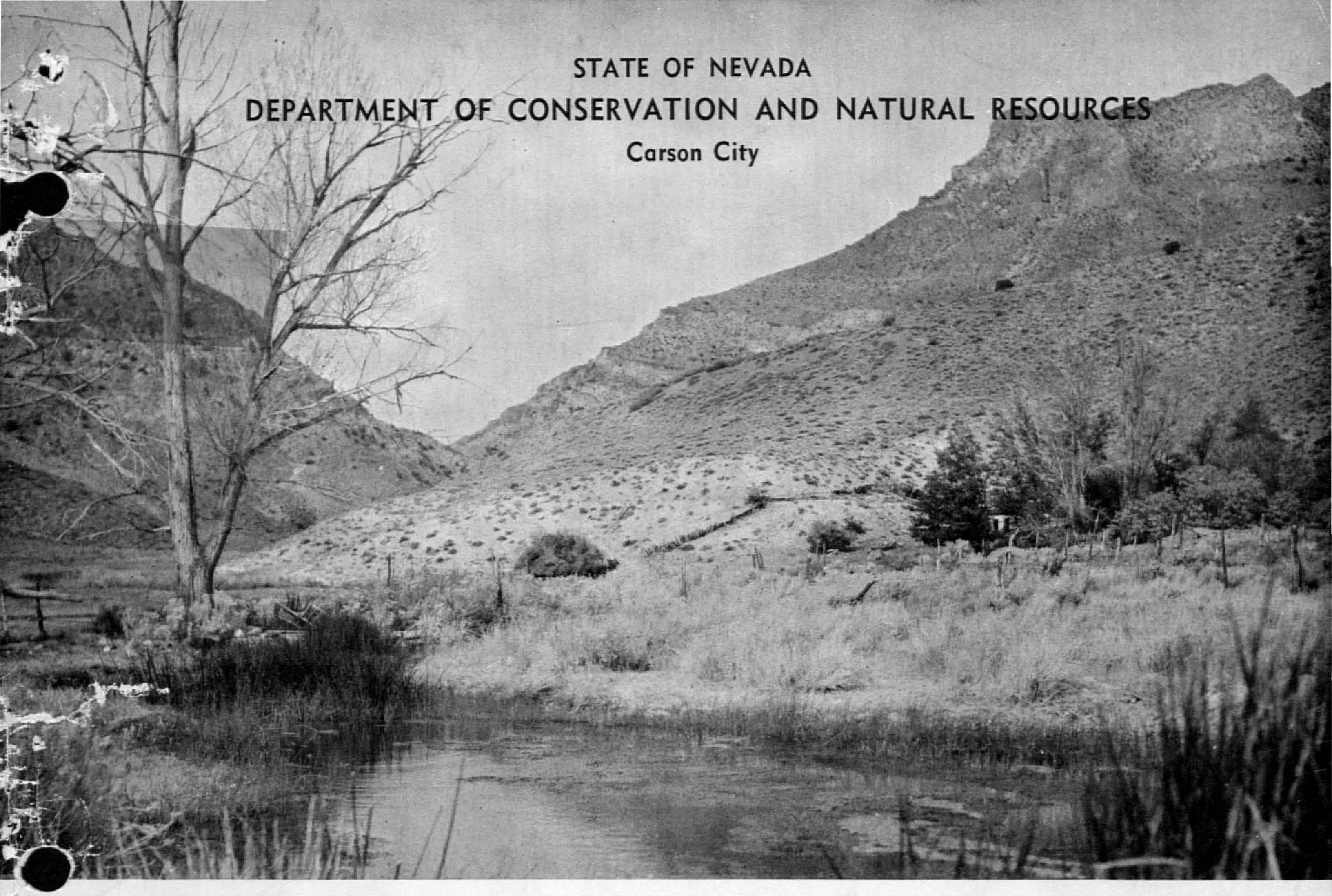
STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Carson City



View of spring discharge in Hot Creek Canyon.

WATER RESOURCES - RECONNAISSANCE SERIES

REPORT 38

WATER-RESOURCES APPRAISAL OF LITTLE FISH LAKE, HOT CREEK, AND LITTLE SMOKY VALLEYS, NEVADA

By

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Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

MAY 1966

WATER-RESOURCES APPRAISAL OF LITTLE FISH LAKE,

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SUMMARY

Little Fish Lake, Hot Creek (including the northern part of Reveille), and Little Smoky (including Fish Creek) Valleys are in central Nevada. The climate is semiarid. Most of the precipitation that contributes to streamflow and to ground-water recharge falls on the mountains in the winter as snow and subsequently melts in the spring. Surface-water runoff is larger on the western mountains bordering Little Fish Lake, Hot Creek, and northern Little Smoky Valleys, but in the southern part of Little Smoky Valley the east side generates more.

The younger and older alluvium constitutes the principal ground-water reservoir. Both volcanic and carbonate rocks in the mountains give rise to major springs. Shallow ground-water is utilized for subirrigation in Little Fish Lake Valley and springflow for irrigation elsewhere. Development of ground-water from wells in 1965 was limited to stock and domestic uses.

Use of water in phreatophyte areas is the largest form of ground-water discharge in each valley except for subsurface outflow from the southern part of Little Smoky Valley. Additional water is available for development in all valleys; however, the depth to water in excess of 400 feet in the southern part of Little Smoky Valley severely limits the type of development presently feasible. A summary of the estimated hydrologic elements for each valley is presented in table 1.

Table 1.--Summary of hydrologic estimates

	Little Fish Lake Valley	Hot Creek Valley	Little Smoky Valley Northern part	Little Smoky Valley Southern part
Valley area (square miles)	435	1,030	585	574
Growing season (above 28°F), range in days	75-100	150-175	75-100	150-175
Water drainage to other valleys:				
Surface water	None	Drained	Drained	None
Ground water	Semidrained	Semidrained	Semidrained	Drained
Presence of Pleistocene lake	Probable	Possible	Two	Probable
Annual precipitation (acre-feet per year)	230,000	390,000	230,000	200,000
Surface-water runoff (acre-feet per year)	18,000	8,000	4,000	1,500
Ground-water recharge:				
From precipitation (acre-feet per year)	11,000	7,000	4,000	1,400
Subsurface inflow (acre-feet per year)	None	200	2,000	None
Total	11,000	7,200	6,000	1,400
Ground-water discharge:				
Phreatophytes (acre-feet per year)	10,000	4,600	1,900	None
Irrigation from springs (acre-feet per year)	None	620	3,300	None
Subsurface outflow (acre-feet per year)	200	700	1,000	2,300
Other (acre-feet per year)	Minor	400	100	Minor
Total (rounded)	10,000	6,300	6,300	2,300
Perennial yield (acre-feet)	10,000	5,500	5,000	1,000

(Continued on next page)

Table 1.--Summary of hydrologic estimates

(Continued)

	Little Fish Lake Valley	Hot Creek Valley	Little Smoky Valley Northern part	Little Smoky Valley Southern part
Ground water in storage in upper 100 feet of saturated alluvium (acre-feet)	800,000	2,300,000	2,600,000	940,000
Quality of sampled water for irrigation	Good	Fair to poor	Good	(Unsampled)
Irrigation development:				
Land (acres)	6,400	1,400	1,700	None
Water (acre-feet per year)	9,600	1,200	3,400	None

INTRODUCTION

Purpose and Scope of the Study

Ground-water development in Nevada has shown a substantial increase in recent years. A part of this increase is due to the effort to bring new land into cultivation. The increasing interest in ground-water development has created a substantial demand for information on ground-water resources throughout the State.

Recognizing this need, the State Legislature enacted special legislation (Chapt. 181, Stats, 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the thirty-eighth report prepared as part of the reconnaissance studies (fig. 1).

During the course of the ground-water studies to date, it was recognized that there also is a deficiency of information on the surface-water resources. Accordingly, this reconnaissance series has been broadened to include preliminary evaluations of the surface-water resources in the valleys studied.

The objectives of the reconnaissance studies and this report are to (1) appraise the source, occurrence, movement, storage, and chemical quality of water in the area, (2) estimate average annual recharge to and discharge from the ground-water reservoir, (3) provide a preliminary estimate of the perennial yield, and (4) evaluate the present and potential water development in the area.

The investigation was made under the general supervision of G. F. Worts, Jr., District Chief in charge of hydrologic studies by the Geological Survey in Nevada.

Location and General Features

The area covered by this report is in central Nevada (fig. 1) and includes Little Fish Lake, Hot Creek, northern Reveille, Little Smoky, and Fish Creek Valleys. Hydrologically these areas are grouped into four basins: Little Fish Lake Valley; Hot Creek Valley, including that part of Reveille Valley north of the drainage divide which separates the northern and southern parts of the valley; southern part of Little Smoky Valley; and northern part of Little Smoky Valley, which includes a small topographically closed valley at the southern end of the valley unit, and Fish Creek Valley at the northern end of the valley unit. These four basins, plus the small topographically closed valley in Little Smoky Valley are shown on figure 2.

