HYDROLOGIC ANALYSIS
UNINCORPORATED PINAL COUNTY, ARIZONA
MARICOPA
for
FEDERAL EMERGENCY MANAGEMENT AGENCY
JULY, 1984

CBA NO. 03012-01-44

CELLA BARR ASSOCIATES

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1.0 INTRODUCTION

Cella Barr Associates (CBA) has been contracted, by the Federal Emergency Management Agency (FEMA), to perform a detailed flood insurance study for the unincorporated area of Maricopa in Pinal County, Arizona.

The purpose of this report is to inform the appropriate Federal, State and local agencies of the peak discharges proposed for use in the above study. Peak discharges for the 100-year events have been developed and will be used to determine water surface elevations and the corresponding flood hazard factors.

2.0 STUDY LOCATION

Maricopa is located in Pinal County, approximately thirty-two miles due south of Phoenix and twenty miles northwest of Casa Grande. (Figure 1) The Southern Pacific Railroad bisects Maricopa and is paralleled by the Maricopa Road, which provides a service route between Casa Grande and Gila Bend. The terrain gently slopes downward toward the north where it drains to the Gila River. The natural vegetation consists of creosote brush, palo verde and cacti with mesquite found in abundance along the Gila River and its tributaries.

3.0 HYDROLOGIC ANALYSIS

The two major flooding sources that impact this study area are from Vekol Wash, and its tributaries, and the Santa Cruz River system. The drainage area for the Santa Cruz River system extends southward into Mexico and thus has a time of concentration of several days while that for Vekol Wash is in terms of hours (Figure 1). For this reason it was assumed that the storm runoff from these two drainage systems would result from totally independent events and they are thus analyzed separately.

3.1 VEKOL WASH

Vekol Wash is a tributary to the Santa Cruz River and joins it approximately 8 miles north of the Southern Pacific Railroad crossing. (Figure 1). At Maricopa it drains an area of 297 square miles extending up into the Vekol Valley. Elevations range from 1160 feet, at the Southern Pacific Railroad, to 4084 feet at the peak of the Maricopa Mountains. The average slope through the Vekol Valley is 0.55% but steepens to over 29% in the mountains.

Vekol Wash tributary, with a drainage area of approximately 156 square miles, drains to Vekol Wash near Maricopa. This drainage area is less well defined than that for Vekol Wash since much of the alluvial plains are presently under agriculture and grading and channelization have changed the natural drainage characteristics.

3.1.1 Method of Analysis

Since there is no streamflow data available fo either Vekol Wash or Vekol Wash tributory the U.S.G.S. regression analysis (Ref. 1) was considered an appropriate alternative. These regression equations may be used to determine the flood magnitudes for selected recurrence intervals for five different regions of Arizona. They are based on annual peak discharge information collected at U.S.G.S. gauging stations with over 10 years of record.

For this region the relationship for the 100-year peak discharge is:

$$Q_{100} = 1{,}100\ A^{0.499} \qquad (1)$$

Using equation (1) and combining the drainage areas from Vekol Wash and Vekol Wash Tributary gives a 100-year peak discharge of 23,300 cfs.

3.2 SANTA CRUZ RIVER SYSTEM

The Santa Cruz River originates in the San Rafael Valley, approximately 20 miles east of Nogales, and flows southward into Mexico before re-entering the United States about 3 miles east of Nogales. From here it flows northward about 70 miles to Tucson and thence northwestward 42 miles to the junction with Greene Canal. Halpenny (Ref. 2) notes that a majority of the flow is directed northwesterly in Greene Canal to Greene Wash. At Chuichu the flow is traversed by Highway 84 and at this point much of the flow is diverted back into the Santa Cruz Wash and the remainder continues in Greene Wash. A Flood Damage Report by the U.S. Army Corps of Engineers (Ref. 3) indicates that for the October 1977 flood about 1/3 of the flow remained in Greene Wash while the remaining 2/3 ponded up behind Highway 84 at Chuichu and flowed northward to the Santa Cruz Wash.

Greene Wash continues northwestward and is channelized by diking from a point just south of Interstate 8 to its confluence with the Santa Rosa Wash, about 1 mile northeast of Stanfield. From here, flow continues northward and crosses the Southern Pacific Railroad approximately 1 mile east of Maricopa. The Santa Cruz Wash crosses the Southern Pacific Railroad approximately 7.5 miles southeast of Maricopa and is joined by the Santa Rosa Wash about 9 miles downstream.

3.2.1 Method of Analysis

In October, 1983, the watersheds contributing to flows within the Santa Cruz River and its tributaries were hit by a record storm. Much of the data resulting from this storm and its flooding is still being collected by the U.S.G.S. and remains in a preliminary unplublished form. Because of the extreme nature of this event it was felt important to include any available data in this hydrologic analysis. The U.S.G.S. agreed to release its initial estimates of discharges on the understanding that they be accepted as subject to change.

No gauging stations are available in the area of Maricopa. The nearest upstream and downstream gauging stations are located at Cortaro and Laveen (Figure 1). It is assumed that discharges within the Santa Cruz River have the potential to increase up to Red Rock, just downstream of the inflow from Los Robles Wash and Brawley Wash. From this point onward the tributary inflow is negligible and the Santa Cruz River is an effluent (losing) stream. Since the construction of the Tat Momolikot Dam, in July 1974, the Santa Rosa Wash is no longer considered an effective flow contributor.

Using all currently available data, including estimates from the last flood, a Log Pearson Type III discharge-frequency relationship was determined for the gauging stations at Cortaro and Laveen (Figures 2 & 3, Appendix A & B). The Laveen peak discharges were adjusted to eliminate major events that originated on the Santa Rosa Wash, prior to construction of the dam, and thus account for the presence of the upstream dam.

Since there is still major tributary inflow to the Santa Cruz River up to Red Rock, the discharge-frequency relationship for Cortaro was adjusted to account for the increase in drainage area using the Roeske regression equations (Ref. 1), (Appendix C). Assuming that the flow losses occur linearly between Red Rock and Laveen, a discharge-frequency relationship for Maricopa was arrived at using river mile as the basis (Figure 4). The resulting discharges for each location are summarized in Table 2. The discharge shown for Maricopa is thus the result of combined flows from the Santa Rosa Wash (Greene Wash) and the Santa Cruz Wash. The flood estimates for October 1983 are detailed in Appendix D.

Table 1: Discharge-Frequency Relationship: Santa Cruz River System

	Discharges (cfs) for Return Period				
Location	10yr	50yr	100yr	500yr	Oct. 1983 Estimates
Cortaro	20,000	34,800	42,400	63,900	65,000
Red Rock	23,900	41,500	50,650	76,400	65,000
Maricopa	8,800	18,600	24,600	44,600	36,400
Laveen	4,400	11,900	16,900	35,200	28,000

