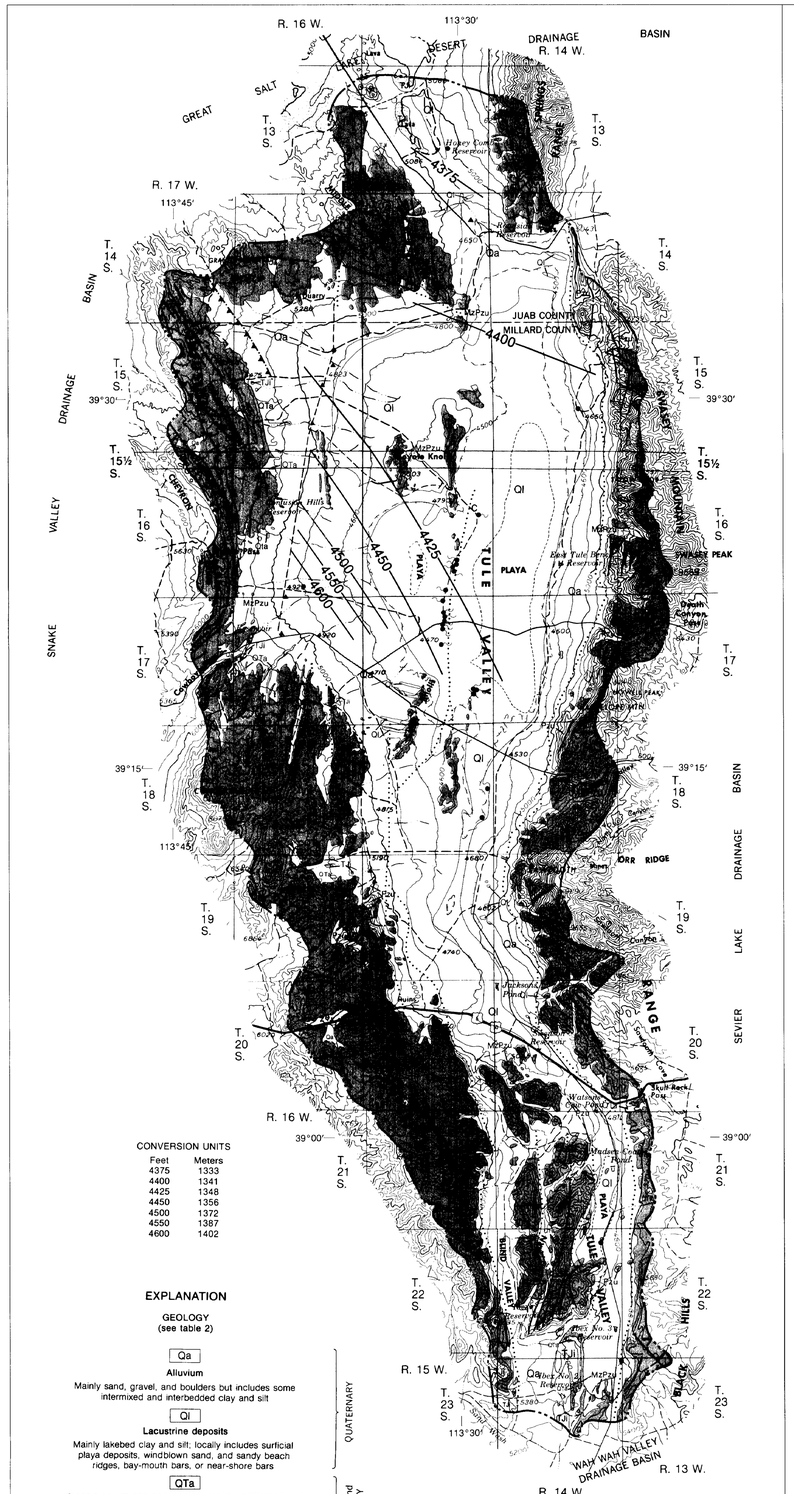


CONVERSION UNITS

Feet	Meters
4375	1333
4400	1341
4425	1348
4450	1356
4500	1372
4550	1387
4600	1402

EXPLANATION

GEOLOGY
(see table 2)

QUATERNARY

Qa — **Alluvium**
Mainly sand, gravel, and boulders but includes some intermixed and interbedded clay and silt

Ql — **Lacustrine deposits**
Mainly lakebed clay and silt; locally includes surficial playa deposits, windblown sand, and sandy beach ridges, bay-mouth bars, or near-shore bars

TERTIARY and QUATERNARY

QTa — **Older alluvium and sedimentary rocks undifferentiated**
Material ranging in size from clay through boulders, intermixed and interbedded, unconsolidated to well cemented; includes some lacustrine deposits in subsurface and locally includes limestone and conglomerate beds of uncertain age

JURASSIC and TERTIARY

TJi — **Igneous rocks undifferentiated**
Primarily extrusive rocks ranging in composition from mafic to felsic; includes local intrusive bodies, breccias, and water-lain volcanic materials

CAMBRIAN to TRIASSIC

MzPzu — **Mesozoic and Paleozoic sedimentary rocks undifferentiated**
Mainly limestone and dolomite with some beds of shale, claystone, siltstone, and sandstone

Paleozoic sedimentary rocks undifferentiated
Mainly quartzite but includes some phyllite and phyllitic shale

Approximate contact

Fault
Dashed where inferred; dotted where concealed by alluvium

Thrust fault
Dashed where inferred; dotted where concealed; barbs on side of thrust sheet

HYDROLOGY

4500
Generalized water-level contours, approximately located
Contour interval 25 and 50 feet (7.6 and 15.2 meters). Datum is mean sea level

Well — Destroyed or abandoned

Drillers' logs in table 9

Spring — C, chemical analysis in table 8

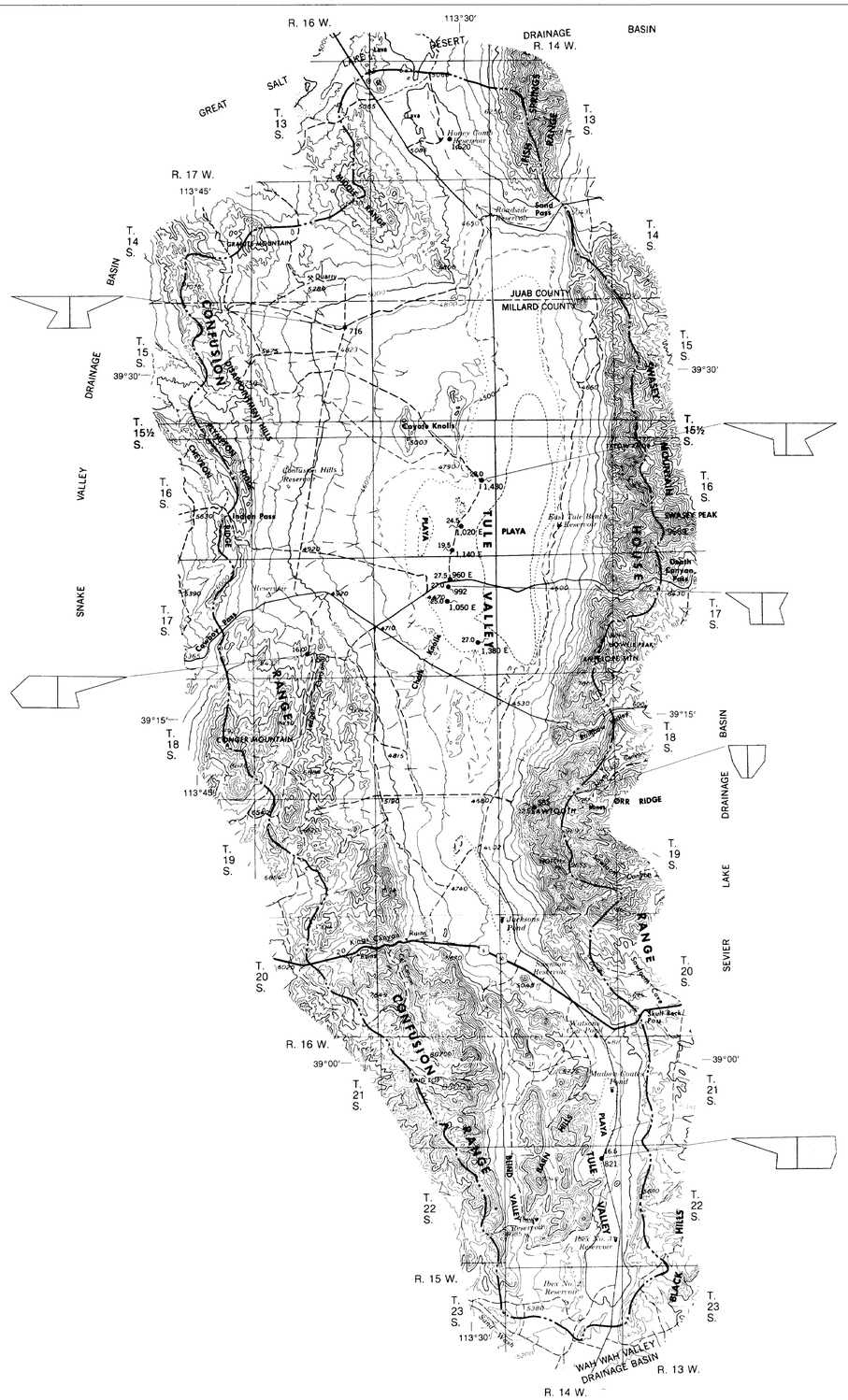
Crest-stage gage — Channel geometry

Surface-drainage divide

Wells and springs listed in table 6; surface-water sites listed in table 4

Base from U.S. Geological Survey 1:250,000 series: Delta, 1953; Richfield, 1953

HYDROGEOLOGY



EXPLANATION

Water-quality diagrams
(after Stiff, 1951)

Sodium (Na) + Potassium (K)
Calcium (Ca)
Magnesium (Mg)
Chloride (Cl)
Bicarbonate (HCO_3)
Sulfate (SO_4)

10 5 0 5 10
Milliequivalents per liter

Chemical data for individual sources given in table 8

Water temperature (°C) — 28.0 — 1,430 — Spring — 16.5 — 821 — Well — Dissolved solids, in milligrams per liter

