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WATER RESOURCES OF BIG SMOKY VALLEY, LANDER, NYE, AND ESMERALDA COUNTIES, NEVADA

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WATER RESOURCES OF BIG SMOKY VALLEY, LANDER, NYE, AND ESMERALDA COUNTIES, NEVADA

By F. E. Rush and C. V. Schroer

ABSTRACT

Big Smoky Valley has an area of 2,926 square miles and lies near the center of Nevada. The valley-fill reservoirs have a maximum thickness of between 3,000 and 5,000 feet. The estimated ground water stored in the upper 100 feet of saturated alluvium is 5,000,000 and 7,000,000 acre-feet, for the northern part of the valley and Tonopah Flat, respectively. Transmissivity of the valley fill probably is less than 50,000 gpd per foot, except in the area between Round Mountain and San Antonio Ranch, where it probably is more than 100,000 gpd per foot. Areas underlain by fine-grained Pleistocene-lake deposits, have lower transmissivities than described above.

In most areas, the ground water is under water-table conditions. The storage coefficient is estimated to average about 0.15 for the valley-fill reservoirs. The depth to ground water is commonly less than 15 feet and generally less than 100 feet in the northern part of the valley and commonly less than 100 feet beneath Tonopah Flat.

Forty potentially usable streams drain from the Toiyabe Range and the Toquima Range; they have a combined average annual flow of about 35,000 acre-feet. About 20,000 acre-feet of flow occurs during the average growing season. Maximum flow generally is at or near canyon mouths. A reasonably good relation exists between stream basin area and estimated annual flow.

Average annual precipitation ranges from as much as 20 inches in the high mountains to 4 to 7 inches on the valley floor. The northern part of the area receives more precipitation, at a given altitude, than Tonopah Flat. Inflow to the valley-fill reservoirs is mostly recharge from precipitation. Outflow from the northern part of the valley is evapotranspiration from phreatophyte areas. Nearly half of the estimated outflow from Tonopah Flat is evapotranspiration; the remainder probably is ground-water outflow probably southward to Clayton Valley. The estimated total average annual inflows and outflows are 65,000 acre-feet in the northern part of the valley and 14,000 acre-feet for Tonopah Flat.

The estimated perennial yields of the valley-fill reservoirs are 65,000 acre-feet and 6,000 acre-feet for the northern part of the valley and Tonopah Flat, respectively.

The transitional storage reserves were estimated to be 2,300,000 and 2,900,000 acre-feet for the northern part of the valley and Tonopah Flat, respectively. In the northern part of the valley and Tonopah Flat, the transitional storage reserves would be depleted in about 70 years and about 1,000 years, respectively, if the ground-water diversion rates were held at the perennial yields of the two areas.

For the northern part of the valley, in 1968, 2,800 acre-feet of surface water and 8,200 acre-feet of ground water were consumed. For an average year, an estimated 4,500 acre-feet of surface water and 7,900 acre-feet of ground water would be consumed. Comparable estimates for Tonopah Flat are all less than 1,000 acre-feet.

Thirteen of the 40 principal streams have been diverted to lined ditches or pipelines. Most of the remaining 27 streams could be developed in this manner. Canyon mouths are generally the best locations for pipeline and lined ditch intakes. The most productive streams not being diverted to pipelines or lined ditches are Kingston, Peavine, Pablo, Ophir, Jefferson, Broad, Barker, Wisconsin, Last Chance, and Decker Creeks.

Dams to impound water for recreation have been constructed on Kingston Creek and proposed for Birch and Jefferson Creeks. Other streams, where such dams may be feasible, are North and South Twin Rivers and Peavine, Pablo, Jett, and Bowman Creeks. Storing water behind dams for irrigation might be feasible in Belcher Canyon and on McLeod Creek and any creeks having similar runoff characteristics.

Long-term ground-water development will be at the expense of natural discharge by phreatophytes. Wells should be in or near phreatophyte areas. Ground-water levels will have to be lowered about 50 feet throughout the phreatophyte areas to capture all natural discharge.

Most alluvial areas yield ground water usable for irrigation; however, shallow wells on or near playas probably would yield unsuitable water. All streams flowing from the mountains are suitable for irrigation.

INTRODUCTION

Purpose and Scope

This is the second quantitative report on the hydrology of Big Smoky Valley (pl. 1). The first was a reconnaissance by Meinzer (1917) wherein he estimated the discharge and its distribution on the valley floor. An earlier report by Meinzer (1915) and a recent report by Robinson (1953) were generally descriptive.

The purpose of this report is: (1) to describe the general hydrologic environment of Big Smoky Valley, (2) to define the valley-fill reservoirs and to delineate the source, occurrence, and movement of ground water and surface water, (3) to estimate the magnitude of the components of inflow to and outflow from the valley-fill reservoirs, (4) evaluate water use in the valley and its effects on the hydrologic systems, (5) to describe water quality, (6) to define the available water supply, and (7) to delineate alternative means of developing future supplies.

The scope of the report is limited to existing data and to field observations made mostly during the summer of 1968. The installation of stream gages and test drilling was beyond the scope of the study.

Historical Sketch

The following is a brief chronology of the recorded history of Big Smoky Valley. Much of the information is from Koschmann and Bergendahl (1968), Elliott (1966), Couch and Carpenter (1943), Vanderburg (1936), and Kral (1951).

1827 Jedediah Smith traversed the valley near Mount Jefferson.

1843 John C. Fremont (2d expedition) explored the valley.

1859 J. H. Simpson (1876) explored a wagon route, which traversed the valley via Simpson Park Canyon.

1860 Pony Express and Overland Stage established along Simpson's route.

1864 Ophir--silver discovered. First important ore discovery in the area.

1865-70 Sante Fe, Bunker Hill, Victorine, Summitt (Toiyabe Range, T. 16 N.), San Antone (near San Antonio Ranch, T. 7 N., R. 42 E.), Manhattan, and Jefferson (Creek) Canyon--mining of silver and gold began.

1875 Twin Rivers District (Toiyabe Range, T. 12 N.)--silver production began.

1886 Twin Rivers District--maximum ore production reached.

1900 Tonopah--silver and gold claims were staked.

1902 Tonopah Water Improvement Co. formed to develop local springs, streams, and artesian wells.

1904 Tonopah--wells drilled in Ralston Valley to supply community.
Narrow-gage railroad built to Tonopah from west.
Weepah--gold and silver production began.

1905 Tonopah--first mill built at Millers on Tonopah and Goldfield Railroad.
Manhattan--gold placer mining began; water scarce.

1906-7 Round Mountain--gold and silver discovered.
Round Mountain Hydraulic Co. piped water from Jefferson and Shoshone Creeks through 12- and 15- inch pipelines.
Cloverdale (Ranch)--placer gold discovered; water scarce.
Manhattan--population about 3,000.

Ruins of a hotel at the ghost town of Ophir.

Ruins of the Ophir mill.

Unidentified Ophir ruins.

Ruins at the site of San Antonio.

1913 Tonopah--Meinzer, in his unpublished field notes (Book 3, p. 94), indicated that the water-supply system had 780 service pipes, 31 fire hydrants, and had an average consumption of 300,000 gpd (gallons per day) in this town of 7,000 population. He reported that about 260,000 gpd were consumed by mining and milling, the rest by the remainder of the community.

1914 Round Mountain--Round Mountain Mining Co. began construction of a pipeline from Jett Creek to Round Mountain, 45,336 feet long, 15 to 30 inches in diameter.

1918-19 Tonopah and Round Mountain--maximum ore production reached.

1921 Round Mountain--concrete dam built 1 mile east to store Jett and Jefferson Creek water.

1935-40 Weepah and Manhattan--maximum ore production reached.

1940 Mining and population declined throughout the valley. Ranching now the principal economic activity.

1950 Population of valley was 1,800 (Robinson, 1953, p. 137).

1967 Population was estimated by the University of Nevada (1967) as follows: Manhattan, 14; Round Mountain, 195; Tonopah, 2,329. The authors of this report estimate that an additional 150 people lived on ranches, between Tps. 7 and 19 N. Therefore, the total population of Big Smoky Valley was about 2,700.

1968 Tonopah--population increased by several hundred to a total of about 2,700. Total population of valley about 3,000. Approximately 30 ranching units and subunits are operated in the valley.

Previous Work

Several reports have been published that describe hydrologic and geologic features of Big Smoky Valley, notably the work by Meinzer (1915, 1917), previously mentioned. Reference to many of them appear throughout this report. Others that are noteworthy are listed here.

Waring (1965) listed data for the thermal springs of the valley. Well, spring, and stream data have been summarized by Robinson and others (1967). Areas adjoining Big Smoky Valley were the subjects of hydrologic reconnaissance as follows: Ione Valley (Everett and Rush, 1964), Upper Reese River Valley (Eakin and others, 1965), Grass Valley (Everett and Rush, 1966), Monitor Valley (Rush and Everett, 1964), Ralston Valley (Eakin, 1962), Alkali Spring and Clayton Valleys (Rush, 1968), Fish Lake Valley (Eakin, 1950), and Columbus Salt Marsh and Monte Cristo Valleys (Van Denburgh and Glancy, 1970).

The geology of the Manhattan area has been described by Ferguson (1924). Similar reports by Spurr (1905) and Nolan (1930) describe the geology at Tonopah. The geology of the Coaldale quadrangle, including that part of Big Smoky Valley west of Blair Junction, was mapped by Ferguson and others (1953). Anderson (1967) published a geologic cross-section that extends southeastward from the southern end of the Toiyabe Range. Stratigraphy in the Pete's Summit area has been described by McKee and Ross (1969). Washburn (1970) published a detailed geologic map and discussion of stratigraphy on that part of the Toiyabe Range between Birch Creek and Kingston Canyon.

The Central Nevada Development Association (1968) has published a plan of action for the conservation and development of the resources of central Nevada, including Big Smoky Valley.

Acknowledgments

The assistance of land owners and water users of Big Smoky Valley in providing information on their water supplies and water use is acknowledged. In addition, personnel of the several local, State, and Federal agencies and the Central Nevada Development Authority kindly provided data on land and water use.

HYDROLOGIC ENVIRONMENT

Location and General Climatic Features

Big Smoky Valley is in central Nevada and includes parts of Lander, Nye, and Esmeralda Counties, and a very small part of Mineral County (pl. 1). Austin is near the north end of the valley; Tonopah, near the south end. According to Rush (1968b, p. 20), Big Smoky Valley is one of the largest valleys in Nevada, having an area of 2,926 square miles and a length of about 130 miles.

Big Smoky Valley is in a rain shadow east of a series of major mountain ranges and is subject to strong orographic influences on its semiarid precipitation regime (Gifford and others 1967, p. 11). In general, winter precipitation is associated with fronts moving in from the west and northwest involving contact between modified maritime air masses from the Pacific and polar continental air masses. The winds behind a front have a component normal to the front and produce lift on the windward (western) slopes of the mountains. As a result of this lifting action, air is cooled about 5°F for each 1,000 feet of lift causing a precipitation increase with land-surface altitude. On the lee, or eastern sides of ranges, the descending air becomes drier and warmer resulting in decreased precipitation.

The principal source of moisture during the summer is the northward flow of warm, moist air from the Gulf of Mexico which produces extremely local, short-lived thunderstorms. During the transition between periods of winter frontal systems and summer thunderstorms, there is a marked increase in the formation of the unique meteorological phenomenon known as the Nevada (or Tonopah) Low. This high-altitude low-pressure system develops most frequently during April or May and October. The vertical movement of air associated with this system covers a wide area and results in rather widespread precipitation. The influence of topography is less marked with this type of storm and, as a general rule, the rate of increase of precipitation with altitude is considerably less than with frontal-type storms of winter.

Precipitation on the floor of Big Smoky Valley averages 6 inches or less per year. The higher mountains generally receive 20 inches or more per year; most of it accumulates as snow in the winter.

Temperatures are mild in the summer, seldom exceeding 100°F, and cold in the winter. The daily range in temperatures during all seasons may be as much as 40°F and frequently is as much as 50°F during the fall season. The average percentage of possible sunshine is about 80.

Some of the quantitative estimates, given later in the report, are based on a dual set of conditions--wet years and dry years. This base was chosen because the authors considered such an identification more meaningful than developing all estimates for average conditions. The year 1968, during which most of the field estimates were made, was considered a dry year; that is, a year during which streamflow was below average. Wet years, as used in this report, are years when the flows of streams were above average, such as 1969. The principal factor controlling the volume of streamflow during a year is the amount of snow accumulation during the previous winter. Other factors, though less important, are spring and summer showers, temperature, and the amount of sunshine.

Nearly one-third of the years have streamflow above average and about two-thirds below average, as indicated by streamflow data for Reese River, which drains from the west flank of the Toiyabe Range (pl. 1). The relation of wet years to dry years, as used in this report, have the same general proportion by definition. Many average annual water quantities were computed from dry-year and wet-year estimates by computing a weighted average using the dry-year to wet-year ratio of 2:1.

Physiography

Big Smoky Valley is near the center of the Great Basin. The valley is composed of two hydrographic areas (Rush, 1968): a southern part, called Tonopah Flat, and a northern part, as shown on plate 1. A small tributary area, Royston Valley, is included as part of Tonopah Flat, as shown on plate 2. A low alluvial divide separates the northern part of Big Smoky Valley from Tonopah Flat.

The northern part of Big Smoky Valley is topographically closed; the area has no external surface-water inflow or outflow. Measured between topographic divides, the area averages about 20 miles wide and is about 70 miles long.

Tonopah Flat receives surface drainage from Ione Valley through a narrow gap in T. 8 N., R. 39 E. (pl.2). The area, however, has no surface-water outlet.

Three gross geomorphic features are recognized: mountains, valley floor, and the intervening alluvial slope, referred to here as the apron. The mountains generally are fault blocks thrust or tilted upward between north-trending fault zones that extend along the consolidated rock-alluvium contact. The valley floors are generally 5 to 8 miles wide and nearly flat. Because no surface water flows out of either hydrographic area, large playas have developed near the center of Pleistocene lake areas (pl. 1 and 2) by the deposition of fine-grained sediments transported to the lowest parts of each area by surface drainage.

The apron is composed of alluvial fans and pediments. Pediments are sloping consolidated-rock surfaces at the foot of mountains and have a thin alluvial cover--generally unsaturated and perhaps a few tens of feet in thickness. An example of a pediment is the area southwest of Lone Mountain (T. 2 N., R. 40 E., pl. 2) between the valley floor and Weepah Hills. Alluvial fans are surfaces underlain by thick accumulations of alluvium washed from mountain canyons and extending basinward and downward to the valley floor. A well-developed fan is at the mouth of Kingston (Creek) Canyon (Tps. 15 and 16 N., R. 44 E., pl. 1).

Table 1 summarizes some of the physiographic features of the area.

Lithologic Units and Structural Features

The consolidated rocks of the area are grouped into four general lithologic types: intrusive, extrusive, carbonate, and clastic rocks. In addition, the alluvium is divided into three types, younger and older alluvium and playa deposits.

The seven lithologic units are shown on plates 1 and 2. Their distribution and identification is based on geologic maps of Kleinhampl and Ziony (1967), Albers and Stewart (1965), and Stewart and McKee (1968a, 1968b), on aerial photograph interpretations, and field checking at widely scattered locations. Table 2 summarizes the general lithologic and hydrologic properties of the seven units.

The principal structural features in the area are faults. Plates 1 and 2 show the more prominent faults identified in the area.

Source, Movement, and Discharge of Water

The source, movement, and discharge of water in Big Smoky Valley is shown diagrammatically in figure 1. The dominant elements of the flow systems are the following: (1) precipitation, (2) infiltration into rock and soil, and (3) evapotranspiration of soil moisture. Each of the elements shown in figure 1 will be discussed in later sections of the report.

Table 1.--Physiographic summary

[Areas in square miles and altitudes in feet above sea level]

	Big Smoky Valley	
	Northern part	Tonopah Flat
Area of alluvium	689	907
Area of consolidated rocks	634	696
Total area	[a] 1,323	[a] 1,603
Altitude of surrounding mountains:		
West	9,000-11,474	5,500-8,039
East	8,000-11,949	6,500-9,274
North	--	9,000-11,000
Altitude of consolidated rock-alluvium contact	6,200-6,600	5,300-6,000
Altitude of valley floor	5,475-5,800	4,720-5,800
Average relief	4,500	3,000
Type of surficial drainage	Internal	Inflow only[1]

a. From Rush (1968, p. 20).

1. Ione Valley drains to Tonopah Flat through a gap in T. 8 N., R. 39 E., pl. 2.

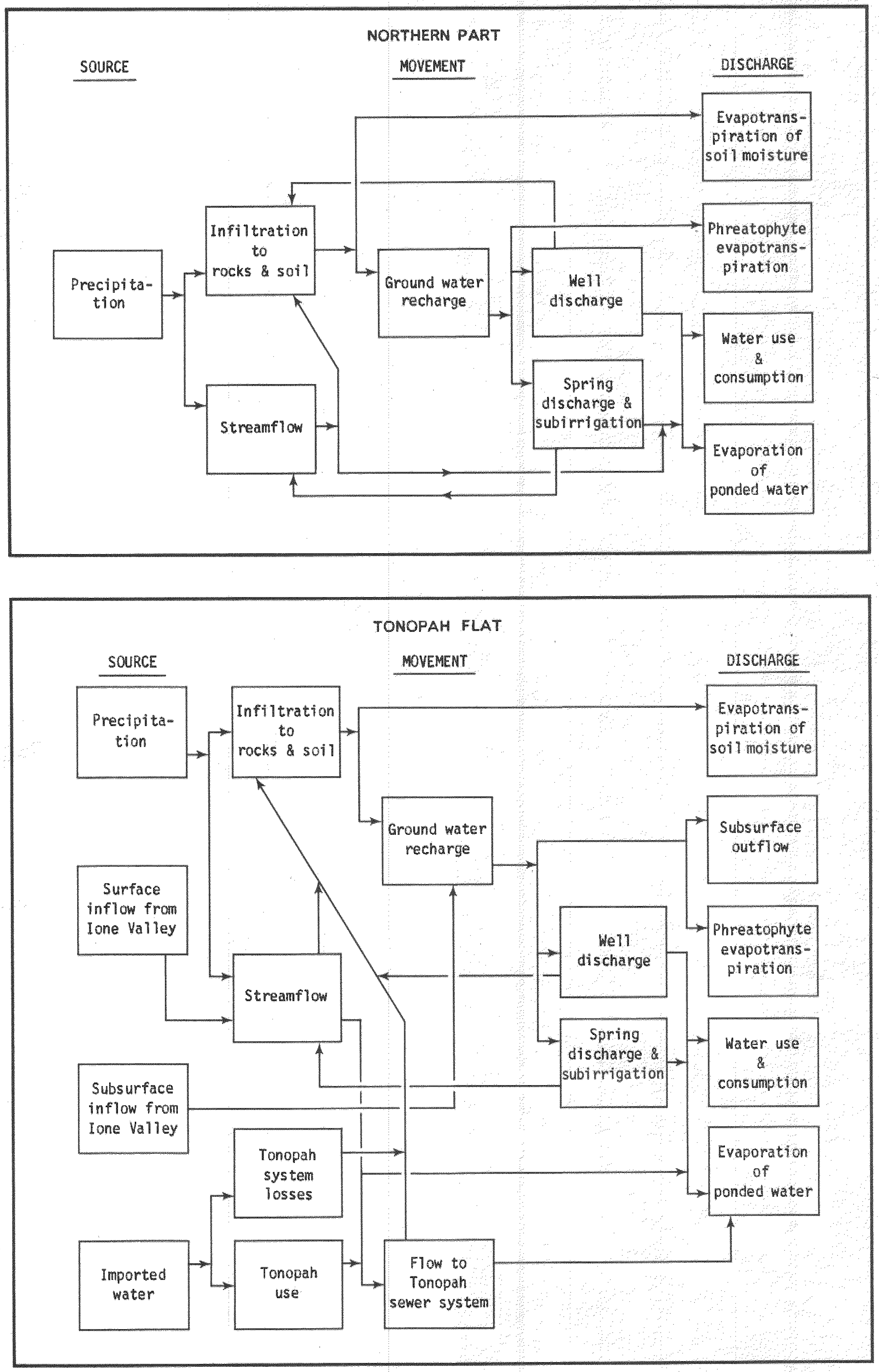

FIGURE 1.—GENERALIZED FLOW DIAGRAMS

Most of the precipitation falls on the mountains. This water moves toward the valley-fill reservoirs in two ways: (1) the water flows from the mountains in streams and as it flows over the apron, part infiltrates and percolates to the water table, and (2) water percolates into the fractures of consolidated rocks of the mountains and then, in the subsurface, flows across the consolidated rock-valley fill contact. The latter is considered to be the smaller of the two quantities of water.

Movement of ground water can be interpreted from the hydraulic gradients shown on plates 1 and 2. In general, the horizontal component of movement is from the mountains toward the phreatophyte and playa-discharge areas in the lower parts of the valley. In most areas, the hydraulic divide is assumed to coincide with the topographic divide bounding the valley.

Infiltration to the water table on the upper parts of the apron and in the mountains produces a downward component of flow; in the phreatophyte- and playa-discharge areas, there generally is an upward component of flow. As a result, in the mountains and the upper part of the apron, hydraulic head generally decreases with depth below the water table; whereas, in discharge areas, head generally increases with depth.

Shallow-circulating ground water generally has a temperature near the average annual air temperature, which is about 50°F (10°C) in the northern part of the valley and perhaps as high as 60°F (16°C) on Tonopah Flat. Figure 2 shows areas of the northern part of the valley where temperature of water samples from wells and springs are 60°F (16°C) or warmer. It is assumed that these warm temperatures are the result of deep circulation of water or shallow circulation in areas of abnormally high geothermal gradient. In Big Smoky Valley, as elsewhere in Nevada, warm ground water seems to be associated with areas of major faulting. The faults may be the principal avenues for deep circulation.

On Tonopah Flat, water warmer than 60°F (16°C) was reported in four wells (1/37-14b, 1/38-3c, 1/38-6b, and 6/40-13aa1, table 32 and pl. 2). Other parts of Big Smoky Valley may have thermal water, but they are unidentified because of insufficient data.

The warmest water was encountered near Darrough Hot Spring and Spencer Hot Springs. Both samples were from wells. The Darrough well (11/43-7d, table 32) had a water temperature of boiling; the well near Spencer Hot Springs (17/45½-11da, table 32) had a temperature of 164°F (73°C). Both springs had slightly lower temperatures.

VALLEY-FILL RESERVOIRS

Table 2 defines the valley-fill reservoir as the alluvium. It includes the playa deposits, which are mostly high-saline silt and clay that generally cannot successfully be tapped by wells for domestic, stock, public-supply, or irrigation uses.

Reservoir Characteristics

Big Smoky Valley has two principal valley-fill reservoirs, one in the northern part of the valley and one beneath Tonopah Flat. The boundary between the two reservoirs was selected to coincide with the ground-water divide, which is near the low alluvial divide in T. 9 N., described earlier. The dimensions of the reservoirs are summarized in table 3. Figure 3 shows estimated thickness of alluvium beneath Tonopah Flat. Robinson (1953, p. 143) indicated that the valley-fill reservoir, at specific locations, is thinner than described here. Meinzer, in his unpublished field notes of 1913 (Book 3, p. 60), indicated that at Salt Well (1/38-9d, pl. 2) the alluvium is less than 18 feet thick.

The reservoirs are composed of lenses of gravel, sand, and clay derived by erosion from the adjoining mountains (table 30). Generally, the alluvium is coarsest and least sorted near the mountains with the grain size decreasing and the sorting increasing toward the axis of the valley and down the slope of the axis toward the playas. Because a large variety of rocks comprise the mountains (pl. 1 and 2), the valley-fill reservoir is made up of a large variety of rock and mineral grains.

Alluvial fans built by streams draining monolithologic terrain have rock and mineral grains reflecting the composition of those rocks. As a result, these deposits may have hydrologic properties significantly different from adjoining fans. Elsewhere in Nevada, alluvium derived principally from extrusive and carbonate rocks generally have better water-yielding properties than alluvium derived from granitic and fine-grained and poorly indurated clastic rocks. The latter two rocks generally disintegrate into smaller grains producing low-permeability aquifers.

Figure 4 shows the distribution of transmissivity of the northern valley-fill reservoir. Transmissivity is an index of the ability of water to flow through an aquifer or reservoir system to a point of discharge, such as a well or spring. Deposits with high transmissivities transmit water more readily than deposits with low transmissivities. The values of transmissivity are based on interpretations

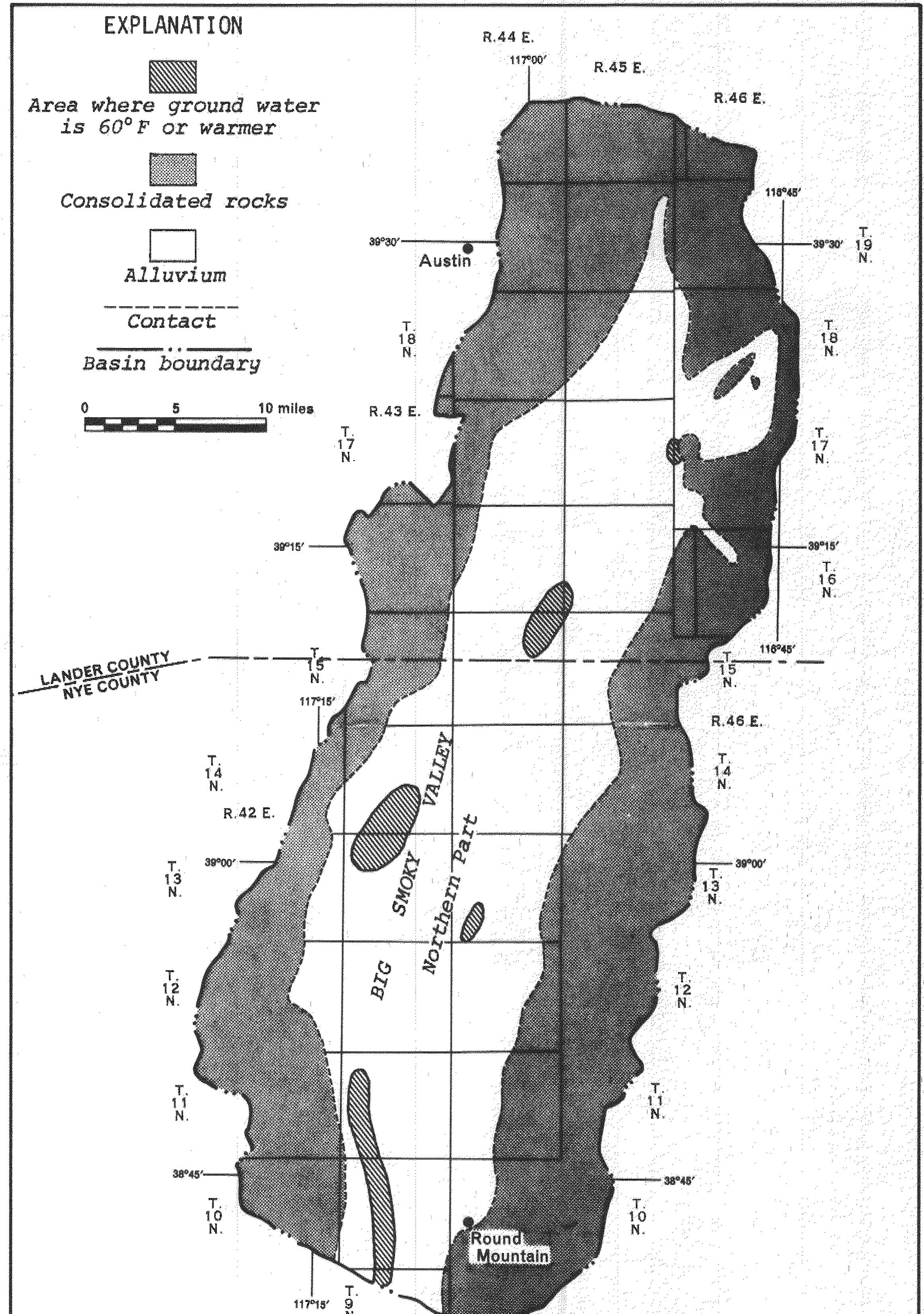

Figure 2.- Areas of the valley-fill reservoir in the northern part of Big Smoky Valley where the temperature of ground water from wells and springs is 60° F (16° C) or warmer

Table 2.--Principal lithologic units

Age		Unit designation		Thickness (feet)	Lithologic units shown on plates 1 and 2		General hydrologic properties
QUATERNARY	Pleistocene and Holocene	Playa deposits	Valley fill	0-500±	Silt, clay, and evaporites. Includes some dune sand. Occurs beneath playas.	Valley-fill reservoir	Very high porosity and very low permeability. Yields water poorly to wells.
		Younger alluvium		0-200±	Unconsolidated lenses of gravel, sand, silt, and clay comprising stream channel and lake deposits; composed of detritus from adjoining mountains. Lenses generally less than 20 feet thick.		Sand and gravel deposits moderately permeable and capable of yielding moderate quantities of water to wel Lake-bottom deposits of fine-graine sand, silt, and clay are less capab of yielding water to wells.
TERTIARY AND QUATERNARY	Miocene to Pleistocene	Older alluvium		0-5,000±	Semiconsolidated to unconsolidated lenses of gravel, sand, silt, and clay underlying alluvial fans, slope-wash areas, and upland alluvial surfaces. Occurs at depth beneath playa deposits and younger alluvium. Includes semiconsolidated beds of shale and siltstone of the Esmeralda Formation.		Sand and gravel deposits have low t high permeability and are capable o yielding moderate to large quantiti of water to wells. Yields of large diameter wells range up to 4,000 gp
PERMIAN TO QUATERNARY		Volcanic rocks	Consolidated rocks	--	Mostly various types of welded and nonwelded tuffs and ash flows, rhyolite and rhyolite flows and breccia, and lava flows of andesite and basalt.		Not tapped by wells. Scoriaceous bed and interflow zones may be good aquif where saturated.
PRECAMBRIAN(?) TO QUATERNARY		Carbonate sedimentary rocks		--	Massive to thin bedded limestone and dolomite; includes minor amounts of shale, and quartzite. Unit is mostly dolomite in Royston Hills, Silver Peak Range, and Lone Mountain area.		Locally transmits large quantities of ground water where solution channels have developed.
		Clastic sedimentary rocks		--	Mostly chert, quartzite, conglomerate, shale, and sandstone.		Not tapped by wells. Do not readily transmit water, except in areas of intense structural deformation where some water may be transmitted along fractures.
JURASSIC TO TERTIARY		Granitic rocks		--	Mostly quartz monzonite and granodiorite.		Not tapped by wells. Virtually no interstitial porosity and permeabilit may transmit small amounts of water through near-surface fractures and weathered zones.

