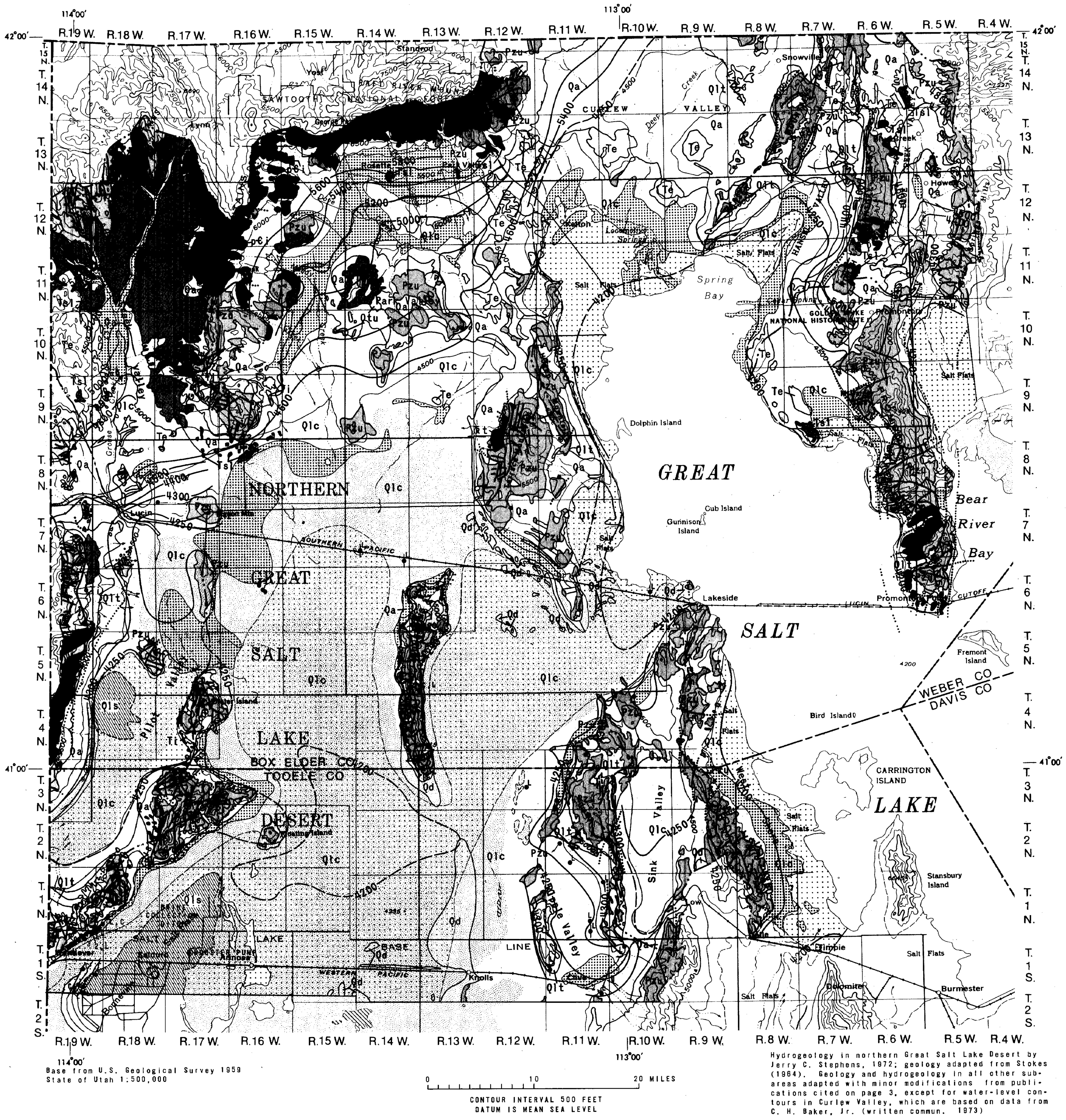
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

TECHNICAL PUBLICATION NO. 42
PLATE I 1974



EXPLANATION

GEOLOGY
(see table I)

CENOZOIC

Quaternary:
- **Qd** Dune sand — Predominantly medium to fine gypsum sand; locally may contain perched ground water
- **Qa** Alluvium and colluvium — Sand, gravel, boulders; generally unsaturated
- **Qls** Evaporite deposits — Coarsely crystalline salt crust; slightly to moderately permeable
- **Qlc** Lakebed deposits — Mostly clay and silt; transmit water slowly except where jointed
- **Qlt** Lakeshore and near-shore deposits — Sand and gravel in bars, spits, and terraces; transmit water readily; generally unsaturated

Tertiary and Quaternary:
- **QTu** Older alluvium — Conglomeratic deposits of clay, sand, and gravel; unconsolidated to well cemented with calcium carbonate; slightly to highly permeable

Tertiary:
- **Te** Extrusive igneous rocks — Chiefly basaltic lava flows and pyroclastics; generally low permeability except where fractured
- **Ti** Intrusive igneous rocks — Chiefly granitic; some basaltic intrusives locally; generally low permeability
- Salt Lake Formation — Interbedded sandstone, claystone, limestone, volcanic ash, and poorly consolidated sand and gravel; slightly to moderately permeable

MESOZOIC

Triassic:
- Thaynes Formation — Sandy to shaly limestone with some dolomite, claystone, and shale; generally low permeability

PALEOZOIC

Middle Cambrian to Permian:
- **Pzu** Sedimentary rocks, undivided — Chiefly limestone, dolomite, and shale; locally include sandstone, quartzite, and evaporites; generally low permeability except where fractured or containing solution openings

PRECAMBRIAN and PALEOZOIC

Precambrian to Early Cambrian:
- Quartzite and associated metamorphic rocks, undivided — Chiefly quartzite; locally include limestone, dolomite, slate, schist, and conglomerate; generally low permeability except where fractured

PRECAMBRIAN
- Intrusive igneous and associated metamorphic rocks, undivided — Chiefly granitic rocks; generally low permeability

Approximate contact, dashed where inferred

Fault, dashed where concealed, dotted where inferred

Thrust fault, barbs on side of thrust sheet

Fault inferred chiefly on geophysical evidence

HYDROLOGY

4300 — Approximate water-level contour. Shows altitude of water level. Contour interval 100 and 200 feet, with supplementary contour at 4,250 feet. Datum is mean sea level

4200 — Inferred water-level contour, based primarily on land-surface altitude

Spring

Well

Abandoned well

Number by symbol refers to number of wells or springs at same location; L, log of well in table 11; c, chemical analysis in table 12. For all subareas except northern Great Salt Lake Desert, refer to publications cited on page 3 for location of data points

Drainage divide
Arbitrary boundary
} Hydrologic subarea boundary

Areas of evapotranspiration

Phreatophytes, chiefly greasewood, saltgrass, rabbitbrush; includes some irrigated areas and areas of open water

Areas of bare soil with water table less than 10 feet below land surface

MAP SHOWING LOCATION, PHYSIOGRAPHY, PRECIPITATION, AND HYDROLOGIC SUBAREA BOUNDARIES OF NORTHWESTERN UTAH

UNITED STATES DEPARTMENT OF THE INTERIOR
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STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

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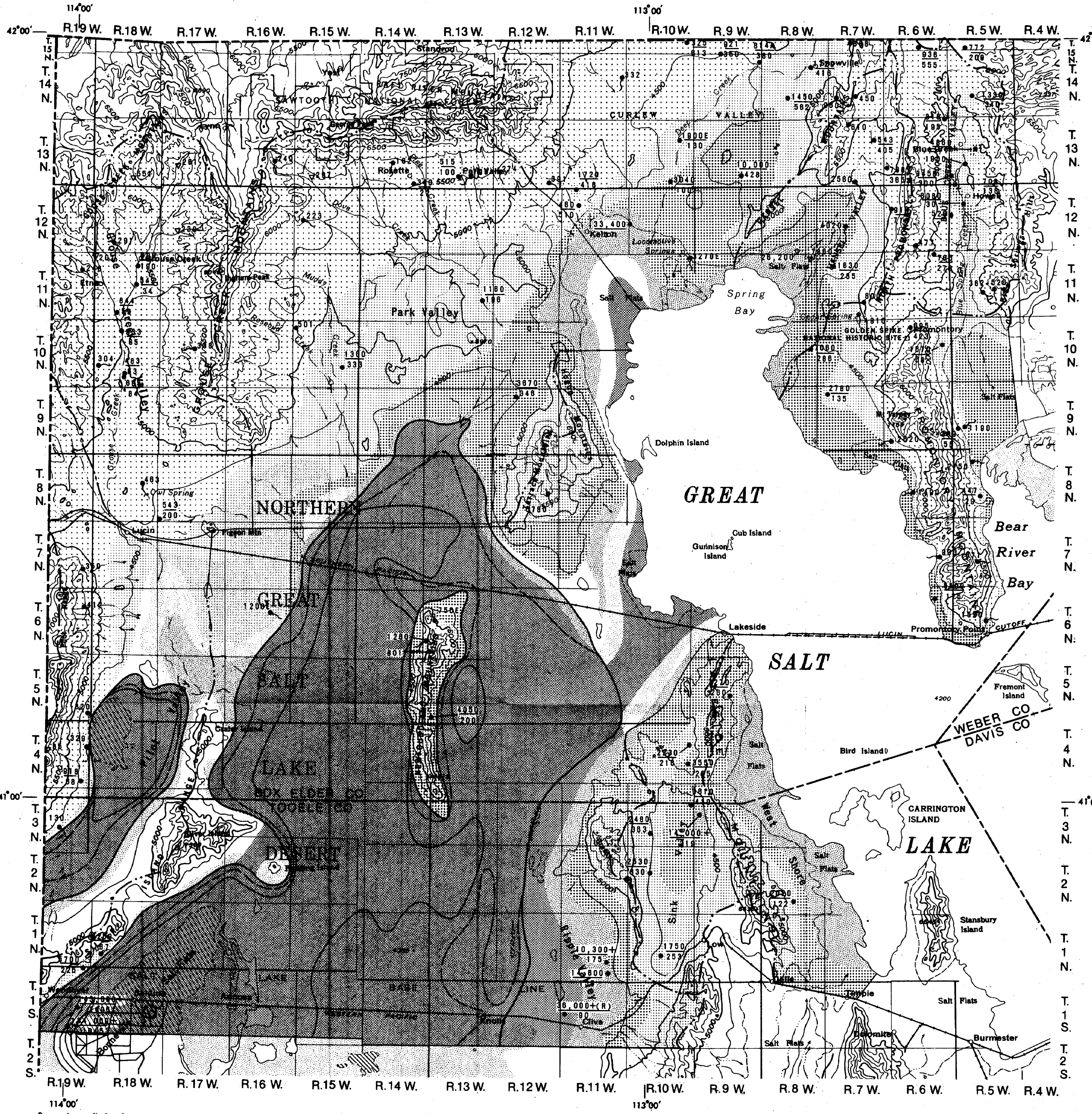

Base from U.S. Geological Survey 1959
State of Utah 1:500,000

0 10 20 MILES

CONTOUR INTERVAL 500 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

Fresh
Less than 1000

Slightly saline
1000-3000

Moderately saline
3000-10,000

Very saline
10,000-35,000

Brine
More than 35,000

Inadequate data

HYDROLOGIC-DATA SITES

Spring 223
Stream 297
Well 36,000+(R) / 90

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER
(R), reported
A, average of several analyses
E, estimated from specific conductance
+, more than
DEPTH OF WELL, IN FEET
?, unknown

Analyses for all data sites are tabulated in publications cited on page 3, except for northern Great Salt Lake Desert, which are given in table 12 and sites in Curlew Valley from C. H. Baker, Jr. (written commun., 1973)

Approximate boundary of shallow brine aquifer

Line of approximately 60,000 milligrams per liter chloride concentration

Line of approximately 100,000 milligrams per liter chloride concentration

After Nolan (1928, pl. 3)

Drainage divide

Arbitrary boundary

Hydrologic subarea boundary

MAP SHOWING GENERALIZED DISTRIBUTION OF DISSOLVED SOLIDS IN GROUND AND SURFACE WATER OF NORTHWESTERN UTAH

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 42

HYDROLOGIC RECONNAISSANCE OF THE NORTHERN GREAT SALT LAKE DESERT AND SUMMARY HYDROLOGIC RECONNAISSANCE OF NORTHWESTERN 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

1974

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GREAT SALT LAKE DESERT AND SUMMARY HYDROLOGIC

RECONNAISSANCE OF NORTHWESTERN UTAH

by

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

ABSTRACT

The northern Great Salt Lake Desert is an area of about 2,100 square miles in the central part of northwestern Utah. Average annual precipitation ranges from about 4.5 to slightly more than 12 inches; total annual precipitation is estimated to average about 620,000 acre-feet. Runoff is scanty and reaches the desert floor only during or immediately after thunderstorms and periods of rapid snowmelt. Drainage is internal except for the part of the area immediately adjacent to Great Salt Lake. Surface outflow to Great Salt Lake is estimated to average less that 500 acre-feet annually.

Three aquifers are present in much of the northern Great Salt Lake Desert. An aquifer composed of crystalline salt and jointed lakebed deposits at and just beneath the land surface averages 25 feet in thickness, underlies about 1,650 square miles of the desert floor, and yields brine. An aquifer of unknown thickness and extent is present in surficial and buried alluvial fans along the mountain flanks and yields fresh to moderately saline water. The most extensive aquifer underlies the entire area where consolidated rocks are not exposed and is made up of unconsolidated to partly consolidated valley fill. This aquifer yields brine to wells completed at depths of 1,000 to 1,600 feet below land surface in the Bonneville Salt Flats area.

Data are incomplete for most ground-water budget items, but these items have been estimated where practicable. The ground-water system receives an estimated 25,000 acre-feet of recharge annually from infiltration of precipitation and at least 5,000 acre-feet from subsurface inflow. Evaporation from the water table under the desert floor discharges about 19,000 acre-feet annually, evapotranspiration by phreatophytes discharges about 2,500 acre-feet, and wells, springs, seeps, and drainage ditches discharge an estimated 4,700 acre-feet.

In general, water under the desert floor contains 150,000 milligrams per liter or more of dissolved solids. Locally in the mountains and peripheral alluvial slopes, fresh to moderately saline ground water is present.

Northwestern Utah includes about 6,000 square miles of saline desert and adjacent uplands north and west of Great Salt Lake. Annual

precipitation in the area ranges from about 4.5 inches on the desert floor to slightly more than 30 inches along the crest of the Raft River Mountains. Total precipitation averages about 2.6 million acre-feet annually and overland runoff averages less than 35,000 acre-feet annually. Surface inflow averages about 9,000 acre-feet annually, and surface outflow to Great Salt Lake is about 15,000 acre-feet.

Ground water is present in alluvium, valley fill, and consolidated rocks. Recharge from infiltration of precipitation is estimated to average about 100,000 acre-feet annually. Subsurface inflow supplies at least 43,000 acre-feet of recharge annually.

Discharge of ground water by direct evaporation and evapotranspiration is estimated to average about 110,000 acre-feet annually. About 13,000 acre-feet of ground water flows out of the area annually in the subsurface, mostly to Great Salt Lake. Discharge by wells, springs, and seeps is estimated to average about 40,000 acre-feet annually.

An estimated 5.6 million acre-feet of ground water could be recovered from storage in the upper 100 feet of saturated aquifer material in northwestern Utah. At least three-quarters of the recoverable water would be highly saline or briny.

Dissolved-solids concentrations in samples from water sources in northwestern Utah range from 85 to 165,000 milligrams per liter. The lowest concentrations are found in surface and ground water in the mountain ranges in the western and northwestern parts of the area, and the greatest concentrations are found in subsurface brines under the desert floor.

INTRODUCTION

This report is the thirteenth in a series prepared by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights, that describes the water resources of selected basins in western Utah. The purpose of this series of reconnaissances is to analyze available hydrologic data, to evaluate present and potential water-resource development, and to identify additional studies that might be needed in the future to provide a fuller understanding of the hydrologic system.

This report presents an overall view of the water resources of the northern Great Salt Lake Desert, its tributary valleys and certain adjacent areas, and summarizes reconnaissances completed through 1971 in northwestern Utah. Basic hydrologic data for the northern Great Salt Lake Desert are contained in the appendix.

