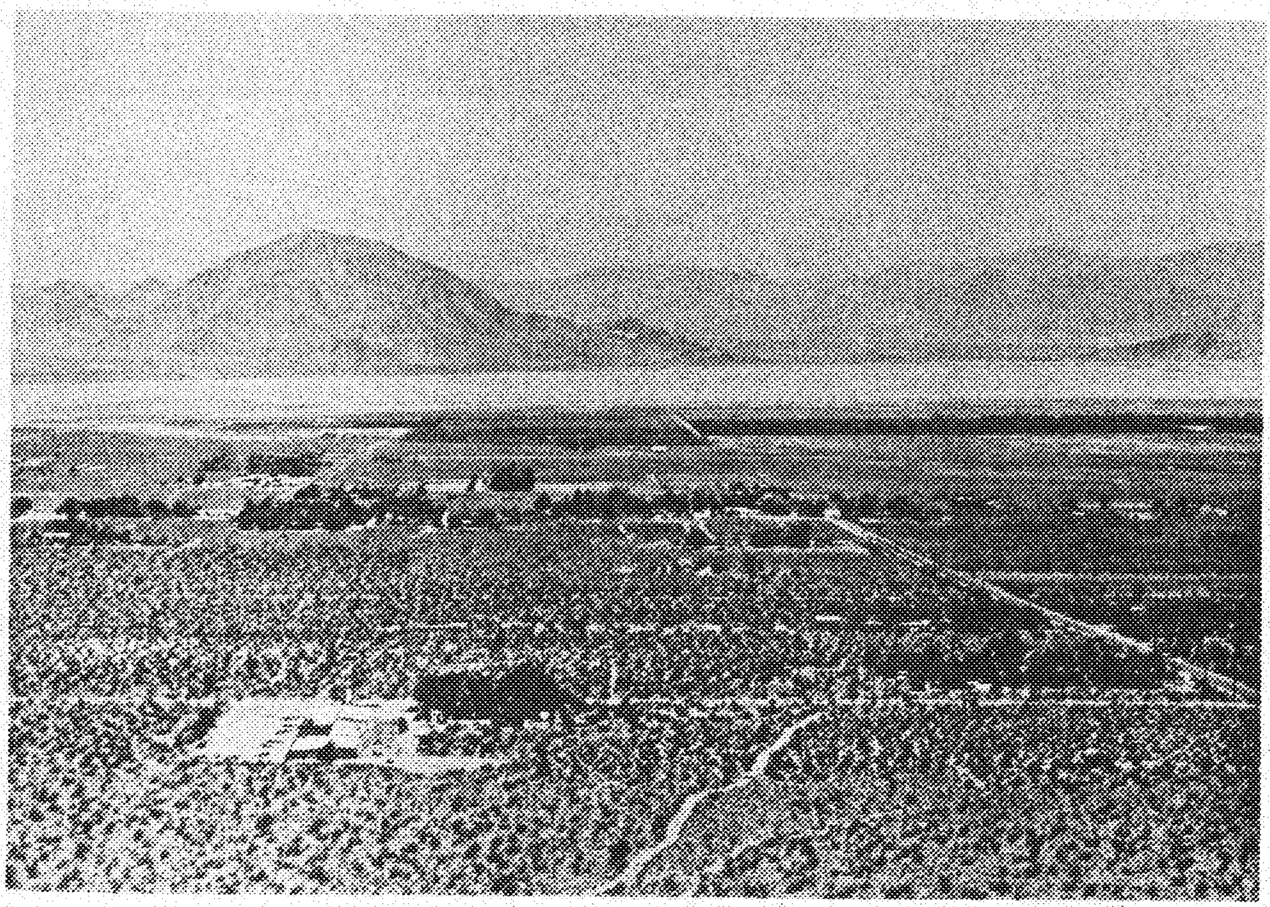
FLOOD-HAZARD STUDY--100-YEAR FLOOD STAGE FOR LUCERNE LAKE SAN BERNARDINO COUNTY, CALIFORNIA



U.S. GEOLOGICAL SURVEY

Open-File Report 77-597

Prepared in cooperation with the San Bernardino County Flood Control District

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

FLOOD-HAZARD STUDY--100-YEAR FLOOD STAGE

FOR LUCERNE LAKE

SAN BERNARDINO COUNTY, CALIFORNIA

By Mark W. Busby

Open-File Report 77-597

Prepared in cooperation with the

San Bernardino County Flood Control District

5020-50

Menlo Park, California

July 1977

CONTENTS

ILLUSTRATIONS

CONTENTS

TABLES

CONVERSION FACTORS

For readers who prefer metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	*By*	*To obtain metric unit*
acres	4.047×10^{-1}	hectares
acre-ft (acre-feet)	1.233×10^{-3}	cubic hectometers
ft (feet)	3.048×10^{-1}	meters
ft/s (feet per second)	3.048×10^{-1}	meters per second
ft^2/s (feet squared per second)	9.29×10^{-2}	meters squared per second
ft^3/s (cubic feet per second)	2.832×10^{-2}	cubic meters per second
in (inches)	2.540×10	millimeters
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.589	square kilometers

The objective of this study was to develop an elevation-frequency curve for Lucerne Lake.

DESCRIPTION OF AREA

Lucerne Lake is in Lucerne Valley in the high-desert part of southwestern San Bernardino County, about 20 mi east of Victorville, 26 mi south of Barstow, and 32 mi north of San Bernardino. The lake occupies the lowest part of a closed desert basin that is about 20 mi wide and 23 mi long with a drainage area of about 335 mi^2. The lakebed is at an elevation of 2,848 ft above sea level with mountains rising to an elevation of 3,900 ft to the east, 5,000 ft to the north, 5,200 ft to the west, and 8,200 ft to the south.

The mountains to the north, east, and west of Lucerne Valley are barren, rugged, and isolated, typical of the deserts of southern California. They are composed mostly of schist and gneiss. Quartzite, quartz monzonite, granodiorite, limestone, and sandstone are also found in the bedrock complex. The higher mountains to the south are the San Bernardino Mountains and are mainly pine covered at the higher elevations and brush and shrub covered at the lower elevations. They are also composed mostly of schist and gneiss, with granitic intrusions and some quartzite, sandstone, and conglomerate. Extensive limestone quarries are operated in the southeast edge of the basin. Figures 2, 3, and 4 show some of the mountains around Lucerne Valley.

Runoff mainly originates in the mountains surrounding the valley, but little generally reaches the playa. All streams in the valley are ephemeral. Most of the channels in the northern part of the basin have well-defined courses only in the mountains; the channels become braided and ill defined and usually disappear within a few miles after leaving the mountains. A multiplicity of parallel channels cross the steeper alluvial slopes below the San Bernardino Mountains, but these too disappear after they leave the steeper slopes. Figure 5 shows some of these features.

Mean annual precipitation on the study area ranges from about 4 in on the valley floor to about 25 in on the San Bernardino Mountains. Data gathered by the California Division of Forestry at its fire station in Lucerne Valley show that the mean annual precipitation for the 22-year period through 1972 was 4.07 in. The mean annual temperature for 24 years of record was 60.7°F, and the mean monthly temperature ranged from 43°F in December to 82°F in July.

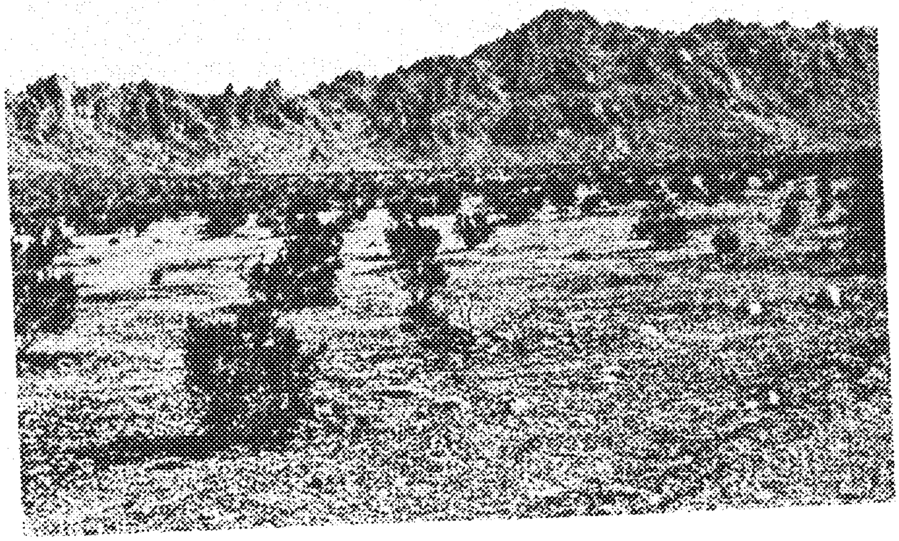


FIGURE 2.--Mountains along the north boundary of Lucerne Valley.

METHOD OF ANALYSIS

Because of the similarity to the hydrologic problems involved in the Apple Valley study (Busby, 1975), a similar synthetic-hydrologic analysis approach is required in this study.

