundwater movement in the basin.	
Cambrian	Lower Cambrian	Sedimentary and meta- sedimentary quartzitic rocks (Pzq)	Mainly quartzites, but include some phyllite and phyllitic shale. Generally resistant, cliff-forming strata exposed in the southern part of the area in the Wah Wah Mountains and near the eastern edge in the San Francisco Mountains. Thickness and subsurface extent unknown, but may underlie most of the area at depth.	Primary permeability low. Because of the dense, relatively impermeable nature of these rocks, most precipitation runs off. Several small ephemeral springs discharge from talus below quartzite outcrops; some springs may discharge directly from fractured quartzite.	
		Metasedimentary rocks undifferentiated (p €)	Mainly quartzite and argillite. Stosion-resistant, cliff-forming strata exposed at northern end of San Francisco Mountains. Thickness and subsurface extent unknown.	Generally similar to Pzq.	

(similar to the area upstream from site 11, table 3) for the approximately 116,000 acres (469 km²) of exposed Tertiary igneous and pre-Tertiary sedimentary and metamorphic rocks; and (2) 0.2 inch (5 mm) (similar to the area above site 2, table 3) for the approximately 30,000 acres (121 km²) underlain by Quaternary and Tertiary sedimentary rocks. Runoff from the uplands is thus estimated to average about 0.6 inch (15 mm) or 7,300 acre-feet (9.00 hm³) annually. Much of this runoff never reaches the valley floor because it is lost by evaporation and infiltration on the lower slopes. This loss is graphically illustrated by comparing the estimated mean annual discharge at sites 1-4 in figure 3. From site 4 to site 1, discharge decreases by about 85 percent whereas drainage area increases by more than 1,000 percent (table 3).

Table 3.--Estimated mean annual runoff from selected streams in southern Wah Wah Valley

			Drainage area	Runc	ff	Dominant hydro-
Site No.	Location (see fig. 3)	Altitude (feet)	above site (square miles)	Volume (acre-feet)	Rate (inches)	geologic units in drainage (see pl. 1)
Wah W	ah Wash south of	State Highway	<u>, 21</u>			
1	(C-27-14)14acd	4,930	121	100	0.015	Te,Qag
2	(C-28-14)2ddc	5,170	57.2	520	.17	Te,Qag
3	26caa	5,400	36.0	580	.30	Te,Qag
Grove	r Wash					
4	(C-28-13)31cdc	5,690	11.4	620	1.0	Te
Willo	w Creek					
5	(C-28-14)16aab	5,380	30.1	440	.27	Te,Qag
6	(C-29-15)2dad	6,140	14.8	1,890	2.4	Pzc,Te
Frisc	o Wash					
7	(C-27-13)28aba	5,540	6.4	790	2.3	Pzc, Te, Ti, Qag
8	26cab	5,950	4.8	1,430	5.6	Pzc,Te,Ti
Unname	ed tributaries					
9	(C-26-15)34bc	5,980	2.6	240	1.7	Pzc
10	(C-28-15)13aad	5,680	9.6	460	.90	Te
Quarta	z Creek					
11	(C-28-15)35aad	6,060	6.4	250	.73	Те

As shown in figure 3, most areas receiving less than 10 inches (254 mm) of precipitation annually are at altitudes below about 5,600 feet (1,700 m). Air temperatures and soil-moisture requirements in these areas are generally high, and surficial deposits are generally unconsolidated; as a consequence, runoff is slight. Total annual runoff from Wah Wah Valley below an altitude of 5,600 feet (1,700 m) is estimated to average less than 500 acre-feet (0.617 hm<sup>3</sup>) although one-half

of the total precipitation falls there. The corresponding annual rate of runoff would average about 0.02 inch (0.5 mm), which is comparable to the rate calculated for the total drainage area above site 1 (table 3).

Several small reservoirs have been constructed in Wah Wah Valley to intercept local runoff. These reservoirs store small quantities of water for livestock at times during the fall and spring, but during much of the summer they are dry. A reservoir at Wah Wah Ranch, which reportedly has a surface area of about 60 acres (24 hm²) and storage capacity of about 200 acre-feet (0.247 hm³), stores water diverted by pipeline from Wah Wah Springs. Both Dutchman and Newhouse Reservoirs (pl. 1) also store some water diverted from the springs.

There is no surface outflow from the Wah Wah Valley drainage basin; thus, the long-term average consumptive use of surface water by evaporation and transpiration must equal the difference between total precipitation and ground-water recharge within the basin (table 4). The estimated consumptive use of surface water (excluding springflow), therefore, averages more than 97 percent of the total precipitation.

# Ground water

Ground water is present in most of the rock units in the Wah Wah Valley drainage basin. At only a few locations are these rocks known to yield water to wells or springs, however, because the top of the saturated zone generally is well below the land surface.

Meinzer (1911, p. 119) concluded that "Conditions are not favorable for finding ground water in this [Wah Wah Valley] region. Beneath the broad slopes that flank the valley water is almost certainly at a great depth, and may be entirely absent. Even along the axis of the valley the gradient is in most places so steep and the altitude so much higher than that of Sevier Lake that it is not likely that water would be found near the surface."

Meinzer's assessment of the ground-water potential of Wah Wah Valley has been verified by exploratory drilling and attempted well developments since 1911. The well records (table 6) indicate the general lack of success of efforts to develop ground-water supplies from shallow wells in the valley.

Figure 3 and table 1 show, respectively, the areal variations in annual precipitation and the average monthly precipitation in Wah Wah Valley. Estimated average annual precipitation over the entire basin is about 9 inches (229 mm), or 290,000 acre-feet (358 hm $^3$ ). An estimated 7,000 acre-feet (8.63 hm $^3$ ), or about  $2\frac{1}{2}$  percent of the total precipitation, recharges the ground-water reservoir. Table 4 gives the derivation of these estimates, based on a method described by Eakin and others (1951, p. 79-81) and modified for use in western Utah by Hood and Waddell (1968, p. 22-23).

Table 4.--Estimated average annual volumes of precipitation and ground-water recharge

(Areas of precipitation zones measured from pl. 1 and fig. 3)

Precipitation zone (inches)	Area in zone (acres)	Estimated  annual precipitation  Feet Acre-feet		Estimated annual Percent of precipitation				
Area where	Area where Quaternary and Tertiary sedimentary rocks are exposed							
Less than 8 8-10 10-12 12-16 More than 16	134,800 55,200 27,800 2,200 100	0.54 .75 .92 1.17 1.38	72,800 41,400 25,600 2,600 140	0 0 3 6 20	0 0 770 160 30			
Subtotal  Area where			142,540 ocks, Paleozoio norphic rocks	c sedimentary roc	960 ks, and			
Less than 8 8-10 10-12 12-16 More than 16	19,300 27,700 71,900 36,900 6,900	0.54 .75 .92 1.17 1.38	10,400 20,800 66,100 43,200 9,500	0 0 0 3 6 20	0 0 1,980 2,590 1,900			
Total (rounded)	380,000		290,000		7,000			

In addition to recharge from precipitation in the drainage basin, the ground-water reservoir in Wah Wah Valley probably receives recharge by subsurface flow from the Pine Valley drainage basin, which is on the west side of the Wah Wah Mountains. The quartzite and carbonate rock strata underlying the central and southern Wah Wah Mountains, except near the intrusive rocks in T. 26 S., are inclined toward Wah Wah Valley, and recharge on the outcrops west of the surface-drainage divide presumably moves downdip toward the east under the divide. The inferred location of the ground-water divide in this area is shown on plate 1. The Wah Wah Valley ground-water basin thus encompasses about 28,000 acres (113 km<sup>2</sup>) of Pine Valley; estimated recharge from west of the surface divide is about 3,000 acre-feet (3.70 hm<sup>3</sup>) annually. Thus, the total ground-water recharge to Wah Wah Valley is estimated to average about 10,000 acre-feet (12.3 hm<sup>3</sup>) annually.

The following sections describe briefly the significant features of the hydrogeologic units that yield water in the drainage basin and assess the present and potential ground-water development in each.

## Quaternary and Tertiary sedimentary rocks

## Stream-channel alluvium

Thin deposits of alluvium in and along the channels of Quartz and Willow Creeks and Wah Wah and Grover Washes (Qay, pl. 1) contain ground water. These unconsolidated deposits probably are less than 20 feet (6 m) thick. They are at least partly saturated much of the time, however, because infiltration of runoff from upslope areas supplies intermittent recharge, and locally seepage from adjacent volcanic rocks may supply relatively constant recharge.

The flows of Quartz and Willow Creeks on June 21, 1973, were observed to disappear entirely into the stream-channel deposits within a short distance after leaving the volcanic rocks. Channel losses were calculated as follows:

### Discharge

Quartz Creek at (C-28-15)36bba Quartz Creek at (C-28-14)19ddb	0.71 ft <sup>3</sup> /s	$(0.020 \text{ m}^3/\text{s})$
Loss Approximate length of reach	.71 ft <sup>3</sup> /s 2.1 mi	$(0.020 \text{ m}^3/\text{s})$ (3.4  km)
Average loss	$.34 \text{ ft}^3/\text{s/mi}$	$(0.0059 \text{ m}^3/\text{s/km})$
Willow Creek at (C-28-14)21bbc Willow Creek at (C-28-14)16acc	1.26 ft <sup>3</sup> /s	$(0.036 \text{ m}^3/\text{s})$
Loss Approximate length of reach	1.26 ft <sup>3</sup> /s 1.0 mi	$(0.036 \text{ m}^3/\text{s})$ (1.6  km)
Average loss	$1.26 \text{ ft}^3/\text{s/mi}$	$(0.0225 \text{ m}^3/\text{s/km})$

At the time of these observations, the flow of both creeks consisted primarily of discharge from the Tertiary igneous rocks of water temporarily stored during the melting of the abnormally large snowpack of the preceding winter.