Table 3.--Generalized dimensions of the valley-fill reservoirs

Characteristics	Northern reservoir	Tonopah Flat reservoir
Average length (miles)	55	a 100
Average width (miles)	13	9
Area (acres)	440,000	580,000
Maximum thickness (feet)[1]	3,500-5,500	3,000-5,000

1. Based on gravity maps by Erwin (1966) and U.S. Air Force (1968). Also see figure 3.

a. Includes major arms to main reservoir and Royston Valley.

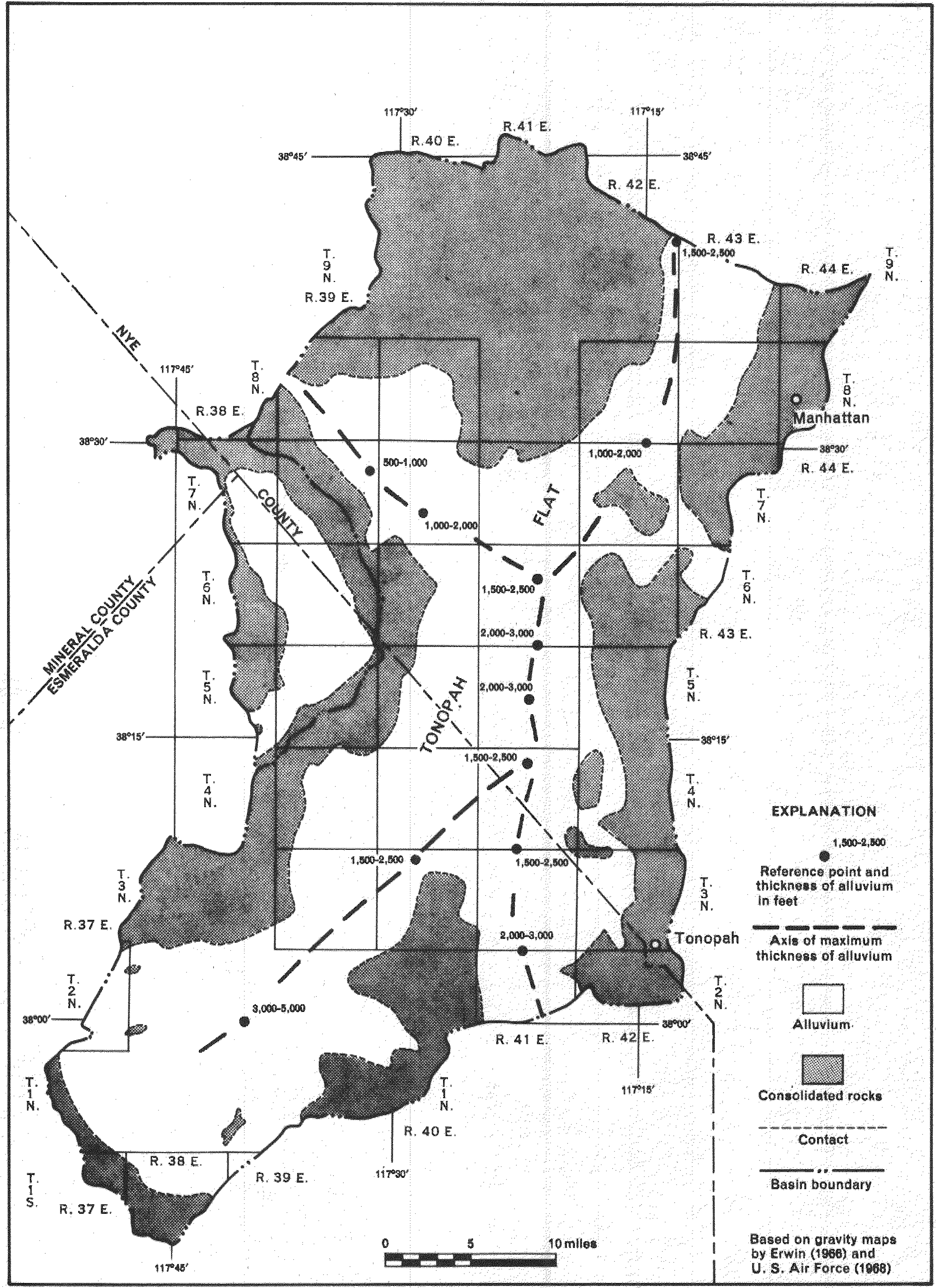

Figure 3.- Estimated thickness of alluvium beneath Tonopah Flat

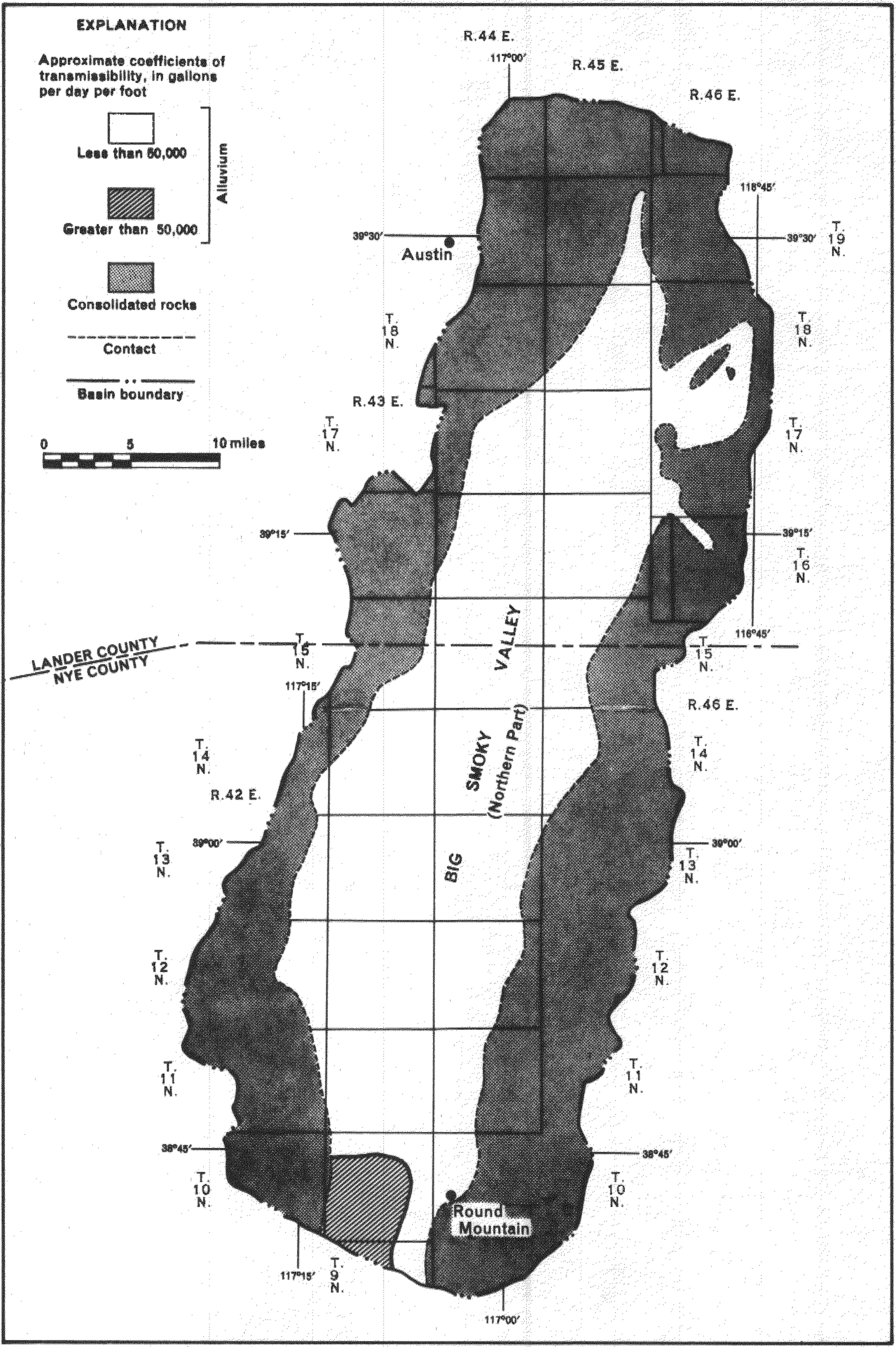

Figure 4.- Preliminary transmissivity of the valley-fill reservoir in the northern part of Big Smoky Valley

of drillers' logs, reported specific capacities of wells, and three pumping tests. Because of the small number of data points and their uneven distribution, future data will provide extensive refinement of this very general map.

No transmissivity map was drawn for Tonopah Flat because of inadequate data; however, some general conclusions can be drawn: (1) transmissivity probably is low in Tps. 1 and 2 N., Rs. 37 to 39 E.; that is, less than 25,000 gpd (gallons per day) per foot, because the lowland deposits probably are thin accumulation of fine-grained sand and clay; (2) the deposits of this southwestern area are partly derived mostly from nearby intrusive and clastic rocks (pl. 2); and (3) because the remainder of the valley-fill reservoir is derived from nearby extrusive and carbonate rocks, transmissivities there should be moderate to high; that is, more than 25,000 gpd per foot.

An area of Tonopah Flat of probable high transmissivity is the southward extension of the high-transmissivity area shown in figure 4. The area may extend as far south as San Antonio Ranch (pl. 2).

The coefficient of storage, which over the long term may be nearly equal to specific yield of the valley-fill reservoir, was computed from well logs to be about 0.15, or about equivalent to a specific yield of 15 percent. Specific yield of the reservoir is the ratio of (1) the volume of water which the reservoir will yield by gravity to (2) the reservoir volume, stated as a percentage. Silt and clay lenses that are interbedded with sand and gravel act as semiconfining beds; however, under long-term pumping, all these lenses would drain slowly.

Most of the existing high-yield wells (table 32) are outside the area of Pleistocene lakes (pl. 1 and 2), and encountered their chief aquifer within 300 feet of land surface.

Hydraulic Boundaries

External hydraulic boundaries of the valley-fill reservoirs are formed by the consolidated rocks (pl. 1 and 2) which underlie and form the sides of the reservoirs. These lateral boundaries are leaky to varying degrees. The carbonate rocks may contribute large amounts of recharge as underflow from the Toiyabe Range in the northern part of the valley. Volcanic rocks, particularly basalt and scoria, may contribute moderate amounts to the valley-fill reservoirs.

Recharge boundaries are formed by the live-stream segments of all streams where and when they flow across the valley-fill reservoirs.

The principal internal hydraulic boundaries are faults (pl. 1 and 2) and marked lithologic changes in the alluvium, such as the transition from sand and gravel to playa deposits. The extent to which these barriers impede ground-water flow or alter the ground-water flow pattern probably will not be determined until substantial ground water has been pumped.

Occurrence of Ground Water

Water in the valley-fill reservoirs occupies the intergranular pores in the zone of saturation and is slowly flowing from areas of recharge to areas of discharge. The valley-fill reservoirs are not fully saturated; that is, the water table does not extend to land surface, as shown by figures 5 and 6.

The depth to water in wells may not be the same as the depth at which water was first encountered when drilling the well. However, the difference is generally not more than 25 to 50 feet. This difference, where it exists, is generally caused by a local fine-grained lense of low transmissibility overlying and confining an aquifer. Where depths to water are (otherwise) shallow, or at the land surface and where confining beds overlie an aquifer, wells may flow. Areas where such conditions exist are shown in figures 5 and 6.

In saturated consolidated rocks, ground water occupies pore space, fractures, and solution cavities. Because of their high topographic position, hundreds of feet of consolidated rock in the mountains are commonly unsaturated. However, water has been encountered in mines at Tonopah (Nolan, 1935, p. 48).

Ground Water in Storage

Recoverable ground water in storage in the valley-fill reservoir is that part of the water moving through reservoirs that will drain by gravity in response to pumping. Under native conditions the amount of stored ground water remains nearly constant. As of 1968, the long-term balance between recharge and discharge, which controls changes of ground water in storage, probably had been disturbed only slightly by diversions of surface and ground water.

Recoverable ground water in storage is the product of the specific yield, the area, and the selected saturated thickness of alluvium. In Big Smoky Valley, the average specific yield of the valley-fill reservoir probably is about 15 percent. Estimated ground water in storage in the upper 100 feet of saturated alluvium (assume 75 percent of alluvial area listed in table 3) is about 5 and 7 million

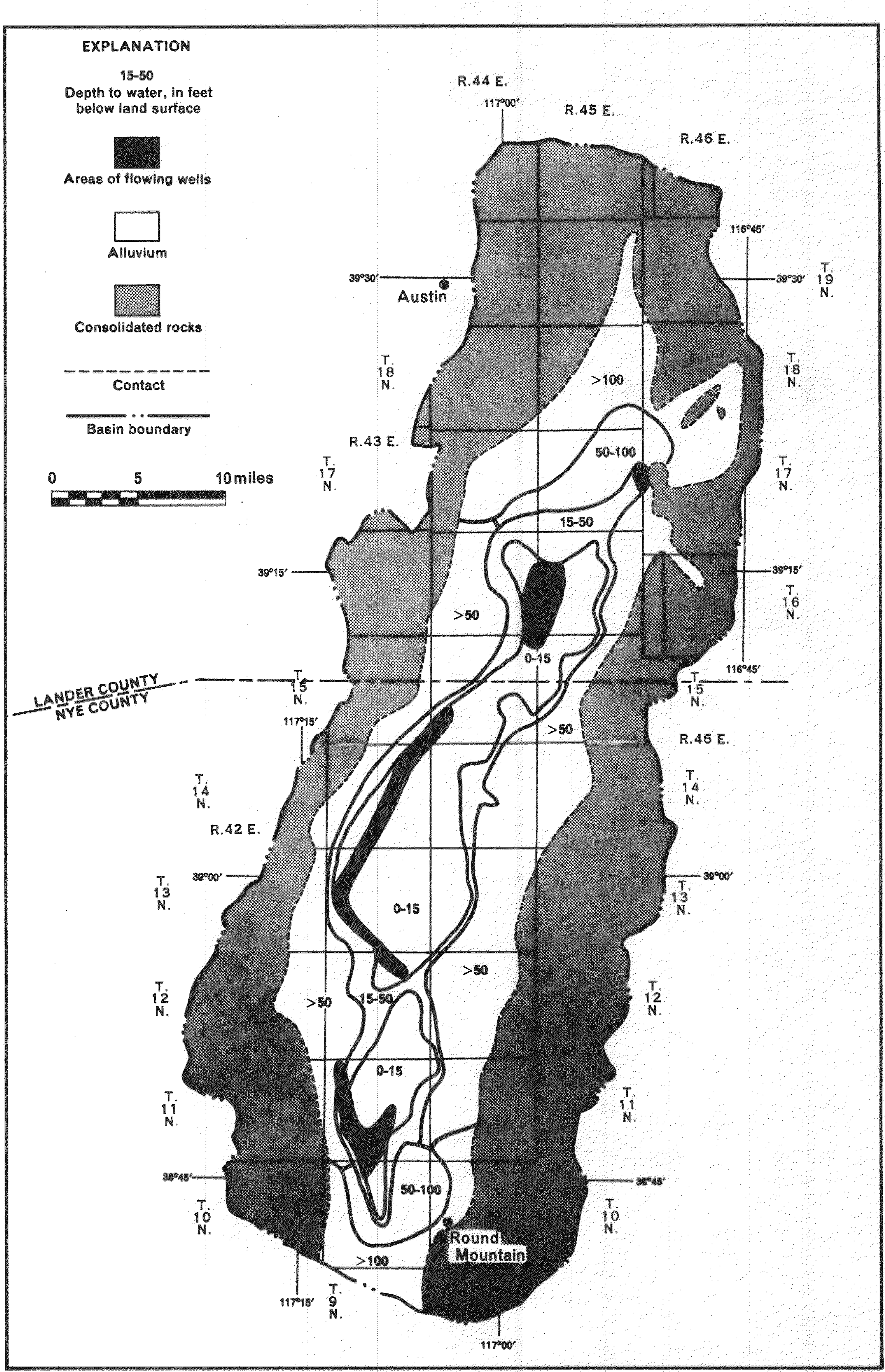

Figure 5.- Generalized depth to water beneath the northern part of Big Smoky Valley

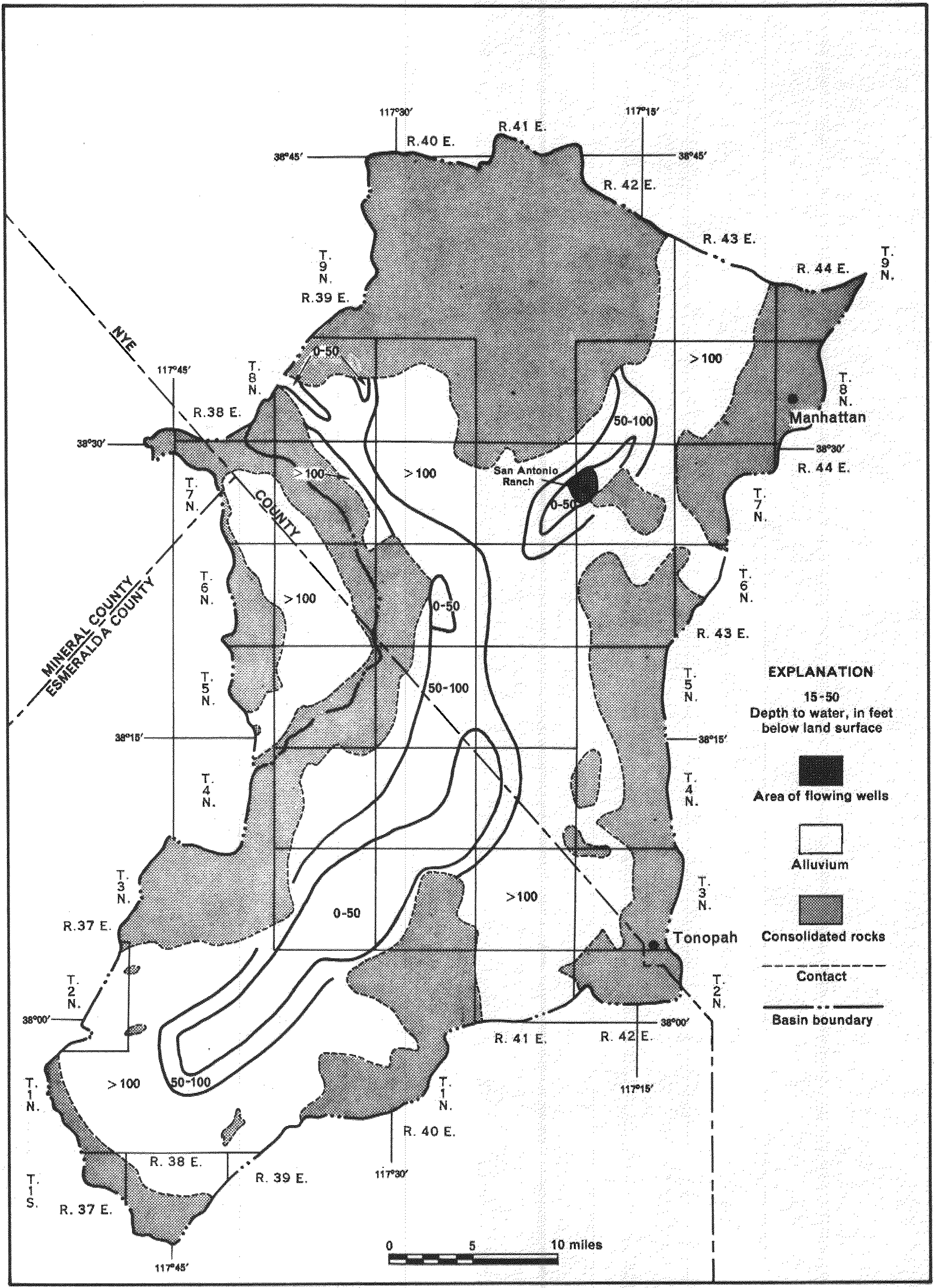

Figure 6.- Generalized depth to water beneath Tonopah Flat

acre-feet in the northern part of Big Smoky Valley and Tonopah Flat, respectively. The depth below land surface to this block of stored ground water is given in figures 5 and 6.

Chemical Character of the Water

As part of the present study, 38 water samples were analyzed in order to make a reconnaissance of the general chemical character and usability of the water. These analyses, plus seven additional analyses previously collected by the Geological Survey during the past two decades, are listed in table 32 (at end of report). Other analyses of water in Big Smoky Valley have been published by Meinzer (1917) and Miller and others (1953).

Most of the recent samples were analyzed at the Geological Survey field office in Carson City and include only analyses of principal ions. Boron, fluoride, iron, and nitrate generally were not determined, although they are important ions affecting the suitability of water for irrigation and domestic use.

Precipitation, the ultimate source of water in Big Smoky Valley, is nearly free of dissolved solids. Streams, when fed by snowmelt and runoff, have a lower dissolved-solids content than at low flow when ground-water seepage constitutes the principal source of flow. Figure 7 is an example of this relation for South Twin River.

As precipitation enters and flows through the hydrologic systems (fig. 1), contact of the water with vegetation, soil, and rock adds to the dissolved-solids content. Where water is evaporated from playas or used by phreatophytes (pl. 1 and 2), most of the dissolved solids remain and become concentrated at shallow depth in the ground water and soil.

The concentrations of dissolved solids in sampled streams, wells, and springs are summarized by specific conductance, an index of dissolved-solids content, in table 4. The dissolved solids in water, in milligrams per liter, is generally 55 to 70 percent of the specific conductance in micromhos per centimeter at 25°C.

The principal ions in all stream samples were calcium and bicarbonate (table 32). As the water seeps into the ground and flows toward areas of discharge, not only does the dissolved-solids content increase, but the concentrations of sodium and chloride increase more rapidly than all other ions. In discharge areas, these two ions generally dominate.

Table 4.--Summary of specific conductance of water samples[1]

[Specific conductance values in micromhos per centimeter at 25°C]

	Northern part of the valley	Tonopah Flat
STREAMS		
Number of samples	15	1
Range of values	94-500	350
Median value	250	--
Range of most common values	94-500	--
WELLS		
Number of samples	12	15
Range of values	150->100,000	450-10,000
Median value	480	1,270
Range of most common values	150-1,100	450-6,000
SPRINGS		
Number of samples	14	2
Range of values	180-1,460	400-810
Median value	330	--
Range of most common values	180-570	--

1. Some specific-conductance values are estimated by multiplying dissolved-solids content by 1.5. Basic data listed in table 32 and from Meinzer (1917) and Miller and others (1953).

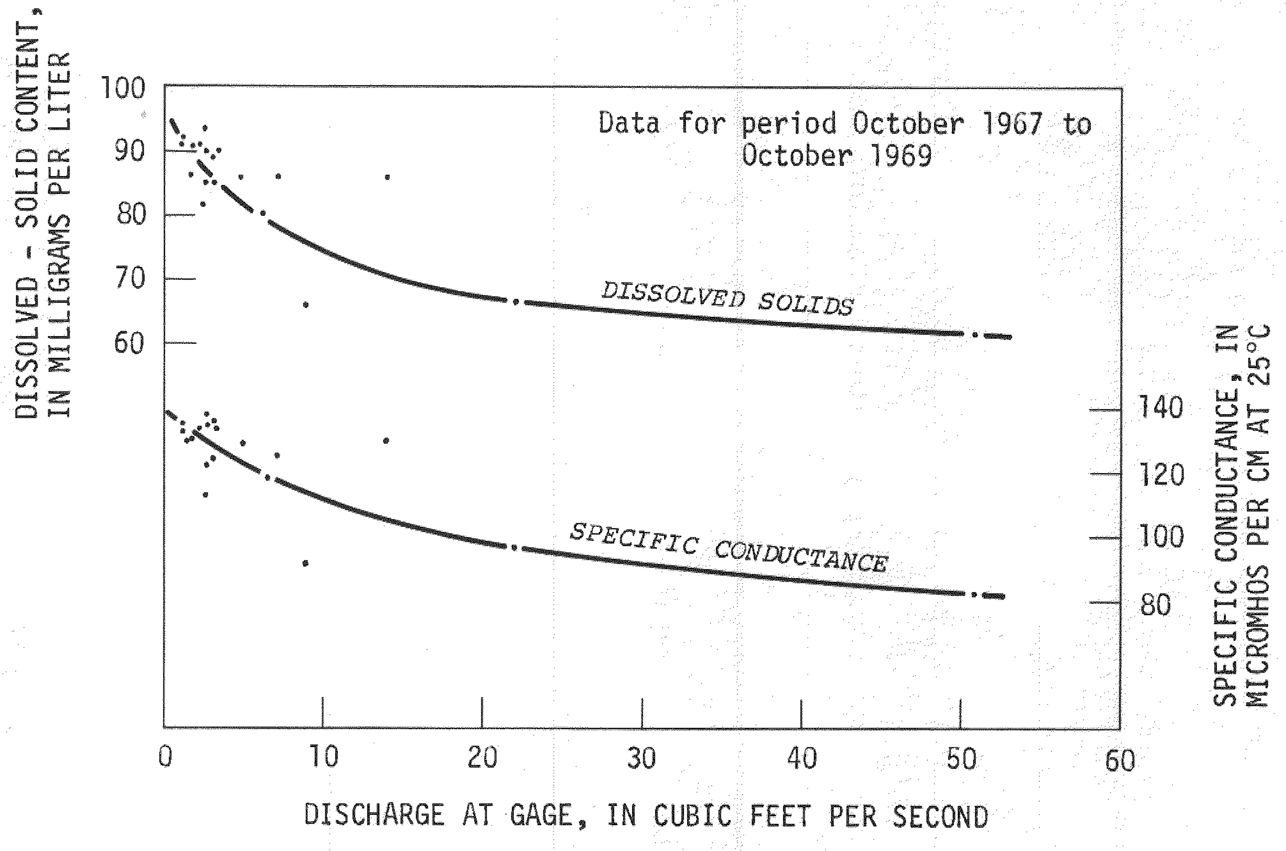

Figure 7. - Relation of flow rate to dissolved-solid content and specific conductance of South Twin River

STREAMS

Nearly all the runoff in Big Smoky Valley is produced directly or indirectly by precipitation on the mountains, with maximum water running off in the spring and early summer. Most perennial streams are diverted to irrigation ditches or pipelines near the canyon mouths to carry water to cropland on nearby ranches. Most of the flow in unlined ditches and stream channels infiltrates into the apron before the flow reaches the valley floor. Surface streams flow to the valley floor only during periods of high runoff. Localized streamflow occasionally develops for short periods on alluvial aprons downstream from the mountain fronts as a result of high-intensity storms, but this type of streamflow is so erratic in frequency and duration that without storage structures it has little economic value.