Adequate regional relations for basin characteristic have not been developed at this time for the desert regions. Other methods such as the rational method or the runoff-curve-number method require coefficients that have not been developed for Lucerne Valley. Channel geometry has been used successfully by others as shown in the Apple Valley study, and the equations were available for this method for the desert areas. Thus, channel-geometry techniques were selected to determine the peak discharges using a simple loss coefficient to route the flows to the playa. Other methods of channel routing and channel losses were investigated for this study, including the

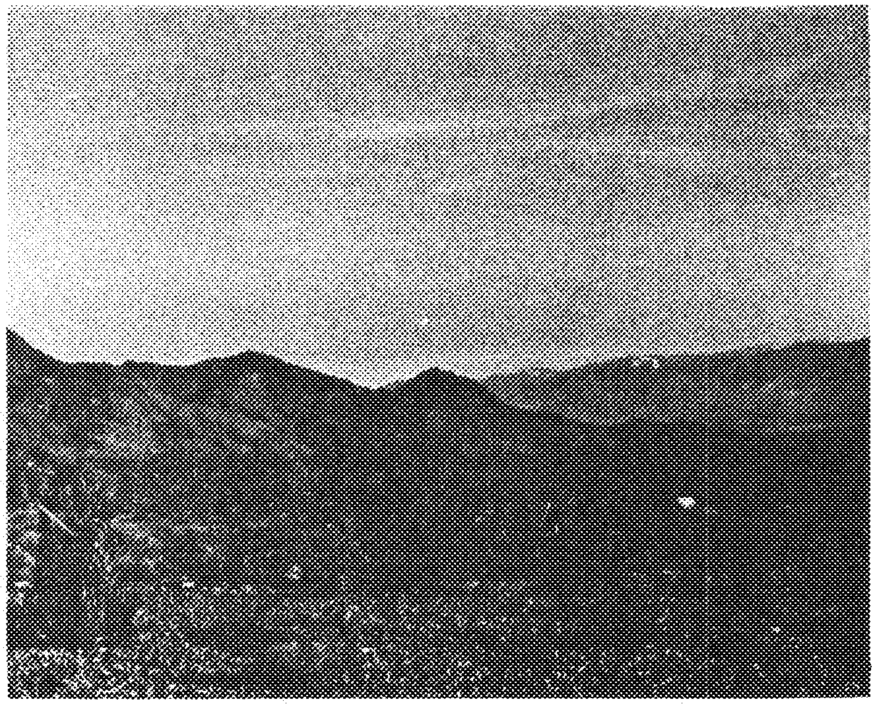


FIGURE 3.--Mountains along the east boundary of Lucerne Valley. A part of the valley is in the right background.

method described by Durbin and Hardt (1974) for the Mojave River, but none of those methods proved to be practical for use at this stage of development of arid-lands hydrologic techniques. The method of Durbin and Hardt (1974) was used, however, as an approximate method to help substantiate the final results. For a detailed discussion of the channel-geometry method used, reference should be made to the Apple Valley report (Busby, 1975). Figure 6 shows typical channel features measured for this study.

Equations relating the width and mean depth of the active channel were developed by the author for the 5-, 10-, 25-, 50-, and 100-year peak discharges for the deserts of southern California. Table 1 presents the equations used to define the flood-frequency relation for each site for this report.

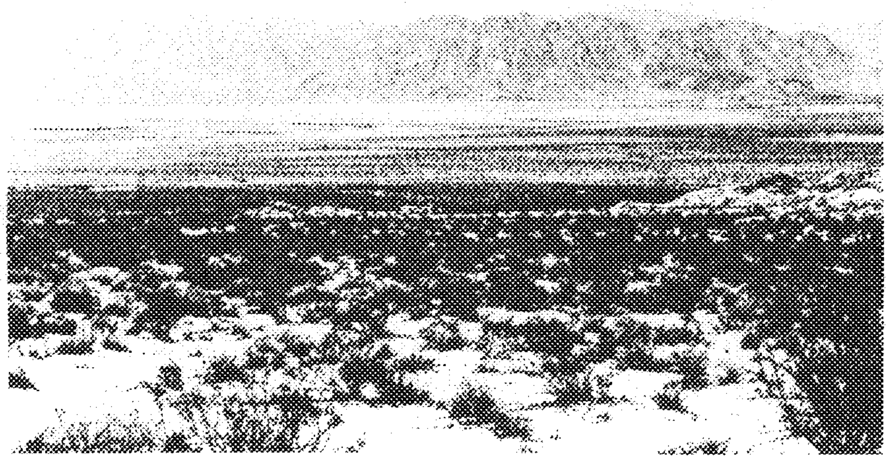


FIGURE 4.--View westward across north end of Lucerne Valley.

TABLE 1.--*Channel geometry flood-frequency equations*

Equations are of the general form $Q_{RI} = KW^aD^b$

where Q_{RI} = discharge for the given recurrence interval, cubic feet per second

W = channel-geometry width, feet

D = channel-geometry depth, feet

Recurrence interval (years)	Coefficient K	Exponent		Standard error	
		Width a	Depth b	Log units	Percent
5	17.6	1.39	0.76	0.57	172
10	31.6	1.68	.86	.54	159
25	82	1.80	1.03	.62	196
50	158	1.86	1.14	.69	235
100	288	1.91	1.25	.78	293

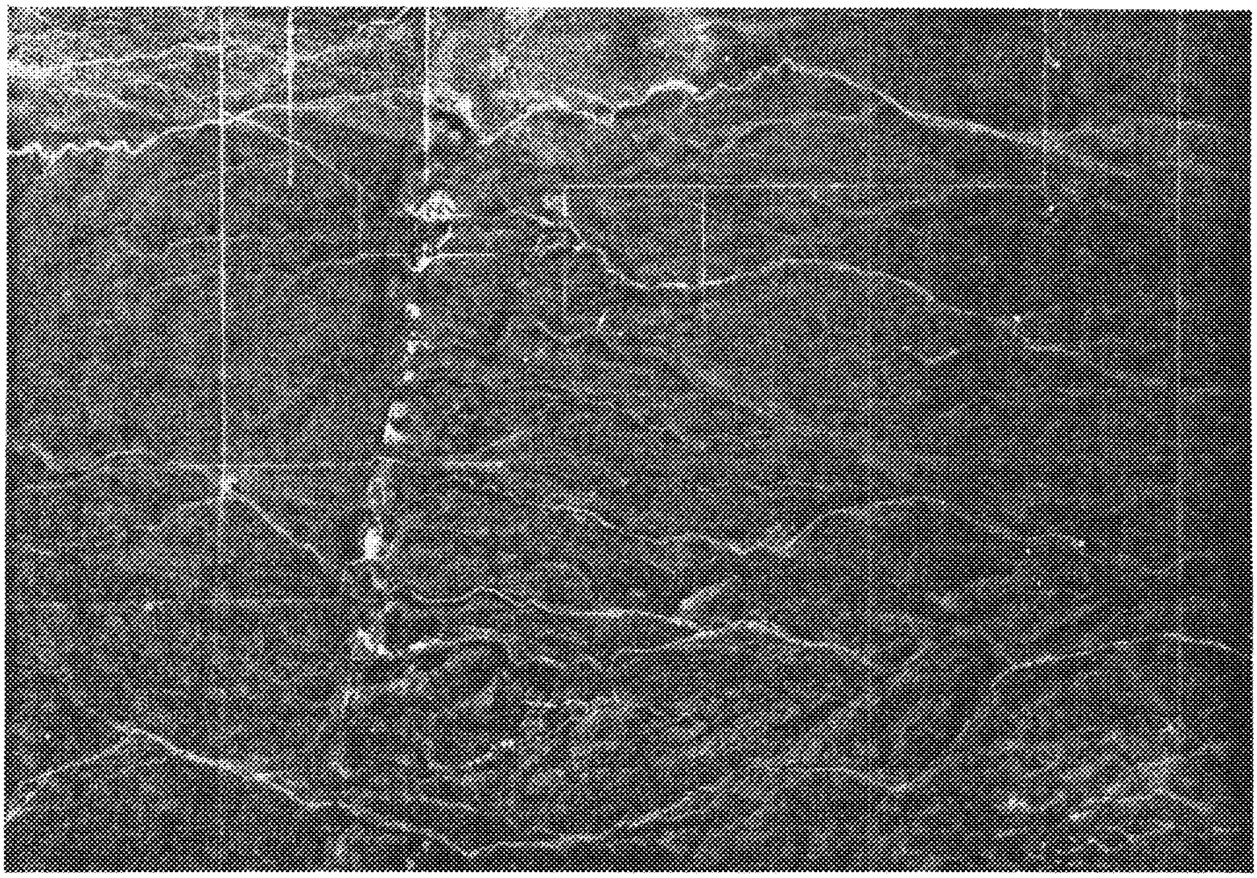


FIGURE 5.--Aerial view of parallel channels crossing the steeper slopes below the San Bernardino Mountains (flow direction is from left to right).

