Estimated Natural Ground-Water Recharge, Discharge, and Budget for the Dixie Valley Area, West-Central Nevada

By James R. Harrill *and* Lawrence B. Hines

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CONTENTS

PLATE

FIGURE

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot (ft^3)	0.3048	cubic meter
cubic foot per square foot (ft^3/ft^2)	0.3048	cubic meter per square meter
foot (ft)	0.3048	meter
foot per year (ft/yr)	.0008351	meter per day
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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ABSTRACT

The Dixie Valley area includes seven valleys in west-central Nevada (Dixie, Fairview, Stingaree, Cowkick, Eastgate, Pleasant, and Jersey Valleys; total, 2,380 square miles). Dixie Valley receives surface-water and ground-water flow from Stingaree, Cowkick, Eastgate, Pleasant, and Jersey Valleys and subsurface flow from Fairview Valley, which is a topographically closed basin.

The relation between precipitation and altitude was re-evaluated for the Dixie Valley area using new data, and empirical estimates of recharge were revised accordingly. The revised estimate of total recharge is 23,000 acre-feet per year.

Re-evaluation of ground-water discharge focused on Dixie Valley as the largest basin in the study area. Phreatophytic vegetation was mapped and partitioned into nine zones on the basis of species composition and foliage density. For woody phreatophytes, annual evapotranspiration rates of 0.7 cubic feet of water per cubic foot of foliage for greasewood and 1.1 cubic feet of water per cubic foot of foliage for rabbitbrush were adapted from lysimeter studies near Winnemucca, Nevada. These rates were multiplied by the foliage density of the respective phreatophytes in each zone to estimate a specific rate for that zone. Rates for saltgrass (0.5 to 0.8 foot per year) and the playa surface (0.1 to 0.3 foot per year) were based on a range of rates used in other recent studies in western and central Nevada. These rates were multiplied by the areas of the zones to produce estimates of the annual volume of ground water discharged. The discharge estimated for Dixie Valley is between 17,000 and 28,000 acre-feet per year. The revised discharge estimate for the entire Dixie Valley area is between 20,000 and 31,000 acre-feet per year.

The revised ground-water budget for the entire Dixie Valley study area has a total recharge of about 23,000 acre-feet per year. This is within the range of estimates of natural discharge—from 20,000 to 31,000 acre-feet per year. For Dixie Valley alone, the total recharge of about 8,900 acre-feet per year and the estimated subsurface inflow from tributary areas of about 11,000 acre-feet per year produce an estimated total inflow of about 20,000 acre-feet per year. This compares with the discharge estimate of 17,000 to 28,000 acre-feet per year.

INTRODUCTION

Dixie Valley is a large basin in western Nevada that receives surface- and ground-water flow from six smaller valleys (Fairview, Stingaree, Cowkick, Eastgate, Pleasant, and Jersey; see pl. 1). This drainage system, which totals about 2,380 mi^2 (Rush, 1968, p. 20), is referred to herein as the Dixie Valley area. Rush (1968, p. 20) assigned each valley a hydrographic-area number as follows: Dixie Valley (128), Fairview Valley (124), Stingaree Valley (125), Cowkick Valley (126), Eastgate Valley (127), Pleasant Valley (130), and Jersey Valley (132). Dixie Valley encompasses about 1,300 mi^2 of the Dixie Valley area. The drainage within Dixie Valley is toward a playa, the Humboldt Salt Marsh, which, at an altitude of about 3,360 ft above sea level, is the lowest point in the northern two-thirds of Nevada. All natural ground-water discharge is by evapotranspiration from areas of shallow ground water beneath or adjacent to the playa.

In the early 1980's, Dixie Valley was selected as a potential area for study and modeling as part of the Great Basin Regional Aquifer-Systems Analysis (RASA) study (Harrill and others, 1983, p. 40-42). After efforts to develop a model revealed uncertainties in the available information that could not be resolved without much additional detailed study, Dixie Valley was not used as an example area for the RASA program. Estimates of the natural ground-water discharge initially developed in support of the RASA effort and subsequent findings of recent studies (Hines, 1992; Nichols, 1992, 1993; Carman, 1993), however, can be used to develop an estimate of the natural discharge from Dixie Valley that is more detailed than the initial reconnaissance estimate developed by Cohen and Everett (1963, p. 21). Also, precipitation data acquired since 1963 allow for a refinement of the estimate of recharge by Cohen and Everett (1963, table 3). The purpose of this report is to present these revised estimates of natural ground-water discharge and recharge for the Dixie Valley area and to discuss briefly their significance.

Field work done in 1983 as part of the RASA study included measuring vegetation types and foliage densities along 15 transects in Dixie Valley, grouping the phreatophytic vegetation into nine zones and mapping the areal extent of each zone, mapping the area of the playa, hand augering shallow holes in the playa deposits at 18 sites to determine depth to the water table, and measuring static water levels in most of the wells in the valley. Water-level measurements and well information are stored in the ground-water site inventory files of the U.S. Geological Survey's National Water Information System (NWIS). This information can be obtained through the U.S. Geological Survey Office in Carson City, Nev., or through any designated National Water-Data Exchange (NAWDEX) assistance center (Edwards, 1987). The other information pertaining to evapotranspiration (ET) and the revised estimates of recharge were compiled for this report in 1993-94.

RECHARGE FROM PRECIPITATION

Natural recharge from precipitation in the Dixie Valley area was estimated to be about 16,000 acre-ft/yr by Cohen and Everett (1963, p. 18). This estimate was made using a method described by Eakin and others (1951). The method estimates the average annual volume of precipitation using a relation between precipitation and altitude zones, and then assigns specified percentages of recharge to each altitude zone. In 1963, only one precipitation station was operating in the entire Dixie Valley area. Precipitation values were assigned to altitude zones solely on the basis of a generalized precipitation map of the entire State that was compiled in the 1930's (Hardman, 1936). The relation between precipitation and altitude zones that was used assumed that the 8-in. line of equal annual precipitation corresponded to an altitude of 6,000 ft, the 12-in. line to an altitude of 7,000 ft, the 15-in. line to an altitude of 8,000 ft, and the 20-in. line to an altitude of 9,000 ft.