E, estimated from specific conductance

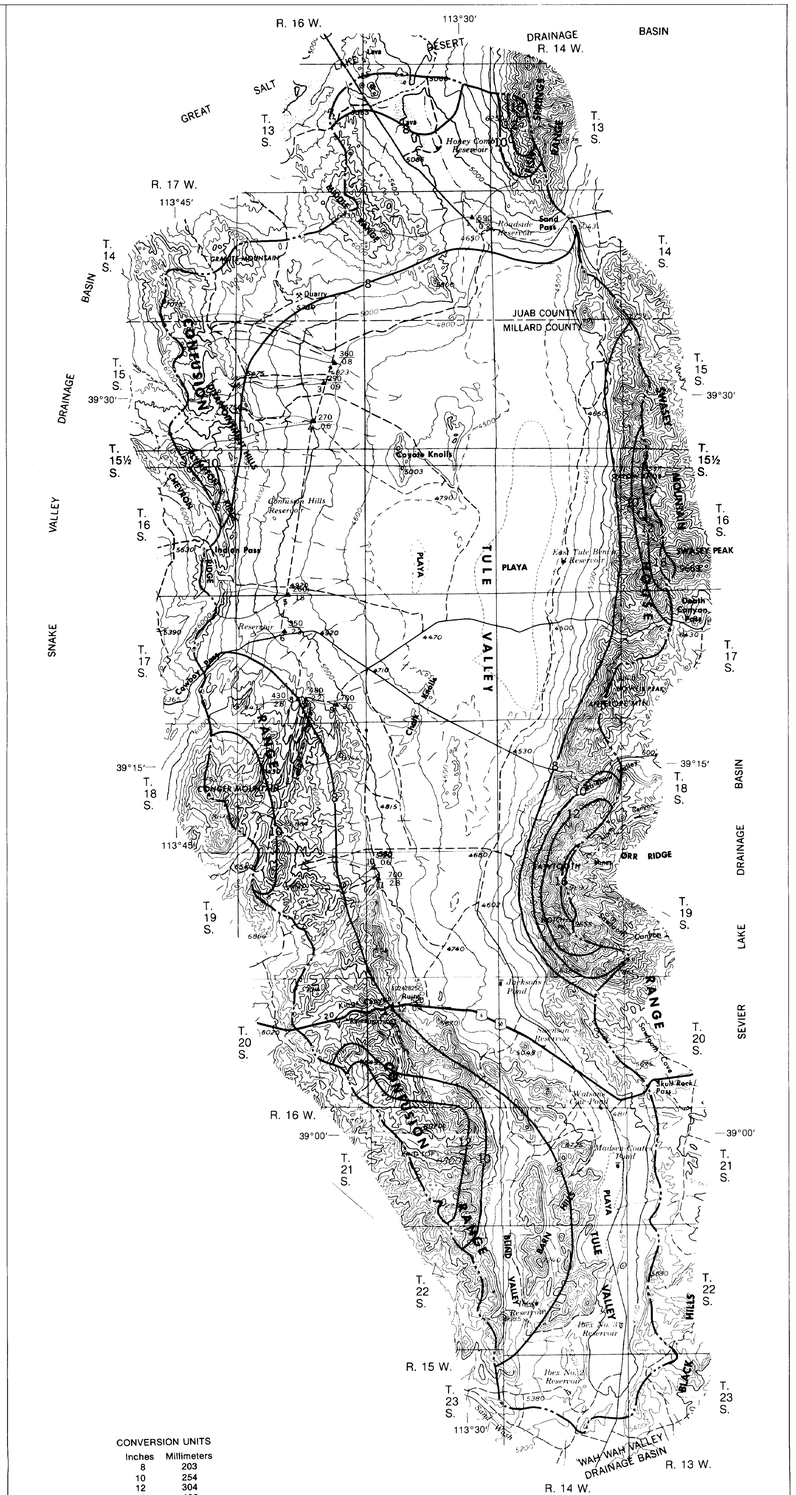
Approximate area of ground-water evapotranspiration

Surface-drainage divide

5 0 5 MILES
5 0 5 KILOMETERS

CONTOUR INTERVAL 200 FEET (61.0 METERS)
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT (30.5 METER) INTERVALS
DATUM IS MEAN SEA LEVEL

CHEMICAL QUALITY OF WATER AND GROUND-WATER EVAPOTRANSPIRATION



CONVERSION UNITS

Inches	Millimeters
8	203
10	254
12	304
16	406

EXPLANATION

10
Line of approximately equal precipitation, in inches
Interval 2 and 4 inches (51 and 102 millimeters)

Site number in table 4
Channel-geometry site
Estimated average annual runoff volume, in acre-feet
Estimated average annual runoff depth in inches

Boundary of contributing drainage area

10242800
Crest-stage gage and number

Surface-drainage divide

PRECIPITATION AND DRAINAGE AREAS

Hydrology by J. C. Stephens 1975. Geology from Stokes (1964), modified in part after Hose (1963, 1974 a, b), Hose and Repenning (1964), and Hintze (1974 a, b, c, d)

MAPS SHOWING HYDROGEOLOGY, CHEMICAL QUALITY OF GROUND WATER, PRECIPITATION, AND AREAS OF EVAPOTRANSPIRATION IN THE TULE VALLEY DRAINAGE BASIN, JUAB AND MILLARD COUNTIES, UTAH

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 56

HYDROLOGIC RECONNAISSANCE OF THE TULE VALLEY DRAINAGE BASIN, JUAB AND MILLARD COUNTIES, UTAH

by

Jerry C. Stephens
Hydrologist, U.S. Geological Survey

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

1977

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[Plate is in pocket]

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ENGLISH-TO-METRIC CONVERSION FACTORS

Most numbers are given in this report in English 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 number in English units.

English Units (Multiply)	English Abbreviation	(by)	Metric Units (to obtain)	Metric Abbreviation
Acres		0.4047	Square hectometers	hm^2
		.004047	Square kilometers	km^2
Acre-feet	acre-ft	.001233	Cubic hectometers	hm^3
Cubic feet per second	ft^3/s	.02832	Cubic meters per second	m^3/s
Feet	ft	.3048	Meters	m
Gallons per minute	gal/min	.06309	Liters per second	l/s
Inches	in	25.40	Millimeters	mm
		2.540	Centimeters	cm
Miles	mi	1.609	Kilometers	km
Square miles	mi^2	2.590	Square kilometers	km^2

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

Micrograms per liter (μg/l) is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter (meq/l). 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 (°F) by the following equation: °F = 1.8(°C) + 32.

HYDROLOGIC RECONNAISSANCE OF THE TULE VALLEY DRAINAGE BASIN, JUAB AND MILLARD COUNTIES, UTAH

by

Jerry C. Stephens
Hydrologist, U.S. Geological Survey

ABSTRACT

The Tule Valley drainage basin is an area of about 940 square miles (2,430 square kilometers) in Juab and Millard Counties in west-central Utah. Precipitation in the basin averages about 8 inches (203 millimeters) annually. There is no surface outflow and all streams are ephemeral. Annual runoff averages about 0.09 inch (2.3 millimeters). Because there is no sustained runoff, and flow is local and infrequent, reservoirs do not provide dependable water supplies.

Ground-water recharge from precipitation in the basin is estimated to average 7,600 acre-feet (9.4 cubic hectometers) annually. Discharge, principally by evapotranspiration, averages about 40,000 acre-feet (49 cubic hectometers) annually. Subsurface inflow from adjacent areas is estimated to average about 32,000 acre-feet (39.5 cubic hectometers) annually.

Nearly all discharge from the ground-water system is evaporated directly from the water table or transpired by phreatophytes in the 68,000 acres (27,500 square hectometers) that constitute a natural discharge area on the northern valley floor.

Dissolved-solids concentrations in the water range from 516 to 1,580 milligrams per liter. Water from all sources sampled apparently is of satisfactory chemical quality for livestock use. The temperature of water discharged by springs ranges from 12.5° to 28.0° Celsius.

More than 700,000 acre-feet (863 cubic hectometers) of water might be obtained from storage and by capture of water now being consumed by evapotranspiration if wells in the principal area of natural discharge were pumped to lower the water table 100 feet (30 meters). Supplies for livestock could be obtained from wells at many locations on the alluvial fans and nearly anywhere on the valley floor.

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 sixteenth 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 Tule Valley drainage basin, report is to present hydrologic data for the Tule Valley[1] 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 report is based largely on an examination of physiography, vegetation, geology, and water sources during brief field reconnaissances in June 1973 and September 1974. Additional information on the geology and water resources of the Tule Valley area was obtained from published reports listed in the selected references. Principal sources of basic hydrologic data are the files of the Geological Survey and of the Utah State Engineer.

Location and general features

The area described in this report includes Tule Valley and its tributary drainage area, a total of about 940 mi^2 (2,430 km^2) in Juab and Millard Counties in west-central Utah (pl. 1). The Tule Valley drainage basin is about 65 mi (105 km) long and ranges from 8 to 22 mi (13 to 35 km) in width. The photographs in figure 2 are representative views of the area.

The Tule Valley drainage basin has no permanent inhabitants; the land is used mainly for seasonal livestock grazing. Based on land-status maps by the U.S. Bureau of Land Management (1970a, b), about 530,000 acres (2,145 km^2) or 88 percent of the land is Federally owned. About 68,000 acres (275 km^2) or 11 percent is owned by the State of Utah. About 1,100 acres (4.5 km^2) or less than 1 percent is privately owned.

Physiography and drainage

The Tule Valley drainage basin is a topographically closed basin bounded in part by drainage divides in the House and Fish Springs Ranges on the east and the Confusion Range on the west (pl. 1). The northern boundary is a broad, low divide connecting the Fish Springs and Middle Ranges, Granite Mountain, and the Confusion Range. The southern boundary is likewise a broad, low divide that connects the House and Confusion Ranges.

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[1]Tule Valley formerly was called White Valley and many published reports and maps used that name. Tule Valley is used throughout this report, however, because it is used on most current maps, including detailed topographic maps recently published by the U.S. Geological Survey.