Much of the ground water moving downgradient through the stream-channel alluvium is consumed by evapotranspiration before it reaches the valley floor. Seveys Well, (C-28-13)28ddc-1, and Willow Spring, (C-29-15)2dad-S1, are the only known sources yielding ground water from stream-channel alluvium in the drainage basin; together they discharge an estimated 40 acre-feet (0.049 hm³) of water annually. (See tables 6 and 8.) Both of these sources are developed in areas of natural discharge. The structures installed at the two sites capture a part of the discharge that would otherwise be consumed by evapotranspiration and divert it elsewhere for livestock use. Evapotranspiration probably accounts for an additional 30-50 acre-feet (0.037-0.061 hm³) of ground water annually from the channel deposits. Ground water moving through

the stream-channel alluvium in excess of that discharged by springflow and evapotranspiration is discharged into the valley-fill deposits under the valley floor.

Because the channel deposits are thin and of small extent, and because at most locations there is no significant source of sustained recharge, the potential for development of dependable ground-water supplies from stream-channel alluvium is severely restricted. In some locations, additional small supplies for livestock probably could be obtained by installation of a perforated-pipe collector system similar to that at Willow Spring. The most promising locations for such development are on Quartz and Willow Creeks and in Grover Wash.

## Spring deposits

The calcareous tufa deposits (QTs, pl. 1) forming the conspicuous terraces at Wah Wah Springs (figs. 4 and 5) yield water to numerous small springs and seeps. As indicated in table 8, at least 8 of the 10 major outlets of Wah Wah Springs discharge from spring deposits. The spring deposits are recharged by inflow from the adjacent and underlying Paleozoic carbonate rocks. A more detailed discussion of this part of the ground-water system is given in the section on Wah Wah Springs.

Small outcrops of calcareous tufa are present near Antelope and Kiln Springs, (C-28-13)18abd-Sl and (C-28-15)10aad-Sl, respectively. At both of these locations, however, the exposed spring deposits cover only a few square feet and are of no consequence as potential sources of water. The springs actually discharge water that is moving through igneous rocks.

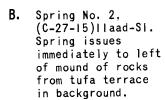
#### Older alluvium

The largest ground-water reservoir in the Wah Wah Valley drainage basin is in the valley fill. The bulk of the valley fill consists of older alluvium (QTa, table 2) that underlies the lacustrine sediments and surficial alluvium. Similar deposits in adjacent areas of western Utah yield large quantities of water to wells. See for example, Hood and Rush (1965), Sandberg (1966), and Mower and Cordova (1974).

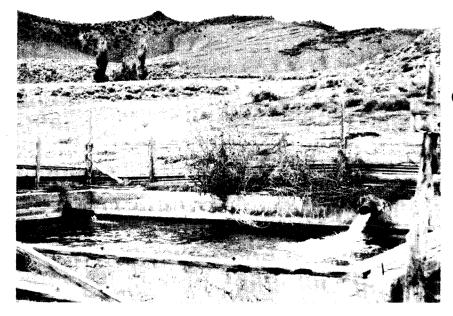
At present (1973) only one well, (C-24-13)34ccb-1, yields water from the older alluvium in Wah Wah Valley; but two other wells have penetrated water-bearing beds in this unit. An oil-test hole, (C-24-13) 33daa-1, drilled within half a mile (0.8 km) of the producing well, reportedly penetrated water-bearing strata in the valley fill at intervals from 233 to 1,140 feet (71-347 m) below land surface. A third well, (C-28-14)11abb-1, which was under construction at the end of 1973, reportedly penetrated water-bearing strata in the interval from 680 to 1,000 feet (207-305 m) below land surface. Drillers' logs of these three wells are given in table 7, together with logs of several unsuccessful wells drilled into the valley fill. Borehole geophysical logs of well (C-28-14)11abb-1 are shown in figure 6.



A. Spring No. 1,
(C-27-15)||aba-S1.
Spring issues from
limestone and gravel
in cattail-filled
excavation at lower
left.

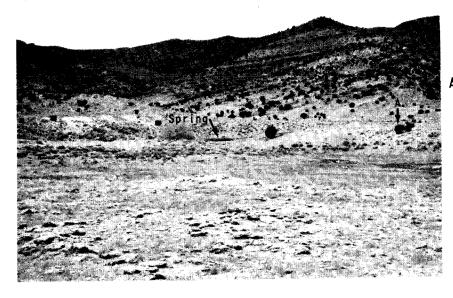




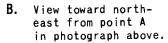


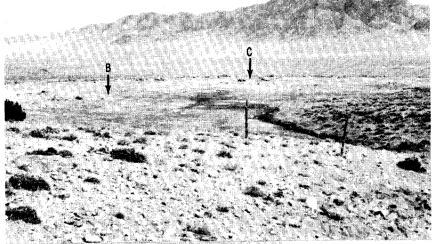
Reservoir at head of pipeline to Wah Wah Ranch. Inflow at right from Spring No. 1; inflow at left from Spring Nos. 2, 3, 5, and 6, located along base of tufa terrace to left of trees.

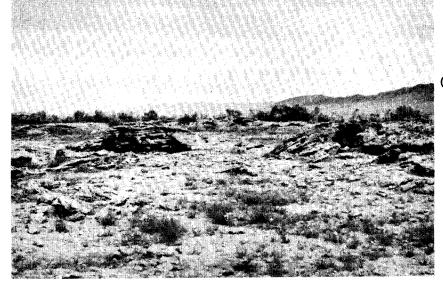
Figure 4. - Wah Wah Springs discharge area.



A. View toward southwest from point B in photograph below. Spring No. I issues in patch of cattails visible in center of photograph.







Close-up view of tufa deposits at point C in photo-graph above. Note low rim around outer edge of terrace.

Figure 5. — Tufa terrace at Wah Wah Spring No. I, (C-27-15) | laba-Sl.

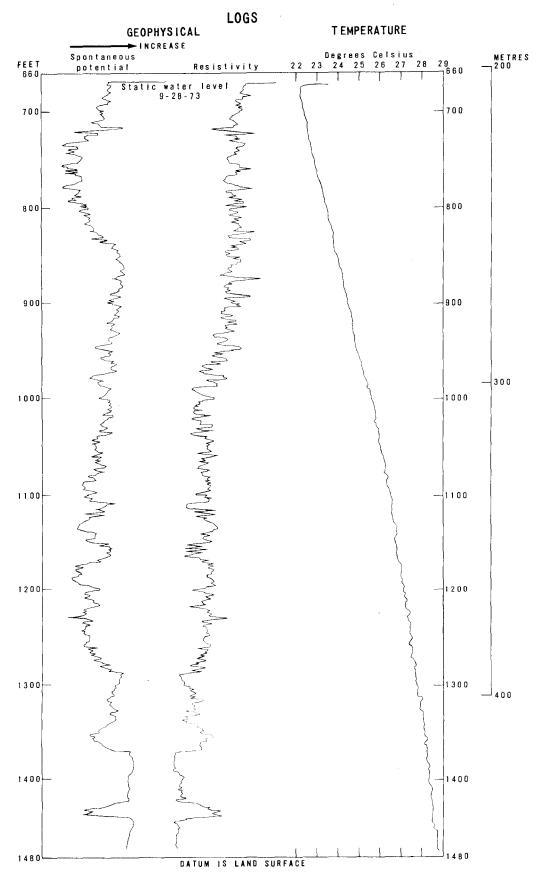


Figure 6.— Geophysical and temperature logs of well (C-28-14)|labb-1.

The older alluvium receives little direct recharge from precipitation on the drainage basin. Much of the precipitation falls on igneous and sedimentary rocks above altitudes of about 5,600 feet (1,700 m) where precipitation exceeds 10 inches (254 mm) annually. The water moves downgradient toward the floor of the valley, where it is discharged by evapotranspiration, springflow, or mine and prospect pit drainage, or eventually recharges the valley fill.

Schmoker (1972, p. 11-23), from his interpretation of gravity data for the area, estimated the maximum thickness of fill--Quaternary and Tertiary clastic material--in Wah Wah Valley to be about 3,600 feet (1,100 m). On the basis of the log of test hole (C-24-13)33daa-1, where the probable base of the valley fill is at a depth of 1,485 feet (453 m), and correlation with gravity analyses and well-log data in the Milford area (Mower and Cordova, 1974, p. 11), it is believed that the actual thickness of fill is only about two-thirds that estimated by Schmoker. (See pl. 1.) Thus, the maximum total thickness of Quaternary and Tertiary sedimentary rocks in Wah Wah Valley is estimated to be about 2,400 feet (730 m).

Because few wells drilled in the Wah Wah Valley drainage basin have found water, little is known concerning the conditions under which ground water occurs or the configuration of the potentiometric surface of water in the valley fill. The assumed potentiometric surface is shown in the geologic sections on plate 1; its position is based on water-level records at wells (C-24-13)34ccb-1 and (C-28-14)11abb-1 and an inferred relationship between land-surface and potentiometric-surface configurations. The sections are not intended to be precise references for ground-water exploration or well drilling. They are intended only as a general picture of the inferred subsurface relations in Wah Wah Valley.