Since 1963, considerable precipitation data have been collected in the Dixie Valley area and, as of 1993, data are available for 5 precipitation stations and 24 precipitation-storage gages within the Dixie Valley area. Records for these stations, one station in adjacent Buffalo Valley, and long-term stations in Austin, Fallon, and Lovelock are listed in table 1. The relation between precipitation at these stations and altitude is shown in figure 1. (Precipitation for the station in Buffalo Valley was anomalously high for the altitude and this station is not shown in figure 1.) The data in figure 1 define the relation between precipitation and altitude for values of precipitation from about 5 in. to slightly more than 12 in. The regression equation shown in figure 1 indicates that an annual precipitation of 8 in. corresponds to an altitude of about 4,900 ft, which is considerably lower than the altitude of 6,000 ft previously used. An annual precipitation of 12 in. corresponds to an altitude of about 7,150 ft, which is in reasonable agreement with the altitude of 7,000 ft previously used. The precipitation values do not exceed about 13 in.; however, the curve was extrapolated to 15 in. because the relation from 5 to 12 in. was well defined and no information was available in the study area to better define the relation at higher altitude. On the basis of the relation shown in figure 1, an annual precipitation of 15 in. corresponds to an altitude of about 8,820 ft.

Table 1. Average monthly and annual precipitation at stations and storage gages in and near Dixie Valley area, Nevada

[All precipitation values in inches; from published records of the U.S. Weather Bureau, except where indicated. Symbol: --, not available]

Station or gage	Altitude (feet above sea level)	Period of record	Jan	Feb	Mar	Apr	Mey	June	July	Aug	Sep	Oct	Nov	Dec	Annual	Adjusted to long term[1]
Austin[2]	6,594	1911-62	1.14	1.14	1.46	1.64	1.43	0.80	0.60	0.53	0.48	0.93	0.85	1.06	12.06	--
Brinkerhoff Ranch[3]	3,660	1966-79	.58	.56	.58	.83	.56	.91	.43	.43	.41	.31	.54	.73	6.87	6.6
Buffalo Ranch[4]	5,430	1966-81	2.08	1.09	1.38	1.14	1.21	1.73	.33	.68	.70	.75	1.29	1.37	13.75	13.3
Dixie Valley[5]	3,540	1972-79	.80	.93	1.07	.53	.22	.23	.13	.28	.52	.28	.54	.45	6.00	5.9
Eastgate[6]	5,020	1956-69	.57	.84	.60	.82	.69	.88	.38	.72	.67	.33	.54	.56	7.59	7.2
Fallon[7]	3,965	1892-87	.55	.54	.46	.44	.60	.42	.18	.21	.28	.43	.36	.50	4.96	--
Lovelock[8]	3,977	1891-87	.63	.54	.46	.43	.48	.45	.17	.21	.33	.44	.41	.48	5.06	--
Paris Ranch[9]	4,136	1966-87	.87	.82	.98	.86	.82	.77	.39	.43	.46	.69	1.02	.90	9.01	8.3
Robbins[10]	3,410	1980-84	.68	.53	.83	.40	.58	.63	.21	.61	.79	.62	.79	.59	7.29	5.6
U.S. Bureau of Land Management precipitation storage gages, Eastgate watershed. Data from Joung and others (1983, p. x-y).																
Can No. 1	4,900	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	7.81	7.5
Can No. 2	5,325	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	7.92	7.6
Can No. 3	5,500	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	8.39	8.0
Can No. 4	5,200	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	8.95	8.6
Can No. 5	5,400	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	8.67	8.3
Can No. 7	6,400	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	10.89	10.6
Can No. 8	5,800	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	9.39	9.1
Can No. 9	6,200	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	10.10	9.8
Can No. 10	5,400	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	8.79	8.5
Can No. 11	6,800	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	12.38	12.0
Can No. 12	5,800	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	10.25	9.9
Can No. 13	6,400	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	12.19	11.7
Can No. 14	5,500	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	10.37	9.9
Can No. 15	7,700	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	13.33	12.8
Can No. 16	6,600	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	12.17	11.7
Can No. 17	6,400	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	10.94	10.5
Can No. 18	6,200	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	10.87	10.4
Can No. 19	5,700	1963-80	--	--	--	--	--	--	--	--	--	--	--	--	10.05	9.6
Can No. 20	5,600	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	10.02	9.7
Can No. 21	5,200	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	9.27	9.0
Can No. 22	5,000	1963-77	--	--	--	--	--	--	--	--	--	--	--	--	8.00	7.8
Can No. 23	4,870	1967-80	--	--	--	--	--	--	--	--	--	--	--	--	8.46	8.5
Can No. 24	4,650	1967-80	--	--	--	--	--	--	--	--	--	--	--	--	8.52	8.5
Can No. 25	6,100	1967-80	--	--	--	--	--	--	--	--	--	--	--	--	9.64	9.6

[1] Adjusted to long-term averages on the basis of comparison with long-term records at Fallon and Lovelock.
[2] In sec. 35, T. 26 N., R. 38 E. in Dixie Valley.
[3] In sec. 15, T. 29 N., R. 40 E. in Buffalo Valley.
[4] In sec. 1. T 21 N., R. 34 E. in Dixie Valley. Aggregated short records at several adjacent sites (Stark, Thilex, and Anderson).
[5] In sec. 25, T. 17 N., R. 36 E. in Eastgate Valley.
[6] In sec. 6, T. 18 N., R. 29 E. in Carson Desert, 25 miles west of study area.
[7] In sec. 26, T. 27 N., R. 31 E. in Lovelock Valley, 35 miles northwest of study area.
[8] In sec. 15, T. 27 N., R. 38 E. in Pleasant Valley.
[9] In sec. 8, T. 21 N., R. 35 E. in Dixie Valley. Records provided by Mr. Ed Robbins.
[10] In sec. 19, T. 19 N., R. 44 E. in Reece River Valley.

