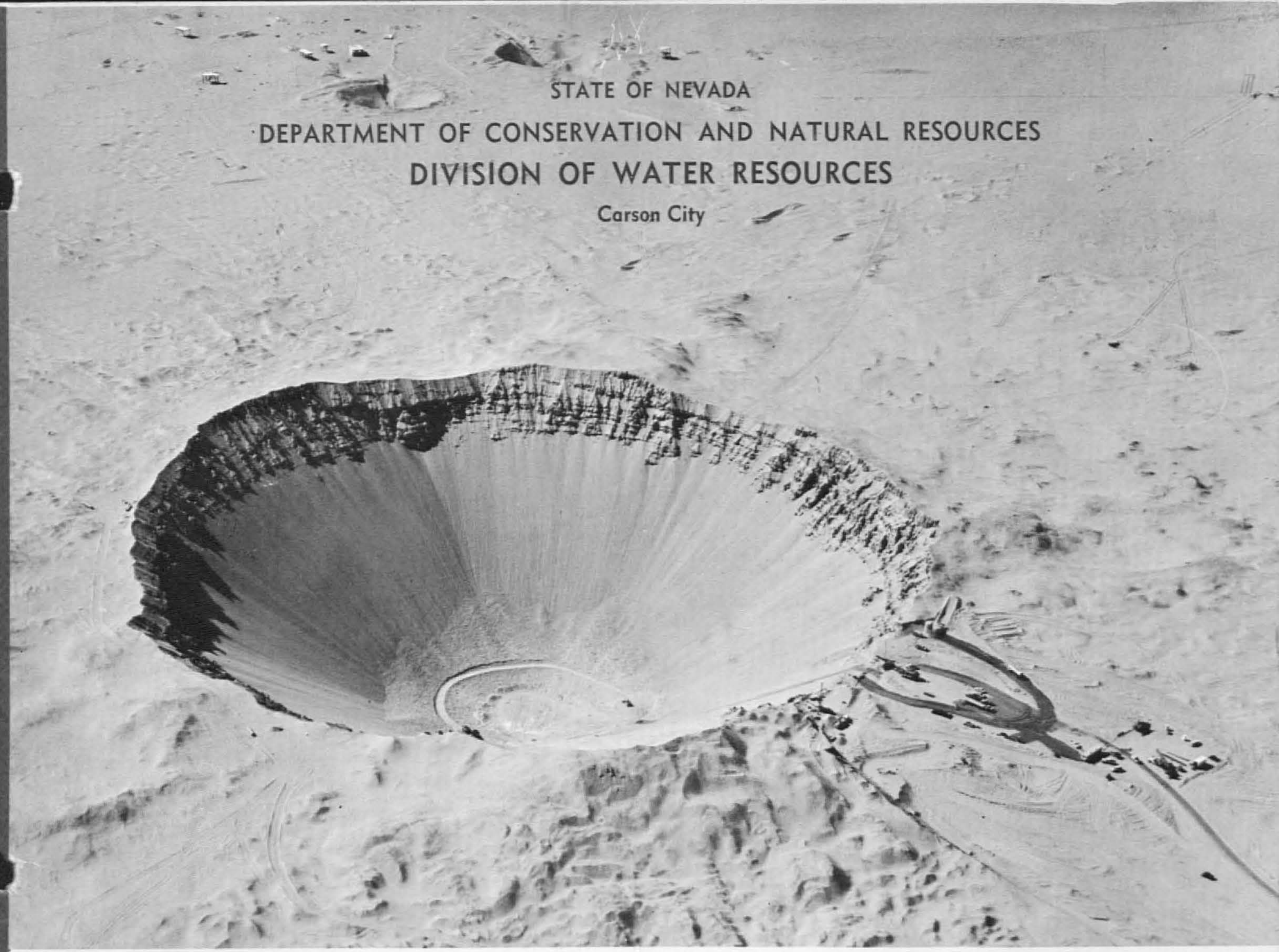
STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

Carson City



Photograph by Lawrence Radiation Laboratory

Sedan Crater was formed in the dry alluvium of Yucca Flat by an underground atomic detonation.

WATER RESOURCES–RECONNAISSANCE SERIES

REPORT 54

REGIONAL GROUND–WATER SYSTEMS IN THE NEVADA TEST SITE AREA, NYE, LINCOLN, AND CLARK COUNTIES, NEVADA

By

F. Eugene Rush

Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

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FOREWORD

The program of reconnaissance water-resources studies was authorized by the 1960 Legislature to be carried on by Division of Water Resources of the Department of Conservation and Natural Resources in cooperation with the U.S. Geological Survey.

This report is the 54th in the series to be prepared by the staff of the Nevada District Office of the U.S. Geological Survey. These 54 reports describe the hydrology of 185 valleys.

The reconnaissance surveys make available pertinent information of great and immediate value to many State and Federal agencies, the State cooperating agency, and the public. As development takes place in any area, demands for more detailed information will arise, and studies to supply such information will be undertaken. In the meantime, these reconnaissance studies are timely and adequately meet the immediate needs for information on the water resources of the areas covered by the reports.

Roland D. Westergard
State Engineer

1971

Division of Water Resources

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REGIONAL GROUND-WATER SYSTEMS IN THE NEVADA TEST SITE AREA, NYE, LINCOLN, AND CLARK COUNTIES, NEVADA

By F. Eugene Rush

SUMMARY

The area covered by this report includes 16 hydrographic areas between Tonopah and Las Vegas, Nevada, and centers about the Nevada Test Site of the U.S. Atomic Energy Commission. The area is arid to semiarid, having an average annual precipitation of about 5 inches on the valley floors to as much as 20 inches in the wetter mountains.