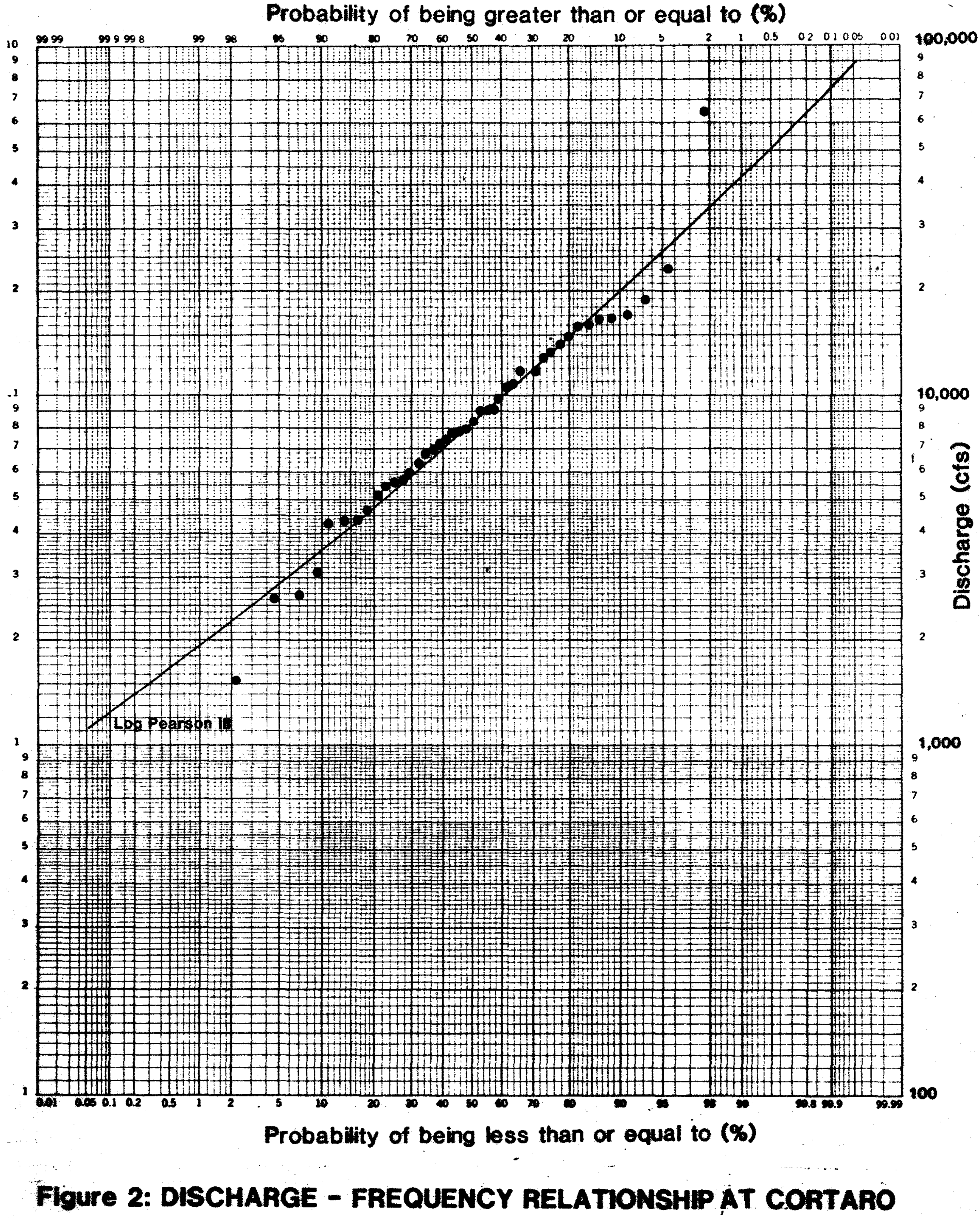

Figure 2: DISCHARGE - FREQUENCY RELATIONSHIP AT CORTARO

Record 1940-1984 Gauge# 09486500

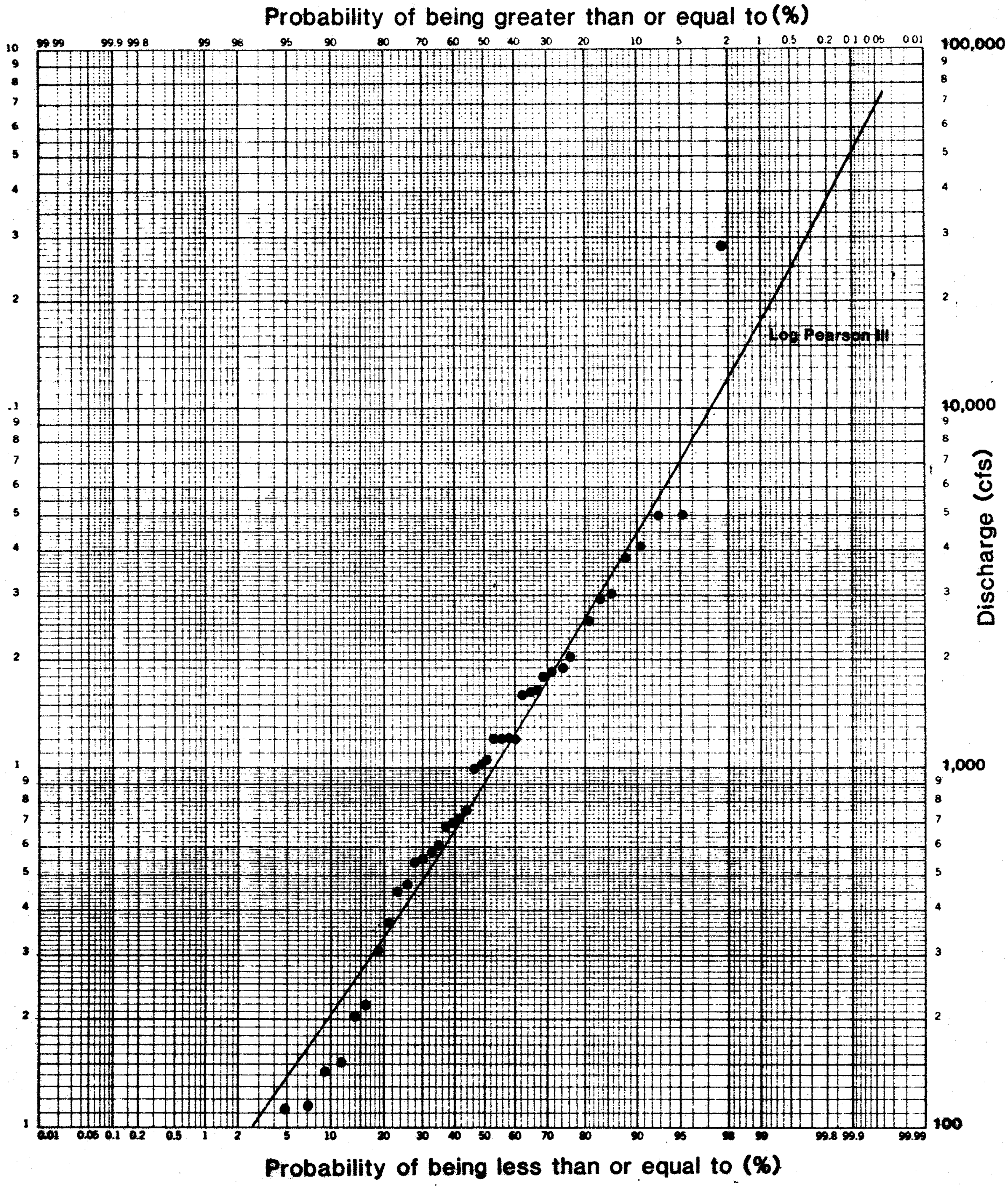

Figure 3: DISCHARGE - FREQUENCY RELATIONSHIP AT LAVEEN

Record 1940-1984 Gauge# 09489000

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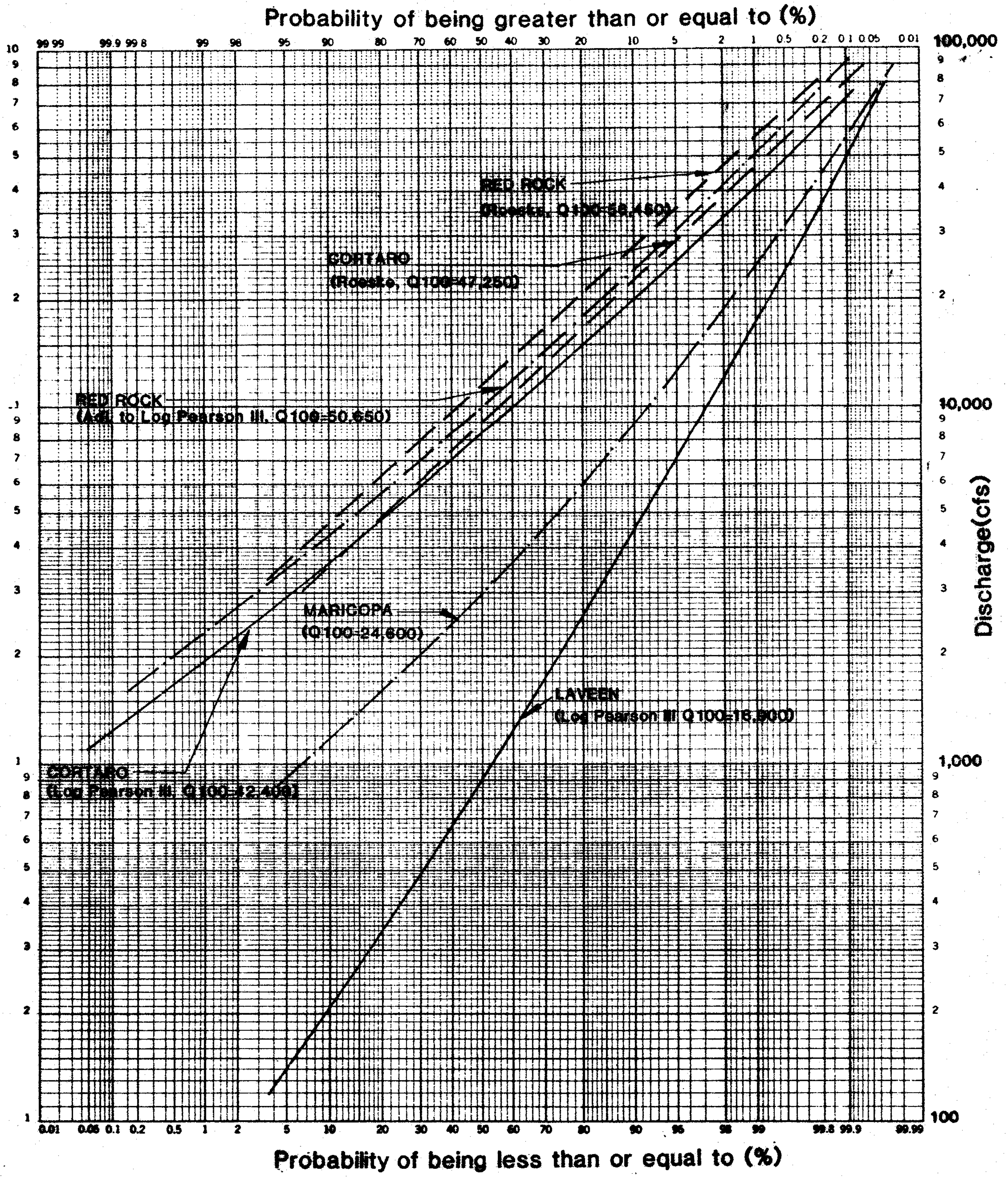

Figure 4: DISCHARGE - FREQUENCY RELATIONSHIP AT MARICOPA

(Based on the gauges at Cortaro & Laveen)

4.0 OCTOBER 1983 FLOOD

The October 1983 flood event caused widespread flooding in the vicinity of the town of Maricopa. From the discharge-frequency curves developed (Figures 2, 3 & 4) the peak discharges exceeded the 100-year flood. However, the extent of flooding has been delineated from aerial photographs and is intended to serve as a guide in determining the 100-year flood limits. Estimates from the gauges at Cortaro and Laveen indicate a peak discharge, from the Santa Cruz River System near Maricopa, of about 36,400cfs (Appendix D). From field measurements of high water marks, estimates have been made of the flow distribution through Maricopa (Figure 5, Appendix D). Using these estimates and actual flooding limits it is intended to determine the flow distribution resulting from the 100-year flood and map the extent of possible flooding.

Observations from aerial photographs and field reconnaissance indicate that flooding in Maricopa resulted from both the Santa Cruz Wash and the Santa Rosa Wash.(Photo 1) Flow in the Santa Cruz Wash exceeded the capacity of the bridge structures underneath the Southern Pacific Railroad and backed up causing water to flow around the dikes (Figure 5). A drainage channel, paralleling the railroad, helped carry the flow toward Maricopa while discharging some flows through in culverts underneath the railroad. Since this channel capacity was exceeded, flow from the Santa Cruz Wash combined with flow from the Santa Rosa Wash and caused sheet flow toward the Santa Rosa Bridge Wash bridge crossing (#16, Figure 5).

Debris build up around the bridge piers restricted the flow capacity here to about 8,500cfs and, along with flows from the Santa Cruz Wash, caused water to back up.(Photo 2) The channel capacity was exceeded and resulted in a breach of the banks. Approximately 15,400cfs then continued as sheet flow, along the south side of the railroad into Maricopa. The water crossed the railroad through the many culverts and continued to flow along the path of Vekol Wash before recombining with the Santa Cruz Wash.