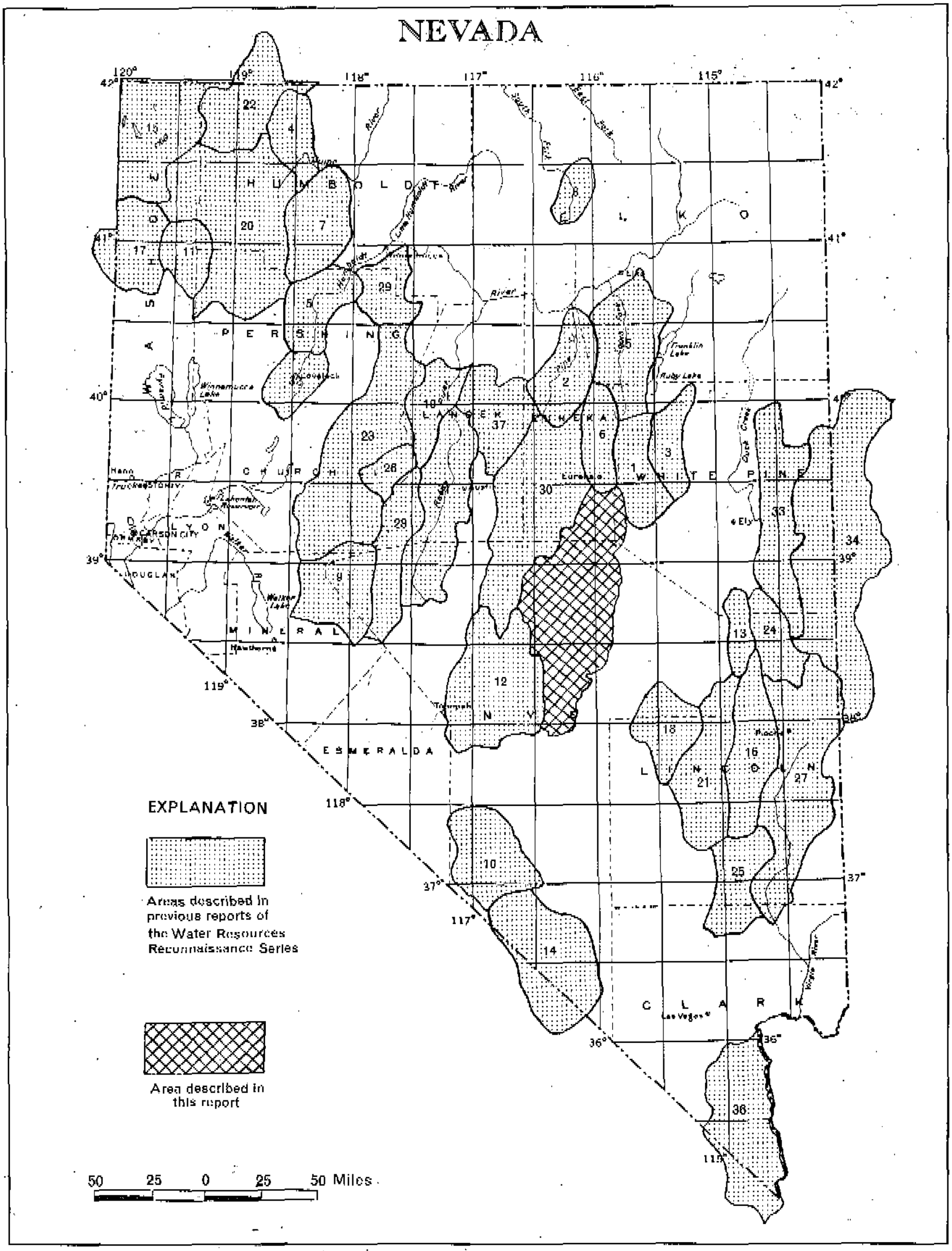

Figure 1.—Map of Nevada showing area described in this report and others in previous reports of the Water Resources Reconnaissance Series

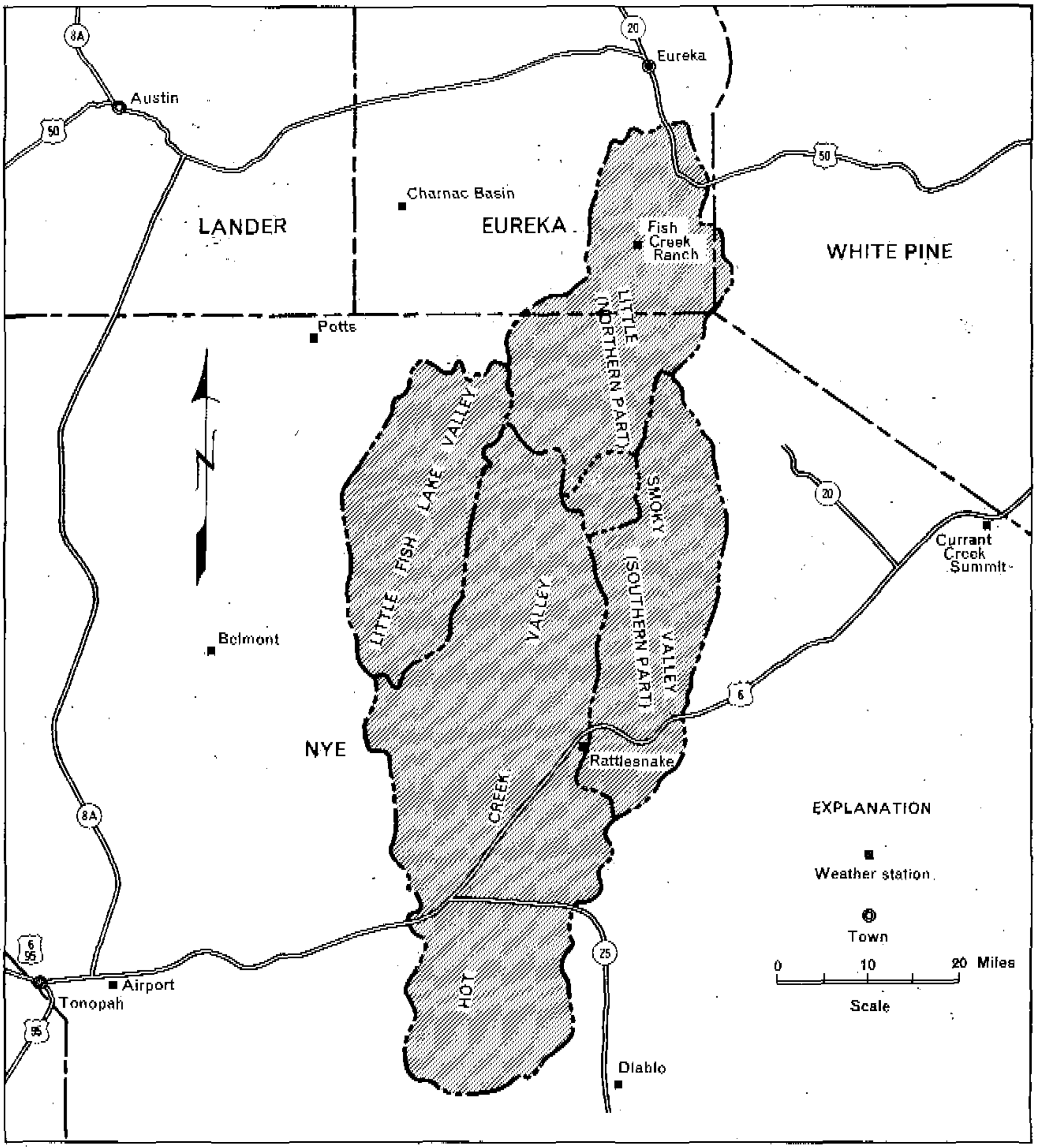

Figure 2.—Locations of paved roads and weather stations

The area is about 110 miles long in a north-south direction and has a maximum width of about 40 miles. Little Fish Lake Valley has an area of about 435 square miles; Hot Creek Valley, 1,030 square miles; and Little Smoky Valley, about 1,160 square miles.

Principal access is by U. S. Highway 50, which extends across the northern end of the area and connects the towns of Eureka and Ely, and U. S. Highway 6, which crosses the southern part and connects the towns of Tonopah and Ely. State Highway 25 extends southeastward from Highway 6 to U. S. Highway 93 in southeastern Nevada. Numerous graded roads and trails extend to many parts of the area.

The economy is basically ranching with most of the land used for cattle grazing. About six ranches are active in the area; the total population probably is about 60 people.

Previous Work

The geology of east-central Nevada has been presented in several reports. Only a few of the more recent and significant reports that relate to this study are mentioned here. Nolan and others (1956) described the stratigraphic section at Eureka, a few miles north of the area. Bissell (1962, 1964) studied the late Paleozoic marine rocks of the area, including those at the northern end of Little Smoky Valley. Merriam (1963) reported on the Paleozoic rocks of the Antelope and Fish Creek Ranges adjoining Antelope and Little Smoky Valleys, and Coogan (1964) on the Paleozoic rocks of the Ely Basin, which includes most of the area covered in this report. Geologic maps were published by Lowell (1965) of Hot Creek Canyon in the Hot Creek Range and Clear Creek Canyon on the east side of the Monitor Range.

The stratigraphy, structure, geomorphology, and history of ore production at Tybo, which is in the Hot Creek Range, were described by Ferguson (1933). Four mining districts, Arrowhead, Morey, Reveille, and Tybo, which are in the mountains surrounding Hot Creek Valley, were described by Kral (1951).

The hydrology of Hot Creek and Reveille Valleys was briefly described by Eakin and others (1951). Snyder (1963) listed well data for part of Little Smoky Valley in his report on stock-water development in the Ely Grazing District.

HYDROLOGIC ENVIRONMENT

Climate

Air masses that move across central Nevada are characteristically deficient in moisture. The valleys are semiarid, whereas the higher mountain areas are subhumid, receiving somewhat more precipitation, especially in the winter. Thunderstorms provide most of the precipitation during the summer. A further discussion of precipitation is included in the hydrology section of this report.

Temperature data have been recorded at Eureka, Fish Creek Ranch, Rattlesnake, and Tonopah, which are shown in figure 2. Freeze data is summarized in table 2. Because killing frosts vary with the type of crop, temperatures of 32°F, 28°F, and 24°F are used to determine the growing season.

The length of the growing season is controlled in large part by elevation of the station in relation to the adjacent floor and its latitude. The topography of the area favors the flow of heavy cold air toward the lower parts of the valley during periods of little wind movement, and causes thermal inversions. The growing season at Rattlesnake, in Hot Creek Valley, is relatively long. This station is on an alluvial apron about 700 feet above the adjacent valley floor. There a crop not seriously affected by temperatures down to 28°F would have an average growing season of about 175 days. About 90 miles north, Fish Creek Ranch on the valley floor has, for crops with the same frost limit, an average growing season of only 77 days. At the nearby station at Eureka, in the mountains, the average growing season is nearly 120 days.

Available data suggest that on the valley floors of Little Fish Lake Valley and the northern part of Little Smoky Valley the average length of the growing season, based on a killing frost temperature of 28°F, probably is about 75 days. Areas about 500 feet higher than the axis of the adjacent valley floors may have an average of nearly 100 days. Farther south, in the southern part of Little Smoky Valley and in Hot Creek Valley, the growing season may average 150 days on the lowlands, and 175 days on the uplands. For any one year the length of the growing season varies from these averages as much as 40 days.

Table 2.--Length of growing season between killing frosts

(Summarized from published records of the U.S. Weather Bureau)

Station	Period of record (years)	Minimum recorded (days)			Maximum recorded (days)			Average (days)		
		32°F	28°F	24°F	32°F	28°F	24°F	32°F	28°F	24°F
Eureka	1953-59	71	96	96	111	134	150	98	116	132
Fish Creek Ranch	1948-64	22	35	88	87	142	146	45	77	117
Rattlesnake	1948-61	128	129	139	147	215	227	137	174	191
Tonopah	1948-53	88	114	146	160	201	237	129	161	188
Tonopah Airport	1955-64	139	158	170	171	200	237	154	180	200

Physiography and Drainage

The report area is in the central part of the Great Basin section of the Basin and Range physiographic province of Fenneman (1931). The bordering mountains trend northward and are separated by valleys that are commonly 10 to 15 miles wide and from 25 to 100 miles long.

Little Fish Lake Valley is presently a topographically closed valley, but at one time surface drainage extended from its southern end to the headwater area of Hot Creek, cutting a deep, narrow canyon. At present, flow from the valley is blocked by alluvial fans that have formed in Tps. 8 and 9 N., R. 49 E. where tributary drainage enters from the west. (See pl. 1.) These fans are low, but effectively block the surface flow to form a small lake and two playas which are frequently flooded.