The consolidated rocks of the area are mostly volcanic rocks; however, some extensive areas of carbonate rocks have been mapped.

Three types of ground-water reservoirs are identified: valley-fill, volcanic-rock, and carbonate-rock aquifers. Alluvium beneath valley floors is commonly saturated only at great depth. Water in the valley-fill reservoirs generally leaks downward to underlying volcanic or carbonate rocks.

Volcanic-rock aquifers in the eastern part of the study area locally transmit water downward to carbonate-rock aquifers. In the western part of the area, the volcanic-rock aquifers transmit a regional flow of water, as do the carbonate-rock aquifers of the eastern part of the area.

The transmissivity of volcanic-rock aquifers of the western part of the study area averages about 10,000 gallons per day per foot. The transmissivity of the carbonate-rock aquifer generally is much higher, resulting in low flow gradients.

Three regional interbasin ground-water flow systems have been identified: The Ash Meadows system in the eastern two-thirds of the area, the Pahute Mesa system in the western third, and the Sarcobatus Flat system west of the study area and including Cactus Flat. Ground water in the Ash Meadows system flows generally southward to Ash Meadows to discharge at springs, by evapotranspiration, and possibly by subsurface outflow across a fault barrier to the south end of the Pahute Mesa system in Amargosa Desert. The Pahute Mesa system flows generally southward to discharge largely by evapotranspiration in Amargosa Desert. Ground water is believed to flow southwestward from

Cactus Flat to Sarcobatus Flat where it is largely discharged by evapotranspiration. Some of the water in the first two systems may move southwestward as underflow to Death Valley through the carbonate rocks of the Funeral Range.

The estimated average annual recharge and discharge for the Ash Meadows regional system are 33,000 and at least 17,000 acre-feet, respectively; for the Pahute Mesa regional system these estimates are 11,000 and 9,000 acre-feet, respectively; and for Sarcobatus Flat regional system, 3,500 acre-feet. For the Ash Meadows and Pahute Mesa systems, which join in Amargosa Desert, the computed excess of recharge over discharge of some 18,000 acre-feet per year may flow southwestward to Death Valley, assuming of course that substantial errors in the estimates do not exist.

Because virtually all the ground-water discharge from the hydrographic areas is by subsurface outflow at considerable depth, most ground-water development probably will be from ground water in storage. One exception is the western part of Groom Lake Valley where an estimated 2,500 acre-feet per year could be salvaged. Beneath valley floors, an estimated 10 million acre-feet of ground water is in transient storage in the uppermost 100 feet of saturation.

INTRODUCTION

Purpose and Scope of the Study

Many reports have been written on various aspects of the hydrogeology of the Nevada Test Site (NTS) and adjoining areas, but most of them were prepared on behalf of the U.S. Atomic Energy Commission by the U.S. Geological Survey as aids to the Commission's testing program. Because of the limited distribution of these reports, much of the information in them is not readily available to the general public. This report has been written to make that information available on the general ground-water conditions of the area. Many of the general conclusions presented here are abstracted from these other reports.

Objectives of this reconnaissance are to (1) describe the general hydrologic environment, (2) appraise the source, occurrence, and movement of ground water in the area, and (3) estimate average annual recharge to and discharge from three major ground-water systems. Because of the physical limitations governing the hydrology, no preliminary estimates of perennial yield were made, as is usually done in these reconnaissance studies. However, the yields estimated for Amargosa Desert (Walker and Eakin, 1963) and Sarcobatus Flat (Malmberg and Eakin, 1962) are considered rough measures of the yields for the Ash Meadows, Pahute Mesa, and Sarcobatus Flat regional ground-water systems of this report.

The compilation of information that forms the basis of this report was made largely in January and February 1970.

Previous Work

A large number of reports have been written on various aspects of the hydrogeology of the area. Many of the conclusions in this report are based on the findings of Eakin and others (1963), I. J. Winograd and others (written commun., 1970), Winograd and Thordarson (1968), Winograd (1963), and R. K. Blankennagel and J. E. Weir (written commun., 1970). In addition, geologic maps have been prepared of the southern part of Nye County by Cornwall (1967), Lincoln County by Tschanz and Pampeyan (1961), and Clark County by Longwell and others (1965). Several hundred additional reports on various aspects of the hydrology and geology of the Nevada Test Site are listed by Ohl (1967).

HYDROLOGIC ENVIRONMENT

Location

The area covered by this report is in southern Nevada, as shown in figure 1, and includes 16 hydrographic areas plus the extreme northern part of Las Vegas Valley, as shown by Rush (1968) and as shown on plate 1 and listed in table 1. The project area is in the southern part of the Great Basin and covers about 6,200 square miles.

Las Vegas is 30 miles southeast of the area; Tonopah, 30 miles to the northwest. U.S. Highway 95 traverses the southern part of the area and State Route 25, the northeast part. The small towns of Indian Springs, Cactus Springs, Lathrop Wells, and Beatty are on Highway 95 in the southern part of the area (pl. 1).

Prior to the development of the Nevada Test Site by the U.S. Atomic Energy Commission, little human activity took place in the area. Since World War II, most of the area has been used as a bombing and gunnery range for Nellis Air Force Base, Las Vegas.

Climate and Precipitation

The area is characterized by short, mild winters with light snow in the mountains and long, hot, and dry summers. At the higher altitudes, the summer nights are cool.