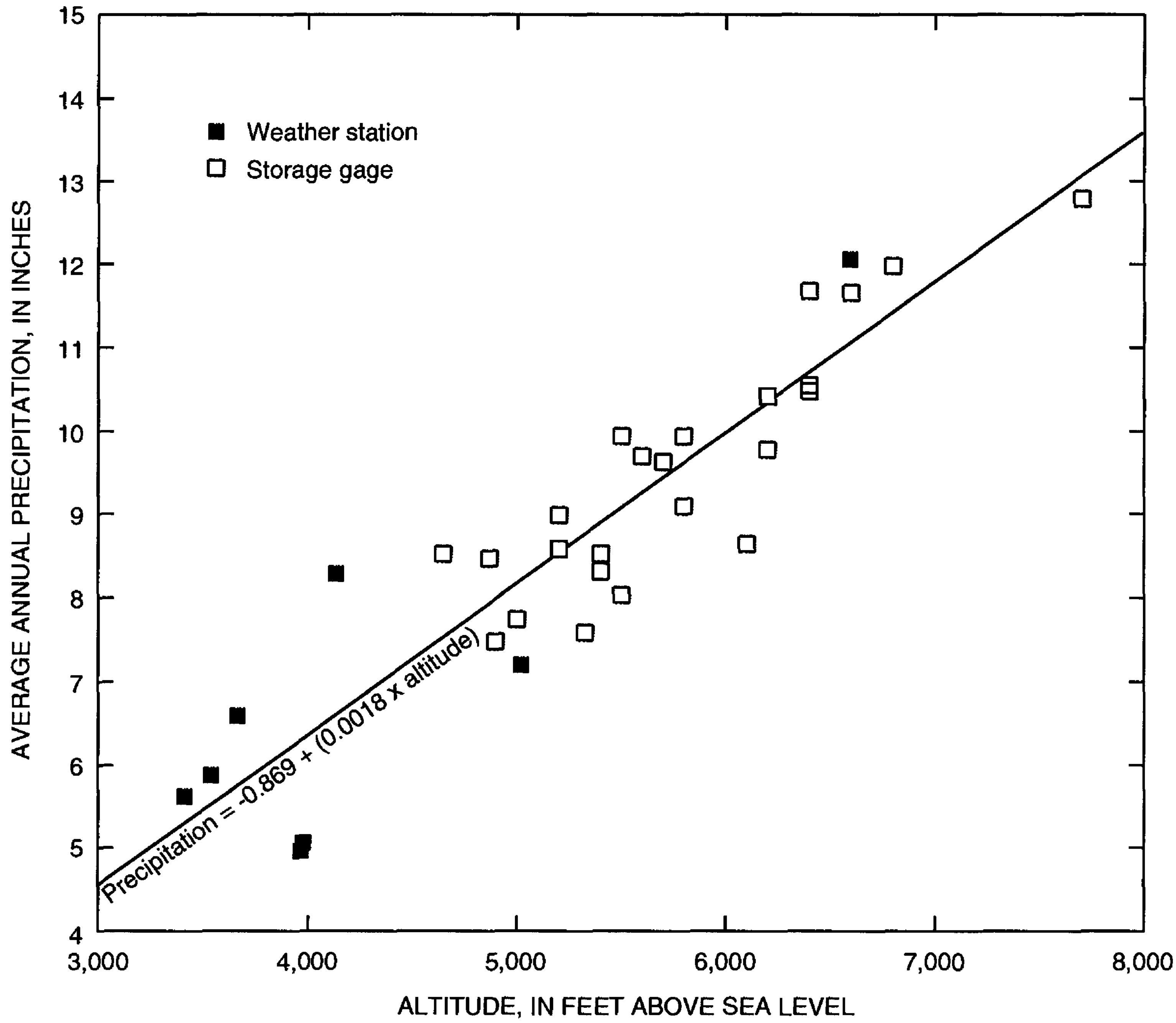

Figure 1. Relation between precipitation and altitude at 32 sites in and adjacent to Dixie Valley area.

Topographic maps of the area indicate that much of the zone between 4,900- and 6,000-ft altitude is on the lower flanks of the mountains, has steep slopes, and contains exposures of consolidated rock. Thus, changing the lower limit of the area that contributes to recharge from 6,000 ft to 5,000 ft appears justified. A value of 5,000 ft was used instead of 4,900 ft to be consistent with the practice of using 1,000-foot increments of altitude to approximate precipitation zones for reconnaissance-level estimates of recharge. Altitudes of 7,000 and 9,000 ft were used to represent annual precipitation values of 12 and 15 in., respectively. These revisions result in an estimate of 23,000 acre-ft/yr of recharge for the entire area (table 2). This estimate is 7,000 acre-ft/yr higher than the 16,000 acre-ft/yr previously estimated by Cohen and Everett (1963, table 3).

The slope of the precipitation-versus-altitude relation shown in figure 1 is less than the slope of the relation used by Cohen and Everett (1963, table 3). A possible explanation for the lesser slope is that the Dixie Valley area may be in a "rain shadow" caused by the Sierra Nevada.