Available Streamflow Data

The availability of streamflow data is summarized in table 5. Gaged and periodic-measurement sites are shown on plates 1 and 2. In addition, estimates of mean annual flow by measuring channel geometry (Moore, 1968) were made on ephemeral channels at numerous sites.

Distribution of Flow with Time and Location

Snowmelt in the Toiyabe Range and in the Toquima Range between Moore Creek and Round Mountain produces most of the streamflow that is generated in Big Smoky Valley. This flow is at its peak from April through July. The seasonal flow pattern for Reese River shown in figure 8 generally is typical for Big Smoky Valley streams. Monthly flows (expressed as a percentage of annual flow) are within the range defined by the quartile curves 50 percent of the time. Flows exceed the upper quartile 25 percent of the time and are less than the lower quartile 25 percent of the time. The median is the midpoint in the distribution of flow.

Mountain streams generally have their maximum flow at the mountain front, shown as the consolidated rock-alluvium contact on plates 1 and 2. Flow across the consolidated rock-alluvium contact is an index to the amount of water potentially available for development. Streamflow generally increases in the mountains and decreases on the alluvial apron. Table 6 provides data on flow gains and losses in relation to the mountain front. Kingston Creek fits the general description as a gaining stream in the mountains; whereas, Shoshone and Clear Creeks had no similar gain. The three examples [Barker, McLeod, and Sheep (Canyon) Creeks] given in table 6 typify the magnitude of loss on the apron.

Table 5.--Availability of streamflow data

Name of station	Location[1]	Drainage area (square miles)	Type of gage	Period of record	Range of flow (cfs)[2] Max.	Min.	Ave.	Remarks
				RECORDING GAGING STATIONS				
Kingston Creek below Cougar Canyon near Austin	16/43-35b	23.4	Continuous recorder	Oct. 1966 to present	17	1.7	5.2	
South Twin River near Round Mountain	12/42-22d	20	Continuous recorder	Aug. 1965 to present	99	0.4	4.6	Located 600 feet upstream from diversion
			Low flow periodic	1965	--	--	--	
			Periodic measurements	1964	--	--	--	
Reese River near Ione	11/40-3b	53	Continuous recorder	Aug. 1951 to present	512	0	10.2	Located in adjacer Reese River Valle
Birch Creek near Austin	10/44-35c	17.5	Fragmentary records	June to Nov. 1913 May 24 to June 17, 1914	--	--	--	Discontinued gage. See Meinzer, 1917
				CREST-STAGE PARTIAL RECORD STATIONS				
Big Smoky Valley tributary near:								
Blair Junction	2/38-13a	13	Peak flow only	1961 to present	86	0	--	
Tonopah	2/42-14d	2.4	Peak flow only	1961 to present	3	0	--	
				PERIODIC MEASUREMENTS				
--	Various	--	None	1968	--	--	--	See tables 6 and 2

1. Location shown on plates 1 and 2.

2. Through Sept. 30, 1968.

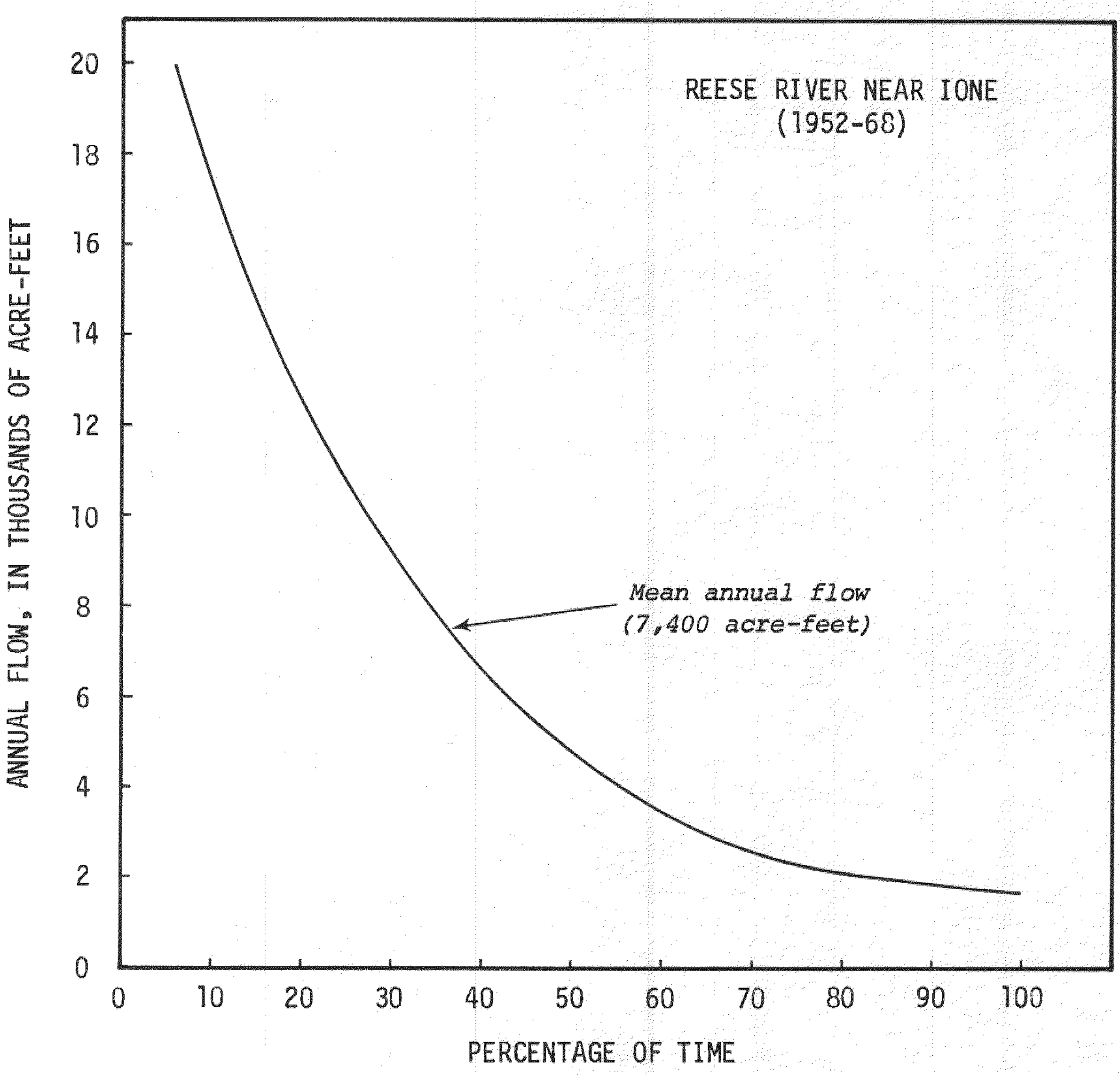

Figure 8. - Percentage of time annual flow equaled or exceeded specified flow

Table 6.--Distribution of flow along stream channels

[All streams are essentially free of diversions in these reaches]

Stream	Date	Location along main channel in relation to mountain front	Flow (cfs)	Remarks
Kingston Creek	4-19-68	4.8 miles upstream	1.4	Gain in flow down to mountain front
		4.5 miles upstream	2.0	
		1.8 miles upstream	2.3	
		At canyon mouth	4.2	
Shoshone Creek (Toquima Range)	7-10-68	2.3 miles upstream	.18	Little change in flow down to mountain front
		At canyon mouth	.17	
Clear Creek	7- 9-68	1.0 mile upstream	1.4	Loss in flow down to mountain front
		At canyon mouth	1.1	
Barker Creek	5-23-68	At canyon mouth	2.8	Loss in flow downstream below mountain front
		.5 mile downstream	2.4	
		1.0 mile downstream	2.2	
		1.5 miles downstream	1.8	
		2.0 miles downstream	1.5	
McLeod Creek	5-22-68	At canyon mouth	1.8	Loss in flow downstream below mountain front
		.3 mile downstream	1.5	
		.5 mile downstream	1.3	
		1.0 mile downstream	.8	
		1.5 miles downstream	.3	
		1.7 miles downstream	.2	
		2.0 miles downstream	0	
Sheep (Canyon) Creek	5-21-68	At canyon mouth	2.0	Loss in flow downstream below mountain front
		.25 mile downstream	1.8	
		.5 mile downstream	1.7	
		1.0 mile downstream	1.7	
		1.5 miles downstream	.9	
		2.0 miles downstream	.7	

The long-term distribution of streamflow in the valley is similar to that experienced on nearby Reese River. Figure 9 shows the percentage of time, for the 17 years of record at the gage site (11/40-3b), that specified annual streamflow was equaled or exceeded. The curve, concave upward, indicates that there are nearly twice as many dry years (below-average years) as wet years (above-average years).

Characteristics of the Major Streams

Table 7 summarizes the characteristics of 40 of the largest streams in the valley. All but four drain from the Toiyabe Range; the remainder drain from the Toquima Range in the vicinity of Mt. Jefferson (pl. 1). Most of the 40 streams have sufficient flow to be used for irrigation. The estimated total flows, in acre-feet, are summarized from table 7 as follows:

	Northern part of valley (37 streams)	Tonopah Flat (3 streams)
Dry years:		
Water year	24,000	2,000
Growing season	12,000	960
Wet years:		
Water year	60,000	6,400
Growing season	36,000	3,800
Average year:		
Water year	32,000	3,500
Growing season	20,000	1,900

Flow during wet years is nearly twice the average annual flow. During dry years the flow averages about 75 percent of average annual flow.

The streams can be characterized by (1) relation of maximum flow to mean flow and by (2) volume of flow. Table 7 lists ratios of maximum flow to mean flow for streams where monthly flow measurements were made during 1968. These ratios range from 1.1 to 17 and have a median of 3.8. Streams with low values, less than about 3, are considered to have a high base flow in relation to maximum and mean flow. Streams that have rapid runoff in the spring and early summer and low base flow have high ratios; that is, more than about 5. Most of the streams probably fall in an intervening group between values of 3 and 5. Ratios obtained during average and high runoff years probably will be higher than those obtained during 1968; however, the relative differences between streams should be about the same.

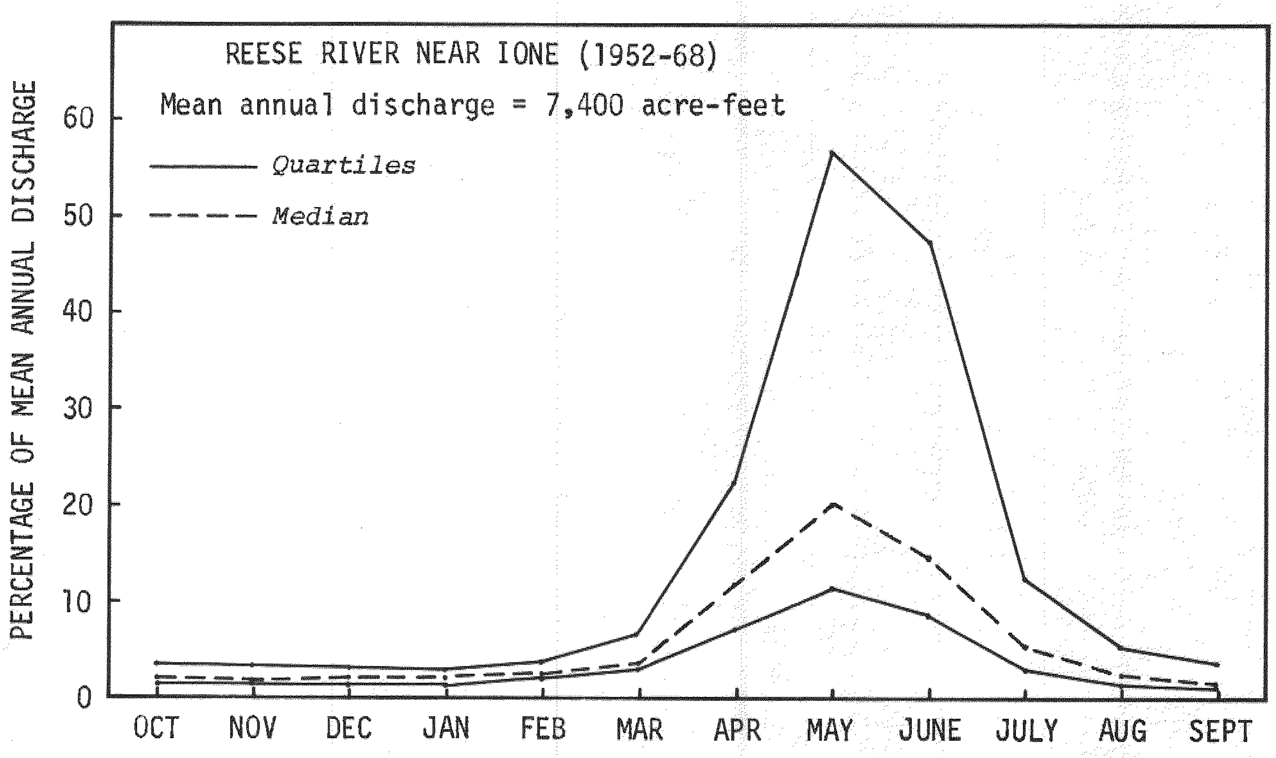

Figure 9. - Seasonal distribution of Reese River flow

Table 7.--Selected stream data

Altitude, in feet: Estimated from topographic maps.
Area of basins: Determined from topographic maps.
Estimated discharge in 1968: Computed from periodic measurements at stream-measuring sites shown on plates 1 and 2.
Estimated water supply: Numbers in parenthesis generally are less accurate, with a potential error of about ±50 percent.
Water consumption: Based on interviews of ranch operators. Number is estimated quantity of water consumed by crops; diversions from streams are somewhat larger.

Stream	Location	Altitude in feet		Area of basin (square miles)	Estimated discharge in 1968 (cfs)				Estimated water supply (acre-feet)					Water consumption			
									In 1968 and under dry conditions			Under wet conditions					
		Canyon mouth	Maximum in basin		Maximum	Minimum	Mean	Max./Mean	Water year	Growing season	Average annual	Water year	Growing season	Ranch	Improvements	In 1968 and under dry conditions (acre-feet per year)	Under wet conditions (acre-feet per year)
NORTHERN PART OF THE VALLEY																	
TOIYABE RANGE																	
Vigus Canyon	T. 20 N.	6,800	8,510	--	--	--	--	--	small	--	(small)	--	--	Lake		0	75
Willow Creek	T. 19 N.	6,600	8,614	8.8	--	--	--	--	(180)	(90)	(240)	(480)	(290)	Willow Creek		0	195
Bade Creek	T. 19 N.	6,950	8,614	2.6	--	--	--	--	(40)	(20)	(50)	(110)	(70)	Streshley		0	[a] 150
Simpson Park Canyon	T. 19 N.	6,100	[a]8,614	--	--	--	--	--	0	0	(50)	100	(60)	Given		0	105
Birch Creek	T. 18 N.	6,150	10,793	17.5	2.4	0.9	1.4	1.7	1,000	440	1,400	2,700	(1,600)	Birch Creek	Pipeline	240	270
Tar Creek	T. 17 N.	6,800	10,793	2.2	.9	0	.2	5.6	120	80	160	300	(180)	--		0	Minor
Sheep Canyon	T. 17 N.	6,400	10,440	2.8	2.1	0	.1	17	90	80	120	200	(120)	Young Bros.		0	(a)
Rock Creek	T. 17 N.	6,800	10,996	1.8	--	--	--	--	(70)	(30)	(90)	(190)	(110)	Young Bros.		0	(a)
Crooked Canyon	T. 17 N.	6,500	11,071	1.7	--	--	--	--	(90)	(40)	(120)	(230)	(140)	--		0	Minor
Globe Canyon	T. 16 N.	6,800	11,071	2.0	--	--	--	--	(120)	(60)	(160)	(300)	(180)	Gilman		0	20
Frenchman Creek	T. 16 N.	6,650	11,033	1.4	--	--	--	--	(60)	(30)	(80)	(160)	(100)	Young Bros.		0	(a)
Sante Fe Creek	T. 16 N.	6,550	11,474	2.3	--	--	--	--	(120)	(60)	(160)	(300)	(180)	Young Bros.	Pipeline		
Shoshone Creek	T. 16 N.	6,650	11,474	1.9	--	--	--	--	(100)	(50)	(130)	(260)	(160)	Young Bros.	Pipeline	600	1,080
Blakeley Canyon	T. 16 N.	6,950	11,394	1.0	--	--	--	--	(50)	(20)	(70)	(140)	(80)	Young Bros.			
Kingston Creek	T. 16 N.	6,300	11,474	23.4	7.4	2.8	4.8	1.5	3,500	1,650	4,700	9,000	(5,400)	Young Bros., Kingston			
Bowman Creek	T. 15 N.	6,450	10,975	7.0	3.8	.7	.9	2.0-2.5	1,200	660	1,600	3,000	(1,800)	Triple T	Lined ditch	225	525
Aiken Creek	T. 15 N.	6,150	10,975	1.8	--	--	--	--	(360)	(180)	(480)	(930)	(560)	Heffern			
Decker Creek	T. 15 N.	6,250	10,453	2.4	3.1	.3	.8	3.8	600	270	800	1,500	(900)	Heffern		275	825
Alice Gendron Creek	T. 14 N.	6,250	10,960	2.1	--	--	--	--	(340)	(170)	(450)	(900)	(540)	Heffern	Rock-lined ditch		
McLeod Creek	T. 14 N.	6,150	10,327	2.9	3.7	.1	.6	6.7	400	240	550	1,000	(600)	Smoky Valley		0	110
Wildcat Creek	T. 13 N.	6,300	10,600	1.2	--	--	--	--	(160)	(80)	(210)	(400)	(240)	Millett	Lined ditch	60	120
Clay Creek	T. 13 N.	6,300	10,600	1.9	--	--	--	--	(360)	(180)	(480)	(930)	(560)	Millett	Lined ditch		
Summit Creek	T. 13 N.	6,600	10,400	2.9	1.0	.2	.6	1.6	450	120	600	1,200	(720)	RO		0	Minor
Wisconsin Creek	T. 13 N.	6,500	10,600	4.0	--	--	--	--	(660)	(330)	(880)	(1,700)	(1,000)	RO		0	Minor
Ophir Creek	T. 13 N.	6,400	10,600	3.9	4.2	.3	1.1	3.8	800	380	1,100	2,100	(1,300)	RO		0	Minor
Last Chance Creek	T. 12 N.	6,600	10,800	3.8	--	--	--	--	(620)	(310)	(830)	(1,600)	(960)	RO		0	Minor
North Twin River	T. 12 N.	6,400	10,800	15.2	13	.8	3.1	4.2	2,300	1,300	3,000	6,000	(3,600)	RO	Lined ditch	1,050	2,300
South Twin River	T. 12 N.	6,400	11,788	20.0	15	1.1	4.0	3.7	2,900	1,450	4,000	7,500	(4,500)	RO	Lined ditch		
Belcher Canyon	T. 11 N.	6,300	11,353	5.1	7.0	.1	1.0	6.7	750	450	1,000	1,900	(1,100)	Berg	Lined ditch	200	550
Cove Canyon	T. 11 N.	6,400	11,353	2.6	--	--	--	--	(450)	(220)	(600)	(1,200)	(720)	Darrough	Pipeline	30	60
Broad Creek	T. 11 N.	6,400	11,353	6.1	4.6	.2	1.0	4.5	720	380	1,000	1,800	(1,100)	Wineglass		0	200
Jett Creek	T. 10 N.	6,300	11,165	7.3	6.8	.1	1.6	4.2	1,200	570	1,600	3,000	(1,800)	J-K	Pipeline[1]	0	90
Pablo Creek	T. 10 N.	6,200	11,165	10.7	8.2	.6	2.2	3.7	1,600	860	2.200	4,000	(2,400)	Pablo Canyon		75	120
Subtotal (rounded) (1)									22,000	11,000	29,000	55,000	33,000				
TOQUIMA RANGE																	
Moore Creek	T. 12 N.	6,800	11,400	8.5	.6	.2	.5	1.1	400	110	540	1,000	(600)	Cornell		20	25
Barker Creek	T. 11 N.	7,000	11,800	7.5	3.1	.5	.9	3.3	670	360	900	1,700	(1,000)	Barker Ranch		0	Minor
Jefferson Creek	T. 10 N.	6,600	11,949	20.6	4.6	0	1.0	4.4	750	380	1,000	1,900	(1,100)	Richard Carver		0	640
Shoshone Creek	T. 10 N.	6,800	10,916	6.1	1.3	0	.2	5.6	170	90	220	450	(270)	--	Pipeline[2]	--	Minor
Subtotal (rounded) (2)									2,000	900	2,700	5,000	3,000				
Subtotal (rounded) (1) + (2)									24,000	12,000	32,000	60,000	36,000				
TONOPAH FLAT																	
TOIYABE RANGE																	
Peavine Creek	T. 9 N.	6,100	11,000	51.4	11	.9	2.8	3.8	2,000	960	2,800	5,000	(3,000)	Peavine, San Antonio		480	720
Cottonwood Creek	T. 8 N.	6,000	9,200	30.6	--	--	--	--	(0)	0	(350)	(700)	(420)	--		0	Minor
Cloverdale Creek	T. 8 N.	5,800	9,400	46.9	--	--	--	--	(0)	0	(325)	(650)	(390)	Cloverdale		100	200
Subtotal (rounded) (3)									2,000	960	3,500	6,400	3,800				
TOTAL (rounded) (1) + (2) + (3)									26,000	13,000	[b]35,000	66,000	40,000				

[a] Included in estimate of other creeks for Young Brothers Ranch.
[b] The estimated average growing-season water supply, based on the relation of wet years to dry years described on page , is 22,000 acre-feet.
[1] Conveys water only to Round Mountain where water was used for mining and milling purposes.
[2] Conveys water only to Round Mountain where water is used for public-supply purposes.

Streams having low ratios temporarily lose substantial amounts of water to the ground-water system during spring snowmelt. The conditions that control this temporary ground-water storage are not well understood; however, the water probably is stored in solution-enlarged fractures of carbonate rocks and (or) alluvium within the canyon. The resultant effect is to reduce the spring snowmelt peak flow and produce a higher and more sustained base flow during late summer and fall, as illustrated by Kingston Creek in figure 10. Kingston, Birch, and Summit Creeks are examples where this interrelation of stream and the ground-water system is significant.

The volume of flow is closely related to stream-basin area, as shown in figure 11. Three curves are shown; the "wettest" curve is for the northern part of the Toiyabe Range (Pablo Creek and north). The graph indicates that the southern part of the Toiyabe Range has less streamflow per unit area. The possible causes could be either less precipitation per altitude zone or above average percolation to the ground-water system and underflow from the mountains. Peavine Creek was observed in July 1968 to possess a series of alternating losing and gaining reaches. Whether such "leaky" conditions are widespread in the southern part of the Toiyabe Range is not known.

Figure 11 shows some departures from the general relation of streamflow to basin area:

(1) South Twin River has more flow than would be expected from the North Toiyabe Range curve. This higher flow, however, probably is due to the fact that the South Twin River basin extends to a higher altitude than other basins (table 7), resulting in a proportionately higher flow from the larger precipitation.

(2) Birch and Broad Creeks have less flow than might be expected. Geologic factors might contribute to above-average underflow from the mountains to the valley area thereby reducing surface runoff.

(3) Willow Creek also has less flow than expected, probably because few areas of high precipitation are within the stream basin, as indicated by data in table 7.

(4) Wall Canyon is commonly dry. Its basin area, nearly 7 square miles, is adequate to produce more runoff; however, the maximum altitude in the basin is only about 8,800 feet. Low precipitation probably accounts for the canyon's dryness.

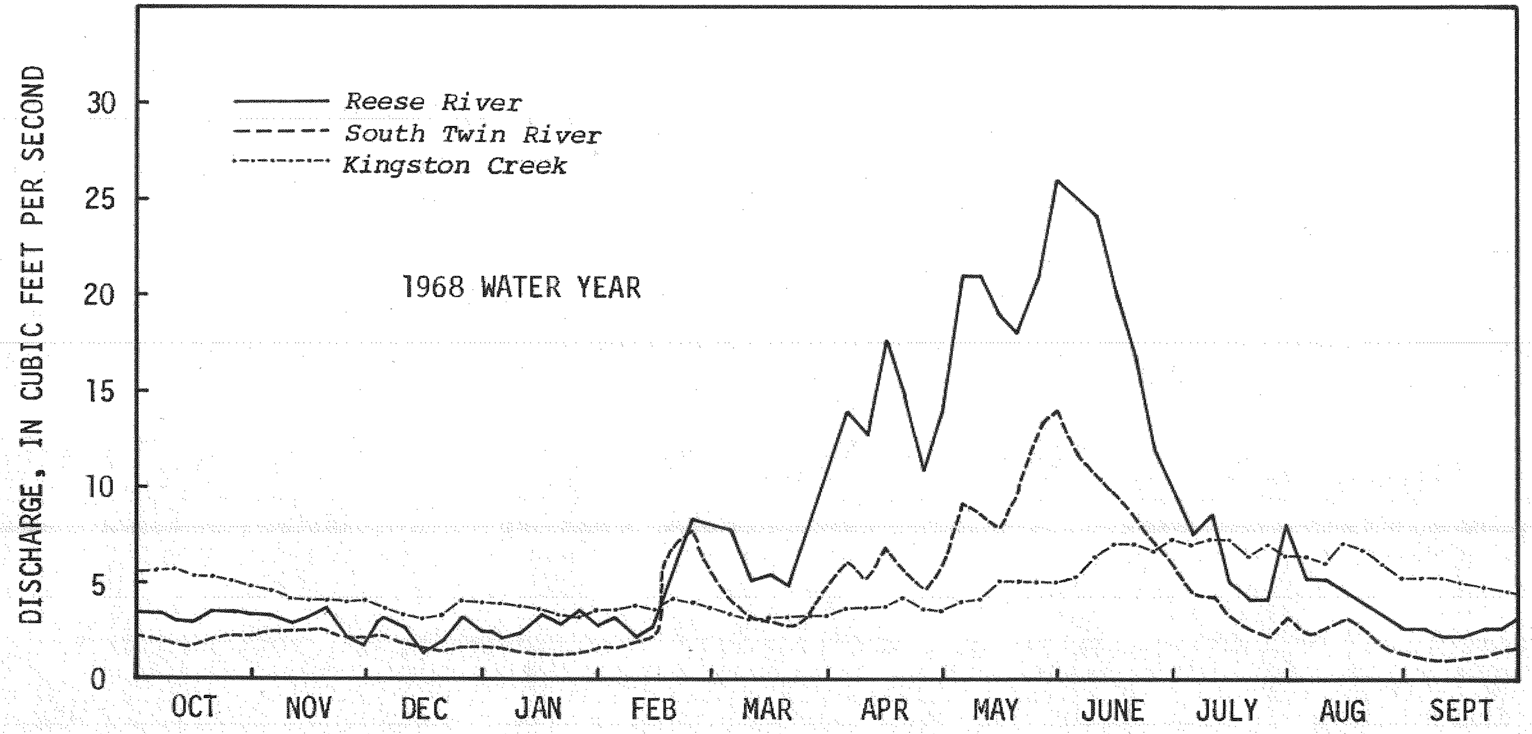

Figure 10. - Hydrographs of Reese River, South Twin River, and Kingston Creek

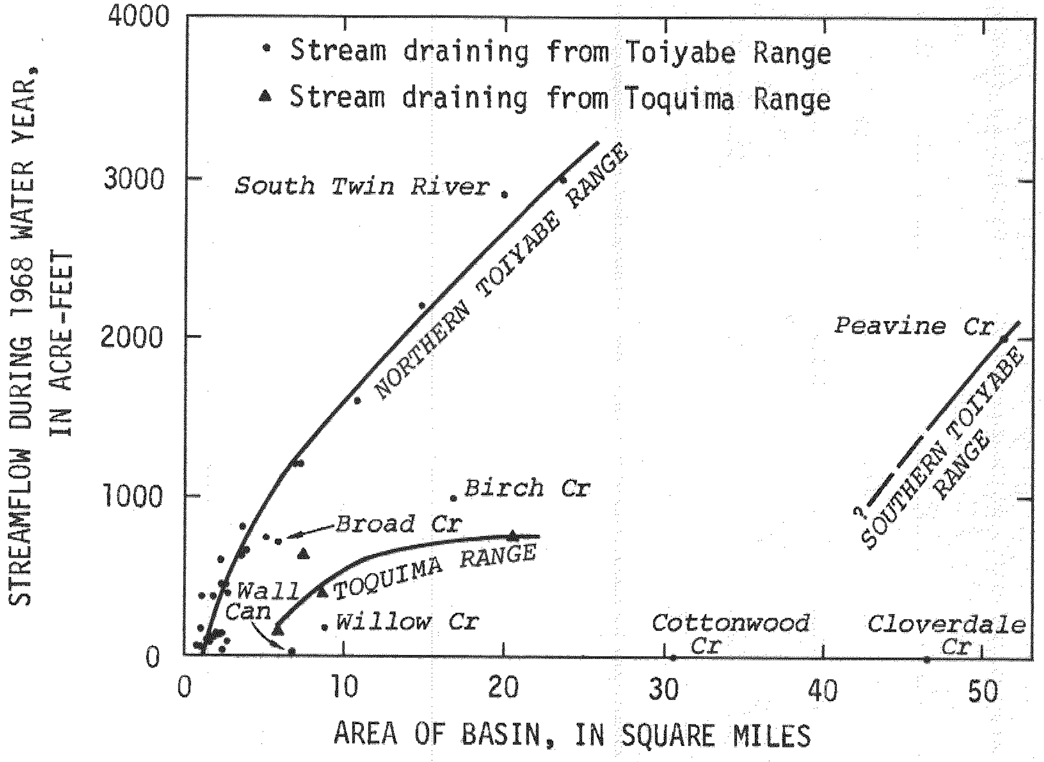

Figure 11. - Relation of stream basin area to streamflow

Monthly runoff values for the 1968 water year for 20 perennial streams were computed from synthesized hydrographs, on the basis of periodic flow measurements. From these values, the percentage of time (based on mean monthly discharge) that various flows were equaled or exceeded were computed and appropriate curves drawn. These curves are presented in figure 12 and provide an approximation for individual rates of flow in a dry year. They also provide a graphic comparison of base-flow characteristics.