The area is generally semiarid to arid. Precipitation ranges from less than 5 to more than 20 inches. The distribution of precipitation is related to the altitude of the land surface and latitude--the higher mountains in the southeastern part of the area receive the largest amounts of precipitation and the northwestern valley floors the least. Most of the precipitation falls in the winter, but some precipitation occurs in the summer as thunderstorms.

The estimated average annual precipitation is summarized by hydrographic areas in the section on recharge (table 3). The distribution of precipitation used in this report is based on estimates presented in other hydrologic reports of this report series (listed in the back of the report) for adjacent areas. The hydrographic area having the smallest average annual precipitation is Rock Valley, receiving an average slightly less than 6 inches; the wettest is that part of Las Vegas Valley included in the report, receiving an average of about 11 inches. Most of the hydrographic areas receive an average of between 6 and 8 inches per year.

Table 1.--Summary of physiography

[Adapted from Rush, 1968]

Hydrographic area	Approximate area (square miles)	Approximate altitude of valley floor (feet)	Stream inflow and outflow
CENTRAL HYDROGRAPHIC REGION			
Cactus Flat	403	5,400	None
Gold Flat	684	5,200	None
Kawich Valley	350	5,500	None
Yucca Flat	305	4,000	None
Frenchman Flat	463	3,200	None
Papoose Lake Valley	104	4,600	None
Groom Lake Valley	663	4,600	None
Tikapoo Valley:			
Northern part	627	4,300	Outflow
Southern part	380	3,400	Inflow
Three Lakes Valley:			
Northern part	298	3,600	None
Indian Springs Valley	655	3,200	None
COLORADO RIVER BASIN			
Three Lakes Valley:			
Southern part	311	3,100	Inflow
Las Vegas Valley, western slope of Sheep Range only	88	3,400	Outflow
DEATH VALLEY BASIN			
Buckboard Mesa	240	5,000	Outflow
Mercury Valley	110	3,200	Outflow
Rock Valley	82	3,300	Outflow
Jackass Flats	279	3,500	Both
Crater Flat	182	3,200	Outflow

Geology

The distribution of consolidated rocks and alluvium is shown on plate 1. The consolidated rocks are mostly volcanic rocks of Tertiary age; however, there are extensive outcrops of carbonate rocks of Paleozoic age that have been mapped by Cornwall (1967), Tschanz and Pampeyan (1965), and Longwell and others (1965). The alluvium is of late Tertiary and Quaternary age.

Only two hydrographic areas do not have outcrops of carbonate rocks--Cactus and Gold Flats (pl. 1). Kawich Valley and Buckboard Mesa have only a small part of the consolidated rock cropping out as carbonate rocks. All other hydrographic areas included in this report have a moderate to large proportion of carbonate rocks making up the consolidated rocks. Under the valley fill, a similar distribution of carbonate rocks is probable.

The distribution of carbonate rocks has hydrologic significance because in this area, as well as in many areas of Nevada, they transmit flow in regional ground-water systems beneath topographic divides.

GROUND-WATER RESERVOIRS

Three types of ground-water reservoirs or aquifers were identified by I. J. Winograd and others (written commun., 1970) and R. K. Blankennagel and J. E. Weir (written commun., 1970): valley-fill, volcanic-rock, and carbonate-rock aquifers.

Alluvium up to 2,000 feet in thickness (Winograd and others, written commun., 1970), derived from the surrounding mountains, underlies the valley floors and where saturated is a reservoir for ground water. Depth-to-water data beneath valley floors are provided in table 2. These data indicate that in some areas the valley fill may not be saturated and often, where saturated, only at great depths. In all valleys, little ground water is discharged to the atmosphere, except at a few springs such as Indian Springs. Indian Spring discharge, less than 500 gpm (gallons per minute), is small in relation to the total recharge to the area. In the topographically closed hydrographic areas, ground water flows through the valley fill and moves laterally or vertically downward to volcanic-rock or carbonate-rock aquifers. Beneath Yucca and Frenchman Flats, Winograd and others (written commun., 1970) estimated that the downward leakage to the carbonate-rock aquifers is less than 100 acre-feet per year in each valley.

The volcanic-rock aquifers locally transmit water through fractures in the eastern two-thirds of the project area. This flow, as in alluvium, is to underlying carbonate-rock aquifers. However, in the western third of the area, where carbonate rocks are absent, the fractured volcanic-rock aquifers transmit ground water beneath topographic divides and unite the area into a regional ground-water flow system. Blankennagel and Weir (written commun., 1970) estimated that the transmissivity of the volcanic-rock aquifers ranges between 1,400 gpd (gallons per day) per foot to more than 100,000 gpd per foot and may have a mean value near 10,000 gpd per foot.

Several thousand feet of saturated carbonate-rock aquifers is believed to underlie most of the eastern two-thirds of the area. These aquifers are highly fractured limestone and dolomite, having transmissivities ranging from as small as about 6 to as large as 6 million gpd per foot (Winograd and others, written commun., 1970). Ground water is transmitted through carbonate-rock aquifers on a regional basis to form a large ground-water system. The gradient of the piezometric surface is commonly only a few feet per mile (pl. 1); however, across major faults, water-level altitudes may differ as much as 500 feet within a valley and 2,000 feet between valleys (Winograd and others, written commun., 1970).

