Ground-Water Hydrology of the Sevier Desert Utah

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1854

Prepared in cooperation with the Utah State Engineer

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By R. W. MOWER *and* R. D. FELTIS

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CONTENTS

ILLUSTRATIONS

[Plates 1-7 are in pocket]

TABLES

GROUND-WATER HYDROLOGY OF THE SEVIER DESERT, UTAH

By R. W. MOWER and R. D. FELTIS

ABSTRACT

The Sevier Desert, as used in this report, comprises the main part of the Sevier Desert, the Tintic Valley, and the southeastern part of the Old River Bed. It covers an area of about 3,000 square miles and occupies a large basin in the eastern part of the Basin and Range physiographic province.

Large alluvial fans extend from the mountain fronts into the basin where they interfinger with eolian and lacustrine deposits and with fluviatile deposits of the Sevier River. These unconsolidated deposits form a multiaquifer artesian system that is more than 1,000 feet thick and that extends from near the area of main recharge along the east side of the basin to Sevier Lake.

Most of the recharge to the ground-water reservoir results from water entering alluvial fans as percolation from streams, irrigation ditches, and irrigated fields. Another important source may be water in the limestone, quartzite, and other consolidated rocks in the mountains that border the basin. Leakage from the Central Utah Canal is a major source of recharge to the water-table aquifer.

Flowing wells are common in the central lowland part of the Sevier Desert, but as a result of below-normal precipitation and an increase in withdrawals from wells during 1950–64, the area of flowing wells has decreased. The quantity of ground water being wasted from flowing wells is not more than a few hundred acre-feet a year.

The amount of water discharged by withdrawal from wells has increased nearly 15 times since 1950 (from 2,000 acre-feet in 1950 to 30,000 acre-feet in 1964). As a result of this increasing withdrawal, the water levels in observation wells have declined 4 feet in areas of small withdrawals to more than 7 feet near centers of pumping for public supplies and irrigation.

An estimated 135,000–175,000 acre-feet of ground water is consumed by evapotranspiration each year in the 440,000 acres of desert that mainly support phreatophytes. This rate of discharge has changed little since 1950. The consumptive waste of ground water by undesirable phreatophytes, principally saltcedar and pickleweed, was not a serious problem in 1964 but could become a serious problem in the near future if saltcedar is permitted to spread.

Water levels in wells changed little during 1935–40. During 1941–50, however, water levels rose in response to the general above-normal precipitation during 1939–47. During 1950–64 water levels declined, partly in response to below-normal precipitation and partly in response to an increase in pumping from irrigation wells. Although the period 1961–63 was one of above-normal precipitation, water levels continued the overall decline that was started in 1950. The decline, therefore, probably is due to increased pumping.

The amount of water that could be obtained from storage if the piezometric surface in the artesian aquifer were lowered 20 feet is estimated to be 120,000 acre-feet. The specific capacities of wells used for irrigation and public supply range from 5 to 215 gallons per minute per foot of drawdown. Specific capacities generally decrease with increasing distances away from the edge of the basin.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation of ground-water conditions in the Sevier Desert was made as part of a cooperative program with the Utah State Engineer to investigate the water resources of the State. The principal purposes of the study were to determine the source, location, and quantity of recharge to the ground-water reservoir; the quantity and quality of the water in storage; the amount and location of natural discharge; the amount of water being pumped; and the effects of pumping on water levels.

Ground water is important to man in the Sevier Desert because springs and streams do not supply all the water he needs. Early settlers near Deseret obtained ground water from shallow wells dug a few feet below the land surface and from deeper wells that were drilled through relatively impermeable beds. The deeper wells penetrated water-bearing materials under artesian pressure, and they flowed naturally. Since about 1900, wells have been the principal source of water for domestic and stock use in most of the lowland areas, and since 1950, they have been an increasingly important source of water for irrigation.

Surface streams are the principal source of water for irrigation in the Sevier Desert, but since 1950, pumped irrigation wells have furnished supplemental water in parts of the area and have been the only source of water for several thousand acres of land not previously irrigated. Increasing withdrawals of ground water and several years of below-normal precipitation have resulted in a general decline in artesian pressures; as a result, many artesian wells have stopped flowing.

Basic hydrologic information is needed by local and State officials who administer water rights, by Federal agencies who are concerned with land and water use, and by water users. Such information assists the State Engineer to administer the State's water laws and to adjudicate rights to the use of water. In striving to conserve land and water and to equitably administer stock grazing permits, farm loans, and Federal land on which homestead and desert-entry applications have been or may be filed, Federal agencies need to know the perennial amount of ground-water supply, the quality of the ground water, and the rate at which the water will deteriorate in quality as more is used.

LOCATION AND EXTENT OF THE AREA

The Sevier Desert occupies a large basin in west-central Utah that includes part of northeast Millard County, central Juab County, and a small part of southeast Tooele County (fig. 1). The area of investigation consisted of the main part of the Sevier Desert excluding the Pavant Valley, the Sevier Lake playa, and part of the desert south of Clear Lake. Because of hydrologic relations, the investigation also included Tintic Valley and the southeastern part of the Old River Bed. For convenience in writing, the term "Sevier Desert," as used in this report, comprises the main part of the Sevier Desert, the Tintic Valley, and the southeastern part of the Old River Bed.

The area studied encompasses approximately 3,000 square miles. It has a maximum length of about 60 miles, from the Simpson and the Sheeprock Mountains on the north to lat 39°N. near Clear Lake on the south; and it ranges in width from 40 to 60 miles, from the McDowell Mountains and the House Range on the west to the East Tintic and the Canyon Mountains on the east. Mountains bound the area on all sides except the south. There the southeast end of the area merges imperceptibly into the Pavant Valley between the Canyon Mountains and Pavant Butte. Similarly, the southwest end of the area merges into the Sevier Lake playa between the Cricket Mountains and the House Range.

PREVIOUS INVESTIGATIONS

The first ground-water investigation that included some of the Sevier Desert was made in 1906 (Lee, 1908). During 1908 and 1909 Meinzer (1911) included the Sevier Desert in a reconnaissance of ground-water resources of Juab, Millard, and Iron Counties. Callaghan and Thomas (1939) described a thermal spring and associated manganese deposits near the center of the basin. Nelson (1952) and Nelson and Thomas (1953) described the status of development of ground water in the basin and the effects of local heavy pumping from the artesian aquifers. A report by Snyder (1963) on the hydrology of stock-water development on the public domain of western Utah discussed a part of the basin. Many individuals and organizations have studied and mapped the geology of the mountain areas (Stokes, 1964). Gilbert (1890), Eardley, Gvosdetsky, and Marsell (1957), and Varnes and Van Horn (1961; and others, 1951) have described the unconsolidated materials of the basin fill.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to all who aided in this study. Well drillers and pump companies supplied logs and informa-

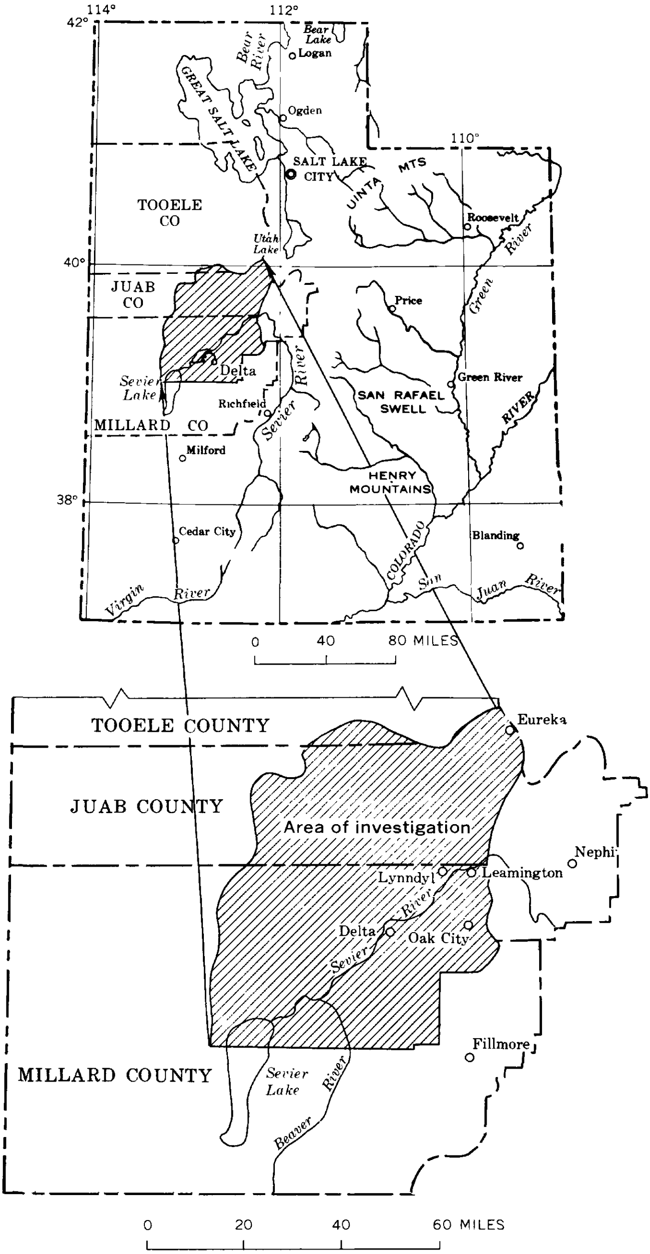

FIGURE 1.—Location of area of investigatior.

tion relating to the drilling and testing of wells. Personnel in the office of the Utah State Engineer gave helpful assistance and suggestions and permitted access to files containing well data. Officers of the Utah Power and Light Co. made records available of power consumption for irrigation and public supply wells. Officials of local irrigation companies, particularly N. S. Bassett and Oswald Johnson, provided much useful information about construction characteristics of wells and data on ground-water pumpage. Many well owners granted permission for the measurement and testing of their wells and supplied other useful information.

METHODS AND PROCEDURES USED IN THE INVESTIGATION

The investigation was started in July 1961. During the summer and fall of 1961 and the summer of 1962, nearly 800 wells were visited. Where possible, the water level was measured, the yield of the well measured or estimated, and a water sample collected for determination of specific electrical conductance. The locations of selected wells in the basin are shown on plate 1. Some wells were located in the field during topographic surveys by the U.S. Geological Survey, and these locations are accurate to 40 feet; some were located by automobile odometer and are accurate to within one-eighth of a mile, whereas others, in areas where wells were not accessible by automobile, were located on aerial photographs taken in 1953 and 1960.

An observation-well network was established. Recording gages were maintained on 2 wells, water levels were measured in 55 wells at intervals ranging from 2 weeks to 2 months, and water levels were measured in about 200 other wells annually in March. Water-level measurements were made from a measuring point near the top of each well. Altitudes of the measuring points were determined by spirit leveling and by interpolation from topographic maps. Water levels were measured with a steel tape which was graduated to hundredths of a foot. Shut-in pressure heads in flowing wells were measured with a mercury manometer or with a transparent plastic hose connected tightly to the discharge pipes. A standard lapse of 10 minutes was allowed between the time that the well was shut in and the time the pressure was observed.

Yields of irrigation wells were measured one to eight times a year. When conditions allowed, the yields were measured with both the Cox flowmeter and the Hoff current meter; other yields were measured with weirs, Parshall flumes, or by the coordinate or projection method (sometimes called the California method). Errors in measurement probably were less than 5 percent; however, measurements made by the coordinate method may have been in error by as much as 15 percent. The yields of small flowing wells were measured by observing the time required to fill a container of known volume.

Pumpage from wells equipped with electric motors was computed by measuring the rate of electric consumption in kilowatts at the time that pumping rates were measured and obtaining the amount of power consumed in pumping for a period of 1 year. The accuracy of the pumpage calculations is limited by the accuracy of the discharge measurements; most of these calculations are estimated to have an accuracy of 95 percent. Pumpage from wells equipped with engines was determined on the basis of the length of time that the engine was operated. About half the engines were equipped with hour meters, and the total time of operation was read directly. For engines not so equipped, estimates of operating time were based on fuel consumption. For engines equipped with hour meters, the accuracy of pumpage calculations is estimated to be more than 90 percent; however, for the wells pumped with engines not equipped with hour meters, the accuracy may be as low as 75 percent.

The following criteria were used to estimate discharge from domestic and stock wells: 1.0 acre-foot of water was discharged if the water was used for both domestic and stock purposes, including yard irrigation; 0.3 acre-foot was discharged if the well was used only for domestic or stock use.

Pumping tests were made at seven sites between Deseret and Leamington to determine the hydraulic properties of the aquifers and to observe interference between wells tapping the same and different aquifers. In addition, detailed pumping tests had been made during 1959–60 at two sites in the basin (Mower, 1961, 1963). During these 9 tests, 7 wells were pumped and 60 wells observed for water-level changes.

Water samples collected from 56 representative wells in the basin were analyzed for chemical content, and the specific electrical conductance of 450 water samples from 375 wells was determined in the field. Water samples were taken once or twice a year from selected wells to monitor changes in chemical quality.

The geology of the unconsolidated basin fill was mapped by reconnaissance, using aerial photographs, to determine recharge areas and to delineate the extent of alluvial fans, sand-dune areas, and deposits of Lake Bonneville. In addition, about 800 well logs were studied to determine the composition of the basin fill. The geology of areas underlain by bedrock was adapted from Stokes (1964).

Upon completion of the fieldwork, a basic-data report was prepared by Mower and Feltis (1964) to make this information available to the public at an early date. The basic-data report contains records of 600 wells; water-level measurements in 61 observation wells; drillers' logs of 95 wells; chemical analyses of 141 water samples from wells; withdrawals from 37 pumped wells; and hydrographs of water levels in 20 wells.

WELL-NUMBERING SYSTEM

The system of numbering wells in Utah is based on the cadastral land-survey system of the U.S. Government. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land net. By this system the State is divided into four quadrants by the Salt Lake base and meridian, and 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. 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 lowercase letters give the location of the well 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. The numbers that follow the letters indicate the serial number of the well within the 10-acre tract. Thus, well (C–17–6)3ada–1, in Millard County, is in the NE¼SE¼NE¼ sec. 3, T. 17 S., R. 6 W., and is the first well constructed or visited in that tract. The following diagram (fig. 2) shows the method of numbering wells.

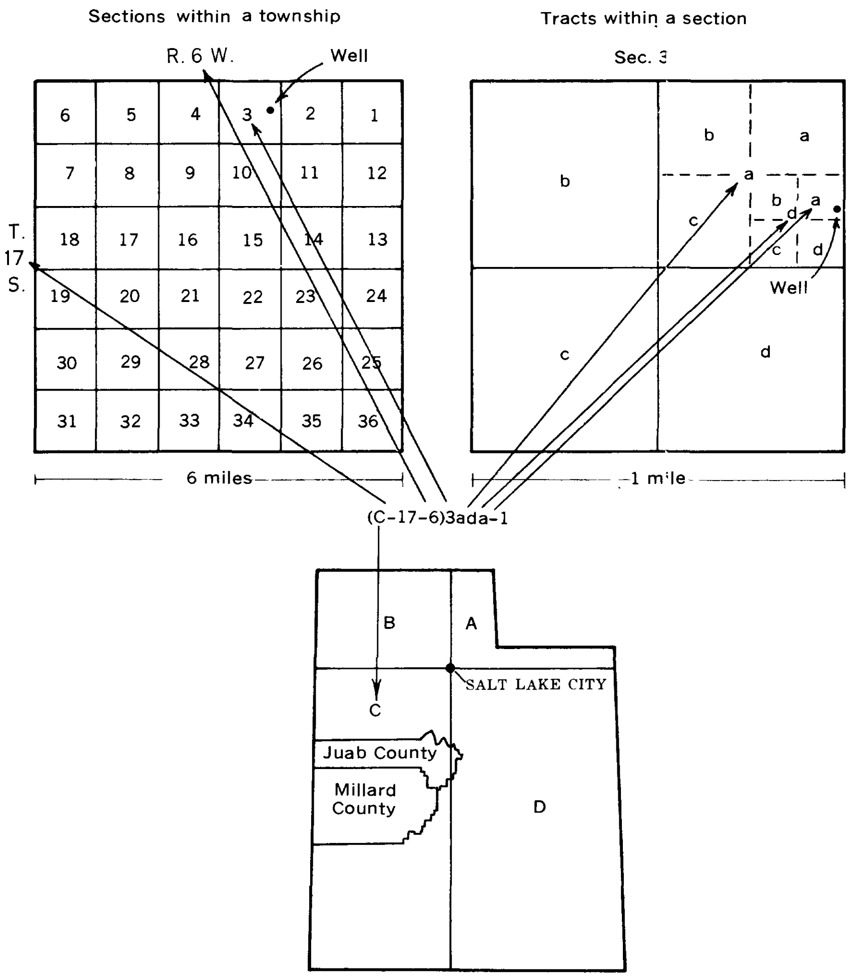

FIGURE 2.—System of numbering wells.

GEOGRAPHY

PHYSIOGRAPHY AND DRAINAGE

The Sevier Desert is in a basin near the east edge of the Great Basin section of the Basin and Range physiographic province (Fenneman, 1931). The Sevier Desert drains into Sevier Lake. The Tintic Valley drains south into the Sevier Desert, and the Old River Bed drains north toward the Great Salt Lake Desert. The Sevier Desert covers such a vast expanse that it gives the impression of being flat and level, but actually the surface slopes generally southwest toward the Sevier Lake playa. Sediment deposited by streams at canyon mouths forms large alluvial fans which extend from the mountain fronts into the basin. Active sand dunes cover a wide expanse of the desert west of Oak City and west and northwest of Lynndyl; smaller wind-blown deposits are common over the remainder of the area. The mountains surrounding the basin are rugged and highly dissected and range in altitude from about 6,500 to 9,700 feet. On the west side of the desert are the House Range, Little Drum and Drum Mountains, Thomas Range, and McDowell Mountains; to the north are the Simpson, Desert, Sheeprock, and West Tintic Mountains; and along the east side are the East Tintic, Gilson (High), and Canyon Mountains. Along the south edge of the desert is Sevier Lake, the north end of the Cricket Mountains, Clear Lake, Pavant Butte and an associated lava field, and several other lava flows.

The topography of the basin was altered by Lake Bonneville during the Pleistocene Epoch. Wave action built spits, bars, and other shoreline deposits and cut terraces and cliffs. One of the largest of the Lake Bonneville deposits in the basin in the delta built by the Sevier River. It extends from Leamington Canyon to Deseret, a distance of about 30 miles. The Bonneville shoreline, marking the highest level reached by Lake Bonneville, is well defined. The present altitude of this shoreline ranges from 5,110 feet in Leamington Canyon, T. 14 S., R. 3 W., to 5,200 feet along the east edge of the Drum Mountains in T. 14 S., R. 10 W.; the variance is due principally to isostatic adjustment caused by the recession of the lake (Crittenden, 1963). The Provo shoreline, an intermediate level of Lake Bonneville, ranges in altitude from about 4,800 to 4,900 feet; it is marked on the upper reaches of the Sevier River delta on the east side of the basin. The Provo shoreline, as well as many others not as well defined, is visible on the sides of low-lying hills and on the surfaces of alluvial fans around the edges of the basin.

The Sevier and Beaver Rivers originate outside the basin in the high plateaus to the east and southeast and terminate in Sevier Lake (fig. 1). Water in the rivers reaches Sevier Lake only during periods of extremely high runoff because most of the flow is stored in reservoirs and diverted for irrigation.

Several perennial streams originate in the mountains surrounding the basin: Oak Creek in the Canyon Mountains, Cherry Creek in the West Tintic Mountains, and Cow Hollow, Pole, Sheeprock, and Hard-to-Beat Creeks in the Sheeprock Mountains (pl. 1). As these streams flow into the basin, water from them percolates into the basin fill.

Intermittent streams which flow during parts of the year in the several mountain ranges include Judd Creek and the stream in Death Canyon in the Simpson Mountains; the streams in Cottonwood, Joes, and Otts Canyons in the Sheeprock Mountains; Road, Birch, and Hop

Creeks in the East Tintic Mountains; and Fool Creek in the Canyon Mountains (pl. 1). These streams seldom flow far beyond the mountain fronts because the water seeps into the basin fill.

Tanner Creek in Tintic Valley is an ephemeral stream that flows mostly in response to summer cloudbursts. The creek discharges into the desert north of Lynndyl; the water infiltrates the basin fill, and the stream channel disappears in an area of sand dunes. Streams in the mountains along the west side of the Sevier Desert are also ephemeral.

A system of dams and canals is used to store and divert water from the Sevier River for irrigation of small areas near Leamington and Lynndyl and a large area near Delta. The Central Utah Canal carries water along the east side of the basin from the Sevier River into Pavant Valley.

A drainage system in the irrigated lands near Delta alleviates waterlogging. These drains carry the excess water that runs off the ends of irrigated fields, the return flow of excess soil moisture from irrigated fields, and the surface runoff of precipitation into low areas to the northwest, west, and south where the water evaporates or is transpired.

The Old River Bed once drained some of the waters of Lake Bonneville from the Sevier Desert toward the Great Salt Lake Desert (Gilbert, 1890, p. 181–184); but now, because the head of the Old River Bed is about 110 feet above the Sevier Lake playa and because a mudflow blocks the channel in sec. 28, T. 10 S., R. 9 W., the Old River Bed drains only an area of about 240 square miles (pl. 4).

CLIMATE

The climate of the Sevier Desert is characterized by mild summers and winters. Daytime summer temperatures in the lowlands seldom exceed 100° F. Winter temperatures usually are below freezing at night but rarely are below 0°F. The mean annual temperature at Deseret is about 50°F. The growing season is 5–6 months long and usually extends from April to October (see table 1).

The average annual precipitation ranges from less than 6 to about 12 inches in the lowlands and from about 8 to more than 25 inches in the mountains (pl. 4), but annual precipitation varies widely. March through May is the 3-month period of greatest precipitation, and June through August is the 3-month period of least precipitation. The curve in figure 3, which shows the cumulative departure from average annual precipitation for the period from 1900 to 1964, denotes periods of greater-than-average precipitation by a rising trend and periods of less-than-average precipitation by a downward trend. The departure from average precipitation is plotted in fig. 3; when precipitation is less than average the curve slopes downward. The normal annual pre-

TABLE 1.—*Climatological data for weather stations in or near the Sevier Desert*

Station	Altitude (feet above sea level)	Precipitation							Temperature					
		Period of record	Mean annual (inches)	Normal annual (1931–60) (inches)	Range in annual				Mean annual (°F)	Range in mean annual		Frost-free period		
					Low		High			Low (°F)	High (°F)	Average date of last killing frost in spring	Average date of first killing frost in fall	Number of days
					Inches	Year	Inches	Year						
Delta FAA AP	4, 759	1939–63	7. 16	------	3. 32	1950	12 87	1941	----	----	----	-------	-------	-------
Deseret	4, 588	1900–63	7. 36	6. 38	3. 11	1950	11. 33	1915	49. 7	−32	106	May 4	Sept. 30	149
Eureka	6, 460	1931–63	14. 33	14. 08	9. 19	1934	22. 69	1946	----	----	----	-------	-------	-------
Oak City	5, 075	1917–63	12. 04	11. 60	6. 59	1934	18. 63	1941	52. 4	−25	108	Apr. 26	Oct. 21	178

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FIGURE 3.—Cumulative departure from average precipitation at Deseret, 1900–64.

cipitation (period 1931–60) is used to analyze observed hydrologic conditions since 1935, and a curve showing cumulative departure from normal precipitation at Deseret for the years 1931–64 is shown in figure 4. Annual mean values, annual normal values, and annual extremes of precipitation collected at four stations in or near the Sevier Desert are given in table 1.

According to records of the U.S. Weather Bureau, evaporation from a class A land pan at Milford, about 70 miles south of Delta, for the months from April to October during 1953–63 averaged about 80 inches a year. The evaporation in the Sevier Desert would probably be slightly less. This was indicated by Kohler, Nordenson, and Baker (1959, pl. 1) who, for the period 1946–55, showed an average annual class A land pan evaporation of 67 inches at Milford and 63–65 inches in the Sevier Desert.