INFLOW TO VALLEY-FILL RESERVOIR

The components of inflow to the valley-fill reservoirs are recharge from precipitation, runoff, subsurface inflow from Ione Valley to Tonopah Flat, and percolation to the water table of water imported to Tonopah. Secondary inflow; that is, return flow to ground water from irrigated fields, lawns, and infiltration of sewage effluent, was not estimated as a part of gross ground-water pumpage or spring flow. The relation of the various elements of inflow to the movement and discharge of water is shown in figure 1.

Precipitation

Climatic changes in western North America have been identified from fluctuations in dated tree-ring widths by Fritts (1965). Based on his work and recent precipitation data, the following tabulation is a summary of general changes in climate for Big Smoky Valley, starting in 1800:

Period	Climatic condition
1800-20	wet
1820-65	dry
1865-75	wet
1875-1900	near average
1900-25	wet
1925-35	dry
1935-50	wet
1950-61	dry
1962-68	wet

Meinzer, in his unpublished field notes of 1913 (Book 1, p. 35), reported that Peavine Creek flowed to Midway Station (T. 5 N., R. 41 E.). Because the flow generally continued until about August 1, a storage reservoir was to be constructed three-fourths mile upstream from the station and H. N. Meyers Ranch. In 1968, under somewhat drier climatic conditions, Peavine Creek seldom had flow that far downstream.

The first precipitation stations in the area were established at Austin and Belmont (10 miles northeast of Manhattan) in 1889 (pl. 1). However, of the 13 stations listed in table 8, most were established in the 1940's and 1950's.

Figure 13 shows the seasonal distribution of precipitation for four stations. The following conclusions are drawn from these data: (1) the northern mountains receive the most precipitation during late winter and early spring

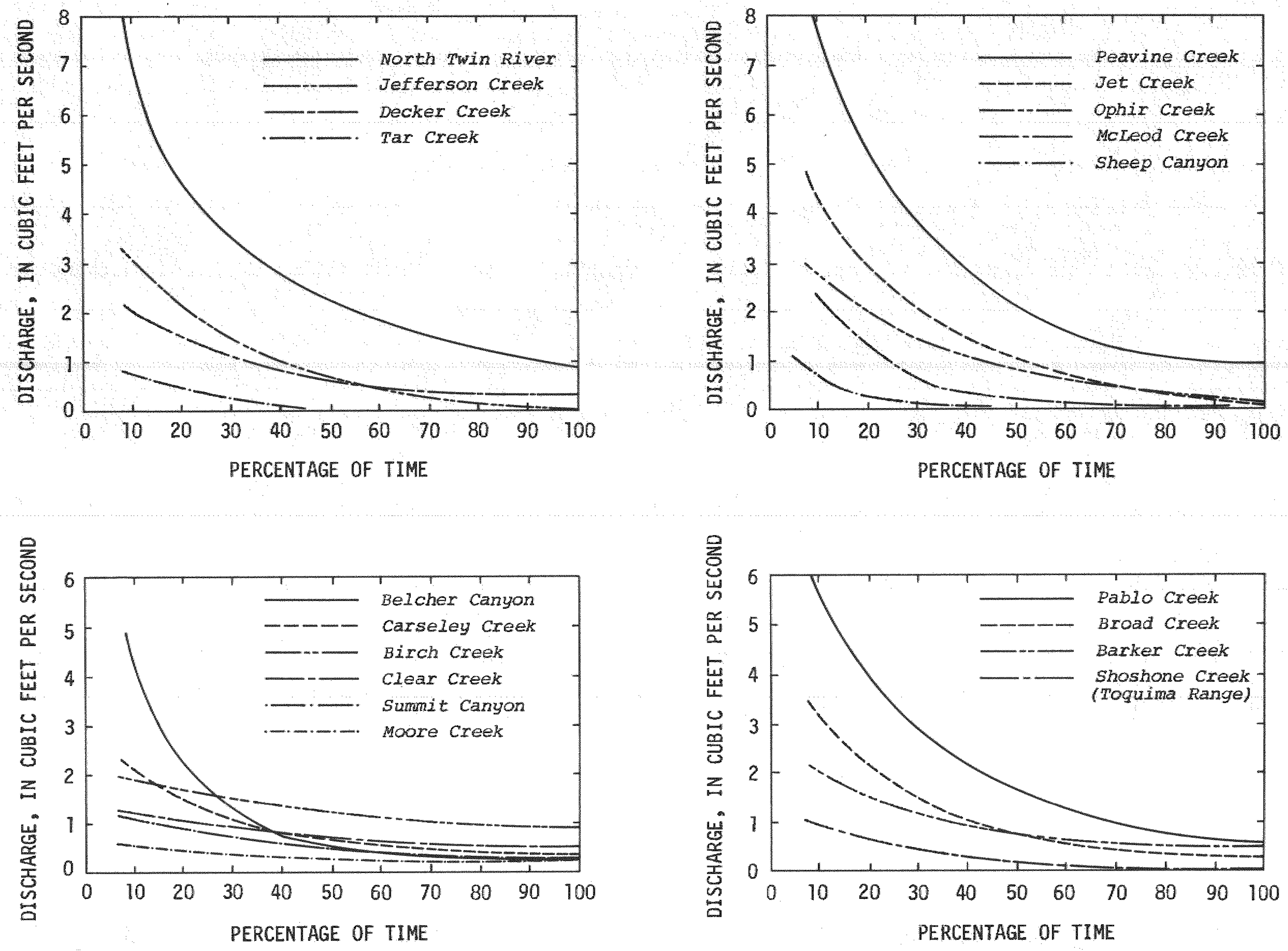

Figure 12. - Percentage of time during 1968 water year in which specified monthly flow was equaled or exceeded

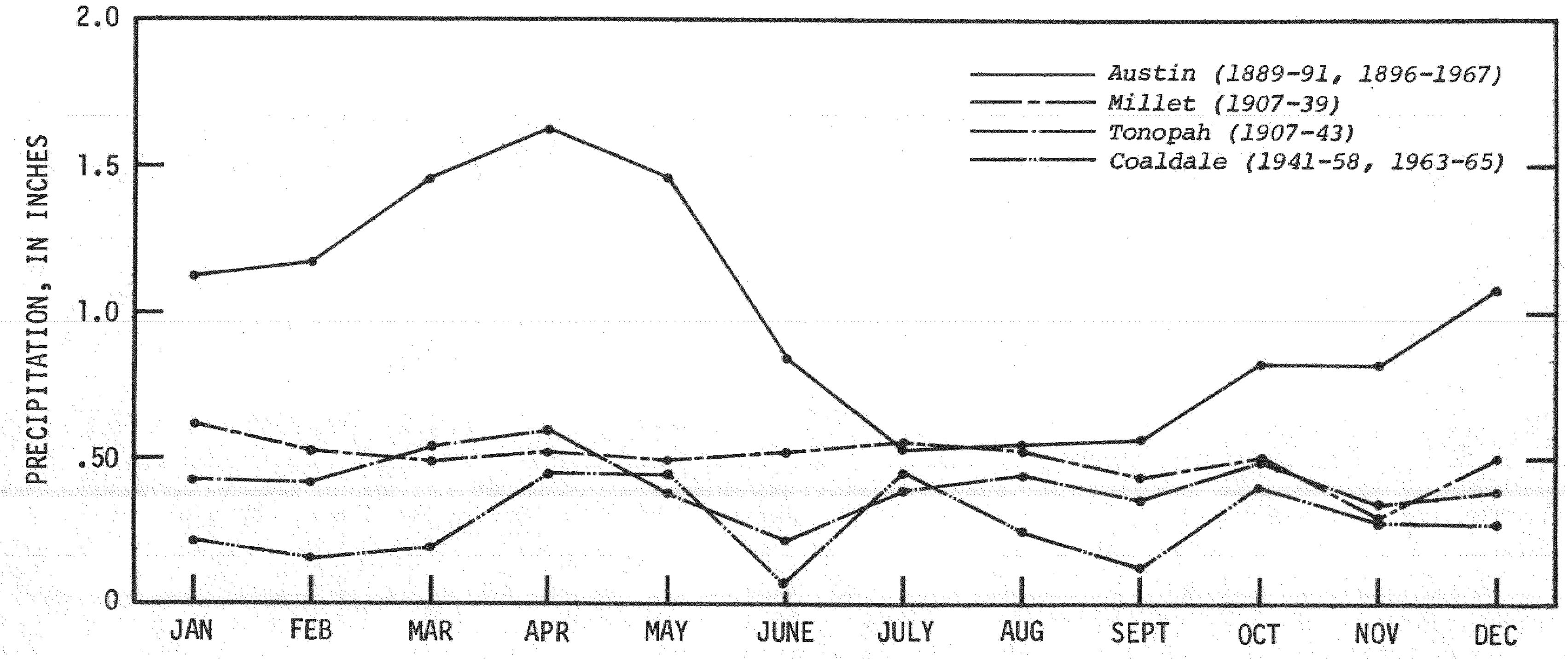

Figure 13. - Average monthly distribution of precipitation at four stations

Table 8.--Average annual precipitation at weather stations

[Compiled in 1968]

Station name	Location number	Period of record[1] (years)	Station altitude (feet)	Average annual precipitation (inches per year) Measured	Average annual precipitation (inches per year) Adjusted to long term
Austin	19/44-19	1889-91 1896-date	6,594	12.15	--
Belmont	10 miles northeast of Manhattan	1889-96 1900-05	7,600	8.53	b 8.5
Coaldale	2/37-8	1941-58 1963-65	4,646	3.33	a 3.2
Ione	17 miles west of Berg Ranch	1952-date	6,986	10.14	b 11.0
Kingston Canyon	16/43-36	1954-date	6,750	13.65	b 14.3
Kingston Summit	17/43-34	1955-date	8,500	16.70	b 17.6
Manhattan Power House	8/44-19	1948-51	6,911	5.78	a 5.4
Millett	13/43-5 and 13/43-19	1907-39	5,500	5.95	b 5.8
Smoky Valley	11/43-29	1949-60	5,625	5.93	b 6.9
Twin Rivers	12/42-15	1956-61	6,500	7.10	b 8.4
Tonopah	2/42-2	1907-53	6,093	4.98	--
Tonopah Airport	8 miles east of Tonopah	1954-date	5,426	4.31	a 4.3
Willow Springs	7/43-30	1941-48	6,120	4.47	a 4.1

1. Last year of published record was 1967.
a. Adjusted, based on record at Tonopah.
b. Adjusted, based on record at Austin.

(Austin curve) and are dry, such as the northern valley floor (Millett curve), during the remainder of the year; (2) the southern mountains (Tonopah curve) show less of an increase in precipitation in the winter than the northern mountains but are wetter than the southern valley floor (Coaldale curve); and (3) summer thunderstorm activity is most apparent in the southern valley.

The altitude-precipitation relation is shown in figure 14. Two generalized curves are given: a "northern curve" for the northern part of the valley and the Toiyabe Range of Tonopah Flat (pl. 2) and a "southern curve" for the remainder of Tonopah Flat. The estimated average annual precipitation, based on these curves, is discussed in the "Recharge" section.

Runoff and Seepage Loss

The method used to estimate runoff from the mountains was described in detail by Moore (1968). In this method, altitude-runoff relations for regions in Nevada have been developed on the basis of long-term records of streamflow, precipitation, local periodic streamflow measurements, and measurements of stream-channel geometry as related to long-term flow.

Runoff during the 1968 water year was about 77 percent of normal, based on the 76-year precipitation record at Austin, or about 74 percent of normal, based on the 17-year streamflow record for Reese River. Most of the deficiency for the year was during April through June, as shown in figure 15.

The 17-year record for Reese River was used as the local base of reference in estimating average annual runoff and streamflow during wet years, dry years, and growing seasons.

Runoff from the mountains, estimated at the mountain front, to the valley-fill reservoir is given in table 9. Little runoff is generated on the apron or the valley floor. Most of the runoff in both Tonopah Flat and the northern part of Big Smoky Valley is from the Toiyabe Range. The streams listed in table 7 have an average annual runoff of about 32,000 acre-feet (about 85 percent of the total runoff in table 9) for the northern part of Big Smoky Valley, and about 3,500 acre-feet (about 70 percent of the total runoff in table 9) for Tonopah Flat. Average annual streamflow crossing the east-west line between Tps. 4 and 5 N. in Tonopah Flat was estimated to be only about 500 acre-feet. Most of the runoff is generated north of this line, but the data indicate that it is greatly dissipated as it flows southward across the valley-fill reservoir.

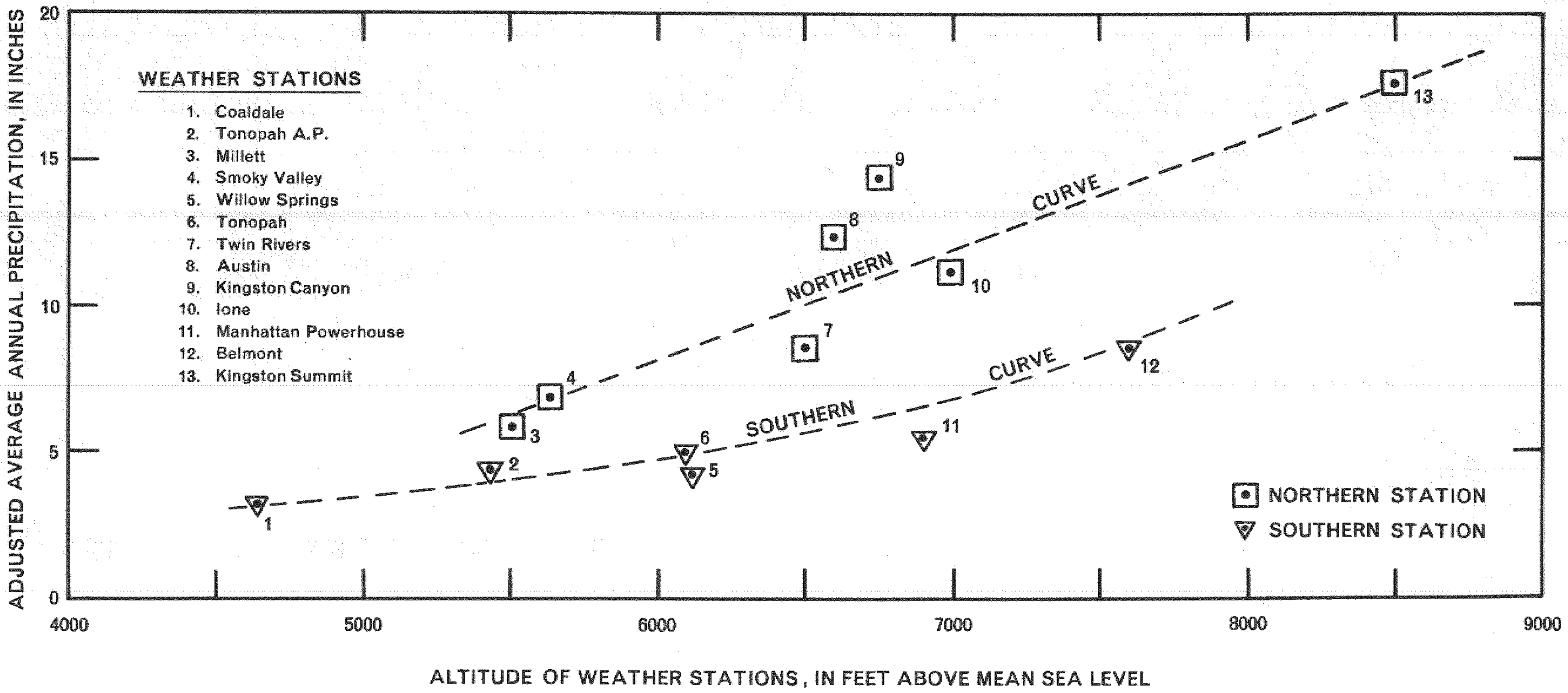

Figure 14.— Altitude — precipitation relation

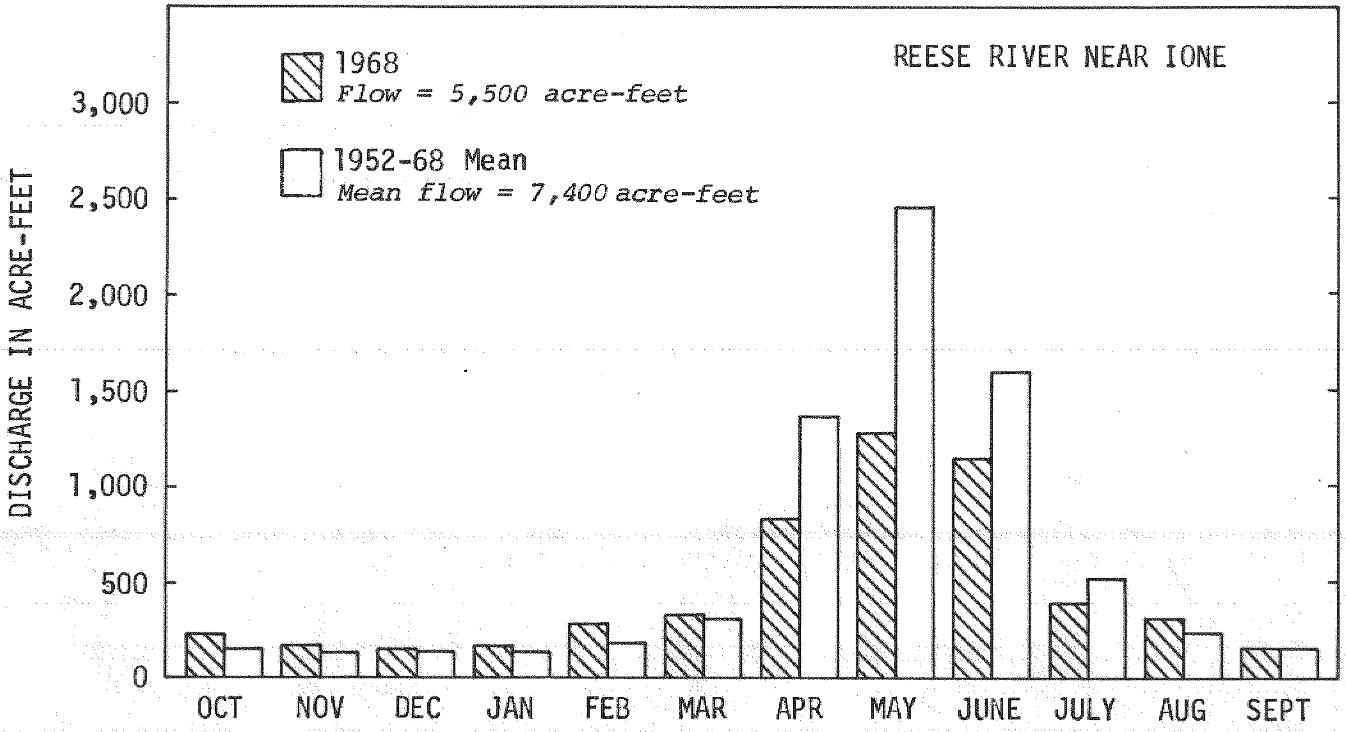

Figure 15. - Flow of Reese River in 1968 and average for 1952-68

Table 9.--Runoff from the mountains

Area	Runoff area (Above an altitude of 7,000 feet)		Estimated average annual runoff	
	Acres	Percentage of runoff area	Acre-feet	Percentage of total runoff
		NORTHERN PART		
Toiyabe Range north of U.S. 50 and Toquima Range north of Moore Creek	100,000	35	2,000	5
Toquima Range south of Moore Creek	56,500	20	4,000	11
Toiyabe Range south of U.S. 50	129,000	45	32,000	84
TOTAL (rounded)	286,000	100	38,000	100
		TONOPAH FLAT		
Toiyabe Range	88,200	68	5,000	99
Other mountain areas	41,900	32	40	1
TOTAL (rounded)	130,000	100	5,000	100

To determine the relation of streamflow losses to ground-water recharge from streams, a total of 12 seepage runs was made on Barker, McLeod, and Sheep (Canyon) Creeks during 1968. On the upper 2 miles of apron, the seepage losses per mile ranged from 0.3 cfs to 1.3 cfs, and averaged about 0.7 cfs. Cooley (1968) made 18 similar seepage runs on Rock, McLeod, and Park Creeks (pl. 1). Seepage losses per mile on these creeks ranged from 0.4 cfs to 2.6 cfs, and averaged 1.4 cfs. The average for the 30 runs is a loss of about 1.0 cfs per mile. The width of the apron, measured between the consolidated rock-older alluvium contact and the older alluvium-younger alluvium contact, averaged about 4 miles. Opposite small streams, the apron was generally narrowest, about 2 miles wide and opposite large streams, such as Kingston Creek and North and South Twin Rivers, as much as 6 miles wide. If 1.0 cfs is a representative loss per mile for stream channel throughout the year, on the upper 2 miles of apron each of the perennial streams has an average loss potential of about 1,500 acre-feet. Because of variations in flow during the season and variations in the ability of the apron to absorb water, this may be too large an estimate for the 40 streams listed in table 7. However, when the width of the apron is considered, nearly all the flow probably can be absorbed before it reaches the valley floor during all but the high-runoff periods when excess flow ponds on the playas and evaporates.

Of the total seepage losses on the aprons, some evaporates, some is consumed by plants, and the bulk becomes ground-water recharge. Under natural conditions, the estimated average annual seepage loss from the 40 major streams is nearly all the estimated average annual streamflow of 35,000 acre-feet (table 7). Because 13 pipelines and lined ditches are used to conduct streamflow diversions across the apron to use areas, the seepage-loss potential in 1968 has been reduced from natural conditions. These diversions were not measured; therefore, the size of the reduction is not known.

Unless the evaporation and transpiration rates from seepage are unusually large and because runoff to playa areas is small during most years, most of 35,000 acre-feet probably becomes ground-water recharge under both natural and 1968 conditions. A hypothetical example of possible ground-water recharge from the 40 streams, under natural and under conditions of total diversion of flow at canyon mouths during the growing season, is shown in table 10. The implication is that such diversions would reduce ground-water recharge.

Table 10.--Hypothetical example of the effect of surface-water development on ground-water recharge

		Estimates for average conditions [Acre-feet per year]	
NATIVE CONDITION			
Flow of stream at canyon mouth during growing season		Assume 1,000	
Infiltration loss on alluvial apron (Assumes about 5 percent reaches ponding areas of valley floor, and evaporates)		950	
Recharge to valley-fill reservoir (Assumes about 20 percent is shallow percolation which is discharged as soil moisture by direct evaporation and vegetation)	(1)	750	
FULLY-DEVELOPED CONDITION			
Flow of stream at canyon mouth during growing season		Assume 1,000	
Delivery to fields by pipeline and sprinkler systems (losses minor)		1,000	
Approximate deep infiltration losses, or recharge (assume 25 percent)	(2)	250	
Reduction in recharge per 1,000 acre-feet of streamflow during growing season	(1) - (2)	500	or about 50 percent

Recharge from Precipitation

A method developed by Eakin and others (1951) was used to compute the estimated average annual recharge from precipitation to the valley-fill reservoirs. These computations are summarized in table 11.

For the southern part of the Toiyabe Range in Tonopah Flat, the precipitation at any given altitude probably is less than that in the northern part of the range, as previously mentioned. This is suggested by the plots of precipitation stations at Kingston Canyon (point 9, fig. 14) in the north and Twin Rivers (point 7, fig. 14) to the south. The position of point 7 with respect to the "northern curve" suggests that precipitation might be about a fifth less in the southern part of the range. Based on these meager data plus the knowledge that precipitation decreases southward, the values of precipitation and recharge shown in parentheses in table 11 are reduced by a like amount.

The relation of recharge from precipitation to other components of the flow system is summarized in figure 1. Nearly 9 percent of the estimated average annual precipitation recharges the valley-fill reservoir in the northern part of the valley, whereas in Tonopah Flat only an estimated 2 percent becomes ground-water recharge.

In the northern part of the valley the distribution of recharge from precipitation is as follows: (1) Toiyabe Range, two-thirds; Toquima Range, one-third, or (2) Lander County, one-third; Nye County, two-thirds.

Because the estimates of runoff (table 9) from the mountains are much smaller than those for recharge (table 11), the implication is that substantial quantities of water must flow through the carbonate and other rocks (pl. 1 and 2) from the mountains and recharge the valley-fill reservoirs or a regional ground-water system. The amount of this underflow is not known, but it probably is about half the estimated average annual recharge computed for the northern part of the valley. Additional discussion of underflow from the Toiyabe Range is in the ground-water budget section.

Inflow from Ione and Royston Valleys

Inflow from Ione and Royston Valleys is in two forms--ground-water inflow and surface-water inflow. Ground-water inflow through alluvium from Ione Valley was estimated by Everett and Rush (1964, p. 12) to be on the order of 2,000 to 3,000 acre-feet per year; the smaller of the two quantities is preferred at this writing. Leakage of ground water through

Table 11.--Estimated average annual precipitation and ground-water recharge

Precipitation zone (feet)	Area (acres)	Range (inches)	Average (feet)	Average (acre-feet)	Percentage of precipitation	Acre-feet
			NORTHERN PART			
9,000-11,949	62,290	>20	2	120,000	25	30,000
8,000- 9,000	84,370	15-20	1.5	130,000	15	20,000
7,000- 8,000	139,000	12-15	1.1	150,000	7	10,000
6,000- 7,000	214,800	8-12	.8	170,000	3	5,100
5,430- 6,000	343,400	<8	.5	170,000	Minor	--
TOTAL (rounded)	843,900	--	0.9	740,000	9	65,000
			TONOPAH FLAT			
			Toiyabe Range			
9,000-10,800	3,220	>20	2	6,400	25	1,600
8,000- 9,000	27,000	15-20	1.5	40,000	15	6,000
7,000- 8,000	58,000	12-15	1.1	64,000	7	4,500
6,000- 7,000	73,900	8-12	.8	59,000	3	1,800
5,070- 6,000	95,500	<8	.5	48,000	Minor	--
Subtotal (rounded)	257,600			a(220,000)		a(14,000)
Adjusted for more arid climate				180,000		11,000
			Royston Valley			
7,000-7,400	460	8-12	.8	370	3	11
5,200-7,000	79,900	<8	.5	40,000	Minor	--
Subtotal (rounded)	80,360			40,000		10
			Other Areas			
9,000-9,274	70	>15	1.5	100	15	15
8,000-9,000	5,630	12-15	1.1	6,200	7	430
7,000-8,000	35,700	8-12	.8	29,000	3	870
4,720-7,000	645,400	<8	.5	320,000	Minor	--
Subtotal (rounded)	686,800			360,000		1,300
TOTAL (rounded)	1,025,000	--	0.6	580,000	2	12,000

a. Considered too large by roughly 20 percent; see text.

consolidated rocks from Ione Valley is possible, but there is no field evidence that any such leakage enters the valley-fill reservoir of Tonopah Flat.

Ground-water inflow from Royston Valley is presumed to be minor and possibly equal to the computed recharge from Royston Valley (table 11), or about 10 acre-feet per year.

Surface-water inflows from Ione and Royston Valleys, estimated from measurements of stream-channel geometry (Moore, 1968, p. 36), were 300 acre-feet and 60 acre-feet, respectively.