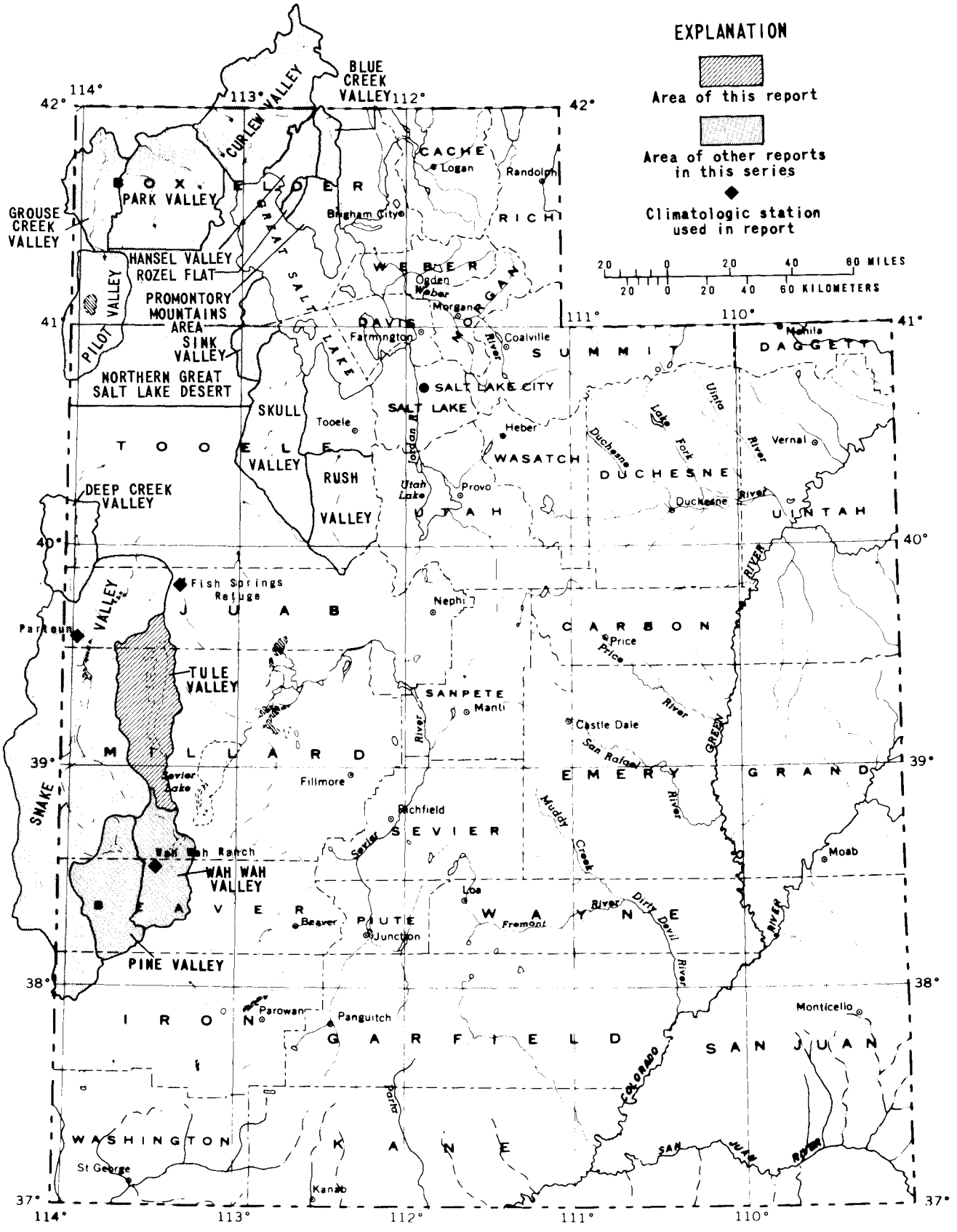
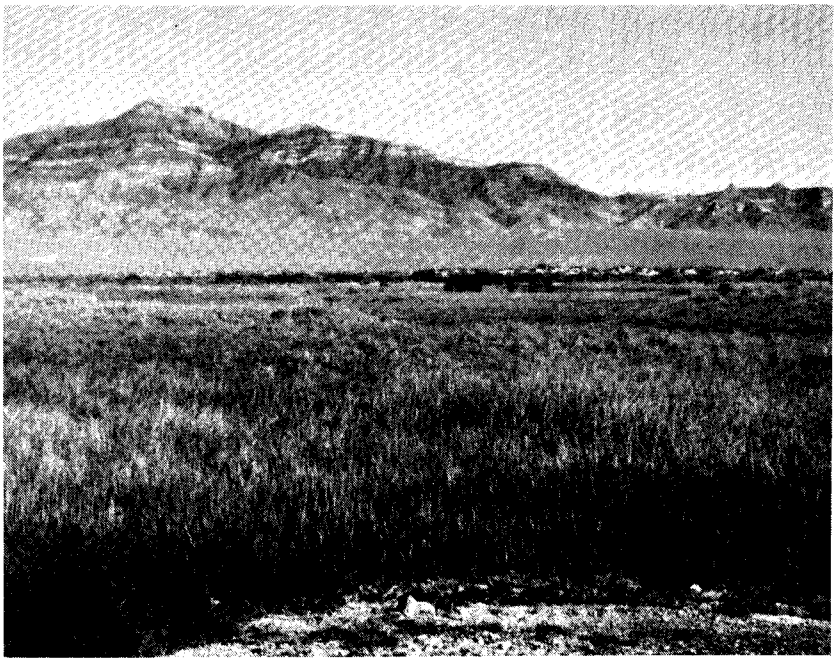
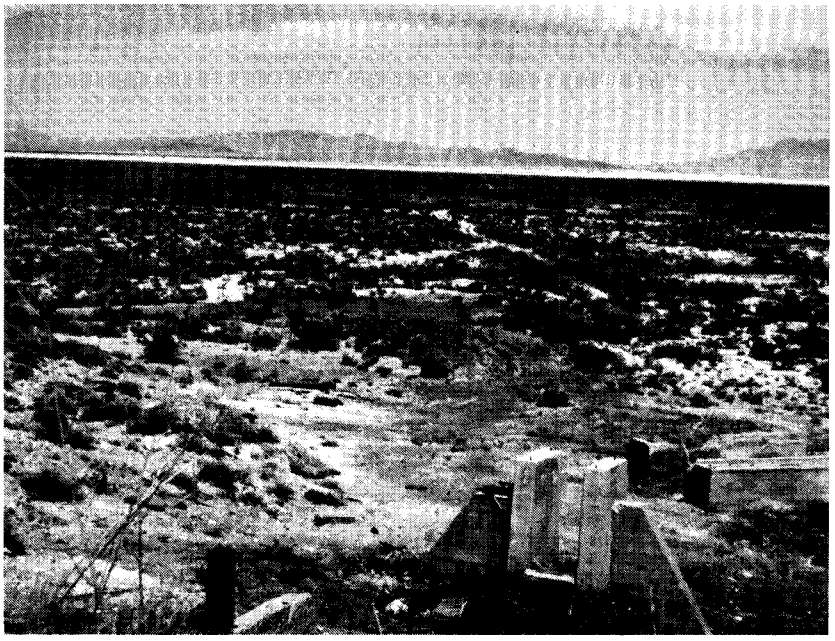


Figure 1.—Location of the Tule Valley drainage basin and areas described in other reports in this series.

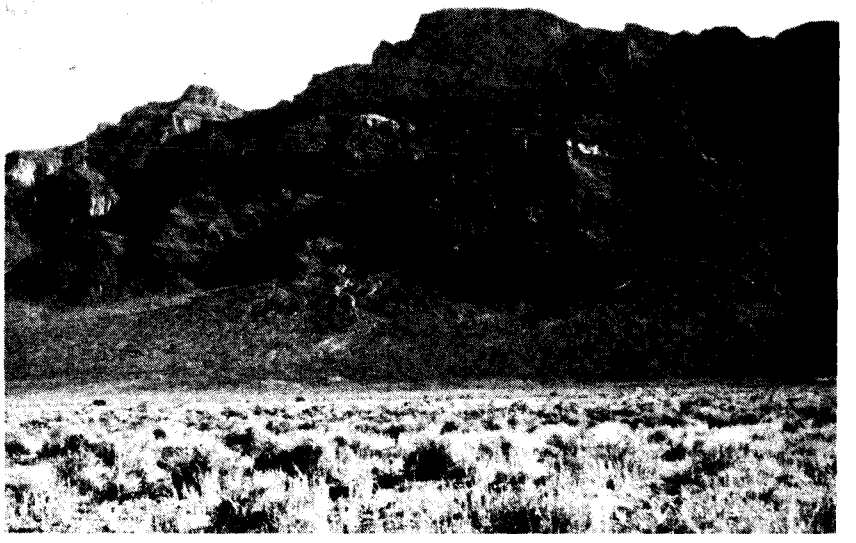


A. Coyote Springs discharge area in foreground with dense growth of marsh bulrush; taller, dark shrubs in middle ground are saltcedar; House Range in background with Swasey Peak on left.



B. Northern end of valley with extensive growth of greasewood, pickleweed, and saltgrass; Fish Springs Range in middle background; Sand Pass in low gap on right; House Range on extreme right; playa (white band) in distance.

Figure 2.—Tule Valley.



C. Notch Peak in House Range; note recently incised channels on upper part of alluvial fan. Vegetation in foreground is shadscale and annual grasses.

D. Alluvial fans and playa (white area in upper right) in southern end of valley; House Range on left and Confusion Range on right. Low shrubs growing on fan are shadscale.

Figure 2.—Tule Valley.--Continued

The crests of the House, Fish Springs, and Confusion Ranges generally are at altitudes of 7,000-9,000 ft (2,130-2,740 m). The minimum altitude on the divide is in Sand Pass, between the House and Fish Springs Ranges, at an altitude of 4,744 ft (1,446 m). The highest point in the basin is Swasey Peak in the central House Range, where the altitude is 9,669 ft (2,947 m). The lowest point is on the playa about 17 mi (27 km) west of Swasey Peak at an altitude of about 4,390 ft (1,338 m). Total relief in the basin thus is about 5,300 ft (1,615 m).

The Tule Valley drainage basin adjoins Snake Valley drainage on the west, Sevier Lake drainage on the east, Great Salt Lake Desert drainage on the north, and Wah Wah Valley drainage on the south (pl. 1). The lower parts of each of these drainage basins, including Tule Valley, were inundated by Lake Bonneville, the large freshwater lake that covered much of western Utah and adjacent parts of Idaho and Nevada (Gilbert, 1890, pl. 1) during Pleistocene time. Maximum altitudes of Lake Bonneville deposits in Tule Valley range from about 5,125 ft (1,562 m) in T. 20 S., R. 15 W., at the mouth of Kings Canyon, to about 5,175 ft (1,577 m) in T. 15 S., R. 16 W., a few miles north of Confusion Hills Reservoir (Crittenden, 1963, p. E6). The maximum stage of the lake, therefore, was at least 380 ft (116 m) higher than the lowest point of the Tule Valley drainage divide and 735 ft (224 m) higher than the lowest point in the valley. As the lake receded, Tule Valley was cut off from the main body by a bay-mouth bar that formed across the gap at Sand Pass. Since that time, Tule Valley has been a topographically closed basin.