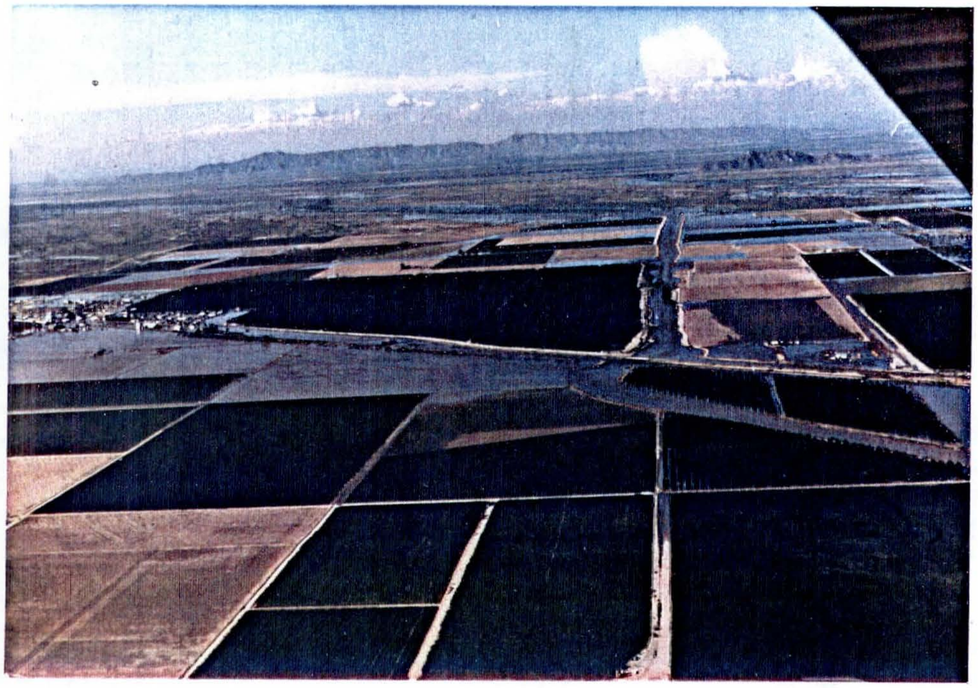

Photo No. 1: Flood Flow near Maricopa, October 4, 1983

Photo No. 2: Debris Load at Santa Rosa Wash Railroad crossing.

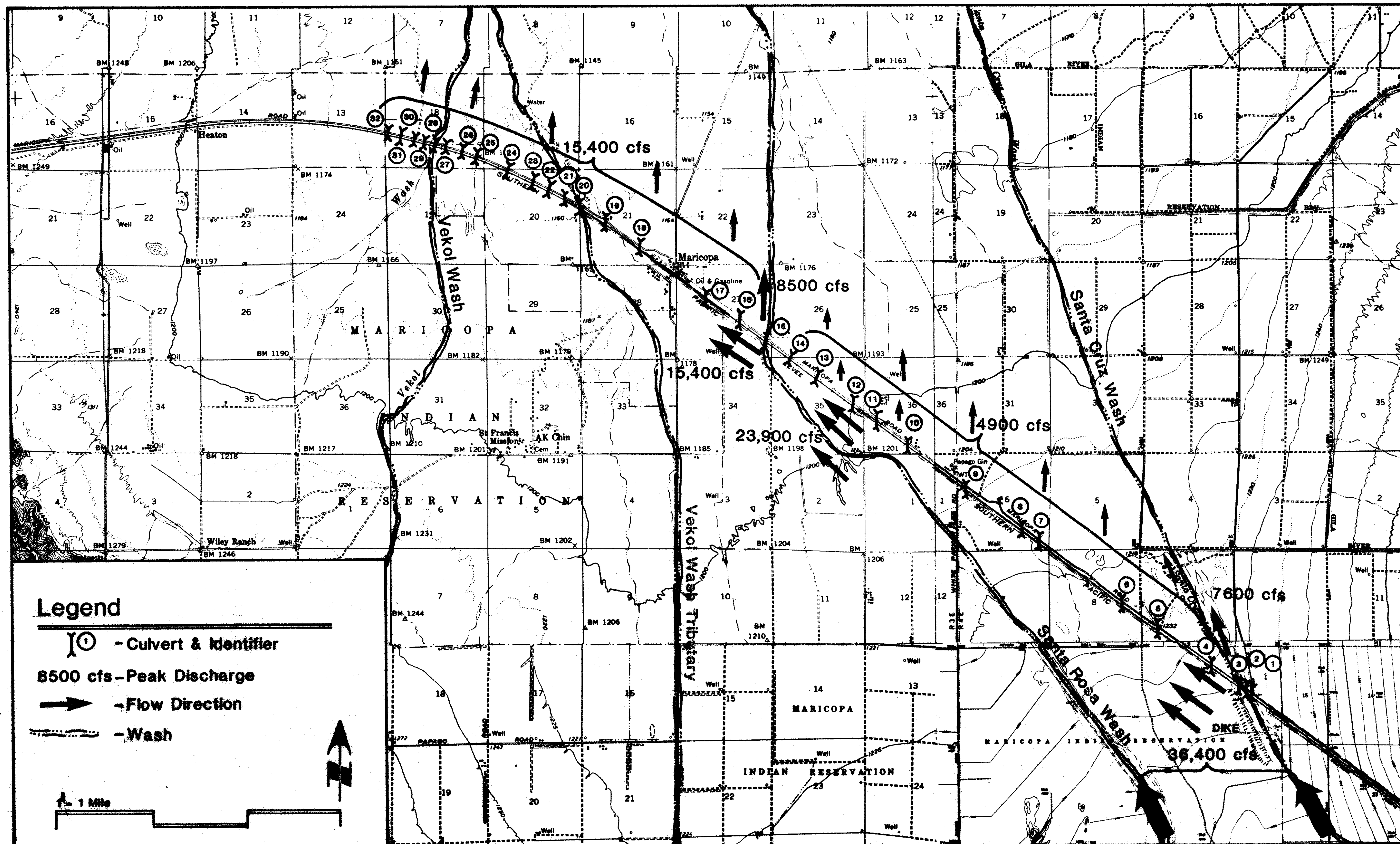

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FIGURE 5: PEAK DISCHARGES AT MARICOPA - October 4th, 1983

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APPENDIX

APPENDIX A

DISCHARGE-FREQUENCY RELATIONSHIP

SANTA CRUZ RIVER AT CORTARO

ANNUAL PEAK DISCHARGES: Cortaro

Year	Peak Q (cfs)	Year	Peak Q (cfs)
1940	17,000	1964	15,900
1941	7,800	1965	2,710
1942	1,550	1966	16,800
1943	5,500	1967	5,740
1944	5,650	1968	15,800
1945	14,000	1969	8,400
1946	4,440	1970	11,200
1947	7,500	1971	9,100
1948	-	1972	7,050
1949	-	1973	9,000
1950	12,900	1974	11,700
1951	6,820	1975	5,200
1952	6,100	1976	10,600
1953	10,800	1977	4,700
1954	9,150	1978	23,000
1955	16,600	1979	18,800
1956	3,150	1980	2,650
1957	4,400	1981	4,310
1958	7,890	1982	13,300
1959	8,000	1983	9,710
1960	6,420	1984	65,000(est.)
1961	14,700		
1962	11,200		
1963	7,240		

PEAK DISCHARGES: Cortaro

Rank	Discharge Q	(100m/n+1)	$\log_{10}Q(X)$	$(X-\bar{X})^3$
1	65,000	2.3	4.813	0.6932
2	23,000	4.5	4.362	0.0817
3	18,800	6.8	4.274	0.0414
4	17,000	9.1	4.230	0.0275
5	16,800	11.4	4.225	0.0262
6	16,600	13.6	4.220	0.0249
7	15,900	15.9	4.201	0.0203
8	15,800	18.2	4.199	0.0199
9	14,700	20.5	4.167	0.0137
10	14,000	22.7	4.146	0.0104
11	13,300	25.0	4.124	0.0075
12	12,900	27.3	4.111	0.0061
13	11,700	29.5	4.068	0.0027
14	11,200	31.8	4.049	0.0018
15	11,200	34.1	4.049	0.0018
16	10,800	36.4	4.033	0.0012
17	10,600	38.6	4.025	0.0009
18	9,710	40.9	3.987	0.0002
19	9,150	43.2	3.961	0.0
20	9,100	45.5	3.959	0.0
21	9,000	47.7	3.954	0.0
22	8,400	50.0	3.924	0.0
23	8,000	52.3	3.903	0.0
24	7,890	54.5	3.897	0.0
25	7,800	56.8	3.892	0.0
26	7,500	59.1	3.875	-0.0001
27	7,240	61.4	3.860	-0.0003
28	7,050	63.6	3.848	-0.0005
29	6,820	65.9	3.834	-0.0008
30	6,420	68.2	3.808	-0.0017
31	6,100	70.5	3.785	-0.0029
32	5,740	72.7	3.759	-0.0048
33	5,650	75.0	3.752	-0.0055
34	5,500	77.3	3.740	-0.0066
35	5,200	79.5	3.716	-0.0095
36	4,700	81.8	3.672	-0.0168
37	4,440	84.1	3.647	-0.0222
38	4,400	86.4	3.643	-0.0231
39	4,310	88.6	3.634	-0.0254
40	3,150	90.9	3,498	-0.0795
41	2,710	93.2	3.433	-0.1213
42	2,650	95.5	3.423	-0.1288
43	1,550	97.7	3.190	-0.4019
			168.890	0.1297

$\bar{X} = 3.9277$

$\sigma_{n-1} = 0.2886$

$$G = \frac{43 \times 0.1297}{42 \times 41 \times 0.2886^3} = 0.1347$$

$\log Q = \overline{X} + KS$

For $p = 0.01$ $k = 2.4248$

$\log Q = 3.9227 + (2.4248 \times 0.2886) = 4.6275$ therefore $Q_{100} =$ 42,413cfs

$\overline{X} = 3.9277$ $\sigma_{n-1} = 0.2886$

p = 0.98	K = -1.9807	logQ = 3.3561	Q = 2,270cfs
p = 0.90	K = -1.2662	logQ = 3.5623	Q = 3,650cfs
p = 0.70	K = -0.5402	logQ = 3.7718	Q = 5,913cfs
p = 0.50	K = -0.0224	logQ = 3.9212	Q = 8,341cfs
p = 0.30	K = 0.5076	logQ = 4.0742	Q =11,863cfs
p = 0.10	K = 1.2950	logQ = 4.3014	Q =20,019cfs
p = 0.02	K = 2.1251	logQ = 4.5410	Q =34,754cfs
p = 0.01	K = 2.4248	logQ = 4.6275	Q =42,413cfs
p = 0.002	K = 3.0421	logQ = 4.8057	Q =63,922cfs

APPENDIX B

DISCHARGE-FREQUENCY RELATIONSHIP

SANTA CRUZ RIVER AT LAVEEN

Laveen Gauge

Measurements for peak discharges at the Laveen gauging station on the Santa Cruz River are available from 1940 - Present. The Santa Rosa Wash was a major flow contributor until 1973 when the Tat Momolikot Dam was built. This Dam is assured to contain a flood discharge that exceeds the 100-year flood and thus the Santa Rosa Wash, upstream of the dam, can no longer be considered a flow contributor. Peak discharges at Laveen have thus been adjusted to remove events that have resulted from major flows in the Santa Rosa Wash. Such years have been omitted from the flow record, as indicated, and treated as a broken record since, in these cases, there were still measurable flows in the Santa Cruz River at Cortaro. If available, the next highest peak discharge for that year which was not influenced by the Santa Rosa Wash was used.