PREVIOUS STUDIES AND ACKNOWLEDGMENTS

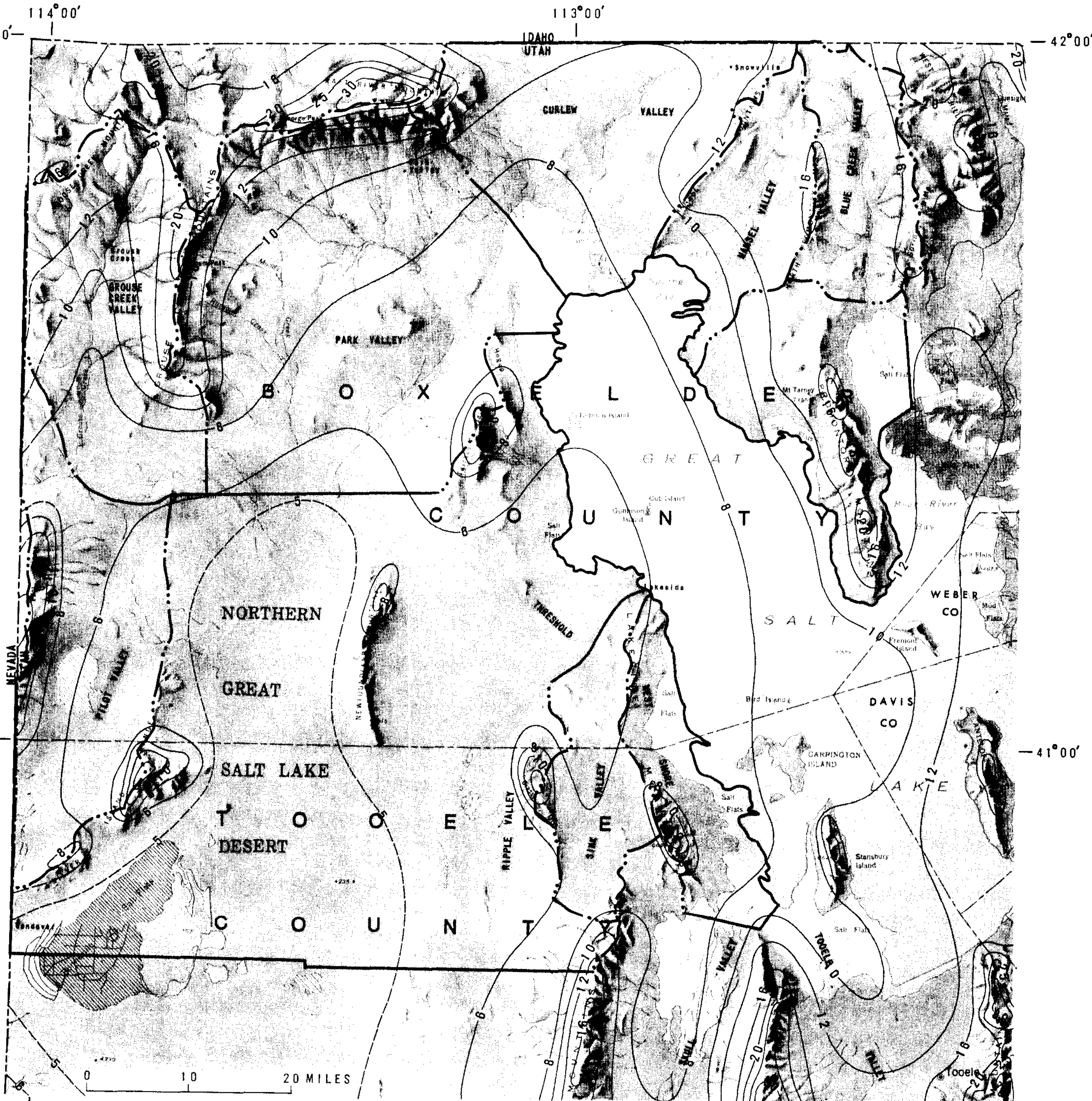
Listed below are references to publications that describe the general environment and hydrology of parts of northwestern Utah for which reconnaissances have been completed. Figure 1 shows the boundaries of the subareas. Table 1 gives a general description of the hydrologic and geologic characteristics of the rocks of northwestern Utah.

Subarea	Reference
Blue Creek Valley	Bolke and Price (1972)
Promontory Mountains	Hood (1972)
Hansel Valley	Hood (1971a)
Curlew Valley	Bolke and Price (1969)
Park Valley	Hood (1971b)
Grouse Creek valley	Hood and Price (1970)
Pilot Valley	Stephens and Hood (1973)
Sink Valley	Price and Bolke (1970)
West Shore	Price and Bolke (1970) Hood and Waddell (1968)

The investigations on which these reports are based consisted largely of studies of available data for geology, streams, wells, springs, climate, and water use. These data were supplemented with field data for landforms, vegetation, geology, and water resources collected during a brief reconnaissance of each area.

In addition to the investigations of specific subareas that are cited above, several other investigations directly or indirectly related to the hydrology of northwestern Utah have been conducted since about 1900. Publications containing the results of many of these investigations are referred to in the text and cited in the list of references.

The help and cooperation of officials of the many State and Federal agencies concerned with water resources of northwestern Utah are gratefully acknowledged. Special thanks are due Mr. M. W. Lallman and Mr. H. C. Ballard, Bonneville, Ltd., Division of Kaiser Aluminum and Chemical Corp., for making available data from their files and for courtesies extended during a visit to the Wendover plant. Mr. J. G. Macey provided valuable information and assistance for the area near Lakeside. J. W. Hood, U.S. Geological Survey, carried out many of the investigations of individual areas that are summarized in this report, and accompanied the writer during field investigations of previously unstudied



EXPLANATION

———5———— Line of equal normal annual precipitation, 1931-60; interval 2 and 4 inches; supplementary 5-inch line and adjusted lines near State line dashed

Drainage divide } Hydrologic subarea boundary
Arbitrary boundary }

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

Climatologic data from U.S. Weather Bureau (1963). Adjusted along State line to reconcile with Nevada data (Hardman, 1965) by J. W. Hood and J. C. Stephens

Figure 1.—Map showing location, physiography, precipitation, and hydrologic subarea boundaries of northwestern Utah.

Table 1.--General description and water-bearing characteristics of hydrogeologic units in northwestern Utah

Hydrogeologic unit: Symbols in parentheses refer to designation on plate 1.

Age			Hydrogeologic unit	Occurrence and lithology	Water-bearing characteristics
CENOZOIC	Quaternary	Pleistocene and Holocene	Dune sand (Qd)	Linear ridges and discontinuous patches along margins of northern Great Salt Lake Desert. Predominantly medium to fine gypsum sand (Eardley, 1962, p. 10). Maximum thickness about 50 feet.	Highly permeable, retains sufficient soil moisture from rainstorms and snowmelt to support a more luxuriant growth of vegetation than the surrounding areas. Generally unsaturated but locally may contain fresh perched ground water during part of the year.
CENOZOIC	Quaternary	Pleistocene and Holocene	Alluvium and colluvium (Qa)	Thin deposits of sand, gravel, and boulders in stream channels near mountains; blanket-like deposits of angular rock fragments (maximum thickness less than 100 feet) locally on lower mountain slopes; fan-shaped deposits of angular rock fragments (maximum thickness less than 200 feet) locally at mouths of larger canyons.	Generally moderately to highly permeable but too thin to store significant quantities of water. Generally unsaturated, but thickest deposits may be saturated in lower parts. Serve as intake areas for recharge by absorbing precipitation and snowmelt and transmitting the water to underlying rocks. This unit and the underlying older alluvium (QTu) make up an aquifer around much of the periphery of the northern Great Salt Lake Desert.
CENOZOIC	Quaternary		Evaporite deposits (Qlsa)	Form land surface in central Pilot Valley and on Bonneville Salt Flats east of Wendover. Permanent crust of coarsely crystalline salt formed on lakebed deposits. Maximum thickness 5 feet.	Crystalline salt crust is saturated with brine to within a few inches of land surface. Generally moderately to slightly permeable; discharges ground water by evaporation.
CENOZOIC	Quaternary	Pleistocene	Lakebed deposits (Qlc)	Underlie nearly all the northern Great Salt Lake Desert below altitude of about 4,250 feet; locally in valleys adjacent to desert form land surface below 5,200 feet. Generally thin (maximum thickness probably less than 100 feet) deposits of clay and silt with moderate to large salt content; deposits of Lake Bonneville.	Deposits on the floor of the northern Great Salt Lake Desert and around the margins of Great Salt Lake are permanently moist, highly saline, and discharge ground water by evaporation. At higher altitudes, the deposits retain sufficient moisture to support the growth of some vegetation; but because of generally slight permeability, most rainfall and snowmelt runs off. Open-joint structure creates locally high permeability under desert floor, but joints generally sealed at land surface by expansion of clays when wet. Yields brine in Bonneville Salt Flats.
CENOZOIC	Quaternary	Pleistocene	Lakeshore and near-shore deposits (Qlt)	Extensively developed in Grassy Mountains and along northeastern flank of Pilot Range and locally around most of the remaining margin of northern Great Salt Lake Desert. Deposits of Lake Bonneville consisting of sand and gravel in spits, bars, and terraces. Generally less than 50 feet thick.	Moderately to highly permeable but generally unsaturated. Locally may contain perched ground water during part of the year. Serve as recharge areas in same manner as alluvium and colluvium (Qa) described above.
CENOZOIC	Tertiary and Quaternary	Pliocene(?) to Pleistocene	Older alluvium (QTu)	Conglomeratic deposits of clay, sand, and gravel in outcrops in Grouse Creek and Park Valleys. Unconsolidated to well cemented with calcium carbonate. Equivalent deposits underlie most of the alluvial and lacustrine deposits of northwestern Utah, where they include sandstone, boulders mixed with clay, and thick beds of hard clay. Thickness increases toward southwest; maximum may be 1,500 feet or more southeast of Wendover under salt flats.	Slightly to highly permeable; functions as a part of one or more aquifers throughout most of area. Yields of more than 1,000 gallons per minute of fresh water reported from irrigation wells in Park Valley (Hood, 1971b, p. 7), and 1,300 gallons per minute of brine reported from industrial wells near Wendover.
CENOZOIC	Tertiary		Extrusive igneous rocks (Te)	Generally small, isolated outcrops around the periphery of the northern Great Salt Lake Desert; exposed over large area west of Grouse Creek Valley. Interlayered with older alluvium or Salt Lake Formation in the subsurface. Volcanic rocks, chiefly basaltic lava flows and pyroclastics, ranging from early to late Tertiary in age and from felsic to mafic in composition.	Permeability highly variable. Rocks basically have low permeability but transmit water through fractures, joints, and vesicular or rubbly zones between flows. In Curlew Valley, this unit and the interfingering older alluvium and Salt Lake Formation constitute the main ground-water reservoir.
CENOZOIC	Tertiary		Intrusive igneous rocks (Ti)	Crop out in Grouse Creek and Newfoundland Mountains and Pilot and Silver Island Ranges. Chiefly granitic rocks; include small basaltic intrusive bodies in Pilot Range.	Generally low permeability, but locally the rocks transmit water through fractures, joints, and fault zones. Yield water to many small springs discharging 10 gallons per minute or less in the Pilot Range and in the Grouse Creek and Newfoundland Mountains.
CENOZOIC	Tertiary		Salt Lake Formation (Tsl)	Crops out extensively in northern part of Grouse Creek valley and locally on the flanks of other mountain ranges, and underlies most of the area where younger rocks are exposed. Consists of interbedded claystone, limestone, volcanic ash, sandstone, and poorly consolidated sand and gravel. Character of material differs greatly from place to place, depending on local conditions at time of deposition.	Unit as a whole probably has low permeability, but some clastic interbeds are moderately permeable locally. Makes up a part of the major ground-water reservoir throughout much of northwestern Utah.
MESOZOIC	Triassic		Thaynes Formation (Ѣt)	Crops out locally on the flanks of the Goose Creek, Grouse Creek, and Terrace Mountains. Subsurface extent unknown. Brown to reddish and maroon, sandy to shaly limestone, with some dolomite, claystone, siltstone, and gray-green shale. Chert lenses common throughout formation.	Generally low permeability but may yield water to small springs and seeps along zones of faulting, jointing, and fracturing.
PALEOZOIC	Middle Cambrian to Permian		Sedimentary rocks, undivided (Pzu)	Crop out extensively in the cores of most of the mountain ranges in the area. Probably underlie most of area at considerable depth. Consist mainly of limestone, dolomite, and shale; locally include quartzite, sandstone, and evaporites.	Permeability of unit as a whole is low; where fractured, jointed, faulted, or containing solution openings, unit may transmit large quantities of water.
PRECAMBRIAN and PALEOZOIC	Precambrian to Early Cambrian		Quartzite and associated metamorphic rocks, undivided (Ꞓp€q)	Form the cores of the Pilot Range and of the Grouse Creek and Raft River Mountains. Subsurface extent unknown. Chiefly quartzite, but includes some limestone, dolomite, shale, schist, and conglomerate.	Unit as a whole has low permeability, but where structurally deformed contains open fractures and joints that transmit water readily.
PRECAMBRIAN			Intrusive igneous and associated metamorphic rocks, undivided (p€i)	Chiefly granitic rocks that crop out locally in Grouse Creek and Raft River Mountains.	Low permeability, but where fractured supports flow of some small springs.

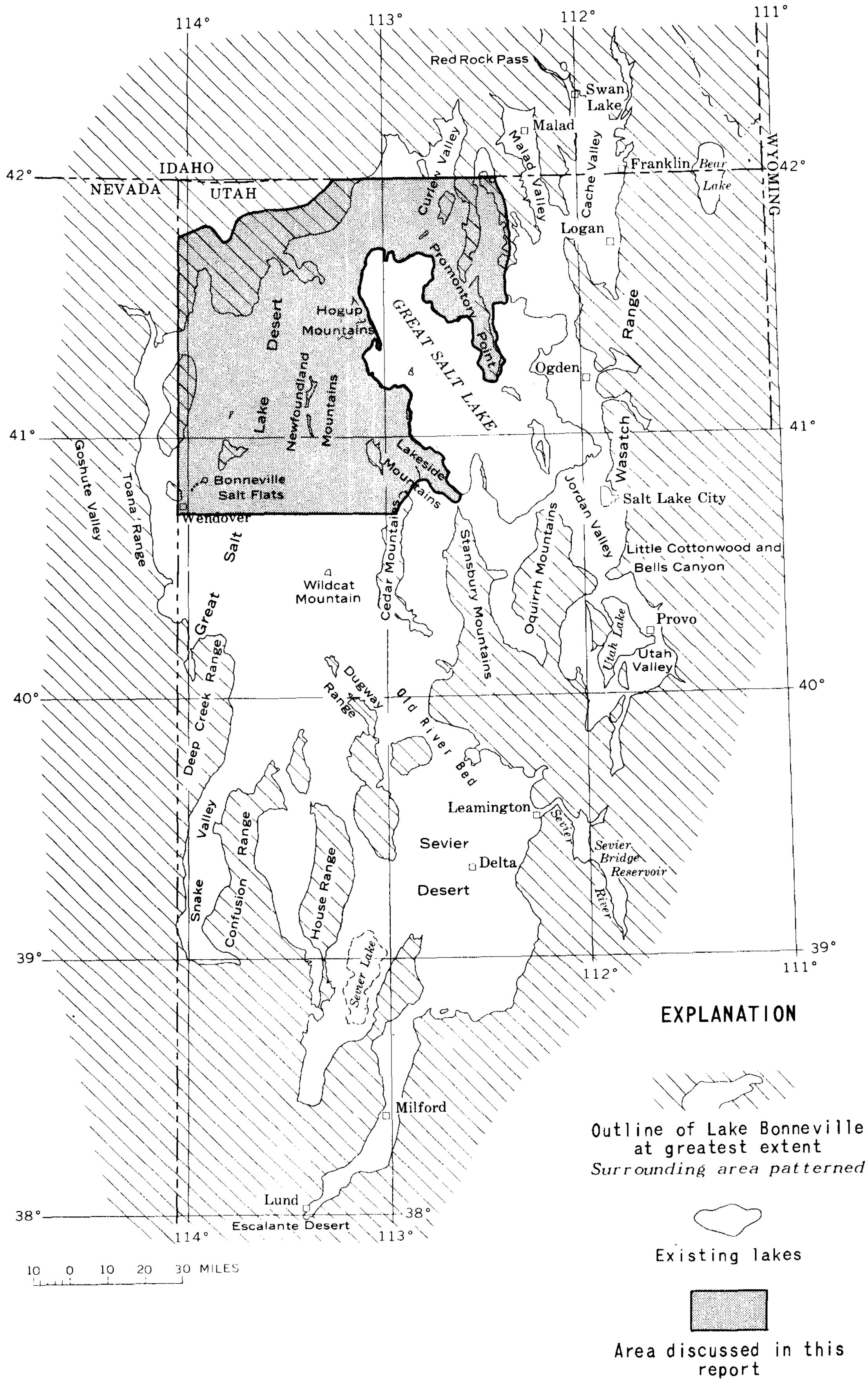


Figure 2.—Map of Lake Bonneville (after Crittenden, 1963).

areas. He provided valuable insight into the application of hydrologic reconnaissance methods to the arid areas of western Utah and the analysis of data resulting therefrom.