Climate

The climate of the Tule Valley drainage basin is generally arid--estimated average annual precipitation over the entire basin is about 8 in (203 mm). Precipitation is extremely variable, both in volume and areal distribution, on a year-to-year basis. Plate 1 shows the long-term average distribution. Based on an assumed similarity with nearby climatologic stations (table 1), annual precipitation on the basin probably ranges from about 3 to 10 in (76 to 254 mm).

Table 1.--Selected climatologic data for stations near Tule Valley

(Data from U.S. Weather Bureau, 1957, 1962-66; U.S. Environmental Science Services Administration, 1967-70; and U.S. National Oceanic and Atmospheric Administration, 1971-74.)

Station (see fig. 1):	Wah Wah Ranch		Partoun		Fish Springs Refuge		
Altitude (ft above mean sea level)	4,960		4,750		4,335		
Period of record:	Sept. 1955-Dec. 1973		Apr. 1950-Dec. 1973		July 1960-Dec. 1973		
Average monthly:	Temperature (°F)	Precipitation (in)	Temperature (°F)	Precipitation (in)	Temperature (°F)	Precipitation (in)	Evaporation[1] (in)
January	28.2	0.27	26.9	0.28	28.7	0.25	-
February	34.6	.41	33.1	.41	36.4	.49	-
March	40.3	.60	38.8	.40	42.0	.52	-
April	47.7	.70	47.7	.66	50.0	1.07	7.26 (1)
May	58.1	.57	57.3	.69	61.3	.76	11.17 (6)
June	67.7	.46	66.5	.86	69.5	1.09	12.14 (10)
July	76.1	.60	75.2	.57	80.0	.54	15.84 (10)
August	74.0	1.05	73.1	.51	77.8	.47	13.23 (10)
September	63.5	.58	62.6	.42	65.9	.65	9.66 (10)
October	51.8	.68	50.9	.42	53.6	.65	5.95 (6)
November	38.4	.50	37.7	.40	40.9	.51	-
December	29.8	.34	27.9	.38	29.2	.48	-
Average annual	50.8	6.76	49.8	6.00	52.9	7.48	-
Maximum/minimum:							
Period of record	106/-27	-	105/-23	-	109/-14	-	-
Annual	-	10.11/3.55	-	9.84/2.03	-	9.63/3.89	-
Monthly	-	2.31/0.00	-	3.29/0.00	-	2.94/0.00	19.68/ -

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

As indicated in table 1, about 70 percent of the average annual precipitation at nearby stations falls during April-October. Much of this precipitation occurs during short-lived, high-intensity, local thunderstorms. Precipitation (mostly snowfall) during November-March accounts for less than one-third of the average annual precipitation.

Vegetation

Rabbitbrush (*Chrysothamnus* sp.) and greasewood(*Sarcobatus vermiculatus*) grow locally in and along stream channels in sandy alluvial soils. These soils absorb precipitation and runoff readily and store it temporarily as soil moisture for subsequent plant use. Where moisture is perennially available in the vicinity of certain springs and in the northern part of the valley (fig. 2A and B) where the water table is shallow, pickleweed (*Allenrolfea occidentalis*), saltgrass (*Distichlis stricta*), greasewood, rabbitbrush, and other phreatophytes are common. Cattail (*Typha latifolia*) and marsh bulrush (*Scirpus paludosis*) are locally abundant, growing in dense stands as hydrophytes in spring ponds and marshy areas. Cottonwood (*Populus* sp.) and saltcedar (*Tamarix* sp.) grow as phreatophytes at a few locations.

Vegetation is absent on the playas in Tps. 15-17 and 21-22 S., R. 14 W. (See fig. 2B and D.) These playas are infrequently inundated by thunderstorm and snowmelt runoff; and saline minerals, which precipitate as the water evaporates, have accumulated to form a highly saline soil that prevents even the most salt-tolerant vegetation from becoming established.

Because of the general aridity, native vegetation in such of Tule Valley consists primarily of "salt-desert" shrubs that are typical of millions of acres of vegetation in the Great Basin. On the gravelly soils adjacent to the playas and covering the lower alluvial slopes, a mixed association of shadscale (*Atriplex* sp.), annual forbs, and bunchgrasses predominates. This vegetation is sparse, generally covering less than 10 percent of the ground. (See fig. 2C and D.)

On steeper alluvial slopes, sagebrush (*Artemesia* sp.) is the dominant vegetation below an altitude of about 6,000 ft (1,830 m). 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.

Geology

Rocks ranging in age from Cambrian to Quaternary crop out in the Tule 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.

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

Erathem	System	Hydrogeologic unit and symbol on pl. 1	Lithology, thickness, and extent	Water-bearing characteristics
CENOZOIC	Quaternary	Alluvium (Qa)	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 and thins toward center of valley where it is present as a thin veneer overlying and adjacent to lakebed clays. Includes colluvial materials adjacent to bedrock outcrops. Maximum thickness probably less than 100 ft (30 m).	Slightly to highly permeable. Direct precipitation and runoff from higher altitudes infiltrates these deposits and moves downward and laterally into underlying aquifers. Deposits are generally above the zone of saturation.
		Lacustrine deposits (Ql)	Mainly lakebed clay and silt. Locally includes surficial playa deposits; small, isolated deposits of windblown sand; and lacustrine beach ridges, bay-mouth bars, or near-shore bars, composed mainly of sand but containing considerable amounts of fine gravel, silt, and clay.	Permeability generally low, except windblown sand, beach ridges, and bars are slightly to highly permeable. Most precipitation and runoff from higher altitudes infiltrates these deposits and moves downward and laterally into underlying aquifers. Deposits are generally above the zone of saturation.
	Tertiary and Quaternary	Older alluvium and sedimentary rocks, undifferentiated (QTa)	Materials ranging in size from clay through boulders, intermixed and interbedded, unconsolidated to well cemented. Includes some lacustrine deposits and colluvium in subsurface, and locally includes limestone and conglomerate beds of uncertain age. Underlies younger deposits throughout most of valley area and locally is interbedded with extrusive igneous rocks. Maximum thickness probably less than 1,000 ft (305 m).	Slightly to highly permeable, depending on size and degree of sorting of materials and degree of cementation in individual strata. The five producing wells in the basin reportedly discharge as much as 25 gal/min (1.6 l/s) (table 6) from sand and gravel beds in this unit from 150 to 515 ft (95 to 157 m) below land surface (table 9).
MESOZOIC AND CENOZOIC	Jurassic and Tertiary	Igneous rocks, undifferentiated (TJi)	Primarily extrusive rocks (ignimbrites, tuffs, and lava flows), ranging in composition from mafic to felsic. Includes some local intrusive bodies, breccias, and water-lain volcanic materials. Thickness and subsurface extent unknown.	Primary permeability generally low except locally in some breccias and interflow zones. Where fractured and broken by faulting, secondary permeability may be high. Spring (C-19-14)5adc-S1 (table 6) issues from decomposed granite of this unit.
PALEOZOIC AND MESOZOIC	Cambrian to Triassic	Mesozoic and Paleozoic sedimentary rocks, undifferentiated (MzPzu)	Mainly limestone and dolomite, with some beds of shale, claystone, siltstone, and sandstone. Altered by contact metamorphism adjacent to intrusive rocks. Form bulk of mountain ranges bordering valley. Probably underlie most of area at depth. Maximum thickness unknown.	Primary permeability generally low; secondary permeability moderate to high where solution openings are present, especially along bedding planes, fractures, and faults. A few springs discharging 10 gal/min (0.6 l/s) or less issue from these rocks. Well (C-17-15)25cbb-1 (tables 6 and 9) reportedly discharged 200 gal/min (12.6 l/s) from fractured limestone.
		Paleozoic sedimentary rocks, undifferentiated (Pzu)	Mainly quartzites, but include some phyllite and phyllitic shale. Generally resistant, cliff-forming strata exposed in the northern House Range and southern Confusion Range. Probably underlie most of area at depth. Maximum thickness unknown.	Primary permeability low; secondary permeability moderate to high where fractured. Not known to yield water to wells or springs in Tule Valley drainage basin.

Valley fill

Tule Valley is bounded on the west by numerous faults in the Confusion Range and on the east by faults along the western base of the House Range (pl. 1 and Stokes, 1964; Hose, 1963, 1974a, b; Hose and Repenning, 1964; Hintze, 1974a, b, c). In addition to the major structural features shown on plate 1, complex and extensive folding, faulting, and fracturing is present, especially in rocks of Paleozoic age.

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-13-15) 23ccb-1 designates the first well constructed or visited in the NW¼SW¼ SW¼ sec. 23, T. 13 S., R. 15 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 3.

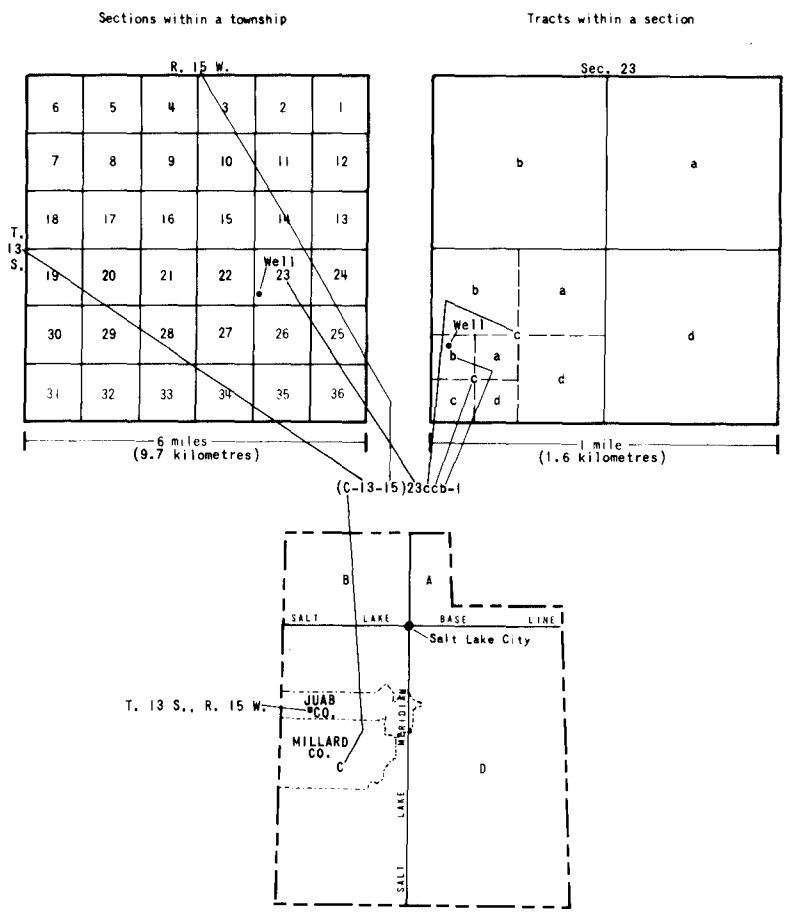


Figure 3.—Numbering system for hydrologic-data sites.