NATIVE VEGETATION

The phrase "native vegetation" is used in this report to denote perennial plants that thrive and propagate naturally within the Sevier Desert and adjoining mountains. Although the plants in this general category vary greatly in their individual characteristics, each plant can be placed into one of three distinctive groups, depending on the relation of the root system of the plant to its water supply. The terms "xerophyte," "hydrophyte," and "phreatophyte" are used to designate these three distinctive groups of plants.

Xerophytes extend their roots only into the belt of soil moisture near the land surface, and they thrive in upland areas where the water table may be a considerable distance below the land surface. These plants depend on rain and snowfall for their moisture requirements, and they survive during dry periods by becoming nearly dormant or by drawing upon moisture stored within the plant system. Shadscale (*Atriplex confertifolia*) is the only important xerophyte growing in the lowlands; it also grows on alluvial fans and low hills. Sagebrush (*Artemisia* sp.), pinyon pine (*Pinus edulis*), and juniper (*Juniperus* sp.) are xerophytes that commonly grow between 5,000 and 8,000 feet above sea level from the upper parts of alluvial fans to the peaks of some mountains.

Hydrophytes grow only in ponded water or in saturated soil where the water table is either at or within a few inches below the land surface. They must have their roots in water. Hydrophytes require much water, but they are only found in a small area in the Sevier Desert. Cattails (*Typha* sp.) bulrush or tules (*Scirpus* sp.), and watercress (*Rorippa nasturtium-aquaticum*) are a few of the hydrophytes growing in the area.

Phreatophytes extend their roots to the water table or to the overlying capillary zone. These plants, therefore, are able to secure a continuous supply of water that is largely independent of changes in soil moisture in the part of the soil profile above the capillary zone. Depending on the species, phreatophytes can thrive where the water table is inches or tens of feet below the land surface. Many phreatophytes are of little or no value to man, but they cover many thousands of acres of land in the Sevier Desert and consume large quantities of water. The principal phreatophytes in the lowlands are greasewood (*Sarcobatus vermiculatus*), saltgrass (*Distichlis stricta*), pickleweed (*Allenrolfea occidentalis*), and saltcedar (*Tamarix gallica*). Willow (*Salix* sp.) and cottonwood (*Populus* sp.) are common phreatophytes in the upland areas, where they grow along perennial streams and near springs. Cottonwood and other trees also grow on the basin flat and are used there as windbreaks and shade trees.

Saltcedar, a phreatophyte which consumes great quantities of water in parts of the west, has spread widely in the Sevier Desert during recent years. The largest, and probably oldest, trees in the area are near homes, thus suggesting that they were originally brought into the basin for ornamental shrubbery. The place and the date of appearance of the first "wild" plants in the basin are not known, but the plants probably appeared along the Sevier River or some diversion canal prior to 1950. Aerial photographs taken in 1953 show saltcedars in parts of the Fool Creek Reservoir. The size and density of the saltcedars observed in the reservoir in 1963 suggest that a few of the plants could have been moderately large in 1953. By 1963, individual plants and small thickets of saltcedar were observed in all parts of the lowlands of the Sevier Desert.

POPULATION, AGRICULTURE, AND INDUSTRY

The population of the Sevier Desert in 1960 was about 5,200 people. Delta was the largest town with 1,576 people. The economy of the area depends upon agriculture, mining, and tourism.

Irrigation farming, dairy farming, dry farming, and stock raising are important in the agricultural economy. Alfalfa, alfalfa seed, and small grain are the principal irrigated crops and wheat is the dryland crop. Many sheet are wintered in the western part of the basin, but they are taken to the mountain rangelands, mostly outside the basin, in the summer. Beef cattle graze in the mountains during the summer and in parts of the desert during the summer and winter.

The mining industry presently consists of the mining of silica and halloysite, but it could expand greatly with the development of known ore bodies near Eureka and near the northwest boundary of the Sevier Desert.

GEOLOGY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The rocks in and around the Sevier Desert range in age from Precambrian to Recent. The mountains surrounding the basin contain rocks of Precambrian through Tertiary age; these rocks are of sedimentary, metamorphic, and igneous types. Volcanic rocks of Tertiary and Quaternary age and consolidated-to-unconsolidated sedimentary deposits compose the basin fill. Table 2 summarizes the water-bearing characteristics of the several rock types, and plate 2 shows the areal distribution of these rocks.

THE PRINCIPAL WATER-BEARING SEDIMENTS

The ground-water reservoir in the Sevier Desert, except in part of Tintic Valley, is composed mostly of clay, silt, sand, and gravel. These sediments were deposited under subaerial and lacustrine conditions in Tertiary and Pleistocene time. Collectively they are referred to as "basin fill." The subaerial deposits are alluvial fans, which are along the front of the mountain ranges; eolian deposits, which are widespread in the basin; and fluviatile deposits, which are sand and gravel laid down by the Sevier River—the major perennial stream in the basin—and the Beaver River. Lacustrine deposits are of several kinds: lake-bottom sediments of fine sand, silt, clay, and marl; deltaic deposits of sand, gravel, silt, and clay; shoreline deposits of sand and gravel reworked from alluvial fans and tributary streams; and offshore lenticular deposits of sand. A combination of deposition, erosion, reworking, sorting, and redeposition of alluvial debris by lake, wind, and stream has produced a complex sequence of interbedded and interfingering rock units of varying lithology.

The geologic section on plate 3 shows typical variations in the lithology of the rocks in the basin fill. The coarser grained deposits of alluvial fans are generally along the edges of the basin (see pl. 3, wells (C–15–4)11add–1 (15–330 feet) and (C–15–4)10cad–1 (125–300 feet) along the east side of the basin and well (C–16–8)21bcb–1 (888–996 feet) near the west edge). Fluviatile deposits of the Sevier River extend from Leamington to Sevier Lake; however, they become progressively finer grained toward the southwest and west (compare well (C–15–5)33dcb–1 (585–825 feet) with well (C–16–8)12ddd–2 (523–954 feet)). Southwest of Delta the fluviatile deposits are generally indistinguishable from fine-grained lacustrine and subaerial deposits. The electrical log of an oil test in sec. 24, T. 16 S., R. 8 W., shows this sequence of lacustrine, fluviatile, and subaerial deposits extending to a depth of 2,140 feet (pl. 3).

The ancestral Sevier River presumably entered the basin through Leamington Canyon, at least as early as Pleistocene time, and followed the same general course as the present river. As it meandered across the desert, the river deposited well-sorted materials, reworked the alluvium in its path, and contributed material to Lake Bonneville for shoreline and lake-bottom sediments. The lake undoubtedly fluctuated in size, thus adding to the complexity of the basin fill. Deposits of Lake Bonneville were laid down in most of the basin, especially on the east side where the Sevier River delta extends from Leamington Canyon to Deseret. The deltaic sediments and contemporaneous lake beds are fine grained and form the impervious beds that overlie and confine the upper artesian aquifer.

The part of the ground-water reservoir that has been developed most fully but which still has the greatest potential for additional development extends from the Leamington-Oak City area west and southwest toward Sevier Lake. The reservoir in this area is a multiaquifer artesian system yielding large quantities of water of good chemical quality. Reports of well drillers and a comparison of well logs indicate

TABLE 2.—*Generalized stratigraphy and water-bearing properties of geologic units in the Sevier Desert*

Era	Period	Epoch	Geologic unit (letter symbols refer to pl. 2)	General character	Water-bearing properties
		Recent	Dune sand (Qs)	Active and stabilized dunes composed predominately of fine to medium, rounded quartz sand. Dark-gray basaltic sand in the southern end of dune area. Active dunes have crescent shape, and long, low ridges trail behind. Stabilized dunes have irregular hummocky surface covered with vegetation. Major dune area is along eastern side of the basin, but minor windblown deposits are in all parts of the basin. Maximum dune height is 40 ft.	Very permeable, but usually underlain by fine-grained lake beds of low permeability which generally prevent recharge to the ground-water reservoir. Recharge does occur in dune area in T. 14 S., R. 5 W. (pl. 4), where water from Tanner Creek is ponded. Does not yield water to wells.
			Silt and clay deposits on playas and mudflats (Qp)	Silt and clay beds containing or interbedded with evaporite deposits. Sevier Lake playa probably contains interbedded silt, clay, and evaporites to some depth. In other playas, the evaporites are only on the surface or in the upper foot of deposits.	Moderate to low permeability. Contains water of poor chemical quality. Not known to yield water to wells.
				Alluvial fan and fluviatile deposits composed of boulders, gravel, sand, silt, and clay; poor to well sorted; unconsolidated to semiconsolidated. Alluvial fans along the mountain fronts partly underlie and interfinger with Pleistocene lake deposits. Coarser sediments are more abundant and angular close to the mountains.	Permeable to only slightly permeable depending upon sorting and grain size. Along the mountain fronts, the alluvial fans are recharge areas for the ground-water reservoir; toward the center of the basin, permeable zones are aquifers. Well-sorted fluviatile

Cenozoic	Quaternary		Alluvium (Qa)	Fluviatile deposits of the Sevier River underlie the basin along the course of the river from Leamington Canyon to Sevier Lake, are interbedded with Pleistocene lake deposits, and range from coarse gravel near Leamington to fine sand in the central and southwestern parts of the basin.	deposits of the pre-Lake Bonneville Sevier River and pre-Lake Bonneville lake deposits are the principal aquifers in the eastern and central parts of the basin. Wells tapping these aquifers yield as much as 3,200 gpm.
		Pleistocene	Lake Bonneville deposits (Qb)	Well-sorted unconsolidated to semiconsolidated lake-bottom sediments of fine sand, silt, clay, and marl; deltaic deposits of sand, gravel, silt, and clay; shoreline deposits of sand and gravel; and offshore lenticular deposits of sand. The fine-grained sediments are nearly as extensive as the limits of Lake Bonneville in the basin; deltaic deposits extend from Leamington Canyon to Delta; sand and gravel form spits and bars along several prominent shorelines around the basin; and the lenticular beds of sand are probably the deposits of longshore currents. Unit ranges in thickness from 0 to 200± ft.	Sand and gravel of the deltaic and other deposits form shallow aquifers. The silt and clay deposits are of low permeability and are aquitards in the artesian system. Many shallow wells derive water from the aquifers. Some shoreline deposits are very permeable and act as recharge areas, but they are not aquifers because they are generally above the water table.
			Pre-Lake Bonneville lake deposits (present only in subsurface)	Same general character as Lake Bonneville deposits but believed to be less extensive. (The sequence of alluvium, Lake Bonneville, and pre-Lake Bonneville lake deposits range in thickness from 0 to 2,150 ft, pl. 3.)	The principal aquifers are in the alluvial-fan and fluviatile deposits. The artesian system of the eastern and central parts of the basin consists of these and other interbedded Pleistocene deposits.

TABLE 2.—*Generalized stratigraphy and water-bearing properties of geologic units in the Sevier Desert*—Continued

Era	Period	Epoch	Geologic unit (letter symbols refer to pl. 2)	General character	Water-bearing properties
Cenozoic—Continued	Quaternary—Continued	Pliocene and Pleistocene	Volcanic rocks (QTv)	Lava flows and volcanic cones, consisting of basalt, tuff, and scoria. Exposed as isolated masses on the floor of the basin; believed to be contemporaneous or antecedent to Lake Bonneville.	Permeable to impermeable. Rocks of this unit were identified in only three wells and apparently are not extensive in the subsurface. May form local recharge areas. Not known to yield water to wells (see pl. 2).
	Tertiary	Pliocene(?)	Salt Lake(?) Formation (Tsl)	Fanglomerate, gravel, silt, marly limestone, and bentonitic tuff which crop out in most of Tintic Valley and along the south side of the Sheeprock Mountains. Probably underlie the Pleistocene deposits in the entire basin.	Moderately permeable to impermeable. Yields to wells are variable but generally are sufficient for stock or domestic uses. A well penetrating the formation in Tintic Valley yields about 400 gpm.
		Eocene(?) to Pliocene(?)	Conglomerates (Tc)	Silt, sand, gravel, and boulders, semiconsolidated to consolidated, moderately to poorly sorted. Gravel and boulders are subangular to rounded. Crop out in several mountain ranges that border the basin. Part may be the same age as the Salt Lake(?) Formation.	Permeable to impermeable. Wells obtain small yields from conglomerates that underlie Pleistocene alluvial and lacustrine deposits along the east side of the basin near Oak City.
			Intrusive and extrusive igneous rocks (Tiu)	Extrusive tuffs, flows, and agglomerates, and intrusive sills, dikes, plugs, and stocks of many petrographic types. Crop out in most mountain ranges. May include flows penetrated by an oil test in the central part of the basin (pl. 3).	Generally of low permeability except where jointed and fractured. Yield 5 gpm or less to small seeps and springs. Permeability of lava flows shown on plate 3 unknown.

Pre-Cenozoic	Precambrian to Cretaceous		Sedimentary and metamorphic rocks (Kp€u)	Sandstone, conglomerate, quartzite, shale, and limestone of Mesozoic and Paleozoic age, and quartzite, tillite, slate, phyllite, and argillite of Precambrian age. At least one or several of these rock types crop out in each of the mountain ranges.	Crop out in the areas of greatest precipitation and are an important source of recharge to the hydrologic system. Joints, fractures, bedding planes, and solution channels transmit water to springs, mine tunnels, streams, and directly to alluvial aquifers in the basin. Not known to yield water to wells.

that the aquifers are a network of lenticular or stringer type sand and gravel deposits interbedded with silt and clay or poorly sorted silt, clay, sand, and gravel. The permeable fluviatile deposits, rather than the lacustrine deposits, seem to be of greatest importance to the aquifer system, as indicated by the occurrence of water of good quality and of wells of high specific capacity along the inferred course of the ancestral Sevier River.

In the Tintic Valley, ground water is derived from alluvial fans of Pleistocene and Recent age and from the Salt Lake(?) Formation. The alluvial fans may be as much as 500 feet thick near the base of the mountains in the northeastern part of the valley (pl. 2). In the remainder of the valley, except in the vicinity of Tanner Creek Narrows, the Salt Lake(?) Formation crops out or is covered by a thin irregular deposit of Pleistocene gravel (Morris and Lovering, 1961). In the vicinity of Tanner Creek Narrows, the formation is covered by Lake Bonneville deposits.

STRUCTURE

The Sevier Desert is in a structural basin, undoubtedly the result of a fault complex that has downdropped the basin relative to the surrounding mountains. It is one of many similar basins of the Basin and Range province whose development began in late Tertiary time and has continued to the present.

The amount of displacement measured from bedrock in the mountains to bedrock in the basin varies. Several wells near the edge of the basin penetrated bedrock in the form of conglomerate of Tertiary(?) age at depths of 300–500 feet. (See logs of wells (C–15–4)10cad–1 and (C–15–4)11add–1 on pl. 3). If the displacement is measured from the center of the basin, the bedrock formations in the basin are more than 8,000 feet below the bedrock penetrated in the wells in T. 15 S., R. 4 W. The test hole penetrated 8,064 feet of sand, gravel, clay, shale, limestone, sandstone, and several basalt flows; however, the well sequence does not contain the limestone, shale, or quartzite sequence that crops out in the House Range or Canyon and Drum Mountains nor the sequence of igneous rocks that are exposed in the Drum and Little Drum Mountains. Heylmun (1965, p. 29) has suggested that red shales at 6,255 feet in this hole might be equivalent to beds of Triassic age which are exposed in the Pavant Range, 50 miles southeast.

WATER RESOURCES

The principal sources of the water supply to the Sevier Desert are precipitation on the contiguous mountains, foothills, and alluvial fans above 4,800 feet on the eastern and northern sides of the basin, inflow in the Sevier River, and underflow from Pavant Valley and from the Beaver River drainage area.

PRECIPITATION

The average annual precipitation on areas above 4,800 feet in altitude east and north of the Sevier Desert ranges from less than 8 to more than 25 inches (pl. 4). Most rain falls in short-term high intensity summer thunderstorms, with rapid runoff and flooding and little infiltration of the soil. Occasionally there are lengthier cyclonic summer storms that replenish soil moisture and also contribute to streamflow. The most important source of water originating within the basin is the snowpack in the mountains. The melt water sustains streamflow and provides recharge to the ground-water reservoir.

The precipitation is disposed of by direct evaporation of rainwater and snowmelt; by sublimation of snow; by runoff in surface streams; by restoration of soil moisture that is later transpired by plants or that evaporates directly to the atmosphere; and by infiltration to the ground-water reservoir. All streams that flow over alluvial fans lose some water by seepage to the ground-water reservoir. Most of the runoff from the perennial streams and some of the runoff from several intermittent streams is diverted to irrigated lands, where a large part of the water is evaporated or consumed by crops, and the water not evaporated or consumed infiltrates to the ground-water reservoir.

SURFACE WATER

FLOW OF THE SEVIER RIVER

The major source of water for irrigation in the Sevier Desert is the Sevier River, and all its water originates outside the basin. The river enters the eastern side of the basin through Leamington Canyon and flows southwestward toward Sevier Lake. No perennial tributary streams reach the river within the Sevier Desert, although Oak Creek and the Beaver River probably did so before they were diverted for irrigation purposes.

The Sevier Bridge Reservoir controls the flow of the Sevier River. The reservoir is in southeast Juab County and is about 18 miles southeast of Leamington, where the irrigation water is stored. In Leamington Canyon, the Leamington, McIntyre, and Central Utah Canals divert water for use near Leamington and Lyndyl and in the Pavant Valley. Diversions near Delta are regulated at the DMAD (Deseret Melville Abraham Delta) and Gunnison Bend Reservoirs.

The total inflow of the Sevier River as measured at the mouth of Leamington Canyon is given in table 3 as the total measured discharge near Lynndyl plus the amount of water diverted by the canals in Leamington Canyon. The gaging station near Lynndyl, however, is about 12 miles downstream from the point where the river begins to flow on basin fill (pl. 4). In this 12-mile stretch, the river loses water by seepage to the ground-water reservoir. The inflow at the mouth of Leamington Canyon, as reported in table 3, is therefore the total inflow of the river into the basin without correction for net seepage loss. (See section on seepage from streams.)

TABLE 3.—*Discharge, in acre-feet, of the Sevier River and canal diversions near the east edge of the Sevier Desert, 1943–64*

Water year [1]	Central Utah Canal [2]	McIntyre Canal [2]	Leamington Canal [2]	Sevier River near Lynndyl [3]	Inflow at mouth of Leamington Canyon [4]
1943	32, 613	2, 115	4, 342	145, 100	184, 170
1944	37, 693	2, 276	4, 995	139, 500	184, 464
1945	33, 159	2, 127	3, 734	119, 200	158, 220
1946	66, 165	3, 448	4, 741	148, 500	222, 854
1947	35, 298	3, 921	4, 352	116, 600	160, 171
1948	60, 673	4, 982	5, 581	161, 100	232, 336
1949	51, 156	3, 883	4, 415	150, 300	209, 754
1950	38, 215	3, 746	4, 160	135, 100	181, 221
1951	30, 902	3, 806	3, 561	131, 000	169, 269
1952	32, 645	3, 340	3, 505	129, 100	168, 590
1953	46, 430	3, 902	3, 915	167, 800	222, 047
1954	33, 254	3, 323	3, 602	132, 100	172, 279
1955	27, 538	3, 283	2, 642	117, 600	151, 063
1956	16, 247	2, 712	3, 164	87, 700	109, 823
1957	8, 715	4, 315	4, 235	85, 270	102, 535
1958	27, 726	3, 625	4, 643	150, 800	186, 794
1959	18, 640	3, 031	4, 026	126, 800	152, 497
1960	10, 980	2, 965	3, 616	96, 780	114, 341
1961	8, 752	2, 552	3, 588	74, 220	89, 112
1962	15, 042	3, 142	4, 357	121, 300	143, 841
1963	8, 665	2, 984	3, 689	84, 900	100, 238
1964	8, 190	2, 848	3, 603	79, 440	94, 081
Average (rounded)	29, 500	3, 300	4, 000	122, 700	159, 500

[1] The water year covers the period from October 1 of the previous year to September 30 of the designated year.
[2] Diversions taken from the annual reports of the Sevier River commissioner.
[3] From records of the U.S. Geological Survey (1960–64).
[4] Inflow at mouth of Leamington Canyon is assumed to be the discharge at Lynndyl plus diversions by Central Utah, McIntyre, and Leamington Canals with no correction for net seepage between the mouth of the canyon and the gage near Lynndyl.

FLOW OF OTHER STREAMS

The flow of other surface water (besides the Sevier River) into the Sevier Desert was not gaged. Instead, the discharge of the other streams was estimated by comparing the stream to one in the Pavant Valley that has a similar sized drainage area, a similar precipitation record, and a similar topographic setting (Mower, 1965, p. 26–27).

The average annual inflow to the basin from Oak Creek during 1943–64 is estimated to be 10,000–15,000 acre-feet. Inflow to the main part of the basin from all other streams is estimated to be 40,000–50,000 acre-feet. Annual runoff in streams draining toward the Old River Bed is about 10,000–15,000 acre-feet.

GROUND WATER

OCCURRENCE

All water beneath the land surface is designated as "subsurface water" (Meinzer, 1923, p. 17–32), and ground water is that part of the subsurface water in the zone of saturation. A body of consolidated or unconsolidated rock that stores and transmits ground water to wells and springs in usable quantities is called an aquifer. One or more aquifers constitute a ground-water reservoir. In the more permeable rocks, such as beds of sand and gravel in the unconsolidated basin fill, individual pore spaces are interconnected and are large enough so that water moves freely through them under the force of gravity. In the less permeable materials, such as the beds of clay and silt, the pore spaces are so small that water moves with difficulty.

Aquifers may be one of two kinds: water table or artesian. In a water-table aquifer the ground water is unconfined and free to move by gravity, and the upper surface of the saturated zone is called the water table. In an artesian aquifer the water is confined beneath relatively impermeable material; because it is under hydrostatic pressure, the water will rise in wells above the bottom of the confining bed. The imaginary surface to which water will rise in a well above an artesian aquifer is called the piezometric surface.

In most of the Sevier Desert, ground water is under water-table conditions in a shallow aquifer and under artesian conditions in a lower and an upper artesian aquifer. Around the western, eastern, and northeastern margins of the basin fill, ground water occurs only under water-table conditions. In the Old River Bed area, ground water is under water-table conditions, and the aquifers are separate from those of the Sevier Desert. In Tintic Valley, ground water is under water-table conditions, but artesian conditions may occur in the central parts of the southern third of the valley.

RECHARGE

The ground-water reservoir in the basin fill of the Sevier Desert is recharged in several ways: by direct penetration of precipitation through coarse unconsolidated sediments, by seepage from streams and canals, by infiltration of unconsumed irrigation water, by flow through fractured consolidated rock, and by underflow from other basins. The main areas of recharge are shown on plate 4.

DIRECT PENETRATION OF PRECIPITATION

Precipitation that falls on the coarse unconsolidated sediments along the north and east edges of the basin may penetrate directly into these sediments and recharge the ground-water reservoir. These unconsolidated sediments are the second and third recharge areas shown in the explanation of plate 4. Most of the precipitation falls as snow during the winter, and snowmelt is a source of water that percolates directly to the ground-water reservoir. Summer showers, on the other hand, provide little water that percolates directly to the reservoir. The showers are so infrequent that the water that does seep into the ground is seldom sufficient to moisten more than the upper few inches of the soil mantle. Occasionally in the early spring, when the soil is saturated with snowmelt, long soaking rains provide water that percolates directly to the ground-water reservoir.