HYDROLOGIC RECONNAISSANCE OF THE NORTHERN GREAT SALT LAKE DESERT

Location and general features

The northern Great Salt Lake Desert (fig. 1) includes about 2,100 square miles of predominantly barren uninhabited salt and saline clay flats in the central part of northwestern Utah. The rather unique surface features of the area reflect its recent geologic history--for thousands of years, until about 10,000 years ago (Eardley, 1962, p. 22), the Great Salt Lake Desert was covered by the waters of Lake Bonneville (fig. 2). The drying up of this extensive fresh-water lake left behind as evaporation residue the salt that so characterizes the present desert.

The mountain ranges that border the northern Great Salt Lake Desert are, for the most part, upraised blocks of Paleozoic and Tertiary rocks partially mantled by Quaternary alluvial and lacustrine deposits (pl. 1). The Newfoundland Mountains, which protrude from the desert floor, are geologically similar. The craggy, sparsely vegetated landforms that have developed are characteristic of arid desert mountains.

The climate of the northern Great Salt Lake Desert, which is generally similar to that of adjacent valleys described in published reports of this series (see p. 3), is temperate, semiarid to arid, with generally hot and dry summers and cold and moderately moist winters. Selected climatologic data for Wendover, the site of the only active long-term weather station in the northern Great Salt Lake Desert, are summarized in figure 3 and table 2. These data show long-term climatic trends and provide some indication of the pronounced annual, seasonal, and monthly fluctuations in precipitation and temperature that characterize the desert climate.

Precipitation averages less than 6 inches annually over the entire floor of the northern Great Salt Lake Desert and in the central part averages less than 5 inches (fig. 1). Only in the Terrace, Hogup, Grassy, and Newfoundland Mountains and in the Silver Island Range does average annual precipitation exceed 6 inches. Total precipitation on the area is estimated to average about 620,000 acre-feet annually (table 3).

Hydrology

Surface water

The only perennial streams in the northern Great Salt Lake Desert are in the Newfoundland Mountains, where small perennial springs discharge enough water to maintain flow for short reaches in channels cut in relatively impermeable bedrock (see (B-6-13)30bc-S, 31ac-S, and 31db-S, table 10).

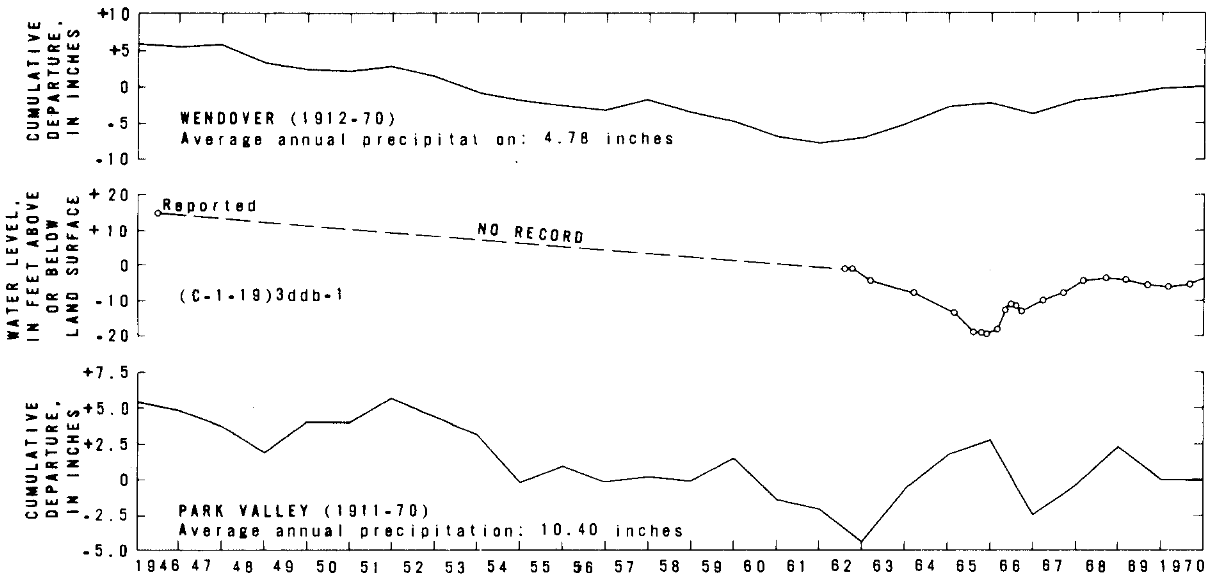


Figure 3.—Water levels in observation well (C-1-19)3ddb-1 and cumulative departure from average annual precipitation at Wendover and Park Valley, Utah.

Computed surface runoff, even from the highest parts of the mountains in the area, averages less than 1 inch annually (Bagley and others, 1964, p. 55; Busby, 1966). Most of the estimated 620,000 acre-feet of precipitation that falls annually on the area is consumed by evapotranspiration or temporarily stored as soil moisture. During and immediately following the frequent late-summer thunderstorms, and during brief periods of rapid snowmelt, some water runs off the steep consolidated-rock slopes of the mountains. Very little of this runoff reaches the base of the mountains, however, because it infiltrates the alluvial stream channels downslope from the consolidated-rock areas. Where stream channels are floored by consolidated rock all the way to the desert floor, ephemeral runoff may flow onto the flats, where it spreads out in a thin sheet and either evaporates directly or is temporarily stored as ice or soil moisture.

Some runoff originating on the desert in and west of the "Threshold" (fig. 1) flows into the Great Salt Lake near Lakeside. The quantity and frequency of occurrence of such flow are unknown, but the long-term average discharge is believed to be less than 500 acre-feet annually. As elsewhere in the northern Great Salt Lake Desert, surface flow in the "Threshold" area occurs only in response to sporadic, intense thunderstorms or rapid snowmelt.

Except for the "Threshold" area and the eastern flanks of the Terrace and Hogup Mountains, surface drainage in the northern Great Salt

Table 2.--Monthly precipitation and mean temperature at Wendover, 1961-1970

[Data from U.S. Weather Bureau (1962-67) and U.S. Environmental Science Services Administration (1968-71)]

Precipitation: In inches; T, trace (amount too small to measure).
Temperature: In degrees Fahrenheit (°F).
Minimum monthly for period 1961-70 underlined with single line; maximum monthly underlined with double line.
Average for period of record: Length of record for January-May precipitation, 59 years; June-December precipitation, 60 years; January-March and October-December temperature, 55 years; April-September temperature, 54 years.

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1961													
Precipitation	T	0.25	0.42	0.08	0.51	0.04	0.03	0.70	0.46	0.67	0.76	0.25	4.17
Temperature	24.4	37.7	42.2	51.6	61.7	78.1	82.4	78.8	61.1	50.6	34.5	29.5	52.7
1962													
Precipitation	.29	1.29	.35	.49	.76	.72	.27	.04	.06	.94	T	T	5.21
Temperature	24.0	31.7	37.8	54.8	59.0	70.1	77.6	76.1	67.9	55.8	41.0	26.5	51.9
1963													
Precipitation	.20	.27	.15	.92	.93	1.96	.00	.26	.58	.56	.73	.25	6.81
Temperature	20.7	41.0	41.1	45.0	64.3	63.5	78.8	77.6	68.9	58.2	38.9	25.7	52.0
1964													
Precipitation	.18	.03	.80	.46	1.48	3.01	.03	.03	T	.13	.16	.86	7.17
Temperature	26.4	30.2	36.8	48.9	58.7	65.3	81.4	74.6	63.1	52.6	36.8	33.8	50.7
1965													
Precipitation	.11	.22	.05	.42	.41	1.13	.41	1.01	.55	.02	.41	.59	5.33
Temperature	33.5	34.5	38.2	52.0	56.7	67.7	77.3	72.5	59.6	54.2	42.7	26.9	51.3
1966													
Precipitation	.07	.28	.18	.27	.26	.23	.44	.02	.37	T	.22	.79	3.13
Temperature	27.9	32.0	41.8	50.7	64.5	70.5	80.6	76.9	68.5	50.2	40.9	25.8	52.5
1967													
Precipitation	.40	.01	.86	.66	1.24	2.00	.63	.01	.42	.28	.03	.15	6.69
Temperature	30.1	37.3	43.6	45.4	59.4	64.9	79.9	79.9	67.8	51.7	41.4	27.3	52.4
1968													
Precipitation	.17	.81	.40	.40	1.06	.97	.39	.49	.06	.35	.16	.20	5.46
Temperature	24.6	38.7	44.7	47.1	59.0	69.4	79.7	70.1	63.5	50.7	39.0	25.8	51.0
1969													
Precipitation	.38	.56	.07	1.02	.04	1.31	.26	.03	.20	.85	.34	.47	5.53
Temperature	30.3	30.3	39.1	50.8	67.4	66.5	79.2	79.9	68.8	46.3	37.4	30.0	52.2
1970													
Precipitation	.08	.06	.12	.30	.42	1.12	.34	.18	.04	.36	1.58	.41	5.01
Temperature	32.0	38.7	40.9	44.8	60.2	69.5	78.3	79.3	59.7	46.9	40.7	25.5	51.4
1961-70 average													
Precipitation	.19	.38	.34	.50	.71	1.25	.28	.28	.27	.42	.44	.40	5.46
Temperature	27.4	35.2	40.6	49.1	61.1	68.6	79.5	76.6	64.9	51.7	39.3	27.7	51.8
Average for period of record													
Precipitation	.28	.32	.35	.48	.65	.62	.31	.32	.35	.44	.29	.33	1/4.78
Temperature	27.3	33.8	42.2	51.5	61.8	70.5	79.8	77.2	66.3	53.0	38.7	29.3	52.6

1/ Not equal to total of average monthly amounts because of rounding.

Table 3.-Estimated average annual volumes of precipitation and ground-water recharge in the northern Great Salt Lake Desert

(Areas of precipitation zones measured from isohyetal and geologic maps, figure 1 and plate 1)

Precipitation zone (inches)	Locality	Area (acres)	Precipitation		Recharge	
			Feet	Acre-feet	Percent of precipitation	Acre-feet
		Consolidated rocks and alluvium				
8-more than 12	West slope Grassy Mountains	7,810	0.88	6,870	8	550
Do	East slope Silver Island Range	10,880	0.88	9,570	8	770
8-more than 10	Terrace and Hogup Mountains	19,260	0.80	15,410	8	1,230
6-more than 8	Newfoundland Mountains	9,020	0.63	5,680	3	170
6-8	Periphery of northern Great Salt Lake Desert	91,650	0.58	53,150	3	1,590
5-6	Flanks of Newfoundland Mountains	24,700	0.46	11,360	2	230
Subtotal		163,320		102,040		4,540
		Lakebed deposits and dune sand				
6-8	Periphery of northern Great Salt Lake Desert	14,530	0.58	8,430	0	0
5-6	Floor of northern Great Salt Lake Desert	648,000	0.46	298,000	0	0
Less than 5	Central part of northern Great Salt Lake Desert	431,000	0.40	172,000	0	0
Do	Bonneville Salt Flats (crystalline salt beds)	96,000	0.40	38,400	(1/)	20,000
Subtotal		1,189,530		516,830		20,000
Total (rounded)		1,350,000		620,000		25,000

1/ See page 13 for discussion of recharge estimate for crystalline salt beds.

Lake Desert is internal. The lowest part of the basin is the Bonneville Salt Flats near Wendover (pl. 1).

Ground water

Ground water occurs in both consolidated and unconsolidated rocks in the northern Great Salt Lake Desert. The major ground-water reservoir, however, is the unconsolidated to partly consolidated valley fill (primarily older alluvium and Salt Lake Formation, table 1), which has a maximum thickness of at least 1,644 feet at well (C-1-19)25baa-1 (see log, table 11) and probably is at least 1,000 feet thick throughout most of the area.

Studies of the hydrogeology of the Bonneville Salt Flats area (Nolan, 1928; Turk, 1969) have produced sufficient data to divide the ground-water system into three distinct segments. The surficial lakebed deposits and crystalline salt comprise an aquifer that yields brines of commercial value near Wendover. Alluvial-fan deposits on the lower slopes of the Silver Island Range and in the subsurface comprise an aquifer that yields moderately saline water. The valley fill that underlies the lakebed deposits and crystalline salt makes up a third aquifer, which also yields brine.

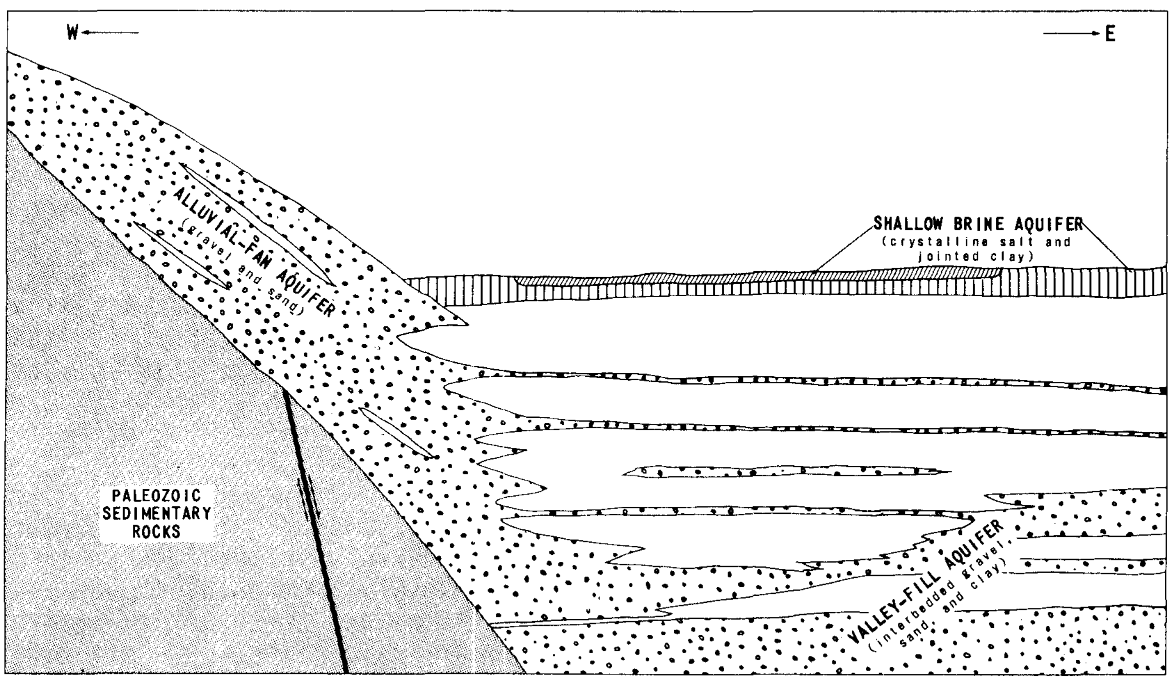


Figure 4.--Inferred subsurface stratigraphic relationships near Wendover.

The inferred stratigraphic relationships among the three aquifers in the Wendover area are shown diagrammatically in figure 4. The following discussions of the three aquifers, although based primarily on studies in the Wendover area, are applicable generally to the northern Great Salt Lake Desert because similar geologic and hydrologic conditions prevail throughout most of the area.

Ground water occurs in the Paleozoic rocks that underlie most of the area. Although these rocks are known to yield water locally, their principal function in the ground-water system may be as conduits for ground-water inflow from adjacent areas.

Shallow brine aquifer

The shallow brine aquifer consists of lakebed clay and silt and crystalline salt and underlies about 1,650 square miles of the northern Great Salt Lake Desert. The U.S. Geological Survey conducted an extensive exploration of the Great Salt Lake Desert in 1925 in order to determine the mode of occurrence, distribution, and general characteristics of potassium-bearing brines in the region. The approximate boundary of the shallow brine aquifer in the northern Great Salt Lake Desert, shown on plate 2, is adapted from the summary report of this exploration (Nolan, 1928).

The shallow lakebed clay and silt throughout most of the northern Great Salt Lake Desert contain brine. According to Nolan (1928, p. 36), "* * *the brine is not uniformly distributed throughout the sediments but is found in thin horizontal zones within them. A few of these zones are determined by sandy beds, but by far the larger number are restricted to thin layers of salt-impregnated clay, which commonly are only a fraction of an inch thick."

Brine movement.-Although the lakebed clay and silt and associated salt deposits may extend to considerable depth, only the upper 25 feet of these materials function as an aquifer (Turk, 1969, p. 104). Brine moves through intercrystalline spaces in the coarsely crystalline salt beds, which reportedly have a maximum thickness of 5 feet near the center of the Bonneville Salt Flats (Nolan, 1928, p. 35). The surface of the salt beds is hard and rigid but the underlying salt deposits are extremely porous and permeable. The salt is saturated with brine to within a few inches of the surface.