[1]Although the basic land unit, the section, is theoretically 1 mi^2 (2.6 km^2), many sections are irregular. Such sections are subdivided into 10-acre (4-hm^2) tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

WATER-RESOURCES APPRAISAL

Precipitation in the Tule Valley drainage basin is estimated to average about 400,000 acre-ft (490 hm^3) annually (table 3), or about 8 in (203 mm) over the entire basin. Estimated annual ground-water recharge from precipitation in the basin is about 7,600 acre-ft (9.4 hm^3), or slightly less than 2 percent of the total precipitation. There is no surface outflow from the basin; thus, more than 98 percent of the precipitation is consumed directly by evapotranspiration.

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

[Areas of precipitation zones calculated from pl. 1; all estimates rounded]

Precipitation zone (in)	Area (acres)	Precipitation (acre-ft)	Recharge: Percentage of precipitation	Recharge: Acre-ft
		Consolidated and unconsolidated rocks		
Less than 8	380,000	220,000	Minor	0
		Unconsolidated rocks		
8-10	50,000	38,000	1	380
10-12	700	600	3	18
Subtotal	51,000	39,000		400
		Consolidated rocks		
8-10	120,000	90,000	3	2,700
10-12	27,000	25,000	8	2,000
12-16	18,000	21,000	10	2,100
More than 16	1,100	1,600	25	400
Subtotal	166,000	138,000		7,200
Total	600,000	400,000		7,600

Surface water

All streams in the basin are ephemeral. Springflow sustains small amounts of perennial flow in headwater reaches of a few streams but is consumed by evapotranspiration within a few feet to a few hundred feet of the source. Although networks of ephemeral stream channels lead

onto the playas in the northern and southern parts of the valley, streamflow occurs only during and immediately after intense thunderstorms and during periods of snowmelt, and only at these times does significant runoff reach the playas.

Continuous records of streamflow are not available for the basin. Peak-flow data from two crest-stage gages maintained by the Geological Survey are given below as an indication of the sporadic nature of flow in the ephemeral streams in the area. The locations of the gages are shown on plate 1.

Station 10242800: Kings Canyon tributary (Cat Canyon) at (C-20-15)7dba; 15 ft (4.6 m) upstream from culvert on U.S. Highway 6 and 50; drainage area 13.2 mi^2 (34.2 km^2); period of record 1961-68.

Water year	Peak flow ft^3/s	(m^3/s)	Date of peak
1961-67	No evidence of flow		-
1968	663[1]	(18.8)	July 31

Station 10242825: Kings Canyon at (C-20-15)7ada; at edge of U.S. Highway 6 and 50 about 0.25 mi (0.4 km) downstream from station 10242800; drainage area 27.8 mi^2 (72.0 km^2); period of record 1961-68.

Water year	Peak flow ft^3/s	(m^3/s)	Date of peak
1961-64	No evidence of flow		-
1965	984[2]	(27.9)	Aug. 16
1966	180[1]	(5.1)	Mar. 8
1967	No evidence of flow		-
1968	2,590[1]	(73.3)	July 31

[1]Estimated from gage height.
[2]Calculated by slope-area method.

The peak flow recorded at station 10242825 for March 8, 1966, resulted from the rapid melting of a snowpack over most of the basin. The other flows resulted from thunderstorm runoff, the local nature of which is indicated by the fact that on August 16, 1965, flow was recorded at station 10242825 but not at station 10242800.

Estimates of average annual runoff in 12 ephemeral streams are given in table 4, together with supplementary information for the areas drained by the streams. The runoff estimates were made by F. K. Fields (written commun., 1973) using a technique based on measurements of channel geometry (Fields, 1975). The locations of the sites and the boundaries of the drainage areas are shown on plate 1.

Table 4.--Estimated average annual precipitation and runoff in selected areas in the western Tule Valley drainage basin

Site No.: See plate 1.
Altitude and drainage area: Determined from U.S. Geological Survey 7½- or 15-minute topographic quadrangle maps; altitudes are above mean sea level.
Precipitation: Determined from plate 1.
Runoff volume: Estimated by channel-geometry methods (Fields, 1975).
Runoff depth: The average depth of water over the entire drainage area that is equivalent to the estimated runoff at the channel site. Calculated from runoff volume and drainage area.

Site No.	Location	Altitude (ft)	Drainage area (mi^2)	Precipitation (acre-ft)	Runoff		Ratio of runoff to precipitation
					Volume (acre-ft)	Depth (in)	
1	(C-14-15)12bb	4,680	57.9	26,500	590	0.2	0.02
2	(C-15-16)11dc	4,830	8.3	3,620	360	.8	.10
3	14cc	4,840	5.9	2,720	290	.9	.11
4	27dbd	4,920	9.0	4,110	270	.6	.07
5	(C-16-16)33cdd	4,920	2.9	1,160	260	1.8	.22
6	(C-17-16)9cbb	5,070	2.9	1,160	350	2.3	.30
7	27cca	5,360	4.0	2,020	480	2.2	.24
8	28ddb	5,440	3.1	1,540	430	2.6	.28
9	35abb	5,090	4.4	2,160	700	3.0	.32
10	(C-19-15)6cac	5,140	17.6	9,120	580	.6	.06
11	7abc	5,130	4.7	2,070	700	2.8	.34
12	(C-20-15)7ada[1]	5,426	27.8	15,500	520	.4	.03

[1]Located at crest-stage gage station 10242825 (page 11); altitude determined by spirit level.

The runoff, as indicated in table 4, is variable. Principal factors influencing runoff are the geology, topography, altitude, vegetation, size of the drainage area, and the volume and rate of precipitation. The analysis of these factors was beyond the scope of the present study. In general, however, the figures in table 4 indicate that depth of runoff decreases with increasing drainage area. Because the alluvial materials adjacent to the mountains are relatively permeable, runoff from the consolidated rocks in the mountains infiltrates rapidly. Drainage areas that have a large percentage of the surface covered by alluvium generally have little runoff.

Total runoff crossing the 4,500-ft (1,372-m) topographic contour, the approximate lower limit of alluvial sand and gravel in Tule Valley (pl. 1), is estimated to average about 4,000 acre-ft (4.9 hm^3) annually. This corresponds to an average depth of runoff of about 0.09 in (0.23 cm) from the surrounding part of the basin.

The development of surface-water resources in Tule Valley consists only of several small reservoirs (table 5) that intercept and

Table 5.--Livestock reservoirs

Original storage capacity: Reported by U.S. Bureau of Land Management (written commun., 1975).

Name	Location (pl. 1)	Original storage capacity (acre-ft)	Remarks
Honey Comb Reservoir	(C-13-15)22d	-	Dry 9-20-74.
Roadside Reservoir	(C-14-14)7cb and (C-14-15)12da	-	Dry 6-20-73 and 9-20-74.
East Tule Bench Reservoir	(C-16-14)27bd	-	-
Confusion Hills Reservoir	(C-16-16)17a	9	-
Unnamed reservoir	(C-17-16)7d	5	-
Jackson Pond	(C-20-14)6b	5	Dry 9-19-74.
Swenson Reservoir	21bb	-	Do.
Watsons Cow Pond	35d	9.5	Do.
Madsen-Coates Pond	(C-21-14)24ab	3	Estimated contents 0.1 acre-ft on 2-13-74; dry 9-19-74.
Ibex Reservoir	(C-22-14)20d	-	-
Ibex No. 3 Reservoir	25db	3.4	-
Ibex No. 2 Reservoir	(C-23-14)10c	2	-

store local runoff for livestock use. These reservoirs rarely store significant amounts of water--only one contained water when visited in 1973 and 1974, and two contained water when visited in 1955 (Snyder, 1963, p. 514). Because there is no sustained runoff, and flow is local and infrequent, reservoirs do not provide significant or dependable water supplies in the area.

Ground water

Ground water is present in most of the rock units in the Tule Valley drainage basin. Dependable water supplies are readily available from springs on the floor of the valley where the water table is at the land surface. On the alluvial fans and in the surrounding mountains, only a few wells and springs provide dependable water supplies. The geologic formations in the basin have been grouped in table 2 into hydrogeologic units. The location and physical characteristics of these units control the recharge, occurrence, movement, storage, and discharge of ground water in the basin.

Under natural conditions, a ground-water system is in dynamic equilibrium--long-term average recharge and discharge are equal, and the volume of ground water in transient storage is nearly constant. Because ground-water development by man in the Tule Valley drainage basin is negligible, seasonal and annual variations in the volumes of recharge, discharge, and storage in the basin balance out in the long term, and a natural dynamic equilibrium prevails.

Recharge

The most direct source of recharge to the ground-water system is from infiltration of precipitation in the drainage basin. Recharge from precipitation is estimated to average about 7,600 acre-ft (9.4 hm^3) annually, or about 2 percent of total precipitation (table 3). The recharge estimate was made using a method developed by Eakin and others (1951, p. 79-81) for use in Nevada and modified by Hood and Waddell (1968, p. 22-23) for use in western Utah.

Although the volume of recharge is estimated by precipitation zones and rock types, actual recharge probably occurs principally where torrential runoff from the consolidated rocks of the mountains is channeled onto the alluvial fans. As the main channels become choked with debris, the flow spreads out into shallower and broader channels until it becomes a sheet-like flood. Because the alluvial materials normally are dry and relatively permeable, they absorb water rapidly, and the surface flow does not persist for long distances.

Figure 2C and D show the general nature of the alluvial fans. Note in figure 2C the pronounced dissection on the upper part of the fans below Notch Peak, whereas the more gently sloping lower parts of the fans are little dissected. Figure 2D shows a relatively undissected alluvial slope extending to the playa and, in the foreground, the nature of the surficial materials on the fan.

In addition to recharge from infiltration of runoff on the alluvial fans, some recharge takes place directly on the outcrops of consolidated rocks in the mountains. Although these rocks generally have low primary permeability (table 2), locally they may take in large quantities of recharge through fractures and other secondary openings.