Little Fish Lake Valley is bounded principally by the Monitor and Hot Creek Ranges. The Monitor Range is the higher of the two, reaching altitudes of 9,000 to 10,500 feet. The Hot Creek Range averages about 9,000 feet. The lowest point in the valley is at its southern end, at an altitude of about 6,400 feet. The internal drainage of the valley is toward the axial drainageway and then southward toward Fish Lake. The valley floor is generally higher than the adjacent valleys, except for Monitor Valley to the west, which is from 100 to 300 feet higher than the corresponding areas in Little Fish Lake Valley.

Hot Creek Valley drains southeastward to Railroad Valley at Twin Springs Ranch (T. 4 N., R. 51 E.). The small perennial flow is carried by Hot Creek through a narrow canyon in the Pancake Range. Hot Creek has two main tributaries, one extending into the narrow northern part of the valley and connecting to Hot Creek in midvalley, and the other, Reveille Wash, draining the northern half of Reveille Valley. Water infrequently flows in these tributaries on the valley floor and then only in response to spring runoff or runoff due to intense thunderstorms.

Hot Creek Valley is bounded on the west by the Hot Creek and Kawich Ranges, and on the east by the Pancake and Reveille Ranges. The Hot Creek and Kawich Ranges, with altitudes of about 9,000 feet, are higher than the Pancake and Reveille Ranges, which crest at about 7,500 feet. The lowest point in the valley is where Hot Creek flows from the valley at an altitude of about 5,100 feet. The valleys to the west are generally higher than Hot Creek Valley; the adjacent part of Railroad Valley to the southeast is about 200 feet lower.

Little Smoky Valley is bounded by the Antelope, Fish Creek, and Hot Creek Ranges on the west, which attain altitudes of about 9,000 feet, and the Pancake Range on the east, which crests between 7,000 and 8,000 feet.

The lowest point in the northern part of the valley is where Fish Creek leaves the valley and enters Newark Valley at an altitude of about 6,000 feet. The lowest point in the central part is on a small playa which has an altitude of about 6,500 feet. In the southern part of Little Smoky Valley, the lowest point is on the playa at the south end of the valley at an altitude of about 5,800 feet. The axial drainageways of the valley are poorly defined, especially in the south.

Of the valleys bordering Little Smoky Valley, Little Fish Lake, and Antelope Valleys are at a higher altitude; Diamond (north of the area), Newark, Railroad, and Hot Creek Valleys are lower. The playa in Railroad Valley is about 1,300 feet lower than the playa at the southern end of Little Smoky Valley.

Three major geomorphic units are recognized in the area: complexly folded and faulted mountain ranges, valley floor, and the apron or intermediate slope between the mountains and the valley floor. Present topographic relief is largely the result of movement along many north-trending faults, some of which are shown on plate 1, and of volcanic activity. At the southern end of Little Smoky Valley the topography is the result of the many recently formed volcanic craters and associated lava flows. About 50 craters are in the area; the largest is Lunar Crater, T. 6 N., R. 52 E., as shown on plate 1. Measured across its lip, it has a diameter of about 0.75 mile and a depth of about 500 feet.

The alluvial apron includes both alluvial fans and pediments. Pediments are erosional surfaces cut on bedrock but commonly are mantled by a thin veneer of alluvium ranging from a few feet to several tens of feet thick. In contrast, the alluvial fans are underlain by thick deposits of alluvium dumped by streams where they leave the mountains. The largest alluvial fans are along the east flank of the Hot Creek Range and are best developed in Tps. 4 to 6 N., R. 50 E. and T. 8 N., Rs. 50 and 51 E. Of these the largest was formed by debris washed from Tybo Canyon (T. 6 N., R. 50 E.). From apex to toe it measures 6 miles and is about 5 miles wide at its toe. The apex rises about 900 feet above the toe. Elsewhere, much of the apron is composed of small, less well defined fans.

Pediments are well developed in the northern half of the report area. In northern Hot Creek Valley a large pediment adjacent to Moores Station (T. 10 N., R. 51 E.) extends northwestward about 5 miles. Another occupies the western third of T. 12 N., R. 49 E., on the west side of Little Fish Lake Valley. In the northern part of Little Smoky Valley the apron areas in the southern half of T. 15 N., R. 52 E., and north of Fish Creek Ranch in the eastern half of T. 17 N., R. 53 E., are pediments. Much of the divide area between the northern and southern parts of Little Smoky Valley is pediment. On plate 1 the pediments are shown as bedrock, because the alluvial veneer is generally unsaturated and the area therefore is hydrologically similar to the mountain areas.

Recently active faults have been mapped, principally from aerial photos, and are shown on plate 1. They are mostly on the apron or separating the apron from the mountains. The fault observed to have the largest vertical displacement is in Hot Creek Valley, a few miles northeast of Tybo at Keystone Canyon, where it cuts alluvial material of the apron. The vertical displacement forms an alluvial scarp about 400 feet in height.

Broad, rather flat valley floors are present at three places: the area situated between Tybo and Twin Springs Ranch in Hot Creek Valley, that part of southern Little Smoky Valley extending from U. S. Highway 6 northward a distance of about 10 miles, and the northern part of Fish Creek Valley. In the other areas, such as Little Fish Lake Valley, the valley floor is limited to the narrow flood plain of the axial drainage.

Pleistocene lakes occupied Fish Creek Valley, the unnamed valley in the central part of Little Smoky Valley, in T. 12 N., R. 53 E., and the south end of Little Smoky Valley. The first had an area of about 46 square miles, a maximum recognized altitude of about 6,060 feet, and a depth within the valley of about 90 feet, as measured from the present valley surface. The other two lakes were small, shallow, and were at the present playa and lake sites in Little Fish Lake Valley.

Snyder and others (1964) show an 88 square-mile Pleistocene lake near Twin Springs Ranch in Hot Creek Valley that spilled to Railroad Valley. The surface materials of this area are silt and clay, similar to those deposited in lakes, but no shore or beach features were recognized by the writers; therefore the lake is not shown on plate 1. The log of well 4/51-13d1 (table 13) indicates the presence of only thin beds of lake-deposit type material rather than the thick beds usually found where a large and persistent lake occupied an area.

Lithologic and Hydrologic Features of the Rocks

Rocks of the report area are divided into three lithologic units: consolidated rocks, older alluvium, and younger alluvium. This division is based largely on their hydrologic properties; however, the hydrologic properties of the consolidated rocks vary widely with differences in their physical and chemical properties. Surface exposures of the units are shown on plate 1. The geologic mapping is based principally on the field work done by the writers, on aerial-photo interpretation, and on works of Lowell (1965), Bissell (1962, 1964), Kral (1951), Ferguson (1933), and Merriam (1963), which were useful in identifying the lithology of the consolidated rocks.

Volcanic rocks dominate principally in the Reveille and Kawich Ranges, in the southern parts of the Pancake, Hot Creek, and Antelope Ranges, and in the northern part of the Hot Creek Range. In the central part of the Hot Creek Range, at the higher altitudes, volcanic rocks dominate. Kral (1951, p. 141-144) reports the presence of limestone in the Reveille Range at Reveille, in T. 2 N., Rs. 51 1/2 and 52 E., underlying Tertiary volcanics.

Carbonate rocks dominate in parts of the Monitor and Fish Creek Ranges, the northern half of the Pancake Range, and on the lower part of the eastern slope of the Hot Creek Range in the Tybo-Hot Creek Ranch area. In the Monitor Range, Kral (1951, p. 50-52) and Lowell (1965) reported the presence of Tertiary volcanic rocks exposed in Danville and Clear Creek Canyons (T. 11 N., R. 48 E.) along with the more abundant carbonate rocks. Other rock types are present in the report area but have little hydrologic significance.

Carbonate rocks commonly contain solution channels, such as are visible on the walls of Hot Creek Canyon, and locally are moderately permeable. Ferguson (1933, p. 56) and Kral (1951, p. 132) reported water in mines at Tybo and Morey. Volcanic rocks at the southern end of Little Smoky Valley also are apparently permeable and capable of transmitting ground water. Because of their topographic position in the mountains and because of their unknown depth and distribution beneath the valley floor, they presently are not considered an economic source of water, except where they give rise to springs.

The older alluvium is late Tertiary and Quaternary in age and is composed mostly of gravel and sand formed from debris washed from the adjacent mountains. These deposits compose the fans and much of the valley floors, and are characteristically unconsolidated or poorly consolidated, dissected, poorly sorted, and commonly deformed.

The younger alluvium, in contrast to the older alluvium, generally is unconsolidated, undissected, and relatively undisturbed. It is reworked sand, silt, and clay deposited by the principal streams on the valley floor and the lake deposits formed principally during Pleistocene time. The younger alluvium is better sorted than the older alluvium and probably is more porous, and except for the lake deposits, is generally more permeable than the older alluvium.

Most of the economically available ground water in the report area is stored in younger and older alluvium which comprise the principal ground-water reservoir. No large-diameter wells are pumped in the area; however, in other areas alluvium characteristically yields water to wells at moderate to large rates. The lake deposits probably would yield very little water to wells but moderate to large water supplies probably can be developed in the alluvium beneath the lake deposits where they occur on the valley floor.

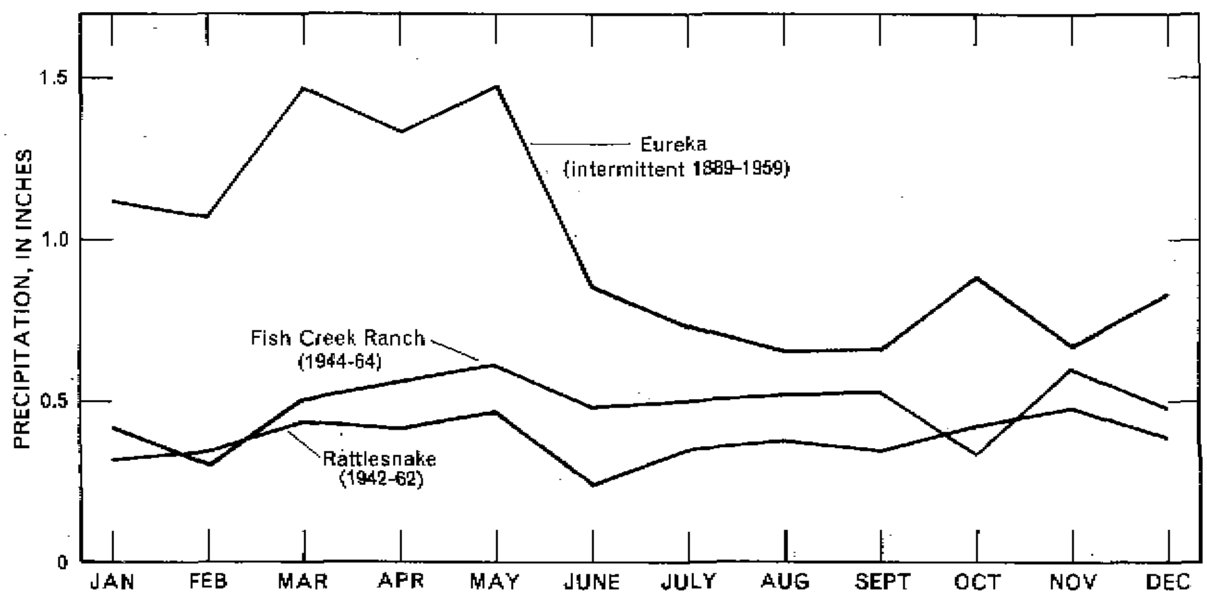

Figure 3.—Average monthly precipitation at Eureka, Fish Creek Ranch, and Rattlesnake

HYDROLOGY

Precipitation

Precipitation has been recorded at 10 stations in and near the project area (fig. 2). Two of the stations, Fish Creek Ranch and Rattlesnake are in the area.