PEAK ANNUAL DISCHARGES

	Cortaro (D.A. = 3503 mi²)		Vaiva Vo (D.A. = 1782 mi²)		Laveen (D.A. = 8581 mi²)	
Year	Date	Q (cfs)	Date	Q (cfs)	Date	Q (cfs)
1940	8/14/40	17000			9/18/40	1200
1941	12/31/40	7800			3/15/41	1580
1942	8/09/42	1550			7/15/42	1890
1943	9/24/43	5500*			9/28/43	1200*
1944	8/16/44	5650			8/25/44	217
1945	8/10/45	14000*			8/11/45	1200*
1946	8/04/46	4440			9/21/46	5020
1947	8/15/47	7500				
1948					8/07/48	1200
1949					9/17/49	1780
1950	7/30/50	12900			8/11/50	685
1951	7/25/51	6820			8/28/51	5060
1952	8/14/52	6100*			8/15/52	1860*
1953	7/14/53	10800*			7/17/53	555*
1954	7/24/54	9150			8/09/54	726
1955	8/03/55	16600*	8/08/55	1150*	8/10/55	2180*I
1956	7/29/56	3150	7/24/56	740	1/30/56	90
1957	9/01/57	4400	8/12/57	492	8/20/57	1040
1958	8/12/58	7890	11/01/57	10000*	11/05/57	3360*I
1959	8/20/59	8000	7/13/59	4120	8/12/59	3010
1960	8/11/60	6420	7/30/60	805	1/15/60	707
1961	8/23/61	14700	7/27/61	892	8/15/61	547
1962	9/26/62	11200*	9/27/62	53100*	9/29/62	9200*I
1963	8/26/63	7240	9/14/63	4180	8/17/63	608
1964	9/10/64	13900	7/25/64	6760	8/14/64	2502
1965	7/16/65	2710	9/04/65	433	6/23/65	309
1966	2/22/65	16800*	9/14/66	1820	12/26/65	2940*
1967	7/17/67	5740	6/26/67	302	9/06/67	448
1968	12/21/67	15800*	7/28/68	840	12/23/67	3820*
1969	8/06/69	8400	8/08/69	514	11/14/68	152
1970	7/20/70	11200	8/10/70	865	9/09/70	1010
1971	8/20/71	9100*	8/04/71	6110	8/22/71	2440*
1972	8/12/72	7050	8/14/72	410	8/07/72	112
1973	10/19/72	9000*	10/21/72	762	10/22/72	1650*
Tat Momolikat Dam Constructed						
1974	7/08/74	11700	8/02/74	364	7/20/74	144
1975	7/12/75	5200*	7/17/75	580	7/14/75	203*
1976	9/25/76	10600*	9/25/76	390	9/25/76	583*
1977	9/10/77	4700	7/17/77	291	10/23/76	472
1978	10/10/77	23000*	2/13/78	66	10/13/77	2010*
1979	12/18/78	18800*	1/17/79	51	12/22/78	4120*
1980	7/19/80	2650*	8/24/80	105	2/20/80	115*

1981	9/22/81	4310	7/16/81	368
1982	8/23/82	13300	9/15/82	751
1983	9/30/83	9710	2/07/83	1620
1984 (est)	10/03/84	65000*	10/05/84	28000*

* - Discharges are related.

I - Laveen gauge influenced by Vaiva Vo gauge.

PEAK DISCHARGES: Laveen

Year	Peak Q (cfs)	Year	Peak Q (cfs)
1940	1,200	1964	2,520
1941	1,580	1965	309
1942	1,890	1966	2,940
1943	1,200	1967	448
1944	217	1968	3,820
1945	1,200	1969	152
1946	5,020	1970	1,010
1947	-	1971	2,440
1948	1,200	1972	112
1949	1,780	1973	1,650
1950	685	1974	144
1951	5,060	1975	203
1952	1,860	1976	583
1953	555	1977	472
1954	726	1978	2,010
1955	I	1979	4,120
1956	90	1980	115
1957	1,040	1981	368
1958	994IR	1982	751
1959	3,010	1983	1,620
1960	707	1984	28,000(est.)
1961	547		
1962	I		
1963	608		

I - Laveen gauge influenced by Vaiva Vo gauge.

R - Peak annual flow replaced with lower peak flow for year.

Discharges - Laveen

Rank	Discharge Q	(100m/n+1)	$\log_{10}Q(X)$	$(X-\bar{X})^3$
1	28,000	2.3	4.447	3.2221
2	5,060	4.7	3.704	0.3954
3	5,020	7.0	3.701	0.3906
4	4,120	9.3	3.615	0.2683
5	3,820	11.6	3.582	0.2292
6	3,010	14.0	3.479	0.1319
7	2,940	16.3	3.468	0.1235
8	2,520	18.6	3.401	0.0801
9	2,440	20.9	3.387	0.0725
10	2,010	23.3	3.303	0.0369
11	1,890	25.6	3.276	0.0287
12	1,860	27.9	3.270	0.0270
13	1,780	30.2	3.250	0.0220
14	1,650	32.6	3.217	0.0151
15	1,620	34.9	3.210	0.0138
16	1,580	37.2	3.199	0.0120
17	1,200	39.5	3.079	0.0013
18	1,200	41.9	3.079	0.0013
19	1,200	44.2	3.079	0.0013
20	1,200	46.5	3.079	0.0013
21	1,040	48.8	3.017	0.0001
22	1,010	51.2	3.004	0.0
23	994	53.5	2.997	0.0
24	751	55.8	2.876	0.0008
25	726	58.1	2.861	0.0013
26	707	60.5	2.849	-0.0018
27	685	62.8	2.836	-0.0024
28	608	65.1	2.784	-0.0064
29	583	67.4	2.766	-0.0085
30	555	69.8	2.744	-0.0115
31	547	72.1	2.738	-0.0125
32	472	74.4	2.674	-0.0259
33	448	76.7	2.651	-0.0325
34	368	79.1	2.566	-0.0659
35	309	81.4	2.490	-0.1106
36	217	83.7	2.336	-0.2548
37	203	86.0	2.307	-0.2914
38	152	88.4	2.182	-0.4893
39	144	90.7	2.158	-0.5354
40	115	93.0	2.061	-0.7511
41	112	95.3	2.049	-0.7812
42	90	97.7	1.954	-1.0488
			381.54	0.6423

$\bar{X} = 2.970$

$\sigma_{n-1} = 0.522$

$$G = \frac{42 \times 0.6423}{41 \times 40 \times 0.522^3} = 0.116$$

$G = 0.116$
$\log Q = \bar{X} + ks$

For $p = 0.01$ $k = 2.4112$

$\log Q = 2.97 + (2.4112 \times 0.522) = 4.229$ therefore $Q_{100} = 16{,}930$cfs

p = 0.98	K = -1.9910	logQ = 1.9307	Q = 85cfs
p = 0.90	K = -1.2684	logQ = 2.3079	Q = 203cfs
p = 0.70	K = -0.5381	logQ = 2.6891	Q = 489cfs
p = 0.50	K = -0.0193	logQ = 2.9599	Q = 912cfs
p = 0.30	K = 0.5100	logQ = 3.2362	Q = 1,723cfs
p = 0.10	K = 1.2933	logQ = 3.6451	Q = 4,417cfs
p = 0.02	K = 2.1154	logQ = 4.0742	Q =11,864cfs
p = 0.01	K = 2.4112	logQ = 4.2286	Q =16,930cfs
p = 0.002	K = 3.0193	logQ = 4.5461	Q =35,162cfs

APPENDIX C

DISCHARGE-FREQUENCY RELATIONSHIP

SANTA CRUZ RIVER AT MARICOPA

DISCHARGE-FREQUENCY RELATIONSHIP: Maricopa

Using Roeske regression equation (Ref. 1) for Region 2 gives the following relationships:

$Q_2 = 87.0A^{0.433}$ -(1)
$Q_{10} = 352A^{0.475}$ -(2)
$Q_{50} = 815A^{0.494}$ -(3)
$Q_{100} = 1{,}100A^{0.499}$ -(4)
$Q_{500} = 2{,}000A^{0.509}$ -(5) where: A = Area in square miles

Using equation (4) above Q_{100} (Cortaro) = 47,250cfs (D.A. = 3503 mi^2)
Using equation (4) above Q_{100} (Red Rock)= 56,450cfs (D.A. = 5222 mi^2)
From Log Pearson III, Appendix A Q_{100} (Cortaro) = 42,400cfs

Adjust Q_{100} @ Red Rock to Log Pearson III $= \frac{42{,}400}{47{,}250} \times 56{,}450$

$= 50{,}650$cfs

Calculate Q_{100} (Maricopa), Drainage Area = 6,159 mi^2 using linear interpolation by river mile.

Red Rock to Maricopa = 53.3 miles
Red Rock to Laveen = 69.0 miles

Q_{100} (Laveen) from Appendix B = 16,930cfs

Q_{100} (Maricopa) $= 50{,}650 - \frac{53.3}{69.0} \times (50{,}650 - 16{,}930)$

$= 24{,}600$cfs

COMPUTED DISCHARGE-FREQUENCY RELATIONSHIP

	Cortaro (Pearson III)	Cortaro (Roeske)	Red Rock (Roeske)	Red Rock (Pearson III adj)	Laveen (Pearson III)	Maricopa (Interpolated)
Q_2	8,300	8,950	11,200	10,400	900	3,050
Q_{10}	20,000	23,050	28,050	24,300	4,400	8,950
Q_{50}	34,800	39,350	47,250	41,800	11,850	18,650
Q_{100}	42,400	47,250	56,450	50,650	16,950	24,600
Q_{500}	63,900	68,050	80,600	75,700	35,150	44,400

APPENDIX D

OCTOBER 1983 FLOOD

OCTOBER 1983 FLOOD

Estimates from U.S.G.S.:

Cortaro = 65,000cfs
Laveen = 28,000cfs

Red Rock is just downstream of the last major tributary inflow to the Santa Cruz River. From Red Rock to Laveen the peak discharge thus attenuates. Accounting for loss rate and tributary inflow between Cortaro and Laveen, a peak discharge of 65,000cfs was assumed at Red Rock.

Calculate peak Q(Maricopa) using linear interpolation by river mile.