GROUND-WATER DISCHARGE

In this report, a revised estimate of discharge by evapotranspiration is made for only the large discharge area in Dixie Valley. This new information is used in conjunction with discharge estimates made by Cohen and Everett (1963, table 4) for Pleasant Valley and Stingaree, Cowkick, and Eastgate Valleys to produce a revised estimate for the entire Dixie Valley area. The estimate made for Dixie Valley in this report is comparable to the estimate for Dixie and Jersey Valleys made by Cohen and Everett (1963, table 4) because virtually all discharge from Jersey Valley occurs as underflow to Dixie Valley where it is ultimately consumed by

Table 2. Estimated average annual precipitation and ground-water recharge in Dixie Valley area, Nevada

Altitude zone (feet above sea level)	Area (acres)	Estimated annual precipitation			Estimated recharge	
		Range (inches)	Average		Assumed percentage of precipitation	Acre-feet per year
			Feet	Acre-feet		
		DIXIE VALLEY (north of T. 22 N.)				
7,000 to 9,000	4,040	12 to 15	1.12	4,500	7	320
5,000 to 7,000	97,300	8 to 12	.83	81,000	3	2,400
Below 5,000	287,000	less than 8	.50	140,000	0	0
Subtotal (rounded)	388,000			230,000		2,700
		DIXIE VALLEY (south of T. 23 N.)				
Above 9,000	979	more than 15	1.46	1,400	15	210
7,000 to 9,000	26,700	12 to 15	1.12	30,000	7	2,100
5,000 to 7,000	154,000	8 to 12	.83	130,000	3	3,900
Below 5,000	267,000	less than 8	.50	130,000	0	0
Subtotal (rounded)	449,000			290,000		6,200
Total (rounded)	837,000			520,000		8,900
		FAIRVIEW VALLEY				
7,000 to 9,000	1,820	12 to 15	1.12	2,000	7	140
5,000 to 7,000	87,100	8 to 12	.83	72,000	3	2,200
Below 5,000	94,900	less than 8	.50	47,000	0	0
Total (rounded)	184,000			120,000		2,300
		STINGAREE, COWKICK, AND EASTGATE VALLEYS				
Above 9,000	2,020	more than 15	1.46	2,900	15	440
7,000 to 9,000	24,900	12 to 15	1.12	28,000	7	2,000
5,000 to 7,000	174,000	8 to 12	.83	140,000	3	4,300
Below 5,000	36,100	less than 8	.50	18,000	0	0
Total (rounded)	237,000			190,000		6,700
		PLEASANT VALLEY				
Above 9,000	702	more than 15	1.46	1,000	15	150
7,000 to 9,000	12,100	12 to 15	1.12	14,000	7	980
5,000 to 7,000	90,500	8 to 12	.83	75,000	3	2,200
Below 5,000	76,900	less than 8	.50	38,000	0	0
Total (rounded)	180,000			130,000		3,300
		JERSEY VALLEY				
7,000 to 9,000	3,860	12 to 15	1.12	4,300	7	300
5,000 to 7,000	44,400	8 to 12	.83	37,000	3	1,100
Below 5,000	38,100	less than 8	.50	19,000	0	0
Total (rounded)	86,400			60,000		1,400
GRAND TOTAL (rounded)	1,520,000			1,000,000		23,000

evapotranspiration. Plate 1 shows the results of detailed phreatophyte mapping in 1983 for Dixie Valley and reconnaissance mapping by Cohen and Everett (1963, pl. 1) for the other valleys. Phreatophyte boundaries shown by Cohen and Everett are adjusted slightly in plate 1 of this report to conform with the extent of basin-fill deposits shown by Stewart and Carlson (1978).

Evapotranspiration in Phreatophyte Areas

Type and Distribution of Vegetation

Plants in Dixie Valley can be subdivided into two general hydrologic groups: xerophytes and phreatophytes. A xerophyte derives water primarily from surface-water infiltration, whereas a phreatophyte derives most of its water from the underlying aquifer (Meinzer, 1927, p. 1). Commonly, phreatophyte species can exist in xerophytic areas where precipitation ponds or where surface-water runoff infiltrates and is temporarily stored as soil moisture or perched ground water. Phreatophytic evapotranspiration, therefore, does not include xerophytic evapotranspiration within the phreatophytic ground-water discharge zone. For this report, the term "phreatophyte" refers to plants that use water derived primarily from the zone of saturation. This excludes plants maintained by localized areas of surface-water runoff or shallow perched water. Sagebrush is the most common xerophyte in the Dixie Valley area, although shadscale and some xerophytic greasewood also are present. The three principal genera of natural phreatophytes in Dixie Valley are big greasewood, rabbitbrush, and saltgrass. Minor areas of cottonwood, willow, saltcedar, and wildrye were too small to be mapped as distinct categories.

Determination of Foliage Cover and Volume

Foliage characteristics for each woody phreatophyte area were measured in April 1983, using the transect method described by Horton and others (1964) for the calculation of zone-specific discharge rates. Fifteen sites were sampled along transects to determine fractional amounts of areal cover, average weighted height, and foliage-volume density for each phreatophyte type. Locations of these sites are shown on plate 1. Sites were chosen that appeared to best represent the area being investigated. A steel surveyor tape was stretched in a quasi-random direction over the foliage crown to form a straight-line transect. Areal cover was calculated by measuring the length of each plant crown intercept (vertical projection of the plant silhouette onto the tape), summing the intercepts of the plant type(s) of interest, and dividing this sum by the total transect length (300 ft at most sites). An assumed 1-ft width along the transect results in physical units of square feet of vegetated cover per square foot of discharge zone area.

Calculation of average weighted height entailed two steps. The first step was to measure the height of each plant at its crest and multiply each height intercept by the corresponding crown intercept. The second step was to calculate average height by dividing the sum of the height-intercept products by the sum of the intercepts. The resulting units are in feet.

The average height, crown cover, and volumetric density of the major phreatophytes (greasewood and rabbitbrush) and other xerophytic vegetation (mostly shadscale, bud sagebrush, fiddleneck, and big sagebrush) present in significant amounts along some transects are listed in table 3. Areas dominated by saltgrass were mapped as a separate zone and the average volume of foliage (grass) was estimated for the entire zone.