Ground-water discharge from the valley fill is by subsurface outflow, except for an estimated 1 to 2 acre-feet  $(1,230-2,470~{\rm m}^3)$  pumped annually from well  $(C-24-13)34{\rm ccb}-1$ . The water-bearing beds are covered by unsaturated materials more than 200 feet  $(61~{\rm m})$  thick; thus, they do not lose water by direct evaporation or transpiration by phreatophytes. Total annual subsurface outflow, therefore, is approximately equal to total annual recharge.

Although details of the gradient and configuration of the potentiometric surface are not definable from observed data, it is inferred that ground water moves toward the axis of the valley from the bordering mountains and in a general northerly direction under the axis of the valley. Meinzer (1911, p. 119) assumed that Wah Wah Valley drained in the subsurface into the Sevier Lake basin, and the topographic and surficial geologic relations in the area tend to support this assumption. However, more recent data indicate that ground water may not move toward Sevier Lake from Wah Wah Valley. Well (C-24-13)34ccb-1 is near the lowest part of the valley. The surface altitude at the well is about 4,645 feet (1,416 m), and the measured depth to water in October 1972 was 212 feet (65 m) (table 6). Thus, the altitude of the water surface was about 4,433 feet (1,351 m). The altitude of the surface of Sevier Lake is 4,519 feet (1,377 m), nearly 90 feet (27 m) higher than the groundwater level at the nearest well in Wah Wah Valley.

These considerations, together with a reported water level at an altitude of about 4,365 feet (1,330 m) in a well in southernmost Tule (White) Valley to the north, suggest that ground water from Wah Wah Valley may discharge northward rather than northeastward to the Sevier Lake basin. Further investigations in the area north of the Wah Wah Valley drainage basin are required to define the subsurface drainage pattern more accurately.

The ground-water reservoir in the valley fill underlies an estimated 115,000 acres  $(465~{\rm km}^2)$  in Wah Wah Valley. The total volume of water stored in the reservoir undoubtedly is large, but the lack of data concerning aquifer characteristics precludes a reliable estimate of the quantity of water that might be recoverable from storage. Recovery of an appreciable quantity of water from storage by pumping from wells would entail the lowering of the potentiometric surface of the reservoir, resulting in increased pumping lifts.

#### Tertiary igneous rocks

# Extrusive rocks

Where they are unweathered and unfractured, the lavas and ignimbrites that make up the bulk of the extrusive igneous rocks (Te, pl. 1) in the Wah Wah Valley drainage basin are relatively impermeable. However, the ignimbrites exposed over large areas at the southern end of the basin are extensively weathered and locally fractured and broken by faulting. Secondary permeability may be relatively high in these weathered and fractured zones.

Recharge to the extrusive rocks is primarily from precipitation on areas of outcrop. Where a surficial weathered zone is present, as it generally is on the ignimbrites near the southern end of the area, precipitation is absorbed readily. Recharge from infiltrating precipitation is transmitted downgradient toward the valley floor through the permeable zones.

Some ground water moves through the weathered zone near the surface and is discharged by evapotranspiration before it reaches the valley floor. Near the base of the upland slopes, some ground water is discharged by flow from springs, mine workings, and prospect pits. As indicated in the section on ground water in stream-channel alluvium, discharge from the extrusive igneous rocks may be a relatively constant source of recharge to the channel deposits along several of the creeks in the southern part of the basin. All the ground water that reaches the level of the valley floor in the extrusive rocks discharges in the subsurface into the adjacent valley-fill deposits.

Antelope and Kiln Springs, (C-28-13)18abd-S1 and (C-28-15)10aad-S1, respectively, each discharge an estimated 5 gal/min  $(0.32\ 1/s)$  of water from extrusive rocks. (See table 8.) The flow from Squaw "Spring," (C-27-13)26caa, which apparently is not natural springflow but

drainage from an abandoned mine adit or prospect, apparently discharges from extrusive rocks, as does water piped from a prospect pit at (C-28-15)11abd. Neither of these latter sources yields more than 2 gal/min  $(0.13\ 1/s)$  of water. (See table 6.) Butler  $(1913,\ p.\ 20)$  listed several other small springs that issued from extrusive rocks in the San Francisco mining district and formerly supplied water for mining and milling operations and livestock. Total discharge by springs, mines, and prospects from the extrusive rocks is estimated to average about 24 acre-feet  $(0.030\ hm^3)$  per year.

Additional small ground-water supplies probably could be obtained from the extrusive rocks, particularly from the weathered ignimbrites in the southern part of Wah Wah Valley. The most promising locations for development would be in areas where the surficial weathered zone is relatively thick and where the rocks are fractured or include brecciated zones.

## Intrusive rocks

The quartz monzonite porphyry intrusive in the central San Francisco Mountains northwest of Frisco (pl. 1) is the only intrusive rock unit in Wah Wah Valley that is known to yield ground water. The water is stored in and transmitted through fractures and fault zones. Recharge is by infiltration of precipitation on the outcrop, and discharge is by drainage from mines and subsurface outflow to the adjacent valley-fill deposits. Total discharge by mine drainage (table 6) probably averages no more than about 24 acre-feet (0.030 hm³) per year.

The movement of water through fractures results in dissimilar yields from different parts of the intrusive rock mass. According to Butler (1913, p. 137), "In the Cactus Mine [(C-27-13)3d] there was but little water on the lowest (ninth) level in the summer of 1909, though this level has been idle for months and no pumping was being done. Later, however, considerable water was encountered on the seventh level." Butler indicated that the approximate upper limit of ground water in the Cactus Mine was at an altitude of about 5,440 feet (1,658 m). The Cactus Mine presently (1973) is drained, at least in part, by a pipeline installed in a 6,000-foot (1,830 m) tunnel. The altitude of the discharge point of the pipeline (see (C-27-13)9aba, table 6) is about 5,780 feet (1,762 m).

Additional water sources might be developed in the intrusive rocks, but only where water-bearing fractures are present. A well intersecting such a fracture or set of fractures might yield a large volume of water for a short time, but individual fractures might drain rapidly. A dependable water supply could be developed only where an extensive, interconnected fracture system is encountered, creating in effect a large storage reservoir. Most wells developed in these rocks probably would yield only a few gallons of water per minute with sustained pumping.

## Paleozoic and Precambrian rocks

#### Carbonate rocks

Limestones and dolomites of Paleozoic age (Pzc, pl. 1) crop out extensively in the Wah Wah Mountains and locally in the San Francisco Mountains and the northern half of Wah Wah Valley. Although the primary permeability of these strata is low, they have moderate to high secondary permeability as a result of solution, fracturing, and faulting.

Recharge to the Paleozoic carbonate rocks is from precipitation on the drainage basin and subsurface inflow from Pine Valley. The Paleozoic rocks in the Wah Wah Mountains dip eastward or northeastward at angles of 5°-15°. Locally, especially along major faults, the attitude of the strata reflects movement along the fault; the beds may be vertical or inclined in any direction. Although detailed subsurface information is lacking, field observations of geologic structure and hydrologic relationships near Wah Wah Springs suggest that movement of ground water through the carbonate rocks is primarily in solution channels along and parallel to bedding planes. Thus, as a consequence of the general eastward to northeastward dip of the rocks, ground water moves generally eastward or northeastward from recharge areas in the Wah Wah Mountains toward the axis of Wah Wah Valley.

Wah Wah Springs discharge an estimated 800 acre-feet (0.987 hm $^3$ ) of ground water annually from Paleozoic carbonate rocks; an additional estimated 600 acre-feet (0.740 hm $^3$ ) is discharged by evapotranspiration in the spring area. (See following section on Wah Wah Springs for a detailed discussion of this part of the ground-water system.) The rest of the ground water moving through these strata is discharged in the subsurface to the valley fill or leaves the basin as subsurface outflow.

Additional water sources probably could be developed in the Paleozoic carbonate rocks, particularly in the area southwest of Wah Wah Springs. Wells penetrating these rocks could be expected to intercept ground water moving downgradient along solution channels; and if an extensive network of interconnected openings is found, wells yielding several hundreds of gallons of water per minute might be developed.

Because ground water in the carbonate rocks moves in fractures, solution channels, and other secondary openings, it is not possible to predict the success of a well drilled at any particular location. Based on surficial evidence alone, it is probable that the secondary openings are extensively developed in many of the rock strata at depth. Thus the probability of finding subsurface conditions favorable for the sustained withdrawal of ground water from the carbonate rocks is thought to be relatively high.

Wah Wah Springs. -- The following descriptions were written more than 60 years ago:

"Wah Wah Valley is entirely destitute of an irrigation supply and contains very few watering places for man or beast. Wah Wah Spring—the only spring of consequence in the region—is situated in Beaver County, on the west side of the valley, and its water is led by gravity through a pipe line to Newhouse, a mining town on the east side." (Meinzer, 1911, p. 119.)

"Water is scarce in the region, and much of it is of inferior quality. \* \* \* the supply for Newhouse and the Cactus Mill is obtained from the Wa Wa [Wah Wah] Springs on the opposite side of the Preuss [Wah Wah] Valley. This group of springs has a flow of about 1,200 gallons a minute and is the largest water supply in the region. The flow from sixteen springs is gathered into a collecting reservoir, from which it is conveyed through a pipe 44,000 feet long to a reservoir situated above the mill and town of Newhouse." (Butler, 1913, p. 20.)