Table 2.--Minimum depths to water beneath valley floors

[Principally based on data from Winograd and others, and Blankennagel and Weir (written commun., 1970)]

Hydrographic area	Aquifer	Approximate minimum depth to water (feet)	Approximate altitude of water surface where depth to water is a minimum (feet above sea level)
	ASH MEADOWS GROUND-WATER SYSTEM[1]		
Groom Lake Valley	Alluvium	100	4,340
Papoose Lake Valley	Carbonate rock	2,100	2,500
Tikapoo Valley			
Northern part	(unknown)	>500	<3,700
Southern part	--	--	--
Las Vegas Valley			
Western slope of Sheep Range only	--	--	--
Three Lakes Valley			
Northern part	--	--	--
Southern part	Alluvium	100-300	2,750-2,900
Indian Springs Valley	Alluvium	a <50?	3,100-3,175
Yucca Flat	Alluvium	b 1,500	2,400
Frenchman Flat	Alluvium	c 800	2,400
Jackass Flats			
Eastern one-third only	--	--	--
Rock Valley	Alluvium or volcanic rocks	1,250-1,300	2,300-2,350
Mercury Valley	Carbonate rock	800-850	2,350-2,400
	PAHUTE MESA GROUND-WATER SYSTEM[2]		
Gold Flat	Alluvium	230-250	4,880-4,970
Kawich Valley	(unknown)	400	4,800-5,000
Buckboard Mesa[3]	Volcanic rock	d 400-450	5,700-5,800
Jackass Flats			
Western two-thirds only	Alluvium or volcanic rocks	e 300-350	2,300-2,350
Crater Flat	Alluvium or volcanic rocks	f 250-600	2,300-2,400
	SARCOBATUS FLAT GROUND-WATER SYSTEM[4]		
Cactus Flat	Alluvium	d 90-150	5,200-5,300

1. Also includes the eastern part of Amargosa Desert.
2. Also includes Oasis Valley, western part of Amargosa Desert, and possibly the southern part of Reveille Valley.
3. No valley floor present; depth is below mesa.
4. Mostly west of report area. Cactus Flat may be part of Pahute Mesa ground-water system.

a. Near Indian Springs.
b. Eakin and others (1963, table 1) reports 670 feet.
c. Eakin and others (1963, table 1) reports 683 feet.
d. Semiperched water.
e. Near Lathrop Wells.
f. Southern part of valley floor.

REGIONAL GROUND-WATER FLOW SYSTEMS

Three regional interbasin ground-water systems have been identified in the study area (pl. 1): (1) the Ash Meadows ground-water system in the eastern part of the area (the Ash Meadows Ground-Water Basin of Winograd and others, written commun., 1970); (2) the Pahute Mesa ground-water system in the western part (informally designated by Winograd as the Oasis Valley-Fortymile Canyon basin); and (3) the Sarcobatus Flat ground-water system, mostly west of the report area and probably including Cactus Flat. Because the first two flow systems converge in the Amargosa Desert, they actually may be parts of one large regional ground-water basin that could extend southward to and include much of Death Valley.

Plate 1 and tables 1 and 2 show that the bulk of the Ash Meadows and Pahute Mesa ground-water systems are made up of the 16 hydrographic areas described in this report. Of these hydrographic areas, 10 are topographically closed valleys. The piezometric contours of plate 1 show that the regional ground-water flow generally is southwestward to the Amargosa Desert.

The north-trending boundary between the Ash Meadows and Pahute Mesa ground-water systems is largely based on the great difference in water levels of at least 2,000 feet near the central part of the area (pl. 1). Southward, the disparity is less pronounced, amounting to less than 100 feet in the Amargosa Desert. Northward, the disparity also seems to decrease, but water-level data are lacking to define the amount. Moreover, the northern extent of the boundary has not been defined.

Ash Meadows Ground-Water System

The boundaries of the Ash Meadows ground-water system have not been precisely fixed, especially at its northern end. A reconnaissance was made of water levels in wells that tap alluvium in the southern part of Penoyer Valley (pl. 1). The water-level data indicate that the local flow in alluvium is northward, suggesting the presence of a ground-water divide probably in the vicinity of the topographic divide between Penoyer Valley and Tikapoo and Groom Lake Valleys. According to Eakin and others (1963, p. 13) Penoyer Valley probably is hydrologically closed.

East of Tikapoo Valley, Eakin (1966) described a separate regional ground-water flow system in the White River area, which may be hydrologically separate from the Ash Meadows system (pl. 1).

The southwestern boundary of the system is within the Spring Mountains. For the purposes of this report it is assumed to coincide with topographic divides, as shown on plate 1 and limited to the study area. In addition, the western flank of the Sheep Range of Las Vegas Valley (pl. 1) probably contributes water to the Ash Meadows system (Winograd and others, written commun., 1970).

At Ash Meadows in the Amargosa Desert one or more faults (pl. 1) form a barrier to ground-water flow, probably causing water from the system to be discharged as springs (Winograd and others, written commun., 1970). However, the effectiveness of the barrier to ground-water flow is not known. Appreciable leakage across the barrier may occur.

Pahute Mesa Ground-Water System

The Pahute Mesa regional ground-water system probably includes the western one-third of the study area (excluding Cactus Flat), Oasis Valley, Amargosa Desert west of the Ash Meadows fault, and possibly that part of Reveille Valley south of the topographic divide near its center in T. 1 N., (Blankennagel and Weir, written commun., 1970). Cactus Flat (pl. 1) may drain southwestward to Sarcobatus Flat as part of the Sarcobatus Flat regional ground-water system. The southern part of Reveille Valley, north of Kawich Valley and an extension of Railroad Valley (pl. 1) may contribute ground water either southward to the study area or eastward to Railroad Valley.