To calculate quantities of recharge from direct penetration of precipitation, it is assumed that recharge takes place only during the period from December 1 to March 31 and that during this period only 20 percent of the precipitation in excess of 6 inches percolates to the ground-water reservoir. The first 6 inches of precipitation is assumed to represent the quantity of water necessary to satisfy soil-moisture requirements in the root zone, and 80 percent of the remainder is assumed to run off or be returned to the atmosphere. The soil types in the recharge area range from clay loam to gravelly loam, and they have an estimated average water-holding capacity of 3.5 inches per foot of depth. In other words, water in excess of 3.5 inches will percolate deeper. It is further assumed that on December 1 each foot of the soil contains 2.5 inches of moisture, the approximate lower moisture limit below which plants cannot extract appreciable quantities of water; that the average depth of the root zone is 6 feet; and that all water reaching a depth of 6 feet below the land surface percolates to the ground-water reservoir. The 80 percent remainder that runs off the recharge area or returns to the atmosphere was estimated on the basis of cursory observations during 1961–64.

The recharge area along the north and east edges of the basin where precipitation may percolate directly to the ground-water reservoir, excluding 100 square miles in the Old River Bed drainage subbasin, covers 350 square miles. Precipitation at Oak City is assumed to be representative of this recharge area. During 1949–64, precipitation from December 1 to March 31 exceeded 6 inches only during 1951–52 and

1961–62. During these two periods, direct recharge from precipitation on the recharge area is estimated to have been 12,000 and 5,000 acre-feet, respectively. During the remainder of the time, recharge from direct precipitation is assumed to have been negligible.

The lower or basinward boundary of the area of recharge is limited by silt, clay, and marl deposits of Lake Bonneville. The fine-grained deposits lap the alluvial fans and their upper boundary generally is the lower boundary of the recharge area (pl. 4). The upper boundary of the fine-grained deposits ranges between 4,800 and 5,200 feet, depending upon the environment of deposition in the lake and isostatic adjustments of the land after recession of the lake.

Little precipitation penetrates directly to the ground-water reservoir on the west side of the basin because of the low annual precipitation. In the Little Drum, Drum, and McDowell Mountains, the average annual precipitation is about 8 inches (pl. 4)—an amount too small to provide significant recharge.

SEEPAGE FROM STREAMS AND CANALS

Seepage losses from streams, the Sevier River in Leamington Canyon, canals, and irrigation ditches are probably the principal sources of recharge to the ground-water reservoir in the Sevier Desert.

The inflow of the Sevier River exceeds the total inflow of all other streams in the mountains and basin, but the seepage from these other streams probably exceeds that of the Sevier River several times. Perennial streams and ephemeral streams, even those flowing only a few hours, lose water by seepage. Large floods of short duration probably are less effective sources of recharge than are intermediate floods of longer duration and streams resulting from snowmelt.

A seepage run on the Sevier River between the Central Utah Canal diversion dam and the gaging station near Lynndyl (pl. 4) showed that the river loses water above Leamington and gains water below (table 4). The river was at base flow (no water had been released from Sevier Bridge Reservoir during the previous month); there were no diversions from the river between the reservoir and the gaging station near Lynndyl; air temperatures were sufficiently low so that evaporation and transpiration were not significant, but not so low as to retain part of the water in the form of ice; thus differences in discharge rate at selected sites along the river indicated gains to and losses from the ground-water reservoir.

The upstream measuring site (site 1 on pl. 4) used in the seepage run is about 200 feet upstream from bedrock that crops out in the channel of the Sevier River. The bedrock forces all underflow in the unconsolidated canyon fill to the surface and makes possible the

TABLE 4.—*Seepage run on the Sevier River, Nov. 28, 1962*

Site	Location	Distance below site 1 (miles)	Rate of discharge (cfs)	Change in rate of discharge in reach (cfs)
1	About 200 ft upstream from Central Utah Canal Co. diversion dam.	------	41	-------
2	About a quarter of a mile upstream from the west edge of sec. 1, T. 15 S., R. 4 W.	3½	34	−7
3	About 300 ft downstream from bridge on State Highway 132 over Sevier River; 2 miles west of Leamington.	8	36	+2
4	Gaging station near Lynndyl-----	15	39	+3

measurement of all the water passing the site. From site 1 to site 2 the unconsolidated fill becomes progressively thicker, and the fill consists mostly of gravel and cobbles, with some intergranular sand and silt, Downstream from site 2 the fill becomes progressively finer grained, and downstream from site 3 it consists mostly of fine sand underlain by silty clay.

The loss of 7 cfs (cubic feet per second) (table 4) between sites 1 and 2 is the minimum loss in streamflow going to recharge in this reach, because it occurred during a period of low flow. The gain in streamflow between sites 2 and 4 probably represents return flow from irrigated lands in the Leamington-Lynndyl area and seepage losses from the Leamington and McIntyre Canals. The water lost by seepage from the canals percolates to the shallow sandy soils that are underlain by relatively impermeable beds of silty clay which retard further downward migration. The water then moves laterally and reappears in seeps in the river channel.

Floodwater from snowmelt and rainfall in the Tanner Creek drainage area is impounded nearly every year, principally in parts of secs. 22, 23, 26, and 27, T. 14 S., R. 5 W. Although the surface deposits are fine grained, part of the water percolates slowly into the ground. Bedrock crops out on the north and southwest sides of the area and probably lies near the land surface under parts of the ponded area, although unconsolidated material was found to a depth of 300 feet in well (C–14–5)22ccc–1. A wide spacing of the contours on the piezometric surface in the area suggests local recharge (pl. 5), and a ground-water mound probably exists beneath Tanner Creek in T. 14 S., R. 5 W.

Other significant areas of recharge from streams are along the south flanks of the Simpson and Sheeprock Mountains where several small perennial streams and several ephemeral streams lose water on alluvial fans. The recharge along the Simpson Mountains and the northwest half of the Sheeprock Mountains contributes to the ground-water reservoir underlying the Old River Bed. The recharge along the southeast half of the Sheeprock Mountains and from the western side of the West Tintic Mountains contributes to the ground-water reservoir in the central part of the Sevier Desert.

The Leamington, McIntyre, and Central Utah Canals, which divert water from the Sevier River in Leamington Canyon, lose water by seepage throughout their entire length. The losses above the mouth of Leamington Canyon, where the canals are on fluviatile deposits that consist largely of gravel, sand, and silt, are considerably greater than below the mouth of Leamington Canyon, where the canals are on lake deposits that consist largely of silty clay. The Central Utah Canal flows across lake deposits also, but for much of its length in the Sevier Desert it is on fine silty sand, and losses are considerable. These losses constitute a major source of recharge to the water-table aquifer. The amount of loss depends on the length of time that water is in the canal, and the range is from less than 40 percent of the total water diverted during years of large diversions to more than 70 percent during years of small diversions. Mower (1965, p. 50 and table 10) reported that about 97 percent of the water lost from the Central Utah Canal is seepage and that 60.7 percent of the losses occur in the reach of the canal in the Sevier Desert.

The average annual seepage during 1934–60 from the reach of the Central Utah Canal in the Sevier Desert was 5,100 acre-feet. Most of this water recharged the unconfined aquifer although a little was consumed by native vegetation or reappeared at the land surface; some eventually reached the uppermost zone of the upper artesian aquifer.

Several ditches, which divert water from Oak Creek and other streams, lose water by seepage in the recharge area. Although data are not available to estimate the amount of recharge, it is probably less than the seepage from the Central Utah Canal.

UNCONSUMED IRRIGATION WATER

Seepage from irrigated fields and unlined ditches is a source of recharge to the aquifers, particularly within an area about 1–2 miles wide along the mountain front between Leamington and Oak City. The amount of water used for irrigation in this area is not known, and a good estimate of recharge cannot be made. The coarse permeable soil

285-002 O—68——4

and underlying deposits are conducive to large seepage losses, however, and these losses probably exceed 25 percent of the water diverted for irrigation.

INFLOW FROM CONSOLIDATED ROCKS TO THE BASIN FILL

Limestone, quartzite, and other rocks in the mountains that border the Sevier Desert transmit water through solution channels, joints, and fractures. Some of the water moves directly into the basin fill in the subsurface at the contact between the fill and the underlying bedrock. The amount of water entering the ground-water reservoir by this means has not been estimated, but it may be an important source of recharge to the reservoir.

UNDERFLOW FROM OTHER BASINS

Ground water enters the Sevier Desert from both the Pavant Valley and Beaver River valley. In 1959, 14,000 acre-feet of water entered the basin by underflow from Pavant Valley (Mower, 1965, table 12). Some of this water discharged into the mudflats north of Pavant Butte and some into Clear Lake.

The average annual underflow contributed by the Beaver River valley is about 1,000 acre-feet. At its entrance into the Sevier Desert, the valley is about 9 miles wide (L), the hydraulic gradient of the water table (I) is about 10 feet per mile, and the coefficient of transmissibility of the sediments (T) is about 10,000 gpd (gallons per day) per foot. The underflow was computed using Darcey's Law, whereby $Q=TIL$.

MOVEMENT OF GROUND WATER

The direction of movement of ground water in the Sevier Desert in 1964 is indicated by water-level contours drawn through points of equal ground-water altitude (pl. 5). The contours were drawn using measurements made in March in order to minimize the effects of seasonal pumping from wells for irrigation. The map shows the water-level surface of the upper artesian aquifer and of the unconfined aquifer in the recharge area. Not enough data were available to prepare a water-level map of the lower artesian aquifer, but water levels in that aquifer in most areas are higher than those shown on plate 5.

The water-level contours on plate 5 and the arrows on plate 4 indicate that ground water in the Sevier Desert proper is moving toward an area of discharge west and south of the cultivated part of the basin near Dry Slough and Mud Lake. In the Old River Bed area, however, movement is toward the northwest, and a ground-water divide exists between that area and the Sevier Desert. Desert Mountain and associated bedrock covered by fill divert water draining from the Simpson Mountains and the northwest half of the Sheeprock Mountains toward the Old River Bed. In Tintic Valley, the few available water-level measurements indicate that the ground water moves southward to Tanner Creek Narrows, sec. 22, T. 13 S., R. 4 W., where it enters the main part of the basin.

The contours on plate 5 could not be extended farther south and southwest because of the lack of water-level measurements; so the direction of ground-water flow had to be inferred from the local topography and the growth patterns of phreatophytes. The inferred direction indicates that ground-water movement in the vicinity of Beaver River and Clear Lake is generally northward toward the Sevier River and Mud Lake. In the southwestern part of the basin, a bedrock barrier extending from T. 17 to 19 S., in R. 11 W., and outcrops of bedrock in the channels of Swasey and Soap Washes suggest that the movement of ground water in the southwestern part of the basin is southward toward Sevier Lake.

The regional configuration of the ground-water surface, and hence the direction of ground-water movement, has not been changed by the withdrawal of ground water through wells. Small local changes in the configuration of the surface, however, can be attributed to such withdrawal of water. The pattern of the piezometric contours in the vicinity of Delta indicate an irregular surface which is the result of withdrawals from about 1,500 wells.

ZONATION WITHIN THE ARTESIAN AREA

A confining layer must be relatively close to land surface in the Sevier Desert because wells flow from depths as shallow as 55 feet. Below this confining layer, for a depth of at least 1,000 feet below the land surface, are many water-bearing zones of sand and gravel separated by layers of clay and silt (pl. 3). Although individual water-bearing beds can be identified for only short distances, in much of the basin they form two definite zones called the upper artesian aquifer and the lower artesian aquifer. The aquifers are separated by a zone of less permeable material called an aquitard. The upper artesian aquifer is tapped by most of the domestic and stock wells and some irrigation wells near Leamington and Lynndyl; the lower artesian aquifer is tapped by most of the public supply, industrial, and irrigation wells.

Both artesian aquifers have been identified near Lynndyl and shown to have little hydraulic connection (Mower, 1961). The aquitard which separates them consists predominantly of sandy and silty clay, with thin lenses of silt and fine sand; it is about 400–500 feet thick at Lynndyl and about 100–175 feet thick at Sugarville. Westward and southwestward from Lynndyl, both aquifers become finer grained and the aquitard becomes thinner. Farther west beneath Dry Slough, the aquitard may be nonexistent, and the upper and lower artesian aquifers probably have coalesced into a single aquifer.

The thinner the aquitard, the less effective it is in preventing the transmission of water and pressure changes between aquifers. Near Lynndyl, no effect was detected on the upper artesian aquifer after pumping for 27 days at well (C–15–5)26baa–1, which is finished in the lower artesian aquifer (Mower, 1961). In the area between Sutherland and Sugarville, however, declines were noted in all observed wells finished in the upper artesian aquifer while pumping for 27 days at well (C–16–7)10bad–1, which is finished in the lower artesian aquifer.

Wells finished in the lower artesian aquifer have higher heads than nearby wells finished in the upper artesian aquifer. The difference in head results from loss of pressure as water from the lower aquifer moves upward through the aquitard to the upper aquifer.

No observable head difference was observed in March 1964 between the upper and lower artesian aquifers in the Leamington–Lynndyl–Oak City area at the east side of the basin, but along a line extending through Delta and Sugarville near the center of the basin, the head difference was about 20–30 feet. Southwest of the Delta-Sugarville line the head difference disappeared near sec. 21, T. 16 S., R. 8 W. The maximum head difference may have been as much as 50 feet in 1917 when the first wells were drilled tapping the lower artesian aquifer. Since 1917, the head difference has diminished progressively as the ratio of withdrawals of water from the lower aquifer has increased in relation to withdrawals from the upper aquifer. The head difference between the two aquifers has disappeared at Topaz Camp and perhaps elsewhere where the perforation of wells opposite both aquifers has permitted movement of water between them.

WATER-LEVEL FLUCTUATIONS

An aquifer is a natural storage reservoir, and ground-water levels are an index of the amount of water in storage. Although fluctuations of water levels are caused by many factors, the most important factor in the Sevier Desert is change in the volume of storage. If the inflow to the ground-water reservoir exceeds the outflow, the water-table or piezometric surface will rise; conversely, if the outflow exceeds the inflow, they will decline. The fluctuation of water levels caused by addition and withdrawal of water in an artesian aquifer is greater than the fluctuations caused by equal addition and withdrawal in an unconfined aquifer because the coefficient of storage of artesian aquifers is much smaller than the specific yield of unconfined aquifers (see p. 36).

Water-level fluctuations in the Sevier Desert were determined from periodic measurements in observation wells and from two continuous water-level recording gages installed on wells. The measurements usually were made in March and December during 1939–59 and monthly or bimonthly during 1935–38 and 1960–64. Many of the measurements are published in water-supply papers of the Geological Survey and in a report by Mower and Feltis (1964, table 2 and fig. 2). The major water-level fluctuations are attributed to discharge by wells and by evapotranspiration, and to recharge from direct infiltration of precipitation and infiltration from stream channels, canals, and irrigated fields. Minor water-level fluctuations observed in wells tapping the artesian aquifers are caused by barometric changes, earthquakes, and moving vehicles; but these usually are of short duration and small magnitude and do not affect the amount of water in storage. Major water-level fluctuations are annual or occur over a period of several years.

The highest annual water level is usually late in March at most places in the Sevier Desert. In areas where recharge is steady throughout the year and water is withdrawn from wells for irrigation, water levels decline during the irrigation season and reach an annual low near the end of the irrigation season. See hydrographs for wells (C–15–4)20dcc–1, (C–16–4)30ddb–1, (C–16–7)4abb–1, (C–17–6)8caa–1, (C–17–7)20cbb–1, and (C–18–6)8cbb–1 in figure 4. The effect on water levels varies with the distance from areas of large withdrawals from wells.

At well (C–15–4)20dcc–1, which is within an area of wells pumped for irrigation, water levels begin to decline within a day after pumping begins and begin to recover within a day after pumping stops. At well (C–17–6)8caa–1, which is more than 2 miles from the nearest large pumped well, the high and low water levels lag at the beginning and the end of the irrigation season by about 3 weeks. At the other three wells, which are 5 or more miles away from a large pumped well, the lag is 2–3 months. The magnitude of the annual range in fluctuations of water levels diminishes as distances increase from heavily pumped wells and from areas of recharge.

In areas where recharge varies, depending upon precipitation and infiltration of unconsumed irrigation water, the pattern of fluctuation of water levels may differ from year to year. At well (C–16–4) 30ddb–1, water levels declined from 1959 to 1961 because of below-

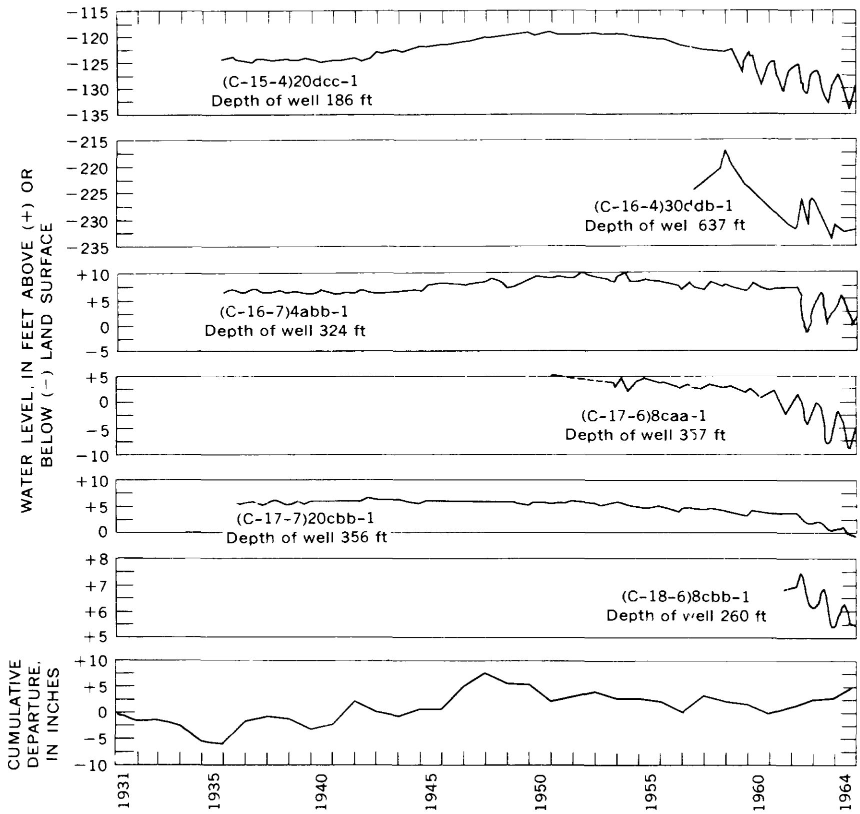


FIGURE 4.—Relation of water levels in six selected wells to cumulative departure from the 1931–60 normal annual precipitation at Deseret.

normal precipitation during that period. During the first half of the 1962 irrigation season, however, water levels rose more than 6 feet in response to recharge from the heavy snow of the previous winter.

The seasonal decline in water levels in the Sevier Desert during the 1964 irrigation season is shown in figure 5. The observed declines ranged from zero along the southwestern side of the basin to more than 5 feet between Delta and Leamington. The largest declines in the 150 wells that were measured are in areas of greatest withdrawal [1] (see pl. 1 and table 6).

The annual change of water levels from March 1963 to March 1964 involved an average decline of about 1 foot throughout the most heavily developed part of the basin, but locally, declines were as much as 3 feet (fig. 6). Most of the decline was caused by with-

[1] The term "withdrawal," as used in this report, refers to water that is pumped or flows from a well.

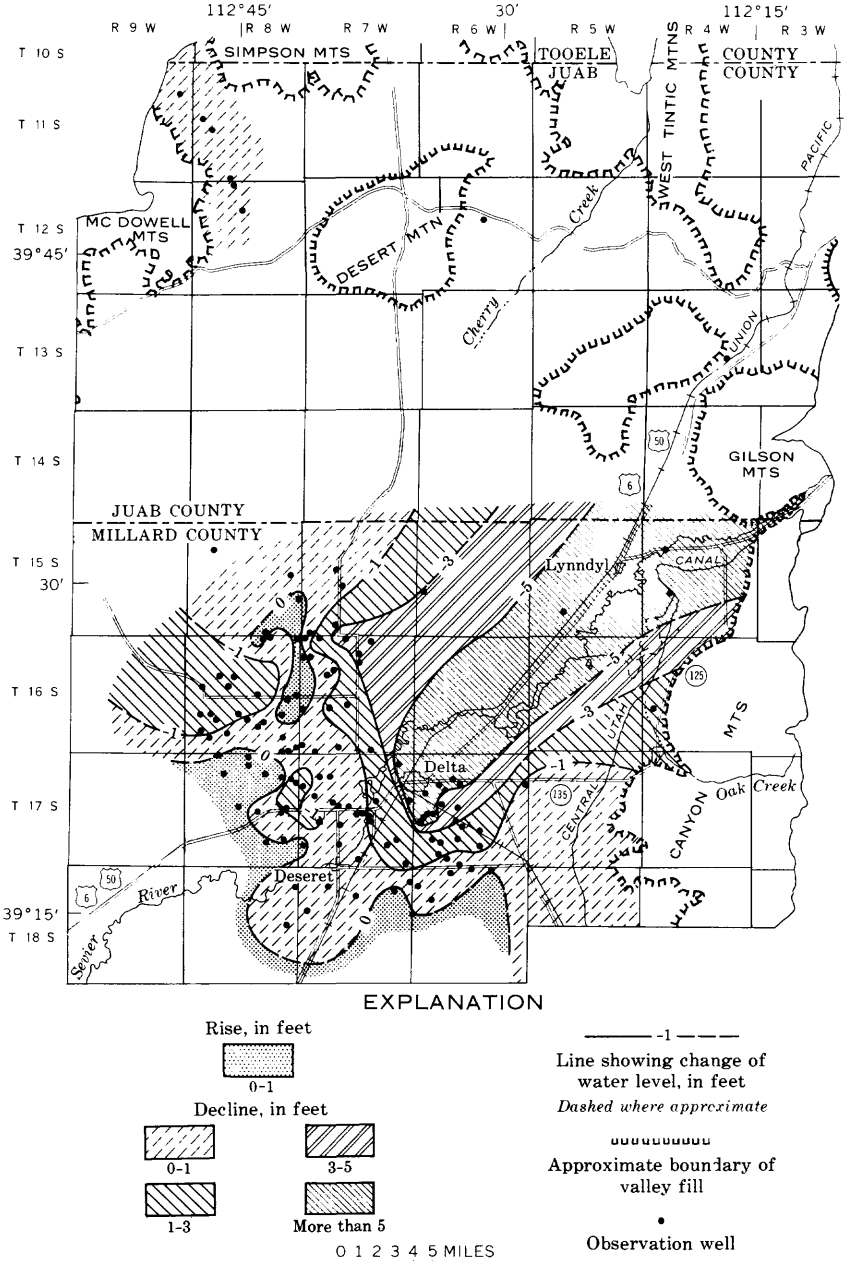


FIGURE 5.—Change of ground-water levels in the upper artesian aquifer, March to August 1964.