The water situation in Wah Wah Valley has changed little in the years since the above descriptions were written. Although Newhouse and the Cactus Mill no longer exist, and much of the springflow is now diverted to Wah Wah Ranch, Wah Wah Springs (figs. 4 and 5) are still the only major water source in the drainage basin. Records of 10 of the springs are given in table 8. Additional springs and seeps that were diverted in the past have become dry or, in some cases, the collection pipes have deteriorated and have been abandoned.

Ground water discharged by Wah Wah Springs originates as precipitation on the Wah Wah Mountains. Recharge is absorbed by the exposed consolidated rocks and is transmitted downward and laterally toward the axis of Wah Wah Valley in accordance with the general inclination of the rock strata.

Although detailed information on the geologic structure in the vicinity of Wah Wah Springs is unavailable, field reconnaissance and examination of aerial photographs indicate that the location of the springs may be determined by geologic structure. The springs appear to issue on the northeast-trending axis of a flexure in the Paleozoic carbonate rocks.

Plate 1 includes a generalized map of the gross geologic structure of a part of the Wah Wah Mountains, based primarily on geologic relationships depicted by Stokes (1964) and supplemented by a few widely spaced field measurements near Wah Wah Springs. Near the west end of the spring-discharge area, the limestone beds strike about N.  $40^{\circ}$  W. and dip toward the northeast. At the east end of the spring area, the beds strike about N.  $10^{\circ}$  W. and dip eastward. The change in attitude of the beds between these two points is believed to reflect folding of the rocks along an axis that extends through the spring area and plunges toward the northeast.

Fracturing of the hard, brittle limestone along the crest of the fold is believed to have created a linear zone of relatively high permeability. The springs issue where the potentiometric surface of water in this zone intersects the land surface.

The inferred recharge area of water discharged by Wah Wah Springs is outlined on plate 1. The volume of recharge available from this area was estimated as follows, using the method described for the estimates in table 4:

Precipitation zone (inches)	Area in zone (acres)	=	timated cecipitation Acre-feet	Estimated annual Percent of precipitation	al recharge Acre-feet
Less than 10	500	0.80	400	0	0
10 <b>-</b> 12	1,700	.92	1,560	3	50
(Wah Wah	<b>-</b> ,		•		
Valley) 10 <b>-</b> 12	1,700	.96	1,630	3	50
(Pine Valley)	1,700	• 50	1,030	3	30
12-16	10,600	1.17	12,400	6	740
More than 16	2,100	1.38	2,900	20	580
Total					
(rounded)	17,000		19,000		1,400

The combination of structure and topography that gives rise to Wah Wah Springs has not been observed elsewhere in the drainage basin. The springs appear to be unique in manner of origin, as well as in being "the only spring of consequence in the region."

The largest of the Wah Wah Springs, (C-27-15)1laba-S1 (table 8), discharges an estimated 450 gal/min (28 l/s) of water directly from limestone strata or from a thin veneer of coarse alluvial gravel immediately overlying the limestone. Most of the other springs apparently issue from tufa deposits adjacent to and downslope from the limestone outcrop. Figure 4 shows the relationship between the tufa terraces and the points of issue of several of the small springs. Figure 5 shows the relationship between spring (C-27-15)1laba-S1 and the tufa deposits that form a conspicuous terrace below its point of issue.

Discharge from the uppermost springs, together with the direct subsurface discharge from the limestone, keeps the tufa deposits perennially saturated nearly to the land surface. Ground water drains by gravity from the tufa and issues as springflow and seepage near the base of the terrace, where part of the water again infiltrates and recharges the next lower terrace. Figure 7 shows the inferred paths of groundwater movement through the terraces.

Total estimated discharge of Wah Wah Springs is about 500 gal/min (32 1/s), or 800 acre-feet (0.987 hm³) annually. (See table 8.) About 380 gal/min (24 1/s) or 600 acre-feet (0.740 hm³) is diverted by pipelines to other parts of the valley. The remaining 200 acre-feet (0.247 hm³) is consumed by evapotranspiration near the point of discharge.

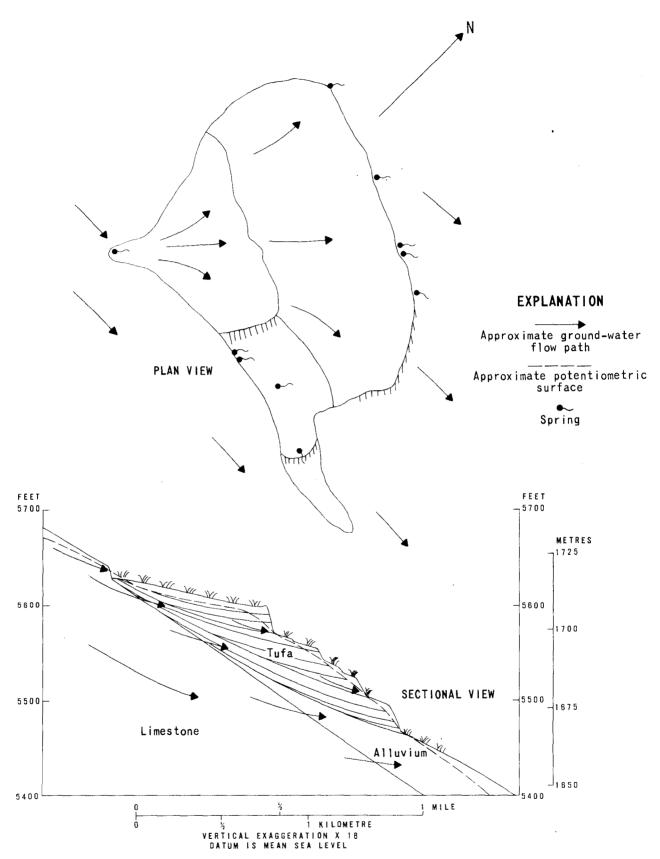


Figure 7.— Diagrammatic sketches showing inferred paths of ground-water movement in the Wah Wah Springs discharge area.

Spring deposits and associated alluvial soils covering an estimated 400 acres (162 hm²) in the immediate vicinity of the springs support a relatively dense growth of grass and in places, rabbitbrush and greasewood (see figs. 2, 4, and 5). The water required to sustain this vegetation comes from precipitation, from undiverted springflow, and directly from the saturated zone.

Annual consumptive use of water by vegetation in the discharge area is assumed to average about 2 feet per acre (1.5 m/hm $^2$ ). Total consumptive use is therefore about 800 acre-feet (0.987 hm $^3$ ). During the growing season (April-September), precipitation and undiverted springflow together may provide as much as 200 acre-feet (0.247 hm $^3$ ) of water to the vegetation. The remaining 600 acre-feet (0.740 hm $^3$ ) is obtained directly from the saturated zone.

Total annual ground-water discharge in the immediate vicinity of Wah Wah Springs thus is estimated to average about 1,400 acre-feet (1.73  $\,\mathrm{hm}^3)$ --800 acre-feet (0.987  $\,\mathrm{hm}^3)$  by springflow and 600 acre-feet (0.740  $\,\mathrm{hm}^3)$  by evapotranspiration. This estimated volume of discharge is equal to the estimated average annual recharge available to the spring area (see p. 23).

## Quartzite and metasedimentary rocks

Quartzite and slightly to highly metamorphosed shale and siltstone beds underlie much of the Wah Wah Valley drainage basin. The major exposed rocks of this group (Pzq and p $\in$ , pl. 1) are the quartzites that form prominent cliffs at the extreme southwestern corner of the area in the Wah Wah Mountains and in the San Francisco Mountains north of Frisco Peak.

These quartzites and associated rocks are relatively impermeable overall. The exposed rocks exhibit local zones of moderate to high secondary permeability that have resulted from fractures and faults, however, and such open fissures may occur also in the subsurface. The rocks crop out over about 12,000 acres  $(49~{\rm km}^2)$  of the drainage basin, mostly above an altitude of about 7,000 feet  $(2,130~{\rm m})$  where annual precipitation averages 12 inches  $(305~{\rm mm})$  to slightly more than 16 inches  $(406~{\rm mm})$ . Most of the precipitation on the outcrops runs off because of the dense surface and the precipitous slopes, especially in the San Francisco Mountains. Where the exposed rocks are fractured, some recharge occurs.

The only known water sources in the drainage basin that yield water from quartzite or associated rocks are Pitchfork and Crystal Springs, (C-25-13)36cba-S1 and (C-26-13)22acc-S1, respectively (table 8). Crystal Spring, which was dry when visited in October 1972, issues near the base of a large talus cone of quartzite blocks below a massive quartzite cliff. Several similar dry spring or seep areas were observed at the base of quartzite talus slopes at the southern end of the Wah Wah Mountains. It is probable that the talus directly absorbs much of the runoff from the steep slopes and also receives ground-water discharge

from the fractured quartzite. The water is released over a period of a few weeks or months to springs and seeps at the foot of the talus slope. Thus, most, if not all, of the springs discharging from quartzite talus are small and ephemeral. Some springs may discharge directly from fractured quartzite, although none were observed in the field.