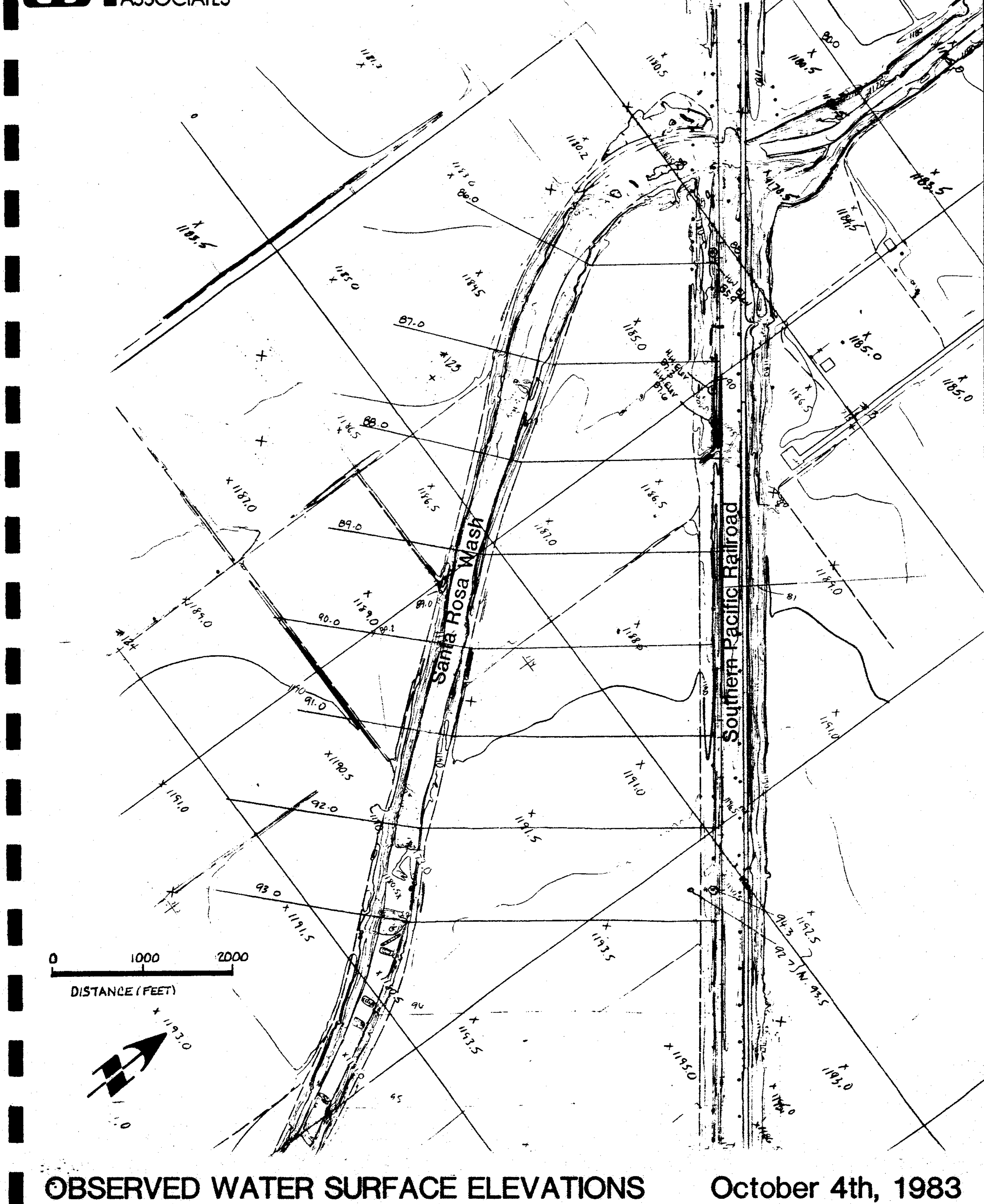
Red Rock to Maricopa = 53.3 miles
Red Rock to Laveen = 69.0 miles

$$Q(\text{Maricopa}) = 65{,}000 - \frac{53.3}{69.0} \times (65{,}000 - 28{,}000)$$

$$= 36{,}400\text{cfs}$$

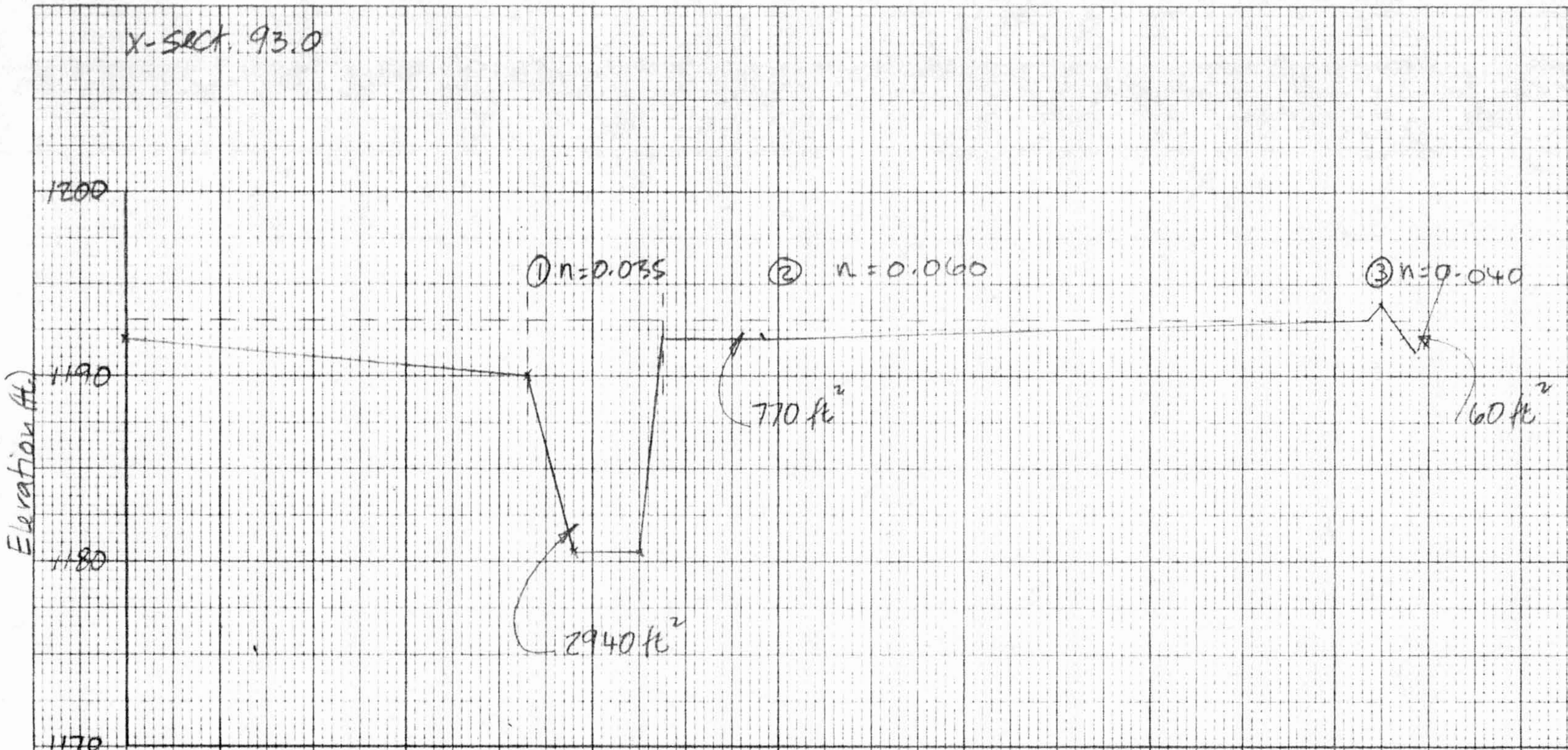
This total peak discharge has been divided up through the various culverts and bridge crossings along the railroad. Aerial and field reconnaissance was used to determine the headwater at each culvert (Figure 5).

CELLA BARR ASSOCIATES



OBSERVED WATER SURFACE ELEVATIONS October 4th, 1983

Santa Rosa Wash



$S = 0.0018$

① $Q = \dfrac{1.49 \times 2940 \times \left(\frac{2940}{300}\right)^{2/3} \times \sqrt{0.0018}}{0.035} = 24{,}300$ cfs

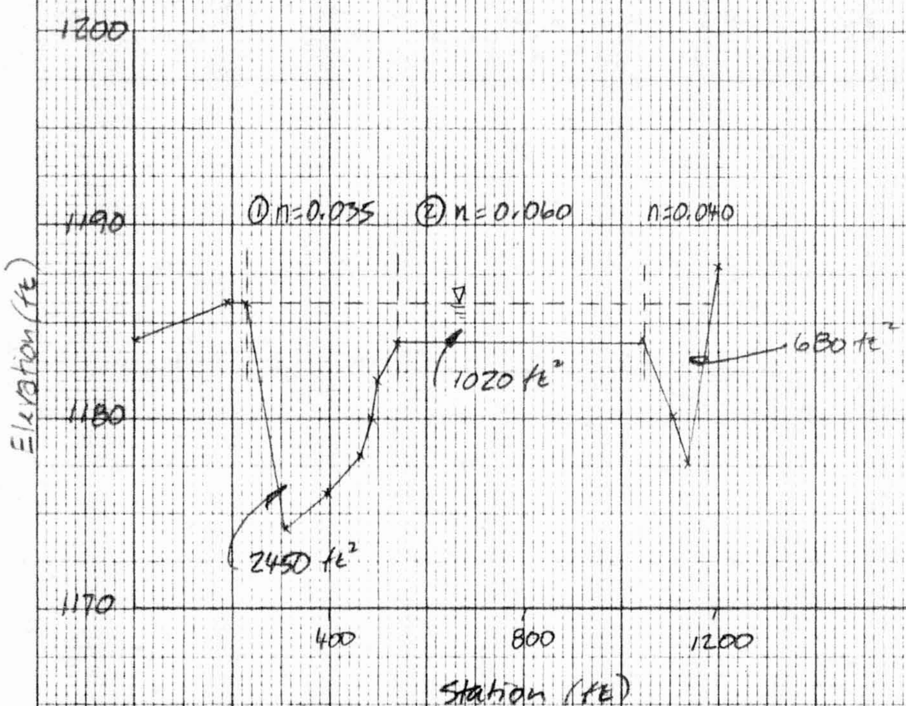
② $Q = \dfrac{1.49 \times 770 \times \left(\frac{770}{1550}\right)^{2/3} \times \sqrt{0.0018}}{0.060} = 500$ cfs

③ $Q = \dfrac{1.49 \times 60 \times \left(\frac{60}{70}\right)^{2/3} \times \sqrt{0.0018}}{0.040} = 85$ cfs

TOTAL Q $= 24{,}900$ cfs

Santa Rosa Wash

X-sect. 86.0



s = 0.0018

① $Q = \dfrac{1.49 \cdot 2450 \left(\dfrac{2450}{320}\right)^{4/3} \times \sqrt{0.0018}}{0.035} = 17{,}200$ cfs