Ground water in the system generally flows through interconnected faults and joints southwestward toward Oasis Valley and southward to the Amargosa Desert where most of the water is believed to be discharged (Blankennagel and Weir, written commun., 1970). The volcanic-rock aquifer is the principal medium through which the regional flow occurs; however, the valley-fill aquifer also transmits flow beneath the Amargosa Desert. Part of the combined ground-water outflow from the Ash Meadows and Pahute Mesa regional systems, as previously mentioned, may flow southward through carbonate rocks to Death Valley.

Sarcobatus Flat Ground-Water System

As stated earlier, Cactus Flat may be part of either the Pahute Mesa of Sarcobatus Flat ground-water systems. Because no local ground water is discharged by evapotranspiration, the drainage may be southwestward toward Sarcobatus Flat or southeastward toward Gold Flat. For the purpose of compiling ground-water budgets in this report, flow is assumed to be toward Sarcobatus Flat. Other areas that probably drain to Sarcobatus Flat are Stonewall Flat and Lida Valley, both west of the study area and north of Sarcobatus Flat. Ground water may also drain to Sarcobatus Flat from Ralston and Stone Cabin Valleys, northwest of Cactus Flat (Rush, 1968, p. 27).

RECHARGE FROM PRECIPITATION

On the valley floors, where the amount of precipitation is small, little of the precipitation directly infiltrates to the ground-water reservoirs. The greater amounts of precipitation in the mountains provide most of the recharge principally by seepage losses from streams; some reaches the ground-water reservoirs from the mountains by lateral or vertical seepage. Most of the precipitation is evaporated either before infiltration or after it temporarily adds to soil moisure at shallow depths. The general distribution of precipitation in the area has been compiled on a map by Hardman (1965).

A method described by Eakin and others (1951, p. 79-81) is used to estimate recharge in this report as in the other reconnaissance reports in Nevada. The method assumes that a percentage of the average annual precipitation recharges the ground-water reservoirs. Table 3 summarizes the estimated average annual recharge for each of the hydrographic areas and the three regional ground-water systems covered by this report. Eakin and others (1963) computed different values for recharge in some of the valleys. Since that time, additional precipitation and other hydrologic data have become available allowing crude refinements in the earlier reconnaissance estimates. According to Blankennagel and Weir (written commun., 1970), the estimated average annual recharge to the northern half of Pahute Mesa ground-water system is on the order of 8,000 acre-feet, which is slightly smaller than the estimate of the recharge for the entire system in this report.

For the Ash Meadows system, recharge averages only about 2 percent of the total precipitation; for the Pahute Mesa system, about 1 percent.

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

Precipitation zone (thousands of feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average (feet)	Estimated precipitation: Average (acre-feet)	Estimated recharge: Percentage of precipitation	Estimated recharge: Acre-feet
			ASH MEADOWS GROUND-WATER SYSTEM			
			GROOM LAKE VALLEY			
>9	50	>20	1.8	90	25	20
8-9	1,000	15-20	1.5	1,500	15	220
7-8	16,000	12-15	1.1	18,000	7	1,300
6-7	69,000	8-12	.8	56,000	3	1,700
<6	336,000	<8	.5	170,000	Minor	--
Subtotal (rounded)	422,000		.6	250,000	1	3,200
			PAPOOSE LAKE VALLEY			
>6	160	>8	.8	130	3	<10
<6	67,700	<8	.5	34,000	Minor	--
Subtotal (rounded)	67,900		.5	34,000	0.003	<10
			TIKAPOO VALLEY, NORTHERN PART			
>9	60	>20	1.8	110	25	30
8-9	1,540	15-20	1.5	2,300	15	340
7-8	13,400	12-15	1.1	15,000	7	1,000
6-7	51,000	8-12	.8	41,000	3	1,200
<6	335,000	<8	.5	170,000	Minor	--
Subtotal (rounded)	401,000		.6	230,000	1	2,600
			TIKAPOO VALLEY, SOUTHERN PART			
>8	600	>20	1.8	1,100	25	300
7-8	5,180	15-20	1.5	7,800	15	1,200
6-7	12,000	12-15	1.1	13,000	7	910
5-6	43,200	8-12	.8	35,000	3	1,000
<5	182,000	<8	.5	91,000	Minor	--
Subtotal (rounded)	243,000		.6	150,000	2	3,400
			LAS VEGAS VALLEY (WESTERN SLOPE OF SHEEP RANGE ONLY)			
>8	6,720	>20	1.8	12,000	25	3,000
7-8	4,530	15-20	1.5	6,800	15	1,000
6-7	6,720	12-15	1.1	7,400	7	520
5-6	7,340	8-12	.8	5,900	3	180
<5	30,650	<8	.5	15,000	Minor	--
Subtotal (rounded)	56,000		.9	48,000	10	4,700
			THREE LAKES VALLEY, NORTHERN PART			
>8	780	>20	1.8	1,400	25	350
7-8	1,250	15-20	1.5	1,900	15	280
6-7	7,970	12-15	1.1	8,800	7	620
5-6	36,000	8-12	.8	29,000	3	870
<5	146,000	<8	.5	73,000	Minor	--
Subtotal (rounded)	192,000		.6	110,000	2	2,000