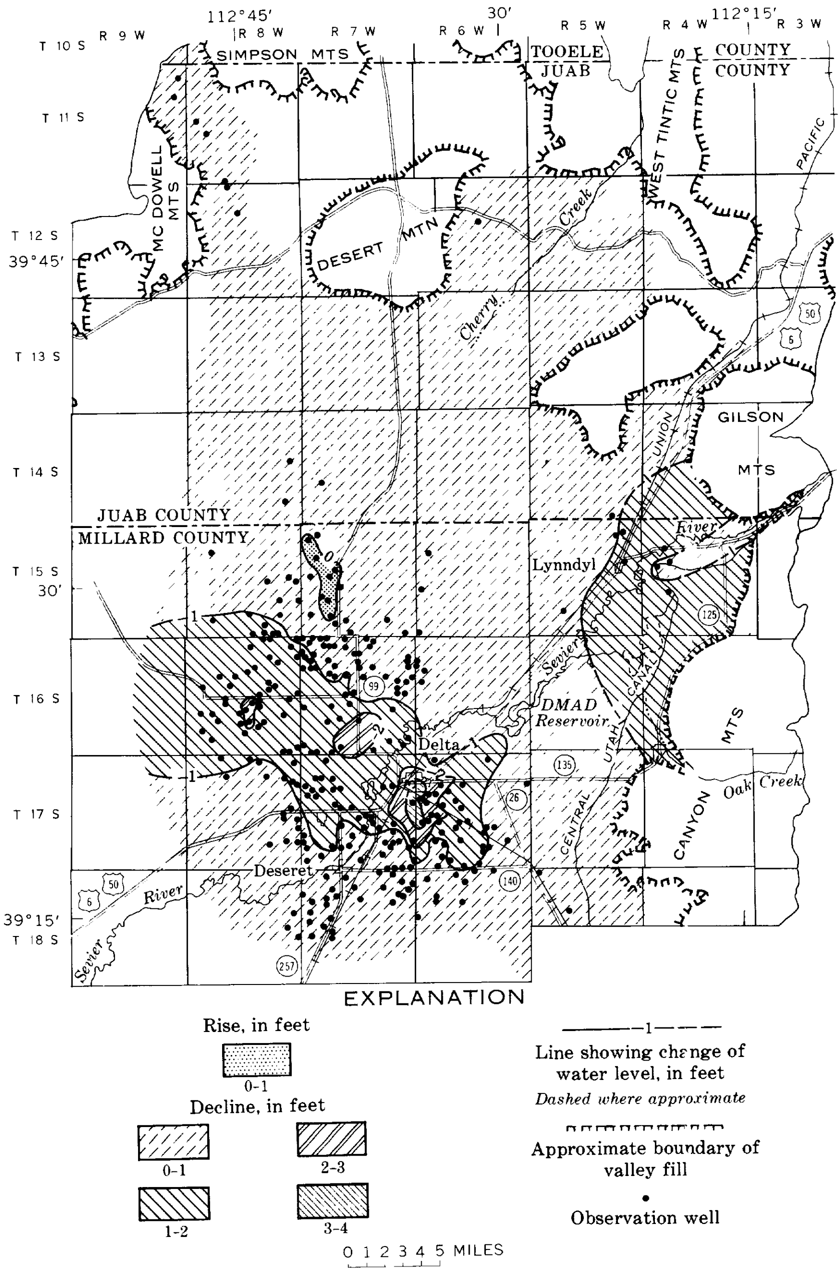


FIGURE 6.—Change of ground-water levels in the upper artesian aquifer, March 1963 to March 1964.

drawal of ground water, as indicated by the coincidence of the centers of greatest decline with the centers of greatest withdrawal. Declines were small or water levels rose in areas remote from centers of withdrawal.

The annual fluctuations of water levels in the Sevier Desert are contained within fluctuations that span several years. This is illustrated in figure 4 in the hydrograph for well (C–15–4)20dcc–1. The long-term trends represent cumulative changes in storage in response to cumulative changes of recharge and discharge to the ground-water reservoir. Water levels changed little during 1935–40. During 1941–50, however, water levels rose in response to the general above-normal precipitation during 1939–47. During 1950–64 water levels declined, partly in response to below-normal precipitation and partly in response to an increase in pumping from irrigation wells (fig. 11). Although the period 1961–63 was one of above-normal precipitation, water levels continued the overall decline that was started in 1950. This suggests that much of the decline was caused by pumping.

GROUND-WATER STORAGE

The ground water in storage in the Sevier Desert was estimated from the area of the ground-water reservoir, the thickness of the saturated materials, and water content of the materials. The area of the ground-water reservoir is assumed to be equivalent to the surface area of the unconsolidated basin fill—about 100 square miles in the Old River Bed and about 2,000 square miles in the Sevier Desert. The average thickness of saturated materials is about 300 feet in the Old River Bed and about 775 feet in the main part of the Sevier Desert, but the thickness of saturated materials exceeds 1,000 feet in much of the Sevier Desert and is in excess of 8,000 feet near the center of the basin (pl. 3). Only the quantity of water in the upper 1,000 feet of unconsolidated materials was computed, however, because little is known about the reservoir below that depth and because data available suggest that the water below 1,000 feet may not be of acceptable chemical quality for domestic use or irrigation.

The water content of the saturated materials was estimated by examining drillers' logs and assigning an estimated water content to various lithologic types, as follows:

Lithologic material as described by drillers	*Estimated water content (percent)*	*Lithologic material as described by drillers*	*Estimated water content (percent)*
Clay; clay and silt	50	Sand	30
Clay and sand; sand and clay; sandy clay	40	Gravel	25
		Sand and gravel	20

A driller's log was examined for each land section for which logs were available, and usually the log of the deepest well in the section was used. On the basis of drillers' logs and the average weighted value of the water content of the various lithologic types, it is estimated that the saturated materials in the basin contain about 40 percent water by volume.

If the area is assumed to be 2,000 square miles and the average saturated thickness 775 feet, the volume of saturated materials in the main part of the Sevier Desert is 1 billion acre-feet. Thus the amount of ground water in storage is about 400 million acre-feet. In the Old River Bed the volume of saturated materials, based on an area of about 100 square miles and an average saturated thickness of 300 feet, was estimated to be 20 million acre-feet, and the amount of ground water in storage 6 million acre-feet.

The amount of ground water in storage is much greater than the amount that is readily available for man's use. One criterion of the amount of water available, however, is the quantity of water that can be removed from storage in an aquifer by lowering water levels. This quantity is determined by the coefficient of storage of the aquifer, which is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The coefficient of storage varies considerably depending on whether the water is under water-table or artesian conditions. Under water-table conditions, lowering of the water table results in a dewatering of the aquifer by gravity drainage. The volume of water drained divided by the total volume of the zone is the specific yield, and for practical purposes for a water-table aquifer the specific yield is equivalent to the coefficient of storage. The storage coefficients of water-table aquifers range from about 0.05 to 0.30. Under artesian conditions, however, lowering the water level results only in a decrease of pressure in the aquifer. Inasmuch as no dewatering of the aquifer is involved, the water released from storage can be attributed only to the compressibility of the aquifer material and of the water. This quantity is very small; therefore, the coefficient of storage of an artesian aquifer is very small. The storage coefficients of artesian aquifers may range from about 0.00001 to 0.001. When the water level in an artisian aquifer declines sufficiently so that the aquifer is actually being dewatered, the storage coefficient changes to one of water-table proportions.

An average change in artesian head of 1 foot over an area of 1 square mile will result in a change in ground-water storage of about 0.3 acre-foot, assuming a coefficient of storage of 0.0005. This relation is valid in the lowlands where the piezometric surface is above or within about 25 feet of the land surface, but it is not valid in or near the recharge areas. In and near the recharge areas and in much of the Old River Bed area where the ground water is unconfined or semiconfined, assuming a specific yield of 0.15, a change in water level of 1 foot over an area of 1 square mile may result in a change of ground-water storage of 100 acre-feet.

An average change of water level of 1 foot over the entire ground-water reservoir in the Sevier Desert will result in a change in ground-water storage of 6,000 acre-feet. Thus, the amount of water that could be obtained if the piezometric surface in the artesian aquifers were lowered 20 feet is estimated to be 120,000 acre-feet. The figure of 20 feet was used because a decline of this amount probably would result in the cessation of free flow of all wells. However, the same relation of yield to decline of water level can be extended to depths as great as 100 feet. In the above calculations, the change in storage in that part of the ground-water reservoir that is under water-table conditions was assumed to be negligible. The error introduced by this assumption is believed to be small because the area where water-table conditions exist is very small compared to the total area of the reservoir.

CHEMICAL QUALITY OF THE WATER

GENERAL STATEMENT

The type and amount of the minerals in solution in ground water depend chiefly on the chemical and physical composition of the soil or rocks through which the water passes, the length of time the water is in contact with the soil or rocks, and other factors such as water temperature and pressure. Reuse of water for irrigation may adversely affect the chemical quality of the water by concentrating minerals by evapotranspiration and by the addition of minerals from fertilizers, pesticides, and herbicides. Selected representative chemical analyses of water samples from 36 wells are given in table 5, and 141 chemical analyses of ground water from the area were compiled by Mower and Feltis (1964). Some chemical characteristics of water from 10 wells are shown in figure 7, and the concentration of dissolved solids in water from wells, springs, and streams is shown on plate 6.

The chemical quality of the ground water changes with depth as well as with area. The deterioration of quality with depth is shown by an electrical log (pl. 3) of an oil test, (C-16-8)24bbb-1, which indicates, by a narrowing of the space between the lateral curve and the short normal curve with depth, a progressive deterioration in water quality. Water quality at about 800 feet in the oil test is similar to analyses 22, 24, 25, and 27 in table 5. In wells (C-16-8)21bcb-1, (C-16-8)26bdb-2, and (C-17-8)11bbc-1, 1-4 miles west and southwest

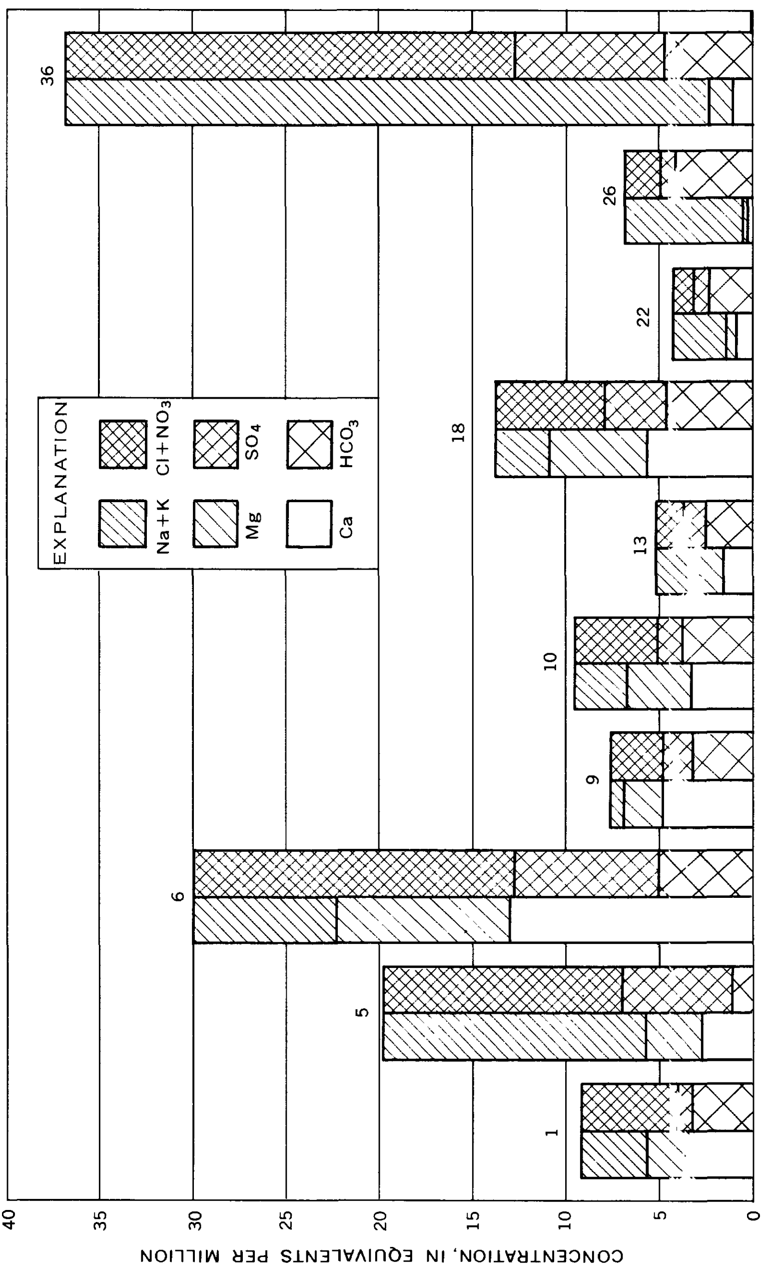


FIGURE 7.—Chemical character of representative ground waters. Numbers refer to analyses in table 5.

of the oil test, water contains 1,470–2,750 ppm (parts per million) of dissolved solids at depths of 790–1,071 feet. The configuration of the fresh- and salt-water contact in the central part of the basin is not known; however, data suggest that the contact becomes progressively shallower south, southwest, and west of Delta.

The chemical quality of the ground water ranges widely throughout the basin (pl. 6). Near Leamington, the ground water contains about 1,000 ppm of dissolved solids and is somewhat similar in chemical quality to water in the Sevier River (Love, 1966, p. 123). This is to be expected, as most of the ground water is derived from recharge from the river or from irrigation water that is diverted from the river. Much of the river water is return flow from irrigated lands upstream, and some of the water may have been used for irrigation several times before recharging aquifers in the Sevier Desert. As a result, the water has a higher concentration of dissolved minerals than was present in the river before the practice of irrigation was begun upstream about 1850.

Between Lynndyl and Delta, the dissolved-solids content of the ground water is less than it is to the east near Leamington (pl. 6), and the lower artesian aquifer contains water of slightly better chemical quality than does the upper artesian aquifer. The freshest water is found near Delta, where the dissolved-solids content is only about 250 ppm. This fresh water is derived from recharge from the Sevier River that entered the ground before irrigation was begun upstream and that percolated through the well-sorted fluviatile deposits that were laid down by the ancestral Sevier River. The ground water north and south of the Delta area is not so fresh because the water had to move more slowly through finer grained deposits. Southwest of Delta, the fine-grained deposits contain considerable residual salts, and the quality of water deteriorates as some of the salts are taken into solution.

In summary, the area near Delta contains a body of relatively fresh ground water that was derived from recharge from the Sevier River before irrigation was practiced upstream. This fresh water is percolating slowly toward the southwest, and it is being followed by saline water that was derived from recharge from the Sevier River after irrigation was begun upstream. Under present hydraulic gradients, water containing 1,000 ppm of dissolved solids could be expected to reach the Delta area in 100–150 years. If the amount of water withdrawn by pumping were substantially increased, the hydraulic gradient would increase, the rate of movement would increase, and the saline water would arrive sooner.

TABLE 5.—*Chemical analyses of water from*

[Concentrations of dissolved constituents, dissolved

No.	Well	Date of collection	Depth of well (feet)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)[1]	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
1	(C-12-8) 9baa-1	5- 2-63	272	64	41	------	68	27	80	------	194	0
2	(C-13-6) 26bac-1	8-23-61	175	60	61	0.00	134	113	424	------	238	0
3	(C-14-5) 36ccc-3	3-23-59	250	------	32	------	126	94	250	------	245	0
4	(C-14-7) 20ccc-1	4-25-63	194	62	23	------	82	51	322	------	90	0
5	(C-14-8) 25ccc-1	4-26-63	340	59	17	------	54	36	324	------	66	0
6	(C-15-4) 8cba-1[3]	6- 2-61	203	56	28	.01	260	114	[4] 173	6.6	306	0
7	11add-1	10- 8-63	485	------	19	------	164	66	105	------	236	0
8	18daa-1	6-23-58	406	63	28	------	134	68	75	------	224	0
9	26dcc-1	9- 1-61	660	60	15	.00	97	25	21	------	194	0
10	(C-15-5) 13bbc-1	6-23-58	310	59	26	------	66	41	67	------	229	0
11	26baa-1	11- 4-58	860	------	26	------	34	19	23	------	178	0
12	29dda-1	9-26-61	132	------	29	.02	43	26	53	------	246	0
13	33dcb-1	8-21-62	825	71	26	.00	31	20	[4] 42	2.3	152	0
14	(C-15-6) 19cac-1	8-23-61	235	59	29	.00	30	22	93	------	202	0
15	(C-15-7) 36cbb-1	9-27-61	420	60	38	.00	30	13	62	------	150	Trace
16	(C-15-8) 29ccc-1	3- 7-63	------	53	19	------	8.0	1.9	183	------	217	0
17	(C-16-4) 18bda-1	8- 1-61	375	62	40	.00	103	45	89	------	212	0
18	30ddb-1	3-28-63	637	56	18	------	113	46	93	------	279	0
19	(C-16-5) 18caa-1	7- 8-61	935	68	29	.00	32	14	22	------	178	0
20	19cbd-1	5-18-62	823	67	24	------	24	17	13	------	158	0
21	(C-16-6) 34bad-2	9-24-62	377	------	29	------	22	18	13	------	168	0
22	(C-16-7) 10bad-1	11-14-62	919	64	23	------	17	6.3	68	------	142	0
23	10bbb-2	11-14-62	350	------	13	------	23	9.7	51	------	125	0
24	24bca-1	8-28-62	855	73	27	------	16	8.0	67	------	149	0
25	(C-16-8) 12ddd-2	6-22-62	954	80	32	------	11	1.9	113	------	210	0
26	21cbb-1	6-28-62	658	66	26	------	6.4	1.9	145	------	251	0
27	26bdb-2	4-23-63	844	79	29	------	10	6.8	206	------	242	0
28	(C-17-6) 17aaa-1	5- 3-63	840	82	29	------	15	9.2	51	------	141	0
29	26daa-3	6-20-62	720	75	42	------	22	12	89	------	253	0
30	28acb-1	5- 8-63	895	77	30	------	8.0	4.4	75	------	183	0
31	(C-17-7) 1ddd-4	8-20-63	865	80	13	------	17	7.1	75	------	156	0
32	34cbd-2[6]	6- 2-61	598	------	27	.01	3.2	4.9	[4] 174	.7	394	12
33	(C-17-8) 13cdd-1	12- 4-57	150	58	27	------	3.8	.4	201	------	401	15
34	(C-18-6) 8cbb-1	8-21-61	260	63	25	.02	18	4.4	76	------	224	0
35	(C-18-7) 5aaa-2	4-15-55	320	------	28	------	7.0	4.8	194	------	362	16
36	(C-18-8) 24ada-2	8-21-61	601	78	36	.22	22	16	791	------	288	0

[1] Sodium (Na) and potassium (K) reported as sodium except as noted.
[2] Dissolved solids calculated from determined constituents except as noted.
[3] Contains 0.58 ppm manganese (Mn).

QUALITY IN RELATION TO USE

IRRIGATION

The characteristics of water that seem to be most important in determining its suitability for use in irrigation are: total concentration of soluble salts; relative proportion of sodium to other cations; under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium; and concentration of boron or other elements that may be toxic (U.S. Salinity Laboratory Staff, 1954, p. 69).

The concentration of soluble salts, or salinity, may be expressed in units of dissolved solids or of specific conductance. The higher the concentration of dissolved solids, the greater the conductivity of the water, and in the Sevier Desert, the average ratio of dissolved solids to specific conductance is 0.58 (see fig. 8). Water of high specific con-

36 selected wells in the Sevier Desert

solids, and hardness in parts per million]

Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids [2]	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos/cm at 25° C)	pH
36	182	------	0.7	0.08	530	280	121	38	2.1	0	964	7.2
547	675	------	5.9	------	2,080	800	605	54	6.5	0	3,280	7.7
250	555	------	2.3	------	1,430	702	501	44	4.1	0	2,480	7.5
268	540	------	2.1	------	1,330	415	341	63	6.9	0	2,340	7.0
283	450	------	2.7	------	1,200	280	226	72	8.4	0	2,100	6.8
369	608	0.0	4.4	.20	1,720	1,120	865	25	2.3	0	2,840	7.6
249	320	------	5.1	.08	1,040	680	486	25	1.7	0	1,700	7.4
144	308	------	11	------	878	614	430	21	1.3	0	1,540	7.7
76	81	------	46	------	456	344	185	12	.5	0	776	7.7
58	164	------	.8	------	536	334	146	30	1.6	0	951	7.7
26	31	------	2.3	------	252	163	17	25	.9	0	411	7.9
57	56	------	.9	------	391	215	13	37	1.7	0	638	7.8
56	52	.3	3.1	.07	308	161	36	36	1.4	0	513	7.5
62	105	------	.3	------	445	166	0	56	3.3	0	762	7.8
55	58	------	.4	------	330	128	5	51	2.4	0	524	8.2
100	102	------	.3	------	521	28	0	93	15	3.00	875	7.7
129	227	------	8.9	------	[5] 849	442	268	30	1.8	0	1,290	7.7
159	174	------	56	------	802	470	241	31	2.0	0	1,350	7.5
10	20	------	2.6	.26	[5] 209	138	0	26	.8	.17	349	7.7
11	22	------	.1	------	195	130	0	24	.7	0	330	7.4
7.4	17	.3	.3	------	196	130	0	24	.7	.17	329	7.2
41	39	.5	.5	------	265	69	0	68	3.5	.96	434	7.8
38	46	.4	.4	------	242	98	0	53	2.2	.10	420	7.6
38	40	------	.0	------	269	73	0	67	3.4	.98	439	7.9
39	57	------	.0	------	363	35	0	88	8.7	2.74	601	7.9
40	65	------	.1	------	407	24	0	93	13	3.64	685	8.0
77	158	------	1.1	------	607	54	0	89	12	2.91	1,050	7.8
22	33	------	1.4	.06	230	76	0	59	2.5	.90	379	7.3
27	32	------	.1	------	339	107	0	62	3.4	2.06	549	7.8
16	24	------	.4	.07	248	38	0	81	5.3	2.24	400	7.8
44	43	------	.5	------	277	72	0	69	3.8	1.12	456	8.0
19	28	3.0	1.5	.56	468	28	0	93	14	6.30	728	8.5
32	43	------	.2	------	519	11	0	97	26	6.56	849	8.6
15	20	------	.6	------	269	62	0	73	4.2	2.41	440	7.9
26	71	------	.1	------	525	37	0	92	14	5.63	870	8.5
387	850	------	2.7	------	2,250	120	0	93	31	2.31	3,820	8.0

[4] Sodium (Na) and potassium (K) determined separately.
[5] Residue on evaporation at 180° C.
[6] Contains 0.00 ppm manganese (Mn).

ductance may not be suitable for irrigation, and it speeds the corrosion of metals in well casings, pumps, and pipelines.

The specific conductance of water from nearly 500 wells in the Sevier Desert was measured during the investigation; the conductivity of the water from 36 representative wells is plotted in figure 9 to indicate the salinity hazard of the water according to the method of the U.S. Salinity Laboratory Staff (1954). Their classification of saline water is as follows:

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

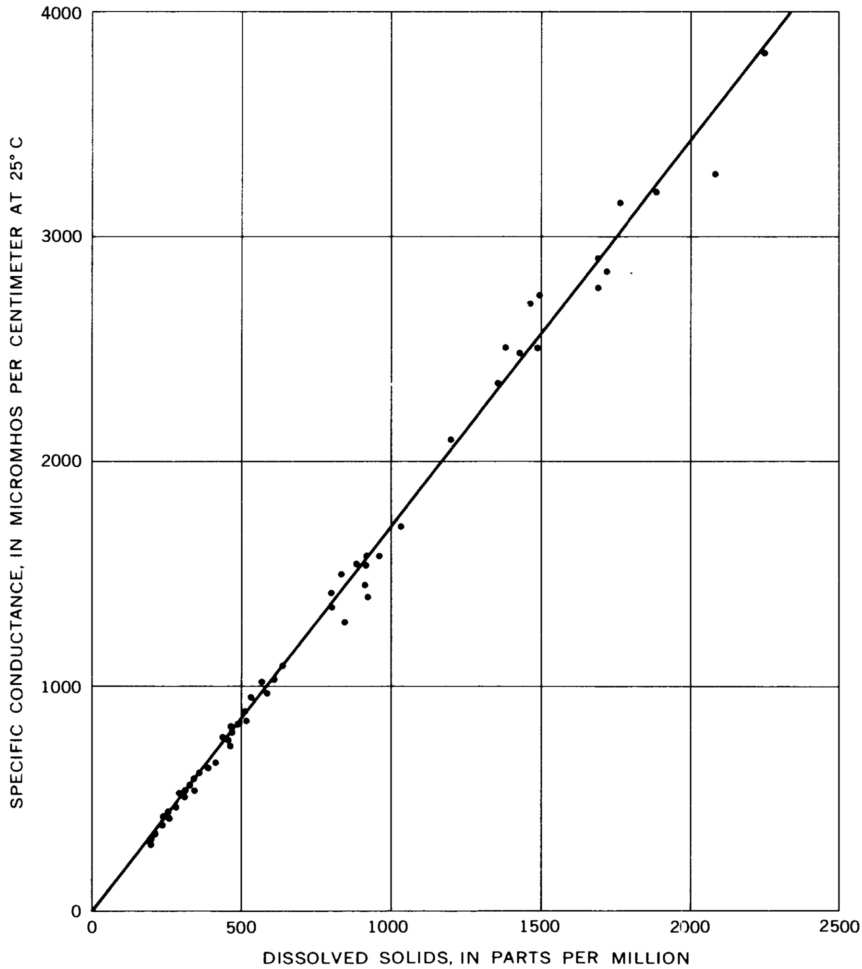


FIGURE 8.—Relation of specific conductance to dissolved solids in ground water.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

A high proportion of sodium in relation to other cations in water used for irrigation tends to break down the friable, granular nature of soil and causes it to become less permeable. In contrast, water containing high proportions of calcium and magnesium in relation to sodium maintains good tilth and texture in soil.