Turk (1969, p. 104) determined that movement of brine through the clays underlying the salt beds near Wendover is primarily through a network of vertical joints having a maximum width of about 1 inch and generally spaced about 1 foot apart. In some cases, the joint network has a generally hexagonal surface plan. Gilbert (1890, p. 211-213) described a system of intersecting vertical joints in the lakebeds at the land surface in the Old River Bed area (see fig. 2) and postulated the existence of such a system in the clays underlying the desert floor. Nolan (1928, p.34) noted that in the western part of the desert,numerous moist zones on the surface appeared to be related to the presence of a system of intersecting joints in the underlying lake clays.

It is noteworthy that numerous playas in the southwestern United States contain zones of relatively high permeability that bear striking similarity to the shallow brine aquifer in the Bonneville Salt Flats. Motts (1970b, p. 122; 1970c, p.82) described an area of "giant desiccation polygons" in Coyote Playa, in the Mojave Desert in California, where fissures extending to a depth of 25-30 feet below the playa surface give rise to a zone of high permeability. Walker and Motts (1970, p. 150) described similar fissured zones in Big Smoky Playa in southwestern Nevada. Motts and Carpenter (1970, p. 41, 59-60) briefly discuss zones of "giant polygons" in Rogers and North Panamint Playas, also in the Mojave Desert.

From the evidence cited above, it is probable that brine moves through the shallow lakebeds in the Bonneville Salt Flats area both by intergranular flow in thin horizontal beds and by flow in open joints. The 25-foot thickness of the shallow brine aquifer probably reflects the depth to which the joints extend. Brines have been encountered in several deeper zones in test holes on the salt flats (Nolan, 1928, p. 36) but these deeper zones are poorly connected hydraulically to the shallow brine aquifer because of the absence of interconnecting joints.

Aquifer properties.-Storage coefficients (see appendix for definition) determined from 22 tests in the shallow brine aquifer ranged from 0.12 to 0.00005, indicating that both water-table (unconfined) and artesian (confined) conditions exist. In citing these results, Turk (1969, p. 115) pointed out that the aquifer is most commonly unconfined to partly confined. The range in value of the storage coefficients is reasonable in view of the manner in which water is transmitted by the aquifer. Where vertical joints are sparse or lacking, hydraulic connections are ineffective, and some degree of confinement would be expected. Where joints are abundant, hydraulic continuity is complete, and water-table conditions should exist.

The transmissivity (see appendix for definition) of the shallow brine aquifer, based on the results of more than 80 aquifer tests in the Bonneville Salt Flats area (Turk, 1969, p. 105, 113), ranges from about 67 ft^2/day (feet squared per day) near the edge of the salt crust to about 6,700 ft^2/day near the center of the flat where the crystalline salt is thickest. Transmissivity at any given location is determined in large part by the degree of interconnection that exists within the joint system in the clay beds as well as between the joints in the clay and the intergranular space in the crystalline salt.

Recharge.-Recharge to the shallow brine aquifer is primarily by infiltration of precipitation and by lateral subsurface inflow from adjacent aquifers. Infiltration of runoff from adjacent uplands contributes minor amounts of recharge.

On the Bonneville Salt Flats, the open structure of the crystalline salt beds allows rapid infiltration. Turk (1969, p. 113) estimated that any rainfall in excess of 0.1 inch in summer or 0.05 inch in winter would contribute to recharge on the salt flats. Based on these estimates and daily precipitation recorded at Wendover (U.S. Environmental Science Services Admin., 1971), maximum potential recharge from precipitation on the Bonneville Salt Flats (an area of about 96,000 acres) in 1970 would have been about 21,000 acre-feet. Approximately half of this total would have been available on a single day in November when 1.19 inches of precipitation was recorded at Wendover. During April-October, precipitation in excess of 0.1 inch occurred on 8 days. During December-March precipitation in excess of 0.05 inch occurred on 5 days.

Precipitation in the area of the Bonneville Salt Flats was about average in 1970. Therefore, the number of days when precipitation exceeded the minimum amounts estimated by Turk (1969, p. 113) and the volume of the excess could reasonably be considered to be representative of average conditions. Thus, the average annual potential recharge from precipitation on the Bonneville Salt Flats may be on the order of 20,000 acre-feet.

Elsewhere in the northern Great Salt Lake Desert, lakebed deposits form the land surface and precipitation contributes little, if any, recharge to the shallow brine aquifer. As soon as the clay and silt becomes wet, the surface becomes a sea of mud, the desiccation cracks disappear, and the water stands in ponds until evaporated. Recharge to the aquifer in these areas is almost entirely by subsurface inflow.

Nolan (1928, p. 37), in describing the occurrence of brines in test holes, noted that "In most of the holes away from the edge of the flat the brine flow, if plentiful, was under a small hydrostatic pressure, as shown by a rise of brine in the hole amounting to several inches and rarely to a foot." He explained the hydrostatic pressure as follows (p. 41): "As each layer represents the surface of the lake floor at a particular time in the past, it would have a slight slope away from the shore of the ancient lake. Water flowing in along such a plane would therefore be under a slight hydrostatic pressure* * *" The source of this inward-draining water is subsurface discharge from the adjacent alluvial-fan aquifers. (See fig. 4.) The volume of such inflow to the shallow brine aquifer in the entire northern Great Salt Lake Desert cannot be determined directly.

Discharge.-The shallow brine aquifer discharges water primarily by evaporation and by gravity flow to ditches. No known wells or springs in the area discharge from this aquifer. The aquifer yields brine by gravity flow to collection ditches in the Bonneville Salt Flats, and the brine is distributed to evaporation ponds. This brine-collection system has been operated intermittently since about 1960. Based on data in the files of the Geological Survey for pumpage at a booster pump at U.S. Highway 40, brine production from the ditch in T.1 N. and T.1 S., R.17 W., was as follows:

	Total production (acre-feet)
July 1966-August 1970	4,650
September 1970-April 1972	0
May-September 1972	1,560
October-December 1972	0
Total	6,210

This ditch was the only ditch operated north of U. S. Highway 40 since 1966. Average brine discharge from the shallow brine aquifer to the ditch north of the highway during the above period was about 960 acre-feet per year.

Direct evaporation from the water table occurs throughout the salt flats, where the crystalline salt is saturated to within a few inches of the surface. In the area where lake clays form the surface, depth to the brine ranges from 2 to 3 feet near the center of the desert floor to 7 to 9 feet at the margins (Nolan, 1928, p. 41). Direct evaporation from the water table may also occur in this area at places where capillarity in the fine-grained sediments raises the water several feet above the water table or where the water surface is exposed in open joints and desiccation cracks in the clay beds.

The rate of evaporation of ground water from a shallow water table underlying bare soils depends on meterological, hydrological, and soil conditions. The primary controlling factors are temperature, humidity, salinity, depth to water, and soil type. No direct measurements of ground-water evaporation have been made in the northern Great Salt Lake Desert. Average ground-water evaporation from the shallow brine aquifer is assumed to be about 19,000 acre-feet annually, equal to the difference between estimated average recharge from precipitation on the salt flats and estimated average brine discharge to the collection ditches.

Most evaporation from the shallow brine aquifer probably takes place on the Bonneville Salt Flats within a short time after the rainstorms and periods of snowmelt that provide recharge. The surface of the salt flats, when dry, is dense and relatively impermeable. Fresh water from rainfall or snowmelt dissolves part of the salt crust and infiltrates to the water table a few inches below the surface. Evaporation from the water table leaves behind the dissolved salts. Because of the large dissolved-solids content of the brine, evaporation residue rapidly seals the openings above the water table and re-establishes the dense, relatively impermeable surface crust. Further evaporation is thus prevented, even though the saturated zone is only inches below the land surface.

The volume of evaporation from the water table in the area where lake clay and silt forms the land surface is unknown. Evaporation of brine from the water table should rapidly produce a seal of residual salt, and since little or no infiltration of precipitation takes place in this part of the shallow brine aquifer, the seal would tend to be permanent. Total evaporation from this part of the aquifer is assumed to balance recharge by subsurface inflow from the adjacent alluvial-fan aquifer.

Storage.-An estimated 9.6 million acre-feet of brine is in storage in the shallow brine aquifer, assuming an average porosity of 45 percent (Turk, 1969, p. 104) and an average saturated thickness of 20 feet. The quantity of brine recoverable by gravity drainage is dependent on the specific yield (see appendix for definition) of the aquifer materials. Turk (1969, p. 104) reports 6.3 percent as the average specific yield of several samples collected from above the water table and saturated with brine in the laboratory. A brine-saturated sample from below the water table had a specific yield of 10 percent. If the average specific yield of the shallow brine aquifer is 6.3 percent, about 1.3 million acre-feet of brine could be recovered by pumping from wells or by gravity drainage into collecting ditches penetrating the full saturated thickness of the aquifer.

Alluvial-fan aquifer

An "apron" of unconsolidated alluvium borders much of the floor of the northern Great Salt Lake Desert (see pl. 1). These surficial alluvial deposits, together with underlying unconsolidated to well-cemented older alluvium (QTu in table 1) that was also deposited as fans or aprons along the mountain flanks, comprise an aquifer referred to herein as the "alluvial-fan aquifer."

Along the east flank of the Silver Island Range, the alluvial-fan aquifer is a significant part of the ground-water system. As indicated in figure 4, the aquifer in this area is in contact with the shallow brine and valley-fill aquifers as well as the underlying Paleozoic rocks. Hydraulic continuity between the various aquifers along the Silver Island Range is incomplete, however, and each unit reacts more or less independently to changes in hydrologic conditions. Elsewhere around the periphery of the northern Great Salt Lake Desert, little specific information is available concerning ground water in the alluvium, but conditions are thought to be similar.

Water in the alluvial-fan aquifer along the eastern flank of the Silver Island Range occurs under artesian conditions. Well (C-1-19) 3ddb-1, drilled there in 1946, reportedly yielded water under sufficient pressure to rise 15 feet above the land surface (table 10). By 1960 the pressure had decreased so that static water levels in wells in this area were approximately at land surface (Turk, 1969, p. 73). In 1972, at least one of the wells, (B-1-18)29ccc-1, was again flowing. A hydrograph showing water-level fluctuations since 1962 in observation well (C-1-19)3ddb-1, completed in the alluvial-fan aquifer, is shown in figure 3; and water-level data for this well are tabulated below. All measurements are by U.S. Geological Survey personnel except those denoted by an asterisk (*), which are from Turk (1969, p. 74).

Date	Water level (feet below land surface)
Aug. 8, 1962	0.53
Oct. 22	.64
Mar. 7, 1963	4.22
Mar. 15, 1964	7.61
Feb. 26, 1965	12.92
Aug. 26	18.32
Oct. 19	18.48
Nov. 30	*18.89
Mar. 3, 1966	17.92
May 7	*12.58
June 18	*10.98
Aug. 18	11.08
Oct. 4	12.47
Oct. 6	*12.52
Mar. 28, 1967	9.45
Sept. 20	7.45
Mar. 7, 1968	4.09
Sept. 18	3.34
Mar. 1, 1969	3.67
Sept. 15	5.19
Mar. 10, 1970	5.91
Sept. 9	5.02
Mar. 1, 1971	3.23
Sept. 20	3.71
Mar. 6, 1972	2.85

Water levels in the alluvial-fan aquifer in the Ripple Valley area range in depth from about 10 feet below land surface at the edge of the Great Salt Lake Desert to at least 360 feet below land surface at higher altitudes in the Grassy Mountains (see wells (B-3-12)23ccd-1 and (C-1-10)5cab-1, table 10). Water in the alluvium in Ripple Valley is generally under water-table conditions.

Movement.-Ground water in the alluvial-fan aquifer moves downgradient from recharge areas in the mountains in and around the northern Great Salt Lake Desert to discharge areas along and under the toe of the alluvial aprons. Gradients on the potentiometric surface are relatively steep near the base of the mountains, as suggested by the contours on plate 1. Throughout much of the area, however, water-level measurements are too few to accurately define the potentiometric surface.

Aquifer Properties.-Aquifer tests were conducted in 1966-67 by Bonneville, Ltd., personnel at wells (C-1-19)2cbc-1 and 2cbd-1 in the alluvial-fan aquifer. Transmissivity values reported by Turk (1969, p. 65) for these tests ranged from 51,600 to 63,650 ft^2/day at the former well and from 21,300 to 26,800 ft^2/day at the latter. Such high values would reflect the presence of open joints, fractures, and solution channels in underlying carbonate rocks that transmit water freely to the alluvial-fan aquifer. Storage coefficients of 0.0005 and 0.0002, respectively, calculated by Turk from these tests, are typical of confined aquifers.

Recharge.-Recharge to the alluvial-fan aquifer is from infiltration of precipitation and from subsurface inflow. Precipitation on areas above the desert floor is estimated to contribute less than 5,000 acre-feet of recharge annually (see table 3). Most of this recharge eventually moves into the alluvial-fan aquifer at the base of the mountains. Available data are inadequate to provide a basis for estimating total subsurface inflow.

Discharge.-Discharge from the alluvial-fan aquifer is by evapotranspiration, by pumping and flow from wells, and by subsurface outflow. No springs in the northern Great Salt Lake Desert are known to discharge from the alluvial-fan aquifer. Estimated annual discharge by evapotranspiration is about 2,500 acre-feet, as indicated in the following tabulation.

Locality (see pl. 1) and types of phreatophytes	Area (acres)	Depth to water (feet)	Water consumption: Acre-feet/acre	Water consumption: Annual total
East flank of Silver Island Range, adjacent to Bonneville Salt Flats; sparse to moderately dense greasewood, locally mixed with sagebrush and rabbitbrush	12,000	Less than 50	0.1	1,200
West flank of Grassy Mountains; phreatophytes as above, extensive patches of bare soil along desert margin	4,700	10-40	.1	470
Clive area; phreatophytes as above	6,400	20-60	.05	320
Flanks of Newfoundland Mountains; phreatophytes as above	5,100	10(?)-more than 50	.1	510
Total (rounded)	28,000			2,500

Four wells discharged water from the alluvial-fan aquifer in the Wendover area in 1972. Three of these, (C-1-19)2adb-1, 3ddb-1, and 10bac-1, are pumped, one at a time and on a seasonal basis, to supply the water needed to remove sodium chloride precipitated as a byproduct in Bonneville, Ltd.'s potash production process. The other well (B-1-18) 29ccc-1, is an unused flowing well. Average total discharge from these wells is estimated at about 650 gpm (gallons per minute) (H. C. Ballard, Bonneville, Ltd., plant superintendent, oral commun., 1972). Adjusted for a production season of about 9 months, total annual discharge is about 250 million gallons (770 acre-ft).

Ground water is pumped from wells completed in the alluvial-fan aquifer for livestock in Ripple Valley and the Newfoundland Mountains during the winter grazing season. In Ripple Valley, use by livestock varies from an estimated 0.6 acre-foot during a wet year to about 1.2 acre-feet during a dry year. On the average, ground-water discharge from stock wells in Ripple Valley is probably about 1 acre-foot annually. About 6,000 sheep are wintered annually on the Newfoundland grazing unit. Based on consumptive-use allowances by Criddle, Harris, and Willardson (1962, p. 23), estimated annual consumption of water by these sheep is about 17 acre-feet. Of this amount, probably less than 1 acre-foot is pumped from the two wells in the area. The remainder is supplied by springs and seeps discharging from aquifers in consolidated rocks.

Direct estimation of subsurface outflow from the alluvial-fan aquifer is not possible from the scanty field data available. The downward trend of the hydrograph of well (C-1-19)3ddb-1 (fig. 3) may indicate that some water has been withdrawn from storage in the aquifer since initial development in 1946. However, because of nearby pumping at the time of or preceding many of the measurements, the water levels shown on the hydrograph may not accurately reflect the potentiometric surface of the aquifer. If no long-term changes in storage are taking place, average recharge and discharge of the aquifer are approximately equal. Under these conditions, subsurface outflow can be estimated indirectly as about 1,300 acre-feet annually, the approximate difference between recharge from precipitation (4,540 acre-feet) and discharge by evapotranspiration and pumping from wells (3,272 acre-feet).

Storage.-The volume of ground water stored in the alluvial-fan aquifer cannot be estimated because the extent of the aquifer is unknown. The lateral boundaries of the aquifer are gradational, as indicated in figure 4, and the vertical boundaries cannot be defined from the few well logs and water-level measurements available.

Valley-fill aquifer

The largest ground-water reservoir in the northern Great Salt Lake Desert is in unconsolidated to partly consolidated valley fill (older alluvium and Salt Lake Formation, table 1). The total thickness of valley fill ranges from zero where older Paleozoic rocks crop out (pl. 1) to 1,385 feet at Lemay (see log of well (B-7-14)29, table 11) and at least 1,644 feet in the Bonneville Salt Flats area (see log of well (C-1-19)25baa-1, table 11).