Most of the 10 stations have not been in operation for more than 10 years; therefore, no long-term variations can be identified. However, three stations were selected to demonstrate regional long-term variations: the station at Austin, 50 miles northwest; Tonopah (and Tonopah Airport), 40 miles southwest; and McGill, 60 miles northeast. The wet and dry periods for these stations are summarized as follows:

Austin	Tonopah	McGill
	WET PERIODS	
1895-1907	--	--
--	1907-09	--
--	1914-16	--
--	--	1916-25
1933-46	1938-39	1936-47
--	1945-54	--
	DRY PERIODS	
--	1926-37	1926-35
1947-60	1955-61	1948-62

Agreement among stations, suggesting regional trends, indicates that in general above normal precipitation occurred during the period 1936-46 and droughts during the periods 1926-35 and 1948-61. Some of the other wet and dry periods probably occurred in the report area.

Average monthly and seasonal precipitation during the year varies greatly. Data for an intermediate-altitude station, Eureka (6,500 feet), and two low-altitude stations, Fish Creek Ranch (6,050 feet) and Rattlesnake (5,913 feet) (fig. 2), are shown in figure 3 to illustrate seasonal variations and station differences. The average precipitation measured at these stations during June-November was similar in total amount and distribution. Larger amounts, however, were measured at Eureka than at the other stations during December-May. Winter and spring are the periods of regional storms. None of the stations show the midsummer increase due to thunderstorm activity common to much of Nevada.

The precipitation pattern in Nevada is related principally to topography; the stations at higher altitudes generally receive more precipitation than those at lower altitudes, as shown by figure 4. However, this relation may be considerably modified by local conditions. For example, Eureka (altitude 6,500 feet), receives nearly twice as much precipitation as Potts, which is about at the same altitude (fig. 2). Stations other than Eureka, as plotted on figure 4, conform reasonably well to a precipitation-altitude relation.

The valley floors probably receive an average of about 4 to 6 inches of precipitation per year. The alluvial aprons of the area, ranging in altitude from about 5,500 to 7,000 feet, probably receive an average annual precipitation of from 5 to 8 inches. The higher mountain areas may have an average annual precipitation of 15 inches or more.

Surface Water

General Conditions

Surface water in the report area is derived from precipitation within the drainage area. On the valley floor, where precipitation is small, little streamflow occurs, except that which is fed by mountain streams during periods of large runoff. Most of the streamflow originates in the mountains where most of the precipitation occurs; it accumulates as snow during the winter.

Moisture from snow and rain in the mountains in part infiltrates the rock material becoming ground water, and in part collects into small, short streams. These streams join to feed the major mountain streams that flow onto the alluvial apron where much of the streamflow is absorbed by the alluvium. Under native conditions, only the major mountain streams flowed to the playa areas or from the valleys, such as Hot Creek and Fish Creek, and then only during periods of large runoff. Most of the larger mountain streams have been diverted and utilized for irrigation, generally reducing flow to the lower parts of the valley floors.

Few data are available on the streamflow in the area. A crest-stage gage has been maintained on Reveille Wash at State Highway 25 since December 1963 and is shown as site 30 on plate 1. The only flow occurring there since its installation was in April 1965, when on the 13th the observed flow was about 10 gpm (gallons per minute).

Observations and measurements of flow in the major watercourses were made during the fall of 1965. This period was preceded by a wet summer in the area, but no rain had fallen for several weeks immediately prior to the time of the observations. Therefore, the flow data presented in table 3 represent wet-summer base flow entirely from ground-water

Table 3.--Estimates of streamflow

Map no.[1]	Site	Location: Town-ship	Location: Range	Date	Discharge (cfs)[2]
		LITTLE FISH LAKE VALLEY			
1	Fish Lake Creek at Crossing	12 N.	50 E.	10-19-65	0
2	Fish Lake Creek	11 N.	50 E.	10-19-65	.05
3	Clear Creek at ranch	11 N.	49 E.	9-01-65	1.5
4	Sawmill Creek at crossing	11 N.	49 E.	9-01-65	.1
5	Danville Creek above spring	11 N.	48 E.	9-01-65	1
5	Danville Canyon Spring	11 N.	48 E.	9-01-65	.1
6	Danville Creek at crossing	11 N.	49 E.	5-31-65 9-01-65	(.81) 1
7	Danville Creek	10 N.	49 E.	10-19-65	.2
8	Clover Creek	10 N.	49 E.	5-31-65	(.20)
9	Fish Lake Creek at crossing	10 N.	49 E.	9-01-65	0
10	Fish Lake Creek at gap	8 N.	49 E.	9-01-65 10-19-65	0 0
		HOT CREEK VALLEY			
11	Hot Creek	8 N.	49 E.	9-01-65 10-19-65	0 0
12	Hot Creek	8 N.	49 E.	9-01-65	.01
13	Hot Creek at upper ranch	8 N.	49 E.	9-01-65 11-03-65	1 (.80)
14	Hot Creek below lower springs	8 N.	50 E.	10-20-65 11-03-65	2 (1.69)
15	Hot Creek below ranch	8 N.	50 E.	10-20-65	1.3
16	Six mile Creek	8 N.	50 E.	10-20-65	.2
17	Six mile Creek	8 N.	50 E.	10-20-65	0
18	Tybo Creek	7 N.	50 E.	10-20-65	0
19	Moores Creek	11 N.	51 E.	9-02-65	0
20	Moores Creek at Moores Station	10 N.	51 E.	9-02-65 10-20-65	.02 .1
21	Moores Creek at crossing	9 N.	51 E.	9-02-65 10-20-65	0 0
22	Mores Creek at crossing	7 N.	51 E.	10-20-65	0
23	Hot Creek at highway	6 N.	51 E.	10-21-65	0
24	Warm Springs	4 N.	50 E.	10-21-65	1.5
25	Warm Springs Creek	4 N.	50 E.	10-21-65	.2
26	Warm Springs Creek	4 N.	50 E.	10-21-65	.15
27	Warm Springs Creek	5 N.	50 E.	10-21-65	0
28	Unnamed Wash	6 N.	50 E.	10-21-65	0
29	Reveille Wash	2 N.	51 E.	10-21-65	0
30	Reveille Wash	4 N.	51 E.	10-21-65	0
31	Hot Creek above ranch	4 N.	51 E.	10-21-65 11-03-65	0 .05
32	Hot Creek below ranch	4 N.	51 E.	11-03-65	.4
		LITTLE SMOKY VALLEY (northern part)			
33	Fish Creek Springs	16 N.	53 E.	11-01-65	(5.4)
34	Fish Creek at road	16 N.	53 E.	9-03-65 10-18-65	.05 .05
35	Willow Creek	14 N.	51 E.	6-01-63	(.14)
	Fish Creek	17 N.	54 E.	10-18-65	0
36	Unnamed Wash	15 N.	53 E.	10-20-65	0
37	Fish Creek at gap	17 N.	54 E.	10-20-65	0
38	Unnamed Wash	9 N.	53 E.	10-21-65	0
39	Unnamed Wash	7 N.	53 E.	10-21-65	0

1. Map number corresponds to the measuring site number shown on plate 1.

2. Numbers in parenthesis were measured with a flow meter.

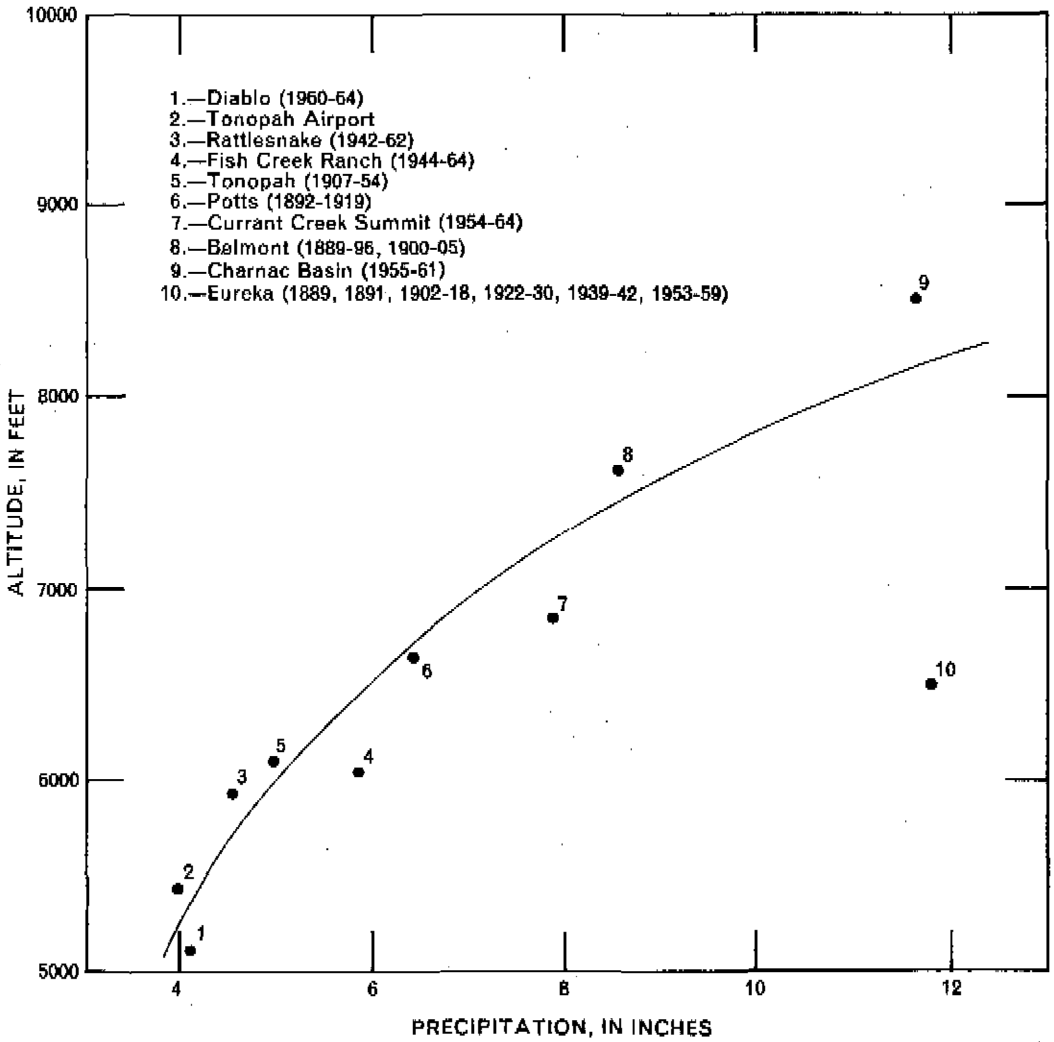

Figure 4.—Relation of weather station altitude to measured precipitation

sources. The data indicate that the largest flows in summer and fall in Little Fish Lake Valley can be expected in Clear and Danville Creeks, in Hot Creek Valley in Hot Creek within the canyon, and in the northern part of Little Smoky Valley from Fish Creek Springs. During this time of the year, base flow generally would not be expected to occur in the washes in the central and southern parts of Little Smoky Valley.