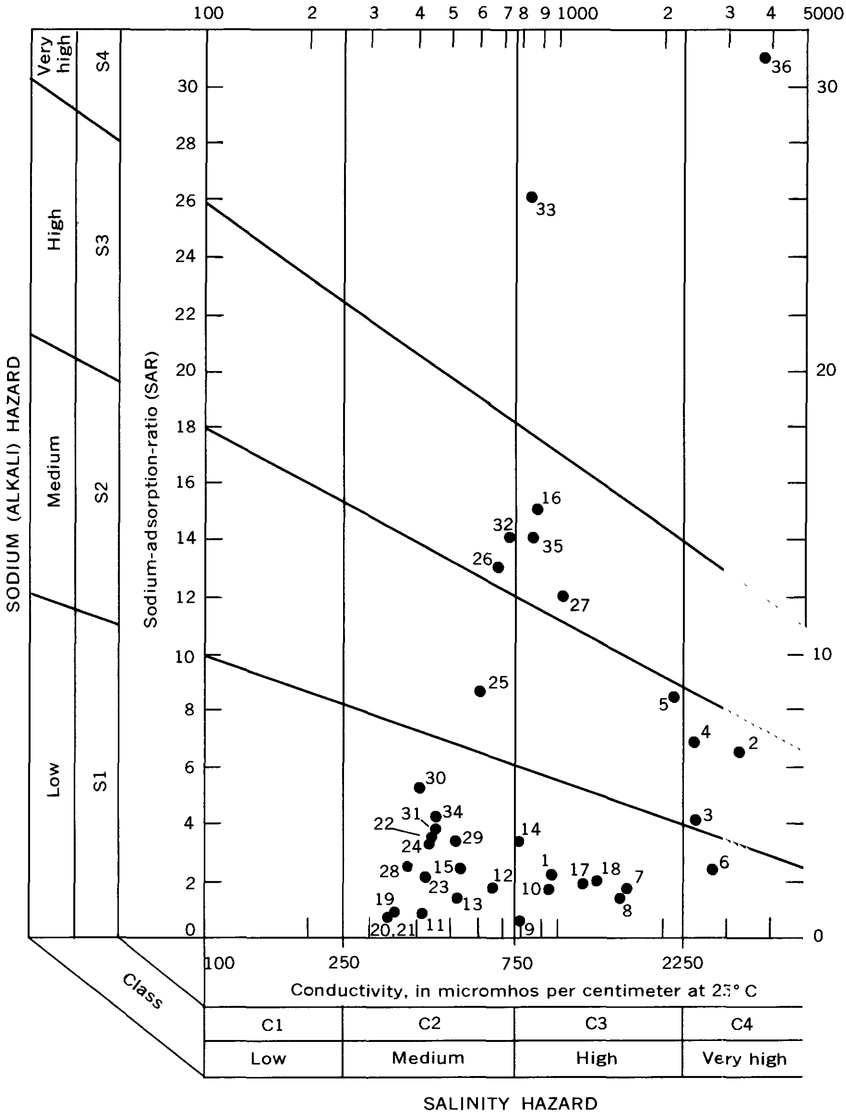


FIGURE 9.—Analysis of irrigation water (method of the U.S. Salinity Laboratory Staff, 1954). Number by circle refers to table 5.

The sodium hazard can be expressed in terms of the sodium-adsorption-ratio (SAR), where

$$SAR=\frac{Na^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$$

The concentrations of sodium, calcium, and magnesium in the formula are expressed as equivalents per million.

Classifying water according to the harm that its sodium content will do to soil is not simple because the suitability of water for irrigation is influenced by soil drainage, water management, and application of soil amendments. Also, the presence of gypsum and calcium in the soil tends to counteract the effects of sodium. The classification of the U.S. Salinity Laboratory Staff (1954, p. 81) for sodium hazard is described below, and figure 9 shows the sodium hazard of the water from 36 representative wells plotted according to this classification.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

In parts of the Sevier Desert, the ground water obtained from shallow wells is less suitable for irrigation than the water obtained from deeper wells to a maximum depth of about 1,000 feet. For example, water from well (C–15–5)26baa–1, which is finished in the lower artesian aquifer, is classified S1–C2 in figure 9; whereas water from well (C–15–5)13bbc–1, which is finished in the upper artesian aquifer, is classified S1–C3 in figure 9.

Ground water close to recharge areas generally is more suitable for irrigation than water considerably downdip from these areas because percolating water tends to dissolve salts from fine-grained sediments through which it passes. Where recharge is principally from the Sevier River, however, the water close to the river is less suitable for irrigation than water several miles downdip. (See p. 39.) This is illustrated by a comparison of the quality of water from wells (C–15–4)8cba–1 and (C–15–5)13bbc–1 (see analyses 6 and 10 in table 5 and in fig. 9), both of which tap the upper artesian aquifer. Water from well (C–15–4)8cba–1, which is about 3 miles downgradient from the area of recharge, has a classification of S1–C4; whereas water from well (C–15–5)13bbc–1, which is about 5 miles downgradient, has a classification of S1–C3.

Another expression of the sodium hazard in water used for irrigation is by means of the residual sodium carbonate (RSC), where

$$RSC=(CO_3^{-1}+HCO_3^{-1})-(Ca^{+2}+Mg^{+2})$$

The concentrations of carbonate, bicarbonate, calcium, and magnesium are expressed in equivalents per million (epm) (Eaton, 1950, p. 127). The RSC is a measure of the tendency of water to become more alkaline when calicum and magnesium carbonates precipitate as water is transpired by irrigated crops. This contributes to the soil condition referred to as "black alkali." Concentrations of residual sodium carbonate greater than 2.5 epm are considered to be unsuitable for irrigation (U.S. Salinity Laboratory Staff, 1954, p. 81). In the Sevier Desert, only the ground water in the western one-fourth of the principal irrigated area (fig. 10) is known to contain more than 2.5 epm of RSC. None of the water in the eastern and northern parts of the area had RSC that exceeds 2.5 epm.

Boron is essential to plant growth, but excessive concentrations of boron are toxic to plants. According to the U.S. Salinity Laboratory Staff (1954, p. 81), the permissible limits of boron range from 0.33 to 1.25 ppm for crops sensitive to boron to 1.00–3.75 ppm for crops tolerant to boron. In the Sevier Desert, the concentration of boron in ground water ranges from 0.04 to 0.56 ppm.

DOMESTIC USE

The U.S. Public Health Service (1962) recommended drinking water standards that may be used as a guide in determining the suitability of water for human consumption. The maximum recommended concentrations for selected chemical constituents are:

Constituent	*Recommended maximum concentration (ppm)*
Iron	0.3
Sulfate	250
Chloride	250
Fluoride	[1]
Nitrate	45
Dissolved solids	500

[1] The recommended maximum fluoride concentration is variable, depending on air temperature. For temperatures similar to that at Delta, the maximum recommended fluoride concentration is 1.2 ppm (U.S. Public Health Service, 1962, p. 8).

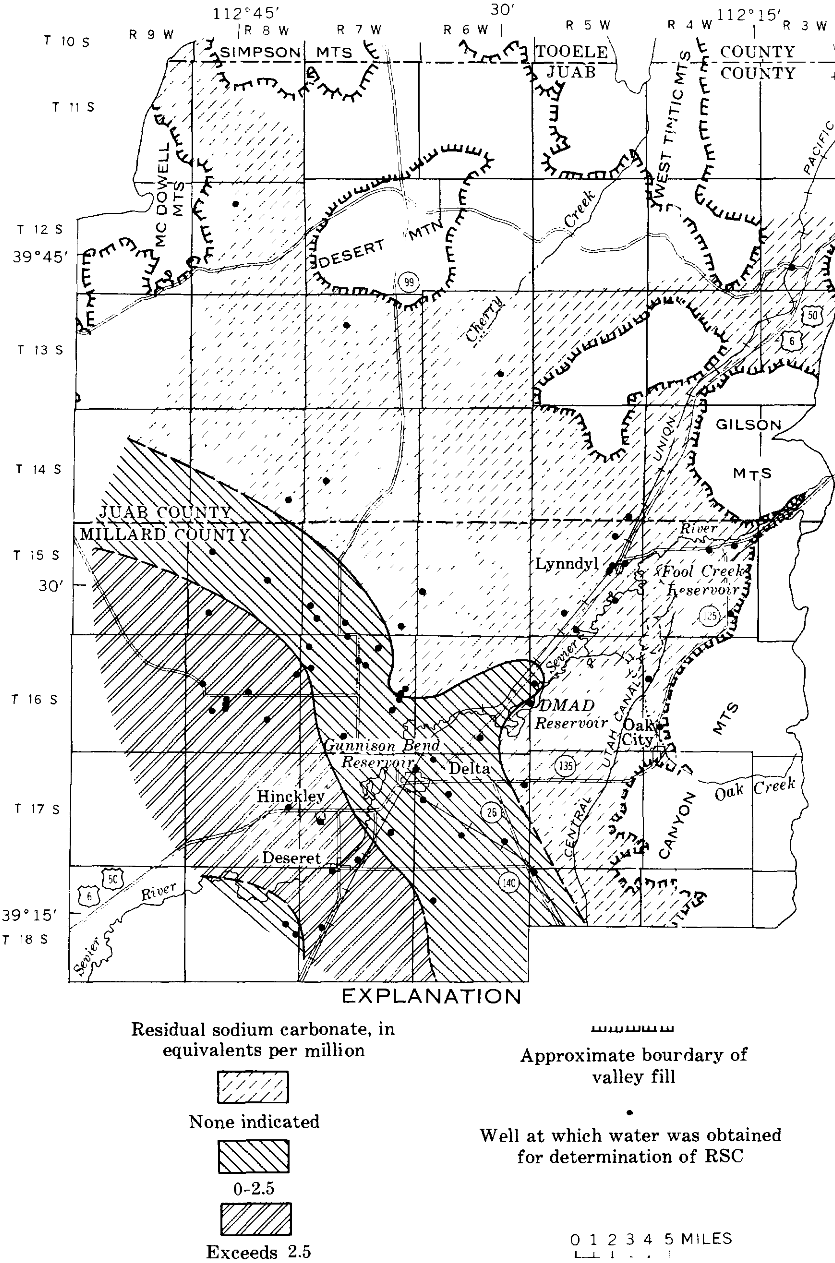


FIGURE 10.—Residual sodium carbonate (RSC) of ground water.

Iron in water in concentrations exceeding 0.3 ppm may stain plumbing fixtures and laundry and impart an objectionable taste to the water (U.S. Public Health Service, 1962, p. 43). None of the analyses of ground water in the Sevier Desert indicate, however, that the water contains more than 0.3 ppm of iron.

Chloride in concentrations greater than 250 ppm may give a salty taste to water, and sulfate in concentrations greater than 250 ppm may have a laxative effect. The concentration of chloride in ground water exceeds 250 ppm near Leamington and in the extreme western third of the area. Analyses from a few wells in small, remote parts of the basin show concentrations slightly greater than this limit. Sulfate is in concentrations greater than 250 ppm in the ground water in the Sevier Desert in three rather small areas: near Leamington, in a part of the natural discharge area about 5–10 miles northwest of Sugarville, and for a distance of at least 6 miles south and southwest of Deseret. Hydrogen sulfide generally is in the ground water south of State Highway 140, where its presence is noted by the offensive odor and taste of the well water. Aerating the water or allowing the water to stand exposed to the atmosphere for a few minutes permits the gas to escape and makes the water more suitable for domestic use.

Concentrations of fluoride greater than 1.2 ppm in drinking water in areas where the annual average of maximum daily air temperatures are similar to that of the Sevier Desert have been associated with a dental defect known as "mottled enamel." Concentrations of 0.7–1.2 ppm (U.S. Public Health Service, 1962, p. 8), however, are considered to be beneficial in the prevention of tooth decay, especially for children. The concentration of fluoride was determined in water samples from 21 wells in the Sevier Desert; and of these, the recommended maximum was exceeded only at well (C–16–8)21bcb–1, west of Abraham (1.5 ppm), and at well (C–17–7)34cbd–2, at Oasis (3.0 ppm).

Drinking water that contains nitrate concentrations exceeding 44 ppm has been associated with cyanosis in infants (Hem, 1959, p. 239). The nitrate concentration exceeded this limit in only two of the wells tested: (C–15–4)26dcc–1, about 2 miles south of Leamington, and (C–16–4)30ddb–1, about 1 mile north of Oak City.

The classification used by the U.S. Geological Survey to describe water with reference to hardness is as follows:

Hardness (ppm)	*Adjective rating*
0–60	Soft
61–120	Moderately hard
121–180	Hard
181+	Very hard

Soft water is suitable for all uses in the home, but very hard water is not; it usually requires softening for most uses. The use of synthetic detergents, however, has eliminated or reduced many problems associated with the use of hard water for domestic purposes.

Ground water in the Sevier Desert ranges from soft to very hard, and about half the water has noncarbonate (permanent) hardness. In general, the softest water is in the low-lying lands in the vicinity of Delta and nearby communities, and the hardest water is near the mountains along the northern and eastern edges of the basin.

STOCK WATER

According to Hem (1959, p. 241):

> Water to be used by stock is subject to quality limitations of the same type as those relating to quality of drinking water for human consumption. However, most animals seem to be able to use water considerably poorer in quality than would be considered satisfactory for human beings. The literature does not contain many references to quality standard for stock-water supplies. Range cattle in the western United States seem to be able to use water containing 5,000 ppm or more of dissolved solids, and animals that have become accustomed to highly mineralized water have been observed, in the course of investigations of water quality by the author, to drink water containing nearly 10,000 ppm of dissolved solids. A high proportion of sodium or magnesium and sulfate in such highly mineralized waters would make them very undesirable for stock use, however. Probably a supply of considerably better quality than the upper limit of tolerance is generally desirable for the best growth and development of the animals.

On the basis of available analyses, all the ground water in the Sevier Desert may be used for stock watering, although in some areas it would be desirable to have better quality water. The maximum known dissolved-solids content of ground water is 6,360 ppm (from a well southwest of Deseret).

DISCHARGE

Ground water in the Sevier Desert is discharged primarily by subsurface outflow, by wells, and by evapotranspiration. A small additional amount is discharged by seeps and springs. Before wells were constructed, the average annual discharge during a long term of years equaled the average annual recharge. Discharge through wells may result in an increase of recharge to the ground-water reservoirs, a decrease of the natural discharge, a decrease in the amount of ground water in storage, or in a combination of these effects. During 1961–64, most of the ground water discharged through wells was taken from storage or represented a reduction in natural discharge. The principal types of ground-water discharge are discussed below.

SUBSURFACE OUTFLOW

Ground water moves out of the Sevier Desert as subsurface outflow to the south toward Sevier Lake playa and to the north beneath the Old River Bed. The rate of evaporation of the ground water underlying Sevier Lake playa is discussed on page 59. All the outflow to the north is derived from nearby recharge in the Old River Bed drainage area. The exact amount of outflow is not known, but it is probably less than 5,000 acre-feet a year.

FLOWING WELLS

The first flowing well in the Sevier Desert was constructed in 1888 near Deseret. The number of wells must have increased rapidly, for by 1908 Meinzer (1911, p. 41) reported, "The Deseret area * * * contains several hundred wells whose water either overflows or rises so near the surface that no pumps are required." By 1964 about 1,875 flowing wells had been constructed, but by March many had ceased flowing because of declining hydrostatic heads, even though some wells had been plugged. No accurate count is available for the actual number of existing flowing wells, but it is estimated that 1,050 wells capable of flow existed in March 1964. The probable area of artesian flow at the land surface in 1935 included more than 425 square miles, but by March 1964 the area had diminished to about 225 square miles (pl. 5). Most of the flowing wells tap the upper artesian aquifer.

Water from flowing wells is used primarily for domestic purposes and stock watering; however, some is used for irrigation of native grass pastures. The amount of water discharged from flowing wells was about 1,000 acre-feet in 1950; the peak was probably reached in 1960 when the discharge was about 3,000 acre-feet. Since 1960 the amount has diminished, partly as a result of drought and partly as a result of pumping, to about 1,500 acre-feet in 1964. The amount will continue to diminish as the cones of depression on the piezometric surface around pumped wells become deeper and spread to other areas.

The annual discharge from flowing wells in the basin was estimated by extrapolating the rate of flow and head measurements made in 25–50 selected observation wells during 1935–60 and in 400–600 wells during 1961–64 to all flowing wells of record. During 1961–64, the degree of control flow, including length of time each year that the well is closed, was observed at more than three-fourths of the flowing wells. It was assumed that similar flow controls were exercised prior to 1961.

PUMPED WELLS

About 29,000 acre-feet of water was pumped or flowed from wells in the Sevier Desert during 1964 (table 6). Of the total, 27,500 acre-feet was for irrigation, 1,000 acre-feet for domestic and stock supply, and about 500 acre-feet for public and industrial supply. Figure 11 shows that the total withdrawal has increased steadily since 1950 and that it has kept pace with the increased number of pumped irrigation wells.

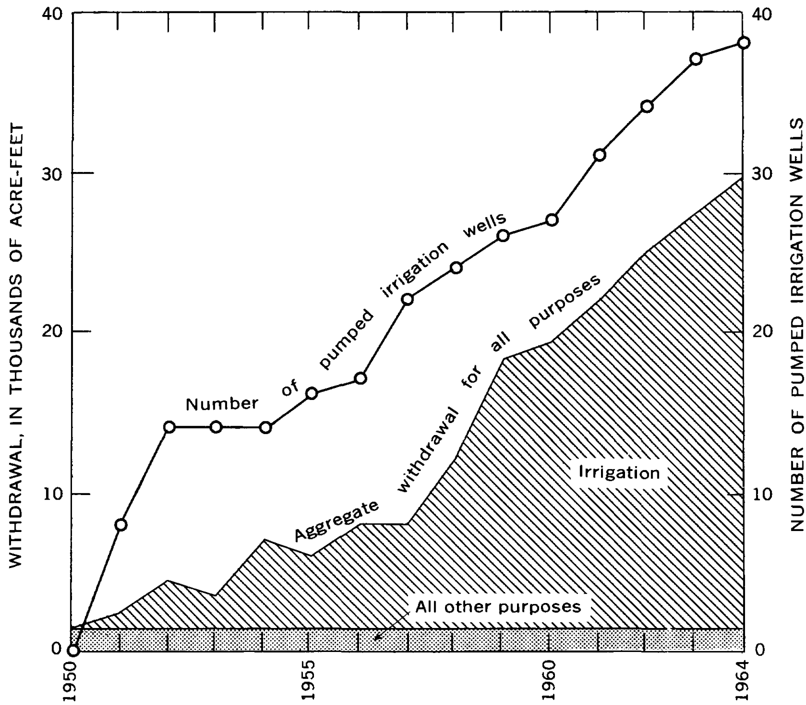


FIGURE 11.—Number of pumped irrigation wells and aggregate withdrawal for all purposes, 1950–64.

IRRIGATION WELLS

The first pumped irrigation wells were put in operation in 1951 to supplement surface-water supplies, and about 1,000 acre-feet of water was pumped from nine wells. The pumpage increased steadily from 1951 to 1964 (fig. 12), and in 1964, 27,500 acre-feet was pumped from 38 wells. This includes an estimated 2,000 acre-feet of water that was pumped from six wells in the Old River Bed. Before 1951, ground water used for irrigation was obtained from small-diameter flowing wells.

The irrigation wells range in depth from 200 to 1,000 feet and tap pre-Lake Bonneville unconsolidated alluvial-fan, river, and lake deposits (table 2). The aquifers are unconfined within 1–2 miles of the

TABLE 6.—*Withdrawal of ground water from wells, in acre-feet, 1960–64*

[Withdrawal in townships having less than 10 acre-feet not reported, but total of these is about 100 acre-feet a year]

Area or township		1960	1961	1962	1963	1964
T. (S.)	R. (W.)					
Old River Bed		1, 000	1, 200	1, 500	1, 500	3, 000
14	5	1, 000	950	1, 060	970	1, 000
15	4	5, 780	5, 590	4, 560	6, 300	6, 775
15	5	5, 020	5, 640	6, 250	8, 750	8, 330
15	6	20	20	10	10	10
15	7	1, 240	1, 180	1, 340	220	480
15	8	40	30	30	30	30
16	4	1, 060	920	500	970	650
16	5	520	2, 540	3, 320	3, 190	4, 410
16	6	130	120	100	100	100
16	7	1, 230	1, 370	2, 270	2, 000	1, 970
16	8	620	1, 060	1, 250	1, 190	910
17	6	590	400	530	820	1, 000
17	7	400	390	490	570	720
17	8	10	10	10	10	10
18	6	210	210	210	120	120
18	7	260	260	250	220	200
18	8	20	40	40	30	30
Totals (rounded)		19, 200	21, 900	24, 700	27, 000	29, 800

mountains between Leamington and Oak City; but westward, probably as far as Sevier Lake, the aquifer system is artesian.

Irrigation wells are equipped with turbine pumps driven by electric motors or diesel engines. Wells tapping the upper artesian aquifer yield from 1,000 to 2,000 gpm (gallons per minute) and average about 1,600 gpm. The approximate yields of irrigation wells in the aquifer beneath the Old River Bed, range from 500 to 1,200 gpm and average about 800 gpm.

DOMESTIC, STOCK, MUNICIPAL, AND INDUSTRIAL SUPPLY

Most residents of the rural areas and of some towns and villages including Hinckley, Deseret, Oasis, Abraham, Sutherland, and Sugarville rely on about 1,500 small-diameter wells to supply their domestic and stock water needs. Most of the wells are 2 inches or less in diameter, but a few are as large as 8 inches in diameter. Most of the wells used for domestic purposes also supply water for stock. Many domestic wells and some stock wells are equipped with pumps and pressure systems, but the stock wells generally are equipped with lift pumps driven by windmills or gasoline engines. Some farms still depend on the natural flow of artesian wells for their domestic and stock supplies, but since 1946 the number has been steadily decreasing. It is estimated that the total annual withdrawal of water since 1935 for domestic and stock supply is about 1,000 acre-feet.

Most domestic and stock wells tap water in unconsolidated basin fill of pre-Lake Bonneville age, and most of them are finished only in the upper artesian aquifer. Yields usually range from about ½ to 5 gpm.

The municipal water supplies for Delta and Lynndyl are obtained from pumped wells. Delta obtains water from two wells, and the estimated total annual use was 340 acre-feet in 1950 and in 1951, and 460 acre-feet in 1964. The town has two other wells not presently in use. The four wells range in depth from 638 to 865 feet, and all tap the lower artesian aquifer. Before the water system was installed in 1940, residents obtained supplies from more than 300 individually owned small-diameter wells that tapped the upper artesian aquifer. Lynndyl is supplied with water from a well owned by the Union Pacific Railroad Co. The well is 700 feet deep and is believed to tap both the lower and the upper artesian aquifers. The estimated annual pumpage is 50 acre-feet.

About 50 acre-feet of water was pumped from wells annually during 1961–64 for industrial supply. The major use is the processing of ore and washing of concrete aggregate. Small quantities of water are used in cheese manufacturing and processing of other farm produce. In the past, before 1950, when a sugar factory was operating in Delta and when steam locomotives were used by the Union Pacific Railroad Co., the industrial use probably was about 200–400 acre-feet a year.