Importation of Water

Since 1904 water has been imported to Big Smoky Valley from Ralston Valley to supply the town of Tonopah (Eakin, 1962, p. 20). According to Eakin (1962, p. 22), pumpage to Tonopah in the period 1913-22 averaged about 350 acre-feet per year; the average from 1923 to 1942 was about 120 acre-feet. During World War II the pumpage increased, but much of the water was used at a military base in Ralston Valley. Table 12 summarizes importation, use of water at Tonopah, and assumed recharge of the imported water in 1968.

Table 12.--Summary of estimated water use at Tonopah, 1968

[Based on an interview at Tonopah Public Utilities]

		Acre-feet
Water imported from Ralston Valley		a 328
Supply from sources in Big Smoky Valley		a 0
Total supply (rounded)	(1)	330
System losses due to leakage (assume about 25 percent)	(2)	80
Delivered water	(1) - (2) = (3)	250
Delivered water consumed (assume about 25 percent)	(4)	60
Water entering sewer and septic-tank systems[1]	(3) - (4) = (5)	190
Evapotranspiration of sewage (assume about 30 percent)	(6)	60
Sewage effluent percolation to water table	(5) - (6) = (7)	130
Consumed water	(4) + (6)	120
Recharge of imported water to valley-fill reservoir (rounded)	(2) + (7)	200
Approximate rate of importation	$= \frac{\text{328 ac ft per yr x 325,851 gal per ac ft}}{\text{2,700 population x 365 days per year}} =$	100 gal per person per day
Estimated rate of consumption	$= \frac{\text{120 ac ft per yr x 325,851 gal per ac ft}}{\text{2,700 population x 365 days per year}} =$	40 gal per person per day

1. Sewage entering the system's disposal pond in 1957, when the population was about 1,700, was about 80 acre-feet (U.S. Public Health Service, 1958, p. 168).

a. Reported by Tonopah Public Utilities.

OUTFLOW FROM THE VALLEY-FILL RESERVOIRS

The components of outflow from Big Smoky Valley are considered under headings of evapotranspiration, spring discharge, subsurface outflow, irrigation, and other consumptive uses. The relation of the various elements of outflow of water from the valley-fill reservoirs to the source and movement of water is shown in figure 1.

Evapotranspiration

Plants called phreatophytes extend their roots to a shallow water table and consume ground water. The most common phreatophytes in Big Smoky Valley are listed in tables 13 and 14. In addition, cottonwood, willow, and wildrose grow near springs and in mountain canyons. Their acreage is small and therefore, is not listed. Areas of principal phreatophytes are shown on plates 1 and 2. Estimates of evapotranspiration of ground water, under native conditions, are listed in tables 13 and 14. The phreatophyte areas shown on the plates are based on forage inventories by the U.S. Bureau of Land Management and field inventory by the authors. Evapotranspiration rates are based on research done by Lee (1912), White (1932), Young and Blaney (1942), Houston (1950), and Robinson (1965) in other areas.

Meinzer (1917, p. 102-104), utilizing the work done by Lee (1912) on water use by vegetation in Owens Valley, California, estimated that the evapotranspiration in the northern part of the valley was between 50,000 and 100,000 acre-feet per year. Similarly, for Tonopah Flat, he estimated the evapotranspiration to be 10,000 to 30,000 acre-feet per year. Considering the state of knowledge half a century ago, those estimates are remarkably similar to those made for the present report.

The report by Robinson (1953, p. 143) on Big Smoky Valley states, "From this area, therefore, evaporation must be at least 500,000 acre-feet per year."

This quantity is an obvious misprint, and should be corrected to read, ". . .at least 50,000 acre-feet a year."

Some native phreatophytes constitute crops; that is, native grass is pastured or cut as hay. Also, some native phreatophytes have been eradicated and replaced by irrigated fields. All native phreatophytes are included in tables 13 and 14. Their use of water and land will be discussed further in the irrigation section of this report.

Table 13.--Evapotranspiration of ground water from the northern part of Big Smoky Valley under native conditions

Vegetation	Phreatophyte ground cover (percent)	Depth to water (feet)	Area (acres)	Average annual evapotranspiration Acre-feet per acre	Average annual evapotranspiration Acre-feet (rounded)
Mostly greasewood and rabbitbrush; mixed with various amounts of big sage, dryland greasewood, and shadscale. Saltgrass less than 10 percent.	5-15	10-50	49,400	0.2	9,900
Greasewood, rabbitbrush, and saltgrass. Saltgrass more than 10 percent. Mostly pickleweed in some small areas.	(a)	5-15	37,700	.5	19,000
Meadow. Mostly saltgrass, sacaton, and other native grasses.	(a)	1-10	30,800	1.0	31,000
Wet meadow, tules, and marsh.	(a)	0-5	1,000	2.0	2,000
Bare soil of playa	0	1-12	23,300	.1	2,300
Total (rounded)			142,000		64,000

a. Not estimated.

Table 14.--Evapotranspiration of ground water from Tonopah Flat under native conditions

Vegetation	Location	Phreatophyte ground cover (percent)	Depth to water (feet)	Area (acres)	Average annual evapotranspiration	
					Acre-feet per acre	Acre-feet (rounded)
Mostly greasewood and rabbitbrush; mixed with various amounts of dry-land greasewood and shadscale. Minor amounts of saltbush at San Antonio Ranch	Near Millers, San Antonio Ranch, Cloverdale, and in Peavine (Creek) Canyon[1]	5-15	10-50	22,400	0.2	4,500
Greasewood and rabbitbrush mixed with large amounts of dry-land greasewood and shadscale	Adjoining playa and in T. 6 N.	5-10	30-50	8,400	.1	840
Meadow; mostly saltgrass, sacaton, and other native grasses	Cloverdale and San Antonio Ranches and minor amounts at Crow Springs[1] (T. 5 N., R. 39 E.)	(a)	1-10	400	1.0	400
Bare soil of playa	--	0	1-15	4,000	.1	400
Total (rounded)				35,000		6,000

1. Phreatophytes in Peavine Canyon and at Crow Springs not shown on plate 2 because of their limited area.

a. Not estimated.

Springs

Many springs are in Big Smoky Valley; however, most of them are small mountain springs that are used only for stock watering when they flow. Some large springs flow on the alluvial aprons and on the valley floor, and are, or were in the past, diverted for irrigation. Table 31 summarizes data on most of the large springs and some of the small ones. Their locations are shown on plates 1 and 2.

Discharge from springs supports phreatophytes or ponds, is used to irrigate crops, or percolates back to the water table. Estimates of phreatophyte discharge in tables 13 and 14 include that part of the spring discharge that is evapotranspired.

Spring water ranges in temperature from about 55°F (13°C) for the many cold springs to 179°F (82°C) for Darrough Hot Spring. Spencer Hot Springs, another notably high-temperature spring, has a temperature of 139°F (59°C). Concrete swimming pools have been constructed at both hot springs.

A large number of springs issue from the alluvium at an altitude of about 5,500 feet along the west side of the valley floor in the northern part of the valley (pl. 1). Most of these springs have small individual flows, but the combined flow is probably a few thousand gallons per minute. The estimated total spring discharge in Big Smoky Valley is at least 3,000 gpm, or about 5,000 acre-feet per year.

Subsurface Outflow

Meinzer (1917, p. 86) said: "The principal leakage out of the basin is believed to be at the west end of the lower valley." With additional ground-water data gathered since 1913, this still remains a possibility, although Robinson (1953, p. 144) described Big Smoky Valley as a closed basin.

Voluminous subsurface outflow from the valley-fill reservoir in the southwestern part of Tonopah Flat to the lower-altitude reservoirs in either Columbus Salt Marsh, Fish Lake, or Clayton Valleys is unlikely. First, there is no evidence of loss of head with depth below land surface in the area, and second, it is unlikely that the valley-fill reservoir has sufficiently high transmissivity to transmit large quantities of water to the southwestern end of the basin from the major recharge area in the northern part of Tonopah Flat with the low gradients indicated by water-level data in figure 16 and plate 2. Whether there is hydraulic continuity between the playa and the wells to the west, and therefore probable subsurface outflow due to apparent outflow gradient (fig. 16), is not known; however, such outflow probably would be very small because of the low gradient (about 1 foot per mile) and a narrow flow path.

The most plausible explanation for any subsurface outflow would be water entering a regional consolidated rock ground-water system in the northern part of Tonopah Flat and flowing to Clayton Valley. Previous work by Rush (1968a, p. 15) indicates that Clayton Valley probably receives substantial ground-water inflow from Big Smoky Valley; however, the quantity probably is less than the 13,000 acre-feet per year estimated by Rush (1968, p. 26). Subsurface outflow is further discussed in the "Water budget" and "Analog model simulation" sections.

Figure 16 shows two wells with what appears to be unusually high water levels. West of Highway 47, well 1N/38-9d (also listed in table 29) has a water-level altitude of 4,785 feet. Several acres of greasewood grow about the site and salt was present on the ground, both confirming the shallow water level observed in an auger hole at the destroyed well site. Data and field observations indicate that a small mound of ground water is present, but the cause is not known. The other high-water level was observed in well 1N/39-3a (table 29) which was drilled in a thin alluvial, upland area. The ground water is probably saturating a lower alluvial zone just above relatively impermeable bedrock. This water could be hydrologically perched.

Irrigation

Growing Season for Crops

Length of growing season for crops was estimated from temperature data (table 15) for stations at Austin, Smoky Valley, and Tonopah (table 8). Assuming that killing frosts generally occur at a temperature of about 28°F for the principal crops, grass and alfalfa, the following estimates were made: (1) for the northern part of the valley and Tonopah Flat north of San Antonio Ranch, the average growing season on the valley floor is 130 ± 20 days; and (2) for Tonopah Flat south of San Antonio Ranch, the average for the valley floor is 150 ± 20 days, and for the apron and the mountains, 160 ± 20 days. Houston (1950) estimated the growing season for Upper Reese River Valley (pl. 1), an area probably having a growing season nearly as long as in the northern part of Big Smoky Valley, as 117 days and for the Tonopah area, as 144 days. The growing season generally extends from May through September.

The ground and the layers of air near it are rapidly chilled after sunset by terrestrial radiation through the clear, dry air. Because of the increased density of the cooled air, it cascades down mountain slopes and the apron, to where it concentrates in the basin, restricting the growing season on the valley floor.

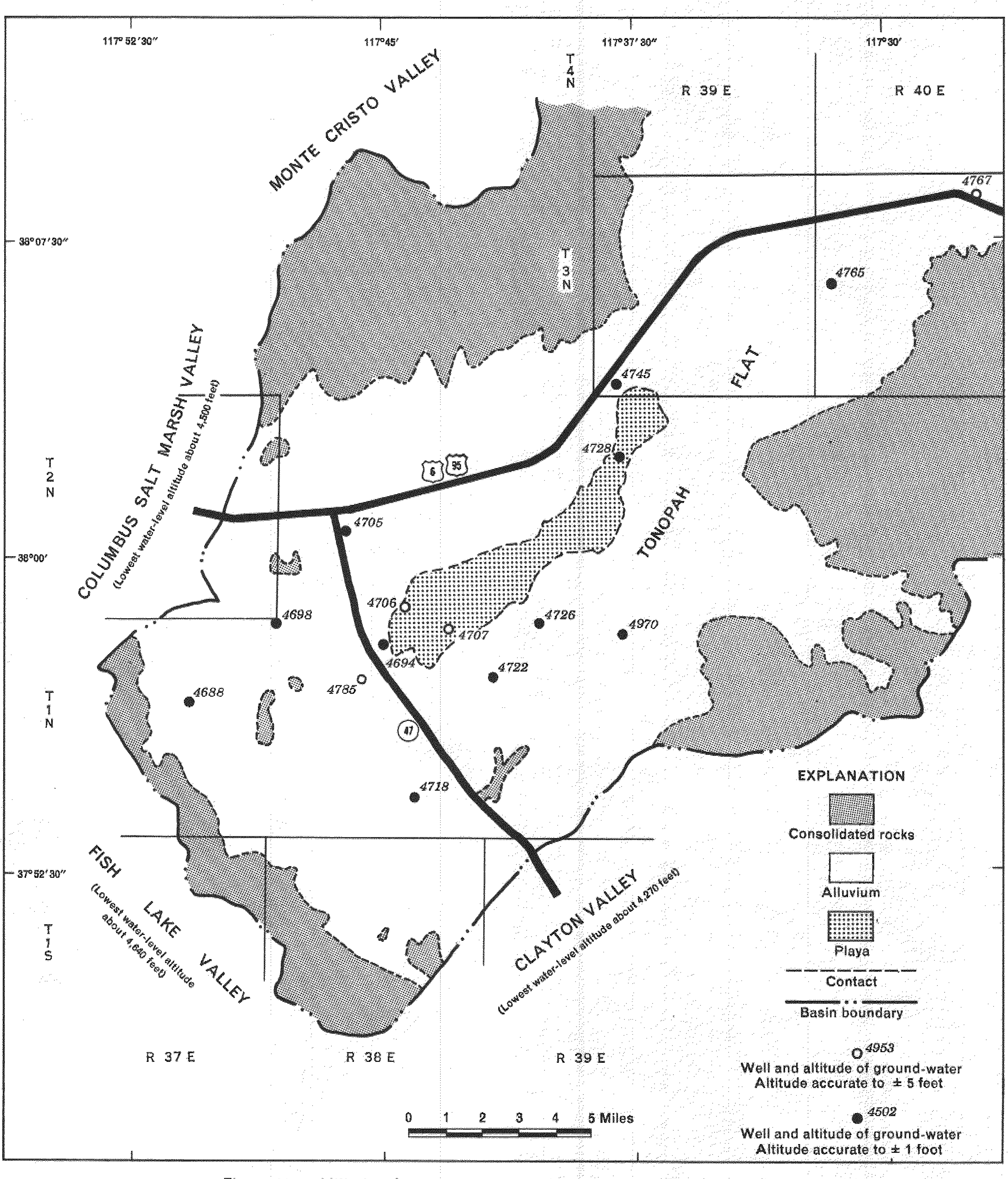

Figure 16.— Altitude of water-table beneath southwestern Tonopah Flat

(Upper photographs): Irrigated alfalfa fields. (Lower left photograph): A large greasewood mound on the playa of Tonopah Flat.

Table 15.--Length of periods between temperatures of 32°, 28°, and 24°F

[For station locations see table 7]

	Austin[1]			Smoky Valley[2]			Tonopah[3]		
	32°F	28°F	24°F	32°F	28°F	24°F	32°F	28°F	24°F
Minimum recorded (days)	84	113	133	68	91	114	88	114	142
Maximum recorded (days)	134	162	198	142	180	202	171	201	237
Average (days)	112	134	165	107	139	158	143	170	195
Normal range (days)	100-130	120-155	150-180	100-130	115-150	145-180	140-160	160-180	170-210

1. Period of record, 1948-66.
2. Period of record, 1950-66.
3. Period of record, 1948-66.

Suitability of Water for Irrigation

Based on the partial chemical analyses in table 32, all streamflow from the mountains probably is suitable for irrigation. Most alluvial areas yield usable ground water; however, shallow wells on or near playas probably would yield unsuitable water, based on criteria established by the United States Salinity Laboratory Staff (1954) and the National Technical Advisory Committee (1968, p. 143-177). If doubt exists as to the quality of an irrigation water, contact the local County Agricultural Agent or the University of Nevada Cooperative Extension Service for advice.

Water Consumption by Crops

The following estimates of optimum water consumption by crops in Big Smoky Valley are based on work by Houston (1950), Tovey (1963), Dylla and Muckel (1964), and the California Division of Water Resources (1942): (1) grass pasture, 1.5 feet; (2) grass hay, usually one cutting and then pastured, 2 feet; (3) alfalfa hay, usually two cuttings and then pastured, 2 feet; and (4) alfalfa hay, usually two to three cuttings, 2.5 feet. Because of local water shortages, some crops consume water at effective rates less than the optimum rates listed above.

These criteria were used to estimate the water consumption by crops in each ranch or ranch subdivision. The areas of cropland, and volumes of irrigation water listed in tables 16 and 17 are totals for the various crops, water sources, and volume of irrigation water, as compiled from information supplied by ranch owners and foremen. As indicated in table 17, water from several sources was used to irrigate some fields. Therefore, some acreage is listed more than once in table 17 and acreage totals are not the sum of the listed acreage items, but are the actual area under irrigation.

In most cases, water in excess of the quantities listed in tables 16 and 17 was diverted from streams, wells, and springs. The difference between the diversions and water consumption by crops is water needed for leaching, water percolating to the water table from ditches and fields, and water lost by evapotranspiration from ditches and areas of vegetation adjoining fields where water may drain.

In addition to irrigation water, the average precipitation on fields during the growing season is about 2 inches.

Table 16.--Crops and irrigation consumption

[Based on interview of ranch operators]

Area	Crop	Wet years		Dry years and 1968		Average year[1]	
		Acres	Acre-feet per year	Acres	Acre-feet per year	Acres	Acre-feet per year
BIG SMOKY VALLEY, NORTHERN PART							
Lander County	Grass pasture	660	970	580	500	610	660
	Grass hay	300	300	300	150	300	200
	Alfalfa hay	340	780	340	670	340	710
Subtotal (rounded)		1,300	2,000	1,200	1,300	1,200	1,600
Nye County	Grass pasture	4,300	5,700	4,100	4,300	4,200	4,700
	Grass hay	2,200	3,700	1,500	2,000	1,700	2,600
	Alfalfa hay	1,100	2,900	[a] 1,200	2,800	1,200	2,800
Subtotal (rounded)		7,600	12,000	6,800	9,000	7,100	10,000
TOTAL (rounded)		8,900	14,000	8,000	10,000	8,300	12,000
TONOPAH FLAT							
Nye County	Grass pasture	400	550	400	350	400	420
	Grass hay	0	0	0	0	0	0
	Alfalfa hay	250	510	250	510	250	510
Subtotal (rounded)		650	1,100	650	850	650	930
Esmeralda County	(No irrigation or subirrigation)						
TOTAL (rounded)		650	1,100	650	850	650	930

1. Based on proportion of wet years to dry years, described on page

a. Includes 160 acres irrigated in 1968 for the first time in many years.

Table 17.--Source of water and irrigation consumption

[Based on interviews of ranch operators]

		Wet years			Dry years and 1968			Average year[1]		
Area	Source of water	Acres	Acre-feet per year	Water consumption (percent)	Acres	Acre-feet per year	Water consumption (percent)	Acres	Acre-feet per year	Percent of total water consumption
				BIG SMOKY VALLEY, NORTHERN PART						
Lander County	Streams	1,300	1,900	14	700	840	8	900	1,200	10
	Wells	0	0	0	0	0	0	0	0	0
	Springs and subirrigation	320	170	1	900	470	5	710	370	3
	Subtotal (rounded)	a1,300	2,100	15	a1,200	1,300	10	a1,200	1,600	15
Nye County	Streams	5,500	5,600	40	1,800	1,900	19	3,000	3,100	26
	Wells	960	1,500	11	b 960	1,700	17	960	1,600	13
	Springs and subirrigation	5,800	5,300	38	5,700	5,600	56	5,700	5,500	46
	Subtotal (rounded)	a7,600	12,000	85	a6,800	9,000	90	a7,100	10,000	85
TOTALS (rounded)	Streams	6,800	7,500	54	2,500	2,700	27	3,900	4,300	36
	Wells	960	1,500	11	960	1,700	17	960	1,600	13
	Springs and subirrigation	6,100	5,500	39	6,600	6,100	61	6,400	5,900	49
	Total (rounded)	a8,900	14,000	100	a8,000	10,000	100	a8,300	12,000	100
				TONOPAH FLAT						
Nye County	Streams	640	920	84	440	580	68	510	690	74
	Wells	10	10	Minor	10	10	Minor	10	10	1
	Springs and subirrigation	320	160	15	400	260	31	370	230	25
	Subtotal (rounded)	a650	1,100	100	a650	850	100	a650	930	100
Esmeralda County				(No irrigation or subirrigation)						
Total (rounded)		a650	1,100	100	a650	850	100	a650	930	100

1. Based on proportion of wet years to dry years, described on page .

a. Because water from several sources was used to irrigate some fields, this subtotal is not the sum of the above; rather it is the actual area under irrigation (table 16).

b. Includes 160 acres irrigated in 1968 for the first time in many years.

Water Used for Leaching Fields

Leaching of soils to keep salts moving downward below the effective root zone of crops is a necessary irrigation practice. Leaching requires that more water be applied to fields than otherwise is necessary to grow a crop.

Water samples collected in Big Smoky Valley, where irrigation is possible (in the nonplaya areas), generally had specific conductances less than about 600 micromhos per centimeter, and averaged about 300 micromhos per centimeter. Based on data listed in table 18, leaching requirements per 1,000 acre-feet of water applied to alfalfa and similar salt-tolerant crops, with the decrement of crop yield limited to 10 percent, is about 50 acre-feet. For the northern part of the valley and Tonopah Flat, the average annual leaching requirements for the above crops and decrement would be about 650 acre-feet and 50 acre-feet, respectively, on the basis of water consumption data in table 17. In 1968, those required quantities were about 530 acre-feet and 45 acre-feet, respectively.

Streamflow

Thirty-six streams are diverted for irrigation. All but three, Moore, Barker, and Jefferson Creeks, drain from the Toiyabe Range. During dry years, such as 1968, about one-half of them do not flow to fields because of stream-channel and ditch-infiltration losses of the smaller flows. Table 17 summarizes the amount of streamflow consumed by crops. The principal streams are listed in table 7 and shown on plates 1 and 2. During the average growing season, the 40 streams listed in table 7 have a total flow of about 22,000 acre-feet.

Wells

In 1968, 22 wells were used for irrigation; of these, 6 were pumped; the remainder were unpumped flowing wells.

Table 17 summarizes irrigation from wells. Of the 960 acres of cropland irrigated by wells in the northern part of the valley, about 700 acres was irrigated by water from pumped wells; the remainder from flowing wells along the west margin of the valley floor. In 1968, on Tonopah Flat, 10 flowing wells were used to irrigate about 10 acres of alfalfa at San Antonio Ranch.

Table 18.--Leaching requirements for alfalfa

[Based on criteria established by Fuller (1965) and Bernstein (1964)]

Specific conductance of irrigation water (micromhos/cm2)	Percentage of applied water needed to leach soils		
	10 percent decrement of crop yield	25 percent decrement of crop yield	50 percent decrement of crop yield
100	1.7	1	.6
200	2.3	2	1
300	5	3	2
500	8	5	3
1,000	17	10	6
2,000	33	20	12

Sprinkler systems were used with the six pumped wells to apply water to fields. The six pumped wells were wells 9/43-9bb, 10/43-5aa3, 11/43-29bc, 12/43-4d, 12/43-9b, and 12/43-9c1 (table 29 and pl. 1). The water from flowing wells was conveyed in ditches. At San Antonio Ranch, water from the flowing wells was collected into a pipeline before being distributed in ditches.

Springs and Subirrigation

The principal springs used to irrigate crops are Gilman, Darrough, Charnock, and Blue Springs (table 17). Many other small springs and seeps are used for irrigation. They are in T. 11 N. to T. 15 N., and generally flow from the valley floor in shallow water-table areas or from the apron along the Toiyabe Range (pl. 1).

Subirrigation, or the use of ground water by deep rooting crops in shallow water-table areas (fig. 6) is limited mostly to the western side of the valley floor of the northern part of the valley. Under native conditions (pl. 1) these areas supported saltgrass, meadow grass, and sacaton.

Table 17 summarizes the irrigation consumption of spring flow and ground water by subirrigation. For the northern part of the valley and Tonopah Flat, an estimated third of the combined consumption by crops of springflow and subirrigation water, listed in table 17, is from springs.

Public-Supply, Domestic, and Stock Consumption

Public-supply water systems are operated at Round Mountain, Manhattan, and Tonopah. The sources of supply for Round Mountain are underflow of Shoshone Creek, west of the town, and Ink House Spring, northeast of town (pl. 1). Water is conveyed in a pipeline system to Round Mountain by gravity. At Manhattan a well is the source of supply. Water is imported to Tonopah from Ralston Valley, as described in the section "Importation of water." Estimates of public-supply, domestic, and stock consumption are listed in table 19.

Wells are the main source of domestic supply; however, some small springs are used. Ground-water supplies for stock are mostly from springs, with wells as a secondary source.

Table 19.--Summary of public-supply, domestic, and stock-water consumption in 1968

Use		Estimated net consumption[1] (acre-feet per year)
BIG SMOKY VALLEY, NORTHERN PART		
Round Mountain public supply (population 195)	a	<10
Domestic, excluding Round Mountain (125 people)	a	<10
Stock, on the order of 1,500 head of cattle	b	10
Total (rounded)		25
TONOPAH FLAT		
Manhattan public supply (population 14)	a	<1
Tonopah public supply import (table 12)		120
Domestic, excluding Manhattan and Tonopah (population on the order of 25)	a	<5
Stock, on the order of 500 head of cattle	b	<5
Total (rounded)		130

[1] All water is from ground-water sources. To compute estimated gross supply, multiply net consumption by a factor of about 2.5, as determined at Tonopah (table 12).

a. Based on the net consumption rate at Tonopah (table 12) of 40 gallons per person per day.

b. Based on a consumption rate by beef cattle of 6 gallons per head per day.

For the chemical constituents listed in table 32, all sampled streams amd most sampled wells and springs met the drinking-water standards established for chemical quality by the U.S. Public Health Service (1962). Areas of poor-quality drinking water are generalized as follows: (1) ground water with concentrations exceeding recommended standards for sulfate (250 mg/l), chloride (250 mg/l), and dissolved solids (500 mg/l) probably will be encountered by most wells drilled on the playas or in the vicinity and southwest of the playa of Tonopah Flat, and (2) ground water near Spencer Hot Springs has excessive concentrations of dissolved solids.

If doubt exists as to the potability of a water supply, contact the Nevada Bureau of Environmental Health, Carson City, Nevada.

Industrial Use

In the past, large quantities of surface water were used by mills at Ophir, Manhattan, and Round Mountain. Ground-water supplies were developed at Millers and near Round Mountain along the pipeline extending from Jett (Creek) Canyon. At Tonopah, mills used the imported water from Ralston Valley.

In 1968, no ground water was pumped and used by nonagricultural industry and only a minor amount of surface water was used at Round Mountain. The Round Mountain industrial supply is from Jett Creek and is piped across the valley (pl. 1) to mining and milling facilities that were receiving only minor use in 1968 and 1969.

GROUND-WATER BUDGETS FOR THE VALLEY-FILL RESERVOIRS

Over the long term and for native conditions, inflow to and outflow from a ground-water system are equal. Accordingly, a ground-water budget for native conditions expresses the quantity of water flowing in a hydrologic system under equilibrium conditions. The budget generally is designed to determine the magnitude of error in the estimates. A budget that balances reasonably will lends credence to the individual elements of inflow and outflow, which are depended upon by those concerned with water development and mangement.

For Big Smoky Valley, equilibrium conditions existed up to the time that man began to develop the area for mining and agriculture. Surface-water diversions from the principal streams began about 100 years ago and have continued to date. Pumping and importation of water have modified the natural condition only to a very small extent. The principal changes have been a slight decrease in the amount of ground water in storage near wells and a small increase of ground water in storage near Tonopah due to water import.

Ground-water budgets, for native conditions, are given in table 20. Elements of inflow and outflow, not associated with native conditions but with development, will be summarized in the section, "Water use in 1968".

Because inflow and outflow are equal over the long term and for native conditions, the imbalance in the budget is attributed to unresolved hydrologic factors. The value selected to represent both inflow and outflow in table 20 is taken as the average of the two values for the northern part of the valley. For Tonopah Flat, the large imbalance is attributed to probable loss of water from the system as subsurface outflow probably to Clayton Valley. (See "Subsurface outflow" section for a further discussion.)

Table 20.--Ground-water budget for native conditions

[All quantities in acre-feet per year]

		Northern part	Tonopah Flat
INFLOW:			
Recharge from precipitation (table 11)		65,000	12,000
Subsurface inflow (p. 32)		None	2,000
Total inflow	(1)	65,000	14,000
OUTFLOW:			
Evapotranspiration (tables 13 and 14)		64,000	6,000
Subsurface outflow (p. 39)		None	(a)
Total outflow	(2)	64,000	6,000
IMBALANCE: (1) - (2)		1,000	b 8,000
Value selected to represent both inflow and outflow:		65,000	14,000

a. No direct estimate made; see footnote b.

b. May be equal to subsurface outflow to Clayton Valley previously estimated by Rush (1968, p. 26) to be about 13,000 acre-feet per year.

ANALOG MODEL SIMULATION

Electrical analog models are simply scaled-down versions of the aquifer flow system constructed from suitable electronic components. Electrical flow through the model and water flow through an aquifer are defined by congruent laws. Steady-state electrical analog models were built to simulate the interrelation of recharge, discharge, hydraulic gradients, transmissivity, and boundary conditions of the valley-fill reservoirs.