Runoff

Surface-water inflow.--A method of estimating runoff in Nevada has recently been devised by D. O. Moore and is applicable to areas of Nevada where few or no streamflow data are available (Eakin and others, 1965, p. 20-23). The method is a reconnaissance technique and is still in the development stage. The estimates are useful in suggesting the magnitude and distribution of runoff in the area. The runoff is estimated at the bedrock-alluvium contact, which ranges in altitude from an average of about 6,300 feet in Hot Creek Valley to about 7,200 feet in Little Fish Lake Valley.

Briefly, the method for estimating the average annual runoff is based on the general condition that areas at higher altitudes receive more precipitation than those at lower altitudes. (See fig. 4.) It is therefore assumed that the higher altitudes also produce more runoff than the lower. Because the relations between precipitation, altitude, and runoff throughout the various parts of the State (and even in the various parts of the study area), different correlation factors are used to adjust the altitude-runoff relation for the several mountain areas. This adjustment is based on streamflow measurements, differences in vegetation, amounts of precipitation, and geology. The estimated average annual runoff, as computed by D. O. Moore, is summarized in table 4.

Runoff is not evenly distributed throughout the mountains. It is estimated that most runoff occurs in the mountains on the western side of all the valleys, except for the southern part of Little Smoky Valley where the eastern range is higher and more productive.

Streams having the highest rate of computed runoff are: in Little Fish Lake Valley, Clover, Danville, and Clear Creeks; in Hot Creek Valley, Fourmile, Water, and Sixmile Canyons; and in Little Smoky Valley, Snowball and Willow Creeks.

Surface-water outflow.--Surface-water outflow from the area occurs in Hot Creek (to Railroad Valley) and in Fish Creek (to Newark Valley) (pl. 1). Fish Creek is an ephemeral stream, and the outflow occurs only during infrequent storms and in the winter. The small channel suggests that the average flow may be on the order of 500 acre-feet per year.

Table 4. --Distribution of estimated average annual runoff

(Runoff computed at the bedrock-alluvium contact)

Western mountains (acre-feet)	Western mountains (percent of total)	Eastern mountains (acre-feet)	Eastern mountains (percent of total)	Total runoff (acre-feet)
LITTLE FISH LAKE VALLEY				
14,000	80	4,000	20	18,000
HOT CREEK VALLEY				
7,000	90	700	10	8,000
LITTLE SMOKY VALLEY, NORTHERN PART				
3,200	80	700	20	4,000
LITTLE SMOKY VALLEY, SOUTHERN PART				
200	15	1,300	85	1,500

Hot Creek is sustained by a perennial flow of about 300 acre-feet per year. Most of the flow is diverted from the stream for irrigation in Railroad Valley. The moderately large channel suggests that infrequent storms may produce an average flow on the order of 1,000 acre-feet per year.

Surface-water development.--Streamflow from snowmelt and discharge of springs constitute the two principal sources of water used for irrigation in the area. Table 5 summarizes the surface-water and spring development. South of Warm Spring in Hot Creek Valley, a few small-diameter pipelines are used to convey small amounts of water from springs in the Kawich Range to stock tanks on the western alluvial apron of the valley.

Ground Water

Occurrence and Movement

Ground water in the alluvium occurs under both confined (artesian) and unconfined (water-table) conditions. Hydrostatic heads in a few wells and all springs are at or above land surface, and occur principally along the axial wash of Little Fish Lake Valley, in Hot Creek Canyon, at Fish Creek and Twin Springs Ranches, and in some of the canyons of the various mountain ranges. The largest spring complex of the area is Fish Creek Springs (T. 16 N., R. 53 E.), having a measured flow of 5.4 cfs (cubic feet per second).

The maximum thickness of the ground-water reservoir is not known; no wells penetrate the entire thickness of the alluvium. Bedrock was reached in two wells (16/53-30b1 and 15/52-13b1 in table 15) in the northern part of Little Smoky Valley at depths of 186 feet and 376 feet, respectively; however, both wells are on the western valley apron where the alluvial thickness is considerably less than beneath the valley floor. Well 15/52-13b1, in Little Smoky Valley, is the deepest well for which data are available in the area. No data are available for any wells penetrating bedrock in the other valleys.

In most parts of the area ground-water movement is in the direction of surface flow; that is, from the mountain areas toward the valley floor and then along the sloping axes of the valleys to areas or points of discharge. Subsurface flow occurs principally in the alluvium, the water moving through the intergranular spaces.

In Little Fish Lake Valley, ground water moves toward the trough of the valley where most of the flow is discharged by evapotranspiration. A small amount of water moves southward beneath the alluvial divide to the headwaters of Hot Creek. In Hot Creek Valley, ground-water flow is toward

Table 5.--Surface-water and spring development for irrigation[1]

Ranch or place	Crop	Area (acres)	Source of water	Estimated water use (acre-feet per year)	Remarks
			HOT CREEK VALLEY		
Hot Creek	Alfalfa	100	Springs	200	Springs flow 1.7 cfs
	Meadowgrass	100	Springs	200	
Upper Hot Creek	Meadowgrass	100	Springs	200	Spring flows 0.8 cfs
Moores Station	Alfalfa	15	Spring and creek	30	
Warm Spring	Alfalfa	10	Warm Spring	20	Spring flows 1.5 cfs
Total (rounded)		300		600	
			LITTLE SMOKY VALLEY (northern part)		
Fish Creek	Meadowgrass	1,500	Fish Creek Springs	3,000	Springs flow 5.4 cfs
	Alfalfa	100	and associated high water table	200	
Willow Creek	Meadowgrass	40	Pine Spring and Willow Creek	80	Spring flows 1 cfs
Snowball Creek	Meadowgrass	20	Springs and	40	Springs flow about 100 gpm
	Alfalfa	20	Snowball Creek	40	
Indian Spring	Meadowgrass	15	Indian Creek and Indian Spring	30	Spring flows about 20 gpm
Total (rounded)		1,700		3,400	

1. No surface water or springs are used for irrigation in Little Fish Lake Valley or the southern part of Little Smoky Valley.

the east-central part of the valley where most is discharged by evapotranspiration and a small part moves eastward through alluvium beneath Hot Creek to Railroad Valley.

In the northern part of Little Smoky Valley, ground water flows northward where most is discharged by evapotranspiration and part discharges northward through the alluvium to Newark Valley. The depth to water beneath the small unnamed valley and playa at the south end of this valley reportedly is about 500 feet (well 11/53-6c1), which is too deep for discharge by evapotranspiration. Ground-water flow from this valley is presumed to be northward through the alluvium rather than eastward through the consolidated rocks.

In the southern part of Little Smoky Valley, ground-water movement probably is southward from about the surface divide and consolidated rocks to the southern third of the valley, where movement is presumed to be eastward through the Pancake Range to Railroad Valley. Except for a few high-level springs, no natural ground-water discharge occurs within the southern part of Little Smoky Valley. However, along the northeastern side of the valley, limestone in the Pancake Range could convey part of the water to the vicinity of Duckwater (off pl. 1), about 7 miles to the east, in Railroad Valley. For the purposes of this reconnaissance, all movement is assumed to be southward, then eastward to Railroad Valley.

Recharge

Ground water in the area, like the surface water, is derived from precipitation within the drainage basins. On the valley floors where precipitation is small, little if any precipitation infiltrates to the ground-water reservoir. Greater precipitation in the mountains and some on the alluvial apron provides most of the recharge. Much of the precipitation is evaporated before and shortly after infiltration, some adds to soil moisture, and some percolates to the water table and recharges the ground-water reservoir. The water that reaches the main stream channels by surface and subsurface flow in large part is absorbed by the alluvium as it flows toward the lowest parts of the valley floors.

A method described by Eakin and others (1951, p. 79-81) is used to estimate recharge in this report. The method assumes that a percentage of the average annual precipitation recharges the ground-water reservoir. Hardman (1936) showed that in gross aspect the average annual precipitation in Nevada is related closely to altitude and that it can be estimated with a reasonable degree of accuracy by assigning precipitation rates to various altitude zones.

The amount of precipitation and percentage of recharge from precipitation in the area seems to be less than that generally occurring in many areas of Nevada covered to date by the Reconnaissance Series. Similar conditions to those of this area were found in Monitor and Antelope Valleys, adjoining this area to the west (Rush and Everett, 1964, p. 17-19). This was not recognized by Eakin and others (1951, p. 155), because many of the precipitation stations were put into operation since their work and most of the data used in this report are for the period since the earlier study. Accordingly, their estimate of average annual recharge in Hot Creek Valley of 10,000 acre-feet is somewhat larger than the 7,000 acre-feet shown in table 6.

Table 6 shows the precipitation zones and the estimated precipitation and ground-water recharge in the study area. For the entire area the estimated recharge is only about 2 percent of the estimated precipitation, and ranges from less than 1 percent in the southern part of Little Smoky Valley to nearly 5 percent in Little Fish Lake Valley.

Table 7 shows the distribution of precipitation, recharge, and surface-water runoff in the area. The data indicate that the precipitation, recharge, and runoff are closely related and are larger for the western mountains, which generally are higher, as compared to those on the east sides of the valley, except for the southern part of Little Smoky Valley.