Volcanic rocks underlying the unconsolidated sediment (Heylmun, 1965, p. 28-29) may also constitute a part of the major ground-water reservoir, as do the younger volcanic rocks in Curlew Valley (Bolke and Price, 1969, p. 15). If these rocks are included, the total thickness of the reservoir rocks may be more than 5,000 feet throughout much of the area, based on interpretation by Cook and others (1964, p. 715-740) of data from a regional gravity survey of the northern Great Salt Lake Desert.

Movement.-Water moves laterally into the valley-fill aquifer from the alluvial-fan aquifer, and some brine may move downward from the shallow brine aquifer through ruptured well casings and interfingering permeable strata. The lack of reliable water-level data throughout most of the northern Great Salt Lake Desert precludes any precise determination of the direction of ground-water movement within the valley-fill aquifer.

Aquifer properties.-The valley fill does not transmit water uniformly. As indicated by the drillers' logs of wells (B-7-14)29, (C-1-19)25baa-1, 34cdc-1, 35bcb-1, and 35ccc-1 in table 11, most of the uppermost 1,000 feet of material is clay. Below this depth, conglomerate, sand, and gravel beds yield or have yielded brine to several wells ((C-1-19)23cbc-1, 25baa-1, 34abb-1, 34bdc-1, 35bcb-1, and 35ccc-1, table 10) owned by Bonneville, Ltd.

In some parts of the northern Great Salt Lake Desert, the valley fill is relatively permeable at shallow depths. The log of well (B-3-12)23ccd-1 (table 11) indicates that the fill from 23 feet to at least 500 feet below land surface at that location is all sand and clay, with beds of sand ranging from 5 to 16 feet in thickness reported at intervals below 94 feet. A well drilled at the southern end of Park Valley, (B-9-12)9bbb-1 (Hood, 1971b, p. 43), penetrated relatively permeable materials, including beds of sand and gravel, to the total depth of 346 feet. Well (B-8-17)31ccc-1, near Lucin, penetrated 40 feet of sand bearing fresh water at a depth of 160-200 feet (Hood and Price, 1970, p. 46).

Aquifer test results furnished by M. W. Lallman (written commun., 1972) indicate that transmissivity of the valley-fill aquifer near Wendover averages about 13,400 ft^2/day, and the storage coefficient is about 0.0004.

The potentiometric surface of the valley-fill aquifer was 20-30 feet below land surface in the Bonneville Salt Flats area in 1949-51 (see wells (C-1-19)34bdc-1, 34cdc-1, 35bcb-1, 35ccc-1, table 10). Water levels reported for wells (C-1-19)34cdc-1 and 35bcb-1 indicate that by 1968-70, the potentiometric surface in the area of brine withdrawal was 50-60 feet below land surface.

Recharge.-The volume of recharge to the valley-fill aquifer cannot be accurately determined from available data. Subsurface data are scanty throughout most of the area, and quantitative estimates of aquifer properties are lacking except for the Bonneville Salt Flats area near Wendover. Subsurface outflow from Park Valley into the valley fill of the northern Great Salt Lake Desert is estimated to be about 5,000 acre-feet annually (J. W. Hood, oral commun., 1972). Recharge from precipitation in the northern Great Salt Lake Desert is negligible. Except where the aquifer materials are exposed at the surface, they are generally overlain by relatively impermeable lakebed clays. Throughout most of the northern Great Salt Lake Desert, recharge is entirely by subsurface inflow from adjacent aquifers in the alluvial fans and consolidated Paleozoic rocks.

Discharge.-Discharge from the valley-fill aquifer in the northern Great Salt Lake Desert is by pumping from wells. Subsurface outflow from the area is probably negligible, but detailed regional studies would be required to fully determine inflow-outflow relationships in the aquifer.

Wells owned by Bonneville, Ltd., are pumped to supply brine for potash production. At present (1972) only four of the company's deep brine wells are in use. (See wells (C-1-19)23cbc-1, 34abb-1, and 34bdc-1, table 10. The fourth well is at (C-2-19)3bcc-1, just beyond the boundary of the area considered in this report.) A fifth well, (C-1-19)34cdc-1, was pumped intermittently until October 1969.

Based on data in the files of the Geological Survey, estimated discharge from the four wells in the area considered in this report was about 2,600 acre-feet in the period October 1969-September 1970 and about 2,400 acre-feet in the period January-September 1972.

Total discharge from the four wells, calculated from the data for these 21 months, averages about 2,900 acre-feet per year.

Storage.-Total ground-water storage in the valley fill is estimated to be about 220 million acre-feet, on the basis of (1) an assumed average porosity of 40 percent; (2) a total area underlain by the aquifer of about 1.1 million acres; and (3) an assumed average thickness of saturated material of 500 feet. The volume of stored water potentially recoverable by pumping from wells, assuming an average storage coefficient of 0.0004 as reported from tests near Wendover, would be about 90,000 acre-feet. All the water in the valley-fill aquifer in the central part of the northern Great Salt Lake Desert would be briny.

Other aquifers

Aquifers in the mountainous areas in the northern Great Salt Lake Desert are discontinuous--water is stored locally in a thin weathered zone and in fractures in Tertiary granite, in fractures and other secondary openings in Paleozoic carbonate rocks, and in intergranular spaces in unconsolidated Quaternary alluvial deposits. The scanty precipitation, steep slopes, extreme surface dissection, and generally dense rocks making up much of the surface all combine to prevent the formation of a continuous saturated zone within the mountain blocks.

An estimated 35-40 acre-feet of ground water is discharged annually in the Newfoundland Mountains by springs and seeps, most of which issue from the Tertiary granite at the north end of the mountains. None of the springs yield more than about 10 gpm, but all appear to be perennial. The generally dense grasses and scattered clumps of hydrophytes and deciduous brush in and around the spring and seep areas cover a total of about 5 acres and discharge an estimated 15 acre-feet of ground water annually by evapotranspiration.

The springs and seeps in the Newfoundland Mountains appear to issue mainly from weathered granite, from "granite wash" immediately downslope from outcrops, or from fractures. Several of the springs discharge as a series of seeps in the bottom of gullies incised in the granite. In March 1972, water could be seen seeping, and in a few instances flowing, from fractures in the relatively unweathered granite at locations above the bottom of gullies. Thus it appears that the granite, although on the whole of low permeability, has a system of intersecting fractures that enable it to transmit significant quantities of water. The weathered zone, where it is present, absorbs precipitation and transmits it downward into the open fractures. The entire area of the Newfoundland Mountains receiving more than 6 inches of precipitation annually (fig. 1) coincides with the highest peaks of the granite outcrop, so that the ground-water reservoir in the granite is more favorably situated with respect to recharge than other rock units in the mountains.

The Paleozoic carbonate rocks, where they are fractured or have solution channels or other secondary openings, transmit and temporarily store some ground water. At least one spring, (B-5-13)18bd-S (table 10), issues from fractures in these rocks.

Discussion of recharge and discharge estimates

The lack of detailed information precludes an exact accounting for all items in the ground-water budget of the northern Great Salt Lake Desert. The volumes of recharge and discharge discussed in preceding sections for the shallow brine, alluvial-fan, and valley-fill aquifers only partially account for the total movement of ground water in the area.

Recharge from precipitation in the area is estimated as about 25,000 acre-feet annually (20,000 acre-feet on the Bonneville Salt Flats and 4,540 acre-feet on the uplands). Although recharge from precipitation in the area where the surface is formed by lakebed clay and silt is assumed to be negligible, desiccation cracks there may allow some inflow of recharge from the surface before expansion of the wetted clays seals the cracks. Such inflow, though the volume per unit area might be quite small, could conceivably account for several thousands of acre-feet of recharge per year over the more than 1 million acres of lakebed deposits involved (table 3).

Subsurface inflow from adjacent areas is estimated to average about 5,000 acre-feet annually from Park Valley into the valley-fill aquifer. Aquifer properties determined from tests on wells in the alluvial-fan aquifer near Wendover (see p. 18) indicate that the underlying and adjacent Paleozoic carbonate rocks transmit water freely to the alluvial-fan aquifer. If such properties are characteristic of the Paleozoic rocks throughout the area, these rocks may transmit several thousands of acre-feet of recharge annually to the northern Great Salt Lake Desert.

About 19,000 acre-feet of ground water is estimated to be discharged annually by evaporation on the Bonneville Salt Flats. The assumption on which this estimate is based--that recharge and discharge to the shallow brine aquifer are equal--appears reasonable, but has not been confirmed by direct field observation. The estimated volume of evaporation is probably of the correct order of magnitude, but both evaporation and recharge figures may be in error by several thousand acre-feet.

Water quality

Water from the northern Great Salt Lake Desert ranges from fresh to briny, according to the U.S. Geological Survey's standard classification (Hem, 1970, p. 219):

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

Plate 2 and table 12 indicate the general chemical character of the water in the area, and table 4 summarizes the results of several partial chemical analyses of brine from wells completed in the valley-fill aquifer.

Fresh water might be encountered in the subsurface locally in perched water zones in sand dunes and at shallow depths in the alluvium. Such areas would probably be of small extent, however, and they would contain relatively small volumes of water.

In general, ground water under the desert floor contains 150,000 mg/l or more of dissolved solids, which precludes its use for nearly anything except mineral production or uses following after desalinization. Locally, around the periphery of the desert in the alluvium, and probably throughout much of the Terrace and Hogup Mountains, fresh to moderately saline ground water is available for livestock.

Several wells that were drilled in Ripple Valley to obtain water supplies for livestock were abandoned because of the highly saline water that was encountered (see wells (B-1-11)35bcc-1, (B-3-11)31aaa-1, and 31ddb-1, table 10).

Water in the Newfoundland Mountains ranges from fresh to moderately saline (pl. 2). Based on specific-conductance measurements of melt water from snowbanks mixed with ground-water discharge from springs (see (B-6-13)31db-S and 32bc-S, table 10), even direct runoff from upland areas probably contains 500 mg/l or more of dissolved solids.

The mountain range, completely surrounded as it is by saline desert, receives large quantities of salt in the form of particles deposited by winds that sweep across the desert floor. The surface accumulation of windblown salt is dissolved by rainfall and snowmelt (which may already contain dissolved salt from airborne particles) and carried back toward the desert by surface runoff or downward into the soil and the underlying ground-water reservoir by the water that infiltrates. Thus, few, if any, water sources in the Newfoundland Mountains can be expected to contain less than 500 mg/l of dissolved minerals.

Water samples collected from springs (B-5-13)18bdb-S1 and (B-6-13)30bc-S and 31ac-S in the Newfoundland Mountains were fresh or

Table 4.--Summary of selected chemical-quality data for Bonneville, Ltd., brine-production wells, 1967-71

Calculated from file data furnished by Bonneville, Ltd. Analyses made by Bonneville, Ltd., personnel at Wendover plant.

	Concentrations, in milligrams per liter					Specific gravity at 20°C
	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	
(C-1-19)23cbc-1; Brine Well No. 13:						
Number of determinations	11	3	12	0	-	12
Average concentration	2,100	50,000	2,700	-	86,000	1.103
Maximum concentration	3,100	52,000	3,500	-	92,000	1.109
Minimum concentration	1,500	49,000	2,200	-	81,000	1.097
(C-1-19)34abb-1; Brine Well No. 10:						
Number of determinations	16	5	18	1	-	18
Average concentration	1,500	46,000	2,200	6,000	77,000	1.095
Maximum concentration	1,800	47,000	2,400	-	80,000	1.099
Minimum concentration	1,200	45,000	1,700	-	73,000	1.092
(C-1-19)34bdc-1; Brine Well No. 8:						
Number of determinations	12	5	15	1	-	15
Average concentration	1,700	48,000	2,300	6,000	81,000	1.098
Maximum concentration	2,400	52,000	2,700	-	90,000	1.108
Minimum concentration	1,400	46,000	1,800	-	77,000	1.093
(C-1-19)34cdc-1; Brine Well No. 6:						
Number of determinations	10	4	11	0	-	11
Average concentration	1,900	50,000	2,400	-	84,000	1.099
Maximum concentration	2,600	53,000	2,700	-	92,000	1.110
Minimum concentration	1,200	46,000	2,100	-	77,000	1.093

slightly saline (table 12). The one well, (B-5-13)31acd-1, from which a sample was obtained for analysis yielded moderately saline water.

Potential for additional water-resources development

Relatively large volumes of ground water are available in the northern Great Salt Lake Desert but the limiting factor for future development is water quality. For any industry in which brine can be used, ample supplies are available. For water supplies for livestock, the potential for additional development is relatively small. Exploratory drilling and detailed local studies might identify areas where water of sufficiently low dissolved-solids content for livestock could be obtained. The northern margin of the desert appears to be most promising for fresh to moderately saline water.

Some of the ground water presently discharged by evapotranspiration might be captured for beneficial use by pumping from properly located and constructed wells. However, the areas of phreatophytes are generally areas where the ground water is saline, and the water captured probably would not be usable without treatment for most existing uses. Interception of the ground water upgradient from the phreatophyte areas might be feasible, and in reality, the existing stock wells in Ripple Valley are doing this already. A large-scale salvage operation would probably not be economically feasible, however, because of the large area and relatively large (100-350 ft) pumping lifts involved.

Additional water sources could be developed in the Newfoundland Mountains to supply water for livestock. Wells constructed in unconsolidated deposits along the mountain flanks might yield water similar in quality to that from the existing wells. The extensive spring and seep areas could be developed to conserve and utilize much of the water now consumed by evapotranspiration.

SUMMARY OF HYDROLOGY OF NORTHWESTERN UTAH

Northwestern Utah, as discussed in this report, includes all the area of the State north and west of Great Salt Lake, except for the Goose Creek and Raft River drainage areas in the extreme northwestern corner (fig. 1). The hydrology of the latter two areas, which drain into the Snake River in Idaho, was described by Piper (1923) and Nace, Fader, and Sisco (1961), respectively.

Figure 1 and plate 1 summarize the general physiography, precipitation patterns, and distribution of hydrogeologic units in northwestern Utah. Table 1 contains a general description of the lithology and water-bearing characteristics of the hydrogeologic units. More detailed descriptions of the physiographic, climatic, and geologic characteristics of individual subareas are given in the preceding sections of this report and in the publications cited on page 3.

Total precipitation in northwestern Utah, an area of about 6,000 square miles, is estimated to average about 2,600,000 acre-feet annually (table 5). Of this total, about 4 percent (100,000 acre-ft)

Table 5.-Summary of estimated average annual volumes of precipitation and ground-water recharge in hydrologic subareas of northwestern Utah

Subarea	Area (1,000 acres)	Precipitation (1,000 acre-ft/yr)	Recharge	
			Percent of precipitation	1,000 acre-ft/yr
Blue Creek Valley	142	184	7.6	14
Promontory Mountains	228	240	5	12
Hansel Valley	152	160	5	8
Curlew Valley	351	332	1.1	3.6
Park Valley	674	520	4.6	24
Grouse Creek valley 1/	302	277	4.5	12
Pilot Valley 1/	313	175	.6	1.1
Northern Great Salt Lake Desert	1,350	620	4	24
Sink Valley 1/	134	70	1.6	1.1
West Shore 1/	124	51	1.6	.8
Total (rounded)	3,800	2,600		100

1/ Estimates have been adjusted from the report cited on page 3 in order to conform to slightly different boundaries used in this report.

Table 6.--Summary of estimated average annual volumes of inflow to and outflow from northwestern Utah

[All volumes are given in thousands of acre-feet. Estimates are from reports cited on page 3 or from calculations based on runoff maps by Bagley, Jeppson, and Milligan (1964) and Busby (1966)]

Subarea	Inflow			Outflow		
	Surface	Subsurface	Origin	Surface	Subsurface	Destination
Promontory Mountains	-		-	4	9	Bear River Bay mudflats and Great Salt Lake
Hansel Valley	-		-	5	1	Great Salt Lake
Curlew Valley	2	36	Curlew Valley, Idaho	6	-	Do.
Park Valley	-	-	-	-	1/3	Do.
Grouse Creek valley	.5	1.6	Grouse Creek drainage, Nevada2/	-	-	-
Pilot Valley	.1	.3	Pilot Creek valley, Nevada (Harrill, 1971, p. 17, 23)	-	-	-
	.8	1.8	Thousand Springs Valley, Nevada (Rush, 1968, p. 38)	-	-	-
	.4	2.3	Pilot Valley drainage, Nevada2/	-	-	-
Northern Great Salt Lake Desert	.15	-	Goshute Valley, Nevada3/	.5	-	Great Salt Lake
West Shore	5.4	1.2	Skull Valley2/	-	-	-
Total (rounded)	9	43		15	13	

1/ Estimate by J. W. Hood (oral commun., 1972).