Using the method described in the Apple Valley report (Busby, 1975), channel dimensions were measured at 59 sites in Lucerne Valley. Drainage area-discharge relations developed from channel-geometry data for sites nearby (fig. 7) were used to estimate the discharge at 12 additional sites where channel geometry could not be measured. Figure 8 shows the location of these 71 sites. Table 2 lists the channel dimensions as measured in the field and the computed discharges for these data.

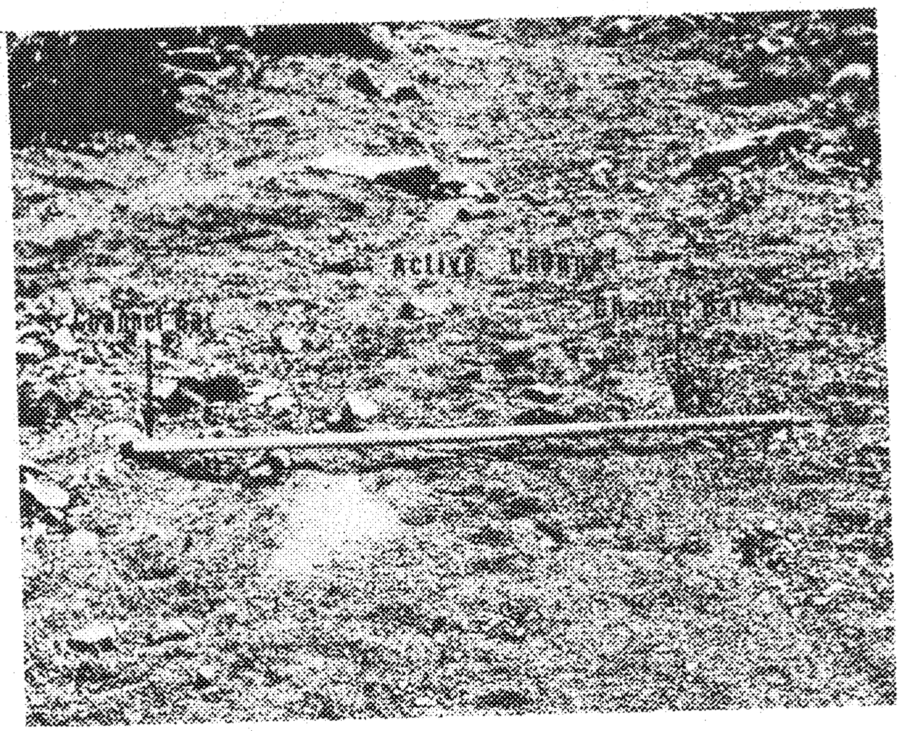


FIGURE 6.--Channel features, site 102, Lucerne Valley.

Obviously, in order to compute the total volume discharged into the playa it is necessary to convert the peak discharges to volumes. This could be done either before or after the routing. Because the relation between peak and volume is nonlinear, it was decided to convert to volumes before routing. From the Apple Valley report (Busby, 1975) the relation between peak discharge and flood volume for the deserts of California was:

$$V = 0.034\ P^{1.15} \qquad (1)$$

where V is the flood volume, in acre-feet, and P is the peak discharge, in cubic feet per second (fig. 9). This equation was used to compute the flood volumes for routing into Lucerne Lake.

The conversion from peaks to volumes before routing also reduces the problem of timing of the flood peaks from the various areas. Obviously, flood volumes can be added to give a total volume regardless of timing of these volumes, whereas peaks must occur simultaneously in order to be added.

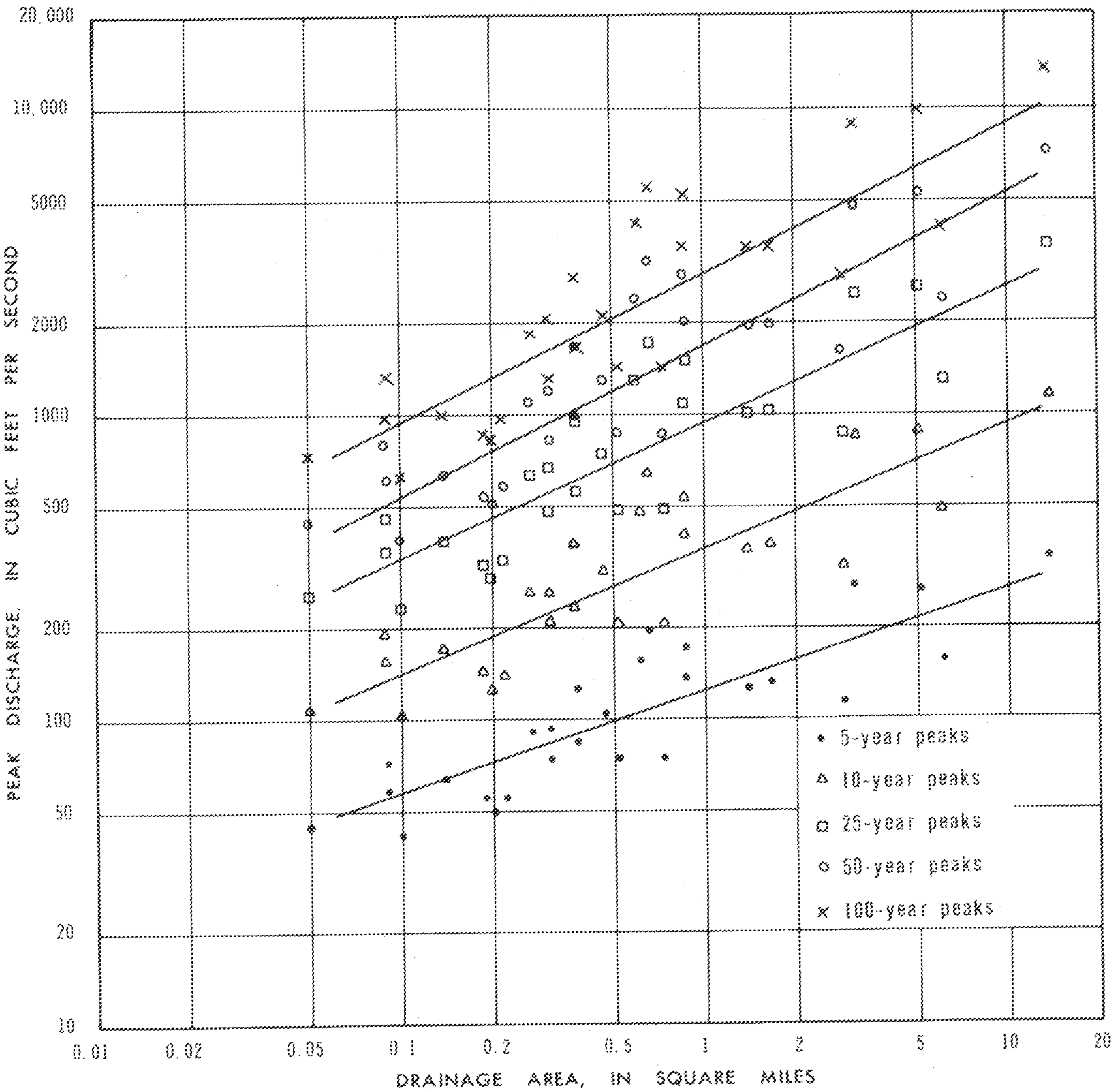


FIGURE 7.--Relation of discharge to drainage area for Lucerne Valley.