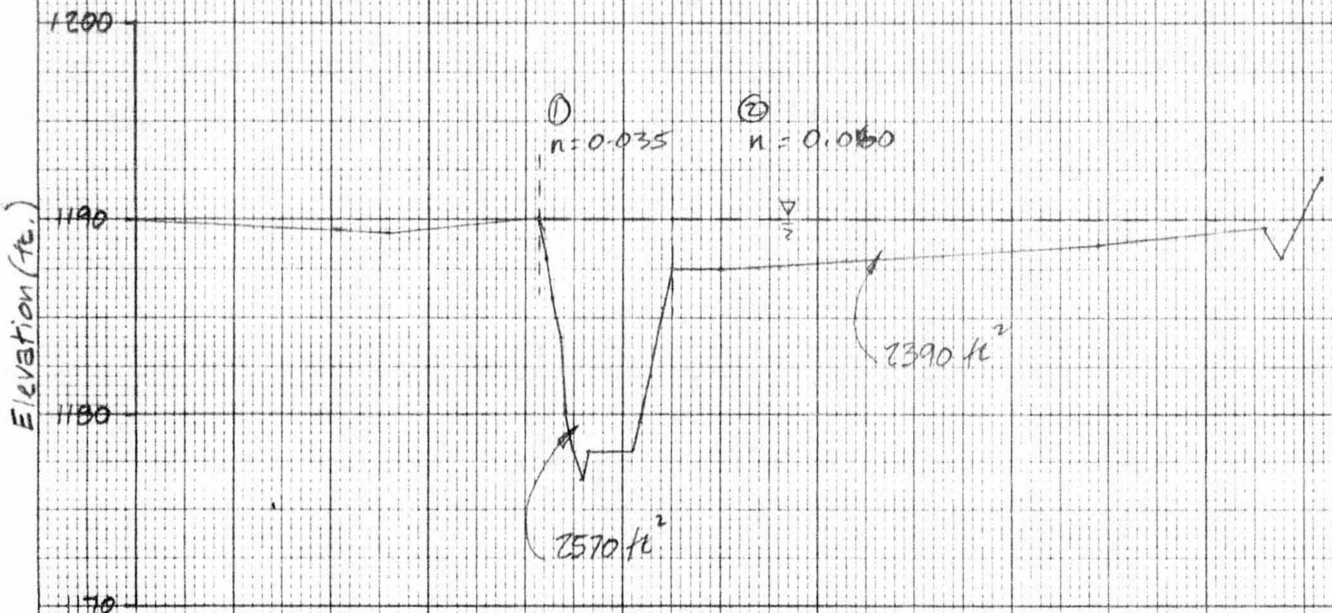
② $Q = \dfrac{1.49 \times 1020 \times \left(\dfrac{1020}{510}\right)^{2/3} \times \sqrt{0.0018}}{0.060} = 1{,}700$ cfs

③ $Q = \dfrac{1.49 \times 680 \times \left(\dfrac{680}{150}\right)^{4/3} \times \sqrt{0.0018}}{0.040} = 2{,}900$ cfs

TOTAL Q = 21,800 cfs.

Santa Rosa Wash

X-Sect 90.0



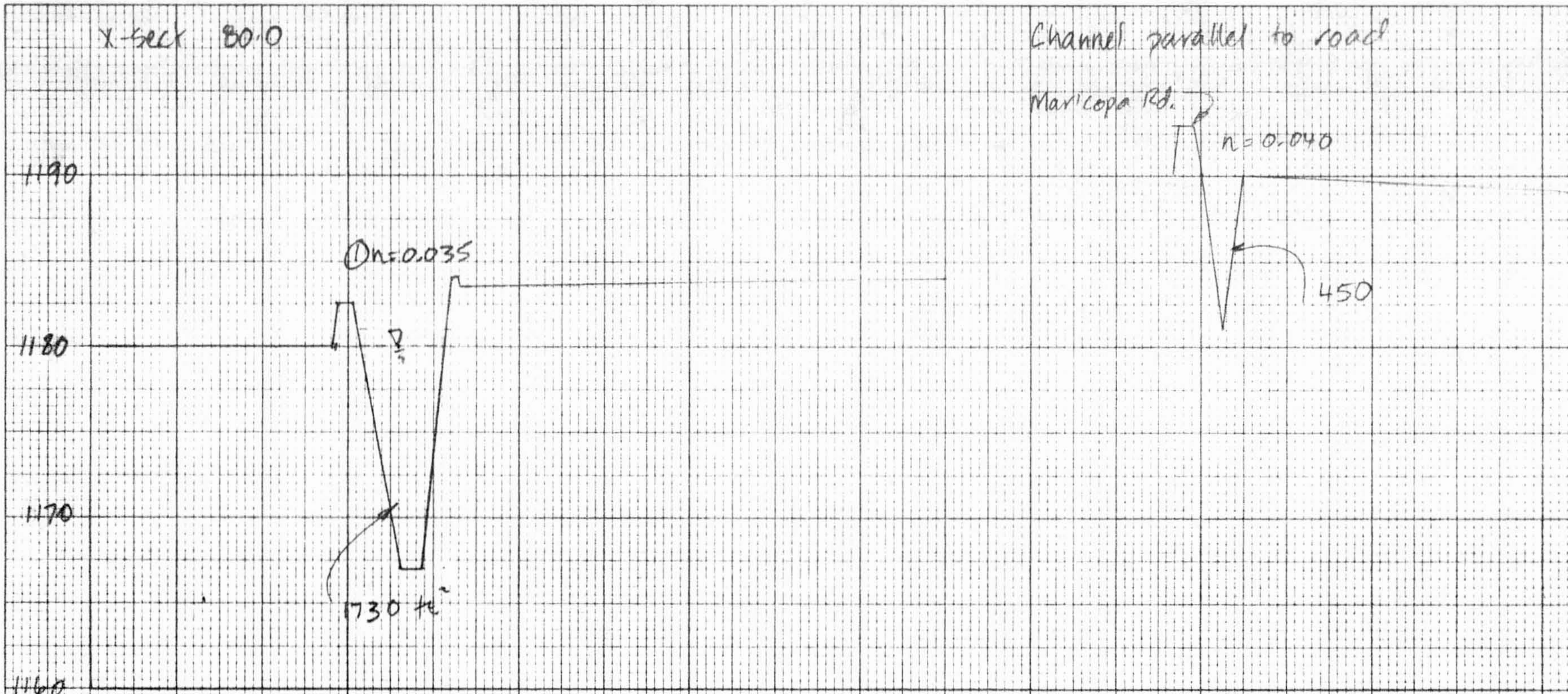
$S = 0.0018$

① $Q = \dfrac{1.49 \times 2570 \times \left(\dfrac{2570}{270}\right)^{2/3} \times \sqrt{0.0018}}{0.035} = 20{,}850 \text{ cfs}$

② $Q = \dfrac{1.49 \times 2390 \times \left(\dfrac{2390}{1320}\right)^{2/3} \times \sqrt{0.0018}}{0.060} = 3{,}750 \text{ cfs}$

TOTAL Q = 24,600 cfs

Santa Rosa Wash



S = 0.0018

① $Q = \frac{1.49 \times 1730 \times \left(\frac{1730}{200}\right)^{2/3} \times \sqrt{0.0018}}{0.035} = 13{,}200$ cfs

$Q = \frac{1.49 \times 450 \times \left(\frac{450}{100}\right)^{2/3} \times \sqrt{0.0023}}{0.040} = 2200$ cfs

Flow under railroad bridge = 13,200 − 2200 = 11,000 cfs

If flow depth is 79.0 then Q = 10,700 cfs

10,700 − 2200 = 8500 cfs (Approx. computed flow through bridge)

Santa Cruz Wash - Culverts 1-3

Total discharge = 7620 cfs ≈ 7600 cfs

Culverts 4-14

Total discharge = 4904 cfs ≈ 4900 cfs

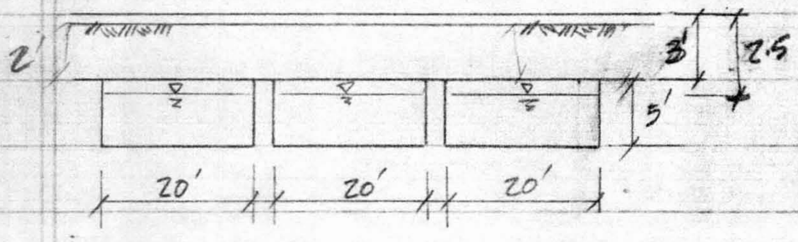
Culvert 15

Total discharge = 8500 cfs

Culverts 16-33

Total discharge = 13,320 cfs (Close to estimated 15,400 cfs)

Culvert #1 - Santa Cruz Wash

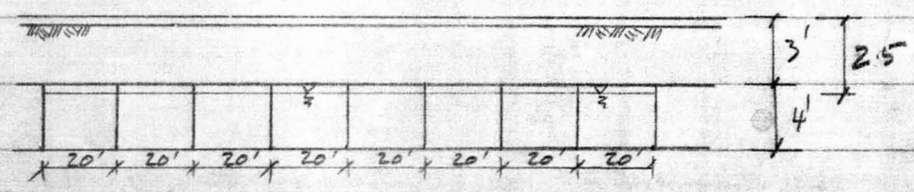


HW Depth = 5.5'   HW/D = 5.5/5 = 1.1

Q = 34 cfs/ft

Q_{Total} = 34 x 60 = 2040 cfs.

Culvert #2 - Santa Cruz Wash

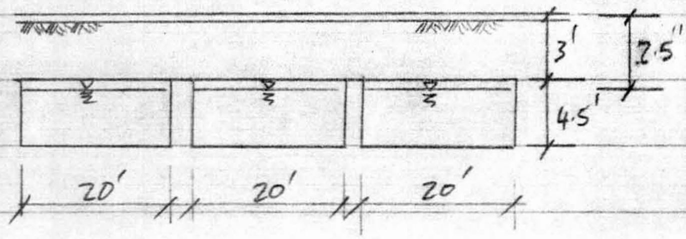


HW Depth = 4.5   HW/D = 4.5/4 = 1.1

Q = 24 cfs/ft.

Q_{Total} = 24 x 8 x 20 = 3840 cfs.

Culvert #3 - Santa Cruz Wash



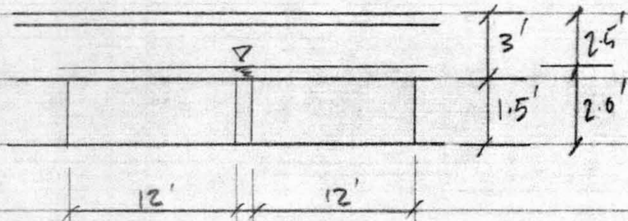
HW Depth = 4.5'   HW/D = 5.0/4.5 = 1.1

Q = 29 cfs/ft.