Some recharge to the ground-water system is supplied by subsurface inflow from adjacent drainage basins to the south and west. Field data are inadequate to provide a direct estimate of the volume of such inflow. A further discussion of this probable source of recharge is given in the section on ground-water balance.

Occurrence and movement

Ground water in the Tule Valley drainage basin probably occurs under both water-table (unconfined) and artesian (confined) conditions as a result of local variations of lithology and structure in the different hydrogeologic units. The scanty available subsurface data are not adequate to define the altitude and configuration of the potentiometric surface in most of the basin.

In the consolidated rocks of the mountains, ground water moves principally through secondary openings. Structural deformation of these rocks caused extensive jointing, fracturing, and faulting. In the carbonate rocks, moving ground water has further enlarged many of the openings by solution. The permeability resulting from these interconnected secondary openings is much greater than the original permeability of the rocks.

Direct recharge from precipitation in the mountains moves generally downward and laterally through interconnected openings in the consolidated rocks toward the valley floor. In detail, the path followed by the moving water may be quite circuitous. Some of the water circulates to considerable depths and travels many miles before it discharges at the land surface. In other cases, shallow, interconnected fractures discharge water within short distances of the intake area. In the Tule Valley drainage basin, most of the water moving through the consolidated rocks probably discharges into the valley fill beneath the lower alluvial slopes and the valley bottom.

Although some recharge occurs directly on the outcropping consolidated rocks in the mountains, the principal recharge in the Tule Valley drainage basin is from streams that cross the upper alluvial slopes. From these intake areas, the general path of ground-water movement also is downward and laterally toward the valley floor. Below an altitude of about 4,425 ft (1,349 m), most of the ground is perennially saturated, and ground water is discharged directly from the water table by evapotranspiration and springflow.

Water levels in wells and drill holes in Tps. 13-18 S. (table 6) indicate that the potentiometric surface in the northern part of Tule Valley (pl. 1) probably slopes northeastward toward the Fish Springs

Range. Additional water-level data would be necessary to verify the gradient in this area.

The relatively high temperatures of water discharging from springs on the northern part of the valley floor (tables 6 and 8) indicate that the water has circulated to considerable depth. These data, together with the alinement of the numerous warm springs parallel to the major structural features of the area (pl. 1), are believed to indicate the presence of a fault or fault zone intersecting the valley fill in the subsurface. This fault provides a path for water moving upward under artesian pressure to discharge into the valley fill and eventually to the land surface.

The water level in the only well in southern Tule Valley, (C-22-14)1cba-1 (table 6), reportedly is at a lower altitude than farther north. The reported water level could not be verified during this study, and no additional data are available to enable an estimate of the depth to water in this part of the valley.

The north-trending fault along the western base of the House Range (pl. 1) may be the sink for water moving through the consolidated rocks and valley fill in Tule Valley. This major fault crosses the Tule Valley topographic divide at Sand Pass and extends northward along the eastern base of the Fish Springs Range (Stokes, 1964), and it may be a significant pathway for ground-water movement through and out of Tule Valley.

Storage

The total volume of ground water in storage in the Tule Valley drainage basin is unknown. In order to estimate total storage with reasonable accuracy, the following would have to be known in greater detail: the thickness and porosity of the valley fill, the altitude of the potentiometric surface and of the surface of the consolidated rocks underlying the valley fill, and ground-water conditions in both the valley fill and the consolidated rocks.

Changes in the volume of ground water in storage are reflected by changes in water levels or artesian pressures in the aquifers. There are no data from the Tule Valley drainage basin to document such changes. Development by man has not altered the natural system significantly, and natural conditions probably have changed little in the last few thousand years. Therefore, it is assumed that the average volume of water in storage remains constant.

The principal area of natural ground-water discharge includes most of the northern valley floor (pl. 1). In this area, where the depth to the water table ranges from 0 to about 40 ft (12 m) below land surface, an estimated 680,000 acre-ft (838 hm^3) of ground water might be recovered from storage in the upper 100 ft (30 m) of saturated material by gravity drainage to wells. This estimate is based on (1) an assumed average specific yield of 10 percent, (2) a total area of 68,000 acres (27,500 hm^2), and (3) dewatering of the upper 100 ft (30 m) of saturated material.

Table 6.--Records of wells and selected springs

[All wells and springs owned by U.S. Bureau of Land Management and supply water used by livestock.]

Location: See description of numbering system in text.
Geologic source of water: TJi, igneous rocks; MzPzu, sedimentary rocks; Ql, lacustrine deposits; QTa, older alluvium. See table 2 for description.
Altitude of land-surface datum: Above mean sea level, interpolated from U.S. Geological Survey topographic maps.
Water level below land-surface datum: Reported, except m, measured by U.S. Geological Survey personnel; D, reported dry by driller.
Discharge: Reported, except m, measured, and e, estimated by U.S. Geological Survey personnel.
Remarks and other data available: C, chemical analysis in table 8; K, specific conductance, in micromhos/cm at 25°C; L, driller's log in table 9.

Location	Name	Geologic source of water	Year constructed	Depth of well (ft)	Casing Diameter (in)	Casing Depth (ft)	Altitude of land-surface datum (ft)	Date of measurement or report	Water level below land-surface datum (ft)	Discharge (gal/min)	Water temperature (°C)	Remarks and other data available
(C-13-15)23ccb-1	Well 56	QTa	1935	578	6¼	578	4,890	2-10-35	520	25	-	Used during winter grazing season only. Discharges to 5,000-gal storage tank and stock trough near well. Equipped with piston pump.
(C-15-14)22ddd-1	West Swazey Well	QTa	1972	300	6	300	4,545	3- 3-72 1-15-76	148 130m	18 -	- -	Dissolved solids reported 1,620 mg/l. L. Used during winter grazing season only. Discharges to 5,000-gal storage tank and stock trough near well. Equipped with piston pump. Water reportedly milky colored and brackish. Perforated casing 150-260 ft; blank casing 0-150 and 260-300 ft. L.
(C-15-16)11abd-1	Well 58	QTa	1935	521	6¼-4½	521(?)	4,850	1-22-35	440	20	-	Used during winter grazing season only. Discharges to 5,000-gal storage tank and stock trough near well. Equipped with piston pump. C, L.
(C-16-13)33abb-S1	Sinbad Spring	MzPzu	-	-	-	-	7,850	10-12-56	-	4	-	100 ft of 4-in collector pipe in discharge area conveys water to concrete headbox; discharges directly to stock trough.
(C-16-15)13bab-S1	Coyote Spring	Ql	-	-	-	-	4,421	9-19-74 1-15-76	- -	10e 100e	28.0 28.0	Estimated discharge is overflow from 5-ft diameter corrugated steel culvert around orifice at western edge of spring pond. Discharge in and adjacent to spring pond not estimated. K = 2,000 on 1-15-76. C.
26bac-S1	-	Ql	-	-	-	-	4,428	-	-	-	-	
26cab-S1	-	Ql	-	-	-	-	4,428	9-19-74	-	-	24.5	K = 1,700. Sampled at east end of extensive swamp area.
26cba-S1	-	Ql	-	-	-	-	4,428	-	-	-	-	Small spring pond.
26cbd-S1	-	Ql	-	-	-	-	4,428	-	-	-	-	
34dac-S1	Willow Spring	Ql	-	-	-	-	4,419	9-19-74	-	-	19.5	K = 1,900. Nearly circular spring pond about 200 ft in diameter with dense growth of reeds and grass.
(C-16-16)34bcd-1	Indian Trail Well	QTa	1973	260	6	260	4,790	12-20-73 4- 9-76	148 145.8m	55 -	- -	Used during winter grazing season only. Discharges to stock trough near well. Equipped with submersible pump. Water reported "good." L.
(C-17-13)4baa-S1	Wildhorse Spring	MzPzu	-	-	-	-	7,360	-	-	-	-	
(C-17-15)2aba-S1	-	Ql	-	-	-	-	4,419	-	-	-	-	
3dba-S1	-	Ql	-	-	-	-	4,419	-	-	-	-	
3ddb-S1	-	Ql	-	-	-	-	4,419	-	-	-	-	
10aab-S1	-	Ql	-	-	-	-	4,419	9-19-74 1-15-76	- -	- -	27.5 27.5	K = 1,600 on 9-19-74; 1,500 on 1-15-76. Sampled in orifice at south end of spring pond about 100 ft northeast of BLM sign.
10aba-S1	North Tule Spring	Ql	-	-	-	-	4,419	9-19-74	-	-	28.0	Shown on topographic maps as Tule Spring; largest in group of several spring ponds in immediate vicinity of BLM sign.
10aca-S1	-	Ql	-	-	-	-	4,419	9-19-74	-	-	27.0	Spring pond about 300 ft by 40 ft. C.
15abc-S1	South Tule Spring	Ql	-	-	-	-	4,427	9-19-74	-	-	25.0	K = 1,750. Issues in shallow, branching depression, total length about 1,500 ft and average width about 30 ft.
25bca-S1	-	Ql	-	-	-	-	4,428	-	-	-	-	Open-water pool at south end of spring pond full of grass; "swampy" odor; inflow when visited 9-19-74 apparently too slight to keep pond from stagnation.