Precipitation zone (thousands of feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average (feet)	Estimated precipitation: Average (acre-feet)	Estimated recharge: Percentage of precipitation	Estimated recharge: Acre-feet
THREE LAKES VALLEY, SOUTHERN PART						
>8	6,200	>20	1.8	11,000	25	2,800
7-8	6,720	15-20	1.5	10,000	15	1,500
6-7	12,300	12-15	1.1	14,000	7	980
5-6	26,500	8-12	.8	21,000	3	630
<5	147,000	<8	.5	74,000	Minor	--
Subtotal (rounded)	199,000		.7	130,000	5	6,000
INDIAN SPRINGS VALLEY						
>8	7,500	>20	1.8	14,000	25	3,500
7-8	14,200	15-20	1.5	21,000	15	3,200
6-7	22,800	12-15	1.1	25,000	7	1,800
5-6	69,100	8-12	.8	55,000	3	1,600
<5	304,000	<8	.5	150,000	Minor	--
Subtotal (rounded)	418,000		.6	270,000	4	10,000
YUCCA FLAT						
>7	3,000	>12	1.1	3,300	7	230
6-7	20,000	8-12	.8	16,000	3	480
<6	169,000	<8	.5	84,000	Minor	--
Subtotal (rounded)	192,000		.5	100,000	0.7	700
FRENCHMAN FLAT						
>6	4,000	>8	.8	3,200	3	100
<6	292,000	<8	.5	150,000	Minor	--
Subtotal (rounded)	296,000		.5	150,000	0.07	100
JACKASS FLATS 1/						
>7	Minor	>15	1.5	--	15	--
6-7	1,640	12-15	1.1	1,700	7	120
5-6	7,170	8-12	.8	5,700	3	170
<5	50,700	<8	.5	25,000	Minor	--
Subtotal (rounded)	59,500		.5	32,000	0.9	300
ROCK VALLEY						
>5	1,100	>8	.8	900	3	30
<5	50,000	<8	.5	25,000	Minor	--
Subtotal (rounded)	51,100		.5	26,000	0.1	30
MERCURY VALLEY						
>7	200	>15	1.5	300	15	50
6-7	1,250	12-15	1.1	1,400	7	100
5-6	4,380	8-12	.8	3,500	3	100
<5	66,100	<8	.5	33,000	Minor	--
Subtotal (rounded)	71,900		.5	38,000	0.7	250

Precipitation zone (thousands of feet)	Area (acres)	Estimated precipitation Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge Percentage of precipitation	Acre-feet
OTHER AREAS - Eastern part of Amargosa Desert						Minor
TOTAL FOR ASH MEADOWS GROUND-WATER SYSTEM (rounded)						33,000
PAHUTE MESA GROUND-WATER SYSTEM						
GOLD FLAT						
>8	1,260	>15	1.5	1,900	15	280
7-8	17,400	12-15	1.1	19,000	7	1,300
6-7	91,000	8-12	.8	73,000	3	2,200
<6	325,000	<8	.5	160,000	Minor	--
Subtotal (rounded)	435,000		.6	250,000	2	3,800
KAWICH VALLEY						
>8	300	>15	1.5	450	15	70
7-8	18,200	12-15	1.1	20,000	7	1,400
6-7	85,000	8-12	.8	68,000	3	2,000
<6	127,000	<8	.5	64,000	Minor	--
Subtotal (rounded)	230,000		.7	150,000	2	3,500
BUCKBOARD MESA						
>7	6,400	>12	1.1	7,000	7	490
6-7	39,400	8-12	.8	32,000	3	960
<6	105,000	<8	.5	52,000	Minor	--
Subtotal (rounded)	151,000		.6	91,000	2	1,400
JACKASS FLATS[2/]						
>7	Minor	>15	1.5	--	15	--
6-7	3,280	12-15	1.1	3,600	7	250
5-6	14,300	8-12	.8	11,000	3	330
<5	101,000	<8	.5	50,000	Minor	--
Subtotal (rounded)	119,000		.5	65,000	0.9	580
CRATER FLAT						
>6	220	>12	1.1	240	7	20
5-6	8,080	8-12	.8	6,500	3	200
<5	108,000	<8	.5	54,000	Minor	--
Subtotal (rounded)	116,000		.5	61,000	0.4	220
OASIS VALLEY						
>7	420	>12	1.1	460	7	30
6-7	39,300	8-12	.8	33,000	3	990
<6	238,000	<8	.5	120,000	Minor	--
Subtotal (rounded)	278,000		.5	150,000	0.7	1,000
OTHER AREAS						
Western part of Amargosa Desert						Minor
Southern part of Reveille Valley						a 1,000
TOTAL FOR PAHUTE MESA GROUND-WATER SYSTEM (rounded)						12,000

Precipitation zone (thousands of feet)	Area (acres)	Estimated precipitation: Range (inches)	Estimated precipitation: Average (feet)	Estimated precipitation: Average (acre-feet)	Estimated recharge: Percentage of precipitation	Estimated recharge: Acre-feet
		SARCOBATUS FLAT GROUND-WATER SYSTEM[3]				
		CACTUS FLAT[4]				
>9	100	>15	1.5	150	15	20
8-9	3,230	12-15	1.1	3,600	7	250
7-8	13,800	8-12	.8	11,000	3	330
<7	240,000	<8	.5	120,000	Minor	--
Subtotal (rounded)	257,000		.5	130,000	0.5	600
		OTHER AREAS				
Stonewall Flat (Rush, 1968, p. 32)						100
Lida Valley (Rush, 1968, p. 32)						500
Sarcobatus Flat (Malmberg and Eakin, 1962, p. 15)						1,200
TOTAL FOR SARCOBATUS FLAT GROUND-WATER SYSTEM						2,400

1. Eastern one-third only.
2. Western two-thirds only.
3. Composed of several hydrographic areas draining to Sarcobatus Flat, west of the report area.
4. Only hydrographic area in the report area that may drain to Sarcobatus Flat.

a. Estimated by Blankennagel and Weir (written commun., 1970).