Identification and Mapping of Phreatophyte Zones

The area populated by phreatophytes was partitioned into nine zones (pl. 1) on the basis of species composition and foliage-volume density. This partition was accomplished primarily by driving along established roads and mapping the combined visual effect of plant height, crown-cover density, and species composition (see Hines [1992] for a more detailed description of phreatophyte mapping methods). This mapping method positions boundaries to within approximately 1/2 mi of the true locations based on foliage-volume density ratios. The resulting uncertainty is small because the low rates of evapotranspiration and extensive area reduce the error to a magnitude within the range of uncertainties in rate-calculation data used in this study. The area, approximate average percent cover, and approximate average volume of foliage for each of the nine zones are listed in table 4.

Table 3. Areal characteristics of vegetation at transect sites, April 1983, in Dixie Valley, Nevada

			Principal phreatophytes						Other vegetation			
			Greasewood			Rabbitbrush						
Transect site	Location[1]	Zone on plate 1	Average height (feet)	Crown-cover (percent)	Volumetric density (cubic feet per square foot)	Average height (feet)	Crown-cover (percent)	Volumetric density (cubic feet per square foot)	Average height (feet)	Crown-cover (percent)	Volumetric density (cubic feet per square foot)	Type
1	N19 E34 3AC	([2])	1.3	6.5	0.08	0	0	0	1.2 .7	10.0 3.2	0.12 .02	Shadscale Bud sagebrush
2	N21 E34 27CC	1	1.6	5.7	.09	0	0	0	1.0 .5	2.4 .4	.02 .002	Shadscale Bud sagebrush
3	N21 E35 30BB	1	1.8	1.9	.03	1.3	3.0	.04	.8	1.5	.001	Fiddleneck
4	N21 E35 7CC	2	1.9	3.0	.06	2.3	9.1	.21	1.5 3.1	6.5 1.1	.10 .03	Shadscale Big sagebrush
5	N21 E34 10DD	1	2.3	3.2	.07	0	0	0	.7	3.8	.003	Shadscale
6	N22 E34 35CC	1	1.3	3.4	.04	0	0	0	1.4	2.2	.03	Shadscale
7	N22 E34 25AA	3	3.0	14.7	.44	1.9	.5	.01	1.5 1.4	.6 .7	.009 .01	Shadscale Big sagebrush
8	N23 E35 13AD	4	3.2	6.3	.20	0	0	0	.9 .9	.4 .5	.004 .004	Shadscale Bud sagebrush
9	N24 E36 14CC	5	1.6	5.5	.09	0	0	0	1.7	3.3	.06	Shadscale
10	N24 E37 16DB	6	4.2	6.5	.27	1.1	1.2	.01	0	0	0	
11	N26 E38 12CC	5	1.6	5.7	.09	1.0	.1	.001	1.0	5.2	.05	Shadscale
12	N26 E39 32AA	([2])	1.3	1.1	.01	0	0	0	1.4	14.8	.21	Shadscale
13	N25 E39 17BC	7	2.2	26.4	.58	0	0	0	0	0	0	
14	N25 E38 32AB	1	1.6	5.6	.09	0	0	0	.7	.6	.004	Shadscale
15	N21 E35 10AA	1	1.3	3.7	.048	1.3	1.1	.014	0	0	0	

[1] Site designation consists of three units: First unit is township, preceded by N to indicate location north of base line. Second unit is range, preceded by E to indicate location east of meridian. Third unit consists of section number and letters designating quarter section and quarter-quarter section (A, B, C, and D indicate northeast, northwest, southwest, and southeast quarters, respectively).

[2] Transect outside mapped phreatophyte area.

Table 4. Areal characteristics of vegetation zones in Dixie Valley, Nevada

Zone (plate 1)	Area (acres)	Approximate average percent cover: Grease-wood	Rabbit-brush	All shrubs	Approximate average volume of foliage (cubic feet per square foot): Grease-wood	Rabbit-brush	All shrubs
1	79,000	4	1	6	0.06	0.01	0.09
2	4,300	3	9	20	.06	.21	.34
3	3,800	15	trace	19	.44	.01	.57
4	4,100	6	trace	7	.20	trace	.21
5	3,300	6	trace	9	.09	trace	.15
6	13,600	7	1	8	.28	.01	.24
7	1,200	26	trace	26	.59	trace	.59
8 [a]	4,800	--	--	--	--	--	--
Total (rounded)	114,000	--	--	--	--	--	--

[a] Saltgrass; estimated volume of foliage 0.05-0.11 cubic foot per square foot.

Estimation of Evapotranspiration Rates

Discharge from areas dominated by saltgrass was determined by multiplying the zone area by rates of 0.5 and 0.8 ft/yr. This range of annual rates was based on a rate of 0.5 ft/yr previously used by Hines (1992, p. 17) and a rate of 0.80 ft/yr used by Nichols (1992, p. 311) for areas of saltgrass in Smith Creek Valley. These rates are higher than the rate of 0.2 ft/yr used by Cohen and Everett (1963, p. 21), but higher rates can be supported on the basis of preliminary results of field studies in northwestern Nevada as discussed by Nichols (1992, p. 314).

Evapotranspiration rates for woody phreatophytes were based on foliage-volume density, the product of fractional areal cover and average weighted height (table 2). Rates were first determined for each phreatophyte type in a zone by multiplying the foliage volume by an annual volume of ground water discharged per cubic foot of foliage. Annual rates of 0.7 ft^3 of water per cubic foot of foliage for greasewood and 1.1 ft^3 of water per cubic foot of foliage for rabbitbrush were adopted from lysimeter studies by Robinson (1970) near Winnemucca, Nev. The combined evapotranspiration rate for a zone was then formed by summing the rates for individual plant types. Multiplying this rate by the area of the zone produced an estimate of the annual volume of ground water discharged. The results of this calculation are summarized in table 5.