2/ Area included in report cited on page 3 but not included in area of this report. Estimates have been adjusted from those given in cited report in order to conform to boundaries used here.

3/ Diverted by pipeline to Air Force installation at Wendover.

infiltrates to the water table as ground-water recharge. The remainder either runs off, is consumed directly by evapotranspiration, or is held temporarily as soil moisture and ultimately consumed by evapotranspiration.

In addition to precipitation on the area, northwestern Utah receives inflow from adjacent areas, as indicated in table 6. Total inflow, both surface and subsurface, is estimated to average about 52,000 acre-feet annually.

Surface water

Although many streams in the mountainous areas of northwestern Utah are perennial in their upper reaches where baseflow is sustained by spring discharge, all the streams in the area are ephemeral in their lower reaches. Overland runoff, estimated to average less than 35,000 acre-feet annually for the entire northwestern Utah area, occurs only during and immediately after short-lived summer thunderstorms and during the brief early spring snowmelt. Runoff that is concentrated in ephemeral streams is lost rapidly by streambed infiltration and by evapotranspiration on the alluvial slopes. Evapotranspiration on the desert floor and the mudflats around Great Salt Lake consumes what little water remains.

The only continuous streamflow record available for the entire area is for Dove Creek near the town of Park Valley, but partial records of streamflow are available from five crest-stage gaging stations. Discharge records for the Dove Creek station are contained in annual reports prepared by the U.S. Geological Survey (1963, 1962-72). Summaries of available streamflow records for the crest-stage stations and for miscellaneous sites in the area are included in several of the reports cited on page 3.

Because most of the streams in the area are ephemeral, use of surface water is slight. Several small impoundments have been constructed on the larger streams, and water is diverted from these impoundments or directly from stream channels for irrigation in the Grouse Creek, Blue Creek, Curlew, and Park Valley areas. Total irrigated acreage in these areas in 1968 was about 5,700 acres (Foote and others, 1971, p. 8). Assuming an average use of 3 acre-feet per irrigated acre, water use for irrigation in northwestern Utah in 1968 was about 17,000 acre-feet, of which probably 2,000 acre-feet or less was from surface-water sources.

Springflow supplies water for livestock in most of the upland area surrounding the desert. Thus the total use of surface water by livestock in the area is probably less than 500 acre-feet annually.

Ground water

Estimated ground-water budgets for each of the hydrologic subareas of northwestern Utah are given in table 7. The budgets for several of the subareas are not in balance. The studies in which these budgets were made were not meant to provide precise, quantitative answers, and

Table 7.--Summary of ground-water budgets for hydrologic subareas of northwestern Utah

[All amounts are in thousands of acre-feet annually and are from reports cited on page 3 or from preceding sections of this report]

Discharge from wells, springs, seeps: Amounts are exclusive of discharge that is consumed by evapotranspiration.

Subarea	Recharge			Discharge				Remarks
	Subsurface inflow	From precipitation	Subtotal (rounded)	Subsurface outflow	Evaporation and evapotranspiration	Wells, springs, and seeps	Subtotal (rounded)	
Blue Creek Valley	-	14	14	5.5	0.7	7.8	14	Outflow to Promontory Mountains.
Promontory Mountains	5.5	12	18	9	14	4	27	Inflow figure incomplete; outflow to Great Salt Lake and Bear River Bay salt flats.
Hansel Valley	-	8	8	1	7.6	2.4	11	Subsurface inflow not accounted for; outflow to Great Salt Lake.
Curlew Valley	36	3.6	40	-	34	16	50	Imbalance between recharge and discharge due to withdrawal from storage.
Park Valley	-	24	24	8	16	.5	24	Outflow to northern Great Salt Lake Desert and Great Salt Lake.
Grouse Creek valley1/	1.6	12	14	2	11	2	15	Imbalance between recharge and discharge due to withdrawal from storage; outflow to Pilot Valley.
Pilot Valley1/	6.4	1.1	8	0	7.4	.6	8	
Northern Great Salt Lake Desert	5	25	30	0	21	4.7	26	All figures probably incomplete.
Sink Valley1/	-	1.1	1	.9	.2	-	1	Outflow to West Shore.
West Shore1/	2.1	.8	3	-	2.8	.1	3	
Total for northwestern Utah (rounded)	2/60	100	2/160	2/30	110	40	2/180	

1/ Estimate has been adjusted from that given in report cited on page 3 in order to conform to slightly different subarea boundaries used in this report.

2/ Includes approximately 15,000 acre-feet moving between subareas.

the imbalance in some cases stems from inaccuracies inherent in the reconnaissance methods used. In most subareas where the budgets are not in balance, more detailed investigations would be required to account for the budget elements causing the imbalance. In general, however, the reconnaissance methods are believed to provide reasonably accurate estimates that certainly are of the correct order of magnitude.

It is probable that total annual recharge and discharge from the ground-water reservoirs of northwestern Utah are nearly equal, and that long-term changes in storage occur only locally. Average net total recharge and discharge are probably in the range from 150,000 to 200,000 acre-feet annually, with at least 10,000 acre-feet annually being withdrawn from storage in Curlew and Grouse Creek Valleys.

The generalized water-level contours on plate 1 indicate the approximate altitude and configuration of the potentiometric surface of the ground-water reservoir. The water-level data on which the contours are based were collected over a period of several years, but throughout most of the area average water levels changed little during this time. The general direction of ground-water movement, as indicated by the water-level contours, is toward Great Salt Lake or the northern Great Salt Lake Desert. The potentiometric surface under the desert floor is nearly flat.

Table 8 gives estimates of volumes of ground water in storage that can be recovered by wells from the upper 100 feet of saturated aquifer material in each subarea. The total volume of recoverable water is about 5.6 million acre-feet, but at least three-quarters of this probably is saline water or brine. Details of the derivation of the storage estimates are given in the reports cited on page 3, except for the previously undescribed areas discussed in this report.

Water quality

Dissolved-solids concentrations in samples from water sources in northwestern Utah range from 85 to 165,000 mg/l. Concentrations in ground-water samples range from 111 to 165,000 mg/l (table 9). The 412 analyses summarized in table 9 are included in the reports cited on page 3 or in table 12. The samples were collected from 280 wells (range 263 to 165,000 mg/l) and 86 springs (range 111 to 94,400 mg/l). In addition to these 412 samples, analyses of 27 samples from streams in the area show a range in dissolved-solids concentration from 85 mg/l (springflow in Bettridge Creek in the Pilot Range) to 26,400 mg/l (discharge from the Salt Wells Spring group in Hansel Valley Creek near Snowville).

Plate 2 summarizes the general concentration of dissolved solids in water sources in northwestern Utah. The lowest dissolved-solids concentrations are found in the Pilot Range and Grouse Creek and Raft River Mountains, and the concentrations become progressively greater toward the desert floor. The greatest concentrations of dissolved solids occur in brines underlying the Bonneville Salt Flats.

Table 8.--Estimated volumes of recoverable ground water in storage in hydrologic subareas of northwestern Utah

Based on dewatering of upper 100 feet of saturated aquifer material containing fresh water, except as noted. Estimates are from reports cited on page 3, except for those areas described in this report.

Remarks: Saline water contains more than 1,000 mg/l of dissolved solids. Briny water contains more than 35,000 mg/l of dissolved solids.

Subarea	Assumed specific yield or storage coefficient	Volume in storage (1,000 acre-feet)	Remarks
Blue Creek Valley	0.025	200	Includes some saline water.
Promontory Mountains	.05	760	Predominantly saline water.
Hansel Valley	.05	65	
Curlew Valley	.05	1,000	Includes some saline water.
Park Valley	.05 (unconsolidated rocks) .01 (semiconsolidated and consolidated rocks)	500	Do.
Grouse Creek valley	.15 (channel fill) .02 (older alluvium)	160	Complete dewatering of channel-fill deposits and upper 100 feet of older alluvium.
Pilot Valley	.10	500	Includes only area where 100 feet of saturated material present above 4,250-foot altitude; below 4,250 feet water is saline or briny.
Northern Great Salt Lake Desert	.063 (shallow brine aquifer) .0004 (valley-fill aquifer in central part of subarea)	1,400	Complete dewatering of both shallow brine and valley-fill aquifers in central part of subarea; no estimate for alluvial-fan aquifer. All water briny.
	.10 (valley-fill aquifer in Ripple Valley)	50	Southern part of Ripple Valley only; includes some saline water.
Sink Valley	.20 (marginal sand and gravel) .10 (central fine-grained materials)	370	Complete dewatering of saturated materials above 4,195-foot altitude; below 4,195 feet water is saline.
West Shore 1/	.02	600	Predominantly saline water.
Total (rounded)		5,600	

1/ Estimated from information in Hood and Waddell (1968, p. 28-30) and Price and Bolke (1970, p. 18-19). Assumed specific yield reflects fine-grained aquifer material.

Table 9.--Summary of chemical analyses of ground-water samples from northwestern Utah

Subarea	Dissolved-solids concentration, in milligrams per liter											
	Less than 1,000		1,000-3,000		3,000-10,000		10,000-35,000		More than 35,000			
	Number of samples	Percent of samples	Number of samples	Percent of samples	Number of samples	Percent of samples	Number of samples	Percent of samples	Number of samples	Percent of samples	Minimum	Maximum
Blue Creek Valley	28	66	10	24	4	10	-	-	-	-	382	6,080
Promontory Mountains	34	48	19	27	16	22	2	3	-	-	272	24,900
Hansel Valley	12	54	3	14	2	9	1	5	4	18	400	94,400
Curlew Valley	32	64	14	28	3	6	1	2	-	-	323	10,400
Park Valley	27	82	2	6	1	3	3	9	-	-	111	26,100
Grouse Creek valley	28	97	1	3	-	-	-	-	-	-	248	1,100
Pilot Valley	10	77	1	8	2	15	-	-	-	-	170	1,130
Northern Great Salt Lake Desert	1	1	2	2	3	2	-	-	126	95	801	1/165,000
Sink Valley	-	-	6	33	7	39	4	22	1	6	1,750	48,100
West Shore	-	-	-	-	2	100	-	-	-	-	3,380	7,270
Total	172	41	58	14	40	10	11	3	131	32	111	1/165,000

1/ Single analysis given for a composite sample of brine from 126 shallow test holes in the Great Salt Lake Desert by Nolan (1928, p. 39).

Potential for additional water-resources development

The water resources of northwestern Utah are used for domestic, municipal, livestock, and irrigation supplies and for mineral extraction. Dependable surface-water supplies are not available in most parts of the area; where they are available, they are generally fully developed for irrigation. Thus, the major source of additional water supplies in the area is ground water.

The primary constraint on development of ground water in northwestern Utah is chemical quality. All the water underlying the central part of the area is very saline or briny and much of the water at depth in the valleys surrounding the desert is too saline for present uses.

Small additional water supplies for municipal and domestic needs are generally available in the areas where such uses now exist. Additional water supplies for irrigation may be available locally in many of the subareas, but proposals for development should include a more detailed investigation of local ground-water conditions, including test drilling at proposed well sites.

A detailed hydrologic investigation should precede any attempt to recover ground water from storage in any of the subareas. In many places, such as in Pilot and Sink Valleys, pumping from storage would lower the potentiometric surface to the level at which saline water from adjacent areas would begin moving toward the wells, and water quality in the aquifer would deteriorate. In all cases, detailed knowledge of local ground-water conditions would be necessary for proper design and spacing of wells.

The unconsolidated materials that constitute the major ground-water reservoir throughout most of northwestern Utah are not uniform. Where the material is predominantly fine grained, the aquifer may yield water too slowly to supply large irrigation needs. In many parts of the area, and especially in the upper reaches of tributary valleys and under the upper slopes of alluvial aprons surrounding many of the mountain ranges, depths to the water table are too great for economical pumping for irrigation.

Livestock water supplies are generally available throughout the area surrounding the floor of the desert. Because the required yield of a stock well is relatively small, stockwater supplies can be obtained in many areas where the aquifer is thin, is composed of fine-grained materials, and is only slightly permeable. However, such marginal aquifer conditions may also result in the presence in the aquifer of water too saline for livestock use, because where ground-water movement is slow the salts present in the aquifer may not have been flushed out. Thus, each proposed well site should be investigated to determine probable ground-water conditions prior to construction of a supply well.

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APPENDIX

Well- and spring-numbering system

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the Federal Government. The number in addition to designating the well or spring, locates the site in the land net. By this system the State is divided into four quadrants by the Salt Lake base line and meridian. These quadrants are designated by the uppercase letters A, B, C, and D, thus: A, for the northeast quadrant; B, for the northwest; C, for the southwest; and D, for the southeast quadrant. Numbers designating the township and range, respectively, follow the quadrant letter, and the three are enclosed in parentheses. The number after the parentheses designates the section, and the following three letters give the location of the site within the section. The first letter indicates the quarter section, which is generally a tract of 160 acres, the second letter indicates the 40-acre tract, and the third letter indicates the 10-acre tract if known. The number that follows the letters indicates the serial number of a well within the 10-acre tract. Thus, well (B-5-13)31acd-1, in Box Elder County, is in the SE¼SW¼NE¼ sec.31, T.5 N., R.13 W., and is the first well constructed or visited in that tract (see fig. 5). If the location within a 10-acre tract is unknown, no serial number is given.

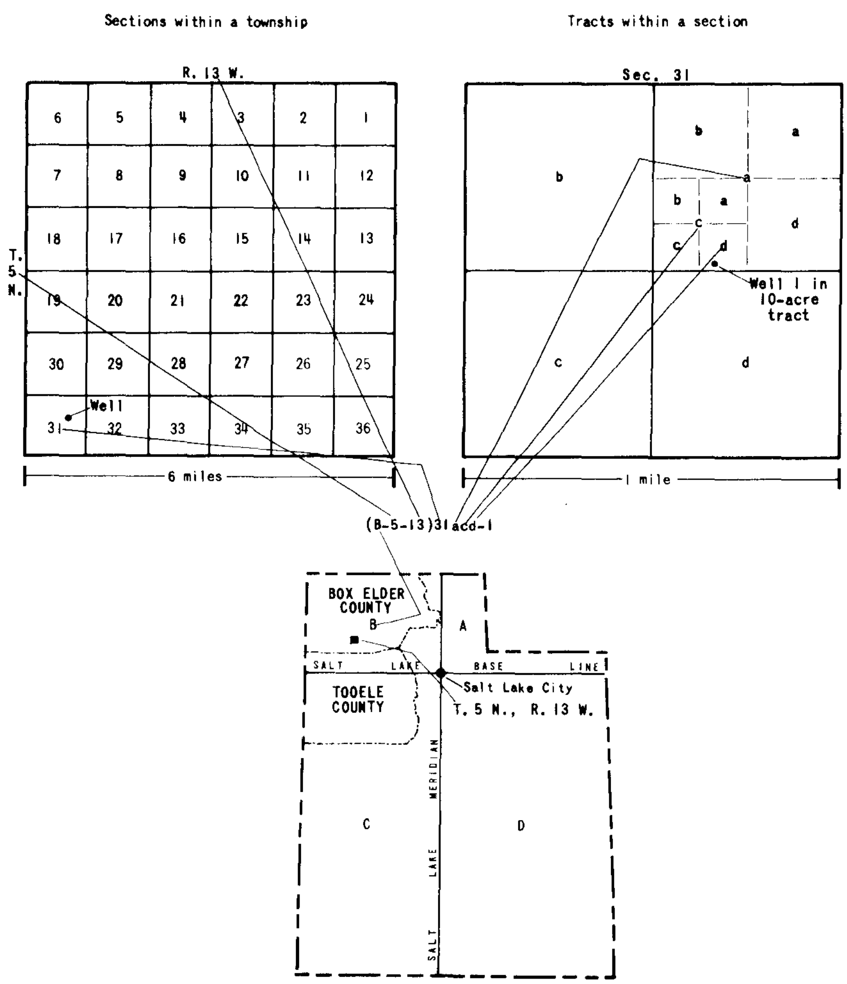

Figure 5.--Well- and spring-numbering system used in Utah.

Springs are designated by the letter S preceding the serial number (final number at the end of the location number), for example, (B-5-13)18bd-S (10-acre tract not determined).

Use of metric units

In this report, the units which indicate concentrations of dissolved solids and individual ions determined by chemical analysis and the temperatures of air and water are metric units. This change from reporting in "English units" has been made as a part of a gradual change to the metric system that is underway within the scientific community. The change is intended to promote greater uniformity in reporting of data. Chemical data for concentrations are reported in milligrams per liter (mg/l) rather than in parts per million (ppm), the units used in earlier reports in this series. For concentrations less than 7,000 mg/l, the number reported is about the same as for concentrations in parts per million. For more highly mineralized water, the concentrations in milligrams per liter must be adjusted for the density of the sample to get the equivalent parts per million and the resulting number is always less than the equivalent number in milligrams per liter. For example, a concentration of dissolved solids of 165,000 milligrams per liter, the average for shallow brine samples collected by Nolan (1928, p. 39) in the Great Salt Lake Desert, is equivalent to 149,000 parts per million.