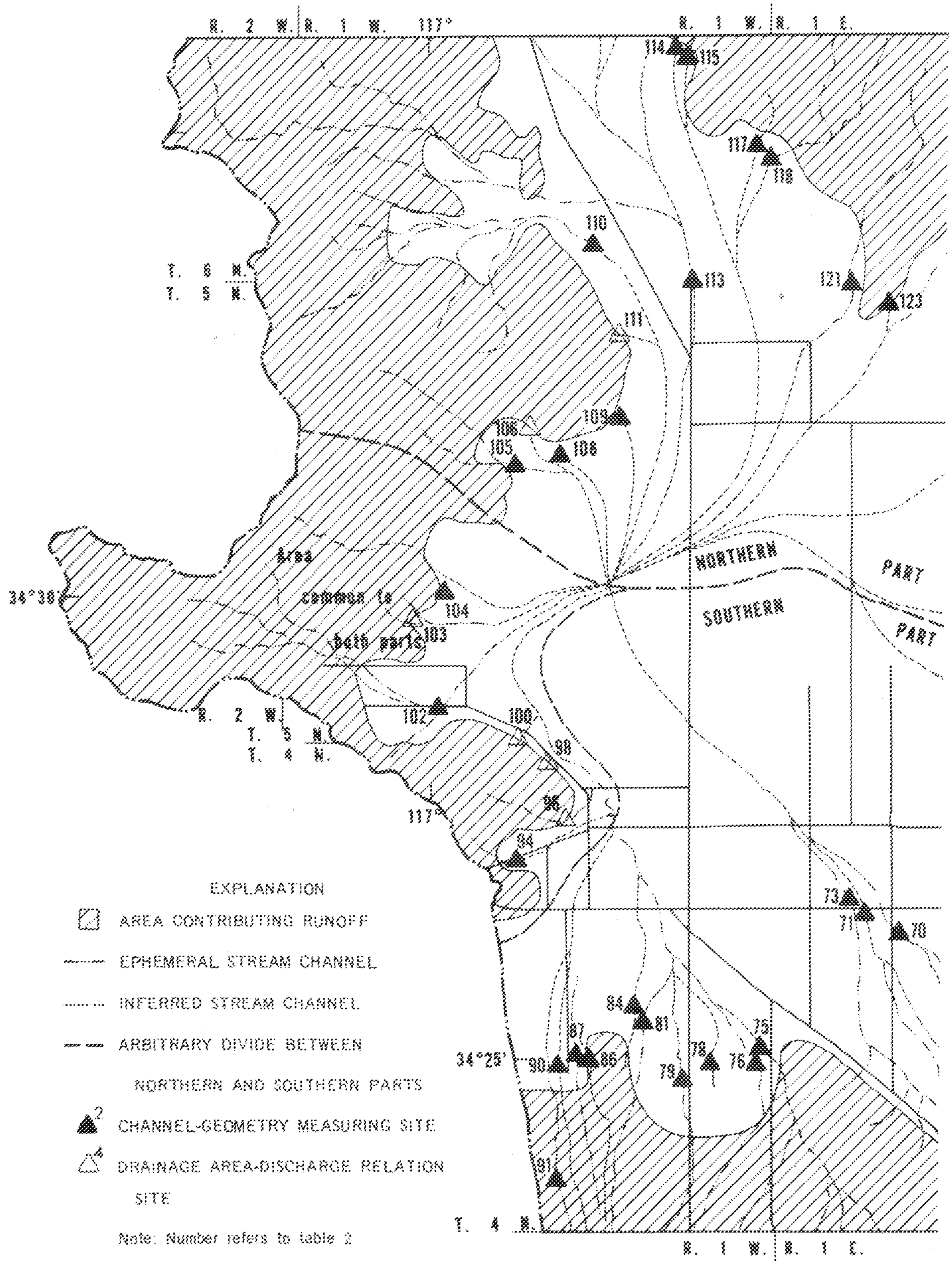


FIGURE 8.--Location of data sites.

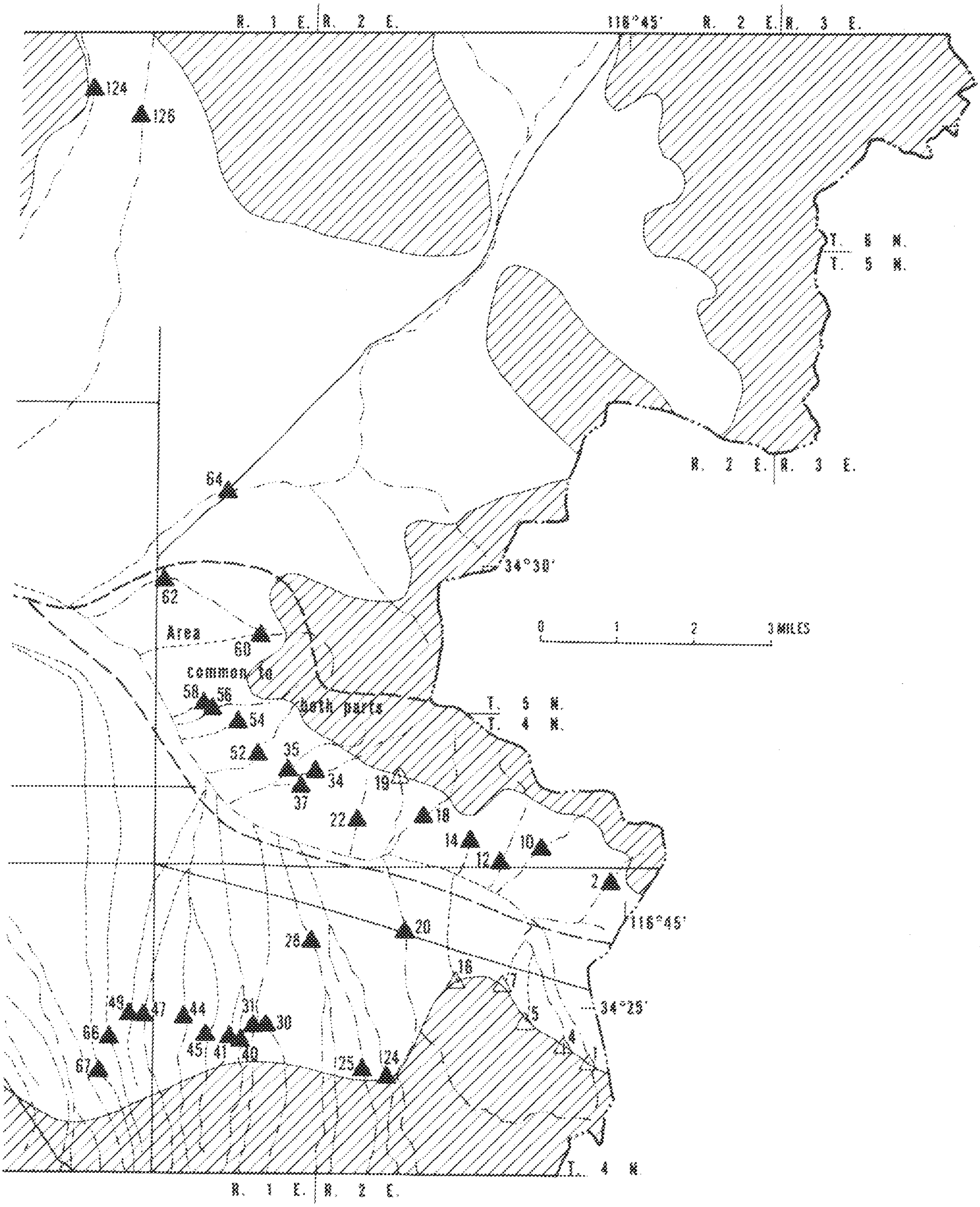


FIGURE 8.--Continued.

TABLE 2.--*Channel geometry and flood-frequency data*

Site	Active channel dimension Width (feet)	Active channel dimension Depth (feet)	Computed peak discharge (cubic feet per second) 5-yr	10-yr	25-yr	50-yr	100-yr
2	12	0.07	74	210	470	770	1,200
10	14	.20	210	670	1,820	3,400	5,970
12	13	.06	74	210	460	750	1,150
14	10	.08	64	170	380	640	1,000
18	13	.12	120	380	940	1,650	2,740
20	20	.46	640	2,490	8,200	17,100	33,300
22	8	.09	51	130	290	480	760
24	10	.21	130	390	1,040	1,920	3,340
25	10	.15	100	300	740	1,310	2,190
28	7	.30	110	290	790	1,490	2,640
30	13	.30	250	830	2,420	4,710	8,590
31	10	.30	170	540	1,510	2,890	5,210
34	10	.16	110	310	790	1,410	2,380
35	15	.17	200	650	1,740	3,210	5,560
37	8	.15	75	200	490	860	1,430
40	13	.13	130	410	1,020	1,810	3,030
41	8	.22	100	280	730	1,340	2,310
44	8	.15	75	200	490	860	1,430
45	9	.14	84	230	570	990	1,650
47	8	.19	90	250	630	1,130	1,950
49	8	.11	59	160	360	610	970
52	8	.15	75	200	490	860	1,430
54	6	.14	48	120	270	470	760
56	13	.10	110	320	780	1,340	2,180
58	6	.12	42	100	230	390	630
60	13	.13	130	410	1,020	1,810	3,030
62	8	.17	83	230	560	1,000	1,680
64	20	.37	540	2,060	6,540	13,300	25,400
66	6	.14	48	120	270	470	760
67	12	.13	120	350	880	1,560	2,600
70	8	.22	100	280	730	1,340	2,310
71	12	.14	130	380	950	1,700	2,850
73	12	.38	270	890	2,680	5,320	9,910
75	14	.39	340	1,180	3,630	7,300	13,700
76	13	.31	280	860	2,500	4,890	8,950