Table 6.--Records of wells and selected springs--Continued

Location	Name	Geologic source of water	Year con-structed	Depth of well (ft)	Casing Diameter (in)	Casing Depth (ft)	Altitude of land-surface datum (ft)	Date of measurement or report	Water level below land-surface datum (ft)	Discharge (gal/min)	Water temper-ature (°C)	Remarks and other data available
(C-17-15)25bcb-S1	-	Ql	-	-	-	-	4,428	9-19-74	-	-	27.0	K = 2,300. Sampled under dense mat of dead reeds in clump at south end of 20-ft wide, 150-ft long, 5-ft deep depression; except for reeds, bottom of depression covered with salt-grass; standing water in and adjacent to reeds.
25cbb-1	-	MzPzu	1953	42	6	-	4,433	11-20-53	4	200	31.0	Unused. L.
								9-19-74	5.35	-	-	
								4- 9-76	4.90m	-	-	
(C-17-16)28dbd-S1	Skunk Spring	MzPzu	-	-	-	-	5,470	2- 5-52 6-20-73	- -	1.5m 3m	- 16.0	Collection system consists of 565 ft of 4-in drain tile, two concrete head-boxes, and 1,280 ft of 1¼-1½-in galvinized iron pipe. From lowermost collection box, water is conveyed by 2-in pipe 310 ft northeast-ward to 5,000 gal storage tank and stock trough. C.
33bac-S1	Willow Spring-north	MzPzu	-	-	-	-	5,640	-	-	-	-	
33bac-S2	Willow Spring-south	MzPzu	-	-	-	-	5,650	-	-	-	-	
(C-18-15)13dc	-	QTa	1976	-	-	-	4,445	4- 9-76	16.9m	-	-	Uncased 6-in diameter drill-hole.
25ba	-	QTa	1976	-	-	-	4,455	4- 9-76	30.9m	-	-	Do.
(C-19-14)5adc-S1	Painter Spring	TJi	-	-	-	-	5,510	1929 1955 9-19-74	- - -	12 10 4.4m[1]	- - 12.5	Collector pipe in decomposed granite in bottom of gully discharges into corrugated steel headbox; pipeline diverts water from headbox to storage tanks and troughs at (C-19-14)5bcc and (C-19-15)1aaa. 3.0 gal/min inflow measured in headbox, 1.4 gal/min discharge measured from two 2-in pipes in streambed about 30 ft west of collection box. On 9-19-74, additional unmeasured discharge was probably less than 5 gal/min. C.
(C-22-14)1cba-1	Well 108 (Ibex Well)	QTa	1935	515	6¼	493	4,780	1935 9-24-48 4- 9-76	414 - .320m	25 13.9 -	- - 16.5	Used during winter grazing season only. Discharges to 5,000-gal storage tank and stock trough. Equipped with piston pump. C, L.
(C-23-14)1aaa	-	-	1935	401	4	-	4,990	5- 1-35	D	-	-	Abandoned and destroyed. L.

[1]See Remarks and other data available.

Discharge

Discharge of ground water in the Tule Valley drainage basin is principally by evapotranspiration. Wells and springs supply water for livestock; but their total discharge, exclusive of that consumed by evaporation, is insignificant.

Annual ground-water discharge by pumping from wells during the winter grazing season probably averages less than 35 acre-ft (0.04 hm^3). This is based on the assumptions that (1) an average of 15,000 sheep in Tule Valley are supplied by water pumped from wells; (2) these sheep require water for an average of 150 days during the grazing season (when there is no snow cover to provide water); and (3) a sheep consumes an average of 5 gal (19 l) of water per day--the consumptive-use allowance of the Utah Division of Water Rights (Criddle and others, 1962, p. 23). Based on these assumptions, the estimated annual withdrawal of water from wells is 34.5 acre-ft (0.04 hm^3).

Springs in the House and Confusion Ranges (table 6) probably discharge less than 100 acre-ft (0.1 hm^3) annually, most of which is evaporated or consumed by vegetation in the spring areas. Because springs on the northern valley floor discharge in swamps and pools, no attempt was made to estimate discharge directly. The flow of these springs, together with direct discharge from the saturated zone by evapotranspiration, is estimated to average about 40,000 acre-ft (49 hm^3) annually.

Estimates of evapotranspiration

Direct measurements of evapotranspiration are not available for Tule Valley. The nearest field investigations of evapotranspiration are those conducted by White (1932) in Escalante Valley, Utah, about 75 mi (120 km) southwest of the discharge area in Tule Valley. Several empirical methods of computing potential evapotranspiration have been developed; that of Blaney and Criddle (1950), which is based on air temperature, duration of daylight, and vegetal species, is considered the most practical (Cruff and Thompson, 1967, p. M27).

Table 7 compares evapotranspiration estimates for Tule Valley derived by three discrete procedures: (1) application of rates used in a hydrologic reconnaissance of the adjacent Snake Valley area (Hood and Rush, 1965, p. 25); (2) application of rates calculated by White (1932) for Escalante Valley; and (3) application of the Blaney-Criddle method, as described by Rantz and Eakin (1971, p. 25-29).

Table 7.--Estimated average annual ground-water discharge by evapotranspiration

Locality and type of phreatophyte	Area (acres)	Depth to water (ft)	Evapotranspiration, based on: Hood and Rush (1965, p. 25) (ft)	(acre-ft)	White (1932, p. 84-89) (ft)	(acre-ft)	Rantz and Eakin (1971, p. 25-29) (ft)	(acre-ft)
Area A. Alkali flats (bare soil)	7,400	0-2	0.75	5,550	0.5[1]	3,700	0.5[1]	3,700
Area B. Northern valley floor: moderate-density growth of greasewood mixed with pickleweed and saltgrass; extensive dense saltgrass meadows; patches of bare soil	20,000	0-2	.5	10,000	1.0	20,000	1.8	36,000
Area C. Margins of northern valley floor: low-density growth of greasewood; scattered rabbitbrush and shadscale; some saltgrass and bare soil	40,000	0-40(?)	.2	8,000	.4	16,000	.4	16,000
Area D. Swamps and spring ponds: locally dense growths of hydrophytes; open-water pools	200	0	1.75	350	2.0	400	3.5	700
Totals (rounded)	68,000			24,000		40,000		56,000

[1]Rate derived by procedure described on page 20.

Evapotranspiration rates were selected from Hood and Rush (1965, p. 25) for discharge areas most similar to those in Tule Valley (areas A-D, table 7). The rate for area A was used by Hood and Rush for evaporation from "playas that are flooded part of year," with depth to water 0-15 ft (0-4.6 m); for area B, their rate for "mixture of meadow grass and rabbitbrush" with depth to water 2-10 ft (0.6-3 m) was used; for area C, their rate for "mixed greasewood and rabbitbrush" with depth to water 10-50 ft (3-15 m); and for area D, their rate for "wet meadow" with depth to water 0-5 ft (0-1.5 m).

White's calculated evapotranspiration rates were applied to Tule Valley on the basis of similarities in conditions. The rate applied for area A (table 7) was calculated from White's experimental data (after Rantz and Eakin, 1971, p. 29) combined with May-September evaporation at Fish Springs Refuge (table 1) as follows:

Freshwater-pan evaporaporation	5.17 ft
x Pan/open-water coefficient	.7
	3.62 ft
x Soil evaporation coefficient for brown clay loam soil at Milford, Utah, with depth to water 2 ft	.13
	.47 ft (rounded in table)

White's (1932, p. 86-89) rates were applied to other discharge areas (areas B-D, table 7) in Tule Valley as follows: Area B, the rate used was that calculated by White for "meadowlands and adjoining lowlands occupied by saltgrass associated with greasewood, rabbitbrush, and pickleweed, with saltgrass dominant (depth to ground water 0-5 feet)"; area C, White's rate for "lowlands occupied chiefly by greasewood, rabbitbrush, and shad scale with scattering saltgrass, seepweed, and pickleweed (depth to ground water 0-8 feet)"; area D, White's rate for "lands irrigated or naturally subirrigated with ground water, chiefly fields of alfalfa." No land in Tule Valley is strictly comparable to this last category of White's, but the evapotranspiration rate for land in area D is judged to be similar.

In estimating evapotranspiration by the Blaney-Criddle method, the pertinent parameters are related by the equation

$$U = [K\Sigma(T)(p)/100]/12$$

where U is evapotranspiration, in feet, during the growing period,
K is an empirical coefficient dependent primarily on vegetal species,
T is the mean monthly temperature, in degrees Fahrenheit, and
p is the monthly percentage of total daytime hours in the year.

To use the equation for Tule Valley, K values were estimated for areas B-D, table 7, from information given by Rantz and Eakin (1971, p. 26-27) as follows: area B, $K = 0.67$, the average values for mesquite and saltgrass with depth to water 2 ft (0.6 m), adjusted to medium density of growth; area C, $K = 0.13$, the value for mesquite with depth to water 8 ft (2.4 m), arbitrarily reduced by one-half to account for the greater average depth to water, and adjusted to light-density growth; area D, $K = 1.30$, the value recommended for dense growths of hydrophytes.

Mean monthly temperatures (T) for May-September in Tule Valley were assumed to equal the average of temperatures for these months at Partoun and Fish Springs Refuge (table 1). Monthly percentages of total daytime hours (p) were interpolated for 39°30' N latitude from a table in Rantz and Eakin (1971, p. 26).

The rates and volumes of evapotranspiration derived using White's experimental data are assumed to be reasonable for use in estimating the ground-water balance in Tule Valley. The rates are based on field observations in a nearby area with similar climatic, vegetative, and hydrologic conditions. As a matter of interest, the total annual evapotranspiration calculated using White's values is equal to the average evapotranspiration calculated by the other two procedures (table 7).

Ground-water balance

The reconnaissance methods used in estimating recharge and discharge are intended to provide reasonable order-of-magnitude estimates. In the Tule Valley drainage basin, the estimated volume of ground-water discharge is more than five times greater than the estimated volume of recharge from local precipitation.

Recharge from precipitation is estimated to average 7,600 acre-ft (9.4 hm^3) annually (table 3). Discharge, principally by evapotranspiration, is estimated to average slightly more than 40,000 acre-ft (49 hm^3) annually. Development of ground water by man is negligible and a natural equilibrium prevails, in which long-term average recharge and discharge are in balance. Thus, about 32,000 acre-ft (39.5 hm^3) of recharge in addition to that from precipitation in the basin is assumed to enter the system each year.

Subsurface inflow from adjacent areas is an additional source of recharge. A detailed regional investigation would be required to confirm the sources and calculate directly the volume of such inflow. Reconnaissances of Snake Valley (Hood and Rush, 1965, p. 20-21) and Wah Wah and Pine Valleys (Stephens, 1974, p. 26-27, and 1976, p. 17, respectively), however, indicate that interbasin ground-water flow does occur, and such flow probably provides the recharge required to balance estimated discharge in the Tule Valley drainage basin.

If the fault at the western base of the House Range is a major conduit for ground-water flow through Tule Valley, as discussed in the section on ground-water occurrence and movement, then the total volume of water moving through the Tule Valley drainage basin may be considerably larger than the estimates given in this report.

Chemical quality and temperature of the water

Exclusive of springflow, the only information available on the chemical quality of surface water in the Tule Valley drainage basin consists of a single field measurement of specific conductance and temperature of water in Madsen-Coates Pond, (C-21-14)24ab (table 5), on February 13, 1974. The specific conductance was 1,150 micromhos/cm at 25°C, from which the concentration of dissolved solids is estimated to be about 700 mg/l. The water temperature was 5.5°C (42°F), about the same as the air temperature at the time of sampling. The water in the reservoir was from local snowmelt. The concentration of dissolved

solids in water in this and other reservoirs in the area could be expected to increase rapidly with prolonged storage and concomitant evaporation.