The aggregate withdrawal of ground water for domestic, stock, municipal, and industrial uses during 1950–64 remained rather constant at about 1,500 acre-feet a year.

EVAPOTRANSPIRATION BY PHREATOPHYTES

An estimated 135,000–175,000 acre-feet of ground water is consumed by evapotranspiration each year in 440,000 acres of nonirrigated, low-lying lands in the Sevier Desert that mainly support phreatophytes. The rate of evapotranspiration is governed by many factors, such as: plant species and growth density, depth to the water table, soil type, water quality, air temperature and movement, and humidity. The plant species is determined, in part, by the depth to water because the root systems of some phreatophytes go as deep as 40 feet, whereas the root systems of others normally penetrate less than 1 foot. Under natural conditions a phreatophyte gets its water supply from the water table or the overlying capillary fringe, but it will grow and thrive if water is supplied artifically from the surface. For example, alfalfa is grown extensively by irrigation in the Sevier Desert without regard to the depth to the water table. Meinzer (1927) and Robinson (1958) gave a more complete discussion of phreatophytes than space allows here, and their works were used freely in preparing the following sections.

METHODS USED IN MAPPING

Most of the mapping of phreatophytes was done from aerial photographs, with some field checking. Several representative tracts of phreatophytes were visited in the field and compared with photographs of those tracts. The photographs were then used as base plots for comparing and delineating density, type, and extent of phreatophytic growth for the remaining tracts. A few tracts were revisited in the field after completion of the office mapping to compare and adjust the mapping to field conditions. Few corrections were needed, and those resulted in only small density adjustments.

Where available, the 7½- and 15-minute topographic quadrangle maps published by the U.S. Geological Survey were used as base maps on which to transcribe tract boundaries from the aerial photographs. Where topographic maps were not available, tract boundaries were transcribed onto the U.S. Geological Survey base used for plate 7.

Areal density

As used in this report areal density is a measure of the areal extent of the green transpiring foliage (leaves or fronds) in relation to the total area in which they grow. The concept of areal density as developed by Gatewood, Robinson, Colby, Hem, and Halpenny (1950, p. 25) can be illustrated by picturing a single plant in full leaf with the sun directly overhead. The area of shade cast on the ground by the plant would be equivalent to the areal extent of the plant. In a unit area of land, for example, 1 acre, where one species of phreatophyte is growing singly and in clusters, the areal density of that acre of land would be the ratio of area of shade to the total area.

Theoretically, in an area having a transpiring foliage growth of 100-percent areal density, the addition of a unit of transpiring foliage would choke out an existing unit of foliage. In the Sevier Desert, few stands of vegetation have an areal density of 100 percent. The areal density of phreatophytes in each tract was converted to an equivalent area of 100 percent density in order to be able to compare the amounts of vegetation in the different tracts of land and to determine the net area occupied by the plants in each tract. For example, a 12-acre tract having a 25 percent natural areal density of phreatophytes is regarded as equivalent to a 3-acre tract having a 100-percent areal density.

Vertical density

As used in this report vertical density is the ratio of the vertical depth of the green transpiring foliage (leaves or fronds) on a plant to the optimum depth for that particular species. A 100 percent vertical density of growth is one in which the addition of one unit of transpiring foliage at the top theoretically would choke out an equivalent unit of transpiring foliage beneath it. The vertical density was estimated for representative tracts of greasewood and saltcedar but not for the other phreatophytes, as it was assumed that their vertical density was about 100 percent.

Volume density

For any particular species, the product of the areal and vertical density is the volume density, and it is expressed as a percentage. In effect, volume density is the ratio of the volume of the green transpiring foliage of a particular species actually contained in an area to the maximum volume of green foliage that the area would contain if the areal and vertical densities each were 100 percent.

Volume density cannot be used directly to compare the volume of green foliage of one species with that of another, because a specific volume density of one species (for example, saltcedar), is not equivalent to the same volume density of a different species (for example, saltgrass). The difference in volume of green foliage at a given volume density is apparent from the fact that the optimum depth of green foliage of saltcedar at 100 percent vertical density is 13 feet, whereas the optimum depth of saltgrass is about 3 feet.

The total amount of water transpired by a tract of phreatophytes is proportional to the total amount of green foliage for a given depth to water. The net acreage of each species was computed at 100 percent volume density. For example, in a hypothetical 12-acre tract, the areal density was 25 percent and the vertical density was 75 percent; therefore, the volume density was 18.75 percent, equivalent to that on a 2¼-acre tract having a 100-percent volume density.

SPECIES

Greasewood (*Sarcobatus vermiculatus*), saltgrass (*Distichlis stricta*), pickleweed (*Allenrolfea occidentalis*), and saltcedar (*Tamarix gallica*) are the principal phreatophytes in the Sevier Desert, and the main areas occupied by these plants in 1963 are shown on plate 7. Saltgrass and pickleweed seldom occur as pure stands, generally they are associated with greasewood. For this reason the tracts containing all three species were mapped and treated as a unit.

Other water-loving plants observed in the basin but not mapped are wirerush (*Juncus balticus*), alkali bulrush (*Scirpus* sp.), giant bulrush (*Scirpus* sp.), cattails (*Typha* sp.), threadleaf sedge (*Carex* sp.), Nebraska sedge (*Carex nebraskensis*), willow (*Salix* sp.), rabbitbrush (*Chrysothamnus nauseosus*), and wild rose (*Rosa* sp.). They occupy relatively small tracts, generally growing where the soil and ground water are only slightly saline or alkaline, or where surface water of good quality supplements the ground-water supply. Other species of phreatophytes grow in mountainous areas, but they are not listed here because a study in those areas was beyond the scope of this investigation.

Greasewood

The most common phreatophyte growing in the Sevier Desert is greasewood (table 7 and pl. 7). It grows in combination with nearly all other phreatophytes where depth to the water table ranges from about 1 to 40 feet below the land surface. In areas where the water table is about 1–10 feet below the land surface, greasewood is associated commonly with pickleweed and saltgrass; in areas where the water table is about 10–25 feet below the land surface, it is associated rarely with rabbitbrush. For calculating transpiration losses, greasewood was assumed to be the only phreatophyte present in the areas where depth to the water table was 10–40 feet. It usually does not thrive where depth to water is less than 5 feet.

The average areal, vertical, and volume densities of greasewood were calculated for 10 random 1 square-mile sections of land. These sections were in the main part of the Sevier Desert and in the Old

TABLE 7.—*Areas occupied by phreatophytes and bare ground and evapotranspiration in a part of the Sevier Desert, 1963*

Phreatophyte species or surface condition	Area mapped (acres)	Area reduced to 100 percent volume density (acres)	Evaporation from class A land pan method (acre-feet)	Extrapolation from other area method (acre-feet)
Phreatophyte:				
Greasewood	311,000	31,000	124,000	80,000
Saltgrass, pickleweed, and greasewood	93,000	9,000	36,000	45,000
Saltcedar	4,000	[1] 800	[1] 3,600	3,600
Total (rounded)	408,000	--------	164,000	129,000
Greasewood (Old River Bed)	12,000	2,000	8,000	3,000
Total (rounded) all phreatophytes	420,000	--------	172,000	132,000
Bare ground (Sevier Lake playa)	21,000	--------	2,000	2,000
Total (rounded) in study area	-------	--------	174,000	134,000

[1] Includes only saltcedar in the Fool Creek Reservoir and immediate area.

River Bed. The average areal density was estimated to be 25 percent in the Sevier Desert and 30 percent in the Old River Bed. The vertical density was derived from two measurements: the maximum vertical depth of foliage in greasewood thickets approaching 100 percent areal density and the average height of the greasewood plants in each of the 10 sections. The estimates of the average vertical density were 40 percent for the Sevier Desert and 50 percent for the Old River Bed. Thus, the computations for the volume densities (the product of the areal and vertical densities) resulted in 10 percent for the Sevier Desert and 15 percent for the Old River Bed.

Saltcedar

In 1963, saltcedar was growing on 4,000 acres in and near the DMAD and Fool Creek Reservoirs (pl. 7) and on another 4,000 acres in other parts of the Sevier Desert. A few saltcedars grew around the Gunnison Bend Reservoir, using water from bank storage. The other areas infested with saltcedar were small and consisted of long, narrow thickets along canals, drainage ditches, and natural stream channels. They were not mapped nor were their areas used in calculations of evapotranspiration because the water consumption in 1963 was not significant.

Most of the saltcedar plants in the DMAD Reservoir in 1963 were seedlings which had sprouted since completion of the reservoir in 1961, and both areal and vertical densities were less than 25 percent. All water used by saltcedars in the DMAD Reservoir is from bank storage; none comes directly from ground-water sources. Saltcedar infestation in much of the Fool Creek Reservoir has reached about 40 percent areal density and 75 percent vertical density. Water used by phreatophytes in the area of the Fool Creek Reservoir is from bank storage, but probably much of it is water that eventually would have recharged the ground-water reservoir.

Unless controlled, saltcedar will overgrow much of the land occupied by phreatophyte grasses and spread into intermittently cultivated low-lying lands. By the time that saltcedar attains 75 percent areal density, it will crowd out nearly all the forage grasses, and will render most of the few remaining inaccessible to stock. Unless growth is checked, volume densities in many places will approach 100 percent within 5–10 years under favorable conditions.

Saltgrass

The extensive stands of saltgrass which grow in the low-lying lands of the Sevier Desert provide forage for beef cattle and thus are important. Saltgrass is hardy and thrives on all but the most saline water and soils of the area. Luxuriant stands are associated with sparse-to-moderate stands of saltcedar in the Fool Creek Reservoir and along stream channels. The height at 100 percent vertical density is about 3 feet. Saltgrass is associated mostly with greasewood and pickleweed and was mapped under the general grouping of saltgrass, pickleweed, and greasewood (table 7 and pl. 7). The most dense growths were observed in areas where the ground water was slightly saline and less than 2 feet below the land surface. A growth of small plants is associated with greasewood in some areas where the water table may exceed a depth of 10 feet. The amount of ground water consumed by the saltgrass in such areas probably is small, however, and saltgrass was not mapped where the depth to the water table exceeded about 10 feet.

Pickleweed

The presence of pickleweed in an area is an indication that ground water is at shallow depth. It grows throughout all the low-lying lands where the depth to water is less than 5 feet and in places where the depth is about 10 feet. Although it usually grows in association with saltgrass and greasewood, there are a few stands of pure pickleweed where the soil is too saline or too alkaline for other plants. In these places it has an areal density of about 25 percent. The vertical density was not estimated in detail, but most plants observed were about 1½–2 feet tall. On plate 7, all pickleweed is included under the general grouping of saltgrass, pickleweed, and greasewood.

BARE GROUND AND WATER SURFACES

The rate of evaporation from bare ground where the water table is close to the land surface (except in the Sevier Lake playa) and ponded water in the Sevier Desert is closely related to evapotranspiration in phreatophyte areas. Other than Clear and Mud Lakes, few small ponds in 1963 were sustained by direct ground-water inflow, and evaporation of ground water from ponded water was negligible. Some ground water evaporated from bare ground in the Mud Lake area, but the tracts were relatively small and irregular and were interspersed among much larger tracts of saltgrass, pickleweed, and greasewood. The tracts of bare ground have been included with the tracts of phreatophytes on plate 7.

QUANTITATIVE DETERMINATION OF EVAPOTRANSPIRATION

Annual evapotranspiration of ground water in the Sevier Desert was estimated by two methods: application of rates of water use from another area and evaporation from a class A land pan. The estimate by the first method was 125,000 acre-feet, and by the second about 170,000 acre-feet. The first method is believed to give the most accurate result because it uses data collected largely within or near the Sevier

Desert. To the above figures are added separate determinations made for the Sevier Lake playa, greasewood in the Old River Bed, and saltcedar.

Application of rates of water use from another area

During 1925–27, White (1932) investigated water use by phreatophytes in Escalante Valley, Utah. The evapotranspiration rates calculated for the Milford district were applied without change to the Sevier Desert because conditions and phreatophyte species, except for saltcedar, are similar in the Sevier Desert to those in the Escalante Valley. The lands in the Milford district were classified by White (1932, p. 86) as follows:

A, meadowlands and adjoining lowlands occupied by saltgrass associated with greasewood, rabbitbrush, and pickleweed, with saltgrass dominant (depth to ground water 0–5 feet); B, lowlands occupied chiefly by greasewood, rabbitbrush, and shadscale with scattering saltgrass, seep weed, and pickleweed (depth to ground water 0–8 feet); C, uplands occupied by greasewood, rabbitbrush and shadscale (depth to ground water 8–30 feet); D, lands irrigated or naturally subirrigated with ground water, chiefly fields of alfalfa.

The annual evapotranspiration from the three classes of lands were: class A, 1 acre-foot per acre; class B, 2½ acre-inches per acre; and class C, 2 acre-inches per acre.

It is estimated that the Sevier Desert contains 33,000 acres of saltgrass, pickleweed, and greasewood equivalent to White's class A; 31,000 acres of greasewood equivalent to class A; 60,000 acres of saltgrass, pickleweed, and greasewood equivalent to class B; and 280,000 acres of greasewood equivalent to class C. During 1963, evapotranspiration amounted to about 80,000 acre-feet for greasewood and 45,000 acre-feet for saltgrass, pickleweed, and greasewood. Evapotranspiration from saltcedar could not be estimated from White's data because no saltcedar grew in Escalante Valley at the time of his investigation.

Evaporation from a class A land pan

Evapotranspiration will range (depending on the species of phreatophyte) from slightly greater to slightly less than the rate of evaporation from a class A land pan in most phreatophyte areas where plant growth is at 100 percent volume density. It is assumed that with 100 percent volume density in the Sevier Desert, the rates of evapotranspiration of saltcedar would be equal to evaporation from a class A land pan and that the rates of evapotranspiration of other phreatophytes would be about 10 percent less.

Evaporation has not been measured in the Sevier Desert; however, Kohler, Nordenson, and Baker (1959, pl. 1) estimated that evaporation from a class A land pan in the basin usually would be more than

5 feet a year. Thus it is assumed that evapotranspiration by saltcedar would be about 5 feet a year and by all other phreatophytes about 4½ feet a year. An average of about 6 inches of precipitation would be available annually for plant use in the phreatophyte areas, and the remainder of the plant's needs would be derived from ground water. Therefore, the use of ground water by saltcedar at 100 percent volume density is 4½ feet a year and by the other phreatophytes 4 feet a year.

Evapotranspiration rates were assumed to be proportionate to the volume density in estimating the water actually consumed by phreatophytes. For example, if a 10-acre tract of saltcedar has a volume density of 20 percent, then evapotranspiration of ground water from that tract would be 4½ feet by 10 acres by 0.20=9 acre-feet. The 311, 000 acres of greasewood in the main part of the basin has an average volume density of 10 percent. Annual evapotranspiration, therefore, at the rate of 4 feet per acre, is 124,000 acre-feet. Estimated in like manner, annual use of ground water by saltgrass, pickleweed, and greasewood would be 36,000 acre-feet. Use by saltcedar in the Fool Creek Reservoir and immediate area would be 3,600 acre-feet, and use by greasewood in the Old River Bed would be 8,000 acre-feet. The evapotranspiration of ground water in all phreatophyte areas in the lowland part of the area in 1963, as determined by the above method, was about 170,000 acre-feet.

Evaporation from Sevier Lake playa

Evaporation of water leaking from the artesian aquifers underlying the Sevier Lake playa was computed using experimental data compiled by Feth and Brown (1962). In their studies on a mudflat along the east shore of Great Salt Lake, they found that the rate of upward movement of ground water was 0.10 acre-foot per acre per year. These rates were applied to the Sevier Lake playa because the conditions there were comparable to the conditions at the experimental plots near Great Salt Lake. At both places, the sediments are principally clay and silty clay and were deposited under similar conditions; both have underlying artesian aquifers, a crust of salt, saline shallow ground water, and similar climatic conditions. The rate of evaporation of ground water from 21,000 acres of Sevier Lake playa north of the 39th parallel of latitude was calculated to be about 2,000 acre-feet a year.

ABILITY OF AQUIFERS TO YIELD WATER

The quantity of water that an aquifer will yield to a well and the ability of the aquifer to transmit water depend on the physical and hydraulic properties of the materials that constitute the aquifer. Knowledge of these properties enables prediction of hydraulic behavior of the aquifer under a given set of conditions. The terms used to denote the principal hydraulic properties are expressed mathematically as the coefficients of permeability, transmissibility, and storage and as the specific yield. Detailed geologic descriptions of materials discovered in drilling enable one to calculate the hydraulic properties and thickness of aquifers, but more accurate quantitative estimates require more comprehensive laboratory or field tests.

The coefficient of permeability used in this report is the field coefficient of permeability (P_f) and is defined as the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot of an aquifer under a hydraulic gradient of 100 percent at the prevailing water temperature. The coefficient of transmissibility (T) may be expressed as the number of gallons of water transmitted per day, at the prevailing temperature, through a section of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile. It is the average field coefficient of permeability multiplied by the thickness of the aquifer, in feet.

The amount of water released from or taken into storage in a saturated material depends upon the coefficient of storage of that material. The coefficient of storage (S) of an aquifer is the volume of water yielded or taken into storage per unit surface area of the aquifer per unit change in component of head normal to that surface. For artesian conditions, the coefficient of storage represents compaction of the aquifer skeleton and expansion of the water as the head declines; thus, it is small, generally being in the range of 10^{-3} to 10^{-4}. The coefficient of storage under water-table conditions is much larger, generally being in the range of 0.01 to 0.3. Under water-table conditions, it comprises the water that drains by gravity out of the material as the water table declines and the small quantity released by compaction of the aquifer and expansion of the water.

The quantity of water that drains by gravity is called the specific yield, which is defined as the ratio of the volume of water that a saturated material will yield by gravity to the volume of the aquifer dewatered. The specific yield is generally several thousands of times larger than the small quantity released by compaction of the aquifer and expansion of the water; thus, for practical purposes, the specific yield can be considered equal to the coefficient of storage.

Not all the water in the interstices of an aquifer is drained by gravity; some is retained by capillary action. The ratio of the retained capillary water to the specific yield is related to the size and sorting of the aquifer materials. In general, the finer and the better sorted the material particles are, the smaller is the ratio of specific yield to the water held by capillary action. For example, a saturated clay contains more than 50 percent water by volume, but the amount of water that it will release by gravity is generally less than 0.1 percent. At the other extreme, a well-sorted gravel contains water equal to 25–35 percent of its volume; although the water released by gravity will depend on the sorting and arrangement of the grains, such a gravel commonly has a specific yield of 20–30 percent.

AQUIFER TESTS TO DETERMINE HYDRAULIC COEFFICIENTS

The most dependable hydraulic coefficients of the aquifers in the Sevier Desert were determined by 13 aquifer tests. The coefficient of transmissibility at 25 additional sites was estimated from the specific capacities of irrigation and public supply wells.

Data from the aquifer tests were analyzed by means of the nonequilibrium formula (Theis, 1935), the generalized graphical method (Cooper and Jacob, 1946), the recovery method (Theis, 1935), and the leaky aquifer formula (Hantush and Jacob, 1955). The coefficient of transmissibility at some wells was determined by using specific capacity after a method described by Theis, Brown, and Meyer (1963). Methods for analyzing aquifer tests are described by Ferris, Knowles, Brown, and Stallman (1962).

The hydraulic coefficients determined by aquifer tests are given in table 8. During an aquifer test, a well was pumped at a measured constant rate for periods ranging from ¼ to 27 days, and periodic water-level measurements were made in 1–20 observation wells at distances from the pumped well ranging from less than 1/10 to about 9 miles. The area included in most of the tests was relatively small and the results indicate local conditions in the aquifer. Because of differences

TABLE 8.—*Hydraulic coefficients of artesian aquifers in the Sevier Desert*

Pumped well		Aquifer tested	Coefficient of transmissibility (T) (gpd per foot)	Coefficient of storage (S)
(C-15-5)	2ddc-1	Upper	350, 000	3.8×10^{-4}
	26baa-1	Lower	150, 000	2.6×10^{-4}
	33dcb-1	do	150, 000	2.6×10^{-4}
(C-16-5)	18caa-1	do	200, 000	1.0×10^{-3}
	19caa-1	do	150, 000	1.3×10^{-3}
(C-16-7)	10bad-1	do	70, 000	1.1×10^{-3}
	12baa-1	Upper	35, 000	
(C-16-8)	21bbb-1 [1]	Upper and lower	53, 700 (21bbb-1, 21bcb-1, 21cbb-1)	9.73×10^{-3} (21bbb-1, 21bcb-1, 21cbb-1)
	21bcb-1	do		
	21cbb-1	do		
(C-17-6)	6cbd-1	Lower	50, 000	1.0×10^{-4}
	17aaa-1	do	30, 000	
	28acb-1	do	15, 000	

[1] Test reported by Nelson and Thomas (1953).

in composition and thickness of the aquifer from place to place, the hydraulic coefficients given in table 8 should be applied only in the immediate area of the well tested. Although useful as guides to estimate the effects of pumping, the coefficients should not be applied broadly to large areas.

The coefficient of transmissibility of the lower artesian aquifer at points tested ranged from 15,000 to 200,000 gpd per foot, and of the upper artesian aquifer from 25,000 to 350,000 gpd per foot. The coefficient of transmissibility of each aquifer diminishes downstream from the mouth of Leamington Canyon and with increasing distance from the Sevier River (fig. 12) because the aquifer materials become finer grained. Lines of equal *T* shown in figure 12 were extrapolated by comparing logs of tested wells with logs of untested wells and by assuming that change in *T* is uniform between wells tested.

The coefficient of storage of the lower artesian aquifer ranged from 1×10^{-4} to 1×10^{-3} at points tested and the range for the upper artesian aquifer was 2.7×10^{-4} to 5×10^{-4}.

PERFORMANCE OF WELLS

Properly constructed wells produce water in amounts near the capacity of aquifers to transmit and yield water, but improperly constructed wells produce less than the capacity of the aquifer. The specific capacity of a well, as used in this report, is the quantity of water yielded by the well, in gallons per minute per foot of drawdown after pumping for 24 hours. The specific capacity of a well represents the combined effects of aquifer and well characteristics; therefore, poor-performing wells do not necessarily indicate low-yielding aquifers. Well characteristics that affect the specific capacity of a well are: the depth of penetration of the well into the aquifer; the diameter of the well; the extent, type, and location of the perforations or screen; and the development of the well. Well development increases specific capacity by removing some of the fine-grained material from an aquifer and forming a more permeable pack of coarse-grained material around the casing.