Evaporation from the Playa

In 1983, the area of bare soil mapped on the Dixie Valley playa was about 44,000 acres. In August-November 1984, shallow holes were hand augured at 18 sites east and north of the Humboldt Salt Marsh to evaluate the general range in depth to the water table. Depths to the water table ranged from less than a foot to about 7.5 ft. At most sites, the water table was less than 5 ft below the land surface. Evaporation of ground water from the playa can be a significant component of the ground-water budget because of the large surface area of the playa. Average discharge rates from playa surfaces are difficult to estimate because of year-to-year variations in the extent and duration of surface flooding and because of uncertain effects from the development of a salt crust, which could suppress evaporation. Cohen and Everett (1963, p. 21) used 0.1 ft/yr to represent the average long-term rate of evaporation from the playa. This rate was commonly used in reports of the Nevada ground-water reconnaissance series to estimate evaporation from bare playa soils; however, virtually no field measurements could be used to validate this estimated rate. Hines (1992, p. 17-19) used Darcy's law and hydraulic gradients to calculate estimates of vertical and horizontal flow for specified zones of the playa surface in nearby Smith Creek Valley. His calculations produced estimates ranging from 0.02 to 0.50 ft/yr for specific zones, depending primarily on measured variations in vertical hydraulic gradient. The average rate estimated by Hines for the entire main playa of Smith Creek Valley was 0.2 ft/yr. In recent years, several investigators

Table 5. Estimated ground-water discharge due to evapotranspiration from phreatophytes and evaporation from bare soil in Dixie Valley, Nevada

Zone number (plate 1)	Foliage-volume density (cubic feet per square foot): Phreatophytes: Greasewood	Rabbitbrush	All	Xerophytes	All plants	Evapotranspiration rate (feet per year)	Aree (acres)	Estimated annual evapotranspiration (acre-feet per year)[1]
				NORTH OF TOWNSHIP 22 NORTH				
1	0.06	0.01	0.07	0.02	0.09	0.05	50,800	2,500
4	.20	trace	.20	.01	.21	.14	3,600	500
5	.09	trace	.09	.06	.15	.06	3,300	200
6	.28	.01	.29	trace	.29	.21	13,600	2,900
7	.59	trace	.59	trace	.59	.41	1,200	500
8		saltgrass only				[2]0.5 - 0.8	4,100	2,000-3,300
Playa		bare soil				[3]0.1 - 0.3	26,000	2,600-7,800
						Subtotal	102,600	11,000-18,000
				SOUTH OF TOWNSHIP 23 NORTH				
1	0.06	0.01	0.07	0.02	0.09	0.05	28,200	1,400
2	.06	.21	.27	.13	.40	.27	4,300	1,200
3	.44	.01	.45	.12	.57	.32	3,800	1,200
4	.20	trace	.20	.01	.21	.14	500	70
8		saltgrass only				[2]0.5 - 0.8	700	350-560
Playa		bare soil				[3]0.1 - 0.3	17,900	1,800-5,400
						Subtotal	55,400	6,000-9,800
						TOTAL FOR VALLEY (rounded)	158,000	17,000-28,000

[1] Evapotranspiration estimates are rounded off to two significant figures or less.

[2] Annual rate of 0.5 foot per year is rate used by Hines (1992, p. 17) and annual rate of 0.8 foot per year is rate used by Nichols (1992, p. 311) to estimate ground-water evapotranspiration by saltgrass in Smith Creek Valley.

[3] Range 0.1 to 0.3 foot per year is range in rates used by Maurer and others (1994, p. 69) to estimate average annual ground-water discharge from Carson Sink playa. Following wet periods, such as 1983-84, annual rate of ground-water evapotranspiration may be as high as 0.5 foot per year.

have measured evapotranspiration rates at several playa sites. Nichols (1992) used a rate of 0.26 ft/yr to represent ground-water evapotranspiration from the Smith Creek Valley playa. This value is based on field measurements made between mid-July and early September 1989. During the summer of 1993, measurements were made at two sites on the Railroad Valley playa (in east-central Nevada) and a preliminary evaluation of data collected during the last half of July suggests an annual evaporation of ground water from the Railroad Valley playa of between 0.1 and 0.2 ft/yr (Michael J. Johnson, U.S. Geological Survey, written commun., 1993). Finally, as part of an evaluation of the Newlands area of the Carson Desert, just west of Dixie Valley, a range in rates of 0.1 to 0.3 ft/yr was used to encompass the uncertainty of the available estimates (Maurer and others, 1994, p. 69). The same range in rates, 0.1 to 0.3 ft/yr, is used in this report (table 5). Additional field study will be required before ground-water discharge from the playa can be estimated more precisely.

Discussion of Discharge Estimates

The ground-water discharge of 17,000 to 28,000 acre-ft/yr estimated in table 5 is larger than the discharge of 16,500 acre-ft/yr estimated by Cohen and Everett (1963, p. 21) for Dixie and Jersey Valleys. The total area mapped as an area of ground-water discharge was similar in the two studies. Most of the difference in estimates is due to more extensive mapped areas of saltgrass and bare soil (playa) and to higher evapotranspiration rates being used in this report for both areas. The higher evapotranspiration rates used are based in part on recent results reported by Nichols (1992) and Hines (1992). These reported results are, in turn, based in part on field-measurement studies that are continuing, and future results may indicate some revision of the existing rates. A range in evapotranspiration rates was used for the saltgrass and bare-soil zones in this current study to allow for the existing uncertainty. Additional field studies will be needed to support more specific refinements. The area of woody shrubs in table 5 (zones 1-7) totals about 110,000 acres, which is smaller than the 125,100 acres mapped by Cohen and Everett (1963). The difference of 15,800 acres is about equal to the difference in the areas mapped as bare soil by Cohen and Everett (1963) and by this study. Some areas mapped as sparsely vegetated areas of greasewood and rabbitbrush by Cohen and Everett probably were mapped as bare soil during this investigation. Because this study was made just after a period of extensive playa flooding, the area of bare soil may have been more extensive in 1983 than in 1963. Estimated evapotranspiration rates for the seven zones of woody phreatophytes shown in table 3 ranged from 0.05 to 0.41 ft/yr, with the average rate for all zones being approximately 0.1 ft/yr. This is identical to the rate used by Cohen and Everett (1963, p. 21) to represent the entire area of woody phreatophytes.