Table 6.--Estimated average annual precipitation and ground-water recharge

Precipitation zones (altitude in feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average (feet)	Estimated annual precipitation: Average (acre-feet)	Estimated recharge from precipitation: Percentage of precipitation	Estimated recharge from precipitation: Acre-feet per year
LITTLE FISH LAKE VALLEY						
Above 10,000	2,390	More than 20	1.75	4,200	25	1,000
9,000 to 10,000	13,450	15 to 20	1.46	20,000	15	3,000
8,000 to 9,000	52,240	12 to 15	1.12	58,000	7	4,100
7,000 to 8,000	119,200	8 to 12	.83	99,000	3	3,000
Below 7,000	90,980	Less than 8	.50	46,000	0	0
Total (rounded)	278,300			230,000		11,000
HOT CREEK VALLEY						
Above 9,000	4,740	15 to 20	1.46	6,900	15	1,000
8,000 to 9,000	32,050	12 to 15	1.12	36,000	7	2,500
7,000 to 8,000	133,100	8 to 12	.83	110,000	3	3,300
Below 7,000	488,100	Less than 8	.50	240,000	0	0
Total (rounded)	658,000			390,000		7,000
LITTLE SMOKY VALLEY (northern part)						
Above 9,000	2,030	15 to 20	1.46	3,000	15	450
8,000 to 9,000	18,620	12 to 15	1.12	21,000	7	1,500
7,000 to 8,000	91,330	8 to 12	.83	76,000	3	2,300
Below 7,000	262,400	Less than 8	.50	130,000	0	0
Total (rounded)	374,400			230,000		4,000

(Continued on next sheet)

Table 6.--Estimated average annual precipitation and ground-water recharge (Continued)

Precipitation zones (altitude in feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average (feet)	Estimated annual precipitation: Average (acre-feet)	Estimated recharge from precipitation: Percentage of precipitation	Estimated recharge from precipitation: Acre-feet per year
			LITTLE SMOKY VALLEY (southern part)			
Above 9,000	30	15 to 20	1.46	< 100	15	Minor
8,000 to 9,000	3,225	12 to 15	1.12	3,600	7	250
7,000 to 8,000	43,510	8 to 12	.83	36,000	3	1,100
Below 7,000	319,700	Less than 8	.50	160,000	0	0
Total (rounded)	336,500			200,000		1,400

Table 7.--Estimated distribution of precipitation, ground-water recharge, and surface-water runoff

(Percentage of total)

Hydrologic element	Little Fish Lake Valley	Hot Creek Valley	Little Smoky Valley northern part	Little Smoky Valley southern part
Precipitation and recharge				
(table 5)				
West side	70	90	90	30
East side	30	10	10	70
Runoff (table 4)				
West side	80	90	80	15
East side	20	10	20	85

Discharge

Prior to development by man, all ground water in the area was discharged by evaporation, transpiration, and subsurface and surface outflow. With the advent of mining and agriculture, spring discharge and streamflow were diverted and wells were pumped to satisfy water needs. The net result has been a small increase in the draft on the ground-water reservoir.

Evapotranspiration.--Much of the ground water is discharged by transpiration by phreatophytes, and evaporation from bare soil. The plants that use ground water grow over parts of the valley floors and include greasewood, rabbitbrush, meadowgrass, and saltgrass. In some of the canyons, cottonwood, willow, and wild rose grow along the banks of the creeks.

Table 8 lists the acreage of the phreatophytes mapped in the valleys and summarizes the estimates of evapotranspiration, which are based on rates of consumption of ground water in other areas as described by Lee (1912), White (1932), and Young and Blaney (1942). The dominant phreatophytes are greasewood and rabbitbrush, which cover about 75 percent of the discharge areas.

The 6,400 acres of naturally subirrigated meadowgrass and saltgrass in Little Fish Lake Valley are utilized for pasture. In Hot Creek Valley, near Twin Springs Ranch, an estimated 1,100 acres are similarly subirrigated and used for pasture.

Wells.--Wells pumped in the area are used only for stock and domestic purposes. No irrigation wells were pumped in 1965, although several were under construction in the northern part of Little Smoky Valley. The total discharge by wells is estimated to be no greater than 100 acre-feet per year in Hot Creek and the northern part of Little Smoky Valleys. There is only minor well discharge for domestic use in Little Fish Lake Valley and none in the southern part of Little Smoky Valley.

Springs.--The larger springs in the area are utilized for irrigation. Generally the water is diverted by ditches and applied to nearby fields. The remainder of the spring flow and part of that which is diverted seeps back into the ground, where much of it percolates to the ground-water reservoir. Table 9 lists the larger springs, their discharge, use, and other data.

In Hot Creek Canyon, the combined flow of all springs is 1,800 acre-feet per year. This quantity may be more than can be derived from recharge within the small watershed above the springs. Thus, part of the springflow may be from more distant areas such as Little Fish Lake Valley. In the northern part of Little Smoky Valley, the flow from Fish Creek Springs (about 4,000 acre-feet per year) is larger than can be expected from its

Table 8. --Estimated average annual discharge by phreatophytes

Process of ground-water discharge	Depth to water (feet)	Area (acres)	Average areal density (percent)	Probable average rate of use of water (acre-feet per acre per year)	Approximate discharge (acre-feet)
		LITTLE FISH LAKE VALLEY			
Meadowgrass and saltgrass	0-5	6,400	25-50	1.5	9,600
Greasewood and rabbitbrush	5-50	1,900	15-25	.2	380
Total (rounded)	--	8,300	--	--	10,000
		HOT CREEK VALLEY			
Saltgrass, meadowgrass, and rabbitbrush	0-10	1,100	20-30	.5	550
Greasewood and rabbitbrush	5-50	20,400	15-25	.2	4,080
Total (rounded)	--	21,500	--	--	4,600
		LITTLE SMOKY VALLEY (northern part)			
Meadowgrass	0-10	1,600	25-50	a .5	800
Greasewood and rabbitbrush	10-50	5,300	15-25	.2	1,060
Total (rounded)	--	6,900	--	--	1,900
		LITTLE SMOKY VALLEY (southern part)			
--	--	--	--	--	b None

a. Rate of discharge for Fish Creek Ranch; does not include irrigation of cropland by Fish Creek Springs.

b. None from principal ground-water reservoir in alluvium; minor amounts from high-level springs in mountains.

Table 9.--Inventory of selected springs

Spring number	Name or user	Altitude (feet)	Flow (cfs)	Temperature (°F)	Rock at orifice	Irrigation use (acre-feet per year)	Return to ground-water reservoir [1] (acre-feet per year)	Remarks
				HOT CREEK VALLEY				
8/49-25b1	Upper Hot Creek Ranch	5,850	0.8	92	limestone	200	400	
8/50-29d1,2,3	Hot Creek Ranch	5,600	1.7	(a)	limestone	400	800	Three-spring complex
4/50-20c1	Warm Spring	5,500	1.5	141	volcanic rock	20	1,100	Used in swimming pool also
				LITTLE SMOKY VALLEY				
16/53-8b1,2,3,4	Fish Creek Springs	6,040	5.4	63	limestone	3,200	800	Four-spring complex
14/51-22c1	Pine Spring	7,400	1	--	consolidated rock	60	600	In mountains
14/51-34a1,c1	Snowball Ranch	7,360	.2	--	do	40	100	In mountains
14/51-4b1	Indian Spring	8,600	.05	--	do	15	20	In mountains

1. Of this amount, some is discharged by phreatophytes in shallow water-table areas, commonly near the spring; but all is discharged ultimately by some means.

a. Lower spring of group produces about half the flow; temperature 180°F.

surficial watershed. Here it is probable that part of the springflow is from Antelope Valley (pl. 1).

At the outlet of Hot Creek Valley, Twin Springs, 4/51-12b1 and 13a1 have very little flow and resemble seeps. None of the water is diverted for irrigation within the valley; however, the small part that reaches the canyon and flows through to Railroad Valley is utilized there. All other springs reportedly have small flows.

Subsurface outflow.-- As previously described in the section on ground-water movement, subsurface or ground-water outflow occurs from all four valleys of the study area. Outflow from three can be estimated by a form of Darcy's law: $Q = 0.00112\ TIW$, in which Q is the quantity of underflow, in acre-feet per year; 0.00112 converts gallons per day to acre-feet per year; T is the transmissibility of the alluvium, in gallons per day per foot; I is the hydraulic gradient, in feet per mile; and W is the width of the section through which ground water moves. Crude estimates of the underflow from one valley to another are given in table 10.

Outflow from the southern part of Little Smoky Valley is assumed to be eastward to Railroad Valley through volcanic rocks to the springs at Lockes, which have a combined flow of about 3.2 cfs, or equivalent to 2,300 acre-feet per year. Southwest of Lockes, 6 and 12 miles, additional springflow of 0.15 to 0.2 cfs, or about 120 acre-feet per year, was observed. The combined spring discharge estimate of 2,400 acre-feet per year is far more than could be derived within the small watershed above the springs, where recharge probably does not exceed 100 acre-feet per year. Thus, it is assumed that about 2,300 acre-feet per year is outflow from the southern part of Little Smoky Valley.

Preliminary Water Budget

In these reconnaissances, the estimates of ground-water recharge and discharge are computed independently. Close agreement seldom is achieved. In most instances the estimate of recharge is no more accurate than the estimate of discharge. Accordingly, the average commonly is used to express the general magnitude of both recharge and discharge.

Table 11 shows the several estimates of recharge and discharge for the four valley areas of this report. It also shows the average and the value selected to represent the preliminary estimate of both recharge and discharge. In the northern part of Little Smoky Valley, an unknown part of the discharge from Fish Creek Springs probably is derived from Antelope Valley (pl. 1), which is west of the study area. The difference between the estimated recharge and discharge of about 2,000 acre-feet per year may be the amount of springflow whose source of supply is in Antelope Valley.

Table 10--Estimated average annual subsurface outflow

Outflow from	Assumed transmis-sibility (gpd/ft)	Hydraulic gradient (ft/mi)	Width of out-flow section (miles)	Estimated outflow (acre-feet)
South end of Little Fish Lake Valley	50, 000	30	0. 1	200
East side of Hot Creek Valley	50, 000	25	0. 5	a 700
North end of Little Smoky Valley 1/	100, 000	4	2. 5	1, 000
South end of Little Smoky Valley	--	--	--	b2, 300

1. Estimate by Eakin (1960, p. 14).

a. Same as estimate by Eakin (1951, p. 151).

b. See text; estimated from springflow at Lockes in Railroad Valley.

Table 11.--Preliminary ground-water budget

(In acre-feet per year)

Component	Little Fish Lake Valley	Hot Creek Valley	Little Smoky Valley Northern part	Little Smoky Valley Southern part
ESTIMATED RECHARGE:				
From precipitation (table 6)	11,000	7,000	4,000	1,400
Subsurface inflow from adjacent valley	--	a 200	b2,000±	--
Total	11,000	7,200	6,000	1,400
ESTIMATED DISCHARGE:				
Phreatophytes (table 8)	10,000	4,600	1,900	0
Irrigation from springs (table 9)	0	620	3,300	0
Domestic, stock pumpage	Minor	100	100	Minor
Surface-water outflow	0	c 300	0	0
Subsurface outflow (table 10)	200	700	1,000	d2,300
Total (rounded)	10,000	6,300	6,300	2,300
SELECTED VALUE FOR RECHARGE AND DISCHARGE: (rounded)	10,000	6,500	6,000	2,000

a. Outflow from Little Fish Lake Valley (table 10).

b. Inflow from Antelope Valley supplies substantial part of discharge from Fish Creek Springs.

c. Outflow from rising ground water near valley outlet at Twin Springs Ranch.

d. Springflow at and near Lockes in Railroad Valley provides a more accurate measure of recharge and discharge than estimated recharge from precipitation.