TABLE 2.--*Channel geometry and flood-frequency data*--Continued

Site	Active channel dimension Width (feet)	Depth (feet)	Computed peak discharge (cubic feet per second) 5-yr	10-yr	25-yr	50-yr	100-yr
78	6	0.15	50	130	290	510	830
79	7.5	.29	120	320	870	1,630	2,890
81	8	.15	75	200	490	860	1,430
84	10	.13	92	260	640	1,110	1,840
86	12	.11	100	310	740	1,290	2,110
87	9	.10	65	170	400	680	1,080
90	11	.22	160	480	1,300	2,420	4,240
91	8	.23	100	290	770	1,410	2,440
94	12.5	.13	130	380	950	1,680	2,810
102	8	.09	51	130	290	480	760
104	6	.13	45	110	250	430	690
105	6	.15	50	130	290	510	830
108	7	.10	46	114	250	420	670
109	6	.13	45	110	250	430	690
110	12	.11	100	310	740	1,290	2,110
113	4.5	.14	32	73	160	270	440
114	8	.27	120	340	900	1,690	2,980
115	7	.14	59	150	360	620	1,020
117	8	.14	71	190	460	800	1,320
118	8	.16	79	210	530	930	1,550
121	13	.23	200	660	1,840	3,480	6,170
123	4	.12	24	52	110	180	290
124	19	.27	390	1,440	4,310	8,450	15,500
126	20	.25	400	1,470	4,360	8,510	15,600
1	These are from an area-discharge relation.		60	150	360	580	1,010
4			70	190	450	750	1,300
5			80	220	530	910	1,560
7			100	280	690	1,210	2,080
16			90	260	640	1,100	1,900
19			70	190	450	750	1,300
96			100	280	690	1,210	2,080
98			100	280	710	1,250	2,140
100			90	250	620	1,060	1,830
103			130	390	1,020	1,850	3,170
106			110	310	790	1,390	2,400
111			130	390	1,030	1,880	3,220

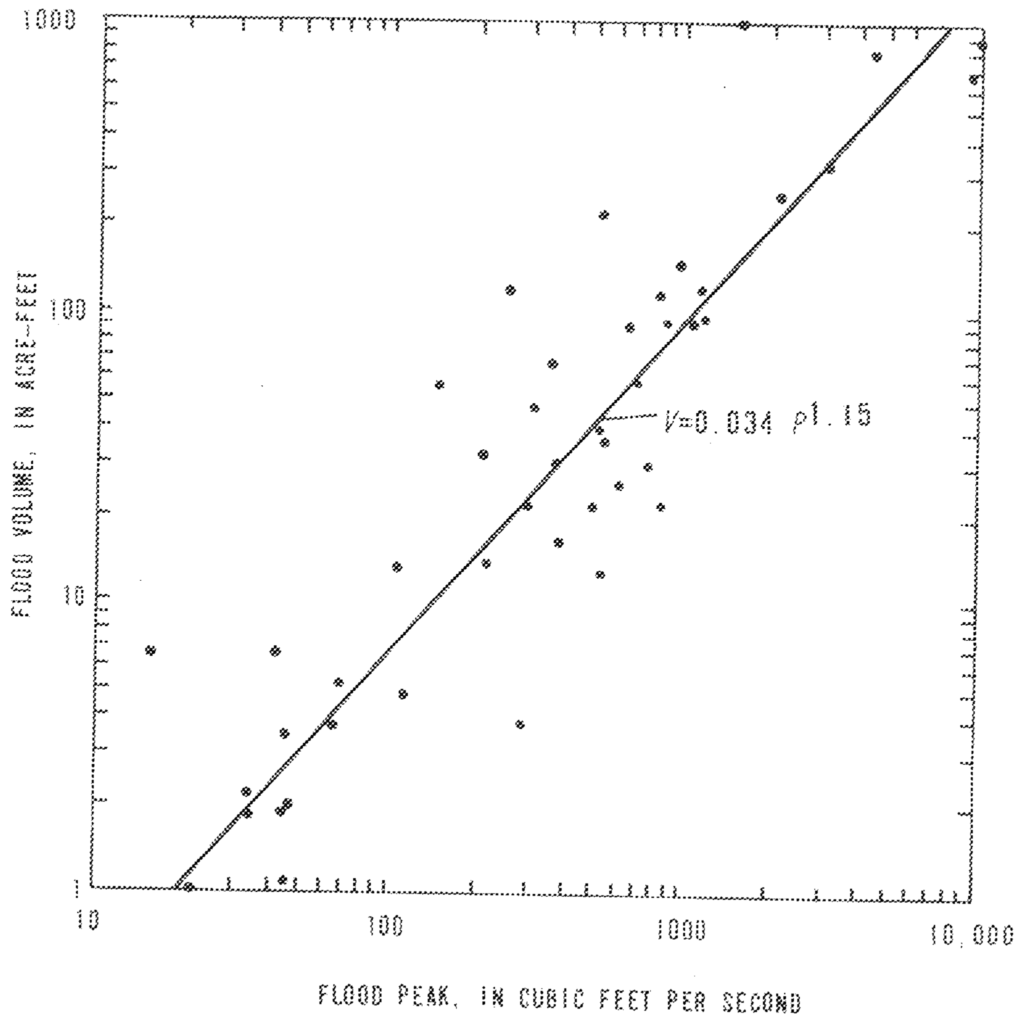


FIGURE 9.--Flood peak versus flood volume for desert basins in California.

One of the basic assumptions in this study is that the flow would increase downstream to the limit of contributing area (see fig. 8) and then would decrease further downstream. An exponential die-away equation can be used to describe discharges downstream from the point at which the channel begins to lose flow.

The equation used for computing the discharge at the downstream end of a losing reach was:

$$V_d = V_u \times e^{-cDi} \qquad (2)$$

where V_d and V_u are the downstream and upstream volumes, in acre-feet, c is an empirical coefficient, and Di is the distance the flows are to be routed, in miles. This equation is a simplistic approximation of the flow process. The coefficient c can vary the rate of loss within a reach and can allow for an increase or decrease in discharge.

Using upstream-downstream pairs of volumes computed from Lucerne Valley data, the equation for the coefficient was computed using the Rosenbrock optimization scheme (Rosenbrock, 1960) in a computer program developed by D. R. Dawdy (written commun., 1972). The developed equation was:

$$c = 0.08 + 0.008\ D \qquad (3)$$

where D is the distance from the downstream limit of contributing flow as outlined in figure 9 to the upstream end of the routing reach. D is defined as negative if the routing is upstream of the limit and positive if downstream. This equation was chosen because it was the simplest relation between c and D that would meet the requirements. A more complex relation involving more variables was not felt justified.

Runoff from the northern part of the valley is usually caused by summer thunderstorms, whereas runoff from the southern part is usually from winter frontal storms. Therefore, probably not all the contributing areas would cause flooding at the same time. The basin was divided into a north part and a south part as shown in figure 8; the areas common to both parts could be affected by either summer thunderstorms or winter frontal storms.

Flow volumes were computed for each part separately, with the larger volume of the two parts being used for further computations. This assumption recognizes flow from only one part or the other, which is probably not adequate. In order to reflect the minor flows probable from the part not used in the computations, 10 percent of the smaller volume was added to the larger volume to give a final total volume of flow into the playa.

COMPUTATIONS

Using channel-geometry methods, 5-, 10-, 25-, 50-, and 100-year peak-discharge estimates were available for all areas that drain into Lucerne Lake.

The entire flow network from the various discharge points into the playa from each of the two parts was schematically represented, and the discharges were routed down to the playa using equations 1, 2, and 3.

Ten percent of the volume from the smaller part was added to the discharge of the other part to obtain the total volume into the playa for each of the five recurrence intervals. Supplemental data at the end of the report show the flow networks used in the routing of the floods to the playa.

RESULTS

Table 3 presents the flood-volume frequency for Lucerne Lake. This represents flow from the north part of the basin, the larger of the two discharges, plus 10 percent of the flow from the south part. The flood-volume frequency of table 3, together with the area-capacity curves of figure 10, were used to develop the elevation-frequency curve of figure 11. The 100-year flood stage for Lucerne Lake was determined to be at elevation 2,849.3 ft with a corresponding surface area of 5,750 acres. Table 3 also has a summary of the elevation frequency developed for this study.

TABLE 3.--*Frequency for flood volume and elevation for Lucerne Lake*

Recurrence interval (years)	Flood volume (acre-feet)	Elevation (feet above mean sea level)
5	170	2,847.2
10	640	2,847.7
25	2,000	2,848.0
50	4,060	2,848.5
100	7,840	2,849.3

As with any analytical technique, the possibility exists of the answer being in error. The magnitude of this error is not directly measurable from a method as involved as the one used in this study. The easiest way to approach the errors would be to discuss each phase of analysis separately. The first step was to compute the peak discharges from the channel dimensions. The standard error of estimate from the channel-geometry equations was 0.78 log units. The next step was to convert to volumes. The graphical standard error of estimate for this was 0.33 log units. The last step is to route the volume to the playa. No error estimators are available for this step, but a sensitivity analysis of the routing equations indicates an error of 0.36 log units to be reasonable. These three values were combined using the square root of the sum of the squares, or 0.9 log units. This would be the standard error of estimate for any one discharge routed to the playa. In determining the final volume in the playa, a number of