Water temperature is reported in degrees Celsius (°C). Air temperature is reported in degrees Fahrenheit (°F) as given in U.S. Environmental Science Services Administration publications. The following conversion table will help to clarify the relation between degrees Fahrenheit and degrees Celsius:

Temperatures in °C are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from °F to °C where two lines have the same value for °F, use the line marked with an asterisk (*) to obtain equivalent °C.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20.0	-4	-10.0	14	0.0	32	10.0	50	20.0	68	30.0	86	40.0	104
-19.5	-3	-9.5	15	+0.5	33	10.5	51	20.5	69	30.5	87	40.5	105
-19.0	-2	-9.0	16	1.0	34	11.0	52	21.0	70	31.0	88	41.0	106
-18.5	-1	-8.5	17	1.5	35	11.5	53	21.5	71	31.5	89	41.5	107
-18.0 *	0	-8.0 *	18	2.0 *	36	12.0 *	54	22.0 *	72	32.0 *	90	42.0 *	108
-17.5	0	-7.5	18	2.5	36	12.5	54	22.5	72	32.5	90	42.5	108
-17.0	1	-7.0	19	3.0	37	13.0	55	23.0	73	33.0	91	43.0	109
-16.5	2	-6.5	20	3.5	38	13.5	56	23.5	74	33.5	92	43.5	110
-16.0	3	-6.0	21	4.0	39	14.0	57	24.0	75	34.0	93	44.0	111
-15.5	4	-5.5	22	4.5	40	14.5	58	24.5	76	34.5	94	44.5	112
-15.0	5	-5.0	23	5.0	41	15.0	59	25.0	77	35.0	95	45.0	113
-14.5	6	-4.5	24	5.5	42	15.5	60	25.5	78	35.5	96	45.5	114
-14.0	7	-4.0	25	6.0	43	16.0	61	26.0	79	36.0	97	46.0	115
13.5	8	-3.5	26	6.5	44	16.5	62	26.5	80	36.5	98	46.5	116
-13.0	9	-3.0	27	7.0	45	17.0	63	27.0	81	37.0	99	47.0	117
-12.5	10	-2.5	28	7.5	46	17.5	64	27.5	82	37.5	100	47.5	118
-12.0 *	10	-2.0 *	28	8.0 *	46	18.0 *	64	28.0 *	82	38.0 *	100	48.0 *	118
-11.5	11	-1.5	29	8.5	47	18.5	65	28.5	83	38.5	101	48.5	119
11.0	12	-1.0	30	9.0	48	19.0	66	29.0	84	39.0	102	49.0	120
-10.5	13	-0.5	31	9.5	49	19.5	67	29.5	85	39.5	103	49.5	121

For temperature conversions beyond the limits of the table, use the equations °C = 0.5556 (°F - 32) and °F = 1.8(°C) + 32. The formulae say, in effect, that from the freezing point of water (0°C, 32°F) the temperature in °C rises (or falls) 5° for every rise (or fall) of 9°F.

Terms describing aquifer characteristics

The U.S. Geological Survey (Lohman and others, 1972) has recently redefined and standardized many of the commonly used technical terms of ground-water hydrology. Three of these terms that are used in this report are transmissivity, specific yield, and storage coefficient. These three terms describe the capacity of an aquifer to transmit and store water.

Transmissivity (T) is the rate at which water of the prevailing viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The units for T are cubic feet per day per foot (ft^3/day/ft), which reduces to ft^2/day. The term transmissivity replaces the term coefficient of transmissibility, which was formerly used by the U.S. Geological Survey and which was reported in units of gallons per day per foot. To convert a value for coefficient of transmissibility to the equivalent value of transmissivity, multiply by 0.134; to convert from transmissivity to coefficient of transmissibility, multiply by 7.48.

The *specific yield* of an aquifer is the ratio of the volume of water it will yield by gravity after being saturated, to the volume of dry aquifer. It is practically equivalent to the storage coefficient for an unconfined aquifer.

The *storage coefficient (S)* of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in head. S is a dimensionless number. Under confined conditions, S is typically small, generally between 0.00001 and 0.001. Under unconfined conditions, S is much larger, typically from 0.05 to 0.30.

Basic data for northern Great Salt Lake Desert

Table 10.--Records of selected wells and springs in northern Great Salt Lake Desert

Location: See Appendix for description of well- and spring-numbering system.
Owner, user, or name: Local name in parentheses.
Casing: Depth - depth to top of perforations.
Altitude: Altitude of land-surface datum above mean sea level; interpolated from topographic map and accurate to 50 feet; except A, estimated with altimeter and accurate to 20 feet; I, determined by instrumental leveling and accurate to 1 foot.
Water level: Static water level; given in feet and tenths if measured by U.S. Geological Survey personnel; all others given in feet.
Rate of discharge: Reported by driller except e, estimated by U.S. Geological Survey personnel.
Drawdown: Below static water level when discharging at rate given in preceding column.
Method of lift: F, artesian flow; Fx, formerly artesian flow; N, none; P, piston pump; S, submersible pump; T, turbine pump.
Use of water or well: I, industrial; O, observation; S, livestock; T, test hole; U, unused.
Water temperature: Reported, except m, measured by U.S. Geological Survey personnel.
Remarks and other data available: C, chemical analysis in table 12; Cs, summary chemical-quality data in table 4; H, hydrograph in figure 3; K, specific conductance, in micromhos/cm at 25°C, measured with portable conductivity meter; L, driller's log in table 11; Lf, driller's log in U.S. Geological Survey files; Sc, specific capacity, in gallons per minute per foot of drawdown, based on figures given in discharge and drawdown columns (length of test given in parentheses if known); S, storage coefficient; T, transmissivity, in feet squared per day (ft^2/day).

Location	Owner, user, or name	Year drilled	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Altitude (ft)	Water level below or above(+) land surface datum (ft)	Rate of discharge (gpm)	Drawdown (ft)	Date of measurement of water level, discharge, drawdown, and temperature	Method of lift	Use of water or well	Water temperature (°C)	Remarks and other data available
(B-1-11)1cab-1	U.S. Bureau of Land Management (Swan Well)	1944	194	4	-	4,460A	165	-	-	1944	T	S	-	Water reported "slightly salty." L.
26bbc-1	Do. (Porter Well)	1953	175	6	135	4,380	140	17	25	3-13-53	T	S	-	K, 16,000; Sc, 0.7. See Connor, Mitchell, and others (1958, p. 150) for chemical analysis. L.
35bcc-1	Do. (Grayback Well)	1951	155	6	78	4,360A	78	30	47	3-26-51	N	U	-	Sc, 0.6; well destroyed because water too saline for livestock. See Snyder (1963, p. 500) for discussion of water quality. L.
(B-1-18)29ccc-1	Bonneville, Ltd. (Well No. 24)	1948	167	12	130	4,250	+15	-	-	1- 6-48	F	U	28m	Discharge estimated 25 gpm on 3-29-72. C, L.
31ccd-1	Do. (Well No. 17)	1948	364	12	300	4,250	+15	600	-	10-23-48	Fx	U	24	L.
31dbb-1	Do. (Well No. 20)	1947	295	12	230	4,250	+15	150	-	12-16-47	Fx	U	24	Water level at land surface on 3-29-72. L.
(B-1-19)36ddd-1	Do. (Well No. 16)	1948	287	12	250	4,250	+15	-	-	7-22-48	Fx	U	24	
(B-2-11)20ba	U.S. Bureau of Land Management	1958	340	-	-	4,400	295	30	-	1958	P	S	-	Well reportedly pumps dry at 60 gpm, but will "hold up" at 30 gpm.
28ccd-1	Do. (Thumb Well)	1948	160	6	118	4,385A	111	40	0	11-21-48	T	S	-	L.
(B-3-11)3ad	Do. (Round Mountain Well)	1940	205	6	-	4,500	160	-	-	5-14-40	-	S	-	L.
31aaa-1	Do. (Finger Well No. 1)	1947	147	6	125	4,310	35	-	-	1- 4-47	N	U	-	Well destroyed because water too saline for livestock. L.
31ddb-1	Do. (Finger Well No. 2)	1947	107	6	85	4,360	87(?)	25	-	2- 3-47	N	U	-	Do.
(B-3-12)23ccd-1	U.S. Air Force	1969	500	8	175	4,240	16	60	134	7-21-69	N	U	-	Sc, 0.4 (10 hours); well drilled to supply water for road construction; water reported salty. L.
(B-5-13)18bd-S	U.S. Bureau of Land Management (Coyote Spring)	-	-	-	-	5,200	-	3e	-	3- 8-72	-	S	12m	Issues from fractures in dolomite(?). C.
31acd-1	L. W. Keller Corp. (Well No. 2)	1963	200	6	150	4,400	141.5	-	-	3- 8-72	S	S	22m	C, L.
(B-5-14)36cbb-1	Do. (Well No. 1)	1963	200	6	150	4,400	150	-	-	10-15-63	T	S	-	L.
(B-6-10)14(?)	Southern Pacific RR (Strongknob Well)	1902	781	-	-	4,206I (?)	-	-	-	-	N	U	-	Well has been destroyed. L.
(B-6-13)18da-S	U.S. Bureau of Land Management	-	-	-	-	4,800	-	.5e	-	3- 8-72	-	S	10.5m	K, 1,260; formerly piped to nearby mining camp which is now abandoned; vegetation in discharge area indicates that spring is perennial.
30bc-S	Do. (North Miners Basin Spring)	-	-	-	-	4,600-4,800	-	2.5e	-	3- 8-72	-	S	11m	Piped to stock tank in NE¼NE¼SE¼ sec. 25, T. 6 N., R. 14 W; discharges in bottom of gully from series of small seeps extending a half-mile upstream from pipeline point of collection. C.
31ac-S	Do. (South Miners Basin Spring No. 1)	-	-	-	-	5,250-5,300	-	10e	-	3- 8-72	-	S	13m	Piped to stock tank at base of mountains to southwest; discharges in bottom of gully from series of small seeps extending a quarter-mile upstream from pipeline point of collection. C.
31db-S	Do. (South Miners Basin Spring No. 2)	-	-	-	-	5,250-5,300	-	1e	-	3- 8-72	-	S	-	K, 1,700; discharges from series of small seeps in bottom of gully; discharge at time of sampling consisted largely of meltwater from snowbanks in bottom of gully.
32bc-S	Do.	-	-	-	-	5,800	-	3e	-	3- 8-72	-	S	-	K, 1,200; discharge at time of sampling consisted largely of meltwater from snowbanks in bottom of gully.
(B-6-16)10d-S	Do.	-	-	-	-	4,230	-	-	-	9-21-71	-	S	-	K, 2,000; large open spring pool bordered by cattails, rushes, saltgrass, and rabbitbrush.

Location	Owner, user, or name	Year drilled	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Altitude (ft)	Water level below or above(+) land surface datum (ft)	Rate of discharge (gpm)	Drawdown (ft)	Date of measurement of water level, discharge, drawdown, and temperature	Method of lift	Use of water or well	Water temperature (°C)	Remarks and other data available
(B-6-16)14bb	Gulf Oil Co. (Williams Federal No. 1)	1954	2,894	13 3/8	1,959	4,230I	-	-	-	-	N	T	-	Electrical and mechanical logs in files of U.S. Geol. Survey.
14bb-S	U.S. Bureau of Land Management	-	-	-	-	4,230	-	-	-	9-21-71	-	S	-	K, 2,100; large open spring pool bordered by cattails, rushes, saltgrass, and rabbitbrush.
(B-7-12)3cdb-1	Perry Land and Livestock Co.	-	-	-	-	4,750	-	7	-	-	-	S	-	
(B-7-14)29	Southern Pacific RR (Lemay Well)	1902	2,502	-	-	4,218I (?)	-	-	-	-	N	U	-	Well has been destroyed. L.
36	Do. (Newfoundland Well)	1902	293	-	-	4,218I (?)	-	-	-	-	N	U	-	Do.
(B-8-11)20dda-1	Basin Land and Livestock Co.	-	-	6	-	4,686	-	7	-	-	-	S	-	
(C-1-10)5cab-1	Utah State Road Commission	-	420	8	390	4,600	-	50	50	9-10-69	N	U	-	Sc, 1 (6 hours); water level measured 360.6 feet below land surface 11-9-71. L.
(C-1-11)16	U.S. Bureau of Land Management (Clive Well)	-	90	-	-	-	-	-	-	-	N	U	-	Well never used; water reported to have contained 35,700 parts per million of sodium chloride.
18bcd-1	Cox Construction Co.	1969	350	8	185	4,350	53	600	120	12-29-69	N	U	-	Sc, 5 (10 hours); well drilled to supply water for road construction, later destroyed. L.
36bba-1	Deseret Livestock Co.	1940	276	6	-	4,550	264	18	-	5- 4-40	N	U	-	Well has been destroyed.
36bba-2	Do.	1946	293	6	265	4,550	263	-	-	11-10-46	P	S	-	L.
(C-1-19)1bbb-1	Bonneville, Ltd. (Well No. 15)	1948	164	12	130	4,250	+15	800	-	6-25-48	Fx	U	24	L.
2aad-1	Do. (Well No. 14)	1948	247	12	200	4,250	+15	600	-	6-16-48	Fx	U	24	L.
2acc-1	Do. (Well No. 12)	1948	280	12	218	4,250	+15	600	-	5-20-48	Fx	U	24	Water level measured 1 foot below land surface 5-10-68. L.
2adb-1	Do. (Well No. 13)	1947	225	12	195	4,250	-	600e	-	3-29-72	Fx, T	I	24.5m	Water level reported 15 feet above land surface 11-25-47. L, C.
2caa-1	Do. (Well No. 11)	1948	247	12	90	4,250	+15	600	-	5-31-48	Fx	U	24	Water temperature 26°C 8-4-67. Lf.
2cbc-1	Do. (Well No. 9)	1947	181	12	150	4,250	+20	2,500	-	10- 3-47	Fx	U	24	S, 5 x 10^{-4}; T, 63,650 (Turk, 1969, p. 65); water level measured 4 feet below land surface 5-10-68. Lf.
2cbd-1	Do. (Well No. 10)	1947	219	12	180	4,250	+15	500	-	10-21-47	Fx	U	24	S, 2 x 10^{-4}; T, 26,800 (Turk, 1969, p. 65). Lf.
2cbd-2	Do. (Well No. 9A)	1949	193	16	130	4,250	+15	600	-	6-23-49	Fx	U	24	Water temperature 26°C 8-4-67. Lf.
3dcd-1	Do. (Well No. 7)	1948	175	12	140	4,250	+15	800	-	1-17-48	Fx	U	24	Lf.
3dda-1	Do. (Well No. 8A)	1949	210	16	140	4,250	+15	600	-	5- 3-49	Fx	U	24	Lf.
3ddb-1	Do. (Well No. 8)	1946	185	10	100	4,250	4.2	-	-	3- 1-71	Fx, T	I, O	-	Water level reported 15 feet above land surface, discharge 400 gpm on 6-2-46. See page 17 for water-level measurements, 1962-72. H, L.
3ddc-1	Do. (Well No. 7A)	1949	171	10	130	4,250	3.0	-	-	3- 1-71	Fx	O	24	Water level reported 15 feet above land surface, discharge 1,000 gpm on 5-16-49. L.
9adc-1	Do. (Well No. 2)	1946	160	1/6,4	100	4,250	+15	330	-	5-25-46	Fx	U	24	Water level measured 7 feet below land surface on 5-10-68. L.
9dbb-1	Do. (Well No. 1)	1946	88	8	60	4,250	+10	280	-	3-22-46	Fx	U	24	L.
10abb-1	Do. (Well No. 6A)	1949	174	10	-	4,250	3.6	-	-	3- 1-71	Fx	O	-	
10bac-1	Do. (Well No. 5)	1948	216	2/12, 10	107	4,250	-	500	-	2-27-48	Fx, T	I	24	Water temperature 31°C 9-8-67. C, L.
10bca-1	Do. (Well No. 4)	1948	176	3/12, 10	123	4,250	+15	600	-	4- 5-48	Fx	U	24	Lf.
23cbc-1	Do. (Brine Well No. 13)	1951	1,496	12	995	4,220	-	-	-	9-13-67	T	I	24.5	C, Cs, Lf.
25baa-1	Do. (Brine Well No. 4)	1951	1,640	16	1,224	4,220	-	-	-	-	U	-	-	L.
34abb-1	Do. (Brine Well No. 10)	1951	1,152	-	-	4,220	66	-	-	2-23-70	T	I	-	Water temperature 27°C 7-24-67; T, >49,000. Cs, Lf.
34bdc-1	Do. (Brine Well No. 8)	1951	1,045	-	-	4,220	22	1,270 1,000	85 70	1951	T	I	-	Sc, 14-15; water temperature 28°C 9-13-67. C, Cs, Lf.
34cdc-1	Do. (Brine Well No. 6)	1950	1,153	4/16, 12	-	4,220	30	1,000	40	7- 6-50	-	U	32	Sc, 25; S, 4 x 10^{-4}; T, 14,300-15,300 (Bonneville, Ltd. file data). Water level 60 feet below land surface 3-24-70; water temperature 27°C 9-13-67. Cs, L.
35bcb-1	Do. (Brine Well No. 9)	1951	1,418	16	1,005	4,220	30	1,200	31	1-14-51	-	U	30	Sc, 39; water level 52 feet below land surface 5-10-68. L.
35ccc-1	Do. (Brine Well No. 2)	1949	1,540	16	1,018	4,220	30	1,500	20	3- 5-49	-	U	34	Sc, 75; water temperature 25°C 9-13-67. L.