GROUND-WATER BUDGET

A revised ground-water budget for the Dixie Valley area is in table 6; it includes the average annual subsurface flow of ground water from valleys tributary to Dixie Valley. Total recharge to the Dixie Valley area of about 23,000 acre-ft/yr is within the range of estimated natural discharge (20,000 to 31,000 acre-ft/yr). Ideally, the two estimates should be equal. The range in estimated discharge is large enough to preclude any detailed evaluation of the difference between estimates of recharge and discharge.

For Dixie Valley, the total recharge of 8,900 acre-ft/yr (table 2) and the estimated subsurface inflow of 11,000 acre-ft/yr produce an estimated average annual inflow of about 20,000 acre-ft/yr, compared to an estimated discharge between 17,000 and 28,000 acre-ft/yr. The estimated inflow is within the range of estimated values of discharge; however, the location of the inflow does not correspond well with the location of the discharge.

The estimated discharge in Dixie Valley north of T. 22 N. is 11,000 to 18,000 acre-ft/yr and the estimated discharge south of T. 23 N. is 6,000 to 9,800 acre-ft/yr (table 5). In contrast, the estimated recharge north of T. 22 N. (2,700 acre-ft/yr, table 2) plus the subsurface inflow from Pleasant and Jersey Valleys (2,200 acre-ft/yr, table 6) total 4,900 acre-ft/yr and the estimated recharge south of T. 23 N. (6,200 acre-ft/yr, table 2) plus the subsurface inflow from Eastgate, Cowkick, Stingaree, and Fairview Valleys (6,300 acre-ft/yr, table 6) total 12,500 acre-ft/yr. The division between the north and south parts of Dixie Valley was selected to pass across the lowest area of the playa; large amounts of ground water would not be expected to flow between the two parts of the valley through this low area.

Table 6. Estimated average annual ground-water budget for Dixie Valley area, Nevada

[All values in acre-feet per year, rounded to two significant figures]

	Valley					
Budget elements	**Dixie**	**Fairview**	**Stingaree, Cowkick, and Eastgate**	**Pleasant**	**Jersey**	**Entire Dixie Valley area (rounded)**
INFLOW						
Ground-water recharge from precipitation (table 2)	8,900	2,300	6,700	3,300	1,400	23,000
Subsurface inflow	[1]11,000	([2])	([2])	([2])	([2])	([3])
TOTAL INFLOW	20,000	2,300	6,700	3,300	1,400	23,000
OUTFLOW						
Ground-water evapotranspiration (table 5)	17,000 to 28,000	([2])	400	2,200	300	20,000 to 31,000
Subsurface outflow[4]	([2])	2,300	6,300	1,100	1,100	([3])
TOTAL OUTFLOW	17,000 to 28,000	2,300	6,700	3,300	1,400	20,000 to 31,000
NET IMBALANCE (inflow minus outflow)	3,000 to -8,000	([2])	([2])	([2])	([2])	3,000 to -8,000

[1] Combined subsurface outflow from other six valleys in Dixie Valley area.
[2] Assumed to be negligible.
[3] Assumed to be negligible; subsurface inflow to Dixie Valley and outflow from other six valleys are internal to overall Dixie Valley area.
[4] Difference between estimated recharge and evapotranspiration, except as indicated.

Either one or more of the estimates are in error, or the distribution of subsurface inflow is different from the original estimate. The second possibility appears to be the best explanation on the basis of current data. Specifically, subsurface inflow from Stingaree, Cowkick, and Eastgate Valleys was thought to enter Dixie Valley by crossing beneath the edge of Stingaree Valley through a flow section that extends from Dixie Wash several miles to the north. An alternate flow path would be for recharge from parts of Stingaree, Cowkick, and Eastgate Valleys to move north through areas of fractured bedrock and enter the basin-fill reservoir of Dixie Valley either in or near the northern part of the valley. This concept has some support from geophysical work by Catchings (1992) and Okaya (1985). They developed geophysically based models indicating that Buena Vista Valley and Dixie Valley are underlain by highly broken rock masses to appreciable depths (6 to 12 mi) and that the Stillwater Range is largely a solid rock mass. Areas of highly fractured rock beneath Dixie Valley and possibly parts of the Clan Alpine Mountains may provide conduits for subsurface flow toward the north part of Dixie Valley. Much additional work is required before this possibility can be confirmed or rejected.

SUMMARY

Dixie Valley is a large basin in western Nevada that receives surface- and ground-water flow from six smaller valleys (Fairview, Stingaree, Cowkick, Eastgate, Pleasant, and Jersey). The total area is about 2,380 mi^2. In this report, Dixie Valley and the six tributary valleys are referred to as the Dixie Valley area. Dixie Valley alone encompasses about 1,300 mi^2 of this area. Drainage within Dixie Valley is toward a playa, which, at an altitude of 3,363 ft, is the lowest point in the northern two-thirds of Nevada.

The relation between precipitation and altitude was evaluated using data from 9 precipitation stations and 24 precipitation-storage gages. The results of this evaluation indicated that 8 in. of average annual precipitation occurred at an altitude of about 5,000 ft and that the rate of change of precipitation with altitude was less than originally estimated. Empirical estimates of recharge for the Dixie Valley study area were revised accordingly. The revised estimate for the total Dixie Valley area is 23,000 acre-ft/yr. This includes 8,900 acre-ft/yr in Dixie Valley, 1,400 acre-ft/yr in Jersey Valley, 3,300 acre-ft/yr in Pleasant Valley, 2,300 acre-ft/yr in Fairview Valley, and 6,700 acre-ft/yr in Eastgate, Cowkick, and Stingaree Valleys. The seven-valley total is greater than the recharge of 16,000 acre-ft/yr estimated by Cohen and Everett (1963, table 3).