Total discharge of all springs issuing from quartzites and associated rocks, or from talus at the base of outcrops of these rocks, is estimated to average no more than 10 acre-feet (0.012 hm³) annually. Some water is discharged by evapotranspiration near the base of the talus slopes, and the remaining ground water moving through these rocks is discharged in the subsurface to adjacent aquifers. Total natural discharge is equal to total recharge.

The potential for development of perennial water supplies from these rocks probably is slight. Some natural discharge areas might be developed to salvage water now being lost by evapotranspiration, but areas susceptible to such development are isolated and in extremely rough terrain, and yields would be small and ephemeral.

Summary of ground-water recharge and discharge

Recharge to the ground-water system in the Wah Wah Valley drainage basin is estimated to average about 10,000 acre-feet  $(12.3 \text{ hm}^3)$  annually (table 5). Estimates and measurements of discharge from the ground-water reservoir in the basin total about 1,500 acre-feet  $(1.85 \text{ hm}^3)$  annually. Because recharge and discharge must be equal over a long period of time, the difference between the two totals must represent subsurface outflow, which it was not possible to measure or estimate directly with any assurance of accuracy.

As pointed out by Snyder (1963, p. 499), the area between the Confusion Range and the Wah Wah Mountains (Tps. 23-24 S., Rs. 14-15 W.) appears to be underlain by a pediment with only a veneer of alluvial material covering the bedrock. The logs of wells (C-23-14)27bcb-1 and (C-24-14)7cac-1 (table 7), however, indicate that there may be 450 feet (137 m) or more of valley fill at those locations. No other well records are available for this part of the drainage basin. The paucity of data on both subsurface lithology and water levels precludes a reliable estimate of volume or direction of ground-water flow.

Until additional data are available to define better the ground-water conditions in adjacent areas, especially to the north and north-west, no better definition of the ground-water budget for the Wah Wah Valley drainage basin is possible. Although it was not possible to prepare a balanced budget by direct measurement or estimate, the quantities given in table 5 are believed to indicate the correct order of magnitude of the various budget items.

Table 5.--Ground-water recharge and discharge in the
Wah Wah Valley drainage basin

	Estimated quantity (acre-feet/year)
Recharge: From precipitation in drainage basin (table 4)	7,000
Subsurface inflow from Pine Valley (p. 12)	3,000
Total	10,000
Discharge:	
Evapotranspiration from:	40
Stream-channel alluvium (p. 13) Wah Wah Springs discharge area (p. 25)	600
Flow and pumpage from wells and springs from:	
Stream-channel alluvium (p. 13)	50
Older alluvium (p. 18)	2
Extrusive rocks (p. 20)	24
Intrusive rocks (p. 20)	24
Quartzite and metasedimentary rocks (p. 26)	
Wah Wah Springs (carbonate rocks and spring deposits) (p. 23)	<u>800</u>
Total (rounded)	1,500

<sup>1</sup>Quantities are estimated total discharge. Includes an estimated 300 acre-feet used for irrigation, stock watering, and wildlife; the rest ultimately is consumed by evapotranspiration not included above.

### Chemical quality and temperature of the water

Exclusive of springflow, the only information available for the chemical quality of surface water in the Wah Wah Valley drainage basin consists of five field measurements of specific conductance. The specific conductance of water impounded in Lawson Cove Reservoir on October 13, 1972, was 270 micromhos per centimetre at 25°C, from which the concentration of dissolved solids was estimated to be about 160 mg/l (milligrams per litre). The water temperature was 10°C (50°F). Water impounded in the reservoir at the time of measurement was runoff from rainfall during the previous week. The specific conductance and concentration of dissolved solids could be expected to increase rapidly with prolonged storage and concomitant evaporation, especially during the summer months.

Specific conductance and temperature measurements of streamflow in Quartz and Willow Creeks were made on June 21, 1973, as follows:

	Discha (ft³/s)	rge (m³/s)	Specific conductance (micromhos/cm at 25°C)	Estimated dissolved solids (mg/1)	Water temperature (°C)
Quartz Creek at	0.20	0.000	2 000	1 200	23
(C-28-15)35acd	0.29	0.008	2,000	1,200	23
Willow Creek at		0.5.0	770	1.60	17
(C-29-15)2dad	2.05	•058	770	460	17
Willow Creek at					
(C-28-14)21bbc	1.26	•036	1,000	600	27
Willow Creek at					
(C-28-14)16acc	(1)		1,000	600	29

<sup>1</sup>Sample collected near point where streamflow was completely depleted by streambed infiltration and evaporation.

Tables 9 and 10 give the results of chemical analyses of ground-water samples from the Wah Wah Valley drainage basin. Plate 1 shows the locations of sampling sites, the general ranges of concentrations of dissolved solids inferred for ground water in parts of the area, and the chemical characteristics of selected water samples.

Concentrations of dissolved solids in 20 samples of ground water from the drainage basin ranged from 99 to 4,550 mg/l (table 9). Nearly all the sources sampled yielded very hard water. As shown on plate 1, water from consolidated rocks generally contained calcium as the predominant cation, whereas in water samples from the valley fill, sodium predominated. Predominant anions in most samples were bicarbonate or chloride, although sulfate was predominant in a sample from the Cactus Mine tunnel, (C-27-13)9aba. Most water sources in the basin yield fresh water (less than 1,000 mg/l of dissolved solids). In general, the highest concentrations of dissolved solids were found in water from igneous rocks, and the lowest concentrations were found in water from quartzite and carbonate rocks.

All the sources sampled apparently yield water of satisfactory chemical quality for livestock use. Several samples contained concentrations of dissolved solids or individual constituents that might make the water undesirable for domestic use. Table 9 lists the U.S. Public Health Service (1962, p. 6-8) standards recommended for drinking water supplies for comparison with analyses of samples from the Wah Wah Valley drainage basin.

Water from Wah Wah Springs, the only source regularly used for domestic supply, meets the recommended standards for all constituents listed in table 9. According to the classification system developed by

the U.S. Salinity Laboratory Staff (1954, p. 79-81), water from these springs has medium salinity hazard and low sodium hazard for irrigation use.

Ground-water temperatures in the drainage basin range from  $11.5^{\circ}$  to  $24.5^{\circ}$ C ( $53^{\circ}$ - $76^{\circ}$ F) (tables 6 and 8). This range is from  $1^{\circ}$  to  $14^{\circ}$ C ( $2^{\circ}$ - $25^{\circ}$ F) higher than the mean annual air temperature of  $10.5^{\circ}$ C ( $50.9^{\circ}$ F) observed at Wah Wah Ranch (table 1). The highest water temperature observed was at well (C-28-14)llabb-1. As shown by the temperature log in figure 6, the geothermal gradient at well (C-28-14)llabb-1 averages about  $0.8^{\circ}$ C ( $1.4^{\circ}$ F) per 100 feet (31 m) below a depth of 680 feet (207 m). Assuming that the mean annual surface temperature at the well is equal to that at Wah Wah Ranch (table 1), the average gradient for the total depth of 1,472 feet (449 m) is about  $1.2^{\circ}$ C ( $2.2^{\circ}$ F) per 100 feet (31 m). The water temperature of  $24.5^{\circ}$ C ( $76^{\circ}$ F) measured during test pumping of the well is indicative of the depth of the water-yielding strata-680 to 1,000 feet (207-305 m) below land surface (table 6).

Wah Wah Springs can be classed as "thermal" or "warm" because the water temperature averages about 8.5°C (15°F) higher than the mean annual air temperature. (See Mundorff, 1970, p. 7.) Assuming a geothermal gradient equal to that at well (C-28-14)11abb-1, the water temperature of the springs could be accounted for by circulation of atmospheric water to a depth of about 700 feet (213 m) below land surface. The vertical distance between the recharge area in the Wah Wah Mountains-mostly above 6,000 feet (1,830 m) (pl. 1)--and the highest discharge point of the springs--5,640 feet (1,720 m) (table 8)--would provide the necessary depth of circulation. Tertiary igneous rocks are exposed nearby and may underlie the spring area at depth, but the observed water temperatures at Wah Wah Springs indicate that these rocks probably have little effect on the local geothermal gradient.

## SUMMARY AND NEEDS FOR FUTURE STUDY

Surface-water supplies in the Wah Wah Valley drainage basin are negligible. Annual overland runoff averages about 7,800 acre-feet (9.62 hm³), and all streams in the area are ephemeral or intermittent. Small surface reservoirs intermittently provide some water for livestock, but except for those receiving diversions from springs, none of the reservoirs provide dependable storage. Evaporation and transpiration within the basin annually consume more than 97 percent of the total precipitation.

Total annual recharge to the ground-water system in the basin is estimated to average about 10,000 acre-feet (12.3  $\,\mathrm{hm}^3$ ) annually-7,000 acre-feet (8.63  $\,\mathrm{hm}^3$ ) from precipitation in the basin and 3,000 acre-feet (3.70  $\,\mathrm{hm}^3$ ) from subsurface flow from Pine Valley under the topographic divide in the Wah Wah Mountains.

Records are available for eight springs that discharge 25 gal/min (1.6 l/s) or less of water from stream-channel alluvium, igneous rocks, and quartzite strata. The extrusive rocks in the southern part of the

valley and the intrusive igneous rocks in the San Francisco Mountains yield small quantities of ground water from fractures and faults by drainage from several mines and prospect pits. The valley-fill deposits underlying about 115,000 acres (465  $\,{\rm km^2})$  of the floor of Wah Wah Valley appear to have some potential as a ground-water source; but only one successful well, which discharges 1 to 2 acre-feet (1,230-2,470  $\,{\rm m^3})$  annually, has been completed in these deposits to date (1973).