Perennial Yield

Perennial yield of a ground-water reservoir may be defined as the maximum amount of water of usable chemical quality that can be withdrawn and consumed economically each year for an indefinite period of time. If the perennial yield is continually exceeded, water levels will decline until the ground-water reservoir is depleted of water of usable quality or until the pumping lifts become uneconomical to maintain. Perennial yield cannot exceed the natural recharge to an area and ultimately is limited to the maximum amount of natural discharge that can be salvaged for beneficial use.

For Little Fish Lake Valley, the estimated total discharge is about 11,000 acre-feet per year (table 11). Most could be salvaged by wells, provided that they were properly spaced in or near the north-trending 20-mile band of phreatophytes (pl. 1). Therefore, the estimated perennial yield is nearly 10,000 acre-feet.

Ground-water development should, by design, lower the ground-water levels beyond the reach of phreatophytes or to about 50 feet below land surface. Flow in Clear and Danville Creeks could then be allowed to seep into the created ground-water storage space, reducing the creek flow to the playas and Fish Lake where water now evaporates. Climatic and soil conditions may prevent large-scale irrigation developments in Little Fish Lake Valley. In this case consideration could be given to exporting the water from Little Fish Lake Valley across the low divide which now separates this valley from Hot Creek Valley. The growing season is about 75 days longer in the latter valley, good soils are presumed to be available, and the water might be used more effectively than is presently the case. Water now ponds in Fish Lake and on adjacent playas where it is lost by evaporation. Both the economics of such a plan and the water quality in the playa and lake areas would have to be carefully evaluated.

For Hot Creek Valley, the estimated total discharge is about 6,500 acre-feet per year (table 11). Most of the surface-water and subsurface outflow probably would continue to Railroad Valley. Thus, the estimated perennial yield probably is not more than 5,500 acre-feet. This agrees closely with Eakin and others (1951, p. 155), who estimated that as much as 5,000 acre-feet per year of ground water could be developed from wells. Pumpage should be concentrated in the phreatophyte area between U. S. Highway 6 and Twin Springs Ranch in order to salvage the natural discharge; however, the needed lowering of water levels to at least 50 feet below land surface possibly would reduce spring and well flow at Twin Springs Ranch. In Tps. 1 through 3 N. in Hot Creek Valley (northern part of Reveille Valley) the water levels in well 3/51-19c1, 280 feet below land surface, indicates that pumping costs probably are too great for successful ranch-type irrigation projects.

For the northern part of Little Smoky Valley, the estimated total discharge is 6,000 acre-feet per year (table 11). Little of the subsurface outflow could be salvaged by pumping. Including the used discharge of Fish Creek Springs (about 3,200 acre-feet per year), the estimated perennial yield is about 5,000 acre-feet. To develop this yield most effectively, wells would have to be near or in the areas of phreatophytes in Tps. 16 and 17 N., Rs. 53 and 54 E. Several irrigation wells were under construction in T. 17 N., R. 54 E. in 1965. Near Fish Creek Springs, substantial ground-water development might affect the spring flow.

The grass covered area on Fish Creek Ranch, which is used for production of hay, probably would be adversely effected by extensive development of ground water in the surrounding greasewood and rabbitbrush area. The result probably would be a lowering of the shallow water table, which in part supports the hay crop. This may have two economic effects: (1) it would reduce the amount of water available to the grass area, tending to reduce the amount of hay produced, or (2) it might be a benefit by creating storage space for leaching water to drain, thus improving the reportedly saline soil of the grass area. These potential effects should be evaluated further; however, their consideration is beyond the scope of this report.

Finally, for the southern part of Little Smoky Valley, where the depth to water is at least 400 feet, the estimated total discharge is 2,000 acre-feet (table 11)--all by subsurface outflow to springs at and near Lockes in Railroad Valley, where most of the flow is utilized for irrigation. The possibility of salvaging all or part of the outflow by pumping in the southern part of Little Smoky Valley is dependent on the manner in which the flow moves through the volcanic rocks of the Pancake Range. If ground water is moving over a "spillway", then most could be salvaged by drawing down the water level below the outlet altitude. On the other hand, if the movement is dispersed through a fault system or joint pattern, or is at great depth in the basin, then only a small amount of the discharge could be salvaged by pumping within the valley. Because the salvable discharge lies between these two limits, the preliminary estimate of perennial yield is considered to be about 1,000 acre-feet.

It is reported that an attempt was made to obtain a water supply near U. S. Highway 6 in the valley, but no water was encountered down to a depth of 400 feet, the depth at which drilling stopped. It is probable that the depths to water in the southern part of the basin, and perhaps through the basin, are great. Such depths to water probably would preclude any economic development of water for irrigation.

Storage

Recoverable ground water in storage is that part of the stored water that will drain by gravity from the ground-water reservoir in response to pumping. Under native conditions the amount of stored ground water remains nearly constant. The balance between recharge and discharge, which controls the changes of ground water in storage, probably has been disturbed somewhat by the diversion of small amounts of surface and ground water.

The recoverable ground water in storage is the product of the specific yield, the area of the ground-water reservoir, and the selected saturated thickness of the alluvium. Specific yield of a rock or soil is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. This ratio is stated as a percentage. In the report area, the average specific yield of the alluvium (the ground-water reservoir) probably is at least 10 percent. The selected thickness is the uppermost 100 feet of saturated alluvium. The areas mapped as alluvium on plate 1, the areas used to compute storage, and the estimated amount of recoverable water are summarized in table 12.

In some areas, part of this stored water can be used when the annual replenishment is below normal or when needs demand its use. The areas of shallow water table in Hot Creek Valley between U.S. Highway 6 and Twin Springs Ranch, along the flood plain of the axial drainageway in Little Fish Lake Valley, and in Tps. 16 and 17 N. in Little Smoky Valley, are favorable for extended pumping from storage when the needs arise.

Chemical Quality of the Water

Seventeen water samples were collected and analyzed as part of the present study to make a generalized appraisal of the suitability of ground and surface water for agricultural use and to help define the relation of quality to the hydrologic system. These analyses are listed in table 13.

Suitability for Agricultural Use

According to the Salinity Laboratory Staff, U.S. Department of Agriculture (1954, p. 69), the most significant factors with regard to the chemical suitability of water for irrigation are: (1) dissolved-solids content, (2) the relative proportion of sodium to calcium and magnesium, (3) the concentrations of elements and compounds that are toxic to plants, and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium. Dissolved-solids content commonly is expressed as "salinity hazard," the relative proportion of sodium to calcium and magnesium as "alkali hazard," and the relative bicarbonate concentration as "residual sodium carbonate" or RSC. No analysis was made for boron or the other toxic elements.

Table 12.--Estimate of water stored in the upper 100-foot thickness of saturated alluvium

Valley	Alluvial area (acres)	Area having 100 feet or more of saturated thickness (percentage)	(acres)	Estimated stored water [1] (acre-feet)
Little Fish Lake	108,000	75	80,000	800,000
Hot Creek	310,000	75	230,000	2,300,000
Little Smoky				
northern part	210,000	75	160,000	1,600,000
southern part	188,000	a 50	94,000	940,000

1. Based on an assumed specific yield of 10 percent.

a. Smaller percentage of alluvial area is used because of the great depth to water, reducing the area where there is 100 feet of saturated thickness.

Streamflow resulting from snowmelt during the spring of the year is low in dissolved material because the water has a minimum contact with rock material of the mountains and the apron. This water is excellent for irrigation in all valleys.

In Little Fish Lake Valley, two samples were collected: one from Danville Creek; the other from the domestic well at Fish Lake Ranch. Both samples would be good irrigation water. Water from well 10/49-11c1, however, is very hard. Because of the absence of rain prior to sampling, the flow in Danville Creek was from ground-water sources.

Seven samples were collected in Hot Creek Valley, three from wells and four from springs. The sample from well 4/51-29c1 had a high salinity hazard rating. Such water should not be used for irrigation on soils with restricted drainage, and then only with special management for salinity control and for crops with good salt tolerance. The other two wells, as indicated in table 13, were satisfactory. Of the four springs sampled, only spring 8/49-24d1 is generally suitable for irrigation use. Spring 7/50-23d1 is rated very high in both salinity and alkalinity hazards, and spring 7/50-23d1 and spring complex 8/50-29d1, 2, and 3 are tentatively rated unsuitable in RSC (residual sodium carbonate) (U.S. Department of Agriculture, 1954, p. 75 and 81) for extended long-term use for irrigation. Water quality may be a problem in the phreatophyte area between U.S. Highway 6 and Twin Springs Ranch, the area of proposed ground-water development, as indicated by analyses of water from well 4/51-29c1 listed in table 13.

Four samples were collected in the northern part of Little Smoky Valley. Two were from Fish Creek Springs, and one from a newly drilled irrigation well (17/54-16b1), as yet unused. All were rated medium in salinity hazard, low in alkalinity hazard, and safe in RSC.

The springs along the eastern side of the Pancake Range in Railroad Valley were sampled because a large part of their flow is believed to be from Little Smoky Valley. The springs at Lockes are suitable for irrigation, as indicated in table 13, but springs 6/54-11a1, 7/55-16d1, 12 and 6 miles south, respectively, are high in salinity hazard and at best marginal in RSC.

The limited data indicate that water supplies of low to medium mineral content probably can be developed throughout much of the alluvial valley areas.