Phreatophytic vegetation in Dixie Valley was mapped and partitioned into nine zones on the basis of species composition and foliage density. The composition and density were extrapolated from measurements made at 15 transect sites. For woody phreatophytes, annual evapotranspiration rates of 0.7 ft^3 of water per cubic foot of foliage for greasewood and 1.1 ft^3 of water per cubic foot of foliage for rabbitbrush were adapted from lysimeter studies near Winnemucca, Nev. These rates were multiplied by the foliage density of the respective phreatophytes in each zone to determine a specific rate for that zone. Rates for saltgrass (0.5 to 0.8 ft/yr) and the playa surface (0.1 to 0.3 ft/yr) were based on a range of rates used in other recent studies in western and central Nevada. These rates were multiplied by the areas of the zones to produce estimates of the annual volume of ground-water discharged. The discharge estimated for Dixie Valley is between 17,000 and 28,000 acre-ft/yr. This is greater than the discharge of 16,500 acre-ft/yr estimated by Cohen and Everett (1963, p. 21).

A revised ground-water budget for the entire Dixie Valley area has a total recharge of about 23,000 acre-ft/yr, which is within the range of estimated natural discharge (20,000 to 31,000 acre-ft/yr). For Dixie Valley alone, the total recharge of about 8,900 acre-ft/yr and the estimated subsurface inflow from tributary areas of about 11,000 acre-ft/yr produce an estimate of average annual inflow of about 20,000 acre-ft/yr, compared to a discharge estimate of 17,000 to 28,000 acre-ft/yr. Ideally, estimated recharge and discharge should be equal. The range in estimates of discharge is large enough to preclude any detailed evaluation of the difference.

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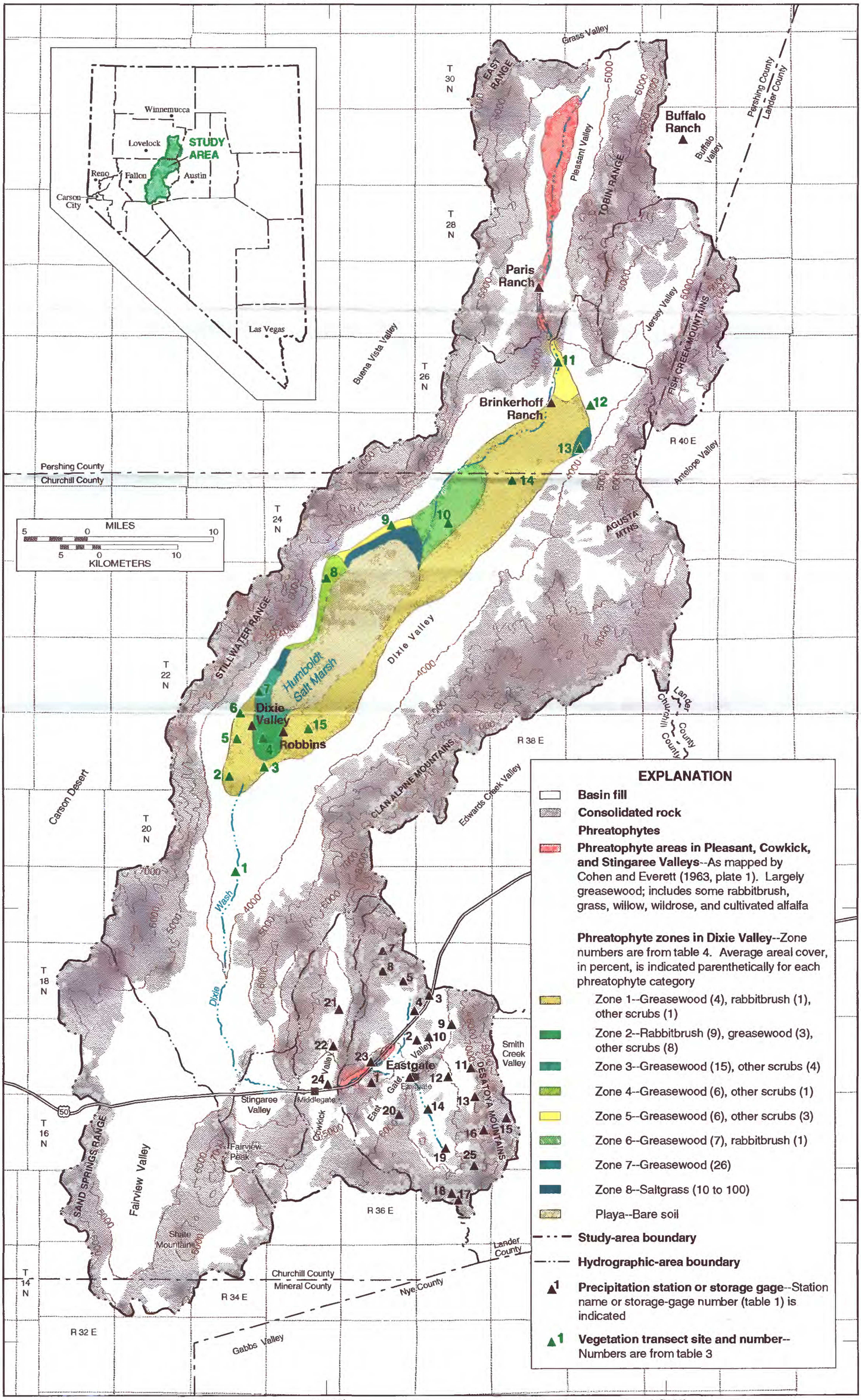

Base from U.S. Geological Survey digital data, 1:100,000, 1979-85; Universal Transverse Mercator projection, Zone 11

Geology modified from Stewart and Carlson (1978); digital data from Turner and Bawiec (1991)

MAP SHOWING GENERAL FEATURES AND AREAS OF PHREATOPHYTIC VEGETATION, DIXIE VALLEY AREA, NEVADA

by
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1995