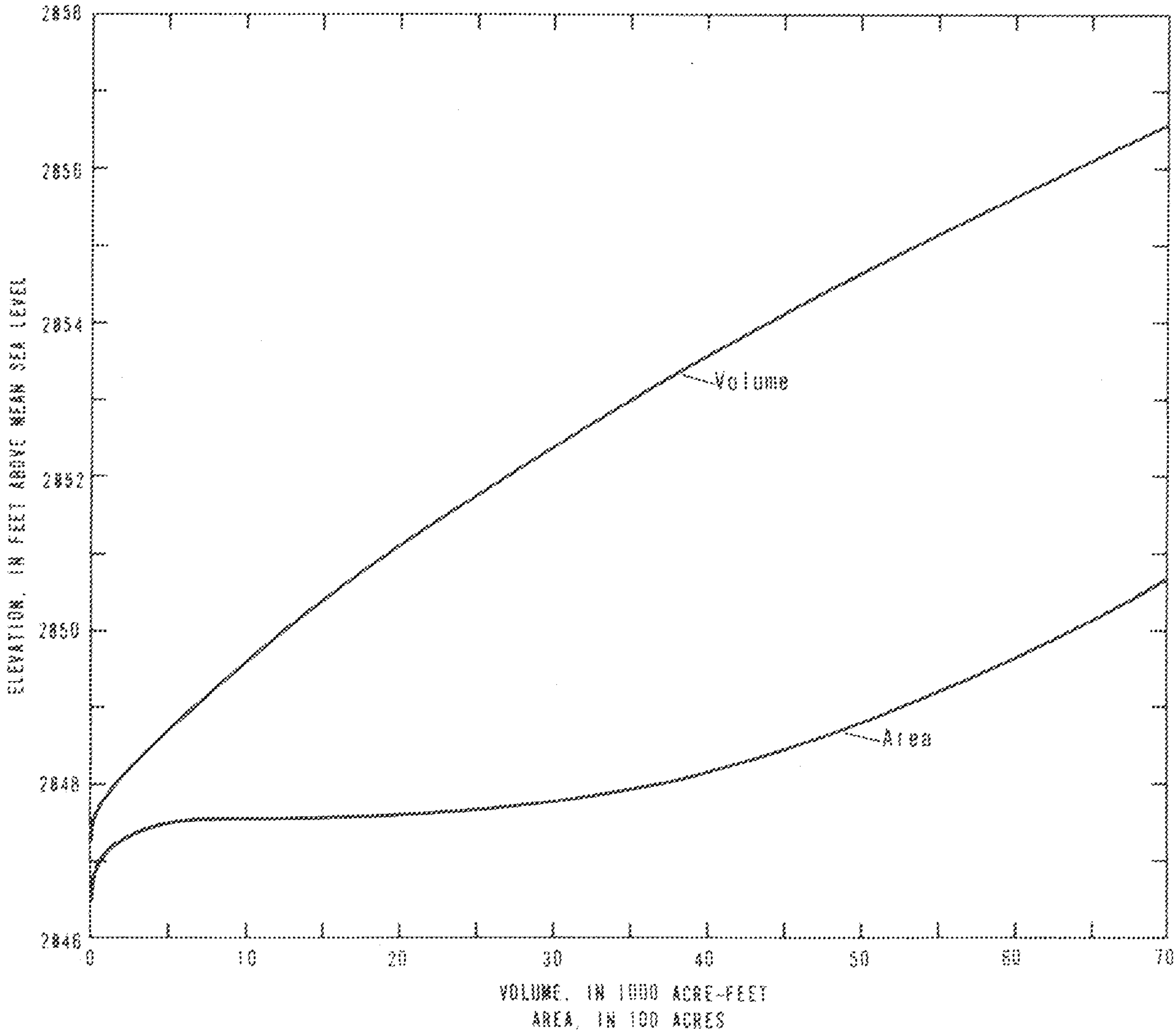


FIGURE 10.--Area-capacity curves for Lucerne Lake, Calif.

discharges were routed, allowing some compensation of positive and negative errors. The individual errors should thus be adjusted for the number of routings. For the north part there are about 15 separate channels into the playa, so the value was adjusted for 15 routings by dividing the total error by the square root of 15. This gave a final error estimator for the volume of 0.2 log units, or about 50 percent. This translates to a stage error of about 0.75 ft. Thus the true 100-year flood stage should probably be within the range of 2,848.5 ft to 2,850.0 ft.

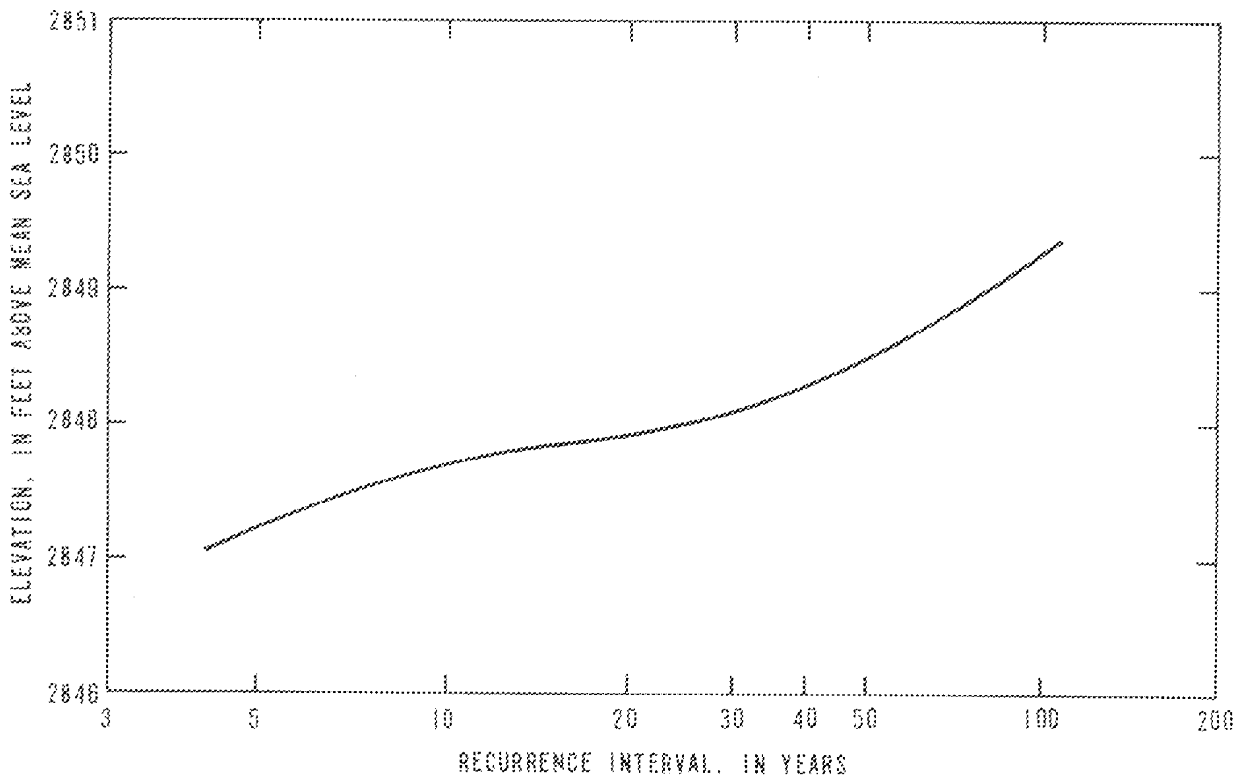


FIGURE 11.--Elevation-frequency curve for Lucerne Lake, Calif.

An examination of photographs taken in the summer of 1969 shows a distinct textural and vegetal change at about the 2,850-ft contour, giving a general confirmation of the probable high water in the past. Figures 12 and 13 show this change.

Possible future channel-improvement work would alter the 100-year flood stage. Channelization would allow the water to reach the playa faster with an appropriate decrease in channel losses and a consequent increase in the 100-year flood stage.

The results presented in table 3 and figure 11 are considered to be the best available at the time of preparation of this report. The results of this study should not be extrapolated to other desert basins.

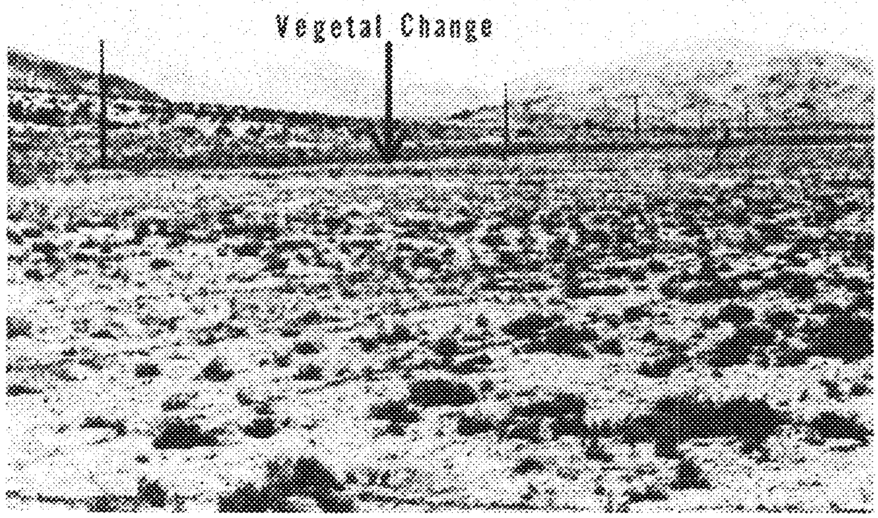


FIGURE 12.--Change in vegetation at about the 2,850-foot elevation, Lucerne Valley.