Table 13.--Chemical analyses of water from selected wells and springs

Chemical constituents in parts per million

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

Location	Date of collection	Source type	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[1]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Chloride (Cl)	Sulfate (SO_4)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Irrigation quality: Salinity hazard	Irrigation quality: Alkalinity hazard	Irrigation quality: SSC	Water type	Rock source
								LITTLE FISH LAKE VALLEY											
10/49-11c1	10-30-65	well	65	37	38	16	260	0	33	105	331	116	626	8.2	medium	low	safe	magnesium bicarbonate	alluvium
a T. 11 N., R. 49 E.	8-29-65	creek	62	33	15	14	148	0	4.6	47	146	25	294	7.9	medium	low	safe	calcium-magnesium bicarbonate	--
								HOT CREEK VALLEY											
b 4/50-20c1	10-17-65	spring	141	55	36	205	712	0	32	98	284	0	1,270	7.9	high	low	unsuitable	sodium bicarbonate	volcanic rock
4/51-13d1	10-20-65	well	53	30	5.4	74	248	0	15	32	97	0	487	7.4	medium	low	marginal	sodium bicarbonate	alluvium
4/51-29c1	10-17-65	well	62	74	25	77	428	0	53	56	288	0	848	7.3	high	low	marginal	bicarbonate	alluvium
6/51-13a1	10-17-65	well	--	19	4.0	59	164	0	12	24	64	0	363	7.6	medium	low	marginal	sodium bicarbonate	alluvium
7/50-23c1	10-17-65	spring	--	55	54	564	1,120	51	156	302	312	0	2,540	8.5	very high	very high	unsuitable	sodium bicarbonate	alluvium
8/49-24c1	8-29-65	springs	92	19	26	52	204	0	22	64	153	0	462	8.0	medium	low	safe	bicarbonate	limestone
8/50-29d1,2,3	8-30-65	springs[2]	94	13	26	124	340	0	33	81	140	0	718	8.2	medium	low	unsuitable	sodium bicarbonate	limestone
								LITTLE SMOKY VALLEY											
15/54-6d1	10-20-65	well	57	30	4.6	16	126	0	6.6	20	94	0	234	7.6	medium	low	safe	calcium bicarbonate	alluvium
c 16/53-8a1	8-30-65	springs	53	28	29	38	267	0	11	37	191	0	444	8.2	medium	low	safe	bicarbonate	limestone
16/53-9a1	8-29-65	springs	64	37	29	36	273	0	8.6	51	211	0	462	8.2	medium	low	safe	bicarbonate	limestone
17/54-16b1	10-20-65	well	57	28	24	21	219	0	9.0	42	169	0	409	7.9	medium	low	safe	bicarbonate	alluvium
								RAILROAD VALLEY											
6/54-11a1	11- 2-65	spring	85	106	30	136	735	0	19	57	390	0	1,170	7.6	high	low	unsuitable	calcium bicarbonate	volcanic rock
7/55-16c1	11- 2-65	spring	130	72	22	70	433	0	15	51	271	0	765	7.4	high	low	marginal	bicarbonate	alluvium
d 8/55-14b1	11- 2-65	spring	95	63	25	58	380	0	12	60	260	0	694	7.6	medium	low	safe	bicarbonate	volcanic rock
e 8/55-15d1	11- 2-65	spring	95	59	23	68	376	0	12	63	243	0	684	8.1	medium	low	marginal	bicarbonate	volcanic rock

1. Computed by difference
2. Mixed water from a three-spring complex

a. Danville Creek at site 6 as shown on plate 1
b. Warm Springs
c. Fish Creek Springs at site 33
d. North Spring
e. Big Spring

Water Quality and its Relation to the Ground-Water System

As previously stated, water of best quality generally has had a minimal contact with chemically reactive rocks and soil. In the hydrogeologic environment of this area, surface water flowing in mountain streams and on the alluvial apron is generally low in mineral content. Surface water that wastes to the playas and ponds can be expected to become poor in quality in time by the processes of concentration by evaporation and solution of concentrated salts from soils of the playas.

Of the samples collected, those from volcanic-rock sources generally have the highest mineral content, as indicated by the specific electrical conductances listed in table 13. Next in concentration, generally, are samples from limestone and least concentrated are those from alluvial sources. In many areas of Nevada bedrock yields water of lowest mineral content, but this is not the case for the samples collected in this area. The difference may be due to a longer distance and time of flow of ground water in this area. For example, the flow of water from Little Smoky Valley through the volcanic rocks of the Pancake Range to Railroad Valley and the flow of ground water several tens of miles through volcanic and carbonate rocks to Hot Creek Canyon.

Water in Hot Creek Valley, as indicated by the samples, is generally a sodium bicarbonate type, probably reflecting the abundance of volcanic rocks in the surrounding mountains. In Little Fish Lake Valley water is generally a calcium-magnesium bicarbonate type, and a mixed bicarbonate type in Little Smoky Valley.

Generally shallow ground water in the alluvium has a temperature near the average annual air temperature of the area, which is approximately 50° to 60° F. Water temperatures appreciably higher than this may indicate high thermal gradients or relatively deep water circulation, or both. Ground water occurring under such conditions may reach boiling; however, the highest temperature in the area of 180° F was at spring 8/50-29d1 in Hot Creek Canyon. Most of the springs, except those at Fish Creek Ranch and Twin Springs Ranch, had temperatures near 90° F.

NUMBERING SYSTEM FOR WELLS AND SPRINGS

The numbering system for wells and springs 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 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 is followed by a letter that indicates the quarter section: the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. Following the letter, a number indicates the order in which the well or spring was recorded within the 160-acre tract. For example, well 15/53-32c1 is the first well recorded in the SW 1/4 sec. 32, T. 15 N., R. 53 E., Mount Diablo base line and meridian.

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

Table 14.--Records of selected wells

Altitude: Interpolated from topographic maps (contour interval 100 and 200 feet)
Measuring point description: TC, top of casing or cribbing
Water level: M, measured; R, reported
Use of water: D, domestic; I, irrigation; S, stock; U, unused
Remarks: Number is log number in files of State Engineer's office

Well number and location	Owner and/or location	Date drilled	Depth (feet)	Diameter of casing (inches)	Principal water-bearing zone (feet)	Altitude (feet)	Measuring point: Description	Water level: Above land surface (feet)	Water level: Below measuring point (feet)	M or R	Date	Temperature (°F)	Use	Remarks
					LITTLE FISH LAKE VALLEY									
10/49-11c1	Fish Lake Ranch	--	--	--	--	6,500	--	--	30	R	1965	--	U	
					HOT CREEK VALLEY									
2/50-34a1	Old Fallini Ranch	--	--	6	--	6,350	TC	1.0	12.66	M	10-17-65	--	S	
3/51-19c1	Fallini Bros., Charlie's Well	1948	320	6	290-320	5,450	--	--	280	R	1964	--	S	672
4/51-13d1	Mrs. E. W. Fallini	1959	300	8	5-300	5,120	--	--	3	R	1959	--	U	5083
5/51-11c1	Twin Springs Ranch	--	--	6	--	5,250	TC	.5	25.24	M	10-18-65	--	S	
5/51-19b1	Fallini Bros.	--	--	48 x 48	--	5,220	TC	0	48.62	M	10-17-65	--	S	
6/50-11b1	Hot Creek Ranch	--	--	6	--	5,540	TC	.5	183.49	M	10-17-65	--	S	
6/50-35a1	Hot Creek Ranch	--	--	--	--	5,320	--	--	--	-	--	--	S	
6/51-15a1	Highway Dept., Bluejay Well	--	--	10	--	5,360	TC	2.5	43.33	M	10-17-65	--	D	
8/51-36c1	Joseph Williams	1948	155	5	125-155	5,500	--	--	110	R	1948	--	S	973
					LITTLE SMOKY VALLEY									
9/54-9a1	Olevia Well	--	--	--	--	6,900	--	--	15	R	1966	--	S	
11/53-6a1	Arambell Well	--	--	--	--	6,550	--	--	500	R	1966	--	S	Depth reported to be 900 feet
15/52-13b1	Fish Creek Ranch, Eightmile Well	1942	376	8	352-355	6,400	--	--	347	R	1942	--	S	213
15/52-35c1	Arambell Well	--	500	--	--	6,435	--	--	400	R	1963	--	S	See Snyder (1963)
15/53-23d1	Fish Creek Ranch, Deep Well No. 2	--	350	--	--	6,160	--	--	186	R	1965	--	S	
15/53-25d1	--	--	200	6	--	6,200	--	--	155	R	1963	--	S	See Snyder (1963)
15/53-28a1	Fish Creek Ranch, No. 1	1956	242	8	228-242	6,180	--	--	220	R	1956	--	S	3421
15/53-32c1	John F. and Bernice Kincaid	1953	300	10,12	150-300	6,260	TC	1.0	245 248.98	R M	1953 10-20-65	--	U	Bailed dry 2405
15/54-11a1	Pogues Station	--	45	--	--	6,395	--	--	15	R	1963	--	S	See Snyder (1963)
15/54-6d1	Fish Creek Ranch	--	164	36 x 48	--	6,100	TC	0	158.50	M	10-20-65	57	S	
15/54-20d1	Bureau of Indian Affairs	--	164	--	--	6,600	--	--	dry	R	1963	--	U	See Snyder (1963)
16/53-10d1	Fish Creek Ranch	--	539	12	--	6,050	--	--	15	R	1963	--	U	See Snyder (1963)
16/53-30b1	Fish Creek Ranch, No. 3	1942	186	8	135-151	6,119	TC	1.0	82 79.17	R M	1942 9- 1-65	--	S	214, Bedrock at 182 feet
16/54-15b1	--	--	--	48	--	6,060	--	--	85	R	1963	--	S	See Snyder (1963)
16/54-20b1	Fish Creek Ranch	1956	175	6	--	6,060	--	--	77	R	1956	--	U	3545
17/53-29b1	Fish Creek Ranch, No. 4	--	--	--	--	6,190	--	--	--	-	--	--	S	
17/54-2d1	Fish Creek Ranch, No. 9	1961	76	10 gauge	68-76	5,960	--	--	30	R	1961	--	S	5988
17/54-14b1	Black Point Well	--	--	--	--	5,980	TC	.5	52.40	M	10-20-65	--	S	
17/53-16b1	--	1965	--	16	--	6,020	TC	1.0	85.31	M	10-20-65	57	I	
17/54-29c1	Fish Creek Ranch	--	61	48	56-57	5,987	TC	2.5	52 54.95	R M	1961 10-14-65	--	S	5635

Table 15.--Selected drillers' logs of wells

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
HOT CREEK VALLEY					
3/51-19c1			8/51-34c1		
Sand, gravel, and dirt	280	280	Clay and silt	20	20
Silt	10	290	Sand and gravel	60	80
Gravel, water-bearing	2	292	Silt	45	125
Silt	18	310	Sand, water-bearing	1	126
Clay	5	315	Clay	4	130
Sand and gravel, water-bearing	5	320	Sand, water-bearing	25	155
4/51-13d1					
Soil	5	5			
Sand	50	55			
Sand, gravel, and clay in thin streaks	245	300			
LITTLE SMOKY VALLEY (northern part)					
15/52-13b1			17/54-2d1		
Gravel, dry	6	6	Soil	6	6
Coarse sand and clay, dry	6	12	Sand and gravel with thin clay streaks	27	33
Caliche, dry	133	145	Clay	6	39
Shale, dry	110	255	Sand and fine gravel	10	49
Sandstone, dry	97	352	Clay	3	52
Gravel, water-bearing	3	355	Gravel, water-bearing, medium	4	56
Clay (decomposed bedrock), dry	2	357	Clay, sandy	2	58
Bedrock - vitreous, igneous rock, dry	19	376	Sand and fine gravel	7	65
15/53-32c1			Gravel, medium to coarse	11	76
Soil	3	3			
Rock, red	67	70			
Sand	150	220			
Rock, red	80	300			

(Continued on next sheet)

Table 15.-- Selected drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
LITTLE SMOKY VALLEY (Continued) (northern part)		
17/54-29c1		
Soil with thin streaks of alkali	4	4
Sand, fine to medium	19	23
Clay and some sand	3	26
Sand and gravel with thin streaks of clay	18	44
Clay and sand	2	46
Sand and fine to medium gravel	10	56
Clay and sand, water-bearing	1	57
Gravel, medium and coarse, water-bearing	4	61

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