The most productive aquifer in the basin is the carbonate rocks of Paleozoic age that crop out in the Wah Wah Mountains and probably extend under most of the drainage basin in the subsurface. The only known ground-water discharge from these rocks is by flow from Wah Wah Springs, the discharge of which originates as precipitation on the Wah Wah Mountains. The estimated total annual discharge of the springs is about 800 acre-feet (0.987 hm³), of which an estimated 600 acre-feet (0.740 hm³) is diverted for irrigation, livestock, and domestic use at Wah Wah Ranch and livestock and wildlife use elsewhere in the valley. About 200 acre-feet (0.247 hm³) of springflow is consumed annually in the discharge area by evapotranspiration, and an additional 600 acre-feet (0.740 hm ) is discharged directly from the saturated zone by this same mechanism.

Ground water originating in the Wah Wah Valley drainage basin that is not discharged locally—an estimated 8,500 acre-feet (10.5 hm $^3$ ) annually—probably moves northward out of the basin as subsurface outflow.

Few data are available from which to estimate the volume of ground water in storage. The total amount of water in storage in the valley fill undoubtedly is large, but the amount that is potentially recoverable from storage cannot be reliably estimated from available data. The volume of water in transient storage in the carbonate rocks of the Wah Wah Mountains probably is large, but storage in the other known water-yielding rocks is minor.

Most known ground-water sources in the Wah Wah Valley drainage basin yield fresh, very hard water. The quartzite and carbonate rocks and the valley fill in the southern part of the basin yield water containing less than 1,000 mg/l of dissolved solids. The igneous rocks and the valley fill in the northern part of the basin generally yield water containing 1,000-5,000 mg/l of dissolved solids. Nothing is known about water quality in the northwestern part of the basin or in possible aquifers below the valley fill.

The valley fill and carbonate rocks are believed to have some potential for additional ground-water development. To verify and further evaluate the estimates and conclusions made in this reconnaissance, the following kinds of information are needed:

1. Exploratory drilling in the valley fill to depths of 800-2,000 feet (244-610 m), especially in the area south of the Wah Wah Valley Hardpan. Most prior attempts to obtain ground water from the valley fill have been unsuccessful, but the conclusions from the reconnaissance indicate

that the valley fill probably is saturated at greater depths than have generally been drilled.

- 2. Exploratory drilling in the carbonate rocks that underlie the valley fill and that are exposed on the eastern flank of the Wah Wah Mountains southwest of Wah Wah Springs to evaluate ground-water conditions.
- 3. Detailed mapping of geologic structure on the eastern flank of the Wah Wah Mountains southwest of Wah Wah Springs.
- 4. Geophysical surveys or exploratory drilling in the areas of extrusive rocks in the southern part of the basin to location and evaluate areas potentially favorable for ground-water development.
- 5. Detailed investigation of water-quality variations, laterally and with depth, in conjunction with test drilling. The carbonate rocks below the valley fill might be expected to contain water comparable in quality to that discharging from Wah Wah Springs, and the valley fill throughout the southern part of the area should contain water comparable in quality to that discharged by well (C-28-14)llabb-1.

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 $<sup>^{1}\</sup>mathrm{See}$  references to U.S. Weather Bureau for data published prior to 1967.

<sup>&</sup>lt;sup>2</sup>See references to U.S. Environmental Science Services Administration and U.S. National Oceanic and Atmospheric Administration for data published after 1966.

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APPENDIX

# Numbering system for hydrologic-data sites

The system of numbering hydrologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the 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 acres (4 hm<sup>2</sup>); 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. If a well or spring cannot be located within a 10-acre (4 hm<sup>2</sup>) tract, one or two location letters are used and the serial number is omitted. Thus, (C-24-13)34ccb-1 designates the first well constructed or visited in the NW4SW4SW4 sec. 34, T. 24 S., R. 13 W. Other sites where hydrologic data were collected are numbered in the same manner, but no serial number is used. The numbering system is illustrated in figure 8.

## Use of metric units

Most numbers are given in this report in English units followed by metric units in parentheses. The conversion factors used are:

Engl:			Metri	<del>`</del> _
Units	Abbreviation		<u>Units</u>	Abbreviation
(Multiply)		(by)	(To obtain)	
<b>A</b>		0.404=	_	. 2
Acres	acres	0.4047	Square hectometres	$hm_2^2$
		•004047	Square kilometres	km <sup>2</sup>
Ac <b>r</b> e-feet	acre-ft	.0012335	Cubic hectometres	hm <sup>3</sup>
		1233.	Cubic metres	m <sup>3</sup>
Cubic feet	ft	.02832	Cubic metres	m <sup>3</sup>
Feet	ft	.3048	Metres	m
Feet per			Metres per square	
acre	ft/acre	.7532	hectometre	m/hm <sup>2</sup>
Gallons	gal	3.785	Litres	1
Gallons per				
minute	gal/min	.06309	Litres per second	1/s
Inches	in.	25.4	Millimetres	mm
Miles	mi	1.609	Kilometres	km
Square miles	s mi²	2.59	Square kilometres	km <sup>2</sup> ·

 $^1$ Although the basic land unit, the section, is theoretically a 1-mile (1.6 km) square, many sections are irregular. Such sections are subdivided into 10-acre (4 hm²) 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.

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per litre (mg/1). For concentrations less than 7,000 mg/1, the numerical value is about the same as for concentrations in the English unit, parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per litre (meq/1). Meq/l is numerically equal to the English unit, equivalents per million.

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

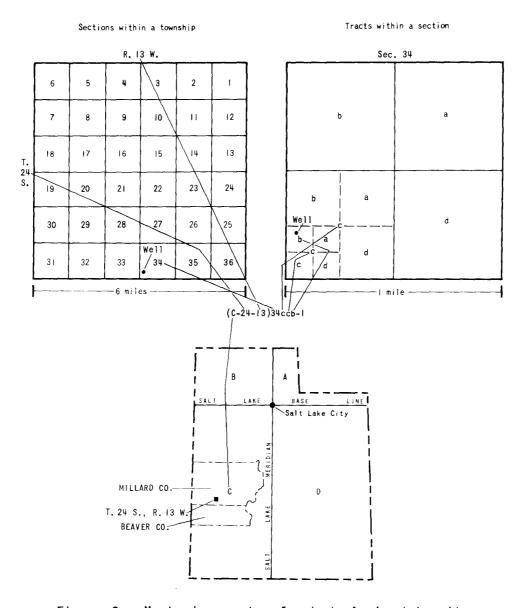


Figure 8. - Numbering system for hydrologic-data sites.

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BASIC DATA

### Table 6 .-- Records of selected wells and mine drains

Owner or user and local name: Local name or description in parentheses; BLM, U.S. Bureau of Land Management.
Geologic source of water: See table 2 for explanation of symbols and description of lithologic units; N, no water-yielding formation reported.
Altitude of land-surface datum: In feet above mean sea level, interpolated from U.S. Geological Survey topographic maps.
Water level below land-surface datum: D, reported dry by driller; R, reported; all others measured by U.S. Geological Survey personnel.
Method of lift: F, flowing; N, none; T, turbine pump.
Yield rate: M, measured by U.S. Geological Survey personnel; all others reported; -, less than.
Use of water: S, livestock.
Remarks and other data available: C, chemical analysis of water in table 9; L, driller's log in table 7; Z, plugged and abandoned or otherwise destroyed.

						Water				eld		Water	
Location	Owner or user and local name	Year con- structed	Depth of well (teet)	Geologic source of water	Altitude of land-surface datum	Below land- surface datum (feet)	Date of	Method of lift		Date of	Use of water		Remarks and other data available
(C-23-14)27hcb-1	BIM (Walter James Well)	1941	445	N	5,160	Đ	5-28-41	N	-	-	-		L, Z.
(C-24-13) 33daa-1	(Von Glahn No. 1 Federal)	1951	1,971	QTa	4,650	-	-	N	-	-	-		Oil test; L, Z.
34cch-1	BIM (Wah Wah Well)	1934	294	QTa	4,645	222R 220R 212.1	12-28-34(?) 1963(?) 10-13-72	Т	30	12-28-34	S	15.5	Cased to 236 ft with 8-in, and 6-in, casing, open hole(?) below 236 ft; C, L.
(C-24 [4)/cac-1	BLM (Grassy Cove Well)	1936	656	N	5,300	D	3-12-36	N	-	-	~	•	L, Z.
(C-27-13) 9aba	(Cactus Mine tunnel)	1905(?)	-	Ті	5,780	-	-	F	10 5 3M	1919 7- 7-36 10-12-72	S	15.0	Water is piped from mine tunnel to stor- age tank and trough near tunnel en- trance; C.
13dbd 14dcd	(Tintic Lead Co. Mine) (Van Horn Mine)	1879(!)	-	Τí	6,500 6,700	-	-	F F	30	1879(?)	ī	13.0	
26сан	(Squaw "Spring")		- -	Ti Te	5,975	-	-	F	.6 1 .25 1 <.1M 1.5M	9- 9-63 1913 1935 570 10-10-72 6-21-73	S S	12.0	C. Water piped from abandoned mine work- ings or prospect pit; C.
(C-27-14)27ahd-1	BLM (Hansen Brothers Well)	<u>1</u> /1951	500	N	5,020	D	9~ -51	N	-	-	-	-	Drilled to 282 it in 1948; deepened to 500 ft in 1951; L, Z.
	BIM (Seveys Well)	-	-	Qay	5,995	-	•	P	<u>2</u> /.35m	6-21-73	s	13.5	Shallow-excavation in stream-channel alluvium; runoff and ground water are collected in 8 ft x 8 ft open-end concrete box; discharge to pipeline outlet slightly helow land surface; gravity flow through pipeline to storage tank and troughs in Sh sec. 32, T. 28 S., R. 13 W.; C.
(C-28-14) (labb-1	(Earth Sciences, Inc.)	1/1973	1,472	QTa	5,190	672	9-28-73	<u>3</u> /T <u>3</u> /9	950	<u>3</u> /2-13-74	- :	<u>3</u> /24.5	Test well. Drilled to 660 ft in 1972; reported dry. Deepened to 1,472 ft in 1973; water-bearing stata reported 680-1,000 ft. Construction and development incomplete Dec. 1973 Geophysical and temperature logs in fig. 6; C, L.
(C-28-15) 2cdb	вім	1932(?)	12(?)	Te	5,660		-	F	<.1M	10-11-72	S	14.0	Specific conductance 1,500 micromhos/cm at 25°C; 5-ft diam- eter pool; water seeping from buried pipe discharging from abandoned pros- pect pit.
35a <b>a</b> d-1	(Baudino Ranch Well)	-	•	Qay	6,050	•	-	N	-	-	-	-	4-ft diameter rock- cribbed dug well in stream channel near abandoned ranch house; caved and partly filled.