The model indicates that: (1) the average transmissivity of the valley-fill reservoir in the northern part of the valley, excluding the highly transmissive area (greater than 50,000 gpd per ft) in T. 10 N. (fig. 4), is generally between 30,000 and 40,000 gpd per ft; (2) for Tonopah Flat the central segment (Tps. 4 to 6 N.) of the valley-fill reservoir probably has a transmissivity generally between 25,000 and 50,000 gpd per ft and in Tps. 6 and 7 N. the values are probably between 50,000 and 100,000 gpd per ft; and (3) recharge from the Toiyabe Range and nearby areas flows southward through the central segment of the valley-fill reservoir in Tonopah Flat with losses to subsurface outflow possibly occurring in the central segment or in the Millers area (Tps. 3 and 4 N.).

The conclusions drawn from the models generally support similar conclusions presented elsewhere in the report.

AVAILABLE WATER SUPPLY

Water for development can be obtained from streams and the valley-fill reservoir. In the following sections, the conceptual quantities of water, streamflow, perennial yield, transitional storage reserve, and system yield, will be discussed and evaluated.

Streamflow

For practical purposes the streamflow that can be developed essentially is limited to the flow of the 40 streams, as summarized in table 7. Because streamflow percolates to the water table becoming ground water, development of streamflow will ultimately reduce the amount of natural ground-water discharge from the system.

The amount of average annual flow of the streams listed in table 7 is estimated to be about 32,000 acre-feet in the northern part of the valley and 3,500 acre-feet in Tonopah Flat.

Perennial Yield

The perennial yield of a valley-fill reservoir may be defined as the maximum amount of natural discharge that can be salvaged each year over the long term by pumping without bringing about some undesired result. For the northern part of Big Smoky Valley, all the outflow (evapotranspiration, table 13) probably can be salvaged; therefore, the estimated perennial yield is about 65,000 acre-feet.

For Tonopah Flat, the estimated average annual natural discharge is 14,000 acre-feet; however, the probable subsurface outflow is such that it may not be readily salvaged. The preliminary estimate of perennial yield, therefore, is limited to 6,000 acre-feet, the quantity of evapotranspiration (table 14).

Transitional Storage Reserve

Transitional storage reserve has been defined by Worts (1967) as the quantity of water in storage in a particular ground-water reservoir that can be extracted and beneficially used during the transition period between natural equilibrium conditions and new equilibrium conditions under the perennial-yield concept of water development. In the arid environment of the Great Basin, the transitional storage reserve of such a reservoir is the amount of stored water available for withdrawal by pumping during the nonequilibrium period of development, or period of lowering water levels. Therefore, transitional storage reserve is a specific part of the total ground-water resource that can be taken from storage; it is water that is available in addition to the perennial yield, but on a once-only basis.

Most pertinent is the fact that no ground-water source can be developed without causing storage depletion. The magnitude of depletion varies directly with distance of development from any recharge and discharge boundaries in the ground-water system.

To compute the transitional storage reserve of the valley-fill reservoirs, several assumptions are made: (1) Wells would be strategically situated in, near, and around areas of natural discharge in the main alluvial area of the valley so that natural losses could be reduced or stopped with a minimum of water-level drawdown in pumped wells; (2) an average water level about 50 feet below land surface would curtail virtually all evapotranspiration losses; (3) over the long term, pumping would cause a moderately uniform depletion of storage throughout most of the valley fill (excluding semi-isolated tributary areas, such as Royston Valley); (4) specific yield of the valley fill is 15 percent; (5) water levels are within the range of economic pumping lift for the intended use; (6) development would have little or no effect on water stored in adjacent valleys; and (7) water is of suitable chemical quality for the intended use.

Table 21 presents the preliminary estimates of transitional storage reserve of Big Smoky Valley, based on the above assumptions. The estimated storage reserve is the product of the area beneath which depletion can be expected to occur, the average thickness of saturated valley fill to be dewatered, and the specific yield.

The manner in which transitional storage reserve augments perennial yield has been described by Worts (1967). The relation is shown in its simplest form by the following equation:

$$Q = \frac{\text{Transitional storage reserve}}{t} + \frac{\text{Perennial yield}}{2}$$

in which Q is the selected or desired rate of diversion (largely ground-water pumping), in acre-feet per year, and t is the time, in years, to exhaust the storage reserve. This basic equation, of course, could be modified to allow for changing rates of storage depletion and salvage of natural discharge. The equation, however, is not valid for pumping rates less than the perennial yield.

Table 21.--Preliminary estimates of transitional storage reserve

[For dewatering 50 feet of alluvium]

Area	Area of depletion[1] (acres) (1)	Dewatered thickness (feet) (2)	Transitional storage reserve (acre-feet) (1) x (2) x 0.15
	BIG SMOKY VALLEY, NORTHERN PART		
Lander County	120,000	50	900,000
Nye County	180,000	50	1,400,000
Total	300,000	50	2,300,000
	TONOPAH FLAT[2]		
Nye County	200,000	50	1,500,000
Esmeralda County	180,000	50	1,400,000
Total	380,000	50	2,900,000

1. Does not include isolated or semi-isolated alluvial areas.
2. Excluding Royston Valley; see text.

Using the above equation and the estimate for the northern part of the valley, as an example (transitional storage reserve, 2,300,000 acre-feet, table 21; perennial yield, 65,000 acre-feet, p. 53) and using a diversion rate (Q) equal to perennial yield, in accordance with the general intent of Nevada water law, the time (t) to deplete the transitional storage reserve is computed to be about 70 years. This assumes that the diversions would be almost wholly by pumping. Similarly, for Tonopah Flat, the time (t) required to deplete the storage reserve would be about 1,000 years.

At the end of the estimated times, the transitional storage reserves would be exhausted, subject to the assumptions given in the preceding section. What is not shown by the example is that in the first year virtually all the pumpage would be derived from storage, and very little, if any, would be derived by salvage of natural discharge. On the other hand, during the last year of the period, nearly all the pumpage would be derived from salvage of natural discharge and virtually none from the storage reserve.

During the period of depletion the ground-water flow nets would be substantially modified. The recharge that originally flowed to areas of natural discharge would ultimately flow directly to pumping wells.

To meet the needs of an emergency or other special purpose requiring ground-water pumpage in excess of the perennial yield for specific periods of time, the transitional storage reserve would be depleted at a more rapid rate than the example given. The above equation can be used to compute the time required to exhaust the storage reserve for any selected pumping rate equal to or in excess of perennial yield. However, once the transitional storage reserve was exhausted, the pumping rate should be reduced to the perennial yield as soon as possible. Pumpage in excess of perennial yield after exhaustion of the transitional storage reserve, would result in an overdraft, and pumping lifts would continue to increase and stored water would continue to be depleted until some undesired result occurred.

WATER USE AND CONSUMPTION AS OF 1968

Table 22 summarizes the use of the water resources of Big Smoky Valley. Irrigation was the principal use of water in 1968. Because of the variation in streamflow from year to year, the quantity of water used varies accordingly. The quantity used in 1968 probably was at or near the yearly minimum because it was a dry year. On the other hand, during wet years more streamflow in the northern part of the valley would be used, probably 75 percent more than in the average year shown in table 22.

Table 22.--Development and estimated consumption of water

[Based principally on interviews of water users. Water quantities in acre-feet per year]

Use		Northern part of valley			Tonopah Flat		
		1968 and dry conditions	Wet conditions	Average year	1968 and dry conditions	Wet conditions	Average year
Irrigation and subirrigation consumption (table 17):							
Surface water	(1)	2,700	7,500	4,300	580	920	690
Ground water	(2)	7,800	7,000	7,500	270	170	240
Subtotal (rounded)		10,000	14,000	12,000	850	1,100	930
Leaching requirement (10 percent decrement limit, p. 45):							
Surface water	(3)	140	380	230	31	46	36
Ground water	(4)	410	350	390	14	8	13
Subtotal (rounded)		530	700	650	45	55	50
Public-supply, domestic, and stock consumption (table 19)[1]:							
Surface water	(5)	--	--	--	--	--	--
Ground water	(6)	25	20	25	10	<5	10
Subtotal (rounded)		25	20	25	10	<5	10
Industrial self supply (p. 47):							
Surface water	(7)	Minor	Minor	Minor	0	0	0
Ground water	(8)	0	0	0	0	0	0
Subtotal (rounded)		Minor	Minor	Minor	0	0	0
Surface water (rounded) (1) + (3) + (5) + (7) = (9)		2,800	7,900	4,500	610	1,000	730
Ground water (rounded) (2) + (4) + (6) + (8) = (10)		8,200	7,400	7,900	290	200	260
TOTAL (rounded)	(9) + (10)	11,000	15,000	12,000	900	1,200	1,000

1. Does not include water imported to Tonopah from outside the valley.

FUTURE DEVELOPMENT

Much greater utilization of the water resources of Big Smoky Valley is hydrologically possible. The economics of greater utilization, however, is beyond the scope of this report. For average years, approximately 12 percent of the perennial yield (p. 53) of the northern part of the valley is presently used and consumed. The percentage for Tonopah Flat is about 4 percent.

The following methods of water development under the perennial yield concept are discussed in the following sections: (1) installation of pipelines and lined ditches to conduct streamflow to fields, (2) construction of dams to store streamflow for recreation and irrigation purposes, and (3) construction and pumping of wells to salvage natural ground-water discharge.

Pipelines

Thirteen of the 40 streams listed in table 7 have been diverted to pipelines or lined ditches near their canyon mouths. This efficient diversion and conveyance of water could be extended to the other streams which are now allowed to flow in their natural channels or diverted to unlined ditches on the apron. The effect of using pipelines or lined ditches is to deliver the maximum amount of streamflow with minimum conveyance loss to the area of use.

The most productive streams not being diverted to pipelines or lined ditches are Kingston, Peavine, Pablo, Ophir, Jefferson, Broad, Barker, Wisconsin, Last Chance, and Decker Creeks, as indicated by data in table 7.

The canyon mouth probably is the best general location for the inlet to a pipeline or lined ditch; however, the most efficient location depends on many geologic and hydrologic factors not investigated during this study.

Dams

Dams have been proposed for Kingston (under construction in 1969), Birch, and Jefferson Creeks. The impounded water would be for recreation--mostly fishing. It may be feasible to construct dams in other canyons, such as on North and South Twin Rivers and Peavine, Pablo, Jett, and Bowman Creeks; however, reservoir-site and dam-site evaluations were beyond the scope of this study. Storing water behind dams for irrigation might be hydrologically feasible. The greatest advantage would be gained by damming streams which have high maximum flow-mean flow ratios and an adequate runoff (table 7), such as Belcher Canyon and McLeod Creek.

Wells

Ground water would be developed in Big Smoky Valley primarily at the expense of natural discharge and moderate storage depletion, with development occurring in or near areas of natural discharge (pl. 1 and 2). To salvage ground water that is now being discharged by phreatophytes and by direct evaporation at land surface, ground-water levels must be either lowered or the nonbeneficial plants eradicated and replaced by beneficial crops.

Ground-water levels in areas of phreatophytes can be lowered by pumping wells in or near the phreatophyte areas. A lowering of water levels to a minimum of about 50 feet below land surface would deprive phreatophytes of ground water.

Diversion of streamflow at canyon mouths to pipelines or lined ditches would reduce, but not eliminate, all water available to the phreatophytes as recharge (tables 10 and 11). As a result the ground-water system would slowly adjust to the reduced supply with an increase in depths to water. The area of phreatophytes and phreatophyte discharge would slowly become smaller as a result of a generally greater depth to water throughout the valley-fill reservoir.

Lowering ground-water levels beyond the reach of phreatophytes by pumping would cause ground water to flow from sources of recharge directly to wells rather than to phreatophytes.

Distribution of wells under full ground-water development is dependent primarily on six factors: (1) distribution of phreatophyte discharge, (2) limitations imposed by land-area development associated with well yield, (3) areal extent of the cone of influence of pumping wells, (4) extent and location of stream diversions, (5) water quality, and (6) hydraulic boundaries (discussed on p. 15). The most limiting factor should ultimately dictate the general spacing of wells.

The distribution of phreatophytes is shown on plates 1 and 2, and their rates of discharge are summarized in tables 11 and 12. Tables 23 and 24 list the distribution of estimated average annual phreatophyte discharge by townships. If the distribution of phreatophyte discharge is not changed, the distribution of pumpage should be about the same to salvage the natural water losses. As described earlier, however, increased stream diversions at canyon mouths to pipelines and lined ditches would eventually cause a reduction in phreatophyte discharge.

Table 23.--Distribution of ground-water evapotranspiration in the northern part of Big Smoky Valley

[Estimated evapotranspiration 65,000 acre-feet per year]

Location (township north)		Average annual evapotranspiration Percent
	LANDER COUNTY	
20	(Lake Ranch area)	<1
19	(Bade and Willow Creeks area)	<1
18	(Simpson Park Canyon)	<1
17		2
16		13
15		5
	Subtotal (rounded)	20
	NYE COUNTY	
15		16
14		17
13		17
12		12
11		16
10		<1
	Subtotal (rounded)	80
TOTAL (rounded)		100

Table 24.--Distribution of ground-water evapotranspiration on Tonopah Flat

Location (township north)		Average annual evapotranspiration Percent
	NYE COUNTY	
8	(Cloverdale Ranch area)	7
7	(San Antonio Ranch area)	17
6		2
	Subtotal (rounded)	25
	ESMERALDA COUNTY	
5	(Crow Springs area)	--
3-4	(Millers area)	57
1-3	(Adjoining playa)	12
1-2	(Playa)	7
	Subtotal (rounded)	75
TOTAL (rounded)		100

Table 25 provides well-spacing information for various well yields based on the intensity of phreatophyte discharge. On a local basis, well spacing can vary somewhat, but for any large area, such as a township, the recommended spacings should average as those indicated in the table to prevent undue lowering of pumping water levels.

Minimal spacing of wells, where there is local variation in well spacings, should be controlled by the ability of the valley-fill reservoir to yield water, as reflected by the size and shape of the cone of influence caused by pumping. Table 26 gives some examples of what minimum spacing of wells might be to limit interference among wells. The examples were chosen to approximate actual conditions in the valley; however, final judgement on minimum well spacing and interference between wells should be based on pumping tests conducted by a hydrologist. As a general rule, spacing between all high-yield irrigation wells, as illustrated in table 26, should be at least 0.5 mile, and depending on aquifer and pumping conditions, distances up to 1.0 mile are recommended.

Land-use requirements associated with well yield cannot be predicted for industry but it can to some extent for agriculture. Table 27 summarizes the estimated acres of alfalfa in the northern part of Big Smoky Valley that could be irrigated per 1,000 gallons per minute of pumpage. For Tonopah Flat, the acreage would be slightly smaller because of its slightly warmer climate. With reference to table 27, if a well had a yield of 1,000 gpm and water is applied to alfalfa by sprinklers on a 24-hour per day basis, the maximum area that could be irrigated in the northern part of the valley is about 160 acres.

Stream diversions would reduce the amount of natural ground-water discharge available for salvage. The largest reductions would be felt in the areas nearest the largest stream diversions; however, the exact relation is dependent on many factors that probably cannot be evaluated until this future cause and effect relation has partly developed.

Dissolved-mineral matter limits the use of some water, as described in sections "Suitability of water for irrigation" and "Public-supply, domestic, and stock consumption". The suitability of water for a particular use should be evaluated during the test-drilling phase of the development of wells. The extent to which hydraulic boundaries impede ground-water flow or alter the ground-water flow pattern probably will not be determined until substantial quantities of ground water have been pumped.

Table 25.--Examples of well yield and spacing per township to salvage natural discharge for irrigation

[See table 26 for examples of water-level drawdown]

Average well yield for 140 days per year (gpm)	Well spacing[1] (Assumes all phreatophyte discharge will be diverted to wells)			Maximum acreage that could be irrigated per well[2]
	Distance apart (feet)	Wells per township	Acres per well	
		NORTHERN PART[3]		
600	4,800	45	510	100
800	5,400	33	700	130
1,000	6,100	27	850	160
1,200	6,600	23	1,000	190
1,500	7,400	18	1,400	240
2,000	8,600	14	1,600	320
2,500	9,700	11	2,100	400
3,000	10,600	9	2,600	480
		TONOPAH FLAT[3]		
300	6,000	28	800	50
400	6,900	21	1,100	65
600	8,600	14	1,600	100
800	10,000	10	2,300	130
1,000	11,000	8	2,900	160
1,200	12,000	7	3,300	190
1,500	13,000	6	3,800	240
2,000	16,000	4	5,800	320

1. The three columns of data are mutually equivalent.
2. For sprinkler system, pumping 24 hours per day, and 25 percent recycling of pumped water. (See p. 64 and table 27.)
3. Based on an average phreatophyte discharge rate of 0.5 acre-feet per acre for the northern part of the valley and 0.2 acre-feet per acre for Tonopah Flat.

Table 26.--Examples of well spacing and water-level drawdown for three types of conditions in Smoky Valley

[Based on work by Theis (1935 and 1963]

	Example A	Example B	Example C
Pumping period[1] (days)	140	140	140
Pumping rate (gallons per minute)	1,500	2,500	1,000
Aquifer characteristics:			
Transmissivity (gpd per ft)	50,000	100,000	25,000
Storage coefficient	.15	.15	.15
Drawdown (maximum)[2]			
0.2 mile from pumping well (feet)	8	10	9
0.5 mile from pumping well (feet)	3	5	2
Radium of cone of influence (miles)[3]	1.3	2.0	.9
Minimum well spacing without excessive interference between wells.[4]	0.75 miles	1.0 miles	0.5 miles
Drawdown of pumping level from static water level during growing seasons (feet)[5]	85	70	110

1. Chosen to approximate the general length of the growing season for the entire valley.

2. Does not take into consideration the effects of any boundary conditions or interference by nearby wells.

3. Drawdown at edge of cone of influence about 0 foot.

4. Interference from all nearby wells limited to about 10 feet of water-level lowering.

5. Assumes efficient well having well loss of 25 percent.

Table 27.--Maximum acreage of alfalfa that could be irrigated by a well in the northern part of Big Smoky Valley

[For 24 hours of well operation per day]

Daily moisture requirement in July[1] (inches)	Application of water			Maximum acreage that could be irrigated per 1,000 gpm of pumpage[2]
	Method	Assumed efficiency (percent)	Application rate to field (inches per day)	
0.25	Sprinklers	75	0.33	160
0.25	Ditches	67	.38	140

1. Based on water-requirement data of Houston (1950).
2. Assumes three cuttings of hay during 140-day growing season.

In designing a well or well field, the depth to water (figs. 5 and 6) should be considered, because it directly affects the economics of the intended use. The total depth of any wells would be governed partly by the depth of the most productive aquifers. As stated previously, most existing high-yield wells in Big Smoky Valley encountered their chief aquifer within 300 feet of land surface, or within a depth beneath the water table of from 200 to 300 feet.

SUMMARY

This report has attempted to describe the two hydrologic systems in Big Smoky Valley. Figure 17 shows quantitative flow diagrams for the two systems.

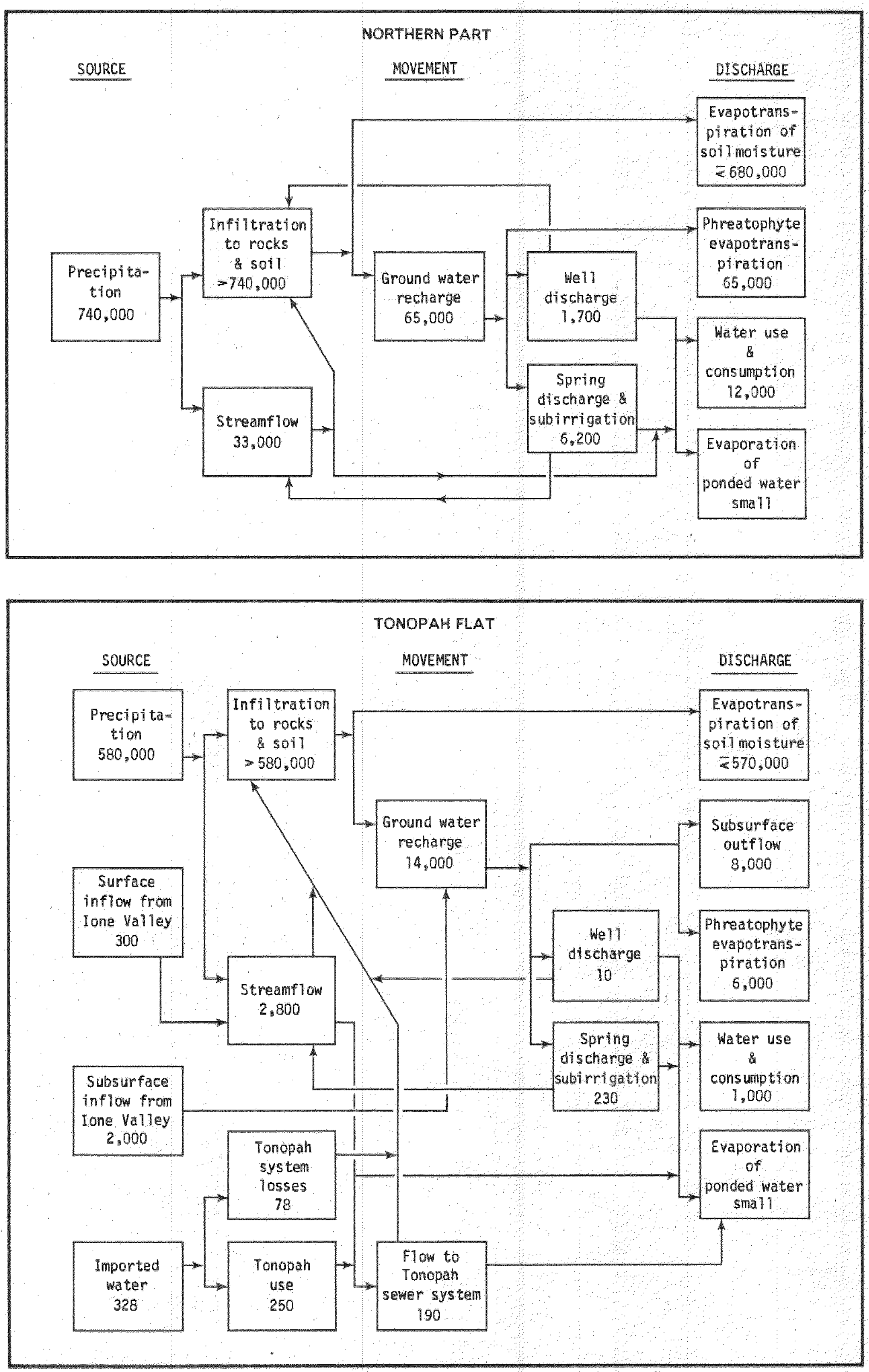

FIGURE 17.— GENERALIZED FLOW, IN ACRE-FEET PER YEAR

UNRESOLVED HYDROLOGIC PROBLEMS

1. The seepage losses from streams that recharge the ground-water reservoir were not estimated because of insufficient data.

2. The relation of the relatively small quantity of runoff from the mountains (43,000 acre-feet per year) to ground-water recharge and discharge (about 80,000 acre-feet per year) suggests that more than half the ground-water recharge is transmitted across the bedrock-alluvium contact in the subsurface. No direct evidence was found to support any large subsurface transmission.

3. The quantity and quality of the runoff reaching and ponding on playas should be investigated. This water may be of usable quality for irrigation or other use.

4. The transmissivity of alluvial-fan deposits that originate from the disintegration of single lithologic types seems to be low where the source rocks are granitic and higher where the source rocks are extrusive or indurated sedimentary types. Any general transmissivity differences should be further evaluated in this valley and elsewhere.

5. Ground water could possibly leak from Monitor Valley to Big Smoky Valley. Meager data do not support any such conclusion; but more data may prove otherwise.

6. The mechanism of leakage of ground water from Tonopah Flat to Clayton Valley, if it in fact occurs, is not understood. A detailed evaluation of the whole Clayton Valley ground-water basin is needed, but sufficient information for such a study is not available as of 1969.

HYDROLOGIC DATA

Streamflow, well, spring, precipitation, and water-chemistry data are presented in this section of the report, as well as in various tables and illustrations throughout the report. The principal places where data are presented are as follows:

Streamflow data: Figures 10, 11, and 12, and tables 5, 6, 7, 9, and 28.
Well data: Tables 29 and 30.
Spring data: Table 31.
Precipitation data: Figures 13 and 14, and tables 8 and 11.
Water-chemistry data: Table 32.

In this section, tables 28 through 32 are presented. These tables do not present data on all streams, wells, springs, and water chemistry, but include data on what is hoped a representative sampling of these hydrologic features. The location numbering system used in these tables, and throughout the report, is described next.

Numbering System for Hydrologic Sites

The numbering system for hydrologic sites in this report is based on the rectangular subdivision of the public lands, referenced to the Mount Diablo base line and meridian. It consists of three units: the first is the township north or south of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; the third unit, separated from the second by a dash, designates the section number. The section number commonly is followed by letters that indicate the quarter section and quarter-quarter section, the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. All townships are north of the base line unless otherwise indicated. The number following the letters, if present, indicate the order the well was recorded in relation to other wells in the smallest land unit identified by the preceding parts of the hydrologic-site number. For example, well 19/45-35cb1 is the first well recorded in the NW¼SW¼ sec. 35, T. 19 N., R. 45 E., Mount Diablo base line and meridian.

Because of the limitation of space, wells and springs are identified on plates 1 and 2 only by the section number and quarter section letters. Township and range numbers are shown along the margins.