Q_{TOTAL} = 29 x 3 x 20 = 1740 cfs.

Combined flow from #1, #2 and #3 = 2040+3840+1740 = 7620 cfs.

Culvert #4



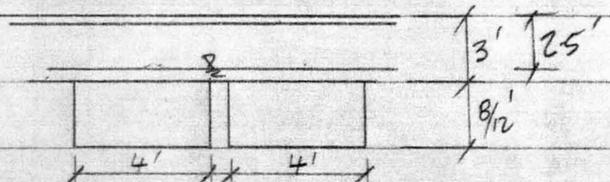
Assumes that water level maintains slope causing water levels to be 2.5' below rail tracks.

HW = 2.0   HW/D = 2/1.5 = 1.33

Q = 6 cfs/ft.

Q_{TOTAL} = 6 x 24 = 144 cfs.

Culvert #5

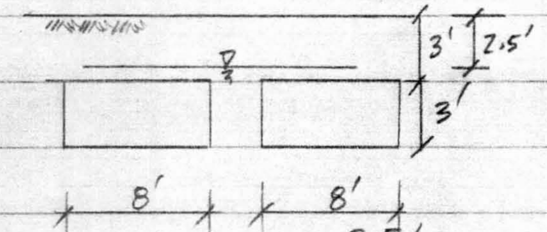


HW = 1.17   HW/D = 1.17/0.67 = 1.75

Q = 2.4 cfs/ft.

Q_{TOTAL} = 2.4 x 8 = 19 cfs.

Culvert #6

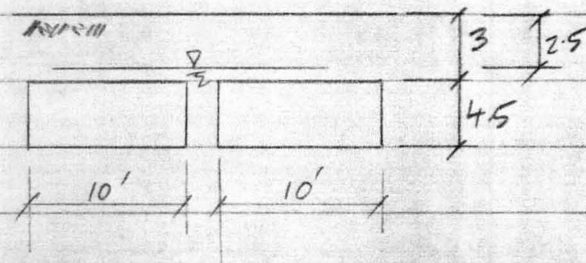


HW = 3.5   HW/D = 3.5/3 = 1.17

Q = 16 cfs / ft

Q_{TOTAL} = 16 × 16 = 256 cfs.

Culvert #7

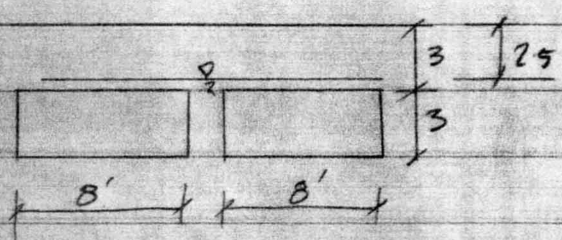


HW = 5.0'   HW/D = 5/4.5 = 1.11

Q = 28 cfs / ft.

Q_{TOTAL} = 28 × 20 = 560 cfs.

Culvert #8

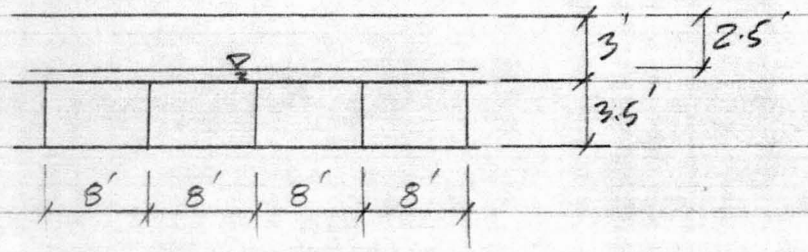


HW = 3.5'   HW/D = 3.5/3 = 1.17

Q = 16 cfs / ft.

Q_{TOTAL} = 16 × 16 = 256 cfs.

Culvert #9

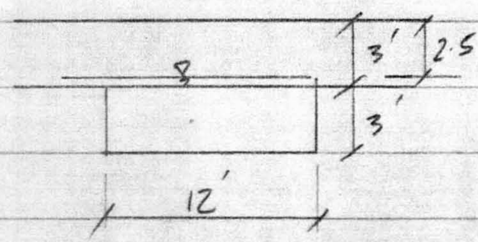


HW = 4.0' HW/D = 4/3.5 = 1.14

Q = 25 cfs/ft.

Q_{TOTAL} = 25 x 32 = 800 cfs.

Culvert #10

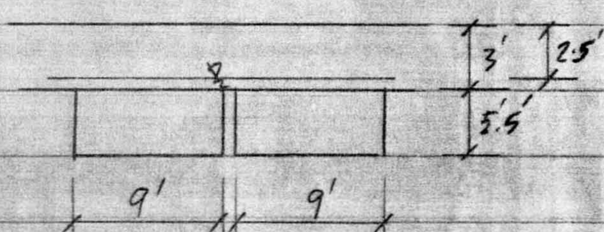


HW = 3.5' HW/D = 3.5/3 = 1.17

Q = 20 cfs

Q_{TOTAL} = 20 x 12 = 240 cfs.

Culvert #11

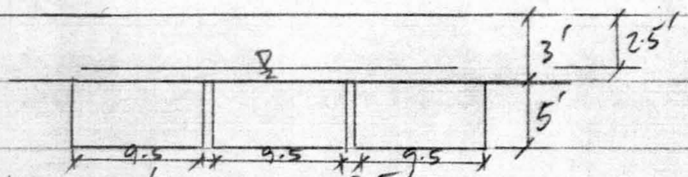


HW = 6.0 HW/D = 6.0/5.5 = 1.10

Q = 42 cfs/ft.

Q_{TOTAL} = 42 x 18 = 756 cfs.

Culvert #12



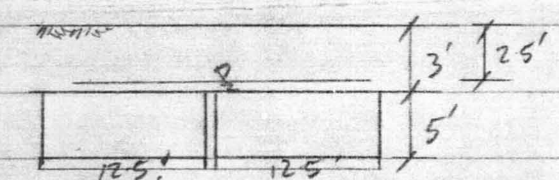
HW = 5.5'   HW/D = 5.5/5 = 1.1

Q = 35 cfs/ft

Q_{TOTAL} = 35 × 28.5 = 998 cfs.

Culvert #13   Negligible.

Culvert #14

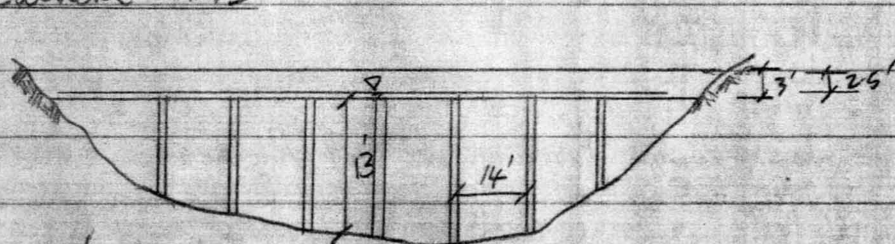


HW = 5.5'   HW/D = 5.5/5 = 1.1

Q = 35 cfs/ft

Q_{TOTAL} = 35 × 12.5 × 2 = 875 cfs.

Culvert #15



6 × 14' spans

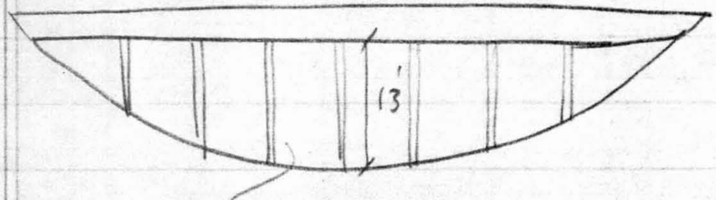
Due to the build up of debris, assume that flow width is limited by 4 ft at each section. Effective width = 10 ft.

HW = 13'   HW/D = 13.5/13 = 1.0

Q = 142 cfs/ft.   142 × 6 × 10 = 8500 cfs

Santa Rosa Wash

Bed slope = 0.0018



Area = 6x14x13 = 1092 ft^2

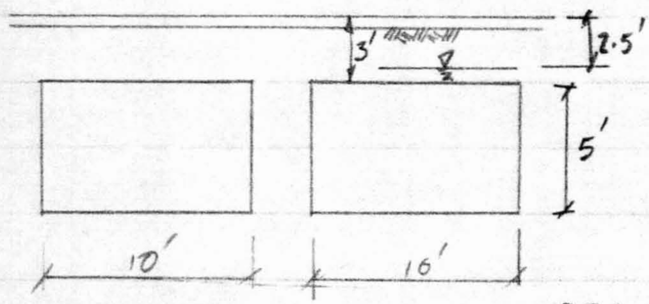
$$Q = \frac{1.49 \times 1092 \times \left(\frac{1092}{84}\right)^{2/3} \times \sqrt{0.0018}}{0.035} \approx 10,900 \text{ cfs.}$$

Reduce Q by $\frac{4}{14}$ = 3100 cfs net Q = 7800 cfs due to brush build up.

If bed slope = 0.0021 Q = 11,800 cfs

Reduce Q by 4/14 = 3400 cfs = 8400 cfs.

Culvert #16

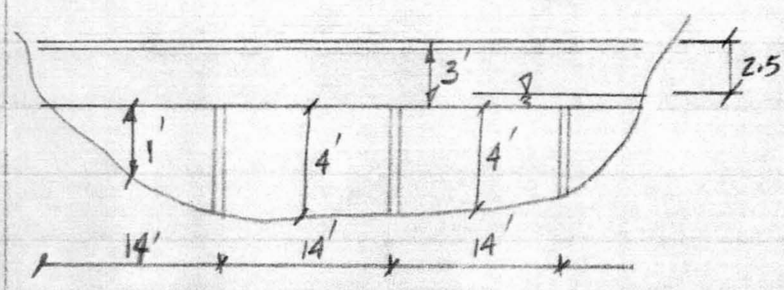


HW Depth = 5.5' HW/D = 5.5/5 = 1.1

Q = 34 cfs/ft

Q_{TOTAL} = 34 x 20 = 680 cfs.