1/ 6-inch casing to 128 feet, 4-inch strainer pipe below.
2/ 12-inch casing to 140 feet, 10 inch below.
3/ 12-inch casing to 82 feet, 10 inch below.
4/ 16-inch casing to 212 feet, 12 inch below.

Table 11.--Drillers' logs of selected wells in northern Great Salt Lake Desert

Material	Thickness	Depth
(B-1-11)1cab-1. Log by L. E. Hale. Alt. 4,460 ft.		
Sand and clay	20	20
Gravel, coarse; clay and boulders	100	120
Gravel and rock	40	160
Sand	10	170
Gravel	7	177
Sand	15	192
Gravel (Driller's report indicates well completed at total depth of 194 ft)	4	196
(B-1-11)26bbc-1. Log by L. E. Hale. Alt. 4,380 ft.		
Gravel and clay mixed	140	140
Sand; water	20	160
Gravel; water	15	175
(B-1-11)35bcc-1. Log by L. E. Hale. Alt. 4,360 ft.		
Clay	78	78
Sand; water bearing	77	155
(B-1-18)29ccc-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	22	22
Gravel	4	26
Clay	83	109
Clay and gravel	2	111
Clay	13	124
Gravel	9	133
Clay	7	140
Conglomerate	11	151
Gravel	4	155
Conglomerate	12	167
(B-1-18)31ccd-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	242	242
Clay and gravel	10	252
Gravel	1	253
Clay and gravel	47	300
Gravel, loose	1	301
Clay and gravel	24	325
Sand, fine	5	330
Sand	12	342
Gravel	1	343
Sand, fine	21	364
(B-1-18)31dbb-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay, sandy	18	18
Clay, blue	151	169
Hardpan	1	170
Clay, blue	50	220
Clay and gravel	5	225
Clay	10	235
Sand and gravel	3	238
Clay	9	247
Clay, gravel, and conglomerate	48	295
(B-2-11)28ccd-1. Log by L. E. Hale. Alt. 4,385 ft.		
Clay	5	5
Gravel and boulders	5	10
Clay	70	80
Gravel	5	85
Clay	10	95
Gravel	7	102
Clay	13	115
Gravel and sand	45	160
(B-3-11)3ad. Log by L. E. Hale. Alt. 4,500 ft.		
Clay, white	6	6
Gravel and rock	154	160
Gravel, loose; water bearing	45	205
(B-3-11)31aaa-1. Log by L. E. Hale. Alt. 4,310 ft.		
Clay	35	35
Sand and gravel; water bearing	112	147
(B-3-11)31ddb-1. Log by L. E. Hale. Alt. 4,360 ft.		
Topsoil	1	1
Rocks and gravel	50	51
Sand and hardpan	36	87
Gravel; water bearing	20	107
(B-3-12)23ccd-1. Log by Robinson Drilling Co. Alt. 4,240 ft.		
Clay, yellow	10	10
Clay, blue	13	23
Clay, blue, and sand	71	94
Sand	12	106
Clay and sand	106	212
Sand	9	221
Clay and sand	152	373
Sand	5	378
Clay and sand	87	465
Sand	16	481
Clay and sand	19	500
(B-5-13)31acd-1. Log by Siaperas Drilling Co. Alt. 4,400 ft.		
Gravel, broken rock	23	23
Clay and sand	11	34
Gravel and boulders	28	62
Boulders, broken rock	2	64
Gravel and boulders	55	119
Boulders	43	162
Clay and boulders	38	200
(B-5-14)36cbb-1. Log by Siaperas Drilling Co. Alt. 4,400 ft.		
Boulders, broken rock	10	10
Gravel and boulders	20	30
Gravel and conglomerate	28	58
Conglomerate with broken rock	6	64
Gravel and boulders	16	80
Sand and small gravel	20	100
Gravel and boulders	20	120
Sand and boulders	20	140
Sand and gravel	20	160
Boulders	20	180
Gravel; water	20	200
(B-6-10)14(?). Log condensed from Schreiber (1954, p. 10-11). Alt. 4,206 ft.		
Quicksand	4	4
Clay, brown, and gypsum	1	5
Clay, brown	2	7
Clay and sandy clay, interlayered; gypsum layers at intervals; predominantly blue, some yellow and brown layers	244	251
Clay, blue to dark blue; white quicksand from 269 ft to 273 ft.	30	281
Clay, sandy clay, and quicksand, interlayered; predominantly blue to brown, some green from 281 ft. to 334 ft.	500	781
(B-7-14)29. Log condensed from Schreiber (1954, p. 5-8). Alt. 4,218 ft.		
Clay, brown, blue, and green	53	53
Clay, interlayered with clay and gypsum beds; occasional thin sandstone beds from 192 ft. to 304 ft; predominantly blue and green	289	342
Sandstone; hard and soft layers	128	470
Clay, shale, and clay with shale streaks, interlayered; very soft to hard; blue	195	665
Clay, soft, blue with hard streaks of rock	15	680
Sandstone, clay, sandy, clay, and sandy shale, interlayered; predominantly blue	532	1,212
Shale, clay, and sandstone; interlayered; predominantly blue	173	1,385
Limestone and shale, interlayered; predominantly blue to black; sandy in part	174	1,559
Lava	17	1,576
Limestone, predominantly brown	114	1,690
Lava, predominantly brown to black	418	2,108
Sandstone and limestone, interlayered; predominantly hard and flinty	214	2,322
Sandstone; white from 2,433 ft. to 2,472 ft.	180	2,502
(B-7-14)36. Log condensed from Schreiber (1954, p. 9). Alt. 4,218 ft.		
Mud, soft	30	30
Clay, blue to dark blue	27	57
Clay with stringers of glassy substance (gypsum?), blue	18	75
Clay, blue	25	100
Clay with stringers of glassy substance (gypsum?), blue	26	126
White substance, apparently soda	4	130
Clay with layers of glassy rock (gypsum?), mostly blue	96	226
Sandstone, white	4	230
Clay, sandy, blue	8	238
Clay, hard transparent substance (gypsum?) and sandstone, about equally divided	20	258
Sandstone	11	269
Clay	20	289
Sandstone	4	293
(C-1-10)5cab-1. Log by Stephenson Drilling Co. Alt. 4,600 ft.		
Topsoil	3	3
Sand	7	10
Clay	15	25
(C-1-10)5cab-1.-Continued.		
Clay and sand	325	350
Clay, sand, and gravel	35	385
Sand and gravel	35	420
(C-1-11)18bcd-1. Log by Petersen Bros. Drilling Co. Alt. 4,350 ft.		
Clay, white	20	20
Clay, white, and small gravel	5	25
Clay and gravel, white	35	60
Clay and gravel, white; harder	10	70
Sand, soft; mud and water	5	75
Clay and sand, white	5	80
Clay and gravel, brown; hard	45	125
Clay, white; little gravel	35	160
Clay and gravel, white	34	194
Gravel	9	203
Clay	4	207
Sandstone	25	232
Clay and gravel	8	240
Clay and gravel; soft	5	245
Sand; hard	7	252
Sandstone	40	292
Clay and gravel, white	10	302
Clay, white, little gravel	18	320
Clay and gravel, white	15	335
Sand, gray; hard	15	350
(C-1-11)36bba-2. Log by L. E. Hale. Alt. 4,550 ft.		
Soil and clay	24	24
Clay, sand, and gravel, mixed	236	260
Sand; water bearing	10	270
Gravel; water bearing	23	293
(C-1-19)1bbb-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	100	100
Clay and gravel	7	107
Gravel	2	109
Conglomerate	12	121
Gravel, loose	1	122
Conglomerate	2	124
Gravel	1	125
Conglomerate	20	145
Clay	11	156
Gravel, loose	8	164
(C-1-19)2aad-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	116	116
Gravel	4	120
Clay	2	122
Gravel	3	125
Clay	2	127
Gravel	3	130
Clay	25	155
Gravel	7	162
Clay	2	164
Gravel	15	179
Clay, hard	20	199
Clay and sand	5	204
Sand and gravel	3	207
Conglomerate	18	225
Gravel and conglomerate	22	247
(C-1-19)2acc-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	122	122
Gravel	4	126
Clay	24	150
Gravel	3	153
Clay and gravel	9	162
Hardpan	1	163
Gravel	4	167
Clay	17	184
Gravel with little clay	11	195
Clay	4	199
Sand	5	204
Clay and gravel	3	207
Clay and sand	29	236
Sand, free-flowing	2	238
Clay and gravel, brown	28	266
Clay and rock, yellow	14	280
(C-1-19)2adb-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	117	117
Gravel	7	124
Clay	23	147
Gravel	1	148
Conglomerate	1	149
Gravel	3	152
Hardpan	2	154
Clay	3	157
Gravel	11	168
Clay	16	184
Gravel	41	225
(C-1-19)3ddb-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	99	99
Gravel	2	101
Clay	8	109

Table 11.--Drillers' logs of selected wells in northern Great Salt Lake Desert - Continued

Material	Thickness	Depth
(C-1-19)3ddb-1-Continued.		
Sand and gravel	7	116
Clay	24	140
Gravel	21	161
Clay	3	164
Clay and gravel	5	169
Gravel, coarse	14	183
Rock, solid	2	185
(C-1-19)3ddc-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	100	100
Gravel	3	103
Clay	9	112
Gravel	7	119
Clay	18	137
Gravel	18	155
Clay and gravel	6	161
Conglomerate	2	163
Gravel, loose	2	165
Sand, brown	6	171
(C-1-19)9adc-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	28	28
Gravel	6	34
Clay	19	53
Gravel	5	58
Clay	7	65
Gravel	5	70
Clay	5	75
Gravel	16	91
Clay	7	98
Gravel, with streaks of clay	18	116
Gravel, good, clear, coarse; water bearing	2	118
Clay and gravel, mixed	28	146
Gravel, coarse, loose	1	147
Clay and gravel, mixed	13	160
(C-1-19)9dbb-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay	40	40
Conglomerate	2	42
Clay	21	63
Conglomerate and gravel	4	67
Clay	4	71
(C-1-19)9dbb-1-Continued.		
Conglomerate and gravel (flow 240 gpm)	8	79
Conglomerate and gravel (flow increased to 280 gpm)	9	88
Clay and gravel	8	96
Unknown (no increase in flow and casing pulled back to 88 ft)	8	104
(C-1-19)10bac-1. Log by J. F. O'Brien. Alt. 4,250 ft.		
Clay, blue	92	92
Conglomerate	3	95
Clay and gravel	12	107
Conglomerate	3	110
Clay and gravel	12	122
Conglomerate	94	216
(C-1-19)25baa-1. Log condensed from detailed driller's log by J. F. O'Brien provided by Kaiser Aluminum and Chemical Corp. Alt. 4,220 ft.		
Clay, with streaks of gypsum	1,102	1,102
Clay, sandy; hard	90	1,192
Gypsum sand; hard	3	1,195
Clay	33	1,228
Gypsum	2	1,230
Gravel	4	1,234
Conglomerate and clay	189	1,423
Mud, brown and gray	10	1,433
Mud, brown; sticky	13	1,446
Conglomerate, green	5	1,451
Mud, brown; sticky	4	1,455
Conglomerate, green, black (Driller's report indicates well completed at total depth of 1,640 ft)	189	1,644
(C-1-19)34cdc-1. Log condensed from detailed driller's log by J. F. O'Brien, provided by Kaiser Aluminum and Chemical Corp. Alt. 4,220 ft.		
Clay	265	265
Gypsum	3	268
(C-1-19)34cdc-1-Continued.		
Clay	47	315
Gypsum	3	318
Clay	137	455
Gypsum	4	459
Clay	28	487
Gypsum	2	489
Clay	3	492
Gypsum	8	500
Clay, with some gypsum streaks	134	634
Gypsum	11	645
Clay	69	714
Gypsum	2	716
Clay	119	835
Clay, hard	40	875
Clay, hard, with small amount of gypsum and gravel	10	885
Clay, sticky	17	902
Clay, hard	16	918
Clay, sand, and gravel	14	932
Clay, hard	12	944
Conglomerate	209	1,153
(C-1-19)35bcb-1. Log condensed from detailed driller's log by J. F. O'Brien, provided by Kaiser Aluminum and Chemical Corp. Alt. 4,220 ft.		
Clay, with gypsum beds up to 4 ft. thick	1,025	1,025
Conglomerate	344	1,369
Gravel and sand	15	1,384
Conglomerate (Driller's report indicates well completed at total depth of 1,418 ft)	40	1,424
(C-1-19)35ccc-1. Log condensed from detailed driller's log by J. F. O'Brien, provided by Kaiser Aluminum and Chemical Corp. Alt. 4,220 ft.		
Clay, with occasional gypsum beds	1,014	1,014
Conglomerate (''solid mass of gravel and sand cemented with lime'')	526	1,540

Table 12.--Chemical analyses of ground-water samples from northern Great Salt Lake Desert

Dissolved solids: Calculated from sum of determined constituents.
Agency making analysis: GS, U.S. Geological Survey; K, Kaiser Aluminum and Chemical Co., San Leandro, Calif.

Location	Date of collection	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite + Nitrate (as N)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH	Agency making analysis
(B-1-18)29ccc-1	3-29-72	28.0	41	0.03	0.01	91	71	2,200	130	180	0	240	3,400	1.4	0.00	0.96	6,260	520	370	87	42	11,000	7.7	GS
(B-5-13)18bd-S	3- 8-72	12.0	23	.02	.0	84	22	300	7.4	365	0	150	400	.5	.01	-	1,170	300	1	68	7.5	2,020	7.6	GS
31acd-1	3- 8-72	22.0	14	.48	.0	95	75	1,300	41	175	0	230	2,200	.6	.94	.71	4,050	550	400	83	24	7,200	7.7	GS
(B-6-13)30bc-S	3- 8-72	11.0	18	.01	.0	81	21	350	6.7	291	0	83	560	.4	.04	.18	1,260	290	50	72	9.0	2,290	7.9	GS
31ac-S	3- 8-72	13.0	20	.01	.0	52	14	230	5.1	243	0	110	250	.6	.01	-	801	190	0	72	7.3	1,420	8.1	GS
(C-1-19)2adb-1	3-29-72	24.5	42	.01	.02	79	63	2,000	120	212	0	190	3,100	1.8	.00	-	5,700	460	280	88	41	10,200	7.5	GS
10bac-1	9- 8-67	31	-	-	-	100	80	2,100	100	-	-	300	3,700	-	-	-	-	-	-	-	-	-	-	K1/
23cbc-1	9-13-67	24.5	-	-	-	1,650	1,540	50,800	2,210	-	-	6,840	80,300	-	-	-	-	-	-	-	-	-	-	K2/
34bdc-1	9-13-67	28	-	-	-	1,760	1,540	45,400	1,980	-	-	6,590	76,800	-	-	-	-	-	-	-	-	-	-	K2/
Composite brine sample3/	1927	-	-	-	-	1,510	1,910	57,300	2,940	-	0	4,080	96,200	-	-	4/0	165,000	-	-	-	-	-	-	GS

1/ Data from Turk (1969, p. 78); also contained 1.2 mg/l lithium.

2/ Data from Turk (1969, p. 97); converted from parts per million to milligrams per liter using average specific gravity of brine from each well (table 4). Analysis for (C-1-19)23cbc-1 also included 8.8 mg/l lithium; (C-1-19)34bdc-1 included 17.6 mg/l lithium. See also table 4 for summary of partial chemical analyses of brine from these wells.

3/ Composite of 126 brine samples from shallow test holes in Great Salt Lake Desert (Nolan, 1928, p. 39). Other constituents determined were (in mg/l): bromine, 0; iodine, 0; lithium, 2; strontium, 0. Specific gravity at 25°C was 1.11.

4/ Reported as borate.

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