<sup>1/</sup> See Remarks and other data available.
2/ Measured at tank in S5 sec. 32, T. 28 S., R. 13 W.
3/ Pump temporarily installed for pumping test. Average yield during 24-hour test on February 12-13, 1974, was about 950 gal/min; maximum pumping rate during test was about 1,350 gal/min. Temperature of water varied from 24.0°C to 24.5°C during test.

Table 7.--Drillers' logs of wells

Altitudes are for the land surface at well, in feet above mean sea level. Thickness, in feet.

Depth to bottom of unit, in feet below land surface.

	Thickness	Depth
(C-23-14)27bcb-1. Log by W. T. Chealey. Alt. 5,160 ft.		
Clay, sandy Boulders (lime) Sandstone, brown Boulders (lime) Gravel Sandstone, broken Boulders (hard lime)	3 109 18 126 4 35 150	3 112 130 256 260 295 445
$\frac{(C-24-13)33daa-1}{Alt. 4,650 ft}$ . Log by J. S. Lee and Sons.		
Clay, white Sand and gravel; water bearing. Clay, white Conglomerate. Clay, white; caving Conglomerate. Clay, red, and conglomerate Sand; water bearing Clay and conglomerate; caving Clay, sticky. Silt and sand	233 9 21 44 54 126 9 181 85 45	233 236 245 266 310 364 490 499 680 765 810
Silt; caving	18 104	828 932
Shale, blue, hard	32 20 81 60 15 35	964 984 1,065 1,125 1,140 1,175
Shale, hard	31 9	1,206 1,215
Shale and "shells"	30 80 160 260 25	1,245 1,325 1,485 1,745 1,770
Lime, hard	55 146	1,770 1,825 1,971

Table 7.--Drillers' logs of wells - continued

	Thickness	Depth
(C-24-13)34ccb-1. Log by H. L. Hall and H. M. Robinson. Alt. 4,645 ft.		
Clay, light-colored	35 65 41 9 80 4 36 20 4	35 100 141 150 230 234 270 290 294
(C-24-14)7cac-1. Log by B. M. Jones. Alt. 5,300 ft.		
Topsoil, clay, and gravel	84 132 264 136 40	84 216 480 616 656
(C-27-14)27abd-1. Log by J. S. Lee (0 to 282 ft) and B. B. Gardner. Alt. 5,020 ft.		
Soil	4 6 272 218	4 10 282 500
(C-28-14)11abb-1. Summary log by H. A. Perry, Earth Sciences, Inc., project geologist (written commun., 1974) from driller's reports by J. S. Lee and Sons Drilling Co. Alt. 5,190 ft.		
Unreported. Conglomerate. Sand and gravel	47 20 3 10 80 19 39 38 469	47 67 70 80 160 179 218 256 725 742

Table 7.--Drillers' logs of wells - continued

	Thickness	Depth
(C-28-14)11abb-1 continued		
Conglomerate, light gray; more tightly		
cemented	20	762
Conglomerate, gray	38	800
Conglomerate	40	840
Conglomerate and boulders	28	868
Conglomerate	52	920
Conglomerate; hard streaks as much as 3 feet		
thick	25	945
Conglomerate	15	960
Conglomerate, hard	4	964
Conglomerate	29	993
Conglomerate and sticky clay streaks	27	1,020
Conglomerate and clay streaks	20	1,040
Conglomerate and sticky clay streaks	20	1,060
Conglomerate and clay streaks	23	1,083
Conglomerate and sticky clay streaks (90 per-		
cent clay and gravel)	25	1,108
Clay and gravel	20	1,128
Clay, sand, and gravel, sticky	21	1,149
Clay and gravel	24	1,173
Clay, sticky, with little gravel	20	1,193
No data	279	1,472

### Table 8. -- Records of selected springs

Owner or user and local name: [ocal name or number in parentheses; BLM, U.S. Bureau of Land Management. Geologic source of water: See table 2 for explanation of symbols and description of lithologic units. Altitude at source: In feet above mean sea level, interpolated from U.S. Geological Survey topographic maps. Yield: E. estimated by U.S. Geological Survey personnel; seep, less than 0.1 gal/min. Use of water: H. domestic; E. irrigation; S. livestock; U. unused. Remarks and other data available: C. chemical analysis of water in table 9.

Location	Owner or user and local name	Geologic source of water	Altitude at source	Yield (gal/ min)	Date of measurement	Use of water	Water temperature (°C)	Remarks and other data available
(C-25-13) 36cba-81	State of Utah (Pitchfork Spring)	p€	6,260	-	-	S	-	
(C-26-13) 22acc-81	BLM (Crystal Spring)	Pzq	6,920	-	-	S	-	Dry when visited 10-12-72; C.
(C-27-13)4dbb-S1	(Cook Spring)	Ti(?)	5,780	317	1963	S	-	Dry when visited 10-12-72.
WAH WAH SPRINGS <sup>17</sup>								
(C-27-15) tece-\$1	Wah Wah Ranch (No. 7)	QTs	5,450	.50	10-12-72	S		
lecc-S2	Wah Wah Ranch (No. 8)	QTs	5,450	Seep	10-12-72	S	15.0	Specific conductance 590 micromhos/cm at 25°C.
2dac-81	Wah Wah Ranch (No. 10)	Pzc (?)	5,520	Dry	10-12-72	S	-	
2dda-S1	Wah Wah Ranch (No. 9)	OTs	5,460	Seep	10-12-72	S	12.0	Specific conductance 540 micromhos/cm at 25°C.
llaad-S1	Wah Wah Ranch (No. 2)	QTs	5,540	108	10-12-72	Н, 1, S	19.0	Piped to Wah Wah Ranch; C.
11aad-52	Wah Wah Ranch (No. 3)	QTs	5,540	5E	10-12-72	H,1,S	19.0	Do.
Haha-Sl	Wah Wah Ranch (No. 1)	Pzc	5,640	450E	10-12-72	н,г,ѕ	19.5	Do.
12bba-S1	Wah Wah Ranch (No. 6)	QTs	5,440	-	-	H, I, S	18.0	Do.
12bbc-S1	Wah Wah Ranch (No. 5)	QTs	5,470	10E	10-12-72	H,I,S	18.0	Do.
12bcd-S1	Wah Wah Ranch (No. 4)	QTs	5,450	20E	10-12-72	S	16.5	Piped to stock tanks on valley floor to southeast.2/
(C-28-13)18abd-S1	BLM (Antelope Spring)	Те	5,530	5E	8-31-63	S	14.5	Flow collected in excavation at base of hill, drained by natural channel toward valley floor; C.
(C-28-15)10abb-S1	BLM (Kiln Spring)	Ye	5,850	5E	10-11-72	S	14.0	Flow channeled to shallow pond about one-tenth of an acre in
25eee-81	~	Te	6,040	100	6-21-73	U	11.5	extent; C.
(U-29-15)2dad-S1	State of Otah (Willow Spring)	Qay	6,150	25E	6-21-73	S	13.0	Part of flow piped to stock tanks on valley floor to northeast. 3/ C.
(C-29-16)2ded-S1	BLM (Arrowhead Spring)	Te	8,050	-	<u>-</u>	s	14.0	Part of flow piped across divide to stock troughs in Escalante drainage basin to southeast.4/ C.

<sup>1/</sup> In addition to the diversion to Wah Wah Ranch, about 14 gal/min of water is diverted from Wah Wah Springs collection system to stock tanks, troughs, and ponds in secs. 8, 20, and 31, T. 26 S., R. 14 W. by a 6.7-mile pipeline (U.S. Bureau of Land Management, written commun., 1966). Total discharge of Wah Wah Springs, including diversions, estimated to be at least 500 gal/min in October 1972.