GROUND-WATER DISCHARGE

Most natural discharge of ground water from the study area is by regional subsurface outflow to Ash Meadows, Amargosa Desert, Sarcobatus Flat, Oasis Valley, and possibly Death Valley, as shown on plate 1. All depths to water are too great for local discharge by phreatophytes (greater than 50 feet) or by appreciable evaporation from bare-soil areas (greater than 15 feet). A few springs, such as Indian Springs (flows about 500 acre-feet per year), discharge a relatively small net amount of water in relation to the total recharge to the report area.

Water supplies have been developed by the U.S. Atomic Energy Commission and the military; the bulk of the water is apparently used for various operational, maintenance, and construction purposes attendant to the nuclear testing program and camp facilities on the Nevada Test Site. The Atomic Energy Commission reported that during the 12-month period ending March 31, 1970, approximately 1,700 acre-feet of ground water was pumped on the Nevada Test Site.

The estimated average annual discharge from just the springs at Ash Meadows is 17,000 acre-feet, according to Walker and Eakin (1963, p. 21) and Winograd and others (written commun., 1970). Additional discharge from the Ash Meadows ground-water system may occur (1) by evapotranspiration in and west of the spring area, and (2) by subsurface flow across the Ash Meadows fault barrier (pl. 1) to the western part of Amargosa Desert and thence to Death Valley.

The estimated average annual discharge from the Pahute Mesa ground-water system is 9,000 acre-feet. Of this amount, 2,000 acre-feet is discharged in Oasis Valley (pl. 1), according to Malmberg and Eakin (1962, p. 25); the remainder, about 7,000 acre-feet, is discharged west of the Ash Meadows fault (Blankennagel and Weir, written commun., 1970).

For the Sarcobatus Flat ground-water system, the estimated average annual discharge is possibly 3,500 acre-feet. Of this total, 3,000 acre-feet is estimated to discharge by evapotranspiration from Sarcobatus Flat and possibly 500 acre-feet as subsurface outflow from Sarcobatus Flat to Grapevine Canyon (northwest of Sarcobatus Flat) (Malmberg and Eakin, 1962, p. 22).

GROUND-WATER BUDGET

For long-term conditions, recharge to and discharge from a ground-water system are about equal, if there has been no net change in stored water in the system resulting from long-term climatic changes or diversions from storage due to development. Thus, the purpose of preparing a water budget is to compare the estimates of recharge and discharge, to determine the magnitude of the difference between estimates, and when possible to select a value that may reasonably represent both the recharge and discharge. The following tabulation shows the water budget for the Ash Meadows, Pahute Mesa, and Sarcobatus Flat regional ground-water systems:

Regional ground-water system	Estimated average annual ground-water recharge (table 3) (acre-feet) (1)	Estimated average annual ground-water discharge (p.) (acre-feet) (2)	Imbalance (acre-feet) (1)-(2)
Ash Meadows	33,000	a 17,000	16,000
Pahute Mesa	12,000	b 9,000	3,000
Sarcobatus Flat	2,400	3,500	-1,100

a. Discharge in Amargosa Desert east of Ash Meadows fault, largely from springs.

b. Discharge in Amargosa Desert west of Ash Meadows fault about 7,000 acre-feet; discharge in Oasis Valley, about 2,000 acre-feet.

For the Ash Meadows and Pahute Mesa systems, the estimated average annual discharge as measured in Amargosa Desert totals at least 24,000 acre-feet (Walker and Eakin, 1963, p. 27). The above table shows that the estimated average annual recharge to the two systems totals about 45,000 acre-feet. The imbalance between recharge and total discharge is seemingly an excess of 19,000 acre-feet per year. Although the excess may reflect errors in the estimates, a substantial part may be accounted for by subsurface flow to Death Valley, as previously described.

Pistrang and Kunkel (1964, p. Y11) estimated that about 4,000 acre-feet of discharge occurs in the Furnace Creek Wash (southwest of Amargosa Desert), not including any subsurface flow to the floor of Death Valley. Based on their recharge calculations (p. Y20), probably only a few hundred acre-feet of recharge could be generated in the Furnace Creek watershed. Therefore, much of the 4,000 acre-feet of discharge in the Furnace Creek Wash area may be from the Amargosa Desert. Moreover, additional quantities of ground water may flow from the Amargosa Desert to the valley floor of Death Valley to discharge largely by evaporation.

An evaluation of the entire Death Valley ground-water basin was beyond the scope of this report. Accordingly, whether a contribution of some 19,000 acre-feet per year from this study area to Death Valley is a reasonable value was not determined.

For Sarcobatus Flat, where the imbalance is computed to be 1,100 acre-feet per year, the writer has no more confidence in one estimate than the other. Therefore, the average quantity of 3,000 acre-feet per year is selected for the value of recharge and discharge.

PERENNIAL YIELD

The perennial yield of a ground-water 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. All the discharge from the project area is subsurface outflow, except for a few springs. This outflow could be salvaged at the discharge areas in Ash Meadows, the Amargosa Desert, Oasis Valley, Sarcobatus Flat, and perhaps in Death Valley. The yields in all these areas, except Death Valley, have been described by Walker and Eakin (1963) and Malmberg and Eakin (1962).

The possibility of salvaging all or part of the outflow by pumping within the study area north of the Amargosa Desert is dependent upon the nature and extent of the transmitting lithology, which is only partly known, and the effectiveness of any structural barriers to ground-water flow. Not until substantial development has taken place will the controlling conditions be defined. In the meantime, in most of these hydrographic area, initial ground-water development probably would be by the depletion of ground water in storage rather than the salvage of any appreciable amount of subsurface outflow.