Figure 13 shows the relation of specific capacity to coefficient of transmissibility determined at the well site for each of nine 16-inch diameter wells in the Sevier Desert. The theoretical specific capacity of a well is calculated with the assumption that the well is 100 percent efficient; that is, when the well is pumped, the water inside and immediately outside the casing is at the same level. Because wells are not 100 percent efficient, the actual specific capacity is less than the theoretical. A cursory study of figure 13 reveals a rather wide range be-

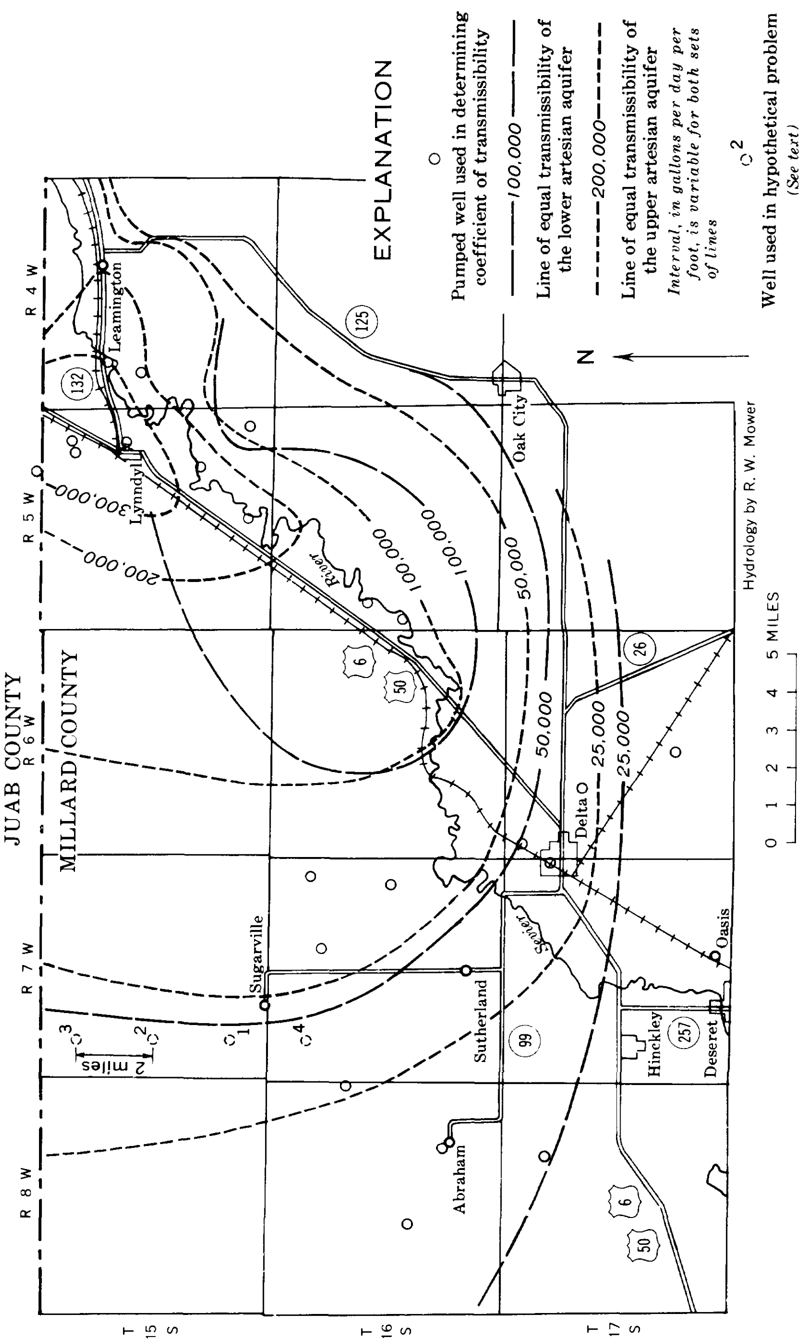


Figure 12.—Transmissibility of the lower and upper artesian aquifers in the Deseret-Leamington area.

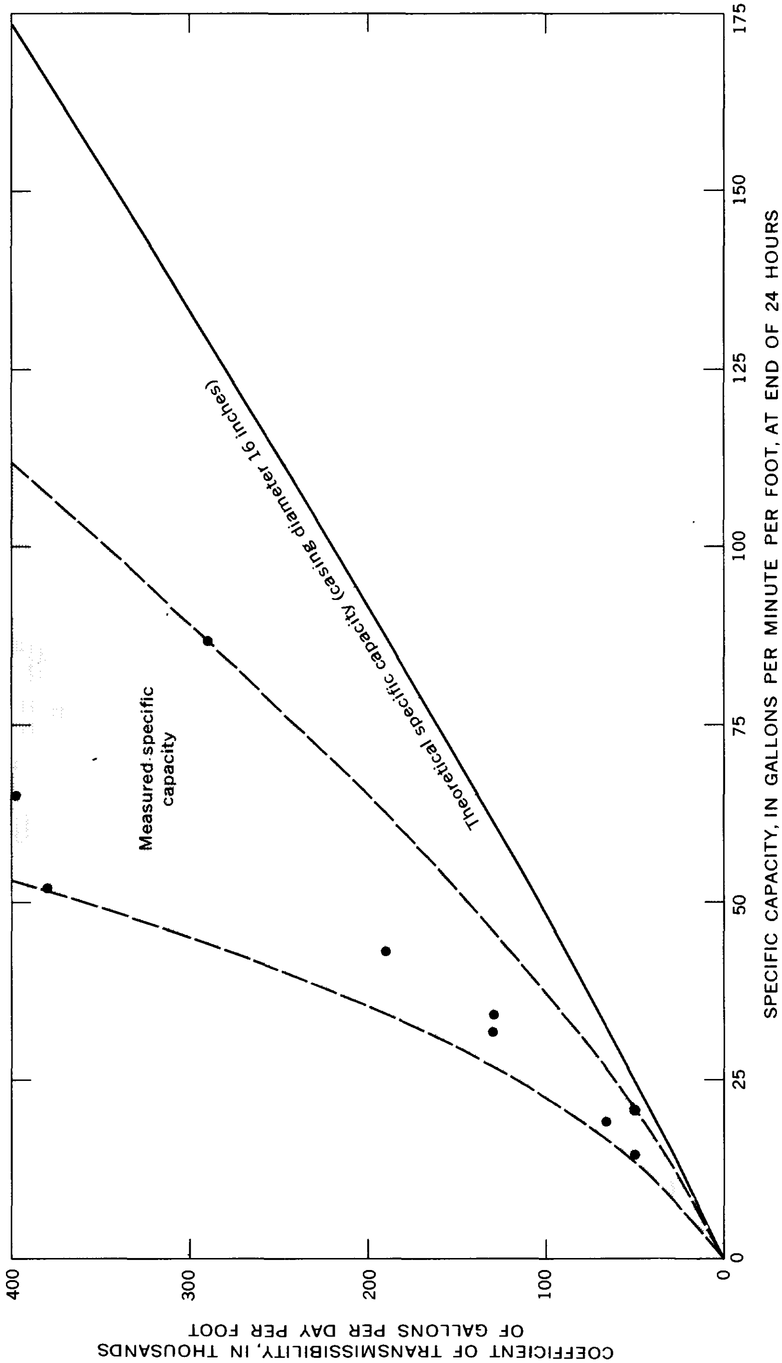


FIGURE 13.—Relation of specific capacity and coefficient of transmissibility.

tween actual and theoretical specific capacity at any given value of transmissibility; perhaps some wells are not as efficient as they might be.

For a given transmissibility, the efficiency of a well approaches 100 percent as the specific capacity approaches the theoretical specific capacity curve. If the specific capacity of a well plots in the left half of the shaded area in figure 13, it may be desirable to investigate means of improving the well efficiency. An error will be introduced if the specific capacity is computed for a period of pumping other than 24 hours. The amount of error is small for high values of transmissibility but increases substantially for low values of transmissibility.

The specific capacities of wells used for irrigation and public supply in the Sevier Desert range from 5 to 215 gpm per foot of drawdown. In general, the newer wells have higher rates of discharge and higher specific capacities than the older wells of the same diameter. This is probably due to better well construction and better development of the newer wells and to encrustation of casing perforations and to partial filling of the casing in the older wells. Wells in the Lynndyl-Leamington area and in the Old River Bed generally have higher specific capacities than those in the Delta area, probably because of coarse-grained aquifer materials near the edge of the basin.

INTERFERENCE BETWEEN WELLS

When an artesian well flows or is pumped, the reduction of the pressure head in the aquifer around the well causes a lowering of the piezometric surface around the well. The area of lowered water surface is called the cone of depression or cone of influence of the well. The amount of lowering decreases with increasing distance from the discharging well and increases with time. The cone of depression around a discharging well sometimes overlaps the cones of other flowing or pumping wells, a situation which results in additional water-level decline at each well. This is called interference between wells. The additional decline results in less discharge from flowing wells and greater pumping lifts or power costs at pumping wells.

Theoretical graphs were constructed for estimating interference between wells and water-level declines due to pumping from the upper and lower artesian aquifers (figs. 14, 15). The graphs in figure 14 apply to the upper artesian aquifer in the Lynndyl area, whereas the graphs in figure 15 apply to both aquifers elsewhere in the Sevier Desert. The graphs were prepared by computing water-level declines for five combinations of T and S for distances of 0.1–100 miles from a hypothetical well pumping 1,000 gpm for periods of 1, 180, and 3,650 days. Average aquifer coefficients from table 8 and figure 12 were used in preparing

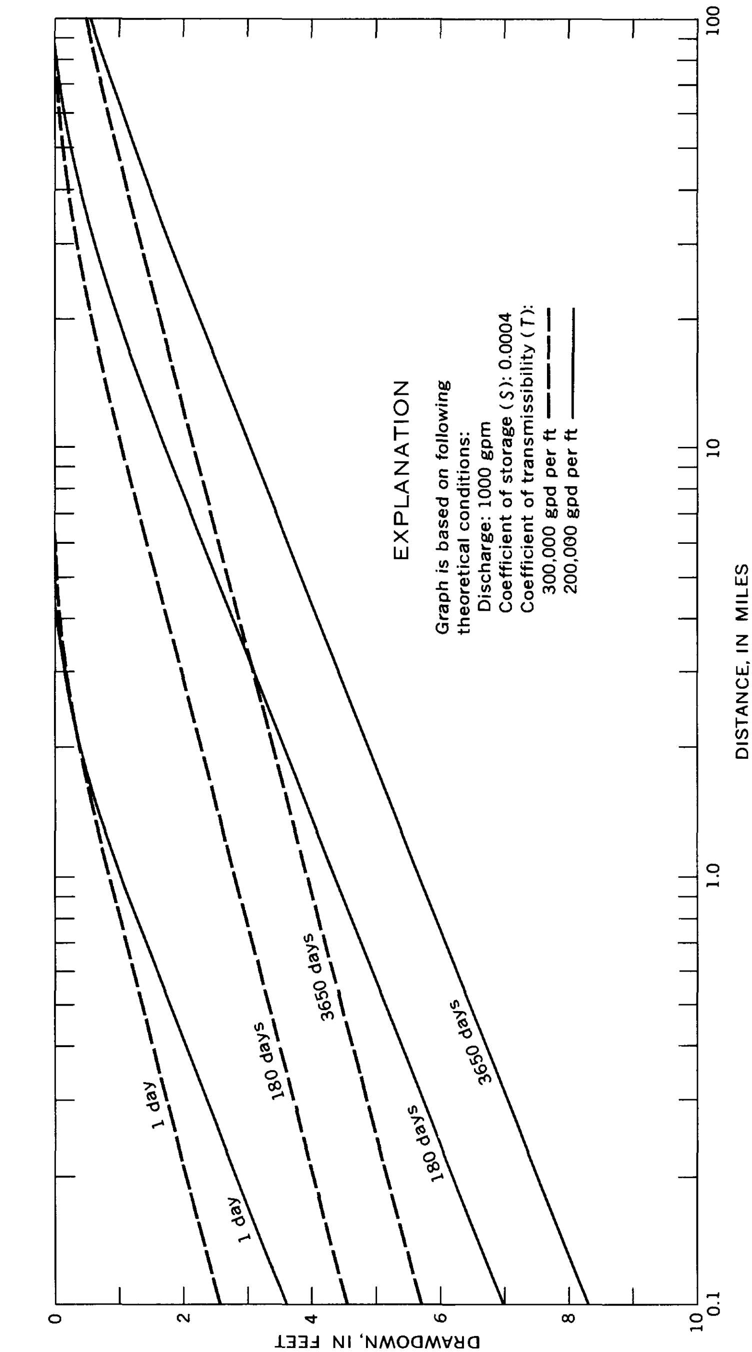


FIGURE 14.—Theoretical time- and distance-drawdown graph for the upper artesian aquifer in the Lynndyl area.

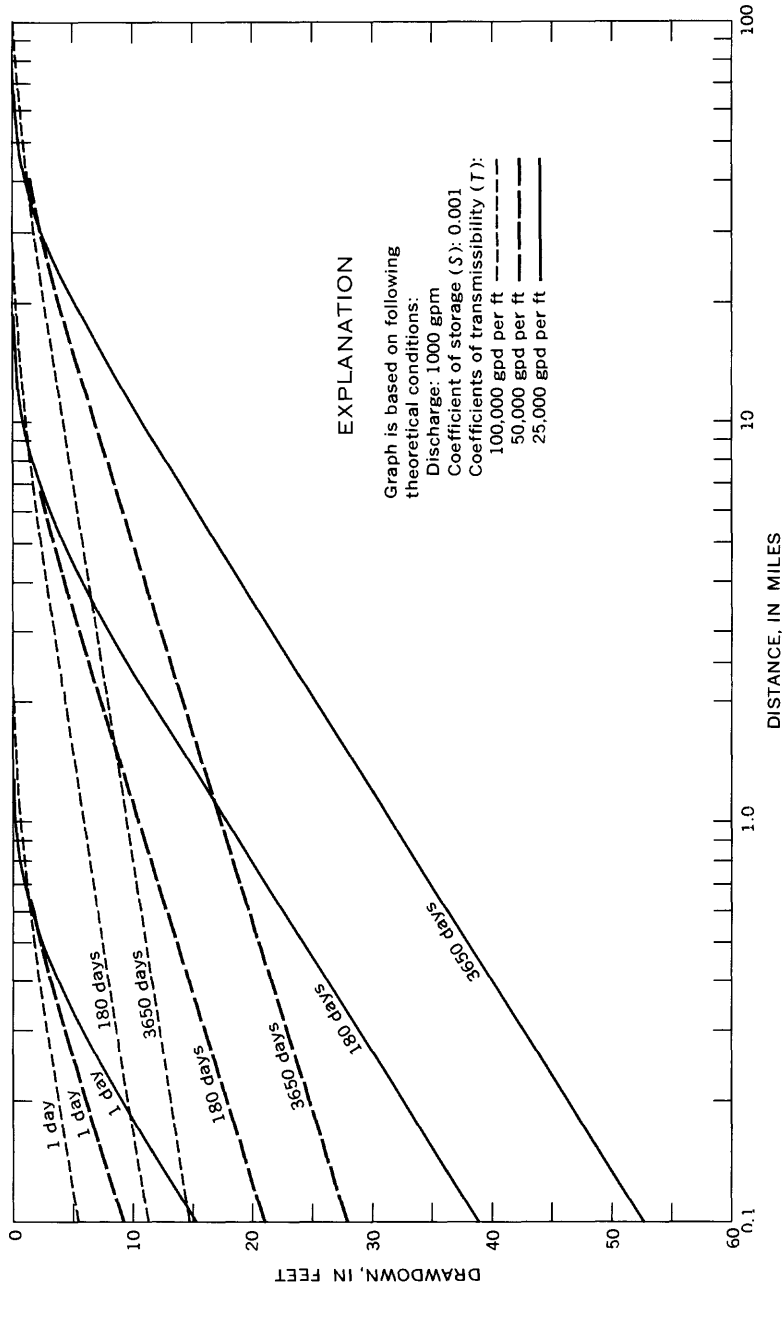


FIGURE 15.—Theoretical time- and distance-drawdown graph for the upper or lower artesian aquifers.

the graphs. When using figure 12, T was assumed to be the average for the zone whose sides lie midway between the next higher and the next lower contours; however, the maximum T used was 300,000 gpd per foot and the minimum T was 25,000. The accuracy of estimated drawdowns determined by using the interference graphs diminishes with distance and time; therefore, drawdown at distances greater than 10 miles or times longer than 180 days should be used only for approximation.

As an illustrative hypothetical interference problem in the Sevier Desert, let it be assumed that three wells will be pumped simultaneously for 180 days a year at 1,000 gpm each. (See table 9 for summary data of the hypothetical problem and figure 12 for the hypothetical well locations.) Wells 1 and 2 will be pumped continuously and well 3 will be pumped 16 hours a day. The three wells lie along a straight line at 2-mile intervals. It is desired to estimate the water-level decline at a fourth well, which is 2 miles south of well 1, at the end of an irrigation season (180 days) and after 10 years (3,650 days). For purposes of illustration it will be assumed that T is 50,000 and S is 0.001, and it is further assumed that intermittent pumping during a given period may be spread over the entire period at a proportionately lower rate. The average pumping rate during an irrigation season for well 3, therefore, is 16/24 of 1,000 gpm or 667 gpm. The average pumping rate during a year for wells 1 and 2 is (180 days/365 days) × 1,000 gpm or 493 gpm each, and for well 3 it is (180 days/365 days) × 667 gpm or 329 gpm.

TABLE 9.—*Approximate water-level declines for hypothetical problem, per foot*

[T=50,000 gpd, per foot S=0.001]

Interfering well	Average pumping rate, in gpm		Distance from interfering well to well 4, in miles	Water-level decline, in feet	
	Irrigation season (180 days)	10-year period (3,650 days)		At end of first irrigation season	At beginning of 11th irrigation season
Well 1	1, 000	493	2	7. 3	7. 0
Well 2	1, 000	493	4	4. 3	5. 5
Well 3	667	329	6	1. 8	3. 0
Total decline, in feet				13. 4	15. 5

The effect on the water level at well 4, caused by pumping at wells 1, 2, and 3, is analyzed separately; the total decline (interference) is the sum of the effects of all three wells on well 4. The effect of well 1, at the end of an irrigation season, is determined thus: On figure 15 locate the intersection of the curve designated 180 days and the vertical line at a distance of 2 miles, then move horizontally to the left edge and read 7.3 feet. Effects of wells 2 and 3 are determined in like manner except that the effect of well 3 is 667/1,000 of that read from the graph because its effective pumping rate is 667 gpm. The approximate effect after 10 irrigation seasons and at the end of the recovery period following the 10th irrigation season (beginning of 11th season) is estimated using the curve designated 3,650 days, the appropriate distances, and pumping rates.

The actual drawdown effects as measured in the field will not be as large as the theoretical effect because the cone of depression will intercept water that is discharging naturally; the theoretical effect will be reduced in a proportion related to the quantity of intercepted water. Most of the intercepted water is water being evaporated or being consumed by phreatophytes. As the cones of depression of the wells reaches ever farther into areas of phreatophytes, this cone will intercept an increasing amount of water being consumed by phreatophytes. This, in turn, lessens evapotranspiration and the rate of water-level decline.

SUMMARY

The Sevier Desert is a hydrologic unit that has water entering from all sides, and this water moves in the general direction of Sevier Lake. In this unit, fluviatile deposits of the Sevier River are interbedded with alluvial-fan, lacustrine, and eolian deposits; the result is a multiaquifer system. The aquifer system in much of the basin exceeds 1,000 feet in thickness and comprises a lower artesian aquifer, an upper artesian aquifer, and a water-table aquifer. The beds of coarser material in each artesian aquifer are interconnected laterally, but locally they are separated vertically by fine-grained beds. The latter impede but do not stop completely the vertical movement of water.

Recharge to the aquifers is from (1) direct penetration of precipitation on coarse unconsolidated sediments that are mainly along the north and east edges of the basin, (2) seepage from streams, canals, and irrigated fields, (3) movement from consolidated rocks, and (4) underflow from other basins. The main area of recharge is along the front of the Canyon Mountains where streams flow on permeable coarse-grained basin fill.

The ground water in most of the inhabitated areas of the Sevier Desert is of such chemical quality as to be suitable for domestic and stock use. Dissolved solids are high in the southern and southwestern parts of the inhabitated area, and hydrogen sulfide occurs in the water of some wells. A relatively high content of dissolved solids in the Leamington and Lynndyl area has resulted from percolation of water from the irrigation system and from the Sevier River. The nitrate concentration in water from two wells near Oak City exceeds the standards recommended by the Public Health Service. A high sodium-adsorption ratio of some of the ground water in the southwestern third of the area may render it of doubtful to unsuitable quality for irrigation.

Dissolved chemical constituents in the ground water range from 195 to 6,360 parts per million, and they generally increase with increasing distances westward from mountains along the east side of the basin. In the recharge areas, however, seepage from irrigated fields and leakage of slightly saline water from the Sevier River and canals has caused an increase in dissolved solids. Dissolved solids also increase vertically in the basin fill, both downward and upward from the lower artesian aquifer.

The principal area of ground-water development in the Sevier Desert, and also the area that still has the greatest potential for additional development, is in the central part of the basin from the Leamington–Oak City area to the vicinity of Delta. There ground-water withdrawal by wells increased from 2,000 acre-feet in 1950 to 30,000 acre-feet in 1964. The discharge from flowing wells in 1964 was 1,500 acre-feet. As a result, during the period 1950–64 the water levels in observation wells declined from 4 feet in areas of small withdrawals to more than 7 feet near centers of pumping for public supplies and irrigation. The decline in water levels caused a reduction in the area of flowing wells from about 425 to 225 square miles between the years 1935 and 1964 and a decline in head in all the artesian wells. The decrease in area of flow is the result of both the increase in withdrawals from wells and the below-normal precipitation. The quantity of ground water being wasted from flowing wells is not more than a few hundred acre-feet a year. The amount of waste diminishes as water levels decline and as the area of flowing wells grows smaller.

The amount of water that could be obtained from storage if the piezometric surface in the artesian aquifers were lowered 20 feet, is estimated to be 120,000 acre-feet.

The specific capacities of wells used for irrigation and public supply range from 5 to 215 gallons per minute per foot of drawdown. Specific capacities generally decrease with increasing distances away from the edges of the basin because deposits become finer and recharge less.

Annual discharge by evapotranspiration from 440,000 acres of native lowland range pastures in the Sevier Desert is about 135,000 acre-feet and has decreased little since 1950. The amount of evapotranspiration will diminish as the area of water-level decline expands to include larger areas of phreatophytes. Evapotranspiration will be infinitesimal when the artesian head is more than about 40 feet below the land surface. Consumptive waste of ground water by vegetation of little or no value (principally saltcedar and pickleweed) is not great, but it will increase substantially if saltcedar is permitted to spread into native meadow pastures, along canal and drain banks, and into surface reservoirs. Saltcedar plants are sufficiently widespread now so that within a few years much of the noncultivated lowland area could become seriously infested.

REFERENCES

Callaghan, Eugene, and Thomas, H. E., 1939, Manganese in a thermal spring in west-central Utah: Econ. Geology, v. 34, no. 8, p. 905–920.

Cooper, H. H., Jr., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, p. 526–534.

Crittenden, M. D., Jr., 1963, New data on the isostatic deformation of Lake Bonneville: U.S. Geol. Survey Prof. Paper 454–E, p. E1–E31.

Eardley, A. J., Gvosdetsky, Vasyl, and Marsell, R. E., 1957, Hydrology of Lake Bonneville and sediments and soils of its basin: Geol. Soc. America Bull., v. 68, p. 1141–1202.

Eaton, R. M., 1950, Significance of carbonates in irrigation waters: Soil Sci., v. 69, p. 123–133.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 510 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536–E, p. 69–174.

Feth, J. H., and Brown, R. J., 1962, Method for measuring upward leakage from artesian aquifers using rate of salt-crust accumulation *in* Geological Survey research, 1962: U.S. Geol. Survey Prof. Paper 450–B, p. B100–B101.

Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, J. D., and Halpenny, L. C., 1950, Use of water by bottom-land vegetation in lower Safford Valley, Arizona: U.S. Geol. Survey Water-Supply Paper 1103, 210 p.

Gilbert, G. K., 1890, Lake Bonneville: U.S. Geol. Survey Mon. 1, 438 p.

Hantush, M. S., and Jacob, C. E., 1955, Non-steady radial flow in an infinite leaky aquifer: Am. Geophys. Union Trans., v. 36, no. 1, p. 95–100.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Heylmun, E. B., 1965, Reconnaissance of the Tertiary sedimentary rocks in western Utah: Utah Geol. and Mineralog. Survey Bull. 75, 38 p.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps for the United States: U.S. Weather Bur., Tech. Paper 37, 13 p.

Lee, W. T., 1908, Water resources of Beaver Valley, Utah: U.S. Geol. Survey Water-Supply Paper 217, 57 p.

Love, S. K., 1966, Quality of surface waters for irrigation, Western States, 1962: U.S. Geol. Survey Water-Supply Paper 1946, 143 p.

Meinzer, O. E., 1911, Ground water in Juab, Millard, and Iron counties, Utah: U.S. Geol. Survey Water-Supply Paper 277, 162 p.