COMPARISON BY LINEAR KINEMATIC WAVE ROUTING

A mathematical model, described by Durbin and Hardt (1974), that simulates the advance of discharge down an initially dry river channel was also used to simulate inflow to Lucerne Lake. This model represents an attempt to simulate the physical conditions in a channel by a mathematical model that is based on the physical laws governing open-channel hydraulics and flow through porous media.

This model was originally calibrated for the Mojave River, a much larger stream than any in Lucerne Valley, so that a new calibration would be needed for Lucerne Valley. Because of the lack of real data, however, the calibration was only partially successful, and firm values for the model parameters could not be determined.

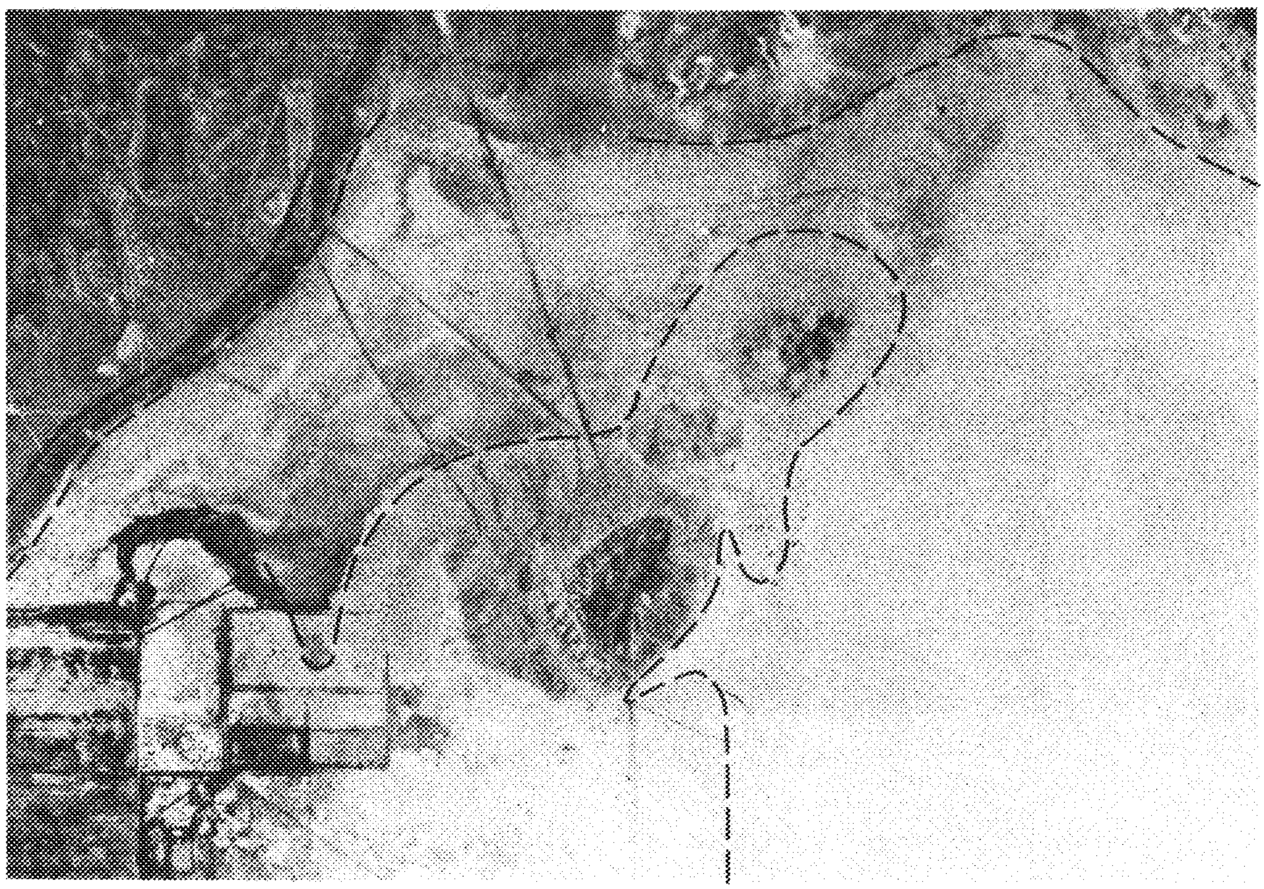


FIGURE 13.--Vertical aerial view of vegetal change at about the 2,850-foot elevation shown in figure 12.

Several sets of parameters were estimated, based partially on the Lucerne Valley calibrations, partially on the Mojave River calibrations, partially on data gathered by Smith (1972a, b), and partially on knowledge of the model, in order to determine a set of approximate results. Table 4 presents the model parameters used for the Lucerne Valley trials.

Using these parameters, the computed discharges into the playa (table 5) ranged from 4,100 to 4,800 acre-ft for the southern part and from 5,600 to 6,200 acre-ft for the northern part. Again using the 10-percent addition for minor flow from the other part, the model results indicate a 100-year flood volume into the playa of 6,000 to 6,700 acre-ft. These values, while smaller, are very close to those presented herein and show, by an independent technique, that the results as shown in table 3 are reasonable.

TABLE 4.--*Model parameters used for Lucerne Valley*

Parameter[1]	Trial No.							Basis for parameter selection
	1	2	3	4	5	6	7	
k ($ft^2/s^{1-\alpha}$)	0.4	0.6	0.8	1.0	1.2	1.4	0.8	Trials
α (dimensionless)	.65	.65	.65	.65	.65	.65	.95	Mojave River calibration and Smith (1972a, b)
f_∞ (ft^2/s)	.00012	.00012	.00012	.00012	.00012	.00012	.00012	Mojave River calibration and Smith (1972a, b)
a (ft/s)	7.5	7.5	7.5	7.5	7.5	7.9	7.5	Lucerne Valley data

[1]See Durbin and Hardt (1974) for a description of the parameters.

TABLE 5.--*Computed discharges into Lucerne Valley*

[acre-feet]

Volume	Trial No.						
	1	2	3	4	5	6	7
Full basin	10,900	6,600	6,500	6,300	6,200	6,100	10,900
South part	4,800	4,600	4,500	4,400	4,300	4,100	4,800
North part	6,200	6,100	6,000	5,800	5,700	5,600	6,200

DISCUSSION

The Apple Valley report (Busby, 1975) discussed the assumptions and difficulties with the synthetic-hydrologic techniques used in that study. Many of the difficulties also are present in this study.

Most of the differences between that study and this one are attempts to improve the techniques and resolve some of the difficulties. For instance, the splitting of the basin into a northern part and a southern part is a partial answer to the summer-winter storm problem.

This study has shown that more research is needed to answer the many problems involving flow onto desert playas.

As with the Apple Valley study, the techniques used in the determination of the 100-year flood stage are far from the final solution, but they are judged to provide reasonable answers.

REFERENCES

Busby, M. W., 1975, Flood-hazard study--100-year flood stage for Apple Valley dry lake, San Bernardino County, California: Menlo Park, Calif., U.S. Geol. Survey Water-Resources Inv. 11-75, 40 p.

Durbin, T. J., and Hardt, W. F., 1974, Hydrologic analysis of the Mojave River, California, using a mathematical model: Menlo Park, Calif., U.S. Geol. Survey Water-Resources Inv. 17-74, 50 p.

French, J. J., and Busby, M. W., 1974, Flood-hazard study--100-year flood stage for Baldwin Lake, San Bernardino County, California: Menlo Park, Calif., U.S. Geol. Survey Water-Resources Inv. 26-74, 18 p.

Rosenbrock, H. H., 1960, An automatic method of finding the greatest or least value of a function: Computer Jour., v. 3, p. 175-184.

Smith, R. E., 1972a, Border irrigation advance and ephemeral flood waves: Am. Soc. Civil Engineers, Irrig. Div. Jour., v. 98, no. IR2, p. 289-308.