The only known exceptions to the above general conclusion exists in Groom Lake and Indian Springs Valleys. According to Winograd and Thordarson (1968, p. 37-41), ground water flows from the western part to the eastern part of Groom Lake Valley over a consolidated-rock "threshold" near the western edge of Groom Lake playa. At this threshold the depth to water is about 100 feet. If ground-water levels were lowered to a level below the threshold, this part of the valley, assuming no other subsurface outlets, would become hydrologically isolated. As a result, the subsurface outflow from this part of the valley could be salvaged. Recharge originating in the western part of the valley is at least 75 percent of the total, or on the order of 2,500 acre-feet. If the western part of Groom Lake Valley becomes hydrologically isolated from the Ash Meadows ground-water system, then ultimately the natural discharge of the system will be reduced a like amount. Because of the very slow rate of ground-water flow in the system and the large distance between Groom Lake playa and Ash Meadows, the natural discharge probably would not be affected for many centuries. The perennial yield of Indian Springs Valley is essentially limited to the flow of Indian Springs or about 500 acre-feet.

GROUND WATER IN STORAGE

The amount of ground water stored, or more precisely in transient storage, in the valley-fill, volcanic-rock, and carbonate-rock aquifers is the product of the selected area, saturated thickness, and specific yield. Although most of the area is underlain by one or more of these aquifers, only the valley-floor areas are used to compute the general magnitude of the stored water in the uppermost 100 feet of saturation. The valley-floor areas are selected largely because they are the areas most likely to be developed for water supplies.

If the specific yield of these aquifers averages 5 to 10 percent, and selected area totals about 1,200,000 acres, the amount of ground water in storage would be roughly 10 million acre-feet. Obviously, if the highland areas were included, the amount would be considerably more.

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LIST OF PREVIOUSLY PUBLISHED REPORTS IN THIS SERIES

(See fig. 1)

Report no.	Valley or area
1	Newark (out of print)
2	Pine (out of print)
3	Long (out of print)
4	Pine Forest (out of print)
5	Imlay area (out of print)
6	Diamond (out of print)
7	Desert
8	Independence
9	Gabbs
10	Sarcobatus and Oasis
11	Hualapai Flat
12	Ralston and Stone Cabin
13	Cave
14	Amargosa Desert, Mercury, Rock, Fortymile Canyon Crater Flat, and Oasis
15	Sage Hen, Guano, Swan Lake, Massacre Lake, Long, Macy Flat, Coleman, Mosquito, Warner, and Surprise
16	Dry Lake and Delamar
17	Duck Lake
18	Garden and Coal
19	Middle Reese and Antelope
20	Black Rock Desert, Granite Basin, High Rock Lake, Mud Meadow, and Summit Lake
21	Pahranagat and Pahroc
22	Pueblo, Continental Lake, Virgin, and Gridley Lake
23	Dixie, Stingaree, Fairview, Pleasant, Eastgate, Jersey, and Cowkick
24	Lake
25	Coyote Spring, Kane Springs, and Muddy River Springs
26	Edwards Creek
27	Lower Meadow, Patterson, Spring (near Panaca), Rose, Panaca, Eagle, Clover, and Dry
28	Smith Creek and Ione
29	Grass (near Winnemucca)
30	Monitor, Antelope, Kobeh, and Stevens Basin
31	Upper Reese
32	Lovelock
33	Spring (near Ely; out of print)
34	Snake, Hamlin, Antelope, Pleasant, and Ferguson Desert (out of print)
35	South Fork, Huntington, and Dixie Creek-Tenmile Creek (out of print)
36	Eldorado, Piute, and Colorado River
37	Grass (near Austin) and Carico Lake
38	Hot Creek, Little Smoky, and Little Fish Lake
39	Eagle (Ormsby County)
40	Walker Lake and Rawhide Flat
41	Washoe
42	Steptoe
43	Honey Lake, Warm Springs, Newcomb Lake, Cold Spring, Dry, Lemmon, Red Rock, Spanish Springs, Bedell Flat, Sun, and Antelope
44	Smoke Creek Desert, San Emidio Desert, Pilgrim Flat, Painters Flat, Skedaddle Creek, Dry (near Sand Pass), and Sano
45	Clayton, Stonewall Flat, Alkali Spring, Oriental Wash, Lida, and Grapevine Canyon
46	Mesquite, Ivanpah, Jean Lake and Hidden
47	Thousand Springs and Grouse Creek
48	Little Owyhee River, South Fork Owyhee River, Independence, Owyhee River, Bruneau River, Jarbidge River, Salmon Falls Creek, and Goose Creek

49 Butte
50 Lower Moapa, Black Mountains, Garnet, Hidden, California Wash, Gold Butte and Greasewood
51 Virgin River, Tule Desert, and Escalante Desert
52 Columbus Salt Marsh, Soda Spring Valley
53 Antelope Valley

Base: U.S. Geological Survey 1:250,000 topographic series; Caliente (1962), Death Valley (1961), Goldfield (1962), and Las Vegas (1962)
Cartography by C. Bosch and P. Offenhauser

Hydrogeology by F. E. Rush, 1970. Geology adapted from Cornwall (1967), Tschanz and Pampeyan (1965), and Longwell and others (1965). Hydrology adapted from Winograd and others (Unpublished maps, 1970), Blankennagel and Weir (Unpublished maps, 1970), and Eakin and others (1963).

PLATE 1.—GENERALIZED HYDROGEOLOGY OF THE NEVADA TEST SITE AREA