——— 1923, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

——— 1927, Plants as indicators of ground water: U.S. Geol. Survey Water-Supply Paper 577, 95 p.

Morris, H. T., and Lovering, T. S., 1961, Stratigraphy of the East Tintic Mountains, Utah: U.S. Geol. Survey Prof. Paper 361, 145 p. [1962].

Mower, R. W., 1961, Relation of the deep and shallow artesian aquifers near Lynndyl, Utah, *in* Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424–C, p. C94–C97.

——— 1963, Effects on the shallow artesian aquifer of withdrawing water from the deep artesian aquifer near Sugarville, Millard County, Utah: U.S. Geol. Survey open-file report, 9 p.

——— 1965, Ground-water resources of Pavant Valley, Utah: U.S. Geol. Survey Water-Supply Paper 1794, 78 p.

Mower, R. W., and Feltis, R. D., 1964, Ground-water data, Sevier Desert, Millard County, Utah: U.S. Geol. Survey open-file report, 34 p. [Duplicated as Utah Basic-Data Rept. 9.]

Nelson, W. B., 1952, Status of development of selected ground-water basins in Utah, Sevier Desert, Millard County: Utah State Engineer Tech. Pub. 7, p. 63–66.

Nelson, W. B., and Thomas, H. E., 1953, Pumping from wells on the floor of the Sevier Desert, Utah: Am. Geophys. Union Trans. v. 34, no. 1, p. 74–84.

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

Snyder, C. T., 1963, Hydrology of stock-water development on the public domain of western Utah: U.S. Geol. Survey Water-Supply Paper 1475–N, p. 487–536.

Stokes, W. L., [ed.,] 1964, Geologic map of Utah: Salt Lake City, Utah Univ.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., 16th Ann. Mtg., pt. 2, p. 519–524.

Theis, C. V., Brown, R. H., and Meyer, R. R., 1963, Estimating the transmissibility of aquifers from the specific capacity of wells *in* Methods of determining permeability, transmissibility, and drawdown: U.S. Geol. Survey Water-Supply Paper 1536–I, p. 331–340.

U.S. Geological Survey, 1960 and 1963, Compilation of records of surface waters of the United States through September 1950 and through September 1960; pt. 10, The Great Basin: U.S. Geol. Survey Water-Supply Papers 1314 and 1734, 485 and 318 p.

——— 1961, 1962, 1963, and 1964, Surface-water records of Utah: Water Resources Div.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 160 p.

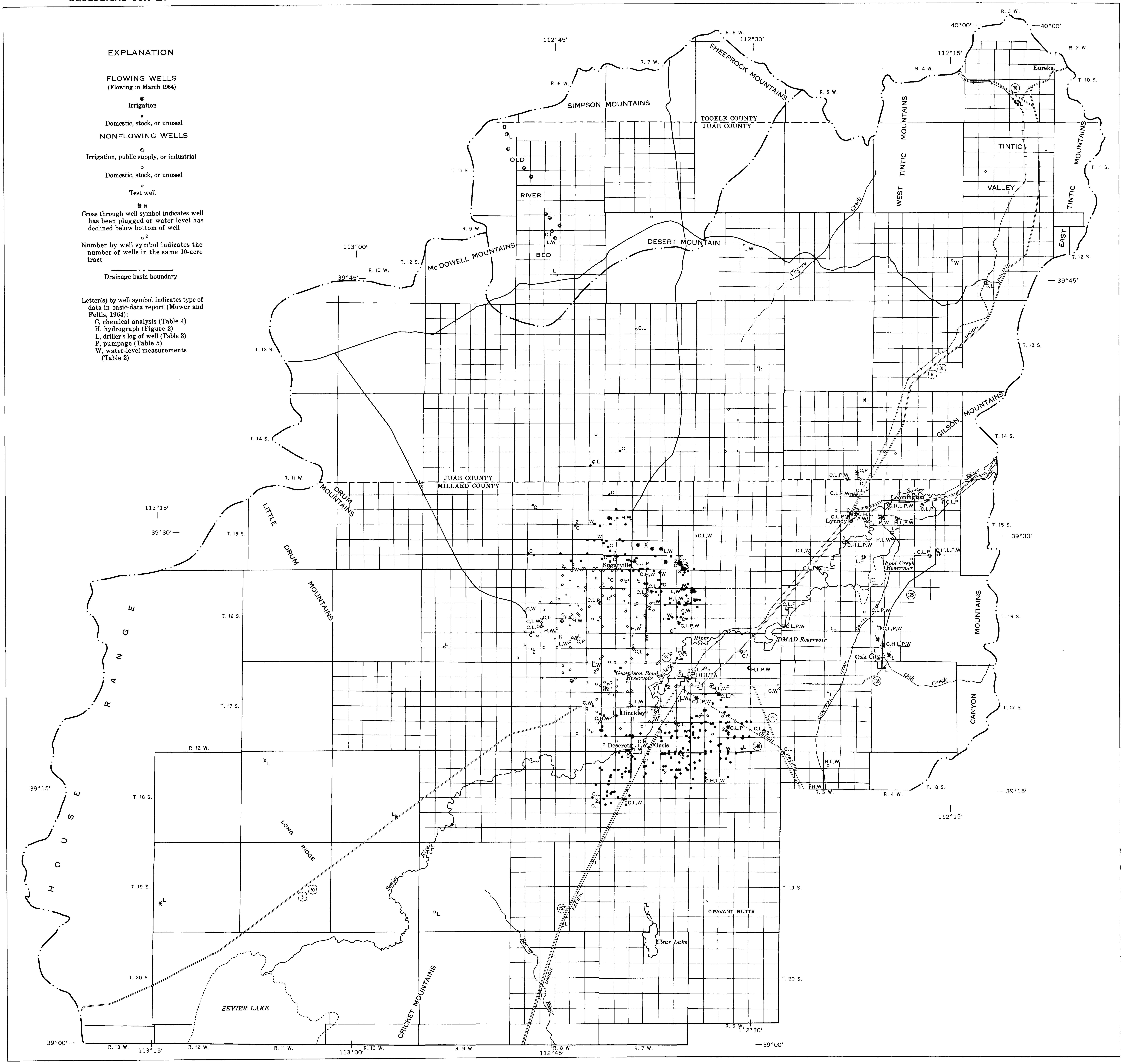
Varnes, D. J., and Van Horn, Richard, 1961, A reinterpretation of two of G. K. Gilbert's Lake Bonneville sections, Utah, *in* Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424–C. p. C98–C99.

Varnes, D. J., Van Horn, Richard, and others, 1951, Surficial geology of the Oak City area, Millard County, Utah: U.S. Geol. Survey open-file report, 2 p.

White, W. N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil—results of investigations in Escalante Valley, Utah: U.S. Geol. Survey-Water-Supply Paper 659–A, p. 1–105.

INDEX

[Italic page numbers indicate major references]



Base from the State of Utah general highway maps

Hydrology by R. W. Mower and R. D. Feltis

MAP OF THE SEVIER DESERT, UTAH, SHOWING LOCATION OF SELECTED WELLS AND HYDROGEOCHEMICAL DATA

5 0 5 10 15 20 MILES

5 0 5 10 15 20 KILOMETERS

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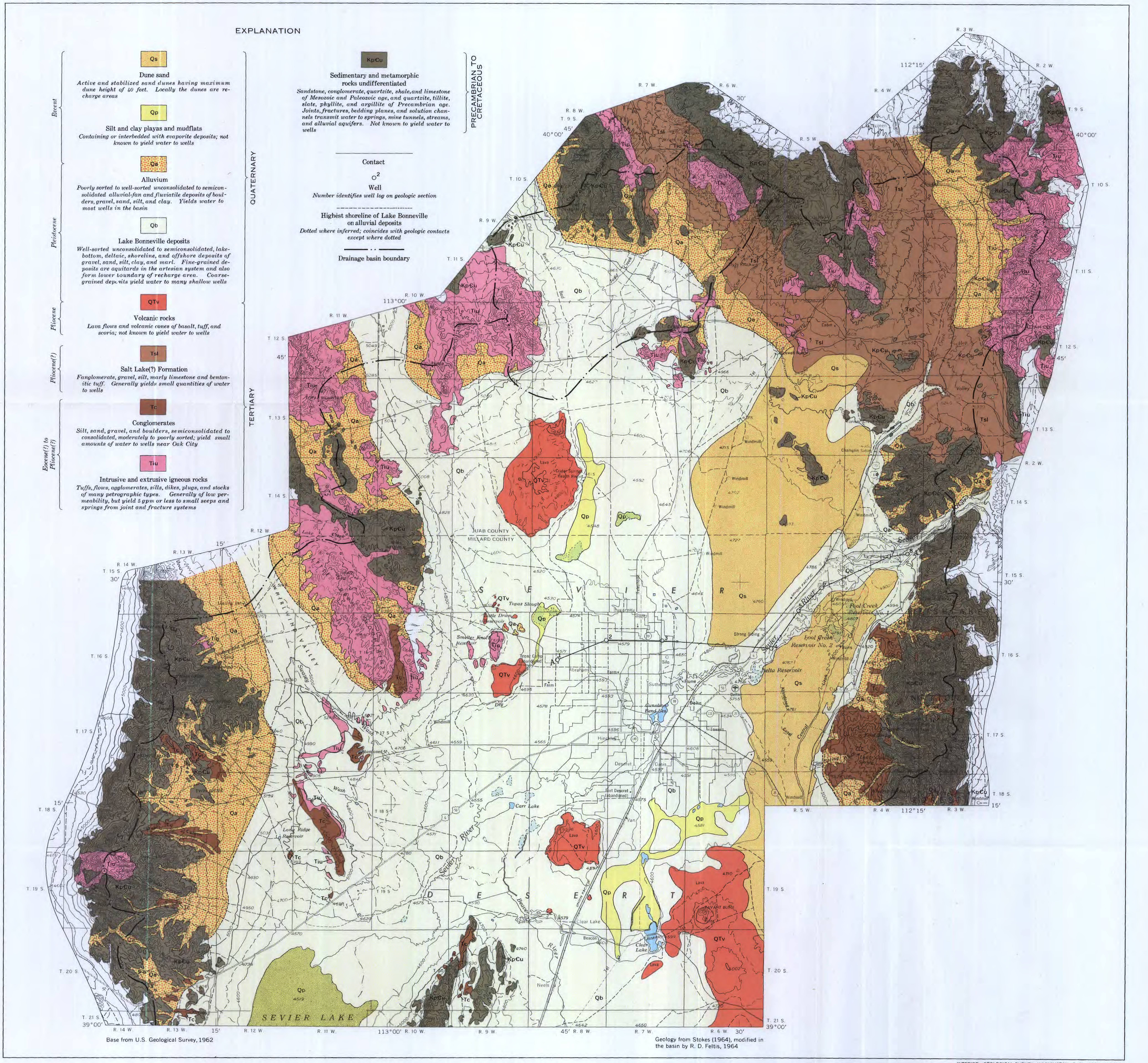
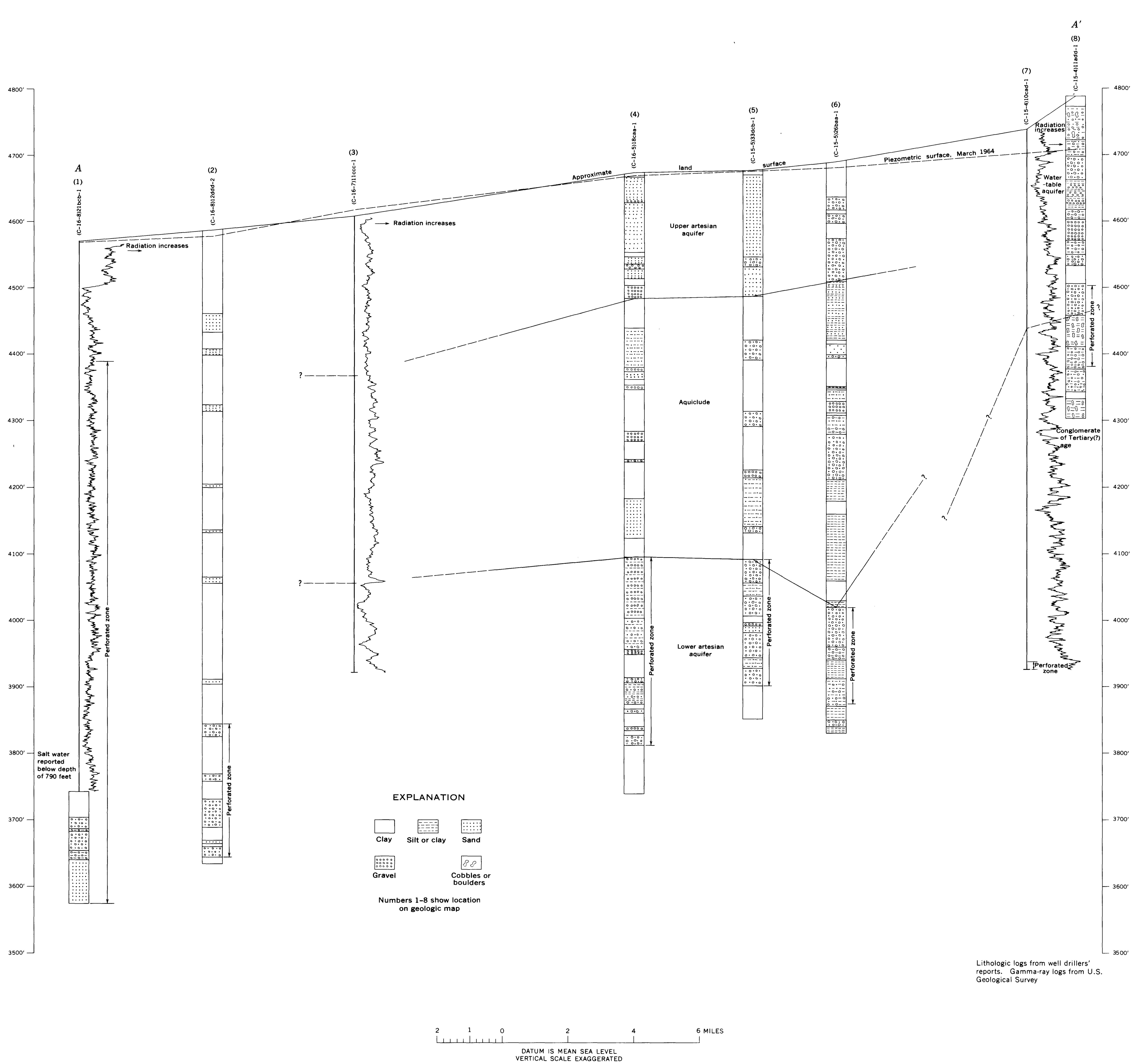


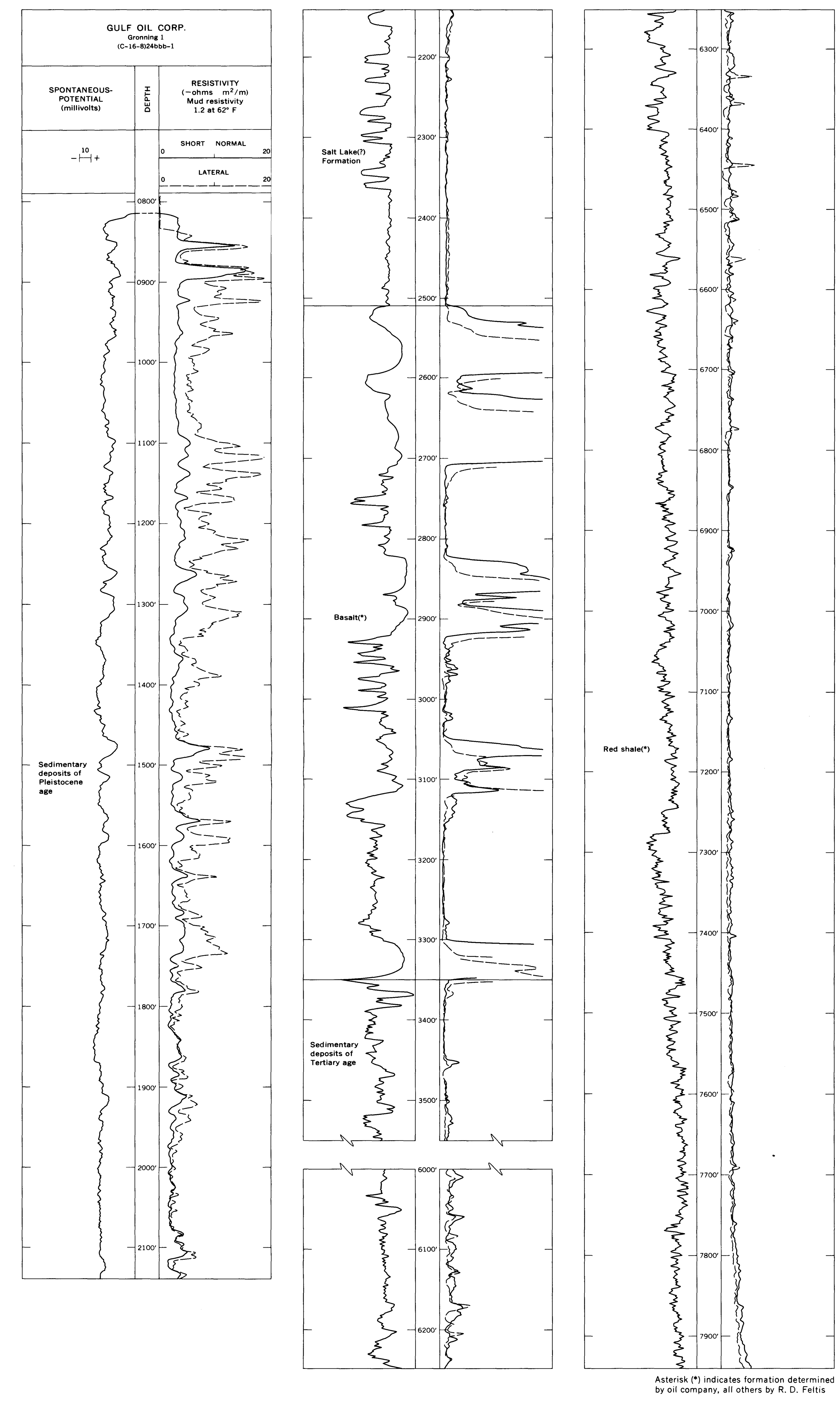
GENERALIZED GEOLOGIC MAP OF THE SEVIER DESERT AND ADJACENT MOUNTAINS, UTAH

SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
SUPPLEMENTAL CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

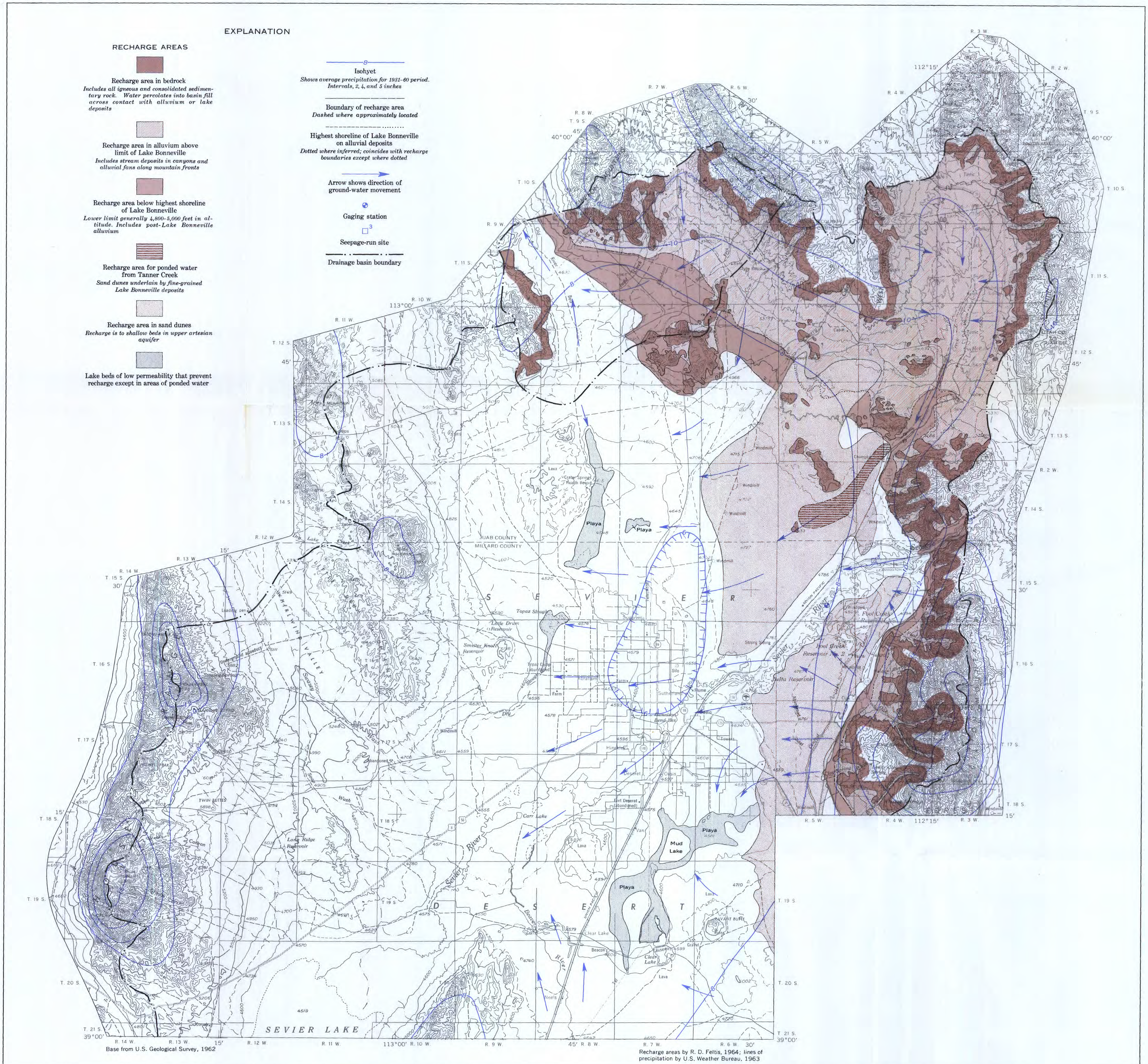
INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67143





GEOLOGIC SECTION ACROSS THE SEVIER DESERT, UTAH, SHOWING GENERALIZED STRATIGRAPHY AND LITHOLOGY AND SELECTED PARTS OF AN ELECTRICAL LOG FROM AN OIL TEST

265-002 O - 68 (In pocket)



MAP OF THE SEVIER DESERT, UTAH, SHOWING AVERAGE ANNUAL PRECIPITATION (1931–60) AND RECHARGE AREAS ALONG THE NORTH AND EAST EDGES

SCALE 1:250 000

5 0 5 10 15 MILES

5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
SUPPLEMENTAL CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67143

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.

MAP OF THE SEVIER DESERT, UTAH, SHOWING AREAS OF ARTESIAN FLOW DURING 1935 AND MARCH 1964 AND WATER-LEVEL CONTOURS IN THE UPPER ARTESIAN AND UNCONFINED AQUIFERS IN MARCH 1964

SCALE 1:250 000

5 0 5 10 15 MILES

5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
SUPPLEMENTAL CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67143

MAP OF THE SEVIER DESERT, UTAH, SHOWING TOTAL DISSOLVED SOLIDS IN WATER FROM WELLS FINISHED IN THE ARTESIAN AQUIFERS, SPRINGS, AND STREAMS

SCALE 1:250 000

5 0 5 10 15 MILES

5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
SUPPLEMENTAL CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67143

MAP OF THE SEVIER DESERT, UTAH, SHOWING AREAS OF PHREATOPHYTE GROWTH IN 1963

SCALE 1:250 000

5 0 5 10 15 MILES

5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
SUPPLEMENTAL CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL