UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Hydrology of Washoe Valley, Washoe County, Nevada

By Freddy E. Arteaga and William D. Nichols

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to International System (metric) units by using the following factors:

Multiply	*By*	*To obtain*
Acres	0.4047	Square hectometers (hm^2)
Acre-feet (acre-ft)	0.001233	Cubic hectometers (hm^3)
Acre-feet per acre (acre-ft/acre)	30.48	Cubic hectometers per square hectometers (hm^3/hm^2)
Acre-feet per year (acre-ft/yr)	0.001233	Cubic hectometers (hm^3)
Feet (ft)	0.3048	Meters (m)
Feet per month (ft/mo)	10.01	Millimeters per day (mm/d)
Feet per year (ft/yr)	0.3048	Meters per year (m/yr)
Inches (in.)	25.40	Millimeters (mm)
Miles (mi)	1.609	Kilometers (km)
Millibars (mbar)	0.1000	Kilopascals (kPa)
Square miles (mi^2)	2.590	Square kilometers (km^2)

ALTITUDE DATUM

The term "National Geodetic Vertical Datum of 1929" replaces the formerly used term "mean sea level" to describe the datum for altitude measurements. The datum is derived from a general adjustment of the first-order leveling networks of both the United States and Canada. For convenience in this report, the datum also is referred to as "sea level."

PREFACE

This report ultimately will be published by the Washoe County Regional Administrative Planning Agency as a formal, three-sheet atlas. Because of current interest in the water resources of Washoe Valley, the report is now being released to the open files of the U.S. Geological Survey in its present format, prior to formal publication.

I. PHYSICAL, GEOLOGIC, AND HYDROLOGIC SETTING

Introduction

The Washoe Valley hydrographic area encompasses approximately 81 mi^2, of which nearly 53 mi^2 is mountainous and the remaining 28 mi^2 is valley floor. The valley, which lies in southern Washoe County, is centrally located between the Carson City and Reno-Sparks metropolitan areas (figure 1). The first settlement in the county was in Washoe Valley, and the initial county seat was Washoe City, at the north end of the valley (figure 2). In the late 19th century, the mountainous western part of the valley was a source of timber for mines in the nearby Virginia City bonanza area, and some of the ore-milling operations were located on the valley floor (Rush, 1967, page 4).

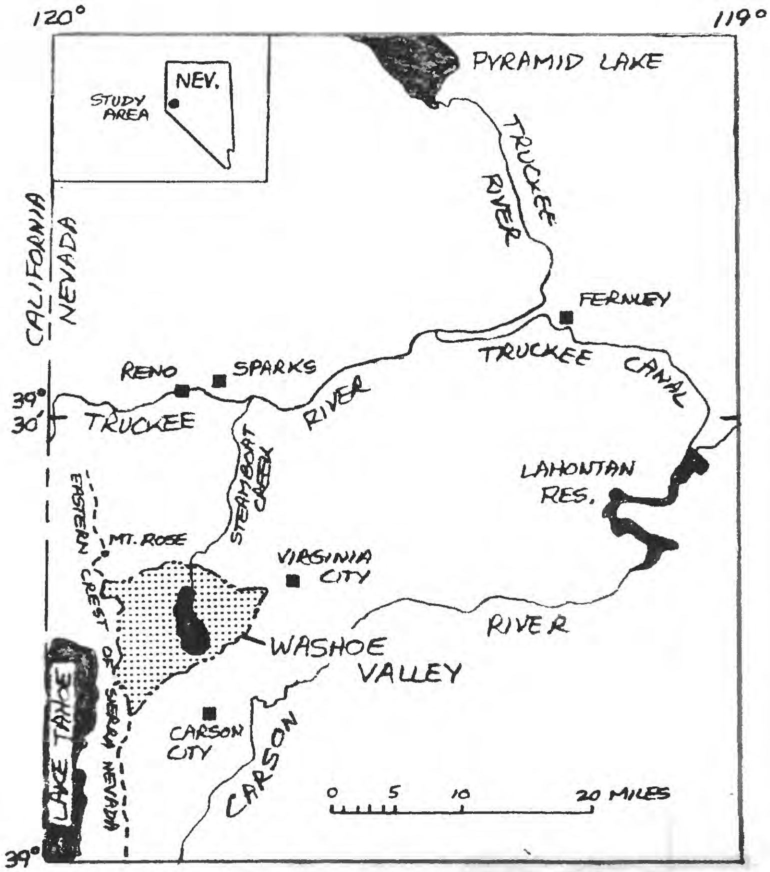

FIGURE 1.--Location of the study area.

In recent times, urbanization began in Washoe Valley in conjunction with the rapid increase in population in the nearby metropolitan areas. The estimated population of the valley expanded from about 1,000 in 1966 to about 3,000 in 1980. This increase has been centered primarily in the New Washoe City area (figure 2), where the number of homes doubled from about 370 in 1971 to nearly 740 in 1979. Residents of the valley rely on individually owned domestic wells for water supply, and use septic-tank/drain-field systems for waste-water disposal. This concentrated development would be expected to cause changes in ground-water storage, flow patterns, and quality.

The purpose of the study upon which this atlas report is based is to reevaluate the hydrologic budget of Washoe Valley. A previous reconnaissance study (Rush, 1967) described the major hydrologic components. Since then, more information and new techniques have become available, making a reappraisal of the system warranted. In scope, the study has included quantitative evaluations of (1) the saturated thickness of the valley fill, (2) the amount and areal distribution of precipitation, and (3) the quantity of lake-surface evaporation--the latter two items for use in updating the previously determined water budget. Newly acquired data include: (1) A precipitation map of Washoe Valley developed by Harold E. Klieforth (Desert Research Institute, University of Nevada, Reno, written communication, 1981); (2) a relationship between precipitation and water yield for mountain areas, derived in a study of adjacent Eagle Valley by Arteaga and Durbin (1978, pages 19-22); and (3) data on the water-surface altitude of Washoe and Little Washoe Lakes collected since 1963 (U.S. Geological Survey, 1964-83). Additional supporting data include geologic maps and related materials presented by Bonham (1969), Tabor and Ellen (1975, 1976), and Trexler (1977).

This chapter provides introductory and background information; chapter II discusses precipitation in the basin and its relation to the water yield from mountain areas; and chapter III describes a hydrologic budget for the basin and develops estimated quantities for the several budget items.

EXPLANATION FOR FIGURES 2-6

VALLEY FILL

BEDROCK

FAULT -- Dashed where inferred. Dotted where concealed

F —— F′ LOCATION OF GEOLOGIC SECTION -- From Tabor and Ellen, 1976

WETLANDS

LAKE

HYDROGRAPHIC-AREA BOUNDARY

The report is a product of a water-resources study made cooperatively by the U.S. Geological Survey and the Regional Administrative Planning Agency of Washoe County. The authors are grateful to the members of that agency who provided substantial support for this study. Leonard E. Crowe's field assistance and knowledge of the area proved particularly invaluable. The authors also benefited from Donald Mahin's critical review of the water budget, which offered new insight toward the conceptualization of the area's water resources.

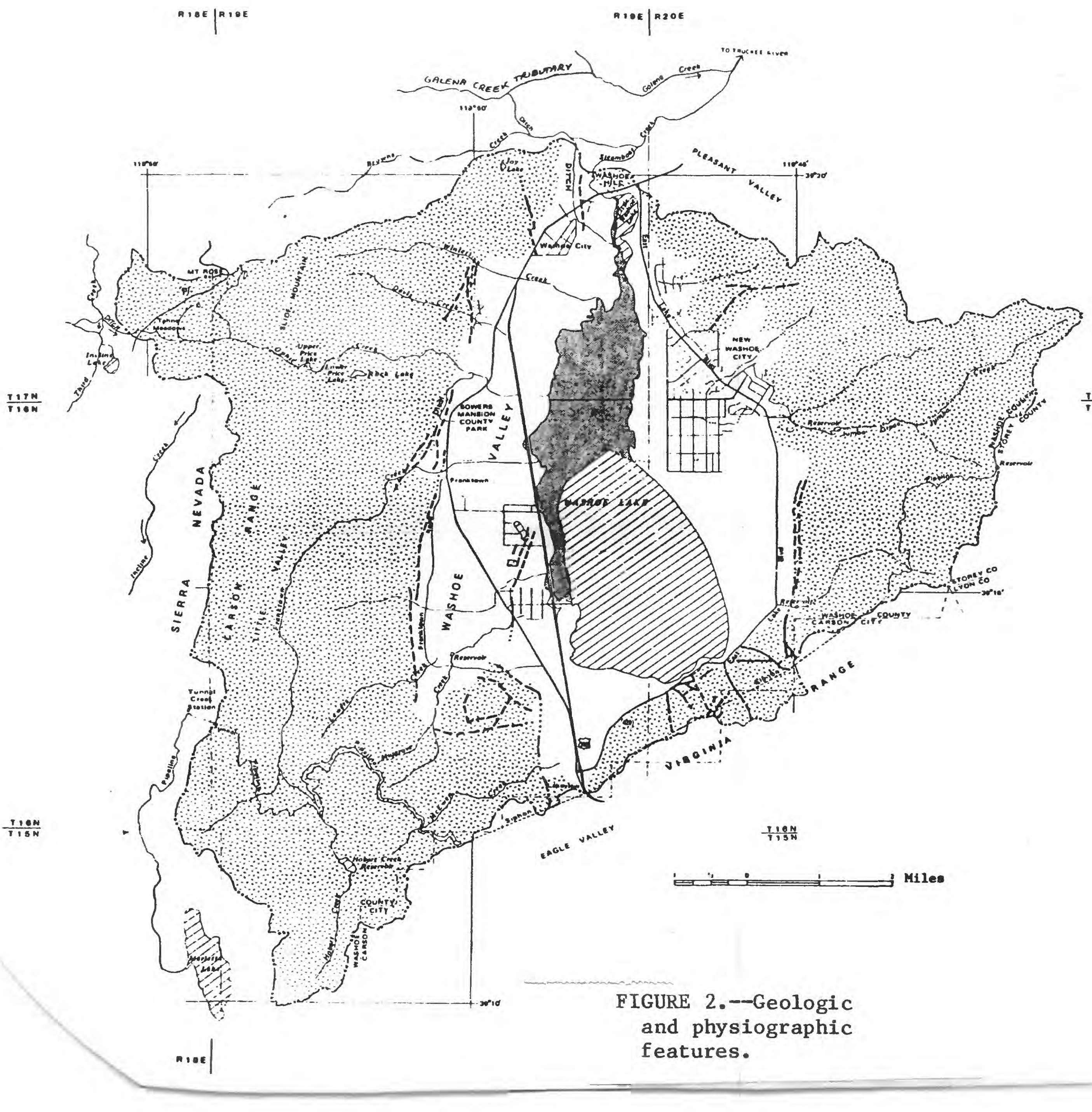

FIGURE 2.--Geologic and physiographic features.

Description of the Study Area

Washoe Valley is bounded on the west by the Carson Range of the Sierra Nevada and on the east by the Virginia Range (maximum altitudes, about 9,900 and 7,500 feet above sea level, respectively). The valley floor (altitude, about 5,050 feet) overlies a structural depression that is partly filled with sedimentary materials. Much of the fill is dominated by lake deposits (Tabor and Ellen, 1976). Beneath the western part of the valley floor, however, the fill is dominated by semiconsolidated to unconsolidated lenses of stream gravel, sand, and silt (Rush, 1967, page 5). The overall thickness of valley-fill deposits exceeds 1,000 feet in midvalley (figure 3). Mountainous areas surrounding the valley floor are composed of volcanic, granitic intrusive, and metamorphic rocks as described by Tabor and Ellen (1975), Trexler (1977), and Bonham (1969).

The most prominent physiographic feature on the valley floor is Washoe Lake (figure 2), with an average area of about 7-1/2 mi^2. The lake overflows northward into Little Washoe Lake, which in turn empties into Steamboat Creek (figure 2), a tributary of the Truckee River about 13 miles north of this area. During periods of abundant inflow, the wetlands between the two lakes become inundated, and the water bodies merge to form a single large lake. Control works at the outlet of Little Washoe Lake allow regulation of lake-water storage and release for downstream irrigation.

The principal streams in the basin are Franktown and Ophir Creeks in the Carson Range and Jumbo Creek in the Virginia Range. Runoff from these and other streams enters the ground-water system or flows directly to Washoe Lake. Three small interbasin diversions enter the valley: from the Galena and Browns Creek basins, to the north; from the Third Creek basin, to the northwest; and from Marlette Lake, to the west (figure 2). The first two imports are for agricultural use, and the third, water from Marlette Lake, is used to augment the exports from Hobart Creek to Carson City and Virginia City.

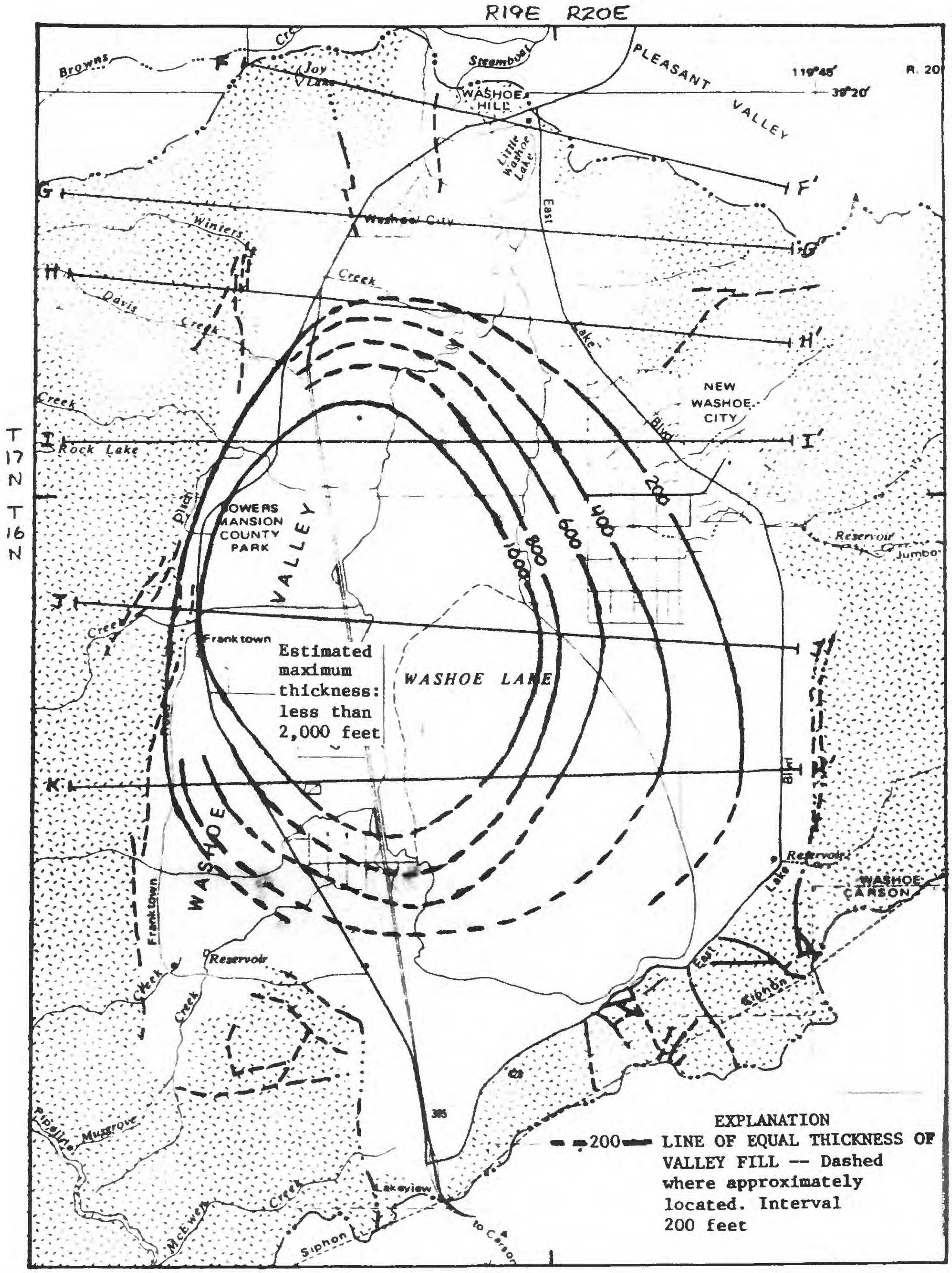

FIGURE 3.--Approximate thickness of valley fill. Adapted from Tabor and Ellen (1976), Trexler (1977), and Russell W. Plume (U.S. Geological Survey, written communication, 1983).

Well Data

To assess current ground-water conditions, drillers' reports for 1,155 wells were obtained from the State Engineer's Office, Nevada Division of Water Resources. The well depths range from about 50 to 996 feet, but only five of the wells are deeper than 500 feet. Of the 1,155 wells, 210 were field checked to ascertain exact location (figure 4) and current depth to water. The water levels and drillers' information indicate that 62 of the 210 wells have penetrated confining units of clay and silt and, as a result, have water levels at or above land surface. Flowing wells are found throughout the west side of the valley and mainly in the New Washoe City area on the east side. Flowing wells on the west side of the valley are generally deeper than 100 feet, whereas most of those on the east side are about 100 feet deep.

The distribution of wells within each township in the valley is as follows:

Township	Total number of wells	Field-checked wells	Flowing wells
16 N, 19 E	228	75	26
16 N, 20 E	337	49	25
17 N, 19 E	101	23	6
17 N, 20 E	489	63	5
Total	1,155	210	62

Depths to water measured in 1965-66 (Rush, 1967), 1974 (Rush, 1975), 1976 (Katzer, 1980), and 1981 indicate that no pronounced changes had as yet occurred in ground-water storage or movement due to the recent urbanization. Thus, the depth-to-water conditions and generalized water-level contours for 1981 (figures 5 and 6) are similar to those shown by Rush (1967, figures 2 and 4).

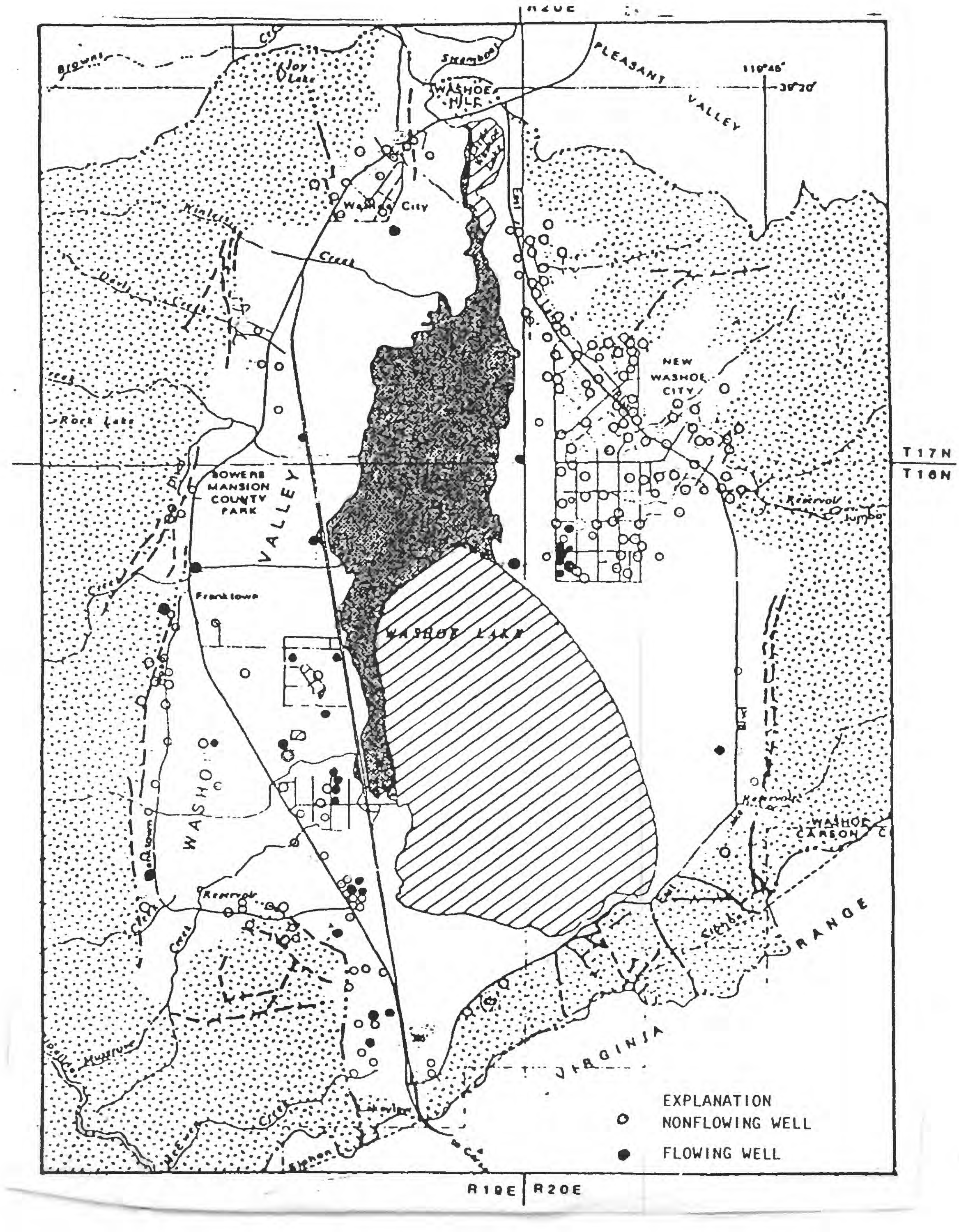

FIGURE 4.--Wells field checked in 1981-83.

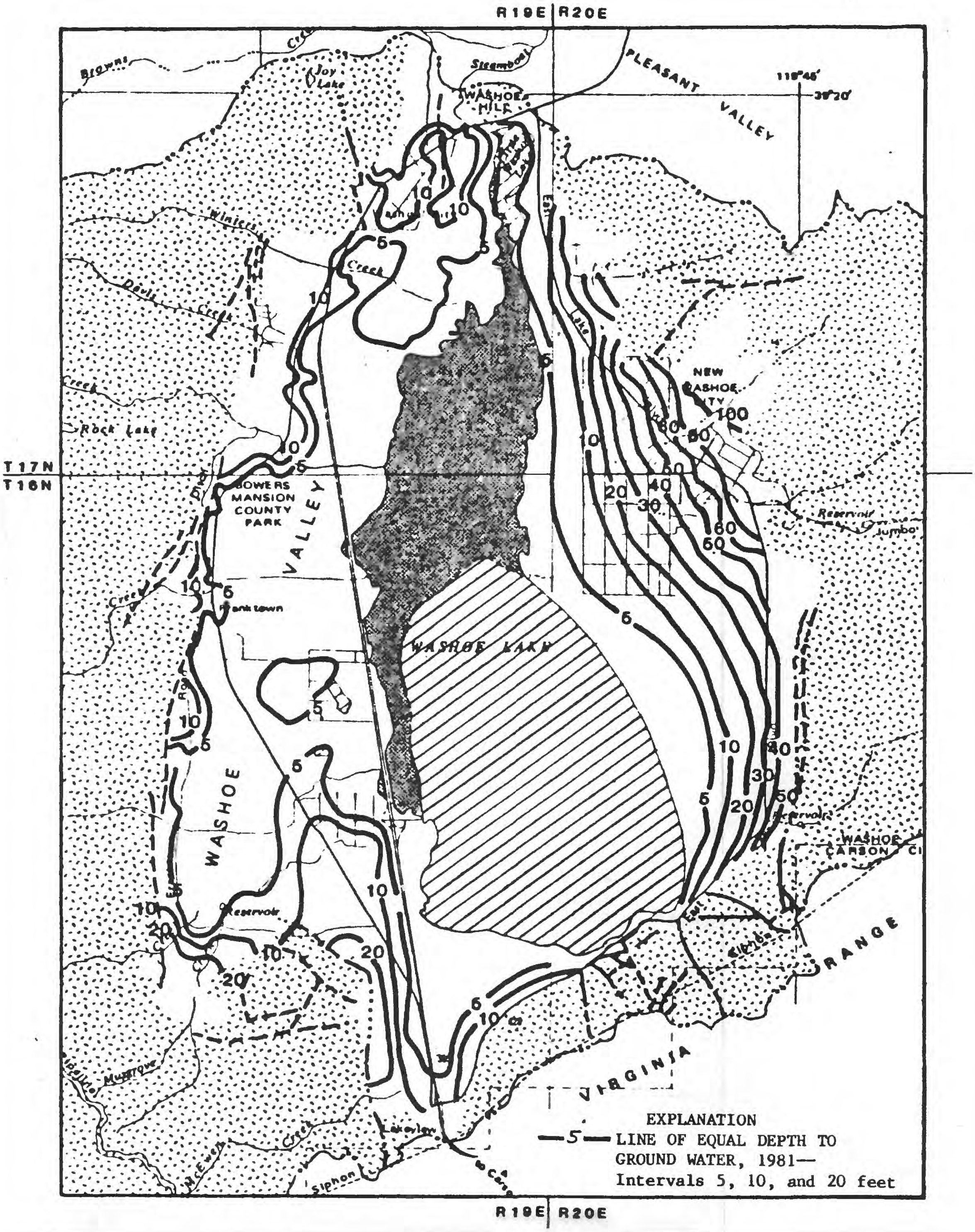

FIGURE 5.--Depth to ground-water. Adapted from Rush (1967, figure 2) and Katzer (1980).

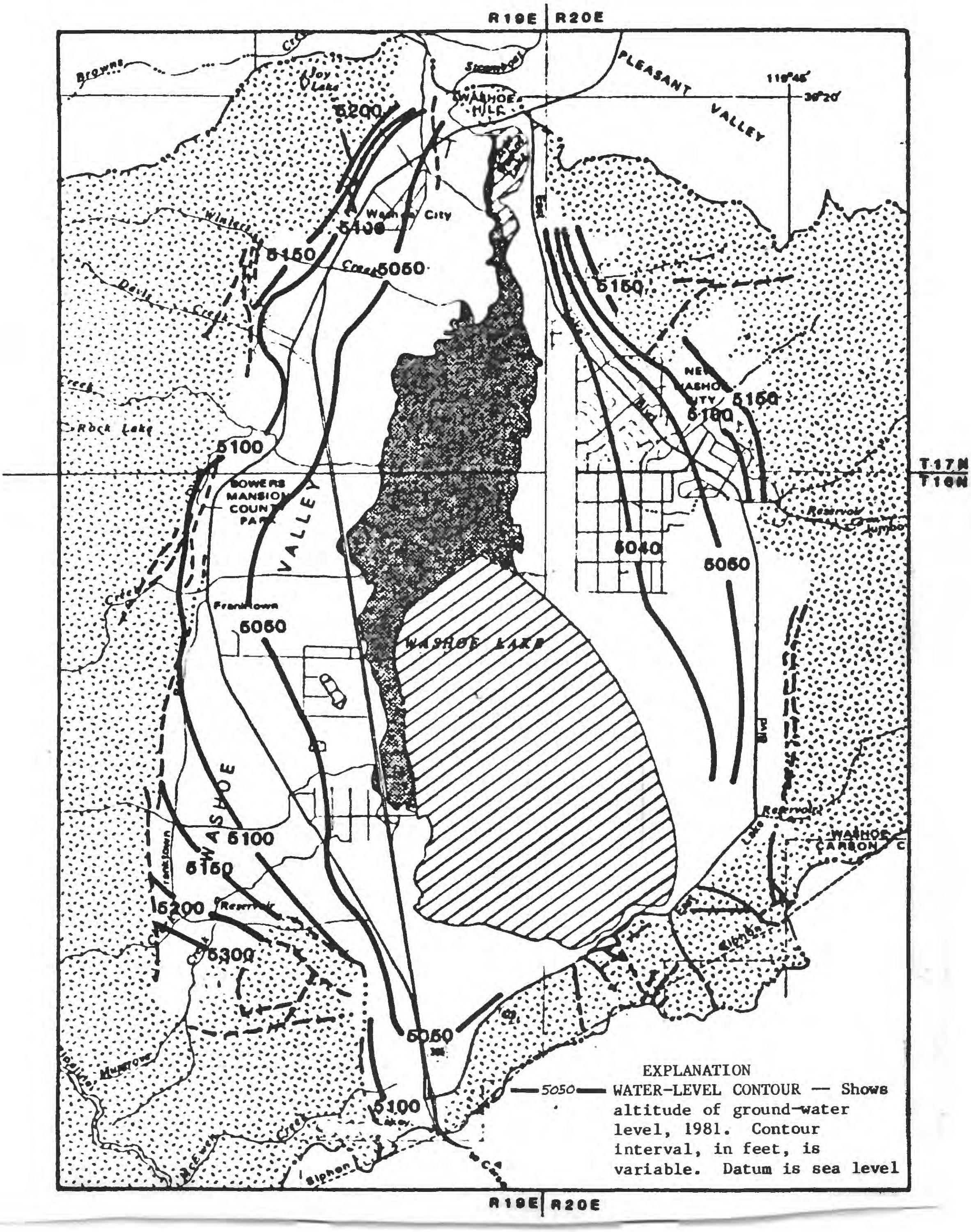

FIGURE 6.--Generalized water-level contours. Based on 1981 measurements and data from Rush (1967, Table 10, page 31).

II. WATER YIELD

General Description of Climatologic and Hydrologic Processes[1]

Areal Distribution of Precipitation

Precipitation-producing air masses generally move eastward across Washoe Valley. As a moisture-laden air mass rises on the windward (Lake Tahoe) side of the Carson Range, the air mass cools. If the moisture content of the air mass is sufficient, this cooling will cause precipitation. Air masses with low moisture content will not drop moisture until lifted to a higher altitude, and any precipitation will occur only on the higher slopes of the Carson Range. Air masses with high moisture content will drop moisture after little lifting, and precipitation will occur along much of the slope. The net effect of many air masses, with differing moisture contents, crossing the mountain barrier is that mean annual precipitation increases with altitude.

On the leeward (Washoe Valley) side of the Carson Range, similar phenomena operate to cause less precipitation on the lower slopes. As an air mass moves down the leeward slope, it warms. While the air mass may have dropped moisture on the higher slopes, warming causes precipitation to decrease or stop at lower altitudes. As air masses move eastward across Washoe Valley and rise on the windward slopes of the Virginia Range, the air is again cooled. If sufficient moisture is still present in the air mass, cooling will either cause or increase precipitation as the air mass rises on these slopes. As a result, mean annual precipitation increases with altitude. Because of the loss of moisture from the air masses in the Carson Range, the rate of increase of precipitation with altitude is less on the Virginia Range than on the Carson Range.

A precipitation map prepared by Harold E. Klieforth (Desert Research Institute, University of Nevada, Reno, written communication, 1981) is shown in figure 7. It is based on data from short-term (1967-79) stations maintained by the Desert Research Institute and longer term stations maintained by the National Weather Service. Figure 7 shows that mean annual precipitation decreases eastward, from almost 60 inches in the highest, westernmost part of the Carson Range to about 10 inches on the eastern part of the valley floor, and then gradually increases farther eastward to as much as about 24 inches in the Virginia Range.

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[1] Arteaga and Durbin (1978, pages 11-22) have discussed the water yield from mountain areas in Eagle Valley, a physiographically similar basin immediately south of Washoe Valley. The following discussion is taken largely from their report.

Runoff and Recharge from Precipitation

Precipitation that falls on the mountain areas adjacent to the floor of Washoe Valley is the source of nearly all runoff reaching the valley floor and ground-water recharge. (Precipitation also falls directly on the valley floor, but most of it is consumed by the native vegetation or is evaporated). Figure 8A schematically depicts conditions on the upper slopes of a mountain canyon. In this area, the fractured bedrock is covered by a shallow mantle of weathered and shattered material. The root zone of the vegetative cover is generally within this mantle, but some roots penetrate deeply into the fractures of the bedrock.

The permeability, slope, and vegetative cover of the soil mantle determine how much of the precipitation will become surface runoff and how much will infiltrate to become soil moisture and ground water. The greater part of the infiltrated precipitation is retained as soil moisture for subsequent evapotranspiration. The remainder percolates to the underlying ground water.

Water in the zone of saturation moves downslope through fractures and along the contact between the soil mantle and the relatively impermeable bedrock. In reaches where the stream is underlain at shallow depth by bedrock, water seeps into the stream channel to become streamflow. The stream receives such contributions along its course from the lateral inflow of subsurface water. As a result, stream discharge tends to increase in the downstream direction.

Conditions in the lower part of a mountain canyon, where the permeable deposits are generally thicker than on the canyon slopes, are shown in figure 8B. Tongues of alluvium generally extend along the stream courses far up into their canyons. In these areas, water moving down the adjacent bedrock slopes enters the alluvial deposits and may or may not contribute to streamflow, depending largely on the amount of subsurface inflow. In some places, significant quantities of streamflow may infiltrate the channel bed and percolate downward through the alluvial deposits to ground water. Therefore, a significant part of the water moving out of the mountains onto the valley floor may be subsurface flow.

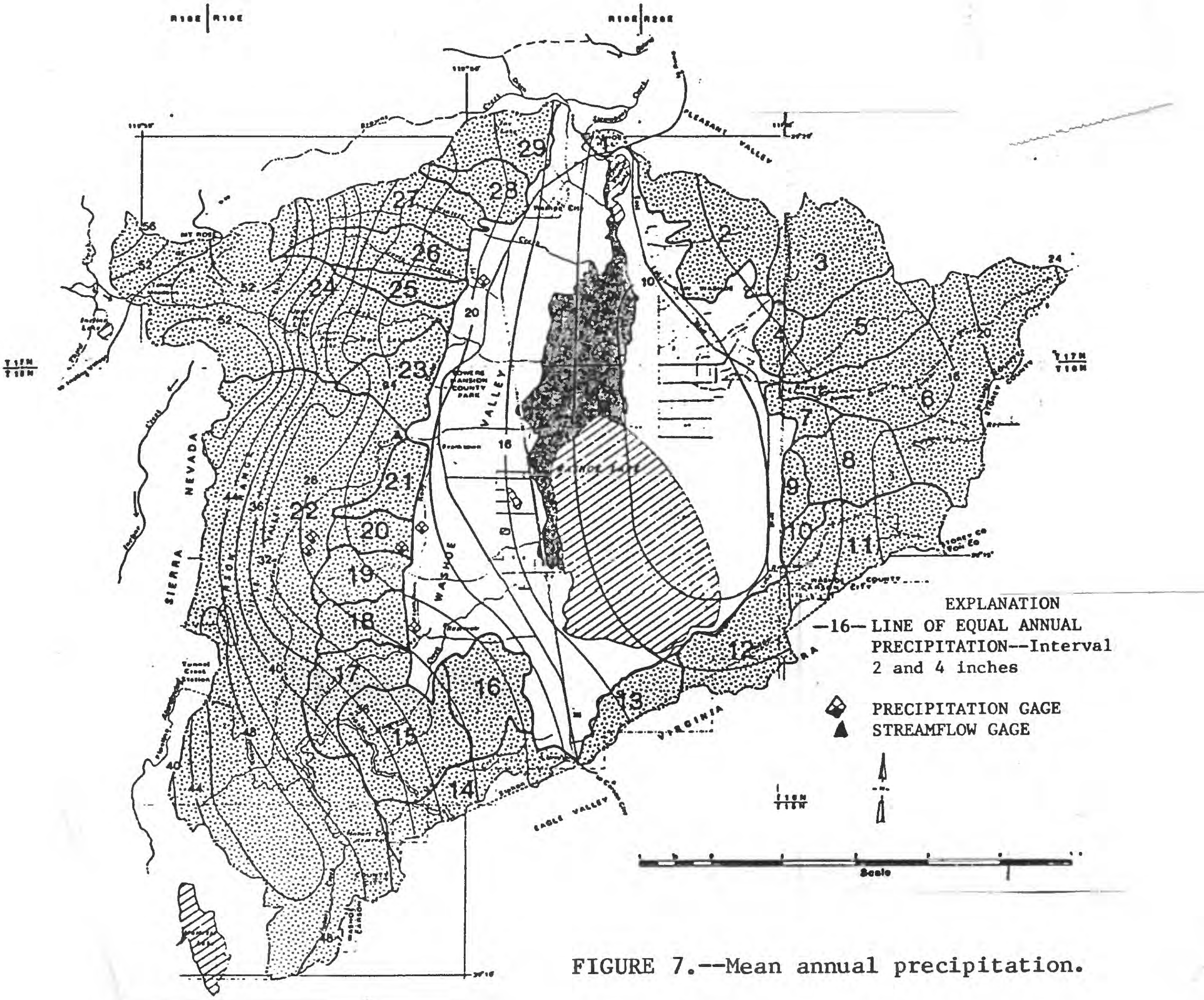

FIGURE 7.--Mean annual precipitation.

EXPLANATION FOR FIGURES 7 AND 10

VALLEY FILL

BEDROCK

WETLAND

LAKE

DRAINAGE-AREA BOUNDARY

18 DRAINAGE-AREA NUMBER (TABLE 1)

HYDROGRAPHIC-AREA BOUNDARY

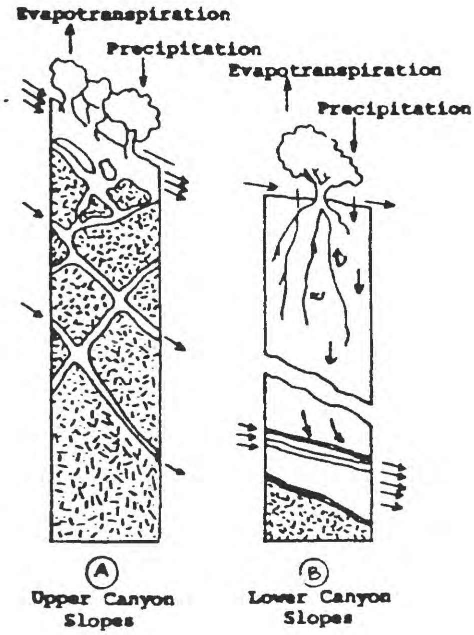

FIGURE 8.--Disposition of precipitation in a mountain drainage basin (modified from Crippen, 1965).

Computed Water Yield From Mountain Areas

The water yield of an area is defined in this report as the contribution of surface- and ground-water outflow from the mountains to a valley area. A relation between precipitation and water yield was derived in the previous study of adjacent Eagle Valley (Arteaga and Durbin, 1978, pages 19-22). The relation, which consists of two straight-line segments connected by a curved transition, is shown in figure 9. It is based on a regression of mean annual precipitation and mean annual runoff. The lower segment (mean annual precipitation from 10 to 30 inches) represents the condition where a unit increase in precipitation results in less than a unit increase in yield. The physical significance is that, in the lower precipitation range, increased precipitation causes an increase in vegetation density and a concomitant increase in water consumed by that vegetation, that is, an increase in transpiration losses. The upper segment of the relation (mean annual precipitation above 30 inches) represents the condition where a unit increase in precipitation results in a unit increase in yield.

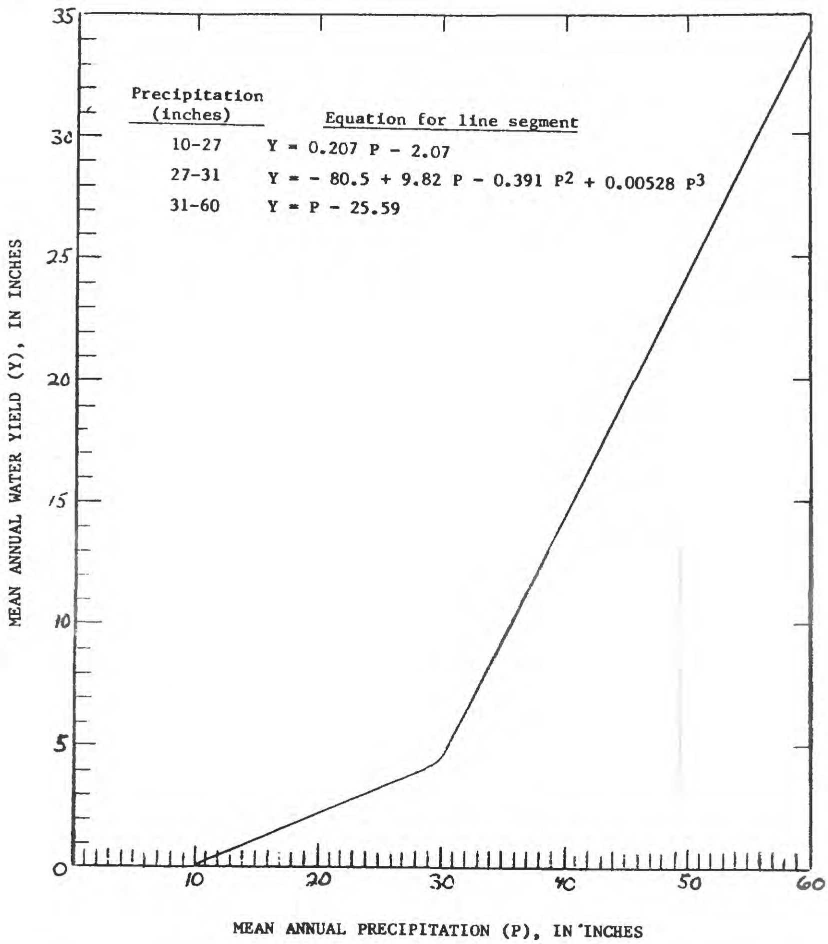

FIGURE 9.--Relation between precipitation and water yield.

Direct application of the equations for relationships shown in figure 9 results in the areal distribution of water yield shown in figure 10. The mean annual water yield from the mountain drainages in Washoe Valley was estimated from the precipitation-yield relation, using a weighted average precipitation for each drainage. The estimated individual water yields from the 29 drainages are shown in table 1. The yields from drainages 1-13 and 14-29 represent the total contributions from the Virginia and Carson Ranges, respectively. The floor of Washoe Valley is not considered in the water-yield analysis; instead, it is addressed directly in the water budget. The estimated yield of Jumbo Creek (drainage No. 6), about 400 acre-ft/yr, constitutes nearly half of the estimated water yield from the entire Virginia Range. Similarly, the estimated yield from Franktown Creek (drainage 22), 13,600 acre-ft/yr, represents more than half the yield from the entire Carson Range. The total water yield for areas surrounding the floor of Washoe Valley is an estimated 26,000 acre-ft/yr. It represents an average value based on the precipitation data for the period 1967-79.

Estimated precipitation quantities and water yields for the Carson and Virginia Ranges are summarized in table 2. The 13,700 acre-feet of annual precipitation in the Virginia Range produces an estimated average yield of only 900 acre-ft/yr. This quantity, which represents only about 7 percent of the total precipitation, is equivalent to an average of 0.08 acre-foot per acre, or an average depth of about an inch over the watershed. Precipitation on the Carson Range, about 72,000 acre-ft/yr, produces an estimated average annual yield of 25,500 acre-feet. This quantity, which is about 35 percent of the precipitation value, is equivalent to an average of 1.12 acre-feet per acre, or an average depth of 1.12 feet.

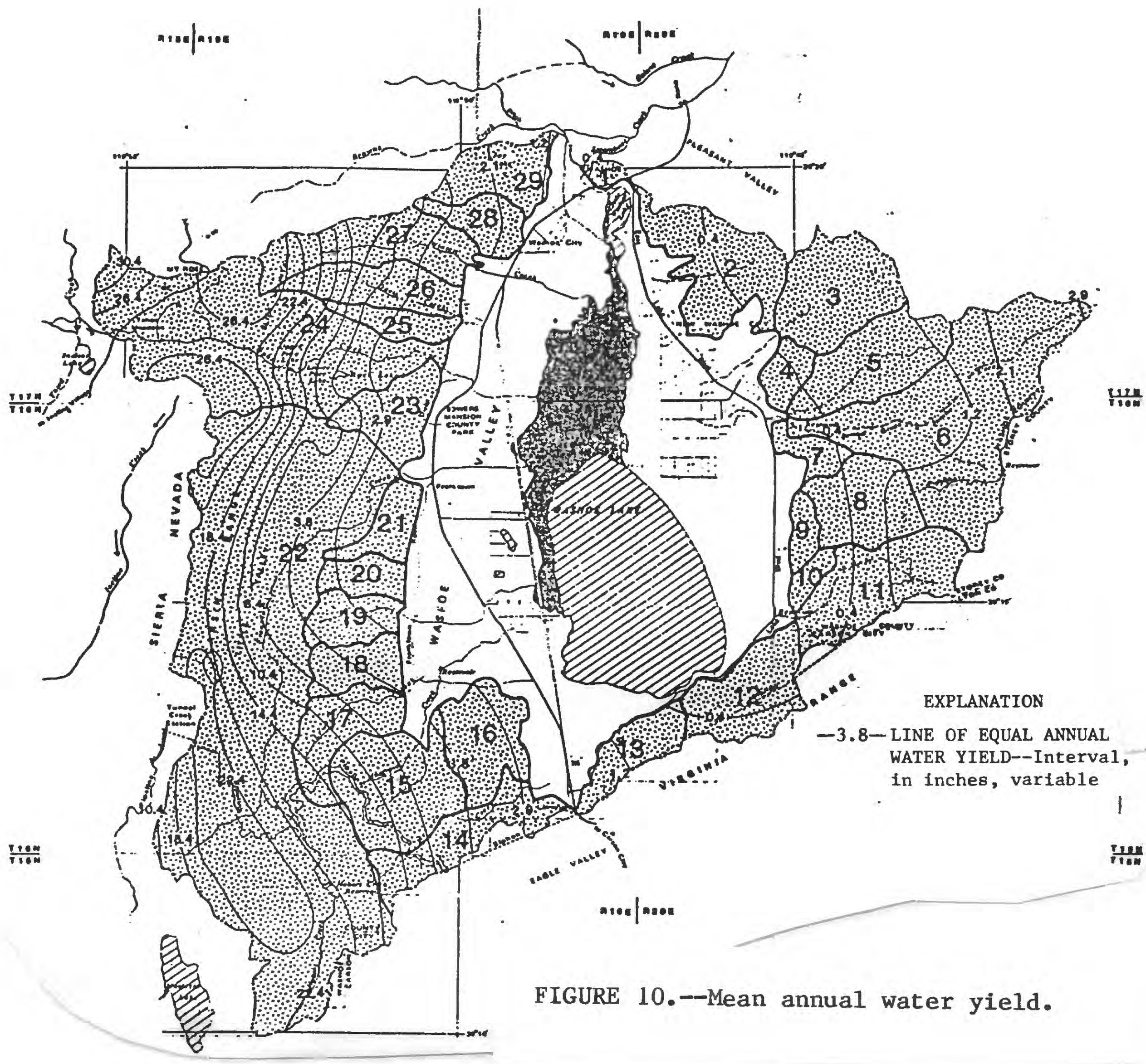

FIGURE 10.--Mean annual water yield.

TABLE 1.--*Area and estimated mean annual precipitation and water yield for drainages in the Virginia and Carson Ranges*

Drainage number in figures 7 and 10	Creek	Area (acres)	Precipitation		Water yield	
			Inches	Feet	Inches	Acre-feet, rounded
Virginia Range						
1	—	178	11.4	1.0	0.3	4
2	—	1,280	11.9	1.0	.4	42
3	—	1,200	14.5	1.2	.9	94
4	—	293	11.6	1.0	.3	8
5	—	1,110	14.4	1.2	.9	83
6	Jumbo	2,960	17.9	1.5	1.7	410
7	—	251	11.3	.9	.3	6
8	—	867	14.0	1.2	.8	60
9	—	204	10.6	.9	.1	2
10	—	163	10.6	.9	.1	2
11	—	1,270	14.5	1.2	.9	98
12	—	1,010	14.9	1.2	.4	33
13	—	502	15.8	1.3	1.2	50
Subtotal (rounded)		11,300	—	—	—	900
Carson Range						
14	McEwen	1,020	31.7	2.6	7.2	610
15	Musgrove	1,350	35.1	2.9	9.8	1,100
16	—	831	25.8	2.2	3.3	230
17	Levers	701	36.7	3.1	11.3	660
18	—	467	29.6	2.5	5.1	200
19	—	501	25.7	2.1	3.4	140
20	—	332	24.2	2.0	2.9	81
21	—	387	22.2	1.8	2.5	81
22	Franktown	9,530	42.7	3.6	17.1	13,600
23	—	687	24.5	2.0	3.1	180
24	Ophir	3,730	46.8	3.9	21.6	6,720
25	—	345	26.4	2.2	4.9	140
26	Davis	704	31.9	2.7	8.2	480
27	Winters	1,090	35.8	3.0	11.7	1,060
28	—	455	22.2	1.8	2.5	96
29	—	638	20.9	1.7	2.3	120
Subtotal (rounded)		22,800	—	—	—	25,500
Total (rounded)		34,100	—	—	—	26,000

TABLE 2.—*Summarized estimates of mean annual precipitation, evapotranspiraton, and water yield for the Virginia and Carson Ranges*

Mountain range	Drainage numbers in figures 7 and 10	Area (acres)	Precipitation		Evapotranspiration[1]		Water yield	
			Feet	Acre-feet	Feet	Acre-feet	Feet	Acre-feet
Virginia	1-13	11,300	1.21	13,700	1.13	12,800	0.08	900
Carson	14-29	22,800	3.16	71,900	2.04	46,500	1.12	25,500
Total (rounded)	--	34,100	--	86,000	--	59,000	--	26,000

[1] Computed by difference: Precipitation minus water yield equals estimated evapotranspiration.

III. HYDROLOGIC BUDGET

General Description of the Budget

Hydrologic data for Washoe Valley for the period 1964-80 are assumed to approximate long-term equilibrium conditions. Existing development has not as yet caused significant depletion of ground-water storage, permanent lowering of lake levels, or sustained reductions in outflow. Stored water and outflow fluctuate in response to annual climatic variations, but there has been little or no long-term net change in the amount of water stored as ground water or in Washoe Lake. Similarly, there has been little or no long-term change in the average outflow. Consequently, the existing nearly steady-state hydrologic budget for Washoe Valley can be described by the components of total inflow to and outflow from the hydrologic system of the valley (not all of the surface-water and ground-water components can be identified as separate elements). The steady-state hydrologic budget can be expressed in the form of an equation, which in its simplest form is:

$$\text{Inflow} = \text{Outflow} .$$

Inflow to the basin is the water yield as determined in chapter II plus precipitation that falls on the valley floor and on the surface of Washoe Lake, and the small amount of water imported to the basin from Third, Galena, and Browns Creek basins (Rush, 1967, page 24), and from Marlette Lake.

Outflow from the basin consists dominantly of evaporation from the lake and evapotranspiration from cropland, pasture, native vegetation, and wetlands. Smaller outflow components include discharge to Steamboat Creek, water exported by way of the Marlette water system, and consumptive use of domestic pumpage.

The simple equation above can now be rewritten as:

$$Y_w + P_l + P_v + SW_i = E_l + ET_v + SW_o + Q_e + Q_d ,$$

where the inflow components are

Y_w = water yield,

P_l = precipitation on the lake surface,

P_v = precipitation on the valley floor, and

SW_i = imported surface water,

and the outflow components are

E_l = evaporation from the lake,

ET_v = evapotranspiration from cropland, pasture, native vegetation, and wetlands,

SW_o = stream outflow,

Q_e = exported water, and

Q_d = consumptive use of domestic pumpage.

Units of measure for all budget items are acre-feet per year.

Evaluation of Individual Budget Components

The hydrologic budget for conditions as of 1980 in Washoe Valley is shown in table 3. Determination of the inflow components is straightforward. Water yield has been calculated as shown in table 2, chapter II. Precipitation on the valley floor and lake surface is determined from figure 7, chapter II. Surface-water imports from the Third, Galena, and Browns Creek basins are assumed to be as reported by Rush (1967, page 24); the import from Marlette Lake is assumed to be negligible in magnitude relative to other budget items, on the basis of information from the Nevada Division of Buildings and Grounds (written communication, 1984).

Determination of the outflow components of the budget, particularly evaporation and evapotranspiration, is more complicated. First, the evaporation rate for an open-water surface (Washoe Lake) and the evapotranspiration rates for croplands and various native vegetation must be determined. The acreages must then be defined, and crop or vegetation densities determined.

Evaporation rates were calculated by using a modified Penman equation for potential evapotranspiration (Doorenbos and Pruitt, 1977, page 15). The form of the equation used is:

$$ET = (W)(R_n) + [1-W][f(u)][e_a-e_d] ,$$

where ET = potential evapotranspiration, in millimeters per day;

W = a temperature-related weighting function;

R_n = net radiation, in equivalant millimeters per day;

$f(u)$ = a wind-related function; and

e_a-e_d = the difference between the saturation vapor pressure at mean air temperature and the actual mean vapor pressure of the air, in millibars.

TABLE 3.--*Hydrologic budget for conditions as of 1980*

Budget item	Area (acres)	Rate (feet per year)	Estimated quantity (acre-feet per year)	
INFLOW				
Water yield	--	--	--	26,000
Precipitation				
Lake surface	4,900	1.0		4,900
Valley floor:				
East side	4,940	.9	4,400	
West side	7,460	1.6	11,800	
Wetlands	1,080	1.2	1,300	
Subtotal (rounded)	--	--		18,000
Imported surface water	--	--	--	4,000
Total inflow (rounded)				53,000
OUTFLOW				
Lake-surface evaporation	4,900	4.6	--	23,000
Evapotranspiration				
East side:				
Cropland	60	4.1	246	
Native vegetation	4,880	1.0	4,900	
Subtotal (rounded)	--	--		5,100
West side:				
Cropland	1,230	4.1	5,000	
Irrigated pasture	1,120	3.0	3,400	
Native vegetation and non-irrigated pasture	5,110	2.0	10,200	
Subtotal (rounded)	--	--		19,000
Wetlands	1,080	3.0	--	3,200
Stream outflow	--	--	--	2,300
Exported surface water	--	--	--	700
Consumptive use of domestic pumpage	--	--	--	100
Total outflow (rounded)				53,000

The value of ET is then recalculated to open-water evaporation using the equation:

$$E_O = (c)(ET) ,$$

where E_O = open-water evaporation, in millimeters per day, and

c = a climatic correction factor.

The data used to solve the Penman equation for monthly ET values are given in table 4. Computed values of E_O for Washoe Valley (converted from millimeters per day to feet per month) are given in table 5 and are shown in figure 11. Values of c used in computing E_O, also given in table 5, are based on data from Doorenbos and Pruitt (1977, table 16).

TABLE 4.—*Climatic data used to solve the Penman equation for potential evapotranspiration*[1]

Month	W	$1-W$	R_n	$f(u)$	e_a-e_d	Potential evapotranspiration (ET): Millimeters per day	Potential evapotranspiration (ET): Feet per month
January	0.46	0.54	0.50	0.73	2.25	1.12	0.11
February	.48	.52	1.25	.75	3.33	1.90	.17
March	.52	.48	2.14	.87	4.31	2.91	.30
April	.56	.44	3.05	.91	5.82	4.04	.40
May	.63	.37	4.09	.88	7.94	5.16	.53
June	.69	.31	5.05	.85	10.67	6.30	.62
July	.73	.27	5.27	.80	14.54	6.99	.71
August	.72	.28	4.62	.77	13.09	6.15	.63
September	.68	.32	3.11	.71	9.96	4.38	.43
October	.61	.39	1.71	.70	6.66	2.86	.29
November	.52	.48	.60	.68	3.74	1.53	.15
December	.46	.54	.32	.67	2.41	1.02	.10

[1] Data are based on climatic measurements at Reno, adjusted for conditions believed to be representative of Washoe Valley. See text for explanation of symbols and units of measure.

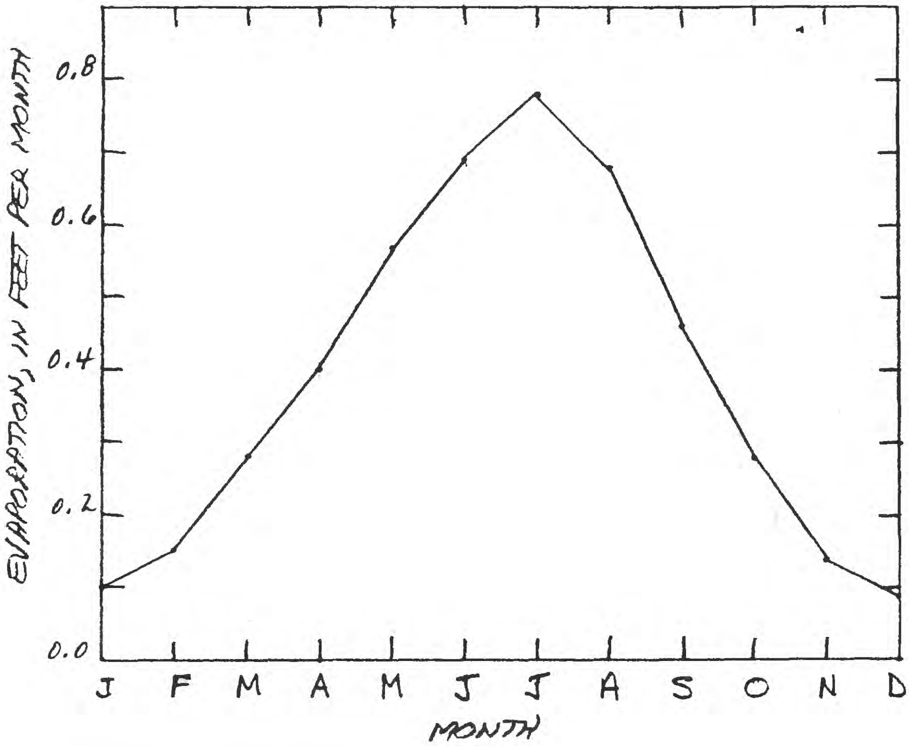

FIGURE 11.--Mean monthly evaporation rates for Washoe Lake (from table 5).

TABLE 5.--*Computed monthly evaporation and evapotranspiration*[a]

Month	*ET* (table 3)	*c*	E_o	*K*	ET_k
January	0.11	0.87	0.10	0.10	0.01
February	.17	.88	.15	.08	.01
March	.30	.92	.28	.20	.06
April	.40	1.00	.40	.55	.22
May	.53	1.08	.57	1.06	.56
June	.62	1.11	.69	.98	.61
July	.71	1.10	.78	1.22	.87
August	.63	1.08	.68	1.15	.72
September	.43	1.08	.46	1.42	.61
October	.29	.96	.28	1.00	.29
November	.15	.91	.14	.53	.08
December	.10	.87	.09	.25	.03
Feet per year	4.44	---	[b]4.6	---	[b]4.1

[a] See text for explanation of symbols. Units of measure: *ET*, E_o, and ET_k, feet per month; *c* and *K*, dimensionless.

[b] Rounded.

The calculated monthly evaporation per unit area for Washoe Lake is given by E_O in table 5. These monthly values, multiplied by the long-term mean monthly lake areas (figure 12), were used to compute a long-term annual lake evaporation of 23,000 acre-feet (table 3). The same result is obtained when the annual evaporation rate of 4.6 feet is multiplied by the mean annual lake area of 4,900 acres. (The relationships among lake stage, area, volume, and depth are shown in figure 13.) Evaporation from the lake is the second largest component of outflow from the valley, accounting for 43 percent of the total outflow.

Evapotranspiration by crops, pasture, native vegetation, and wetlands is the largest component of discharge from Washoe Valley, accounting for 51 percent of the total outflow. These components of water use are more difficult to determine than open-water evaporation because of variations in consumptive use and vegetation density. Land-cover types shown in figure 14 and given in table 3 are used to estimate evapotranspiration from vegetated surfaces.

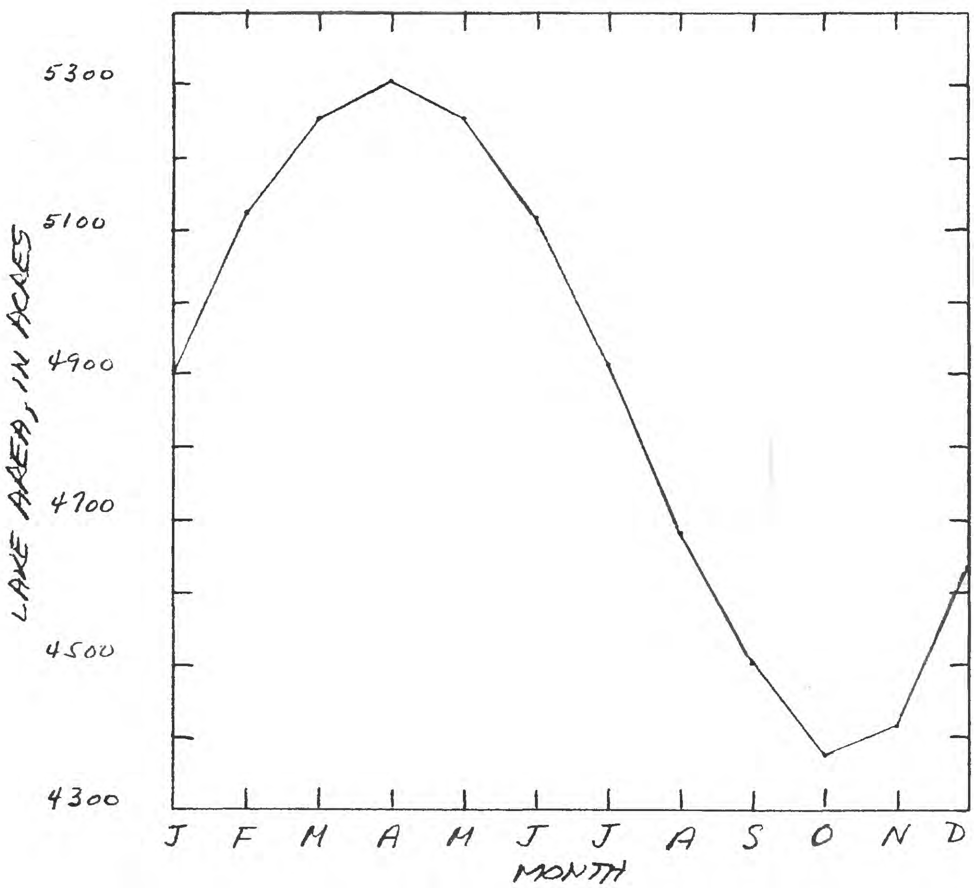

FIGURE 12.--Mean monthly lake area, 1964-80.

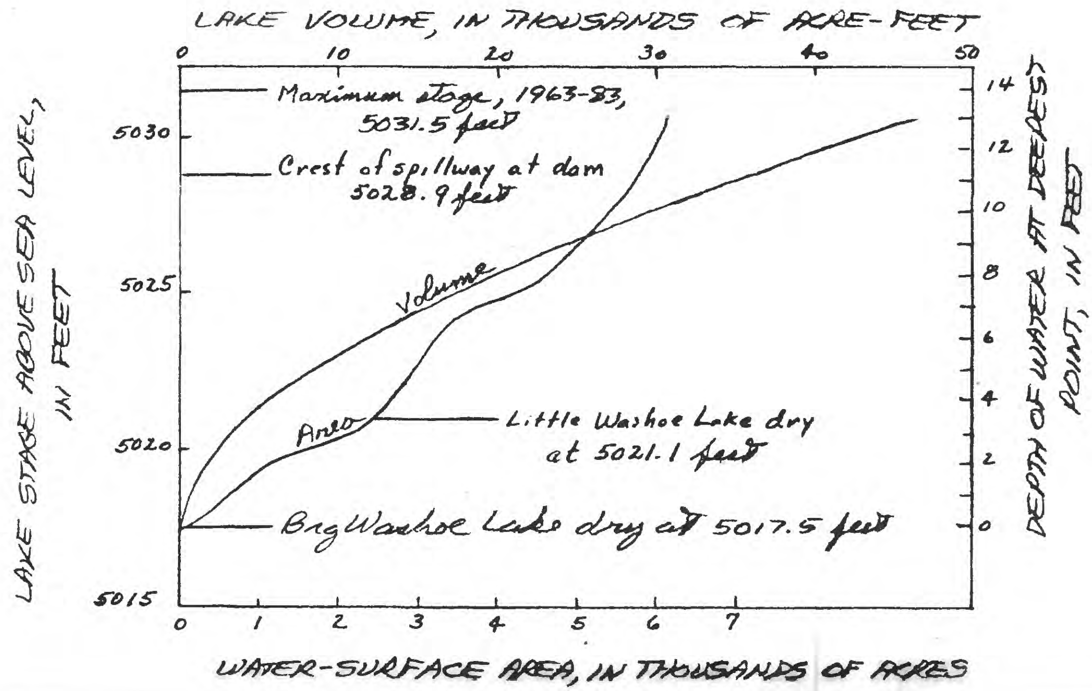

FIGURE 13.--Relation between lake stage, area, and volume for Big and Little Washoe Lakes (modified after Rush, 1972, figure 3). Above a stage of 5021.1 feet, areas and volumes are for combined lake.

Evapotranspiration from irrigated cropland and pasture was computed using the equation:

$$ET_k = (K)(ET)$$

where ET_k = evapotranspiration for a well-watered crop, and

K = a crop coefficient for evapotranspiration.

Calibrated crop coefficients determined by Pennington (1980, table 4) were used; monthly values are given in table 5. Calculated monthly values of ET_k are given in table 5 and shown in figure 15; the annual rate of 4.1 feet was used in estimating the long-term annual evapotranspiration from irrigated areas. Estimates of long-term evapotranspiration rates for nonirrigated pasture, native vegetation, and wetlands given in table 3 are based on data developed during this study (tables 4 and 5), estimates of vegetation density, and estimates made by Rush (1967, pages 20-21).

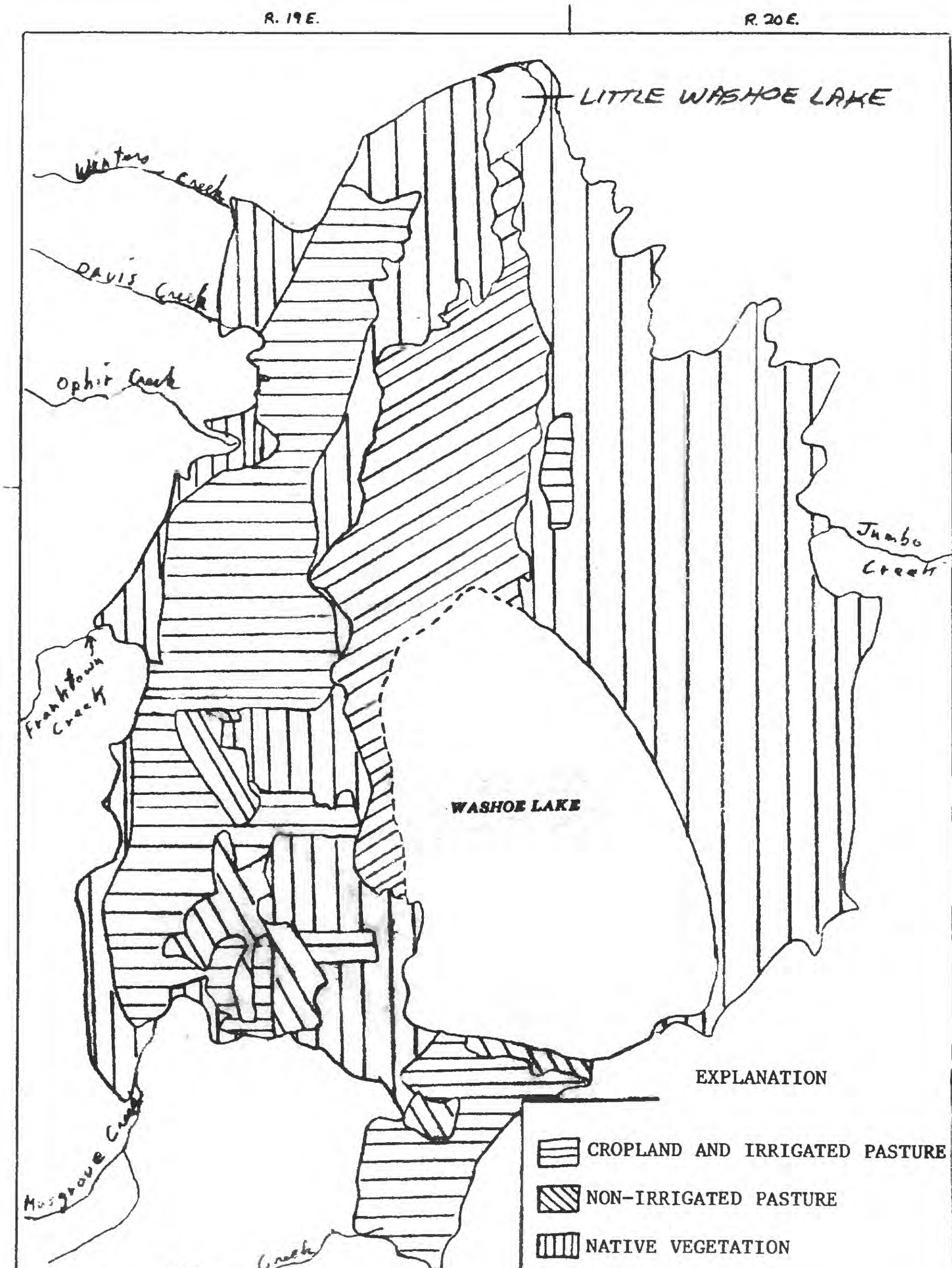

FIGURE 14.—Generalized distribution of vegetation types on the valley floor, June 1979.

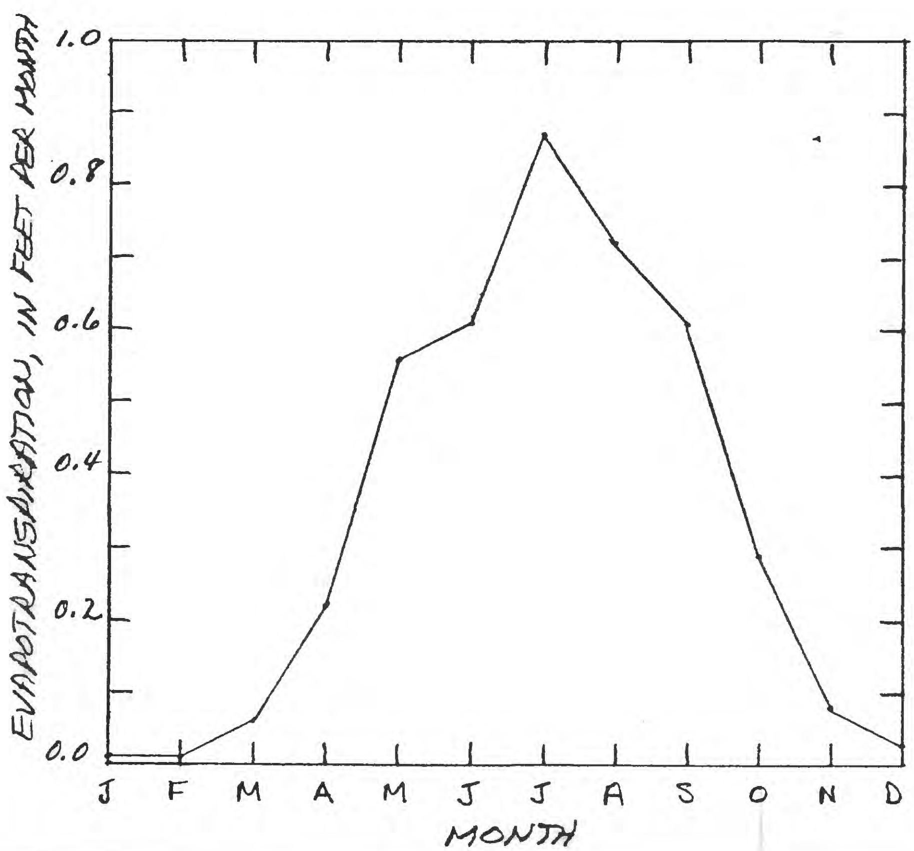

FIGURE 15.--Mean monthly evapotranspiration from well-watered crop in Washoe Valley (from table 5).

The remaining 6 percent of water outflow from Washoe Valley is accounted for through surface-water discharge, export of water from the basin, and domestic and stock use. Consumption of water by livestock is assumed to be negligible in magnitude relative to other budget items. Surface-water outflow from Big and Little Washoe Lakes to Steamboat Creek averages about 2,300 acre-ft/yr (Claude Dukes, Federal Water Master, written communication, 1982). About 700 acre-ft/yr is exported from Hobart Creek and Marlette Lake to Carson City and Virginia City (Nevada Division of Buildings and Grounds, written communication, 1982).

Ground-water consumption associated with domestic use and related pasture irrigation is calculated by assuming that the rates and proportions estimated for urban Cold Spring Valley, north of Reno (Van Denburgh, 1981, pages 43-46), are generally appropriate for the 3,000 residents of Washoe Valley. The assumptions are as follows: (1) Per capita domestic pumpage and consumption are about 0.12 and 0.025 acre-ft/yr, respectively; (2) pumpage for irrigation of domestic pastures is about one-tenth of the amount required for house and garden use; and (3) about 60 percent of the pumpage for pasture irrigation is consumed by evapotranspiration. On the basis of these assumptions, valley-wide domestic consumption of ground water as of 1980 was on the order of 100 acre-ft/yr.

The water budget developed by this investigation estimates about 10 percent more water inflow and outflow than the investigation by Rush (1967). Rush's table 7 suggests an inflow of 33,000 acre-feet and an outflow of 31,000 acre-feet, but Rush (1967, table 3) has excluded 15,000 acre-feet of precipitation on the valley floor from the inflow value and 15,000 acre-feet of evapotranspiration of precipitation from the valley floor from the outflow value. His total inflow and outflow values are actually 48,000 and 46,000 acre-feet, respectively. This compares with the estimate of 53,000 acre-feet from this study. The increase in the inflow component is the result of an increase in the estimate of precipitation in the basin based on 13 years of data collected since Rush's study. The increase in the outflow component is more than accounted for by the increase in estimated evaporation from the lakes. These evaporation rates are based on data and the study by Pennington (1980) that have become available since the earlier study by Rush.

Conclusions

Any major development of the water resources of Washoe Valley that causes significant lowering of the water table will upset the rather delicate balance between inflow and outflow that now exists. The primary buffer that currently reflects changes in these water budget components is Washoe and Little Washoe Lakes. Following periods of less than normal precipitation Little Washoe Lake dries up and Washoe Lake is reduced in area. Following periods of greater than normal precipitation, Washoe Lake increases in area, Little Washoe Lake comes into existence, and outflow to Steamboat Creek increases.

Water resource development in most basins in Nevada requires the lowering of ground-water levels and the salvage of evapotranspired natural discharge. Most other basins in Nevada do not have a permanent lake in them. A similar approach to water resource development in Washoe Valley will have a direct and fairly rapid impact on Washoe and Little Washoe Lakes. Lowered ground-water levels will allow greater infiltration of surface runoff, reducing the amount entering the lakes. Ground-water discharge directly to the lakes will be reduced and eventually will stop. The net result will be the eventual destruction of the lakes. Only after the lakes have been significantly impacted can any salvage of evapotranspiration be expected. Direct development of surface water resources will have the same impact on the lakes.

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