Table 28.--Periodic streamflow measurements

Stream	Location	Drainage area (sq mi)	Date	Discharge (cfs)
Rye Patch Canyon	19/45-25c	56.0	4-20-68	0
			5-21-68	0
Petes Canyon	16/46-8d	5.8	3-15-68	0
			5-21-68	0
Moore Creek	12/44-25d	8.5	10-28-67	0.42
			3-14-68	.46
			4-18-68	.36
			5-23-68	.40
			7-10-68	1.62
			9-11-68	.19
Barker Creek	11/44-15c	7.5	10-28-67	0.79
			3-13-68	.52
			4-17-68	.93
			5-23-68	2.85
			7-10-68	2.04
			9-12-68	.61
Jefferson Creek	10-44/14c	20.6	10-28-67	0.42
			3-13-68	.87
			4-17-68	2.38
			5-23-68	4.29
			7-10-68	1.09
			8-15-68	.15
			9-12-68	0
Shoshone Creek (Toquima Range)	10/44-21d	6.1	10-28-67	0.08
			3-13-68	.22
			4-17-68	.48
			5-23-68	1.23
			7-10-68	.17
			8-15-68	.03
			9-12-68	.01
Bald Mountain Canyon	9/44-31b	1.9	3-12-68	0
Cloverdale Creek	9/39-36d	46.9	4-19-68	0
Cottonwood Creek	8/41-29b	30.6	4-19-68	0
Peavine Creek	9/42-30a	51.4	6- 2-65	13.6
			10-20-67	1.78
			3-12-68	.90
			4-17-68	8.54
			5-24-68	8.54
			7-11-68	1.93
			9-13-68	1.50
Wall Canyon	10/42-35d	6.8	10-17-67	0

Table 28.--Periodic streamflow measurements--Continued

Stream	Location	Drainage area (sq mi)	Date	Discharge (cfs)
Pablo Creek	10/42-25c	--	7-11-68	2.18
			9-12-68	.76
Jet Creek	10/42-13c	7.3	10-20-67	0.50
			4-17-68	4.42
			5-24-68	6.13
			7-11-68	1.26
			8-15-68	.73
			9-12-68	.14
Broad Creek	11/42-36d	6.1	10-17-67	0.30
			3-13-68	.77
			4-18-68	2.40
			5-24-68	4.44
			7-10-68	.79
			8-15-68	.83
			9-13-68	.20
Belcher Canyon	11/42-1c	5.1	5-24-68	5.07
			7-10-68	.58
			8-15-68	.58
			9-11-68	.19
North Twin River	12/42-22b	--	3-10-65	3.32
			3-15-68	1.73
			4-18-68	6.18
			5-23-68	11.8
			7- 8-68	4.82
			9-12-68	1.64
Ophir Creek	13/42-34c	3.9	10-19-67	0.57
			3-13-68	.76
			4-18-68	1.55
			5-22-68	3.52
			7- 9-68	1.01
			8-14-68	.42
			9-11-68	.28
Summit Canyon	13/42-22c	2.9	10-28-67	0.80
			3-14-68	.67
			4-16-68	.87
			5-22-68	.71
			7- 9-68	.48
			9-11-68	.25
Trail Canyon	14/42-25c	0.8	10-18-67	0
			3-14-68	0
			4-18-68	0
			7- 9-68	0

Table 28.--Periodic streamflow measurements--Continued

Stream	Location	Drainage area (sq mi)	Date	Discharge (cfs)
McLeod Creek	14/43-19b	2.9	4-18-68	2.48
			5-22-68	2.33
			7- 9-68	.34
			8-14-68	.17
			9-11-68	.08
Decker Creek	15/43-28d	2.4	10-28-67	0.42
			3-14-68	.72
			4-19-68	1.52
			5-22-68	2.94
			7- 9-68	.65
			8-14-68	.51
			9-11-68	.41
Carseley Creek	15/43-11d2	--	10-19-67	0.64
			3-14-68	.32
			4-19-68	.69
			5-22-68	1.25
			7- 9-68	2.17
			8-14-68	1.18
			9-11-68	.77
Clear Creek	15/43-11d1	3.9	10-19-67	0.65
			3-14-68	.56
			4-19-68	.81
			5-22-68	1.25
			7- 9-68	1.08
			8-14-68	.94
			9-11-68	.57
Frenchman Creek	16/44-7a	--	10-18-67	0
Sheep Canyon	17/44-21b	2.8	10-17-68	Trace
			5-21-68	2.01
			7- 8-68	.04
			8-14-68	.12
			9-10-68	.01
Tar Creek	17/44-16b	2.2	10-18-67	0
			3-15-68	0
			4-16-68	.62
			5-21-68	.83
			7- 8-68	.20
			9-10-68	0
Birch Creek	18/44-34d	17.5	3-15-68	0.94
			4-16-68	2.36
			5-21-68	1.80
			7- 8-68	1.85
			8-14-68	1.89
			9-10-68	1.12

Table 29.--Record of selected wells and testholes

Well number: S, south of Mount Diablo base line; otherwise north of base line
Owner: BLM, U.S. Bureau of Land Management
Use: B, bathing; D, domestic; I, irrigation; Ind, industrial; M, mining; O, observation; P, public-supply; S, stock; U, unused; Des, destroyed
Altitude: Determined from topographic maps
Water-level measurement: +, water level above land surface; otherwise depth below land surface
State log number: Log number in files of the State Engineer

Location number	Owner and (or) name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number	Chief aquifer (feet)	Remarks
								Date	Depth (feet)			
S1/39-5	Fishlake Livestock Co.	1958	320	6	S	15/20	4,900	1958	260	4519	275-325	Cold water
-5dd	Fishlake Livestock Co.	1958	520	6	Des	Dry	4,920±	1958	Dry	4362	--	10 gal/hr seep of hot water at 165 ft.
1/37-14b	--	--	--	--	M,U	--	5,234	7-30-69	546	--	--	Temperature of water, 71°F, 22°C.
1/38-2a	USGS, Tonopah Flat-2	1968	50	1½	O	--	4,724	7-29-69	17.38	--	--	On southwest edge of playa. Temperature of water 59°F, 15°C.
1/38-3c	USGS, Tonopah Flat-4	1968	97	1½	O	--	4,742	7-29-69	47.56	--	--	Temperature of water, 67°F, 19°C.
-6b	Emigrant Well	1963	324	8	S	--	4,882	1963 5-23-68	190 183.5	7164	308-320	First water 308 ft. Temperature of water, 80°F, 27°C.
-9d	Salt Well	--	520	6	Des	Dry	4,788	9-17-68	3.0	--	--	Salt on land surface.
-26c	Minnesota Well	--	--	6	S	--	4,982	1-19-67 9-17-68	263.81 264.20	--	--	Windmill.
1/39-3a	Power-line well	--	--	60	S	--	4,983	9-17-68	13.45	--	--	At power line. Windmill.
-5a	--	--	59	8	U	--	4,777	9-17-68 7-29-69	53.75 50.67	--	--	
-7bd	Allen well	--	--	--	S	--	4,780	1-19-67 7-29-69	57.40 57.87	--	--	Windmill. Temperature of water 64°F, 18°C.
2/38-17d	Highway Junction well	--	--	6	U	--	4,879	9-17-68	Dry	--	--	Dry at 167 ft.
-20d1	Tonopah-Goldfield R.R., Blair Jct. north well	--	114	60	U	--	4,815	9- 2-13 10-23-57 10-11-62	100 102.76 102.45	--	--	
-20d2	Tonopah-Goldfield R.R., Blair Jct. south well	--	114	60	U	--	4,812	7-30-69	106.98	--	--	
-34d	USGS, Tonopah Flat-3	1968	45	1½	O	--	4,734	7-29-69	28.23	--	--	On northwest edge of playa. Temperature of water, 64°F, 18°C.
2/39-2a	--	1967	--	6	U	1/flowing	4,740					
-11c	USGS, Tonopah Flat-1	1968	20	1½	O	--	4,728	7-30-69	+0.28	--	16-22	On playa.
3/39-31d	--	--	--	60	S,U	--	4,750	7-24-69	4.86	--	--	
3/40-2dc	Miller's Highway Rest Area	1968	280	6	P	30/5	4,817	1968	50	9973	--	First water about 80 ft
-11bb	Miller's Mill	--	61	96x60	U	--	4,815	1913 5-13-48 9-14-59	38 39.2 39.38	--	--	
-19ab	Miller Ranch	--	--	8	D,U	--	4,773	7-24-69	8.34	--	--	Located 25 ft N. of house.
3/41-10cb	--	--	210	--	U	--	5,000	8-31-13	202	--	--	From Meinzer (1917).
3/41-21cd	Main Line Well	1949	310	--	S	10/--	5,070	1949	240	1212	300-310	Near old R.R. grade. Temperature of water, 50°F, 10°C.
4/41-16db	Rodger's well	--	98	10	S	--	4,858	9-18-68	55.48	--	--	Windmill.
-30db	Montezuma well	1870	47	--	U	--	4,830	1913	43	--	--	From Meinzer (1917).
5/40-33dc	Wm. Kane well	--	700	6	--	45/--	4,882	1913	90	--	--	From Meinzer (1917).
5/41-5bd1	Midway station	--	135	48	D,S,U	27/7	5,002	9- 6-13 3-30-49	124 130.14	--	--	
-5bd2	Midway well	1965	180	10	S	20/--	5,002	1965	125	8302	155-180	First water 135 ft. Temperature of water, 54°F, 12°C.
6/39-28dd	Royston Valley well	1966	189	--	S	9/--	5,440	--	--	--	--	
6/40-13aa1	Michael McLaughlin	1965	480	14	I	2,100/32	5,080	1965	78	8658	78-82	Water temperature, 67°F 19°C.
-13aa2	Ione Valley Irrigation District, E.K. Jackson, No. 4	1962	387	16	I	--	5,080	1962	80	6723	108-123	Cold water.
-13da	E. K. Jackson	1963	350	12	I	--	5,070	1963	87	7504	185-335	First water, 180 ft.
-24aa	E. K. Jackson	1963	350	12	I	--	5,060	1963	87	7527	185-335	
6/41-7ba1	James C. Jackson	1963	200	16	I	--	5,110	1963	76	6999	120-200	Cold water. First water, 76 ft.
-7ba2	James C. Jackson	1963	350	12	I	--	5,110	1963	92	7553	188-350	
-7ca	Bernard L. McLaughlin	1964	244	16	I	--	5,100	1964	87	7659	100-240	Cold water. First water, 97 ft.
-16cc	Bridge well	1950	230	8	S	30/--	5,098	1950 9-18-68	150 144.36	1309	--	Water temperature, 54°F, 12°C.
-18ca1	Frank Sanderson	1963	400	12	I	--	5,080	1963	92	7505	185-385	
-18ca2	Frank Sanderson	1963	400	12	I	--	5,080	1963	92	7528	185-385	
-18cb1	Frank Sanderson	1962	191	16	I	--	5,080	1962	78	6982	111-191	First water, 78 ft. Cold water.
-18cb2	Ione Valley Irrigation District	1962	200	16	I,U	--	5,075	1962 9-19-68	81 82.63	6346	125-160	First water, 80 ft. East of two wells.
6/43-6cc	--	--	--	6	S	--	5,950	8-22-68	279.80	--	--	Along wash.
7/40-27cb	Marnet A. Halton	1964	300	14	I	--	5,115	1964	96	7662	100-300	Cold water. First water, 102 ft.
-27dc	Morris D. Halton	1964	300	14	I,U	--	5,115	1964 9-19-68	90 86.17	7663	90-300	Cold water. First water, 80 ft.
-28ad	J-K Ranch	1964	560	14	I	1,100/80	5,130	1964	100	7947	530-560	First water, 100 ft.
-28cb	Stanley A. Tanner	1964	300	14	I	2,500/80	5,140	1964	97	7661	105-185	Warm water. First water, 105 ft.
-30a	David Stevens	1949	133	6	S	50/--	--	1949	78	969	90-95	First water, 90 ft. Water temperature, 50°F, 10°C.
-35b	Stephen E. Webb	1958	420(?)	--	--	350/15	5,100	1958	90	--	--	
-35cc	Smoky Valley Water Co.	1958	1,420	8	I	100/--	5,100	1958 9-19-68	87 89.88	3997	224-225½	First water, 126 ft. Water temperature, 63°F, 17°C. On knoll
7/42-17c1	San Antonio Ranch, Well 1	1949	172	14	I	15/flowing	5,400	--	--	956	30-35	First water, 15 ft. Water temperature, 50°F, 10°C.
-17c2	San Antonio Ranch, Well 2	1949	40	14	I	20/flowing	5,400	--	--	957	30-35	
-17c3	San Antonio Ranch, Well 3	1949	64	14	I	10/flowing	5,400	--	--	958	30-35	Flows 112 gpm, 10 ft below land surface.
-17c4	San Antonio Ranch, Well 4	1949	35	14	I	15/flowing	5,400	--	--	959	30-35	First water, 15 ft. Water temperature, 50°F, 10°C.
-17c5	San Antonio Ranch, Well 5	1949	40	14	I	20/flowing	5,400	--	--	960	30-35	
-17c6	San Antonio Ranch, Well 6	1949	40	14	I	25/flowing	5,400	--	--	961	30-35	
-17c7	San Antonio Ranch, Well 7	1949	84	14	S	--	5,400	1949	12	962	45-48	First water, 21 ft. Water temperature, 50°F, 10°C.

Table 29.--Record of selected wells and testholes--Continued

Location number	Owner and (or) name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number	Chief aquifer (feet)	Remarks
								Date	Depth (feet)			
7/42-17c7	San Antonio Ranch, Well 7	1949	84	14	S	--	5,400	1949	12	962	45-48	First water, 21 ft. Water temperature, 50°F, 10°C.
-17c8	San Antonio Ranch, Well 8	1949	36	14	S	7/flowing	5,400	--	--	963	30-35	First water, 15 ft. Water temperature, 50°F, 10°C.
-17c9	San Antonio Ranch, Well C	1949	48	14	I	55/flowing	5,400	--	--	964	30-35	
-17c10	San Antonio Ranch, Well F	1949	100	14	I	45/flowing	5,400	--	--	965	30-35	First water, 15 ft. Water temperature, 50°F, 10°C.
-17c11	San Antonio Ranch	--	14	--	U	50/--	(5,430)	9- 7-13	4	--	--	Temperature of water, 57°F, 14°C. From Meinzer (1917).
-18dc	San Antonio Ranch, house well	1949	30	14	D	150/--	5,380	1949	17	966	21-30	Water temperature, 50°F, 10°C.
-33aa	San Antonio Ranch	1949	240	8	S	50/--	5,617	1949	180	851	180-190	First water 80 ft. Water temperature, 50°F, 10°C. Location 0.3 mi E. of power line along wash.
8/39-13b1	Cloverdale Ranch	1950	42	--	I,U	--	5,680	1950	25	1320	25-40	Consolidated rock at 40 ft.
-13b2	Cloverdale Ranch	1950	36	14	S	--	5,680	1950	15	1322	15-36	Water temperature, 42°F, 6°C.
8/43-21a	--	--	90	--	U	--	6,220	9- 8-13	85	--	--	From Meinzer (1917).
8/44-20c	--	--	60	--	P,U	35/--	7,110	1913	>6	--	--	From Meinzer (1917).
9/42-31ad	Pete Bertolino Ranch	1948	93	14	I	--	6,100	1948	17	550	--	
9/43-5cd	Emma and Harry Rogers	1950	202	6	D,S	20/--	5,790	1950 8-23-68	115 122.70	1423	158-172	First water, 158 ft. Windmill. Water temperature, 61°F, 16°C.
-9bb	Mike Etcheberry, northwest well	1962	513	16	I	1,600/80 1,400/--	5,800	1962 4-16-68	140 139.63	6855	140-150	First water, 140 ft. Water temperature, 64°F, 18°C.
-9db	Helen Etcheberry, southeast well	1966	601	14	I	2,400/50	5,880	1966 4-16-68	225 214.80	9072	225-236	First water, 225 ft.
10/43-5aa1	J-K Ranch, southwest well	1951	300	14	I,U	25/17	5,630	1951 4-15-68	8 4.60	1675	145-155	First water, 14 ft. Water temperature, 64°F, 18°C.
-5aa2	J-K Ranch, west well	--	200	10	I,U	5/flowing	5,630	--	--	--	--	
-5aa3	J-K Ranch, south well	1962	304	16,14	I	300/130	5,620	1962 4-15-68	12 10.15	6991	20-24½	First water, 20 ft. Cool water.
-5aa4	J-K Ranch	1947	55	14	S,I	10/flowing	5,620	--	--	1674	50-55	First water at land surface. Water temperature, 66°F, 19°C.
-20aa1	Ordrich Gold Reserves Co., No. 1	1948	592	12	M,U	1,800/34	5,780	1948 7-24-68	105 106.80	743	250-470	First water, 105 ft. At pump station. Water temperature, 58°F, 14°C.
-20aa2	Ordrich Gold Reserves Co.	1952	372	16,12	M,U	2,000/32	5,770	1952 7-24-68	98 97.97	1999	294-372	First water, 130 ft. Water temperature, 62°F, 17°C. Located 100 yds E. of pump station.
-22b1	--	--	66	8	U	--	5,700	7- 9-68	45.09	--	--	Located 50 yds N. of Jett Creek Road.
-22b2	Ordrich Gold Reserves Co.	--	238	20	M,U	--	5,700	8- 6-48 7- 9-68	40.75 46.43	--	--	Located 50 yds N. of Jett Creek Road.
-22c	--	--	--	12	S,D,U	--	5,710	7- 9-68	57.53	--	--	Located 75 ft SE of shack.
-28cc	Frank Arcelus	1963	485	16	I,U	3,900/37	5,780	1963 4-16-68 7- 8-68	130 118.94 118.82	7211	350-485	
10/44-20b	--	1948	307	20	Ind	900/150	6,260	--	40	747		
-23b	Ted Stevens	1968	65	6	--	--	6,900	8-22-68	23.26	--	--	Mineral exploration hole
11/43-1c	--	--	16	--	--	--	5,570	9-26-13	12	--	--	Water temperature, 53°F, 12°C.
-6db	Karl Berg	1965	372	16	I	50/flowing 100/--	5,625	--	--	8538	186-198	First water, 42 ft. Low yield, poor well. 40 ft E. of fence along 8A.
-7d	Darrough Ranch	--	800±	12	I,S	1,400/flowing	5,700	--	--	--	--	Boiling water. Flow controlled by valve.
-8c	Darrough Ranch	1952	55	6	D	4/flowing	5,590	--	--	1493	5-15	Water temperature, 50°F, 10°C. Hot water cemented off at 55 ft.
-11a1	Arthur Howd	--	10	8	D	--	5,580	8-21-68	5.67	--	--	Located 20 ft SE of house. Water temperature, 58°F, 14°C.
-11a2	Arthur Howd	--	--	48	S,U	--	5,580	7-23-69	2.48	--	--	Windmill.
-12bd	Arthur Howd	1959	75	12	I,U	900/--	5,475	1959	18	4414	58-75	Poor well. Located 75 yds NNW of house.
-22c	--	--	12	--	S	--	5,580	9-10-13	6.5	--	--	Dug well. From Meinzer (1917).
-24aa	Jake's Well	1959	96	6	S	--	5,660	10-10-64 8-21-68	78.46 79.63	--	--	Windmill.
-27d	Richard Carver	1961	750	16,8	I,U	700/140	5,600	1961 7- 9-68	13 17.13	5807 6329	18-77	Deepened from 303 ft in 1962.
-29bc	Willard Getchell	1957	300	16,12	I	200/15 130/--	5,620	1965	flowing	3679	234-280	First water, 14 ft. water temperature, 60°F. 16°C. Also has a flowing domestic well.
-29ca	Highway Maintenance Station	1966	180	8	D	35/flowing	5,600	--	--	8986	120-123	First water, 21 ft. Water temperature, 58°F, 14°C.
-33bd	Leafy Bordine	1965	295	12	I	10/flowing	5,595	--	--	8596	164-173	First water, 17 ft. Cold water.
12/43-4d	R O Ranch, No. 3 (north)	1965	545	16	I	1,500/110	5,525	1965 4-16-68	5 2.08	8668	281-292	First water, 5 ft.
-9b	R O Ranch, No. 2 (west)	1951	207	14	I	1,200/-- 550/--	5570	1951 4-16-68	35 61.98	1608	125-131	Water temperature, 45°F, 7°C.
-9c1	R O Ranch, No. 1 (southwest)	1951	330	14	I	300/-- 170/--	5,580	5- 2-57 3-21-62 7-10-68	31.62 37.77 35.59	1651	60-65	First water, 60 ft. Water temperature, 62°F, 17°C.
-9c2	R O Ranch	1951	190	12	U	650/120	5,550	5- 2-57 12- 1-60	31.62 35.6	--	--	
-11b	R O Ranch	1951	73	6	S	4/flowing	5,520	--	--	1581	50-65	First water, 9 ft. Water temperature, 50°F, 10°C.

Table 29.--Record of selected wells and testholes--Continued

Location number	Owner and (or) name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number	Chief aquifer (feet)	Remarks
								Date	Depth (feet)			
12/43-23b	USGS, playa 1	1968	4	2	O	--	5,535	7-25-68	3.23	--	0-4	Water temperature, 61°F, 16°C.
13/43-5c	--	1914	101	6	D	40/flowing	5,510	--	--	--	--	Water temperature, 64°F, 18°C. From Meinzer (1917).
-6d	Millett Ranch	1964	140	6	D	5/flowing	5,530	--	--	8240	--	Water temperature, 54°F, 12°C. Water level was +15 ft. Was 400 ft deep.
-7d	Millett Ranch	--	265	8,6	S	5/flowing	5,520	--	--	--	--	Reportedly drilled to 400 ft depth.
-19a1	Turks Ranch	--	15	4	D,S	--	5,520	9-29-13	9.0	--	--	Dug well.
-19a2	Turks Ranch	--	142	14	I,U	70/flowing 600/22	5,500	--	--	--	--	Water level was +11 ft.
-20c	--	--	127	6	I	120/flowing	5,490	--	--	--	--	Water temperature, 53°F, 12°C.
13/44-29db	Charnock Ranch	--	--	8	D.U	--	5,475	8-20-68	6.78	--	--	At NW corner of shack.
14/43-2b	Heffern Ranch	1913	190	8	I,U	--	5,530	4-16-68	.10	--	--	Flowed 10 gpm in 1913 (Meinzer, 1917).
-10a	Heffern Ranch	--	60	--	D	--	5,540	1964	20	--	--	
-16d	Heffern Ranch	1950	204	12	I	10/flowing	5,530	--	--	1337	135-172	First water, 16 ft.
-28ca	Smoky Valley Ranch	--	202	6	I	90/flowing	5,490	--	--	--	--	South of house .25 mi. Water temperature, 67°F, 19°C.
15/44-1aa	Kingston Ranch	1954	201	6	S	<1/flowing	5,552	--	--	2670	200-201	Water temperature, 67°F, 19°C.
-2c	E. S. Vigas	--	22	6	S	40/--	5,580	9-19-13	17.4	--	--	Water temperature, 64°F, 18°C.
-20cd	Triple T Ranch	1950	57	6	U	--	5,540	5- 2-57 3-21-64	33.75 32.06	--	--	
-22bc	Daniels Ranch	--	--	24	D,U	--	5,550	7-23-69	14.46	--	--	Located 25 ft SE of house.
-25d	--	1962	100	8	S	--	5,550	10- 8-64	15.55	--	--	Windmill.
-31d	USGS, playa 2	1968	6	2	O	--	5,480	7-25-68	2.10	--	5-6	First water, 5 ft.
16/44-10ab	Dick Bell	1954	30	--	S	--	5,619	10- 3-64	21.56	--	--	Windmill.
-24bb	--	--	15	--	S	--	5,581	9-18-13	11.7	--	--	From Meinzer (1917).
-24bd	Young Brothers Ranch	1948	120	6	S,U	6/flowing	5,570	1948 1964	flowing 2	778	114-120	First water, 6 ft.
16/45-18db	BLM, Alkali Flat well	1963	150	8	S	--	5,570	8-20-68	5.87	--	--	Windmill.
-28ba	--	--	--	36x72	S,U	--	5,569	8-13-68	4.39	--	--	Windmill. Water temperature, 58°F, 14°C.
17/44-1dd	Birch Creek Ranch, house well	1950	322	8,6	D,S	--	5,920	1951 10- 2-64	241 297.6	1397 1695	241-301	Cold water. Deepened from 220 ft in 1951.
17/45-13d	Marie Streshley	1948	60	6	S,D	3/flowing	5,660	--	--	779	50-60	First water at land surface. Water temperature, 110°F, 43°C
17/45½-11da	--	--	--	5	B	5/flowing	5,700	--	--	--	--	Water temperature, 164°F, 73°C.
17/46-6cd	Consolidated Uranium	--	--	12	M,U	--	5,747	8-13-68	131.40	--	--	Reached by trail from north.
18/45-20cb1	Frontier Station	--	200	6	D,P	--	6,120	9-30-64	158.3	--	--	
-20cb2	Frontier Station	1953	78	6	D,P	--	6,120	1953	36	2297	64-72	First water, 64 ft. Cold water.
-20db	--	--	175	6	U	--	6,020	8-12-68	Dry	--	--	Dry at 175 ft. Located 100 yds SE of highway junction.
-25bc	BLM	1934	108	5	S,U	--	5,728	1934 11-19-53 8-12-68	100 96.60 103.41	--	--	Windmill.
18/45½-36da	--	--	95	5	S,U	--	5,699	8-13-68	82.49	--	--	Windmill.
18/46-32da	Peterson well	--	--	--	S	--	5,771	8-19-68	152.45	--	--	Windmill.
19/44-13cd	Marie Streshley	1959	55	6	D	35/--	6,510	1959	12(?)	4864	12-55	Water temperature, 55°F, 13°C.
19/45-35cb1	Givens Ranch, irrigation well	1961	50	12	I,S,U	<1/flowing	5,960	1961 4-16-68	.10 flowing	6304	8-50	First water, 2 ft. Water temperature, 57°F, 14°C. Located 150 yds E of house.
-35cb2	Givens Ranch, house well	1948	40	6	D	5/--	5,980	1948	20	451	--	
20/45-22ca	Lake Ranch	--	--	6	S	--	6,625	10- 1-64	28.95	--	--	Northern of 2 windmill wells.

Table 30.--Selected drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
1/38-6b		
Shale, brown	160	160
Shale, blue	148	308
Sand, blue	12	320
Shale, hard, blue	4	324
3/40-2dc		
Sand and gravel layers	53	53
Sand and gravel	12	65
Stone	10	75
Sand and gravel	10	85
Stone, sand, and gravel layers	58	143
Sand and gravel	2	145
Clay, sandy	10	155
Stone and sand layers	25	180
Clay, sandy	50	230
Stone	10	240
Sand, gravel, and stone	20	260
Stone	5	265
Sand and gravel	5	270
Stone	5	275
Clay, blue	5	280
5/41-5bd2		
Topsoil, sandy	2	2
Boulders in clay	38	40
Sand and fine gravel in clay	95	135
Sand and gravel, water-bearing	45	180
6/40-13aa1		
Sand, gravel, and rock	78	78
Sand	4	82
Sand, gravel, and rock	113	195
Conglomerate	40	235
Sand, gravel, and rock	15	250
Conglomerate	54	304
Rock and sand	4	308
Gravel and rock in clay	34	342
Sand, gravel, and rock	138	480
7/40-35cc		
Topsoil	31	31
Gravel	7	38
Clay with gravel	82	120
Bentonite	6	126
Clay with streaks of sand	98	224
Gravel, water-bearing	1½	225½
Clay	22½	248
Sand, packed, white	13	261
Clay and sandy clay	149	410
Rock	2	412
Clay with hard layers of rock	60	472
Clay, yellow	158	630
Sandstone	122	752
Pumice stone, gray	23	775
Clay	121	896
Sand, clayey	36	932
Sandstone, water-bearing	112	1044
Sandstone with clay streaks	66	1110
Shale, blue	20	1130
Rock	8	1138
Sandstone with clay	52	1190
Shale	14	1204
Rhyolite	87	1291
Shale, brown	39	1330
Shale, gray	30	1360
Shale, blue	60	1420
7/42-17c1		
Clay, blue	15	15
Gravel, coarse	5	20
Gravel, cemented	10	30
Gravel	5	35
Clay, yellow	27	62
Gravel	1	63
Clay, yellow	9	72
Gravel, cemented	24	96
Gravel	2	98
Clay, yellow	44	142
Gravel	2	144
Clay, yellow	28	172

Table 30.--Selected drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
9/43-9db		
Sand and gravel	44	44
Clay, sandy	42	86
Gravel, cemented	5	91
Clay, sandy	134	225
Sand, water-bearing	11	236
Gravel and sand, cemented	15	251
Sand, water-bearing, and sandstone layers	86	337
Sand and gravel	12	349
Conglomerate and sand layers	125	474
Clay, sandy	53	527
Sand	7	534
Clay, sandy, with streaks of sand	57	591
Gravel	7	598
Clay, sandy	3	601
10/43-5aa3		
Clay, sandy	20	20
Gravel, water-bearing	5	25
Clay	37	62
Gravel, water-bearing	7	69
Clay	163	232
Gravel	6	238
Clay, brown	66	304
10/43-20aa1		
Surface material, mixed	95	95
Clay, yellow, and gravel	25	120
Gravel, water-bearing	8	128
Clay, yellow, and gravel	30	158
Gravel	4	162
Clay, yellow, and gravel	14	176
Clay, hard, yellow	74	250
Gravel, water-bearing	22	272
Clay, yellow, and gravel	68	340
Sand and rock	23	363
Clay, yellow	2	365
Gravel, water-bearing	11	376
Gravel	4	380
Sandstone	29	409
Clay and rock	2	411
Rock	86	497
Clay, hard, sandy	83	580
Rock	10	590
Clay, yellow	2	592
10/43-28cc		
Topsoil	4	4
Sand and gravel	126	130
Gravel, boulders, and sand	220	350
Sand, gravel, and boulders	130	480
Sand, cemented	5	485
11/43-27d		
Topsoil	4	4
Clay, sandy	14	18
Sand and gravel, water-bearing	55	73
Boulders, water-bearing	4	77
Sand, coarse	130	207
Sand, hard	1	208
Clay, sandy	95	303
Clay, brown	447	750
11/43-29bc		
Gravel	40	40
Clay, sandy	29	69
Gravel	16	85
Sand and clay layers, thin	45	130
Clay, gray	40	170
Gravel	26	196
Clay	8	204
Gravel	5	209
Clay and gravel	25	234
Sand and gravel, water-bearing	46	280
Clay	20	300
12/43-4d		
Topsoil	5	5
Gravel and clay layers, thin	21	26
Clay, sandy	27	53
Gravel and clay layers, thin	75	128
Gravel	15	143
Clay and gravel layers, thin	20	163
Gravel and sand	28	191
Clay	3	194
Gravel	15	209
Clay and gravel layers, thin	83	292
Clay	46	338
Clay and sand layers, thin	207	545

Table 30.--Selected drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
12/43-9b		
Topsoil	4	4
Gravel	6	10
Soil (probably silt and sand)	25	35
Mostly cemented gravel in 10 to 25 foot layers interbedded with gravel in 5 to 10 foot layers	172	207
17/44-1dd		
Clay and gravel	80	80
Sand, water-bearing	4	84
Clay and gravel	86	170
Clay, rock, and gravel	20	190
Gravel, water-bearing	30	220
Rocks and boulders	8	228
Gravel and clay, mixed	20	248
Gravel and sand	7	255
Gravel, clay, and sand	38	293
Sand, fine	8	301
Rock, granite	21	322
19/44-13cd		
Hardpan	3	3
Clay, sandy	9	12
Gravel, water-bearing	15	27
Clay, sandy	11	38
Gravel, water-bearing	12	50
Clay, water-bearing	5	55

Table 31.--Records of selected springs

[Use: S, stock; D, domestic; I, irrigation; P, public supply; B, bathing; U, unused]

Location number	Owner and (or) name	Yield Use	Yield gpm	Yield Date	Altitude (feet)	Source rock	Water temperature °F	Water temperature °C	Remarks
1S/38-16dd	Minnesota Spring	S	<1	8- 1-69	6,080	Carbonate rock	--	--	
1/39-9d	Sheep Mountain Spring	S	<1	9-15-66	5,000	Alluvium	--	--	
2/39-13d	Jackson Spring	S	<1	7-26-67	6,040	Carbonate rock	--	--	
2/40-19c	Chuckar Spring	S	<1	9- 1-67	6,400	Carbonate rock	--	--	
5/39-33a	Crow Springs	S	3	1913	5,200	Volcanic rock	59	15	At mouth of Royston Valley
			<1	8- 1-69					
6/38-36b	Sparks Spring	S	1	7-14-67	6,000	Volcanic rock	--	--	
8/39-13b	Cloverdale Spring	D	1	1967	5,700	Alluvium	--	--	
10/44-11b	Ink House Spring	I,P	200	8-20-68	7,300	Volcanic rock	68	20	Used for public supply at Round Mountain
10/44-14c	Shoshone Spring	P	--	--	7,000	Alluvium	--	--	Used for public supply at Round Mountain
11/43-17b1	Darrough Hot Spring	I,B	150	1913	5,600	Alluvium	196	91	Swimming pool
			100	7- 9-68					
11/43-17b2	Darrough Ranch	D	1	10-10-64	5,600	Alluvium	64	18	West of house
11/43-20	Wineglass Ranch	I,S,D	a 1,000	1968	5,600	Alluvium	61	16	Owner estimates there are 10 small springs on ranch contributing to flow
11/43-29a	Willard Getchell	S	a 5	1968	5,600	Alluvium	--	--	
13/43-20	Turk Ranch	I,S	a 100	1968	5,500	Alluvium	--	--	Owner estimates about 30 small springs
13/44-29b	Charnock Spring	I,S	450	1913	5,480	Alluvium	80	27	
			350	7-25-69					
13/44-31a	Charnock Ranch	I,S	<1	7-25-69	5,490	Alluvium	68	20	Many other nearby springs with a combined flow of about 100 gpm
14/43-34ca	Hot Spring	U	<1	1968	5,498	Alluvium	Hot	--	Rises from mound on playa
14/43-15cc	Blue Spring	I,S	175	9-13-68	5,530	Alluvium	--	--	
14/43-32ad	Smoky Valley Ranch	I,S	200	9-22-68	5,500	Alluvium	65	18	South of house
15/44-15	Daniels Spring	S,I	450	1913	5,540	Alluvium	--	--	No flow detected in standing water area in 1968
17/44-32da	Gilman Spring	I,S	225	1913	6,420	Carbonate rock	57	14	
			170	9-29-14					
			250	10-18-67					
17/45-24aa	Spencer Hot Springs	B	6	1913	5,660	Volcanic rock	139	60	Swimming pool
15/43-13db	--	S	65	5-22-68	5,920	Alluvium	Cold	--	
18/44-1ab	Blackbird Spring	S	dry	1968	7,360	Intrusive rock	--	--	
18/45-5cc	Reeder Spring	S	small	1968	6,670	Intrusive rock	--	--	
18/45-9cb	Lower Reeder Spring	S	1	10- 1-64	6,350	Intrusive rock	--	--	
19/46-27bb	Trough Spring	S	small	1968	6,920	Volcanic rock	--	--	
16/46[illegible]ac	Petes Spring	S	1	8-13-68	[illegible],980	Clastic rock	--	--	

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a Estimated by owner.