______1972b, The infiltration envelope; results from a theoretical infiltrometer: Jour. Hydrology, v. 17, p. 1-21.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA

Flow network		Routing distance (D_t) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Whole basin contributing				
1	-	2.2	1,010	0.0
2	-	1.1	1,200	.5
3	1,2	.25	-	1.6
4	-	1.45	1,300	.0
5	-	1.05	1,560	.0
6	4,5	.3	-	1.05
7	-	.65	2,080	.0
8	6,7	.4	-	1.35
9	3,8	.55	-	1.75
10	-	.8	5,970	1.0
11	9,10	.3	-	2.3
12	-	.3	1,150	1.2
13	11,12	.25	-	2.6
14	-	.5	1,000	.5
15	13,14	.1	-	2.85
16	-	1.6	1,900	.0
17	15,16	.9	-	2.95
18	-	.8	2,740	.4
19	-	.8	1,300	.3
20	-	.95	33,300	1.4
21	17,18,19,20	.35	-	2.35
22	-	.5	760	.8
23	21,22	.9	-	2.7
24	-	2.05	3,340	.0
25	-	1.85	2,190	.1
26	24,25	1.4	-	2.05
27	23,26	.2	-	3.6
28	-	1.5	2,640	1.9
29	27,28	.4	-	3.8
30	-	.1	8,590	.65

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_ξ) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Whole basin contributing--Continued				
91	-	3.1	2,440	-1.1
92	90,91	1.5	-	1.95
93	89,92	.25	-	3.5
94	-	1.25	2,810	.3
95	93,94	.6	-	3.75
96	-	.8	2,080	.0
97	95,96	.3	-	4.35
98	-	.1	2,140	.0
99	97,98	.65	-	4.65
100	-	.3	1,850	.0
101	99,100	2.3	-	5.3
102	-	2.55	760	1.9
103	-	2.25	3,170	.0
104	-	2.3	690	.6
105	-	.7	830	.75
106	-	.3	2,400	.7
107	105,106	1.9	-	1.0
108	-	2.2	670	.4
109	-	2.3	690	.2
110	-	1.6	2,110	1.5
111	-	.55	3,220	.0
112	110,111	3.35	-	.55
113	-	4.25	440	11.4
114	-	1.25	2,980	.0
115	-	1.1	1,020	.2
116	114,115	1.65	-	1.25
117	-	1.1	1,320	.3
118	-	.95	1,550	.25
119	117,118	.5	-	1.2
120	116,117	1.9	-	1.3

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_{ℓ}) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Whole basin contributing--Continued				
121	-	2.1	6,170	0.6
122	120,121	3.2	-	3.2
123	-	.25	290	.0
124	-	3.4	15,500	2.2
125	123,124	5.1	-	5.6
126	-	9.6	15,600	3.6
127	69,74,101, 102,103,104, 107,108,109, 112,113,122, 125,126	-	-	-
Northern part contributing				
2	-	1.1	1,200	0.5
10	-	.8	5,970	1.0
11	2,10	.3	-	2.3
12	-	.3	1,150	1.2
13	11,12	.25	-	2.6
14	-	.5	1,000	.5
15	13,14	1.0	-	2.85
18	-	.8	2,740	.4
19	-	.8	1,300	.3
21	15,18,19	.35	-	2.35
22	-	.5	760	.8
23	21,22	1.8	-	2.7
34	-	.5	2,380	.7
35	-	.15	5,560	.8
36	34,35	.2	-	.95
37	-	.45	1,430	.9
39	23,36,37	.65	-	4.5
52	-	.8	1,430	.9
53	39,52	.45	-	5.15
54	-	.75	760	.75

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_l) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Northern part contributing--Continued				
55	53,54	0.1	-	5.6
56	-	.55	2,180	.85
57	55,56	.1	-	5.7
58	-	.5	630	.6
59	57,58	1.1	-	5.8
60	-	1.7	3,030	.3
61	59,60	.7	-	6.9
62	-	1.1	1,680	1.7
63	61,62	.3	-	7.6
64	-	2.75	25,400	15.7
65	63,64	2.05	-	18.45
94	-	1.85	2,810	.3
96	-	.8	2,080	.0
97	94,96	.3	-	4.35
98	-	.1	2,140	.0
99	97,98	.65	-	4.65
100	-	.3	1,830	.0
101	99,100	2.3	-	5.3
102	-	2.55	760	1.9
103	-	2.25	3,170	.0
104	-	2.3	690	.6
105	-	.7	830	.75
106	-	.3	2,400	.7
107	105,106	1.9	-	1.0
108	-	2.2	670	.4
109	-	2.3	690	.2
110	-	1.6	2,110	1.5
111	-	.55	3,220	.0
112	110,111	3.35	-	.55
113	-	4.25	440	11.4

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_i) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Northern part contributing--Continued				
114	-	1.25	2,980	.0
115	-	1.1	1,020	.2
116	114,115	1.65	-	1.25
117	-	1.1	1,320	.3
118	-	.95	1,550	.25
119	117,118	.5	-	1.2
120	116,119	1.9	-	1.3
121	-	2.1	6,170	.6
122	120,121	3.2	-	3.2
123	-	.25	290	.0
124	-	3.4	15,500	2.2
125	123,124	5.1	-	5.6
126	-	9.6	15,600	3.6
127	65,101,102, 103,104,107, 108,109,112, 113,122,125, 126	-	-	-
Southern part contributing				
1	-	2.2	1,010	0.0
2	-	1.1	1,200	.5
3	1,2	.25	-	1.6
4	-	1.45	1,300	.0
5	-	1.05	1,560	.0
6	4,5	.3	-	1.05
7	-	.65	2,080	.0
8	6,7	.4	-	1.35
9	3,8	.55	-	1.75
10	-	.8	5,970	1.0
11	9,10	.3	-	2.3
12	-	.3	1,150	1.2
13	11,12	.25	-	2.6
14	-	.5	1,000	.5
15	13,14	.1	-	2.85

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_i) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Southern part contributing--Continued				
16	-	1.6	1,900	0.0
17	15,16	.9	-	2.95
18	-	.8	2,740	.4
19	-	.8	1,300	.3
20	-	.95	33,300	1.4
21	18,19,20	.35	-	2.35
22	-	.5	760	.8
23	21,22	.9	-	2.7
24	-	2.05	3,340	.0
25	-	1.85	2,190	.1
26	24,25	1.4	-	2.05
27	23,26	.2	-	3.6
28	-	1.5	2,640	1.9
29	27,28	.4	-	3.8
30	-	.1	8,590	.65
31	-	.1	5,210	.55
32	30,31	2.65	-	.75
33	29,32	.3	-	4.2
34	-	.5	2,380	.7
35	-	.15	5,560	.8
36	34,35	.2	-	.95
37	-	.45	1,430	.9
38	36,37	.6	-	1.15
39	33,38	.25	-	4.5
40	-	.8	3,030	.4
41	-	.75	2,310	.55
42	40,41	2.5	-	1.2
43	39,42	.2	-	4.75
44	-	1.5	1,430	.9
45	-	1.75	1,650	.6

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_i) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Southern part contributing--Continued				
46	44,45	.5	-	2.4
47	-	2.05	1,930	1.05
48	46,47	1.1	-	2.9
49	-	3.2	970	1.1
50	48,49	.1	-	4.0
51	43,50	0.2	-	4.95
52	-	.8	1,430	.9
53	51,52	.45	-	5.15
54	-	.75	760	.75
55	53,54	.1	-	5.6
56	-	.55	2,180	.85
57	55,56	.1	-	5.7
58	-	.5	630	.6
59	57,58	1.1	-	5.8
60	-	1.7	3,030	.3
61	59,60	.7	-	6.9
62	-	1.1	1,680	1.7
63	61,62	2.35	-	7.6
66	-	5.9	760	1.05
67	-	6.1	2,600	.7
68	66,67	1.5	-	6.95
69	63,68	3.0	-	21.45
70	-	1.55	2,310	3.85
71	-	1.15	2,850	4.2
72	70,71	.4	-	5.35
73	-	1.35	9,910	4.25
74	72,73	3.55	-	5.6
75	-	.7	13,700	.3
76	-	.8	8,950	.8
77	75,76	.7	-	1.0

See footnotes at end of table.

SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

Flow network		Routing distance (D_i) (miles)	100-year discharge at upstream end[2] (Q) (cubic feet per second)	Distance from contributing flow point (D) (miles)
Upstream point[1]	Point routed from			
Southern part contributing--Continued				
78	-	1.2	830	.75
79	-	1.2	2,890	.6
80	78,79	.1	-	1.8
81	-	.8	1,430	1.05
82	80,81	.1	-	1.9
83	77,82	1.25	-	1.7
84	-	1.7	1,840	.95
85	83,84	.1	-	2.95
86	-	.4	2,110	.0
87	-	.3	1,080	.5
88	86,87	2.2	-	.4
89	85,88	.45	-	3.05
90	-	1.5	4,240	.45
91	-	3.1	2,440	-1.1
92	90,91	1.5	-	1.95
93	89,92	.25	-	13.5
94	-	1.25	2,810	.3
95	93,94	.6	-	3.75
96	-	.8	2,080	.0
97	95,96	.3	-	4.35
98	-	.1	2,140	.0
99	97,98	.65	-	4.65
100	-	.3	1,830	.0
101	99,100	2.3	-	5.6
102	-	2.55	760	1.9
103	-	2.25	3,170	.0
104	-	2.3	690	.6
127	69,74,101, 102,103,104	-	-	-

[1]Upstream point is the upstream end of routing reach, routed as defined in point routed from. Numbers refer to points used in computation (fig. 8).
[2]Discharge is from data on channel geometry or drainage area relation.

☆ GPO 780-107/64