<sup>2/</sup> Collection system consists of 4-inch drain tile buried in spring area and running to concrete headbox. A 5-mile pipeline conveys about 8 gal/min of water from the headbox to stock troughs in secs. 24 and 25, T. 27 S., R. 15 W., and sec. 29, T. 27 S., R. 14 W. (U.S. Bureau of Land Management, written commun., 1960).

<sup>3/</sup> Collection system consists of 200 feet of 4-inch drain tile buried in spring area and running to a concrete headbox. A 4-mile pipeline conveys about 10 gal/min of water from the headbox to a 5,000-gallon storage tank and stock troughs in sec. 29, T. 28 S., R. 14 W. (U.S. Bureau of Land Management, written commun., 1954).

<sup>4/</sup> Collection system consists of 8-inch drain tile buried in spring area and running to corrugated-steel headbox. A total of 18 miles of pipeline conveys water from the headbox to stock troughs in secs. 26 and 35, T. 28 S., R. 15 W., and secs. 4, 14, 20, 22, and 35, T. 29 S., R. 15 W. (U.S. Bureau of Land Management, written commun., 1966).

### Table 9. -- Chemical analyses of ground water

[Analyses by U.S. Geological Survey unless otherwise noted]

Geologic source: See table 2 for explanation of symbols and description of lithologic units.
Dissolved solids: c, calculated from sum of determined constituents; all others are residue on evaporation at 180°C.
Additional data: M, data for certain minor chemical constituents given in table 10.

											Mil.	ligi	rams p	er li	tre									S°C)		
Location	Geologic source	Date of collection	Temperature (°C)	Dissolved silica (S102)	Dissolved iron (Fe)	Dissolved manganese (Mn)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (RCO <sub>3</sub> )	Carbonate (CO3)	vo.	Dissolved chloride (C1)	Dissolved fluoride (F)		Dissolved phosphate ( $PO_{d}$ )		Dissolved solids	Hardness as CaCO <sub>3</sub>	Noncarbonate hardness	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos/cm at 25°C)	Hq	Additional data
Public Health Servi	ce stand	ards <u>l</u> /	-	-	0.3	0.05	-	-		-		-	2.50	250	1.2	45			500	-	-	-	-	-	-	-
(C-24-13)34ccb-1	QТа	2/1935 9-14-62 12-17-62 9-25-63	15.5	26 - 33 30	0.12	 - 00, 00	64 70 77 64	55 47 29 45	456 366 436	18 15 18	198 160 186	0 0	316 199 179 205	846 678 585 670	0.5	- 5.3 4.9	0.60	0.11 .20 .19	2,640 1,620 1,380 1,370c 1,600 1,560c	370 312 346	208 181 193	- 72 71	10 9	2,770 2,380 2,710		- - - M
(C-26-13)22acc-S1	Pzq	9- 8-63	-	11	. 16	.00	18	2,4	9.5	1.1	50	0	16	14	. 3	1.0	1.4	.03	99 99c	56	15	26	.6	158	7.3	м
(C-27~13) 9aba 14dcd	Ti Ti	10-12-72 9- 9-63	15.0 13.0	24 17	.02 .45	.02 .19	650 224	190 11	100	8.7 5.6	132 140	0	1,600 288	600 420	1.1	$\frac{3}{73}$ /.04	.12 1.0	. 10 . 01	3,240c 1,650 1,260c	2,400 895	2,300 780	8 17	.9 1.2	4,020 2,100		- м
26ca <b>a</b>	Te	10-10-51 99-63	14.0 16.0		.12	.00	148 145	46 42	4/66 71	- .6	223 232	0	74 76	303 295	. 2	18 11	1.0	.21	799c 1,000 781c	558 536	376 346	20 22	1.3	1,420 1,410		- M
(C-27-15) 11aba-S1	Рис	9-14-62 5-27-68	19.5	13	-	-	67 63	29 32	22 20	1.5	316 310	0	14	37 42	.1	5.7	-	.02	340 344c 338	286 286	27		.6	624		-
12bcd-S1 Combined sample: 11aad-S1; 11aad- S2; 12bba-S1;	QTs	10-12-72	16.5		.03	.00	64	31	21	1.4	318	0	15	38		6.9 <u>3</u> /1.4	,03	.12	344c 348c	290	32 27		.5		7.8	-
12bbc -S1	QTs	9-14-62	19.0	13	-	-	60	30	20	1.2	298	0	14	36	. 1	4,9	-	.02	324 326c	274	30	14	. 5	592	7.9	-
(C-28-13) 18adb-S1 28dde-1	Te Qay <sup>5</sup> /	8-31-63 8-31-63			. 15 6.6	.05	59 27	17	7.6	5.3	144	0		116 ) 7.6		2.5	.56 1.5	.10	446 400c 149 146c	216 99	98 1	32 14	1.4		7.9	
(C-28-14) 11abb-1	QTa	9-27-73	4	58	-	_	21	6.4	86	11	169	13	82	32	1.0	3/.85	.67	.21	385c	79	0	67	4.2	535	8.3	_
(C-28-15) 10abb-\$1 25ccc-\$1	Te Te	10-11-72 6-21-73	14.0 11.5		.02	.01	120 630	39 220	33 200	1.8	389 286	0	39 710-2	110		3/2.8 .68	.18	.12	586c 4,550c	460 2,500	140 2,200	13	.7	985	7.5 7.6	-
(C-29-15) 2dad-S1	Qay	6-21-73	13.0	28	. 30	. 20	190	64	130	1.7	339	U	230	360	. 5	<u>3</u> /.13	.03	.28	1,170c	740	460	28	2.1	1,940	7.7	-
(C-29-16)2dcd-S1	Te	10-11-72	14.0	9.6	.01	.00	100	10	6.3	, б	341	()	14	10	, 1	3/.74	.06	.03	322c	290	11	5	. 2	550	8.1	-

<sup>1/</sup> Recommended maximum limits for public drinking water (F.S. Public Health Service, 1962, p. 7-8). Limit for fluoride based on annual average of maximum daily temperature at Wah Wah Ranch, 1968-72 (C.S. Environmental Science Services Administration, 1969-70; U.S. National Oceanic and Atmospheric Administration, 1971-73).

Table 10,--Minor chemical constituents in ground water from selected sources

(See table 9 for additional chemical data)

Geologic source: See table 2 for explanation of symbols and description of lithologic units.

Location	Geologic source	Date of collection	Copper (Cu)	Dissol Lead (Pb)	ved consti Zinc (Zn)	Bromide (Br)	lodide (1)	s per litre Lithium (Li)	Stront (um (Sr)
(C-24-13)34ccb-1	QTa	9-25-63	0.03	0.00	0.05	0.0	0.02	0.1	0.7
C-26-13)22acc-S1	Pzq	9- 8-63	.01	.00	.15	,0	.01		.0
C-27-13)14dcd	Τi	9- 9-63	.17	.0:2	.45	.0	.03	. 1	9.9
26caa	Te (?)	9~ 9-63	.00	.00	.20	.0	.01	. 3	1.2
C-28-13)18adb-S1	Te	8-31-63	.01	.00	.55	.0	.01	. 2	.0
28ddc-1	Qay 1	8-31-63	.12	.02	.30	.0	.00	. 2	.0

<sup>&</sup>lt;sup>1</sup>Surface runoff from rainfall contaminated the water source prior to date of collection of sample; analysis probably does not truly represent water from Qay at this location.

<sup>19/1-/3).

2/</sup> Analysis reported by H.S. Bureau of Land Management.

3/ Nitrite (NO2) + nitrate (NO3) reported as nitrogen (K).

4/ Sodium (Na) + potassium (K) determined and reported as sodium.

5/ Surface runoff from rainfall contaminated the water source prior to date of collection of sample; analysis probably does not truly represent water from Qay at this location.

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# PUBLICATIONS OF THE UTAH DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RIGHTS

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## TECHNICAL PUBLICATIONS

- No. 1. Underground leakage from artesian wells in the Flowell area, near Fillmore, Utah, by Penn Livingston and G. B. Maxey, U.S. Geological Survey, 1944.
- No. 2. The Ogden Valley artesian reservoir, Weber County, Utah, by H. E. Thomas, U.S. Geological Survey, 1945.
- \*No. 3. Ground water in Pavant Valley, Millard County, Utah, by P. E. Dennis, G. B. Maxey and H. E. Thomas, U.S. Geological Survey, 1946.
- \*No. 4. Ground water in Tooele Valley, Tooele County, Utah, by H. E. Thomas, U.S. Geological Survey, in Utah State Eng. 25th Bienn. Rept., p. 91-238, pls. 1-6, 1946.
- \*No. 5. Ground water in the East Shore area, Utah: Part I, Bountiful District, Davis County, Utah, by H. E. Thomas and W. B. Nelson, U.S. Geological Survey, in Utah State Eng. 26th Bienn. Rept., p. 53-206, pls. 1-2, 1948.
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- \*No. 8. Consumptive use of water and irrigation requirements of crops in Utah, by C. O. Roskelly and Wayne D. Criddle, 1952.
- No. 8. (Revised) Consumptive use and water requirements for Utah, by W. D. Criddle, K. Harris, and L. S. Willardson, 1962.
- No. 9. Progress report on selected ground-water basins in Utah, by H. A. Waite, W. B. Nelson, and others, U.S. Geological Survey, 1954.
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