Table 32.--Partial chemical analyses of water from streams, wells, and springs

[Field-office analyses by the U.S. Geological Survey]

Location	Source	Date sampled	Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]								Specific conductance (micromhos per cm at 25°C)	pH (lab. determination)	Factors affecting suitability for irrigation[2]		
			Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[3]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$[4]			Salinity hazard	Sodium hazard	Residual sodium carbonate (RSC)
								STREAMS							
9/42-30a	Peavine Creek	7-24-69	23 1.15	5 .45	17 .74	107 1.75	0 .00	20 .42	6 .17	80 MH	220	7.9	Low	Low	Safe
10/42-13c	Jett Creek	7-23-69	34 1.70	6 .50	9 .39	112 1.84	0 .00	32 .67	3 .08	110 MH	250	7.9	Low	Low	Safe
10/43-1b	Jefferson Creek	7-23-69	20 1.00	2 .18	13 .58	84 1.38	0 .00	13 .27	4 .11	59 S	170	7.8	Low	Low	Safe
12/42-22d[a]	South Twin River	7-25-69	16 .80	1.3 .11	(a)	62 1.02	0 .00	5.0 .10	1.4 .04	46 S	118	7.8	Low	Low	Safe
12/44-25d	Moore Creek	7-23-69	9 .45	1 .07	8 .34	44 .72	0 .00	3 .06	3 .08	26 S	94	7.4	Low	Low	Safe
13/42-27c	Ophir Creek	7-23-69	34 1.70	7 .58	6 .27	133 2.18	0 .00	14 .29	3 .08	114 MH	240	8.0	Low	Low	Safe
15/44-19b	Bowman Creek	7-23-69	35 1.75	3 .25	6 .24	117 1.92	0 .00	10 .21	4 .11	100 MH	240	7.8	Low	Low	Safe
16/43-35b	Kingston Creek	4-16-68	46 2.30	20 1.66	8 .33	206 3.38	0 .00	40 .83	3.0 .08	198 VH	400	8.1	Low	Low	Safe
16/44-21b	Santa Fe and Shoshone Creeks	7-25-69	--	--	--	--	--	--	--	--	270	--	Low	--	--
17/44-12a	Birch Creek	7-25-69	58 2.89	20 1.65	9 .39	226 3.70	4 .13	46 .96	5 .14	227 VH	440	8.4	Low	Low	Safe
							WELLS								
1/37-14b	Unused well	7-30-69	4 .20	0 .02	431 18.7	136 2.23	0 .00	144 3.00	486 13.7	11 S	2,200	8.2	High	Very high	Marginal
1/38-2a	Tonopah Flat-2	7-29-69	--	--	--	--	--	--	--	--	5,400	--	Very high	--	--
-3c	Tonopah Flat-4	7-29-69	7 .35	15 1.25	5,970 260	1,490 24.4	391 13.0	187 3.89	7,790 220	80 MH	26,000	9.0	Unsuitable	Very high	Unsuitable
-6b	Emigrant well	7-30-69	68 3.39	2 .15	909 39.5	59 .97	0 .00	1,130 23.5	658 18.6	177 H	4,500	8.0	Very high	Very high	Safe
1/39-7bd	Allen well	7-29-69	9 .45	5 .45	368 16.0	416 6.82	19 .63	163 3.39	214 6.04	45 S	1,800	8.4	High	Very high	Unsuitable
2/38-34d	Tonopah Flat-3	7-29-69	--	--	--	--	--	--	--	--	39,000	--	Unsuitable	--	--
2/39-2a	Flowing well	6- 6-67	4.2 .21	1.3 .11	253 11.0	416 6.82	22 .73	72 1.50	81 2.29	16 S	1,060	8.4	Medium	Very high	Unsuitable
-11c	Tonopah Flat-1	7-30-69	1 .04	0 .00	366 15.9	141 2.31	218 7.27	107 2.23	147 4.15	2 S	1,800	9.9	High	Very high	Unsuitable
3/40-2dc[a]	Highway Rest	10-26-68	11 .55	0 .01	(a)	148 2.43	0 .00	28 .58	11 .31	28 S	390	7.9	Low	Low	Marginal
7/40-35cc	Irrigation well	9-19-68	25 1.25	3 .23	70 3.05	128 2.10	0 .00	67 1.39	37 1.04	74 MH	--	8.1	Low	Low	Safe
7/42-17c1-11	Flowing wells	8-22-68	33 1.65	5 .43	47 2.04	132 2.16	0 .00	74 1.54	15 .42	104 MH	490	7.9	Low	Low	Safe
9/43-5cd	Stock well	8-13-68	50 2.50	14 1.16	16 .71	172 2.82	0 .00	65 1.35	7 .20	183 VH	460	8.2	Low	Low	Safe
-9bb	Irrigation well	8-23-68	40 2.00	14 1.14	17 .74	145 2.38	0 0	60 1.25	9 .25	157 MH	420	7.9	Low	Low	Safe
10/43-20aa1[a]	Ordrich no. 1	5-20-52	26 1.30	6.7 .55	(a)	90 1.48	0 .00	26 .54	8.0 .23	92 MH	216	8.0	Low	Low	Safe
11/43-11a1	Domestic well	8-22-68	25 1.25	1 .09	47 2.05	181 2.97	0 .00	9 .19	8 .23	67 MH	370	7.6	Low	Low	Marginal
-29bc	Irrigation well	8- 5-68	24 1.20	2 .14	12 .54	99 1.62	0 .00	7 .15	4 .11	67 MH	200	7.7	Low	Low	Safe
12/43-23b	USGS, playa 1	7-25-68	--	--	3,630 158	1,260 20.6	885 29.5	882 18.4	3,170 89.4	0± S	15,000	9.7	Unsuitable	Very high	Unsuitable
13/43-7d[b]	Flowing well	10- 9-64	--	--	--	--	--	--	--	40 S	140	8.0	Low	--	--
14/43-28ca	Flowing well	8- 5-68	10 .50	0 .02	27 1.16	65 1.07	0 .00	21 .44	6 .17	26 S	200	7.7	Low	Low	Safe
15/44-1aa[b]	Flowing well	10- 3-64	--	--	--	--	--	--	60 1.69	140 H	220	8.0	Low	Low	Safe
-31d	USGS, playa 2	7-25-68	--	--	1,640 71.22	480 7.87	102 3.40	423 8.81	1,820 51.3	10 S	7,800	9.2	Unsuitable	Very high	Unsuitable
16/45-28ba	Stock well	8-13-68	26 1.30	24 1.98	223 9.68	590 9.67	11 .37	68 1.42	53 1.50	164 H	1,400	8.4	Medium	Medium	Unsuitable
17/45½-11da	Flowing well	8-19-68	45 2.25	11 .93	219 9.53	676 11.1	0 .00	44 .92	25 .71	159 H	1,300	7.7	Medium	Medium	Unsuitable
18/45-25bc	Stock well	8-13-68	42 2.10	12 .96	137 5.95	473 7.75	0 .00	4 .08	42 1.18	153 H	930	7.9	Medium	Low	Unsuitable
19/45-35cb1	Irrigation well	9-16-68	30 1.50	23 1.86	148 6.45	300 4.92	2 .07	137 2.85	70 1.97	168 H	910	8.3	Medium	Low	Marginal

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Table 32.--Partial chemical analyses of water from streams, wells, and springs--Continued

			Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]										Factors affecting suitability for irrigation[2]		
Location	Source	Date sampled	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[3]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$[4]	Specific conductance (micromhos per cm at 25°C)	pH (lab. determination)	Salinity hazard	Sodium hazard	Residual sodium carbonate (RSC)
							SPRINGS								
10/44-11b	Ink House Spring	8-21-68	--	--	--	--	--	--	--	--	430	--	Low	--	--
-14c	Shoshone Spring	7-26-68	20 1.00	2 .20	14 .60	82 1.34	0 .00	14 .29	6 .17	60 S	210	7.2	Low	Low	Safe
11/43-17b1[a]	Darrough Hot Spring	1-31-57	1.2 .06	0 .00	(a)	112 1.84	24 .80	40 .83	12 .34	3 S	472	8.7	Low	Very high	Unsuitable
-17b2[2]	Domestic spring	10-10-64	--	--	--	--	--	--	--	65 MH	280	7.0	Low	--	--
-20	Domestic spring	7-25-68	25 1.25	2 .15	12 .50	98 1.61	0 .00	6 .12	6 .17	70 MH	200	7.9	Low	Low	Safe
13/44-29b	Charnock Spring	9-18-68	22 1.10	1 .08	75 3.27	144 2.36	0 .00	61 1.27	29 .82	59 S	530	8.0	Low	Low	Safe
-31a	Small spring	8-20-68	18 .90	3 .24	25 1.09	94 1.54	0 .00	22 .46	8 .23	57 S	260	8.1	Low	Low	Safe
17/44-32da	Gilman Spring	8-19-68	40 2.00	7 .54	6 .25	140 2.29	0 .00	16 .33	6 .17	127 H	300	7.9	Low	Low	Safe
17/45-24aa[a]	Spencer Hot Spring	9-17-53	49 2.44	14 1.15	(a)	682 11.2	0 .00	41 .45	24 .68	180 H	1,160	6.6	Medium	Medium	Safe
18/45-9cb[b]	Lower Reeder Spring	10- 1-64	--	--	--	--	--	--	160 4.51	220 VH	680	8.0	Low	--	--

1. Milligrams per liter and milliequivalents per liter are metric units of measure that are virtually identical to parts per million and equivalents per million, respectively, for all waters having a specific conductance less than about 10,000 micromhos. The metric system of measurement is receiving increased use throughout the United States because of its value as an international form of scientific communication. Therefore, the U.S. Geological Survey recently has adopted the system for reporting all water-quality data.

2. Salinity hazard is based on specific conductance (in micromhos) as follows: 0-750, low hazard (water suitable for almost all applications); 750-1,500, medium (can be detrimental to sensitive crops); 1,500-3,000, high (can be detrimental to many crops); 3,000-7,500, very high (should be used only for tolerant plants on permeable soils); >7,500, unsuitable.

3. Computed as the milliequivalent-per-liter difference between the determined negative and positive ions; expressed as sodium. Computation assumes that concentrations of undetermined ions--especially nitrate--are small.

4. Hardness: S, soft; MH, moderately hard; H, hard; VH, very hard.

a. Detailed analysis; additional determinations, in milligrams per liter: 12/42-22d--silica (SiO_2), 19; sodium (Na), 5.9; potassium (K), 0.9; fluoride (F), 0.2; nitrate (NO_3), 0.6; boron (B), 0.00; calculated dissolved-solids content (with HCO_3 multiplied by 0.492), 81. 3/40-2dc--silica, 92; sodium, 63; potassium, 12; arsenic (As), 0.03; fluoride, 1.6; nitrate, 1.1; phosphate (PO_4), 0.07; boron, 0.42; calculated dissolved-solids content, 293. 10/43-20a--silica, 20; iron (Fe), .26; sodium, 8.6; potassium, 1.0; manganese (Mn), 0; fluoride, 0.1; nitrate, 0.3; boron, 0.04; calculated dissolved-solids content, 141. 11/43-17b1--silica, 105; aluminum (Al), 0.1; iron, 0.05; manganese, 0; sodium, 104; potassium, 2.4; fluoride, 15; nitrate, 0; phosphate, 0.10; boron, 0.27; calculated dissolved-solids content, 369. 17/45-24aa--silica, 84; iron, 0.27; manganese, 0; sodium, 204; potassium, 31; lithium (Li), 1.5; fluoride, 5.0; nitrate, 0.1; phosphate, 0; boron, 0.94; calculated dissolved-solids content, 791.

b. Field data (R. E. Smith, U.S. Geol. Survey, written commun., 1968).

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UNITED STATES DEPARTMENT OF THE INTERIOR
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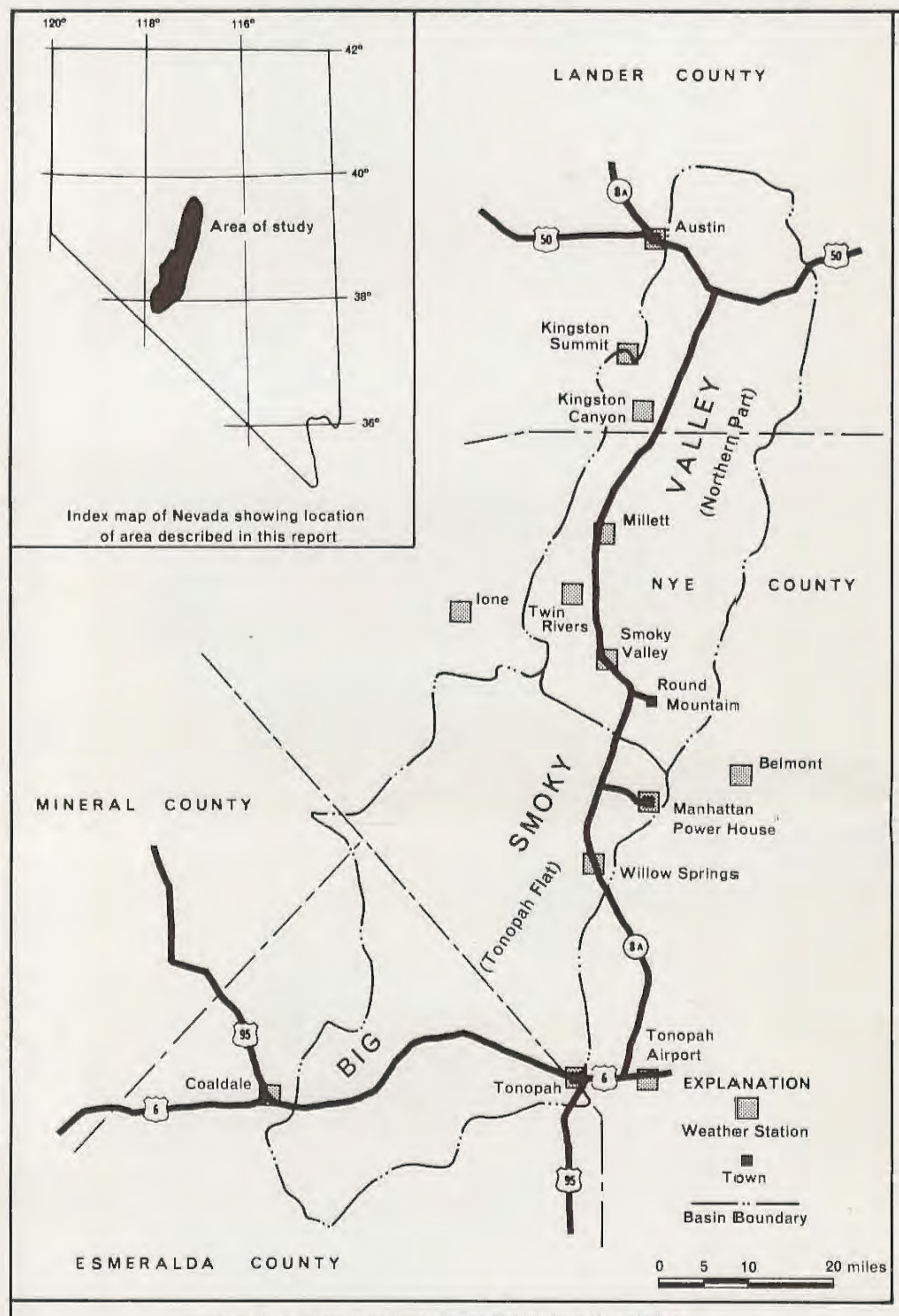
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES



Index map of Nevada showing location of area described in this report

Location of area, principal communities and weather stations

EXPLANATION

Pleistocene and Holocene	▨ Playa deposits	QUATERNARY
	☐ Younger alluvium	
Miocene to Pleistocene	▨ Older alluvium	TERTIARY AND QUATERNARY
	▨ Volcanic rocks	PERMIAN TO QUATERNARY
	▨ Carbonate sedimentary rocks	PRECAMBRIAN (?) TO QUATERNARY
	▤ Clastic sedimentary rocks	
	▨ Granitic rocks	JURASSIC TO TERTIARY

Contact

Fault

PHREATOPHYTE AREAS

🟩 Mostly greasewood and rabbitbrush

🟩 Greasewood, rabbitbrush, and saltgrass

🟩 Meadow

🟩 Wet meadow, tules, and marsh

○ *4db*
Nonflowing, low-yield well and number

● *6c*
Flowing, low-yield well and number

◎ *20bd*
Nonflowing, high-yield well and number

◉ *25aa*
Flowing, high-yield well and number

17d
Spring and number

5200
Water-level contour shows altitude of water-level. Dashed where approximately located. Datum is mean sea level.

Pipeline or lined ditch

▲ *11b*
Streamflow measuring site and number

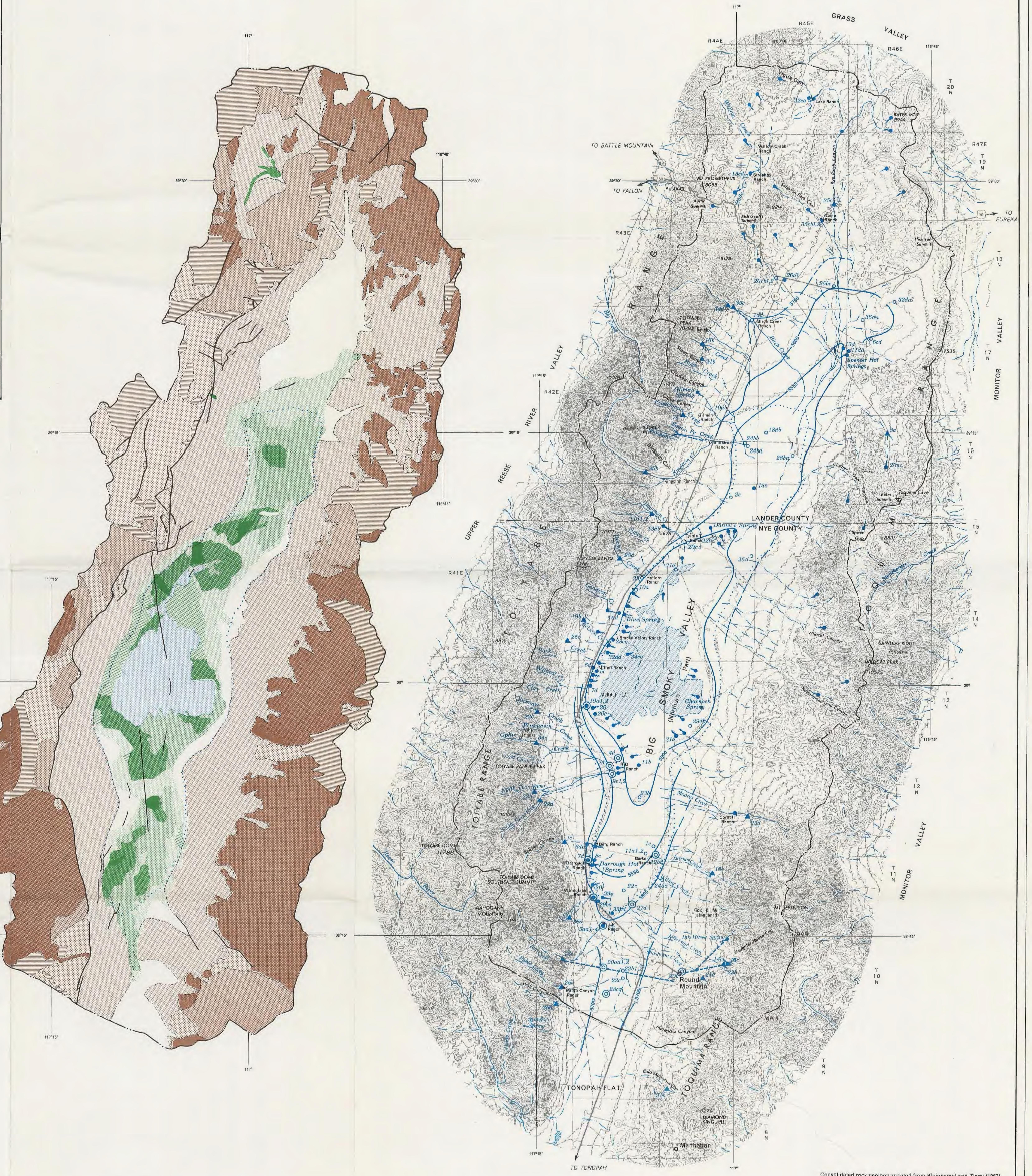
Highest recognized shore line of Pleistocene lake

Basin boundary

0 5 10 miles

Contour interval 200 feet.
Datum is mean sea level.

Base from U.S. Geological Survey—1:250,000 series
Millett (1955) and Tonopah (1962)



Consolidated rock geology adapted from Kleinhampl and Ziony (1967) and Stewart and McKee (1968a, 1968b); unconsolidated deposits and hydrology by F.E. Rush (1969); Cartography by C. Bosch

PLATE 1.—GENERALIZED HYDROGEOLOGY OF THE NORTHERN PART OF BIG SMOKY VALLEY, NEVADA

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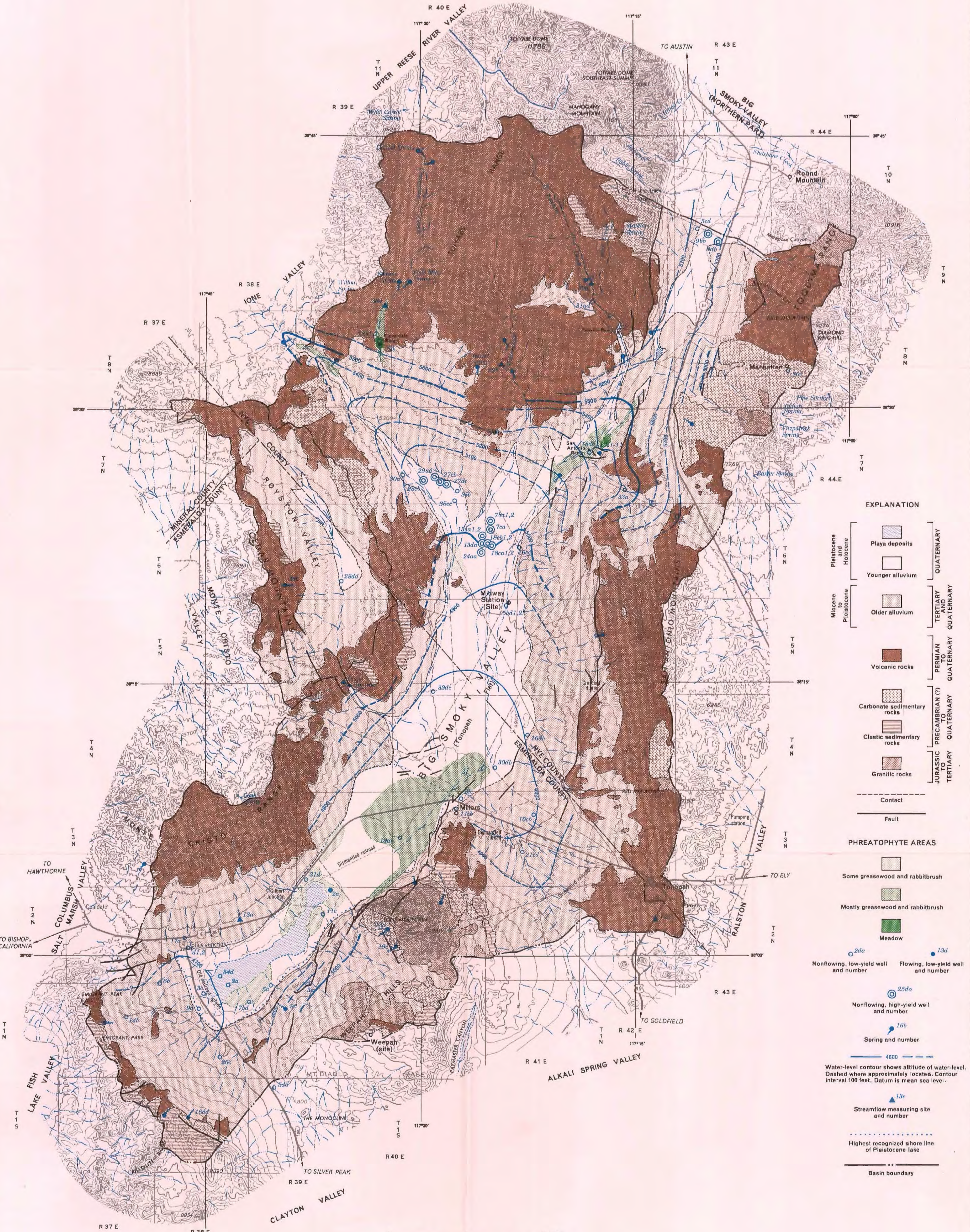
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES



Base from U.S. Geological Survey—1:250,000 series
Goldfield (1954) and Tonopah (1962)

Consolidated rock geology adapted from Kleinhampl and Ziony (1967), and Albers and Stewart (1965) ; unconsolidated deposits and hydrology by F.E. Rush (1969) ; Cartography by C. Bosch

PLATE 2.—GENERALIZED HYDROGEOLOGY OF TONOPAH FLAT, NEVADA