Table 8 gives the results of chemical analyses of ground water in the basin. Plate 1 shows the location of sampling sites, the general chemical character of the water samples, and water temperatures and estimated dissolved-solids concentrations for several springs on the valley floor.

Table 8.--Chemical analyses of ground water

Dissolved solids: Calculated from sum of determined constituents, except r, residue on evaporation at 180°C.

Location and name of source	Date of collection	Temperature (°C)	Micrograms per liter			Milligrams per liter																	Specific conductance (micromhos/cm at 25°C)
			Dissolved iron (Fe)	Dissolved manganese (Mn)	Dissolved boron (B)	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrite (NO_2) + nitrate (NO_3) as N	Dissolved orthophosphate as P	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness	Percent sodium	Sodium-adsorption ratio	
(C-15-16)11abd-1 Well 58	1-15-76[1]	-	-	-	310	24	33	35	160	9.0	132	-	130	240	0.7	4.2	0.01	716	230	120	59	4.6	1,270
(C-16-15)13bab-S1 Coyote Spring	9-19-74	28.0	30	0	610	23	71	38	350	37	266	-	330	450	1.1	.12	.04	1,430	330	120	67	8.3	2,400
(C-17-15)10aca-S1 Tule Spring group	9-12-62	21.0[2]	-	-	240	-	72	41	201	20	248	0	262	230	-	-	-	992r	350	147	54	4.7	1,590[2]
(C-17-16)28dbd-S1 Skunk Spring	6-20-73[3]	16.0	50	20	440	16	240	110	170	2.8	264	0	270	640	.7	.43	.01	1,580	1,100	840	26	2.3	2,700
(C-19-14)5adc-S1 Painter Spring	9-19-74	12.5	70	0	130	27	80	20	110	3.9	259	-	46	170	.4	.06	.01	585	280	70	45	2.9	900
	1-21-75	-	-	-	70	20	73	16	90	2.9	264	-	43	140	.6	.08	.06	516	250	32	44	2.5	931
(C-22-14)1cba-1 Ibex Well	1935	-	-	-	-	-	12	0	-	-	170	-	94	116	-	-	-	522r	-	-	-	-	-
	1-14-76[1]	-	-	-	340	22	47	33	180	19	297	-	200	170	1.1	.53	.01	821	250	10	59	4.9	1,320

[1]Sample collected from storage tank near well.
[2]Temperature in spring pool was 27.0°C; specific conductance was 1,575 micromhos/cm at 25°C on 9-19-74.
[3]Sample collected from stock-tank overflow.

Dissolved-solids concentrations in ground-water samples ranged from 516 to 1,580 mg/l (table 8). All the sources sampled yield water that apparently is satisfactory for stock use. According to the classification system developed by the U.S. Salinity Laboratory Staff (1954, p. 79-81), water from springs listed in table 8 has low or medium sodium hazard and high or very high salinity hazard for irrigation use.

Springs on the valley floor in Tps. 16-17 S., R. 15 W., discharge water at temperatures of 19.5° to 28.0°C (67°-82°F), or about 8.5-17.0°C (15-31°F) higher than the estimated mean annual air temperature of 11.0°C (52°F) on the floor of Tule Valley. Thus, these springs can be classed as "thermal" or "warm" springs. (See Mundorff, 1970, p. 7.)

Measurements are not available on the geothermal gradient in Tule Valley. A recent geothermal-gradient map (American Association of Petroleum Geologists, 1973) shows a probable gradient of about 1°F/100 ft (1.8°C/100 m). Using this gradient, the temperature of the springflow could be accounted for by circulation of atmospheric water to depths of 1,500-3,000 ft (457-914 m) below land surface.

The alinement of springs and consolidated-rock outliers on the floor of northern Tule Valley and the attitude of the rock layers in the outliers are believed to indicate the presence of a north-trending fault in the bedrock near the middle of R. 15 W. in Tps. 16-18 S. (pl. 1). The location and thermal character of the springs in this area are believed to be a direct result of upward movement of water from considerable depth along the fault. The water is assumed to be subsurface inflow from adjacent areas, as discussed on page 21.

SUMMARY AND RECOMMENDATIONS

Surface-water supplies in the Tule Valley drainage basin are negligible. Annual runoff reaching the valley floor averages about 4,000 acre-ft (4.9 hm^3), and all streams in the basin are ephemeral. Small reservoirs intermittently provide some water for livestock. Because streamflow is only local and infrequent, reservoir storage is not dependable; and there is little potential for additional development of surface water.

Annual recharge to the ground-water system from precipitation in the basin averages about 7,600 acre-ft (9.4 hm^3). Ground-water discharge, principally by evapotranspiration on the valley floor, averages about 40,000 acre-ft (49 hm^3) annually. Because the ground-water system is in a state of equilibrium, long-term average recharge and discharge must balance. Thus, an average of about 32,000 acre-ft (39.5 hm^3) of recharge must enter the system each year from sources other than local precipitation. The most probable source of such recharge is subsurface inflow from adjacent areas.

Records are available for six springs that discharge a total of about 100 acre-ft (0.1 hm^3) of ground water annually from consolidated rocks in the House and Confusion Ranges. Numerous other springs issue from the valley fill in the northern part of the valley; their flow is consumed by evapotranspiration and is included in the estimate of total ground-water evapotranspiration. Five wells completed in the valley fill are pumped to supply stock water during the winter grazing season. Total pumpage is less than 35 acre-ft (0.04 hm^3) annually.

Additional ground-water supplies could be obtained in parts of Tule Valley from wells completed in the valley fill. In the 68,000 acres (27,520 hm^2) that constitute a natural discharge area in the northern part of the valley, about 700,000 acre-ft (863 hm^3) of water might be obtained by withdrawals from storage and by capture of water now being consumed by evapotranspiration. An increase of this magnitude in withdrawals would result in dewatering of the upper 100 ft (30 m) of saturated material, eradication of existing phreatophytes and hydrophytes, and cessation of flow from springs.

Any proposal to withdraw large quantities of ground water in the Tule Valley drainage basin should be preceded by exploratory drilling and aquifer testing. The nature of subsurface materials and ground-water conditions are not known well enough to provide a basis for locating, designing, or estimating potential withdrawal rates of wells. The

valley fill is similar to that in other desert basins in western Utah and might yield large quantities of water to individual wells. However, the lithologic and hydrologic characteristics of the valley fill vary from place to place, the aquifer materials are discontinuous and erratically distributed, and the configuration of the potentiometric surface is poorly defined. The potential for large-scale ground-water development at any site, and the overall potential of the basin, cannot be evaluated until more detailed investigations are made.

Ground water in quantities sufficient for livestock supplies probably could be obtained from wells completed in the valley fill, and possibly in the underlying bedrock, at many locations on the alluvial apron at the base of the Confusion Range and nearly anywhere on the valley floor. Depth to ground water should range from zero or a few feet below land surface on the northern part of the valley floor (as at well (C-17-15)25cbb-1, table 6), to 400 ft (120 m) or more in the southern part (as at well (C-22-14)1cba-1), and to 500 ft (150 m) or more on the alluvial fans (as at well (C-13-15)23ccb-1). The drillers' logs in table 9 indicate the general nature of the materials underlying the alluvial slopes and southern valley floor.

The chemical quality of ground water in the basin apparently is satisfactory for livestock. Before other uses are considered, additional water-quality studies should be made.

Water-resources reconnaissances of several adjoining desert basins in western Utah and eastern Nevada, including this one of the Tule Valley basin, provide evidence to support a theory of regional interbasin ground-water flow. A more detailed regional study is needed to obtain direct evidence to verify this theory and to provide a basis for more accurately estimating volumes of interbasin flow. Such a study would be especially helpful in evaluating the potential for additional ground-water development in the Tule Valley drainage basin because about 80 percent of the estimated recharge is attributed to subsurface inflow from adjacent areas.

Table 9.--Drillers' logs of wells

Altitudes are for 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-13-15)23ccb-1. Log by H. M. Robinson. Alt. 4,890.		
Gravel	16	16
Clay, white, and gravel layers	225	241
Clay and gravel	69	310
Sand, fine, and gravel; water	15	325
Clay and gravel in alternating layers	205	530
Sand, fine; water	48	578
(C-15-14)22ddd-1. Log by C. A. Stephenson. Alt. 4,545.		
Topsoil, rocky, brown	1	1
Rocks, large, and loose brown sand	109	110
Rocks, smaller, and slightly clayey red sand	40	150
Clay and sand mixed, tan; water	100	250
Gravel, clean; water	10	260
Shale, green	20	280
Shale, gray	20	300
(C-15-16)11abd-1. Log by H. M. Robinson. Alt. 4,850.		
Sand and gravel	7	7
Clay and sand in alternating layers	283	290
Clay, sandy, yellow	50	340
Clay, yellow	100	440
Gravel; water	6	446
Clay, brown, and some gravel	47	493
Gravel, coarse; much water	17	510
Clay, brown, and gravel	11	521
(C-16-16)34bcd-1. Log by C. A. Stephenson. Alt. 4,790.		
Clay, sand, and gravel mixed, tan	170	170
Clay, sand, and gravel mixed, tan; some water	40	210
Clay, sand, and gravel layers, tan; more water	30	240
Unreported	20	260
(C-17-15)25cbb-1. Log by J. C. Petersen. Alt. 4,433.		
Clay	12	12

Table 9.--Drillers' logs of wells--Continued

	Thickness	Depth
(C-17-15)25cbb-1.--Continued		
Mud, sandy, soft.	18	30
Lime rock, thin layers, with thin layers of sandy mud	9	39
Lime rock with crevices; water.	3	42
(C-22-14)1cba-1. Log by C. W. Anderson. Alt. 4,780.		
Clay and conglomerate boulders.	25	25
Conglomerate.	303	328
Gravel, brown, cemented	13	341
Conglomerate, gray.	22	363
Boulders and conglomerate	62	425
Clay, red, sand, and gravel; water.	90	515
(C-23-14)1aaa-1. Log by W. E. Cook. Alt. 4,990.		
Gravel and boulders	37	37
Sand, gravel, and boulders.	36	73
Clay and fine gravel.	53	126
Clay and sand	17	143
Clay and fine sand.	22	165
Clay, sand, and gravel.	50	215
Gravel, coarse.	4	219
Clay and sand	102	321
Clay, sand, and boulders.	51	372
Gravel, coarse, and boulders.	9	381
Clay, coarse gravel, and boulders	20	401

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