Culvert #17



4'-Section HW Depth = 4.5' HW/D = 4.5/4 = 1

Q = 24 cfs/ft

Q_{TOTAL} = 24 x 28 = 672 cfs

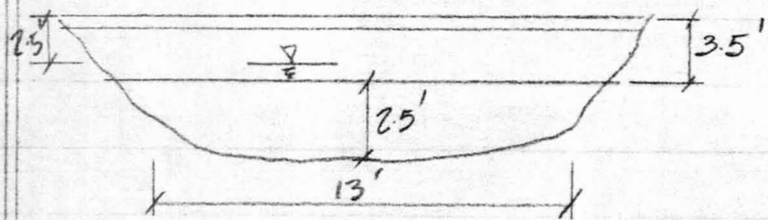
1'-Section HW Depth = 1.5' HW/D = 1.5/1 = 1.5

Q = 3.5 cfs/ft

Q_{TOTAL} = 3.5 x 14 = 49 cfs

TOTAL Q = 49 + 672 = 721 cfs.

Culvert #18

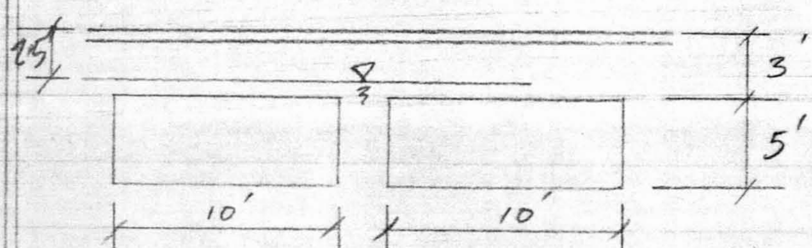


HW Depth = 3.5'   HW/D = 3.5/2.5 = 1.4

Q = 15 cfs/ft

Q_{TOTAL} = 15 x 13 = 195 cfs

Culvert #19

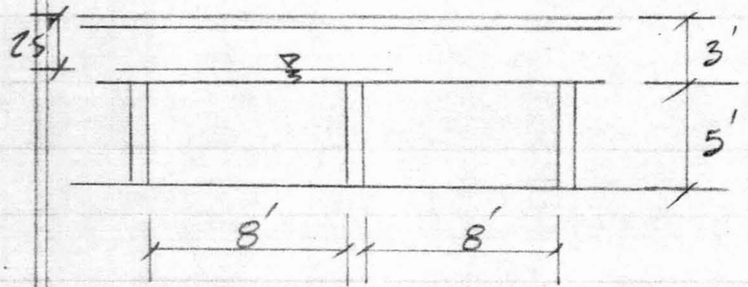


HW Depth = 5.5'   HW/D = 5.5/5 = 1.1

Q = 35 cfs/ft

Q_{TOTAL} = 35 x 20 = 700 cfs

Culvert #20

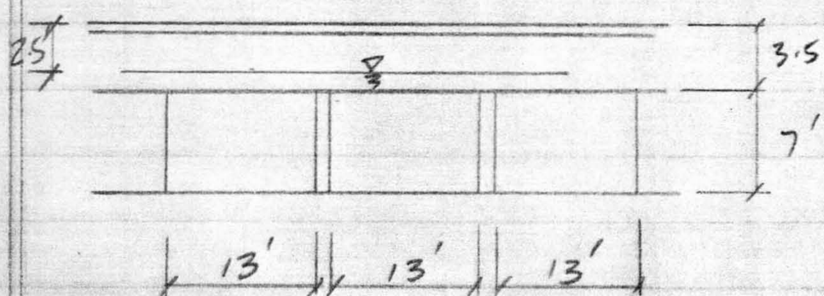


HW Depth = 5.5'   HW/D = 5.5/5 = 1.1

Q = 35 cfs/ft

Q_{TOTAL} = 35 x 16 = 560 cfs

Culvert #21

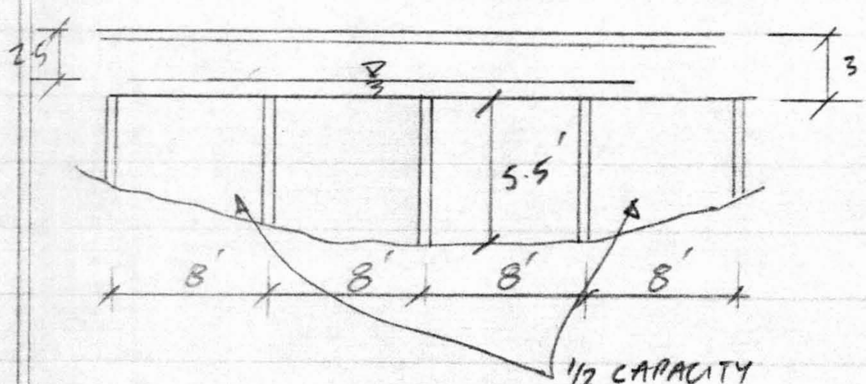


HW Depth = 8'   HW/D = 8/7 = 1.1

Q = 60 cfs/ft

Q_{TOTAL} = 60 x 13 x 3 = 2340 cfs

Culvert #22

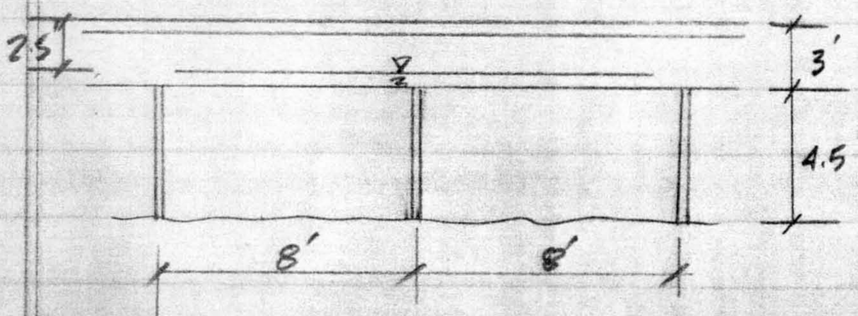


HW = 6'   HW/D = 6/5.5 = 1.1

Q = 40 cfs / ft

Q_{TOTAL} = 40×8×3 = 960 cfs

Culvert #23

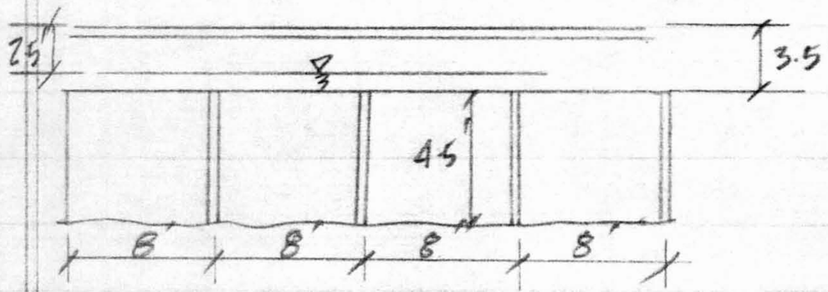


HW = 5'   HW/D = 5/4.5 = 1.1

Q = 30 cfs / ft

Q_{TOTAL} = 30×16 = 480 cfs

Culvert #24

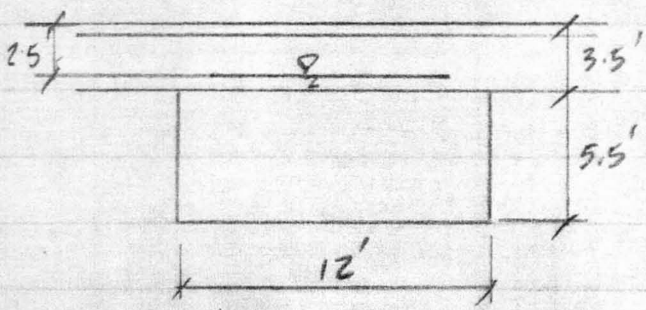


HW = 5.5'   HW/D = 5.5/4.5 = 1.2

Q = 32 cfs/ft

Q_{TOTAL} = 32 × 8 × 4 = 1024 cfs

Culvert #25

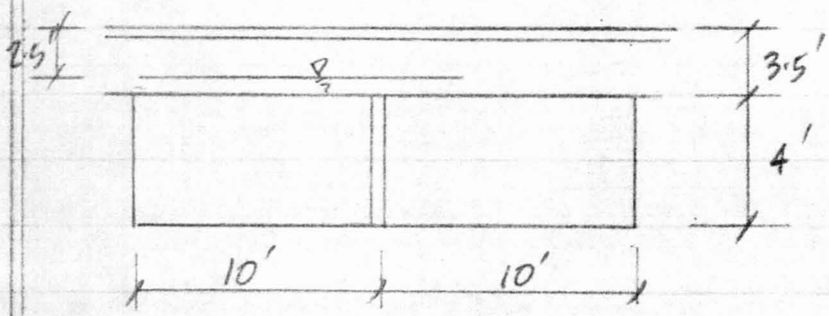


HW = 6.5'   HW/D = 6.5/5.5 = 1.2

Q = 45 cfs/ft

Q_{TOTAL} = 45 × 12 = 540 cfs

Culvert #26

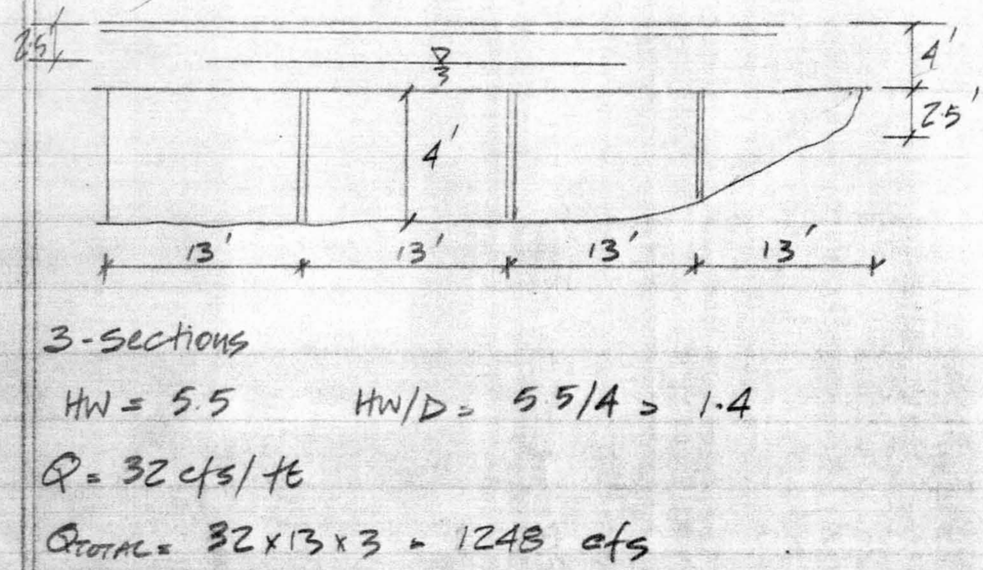


HW = 5' HW/D = 5/4 = 1.25

Q = 28 cfs / ft

Q_{TOTAL} = 28 x 10 x 2 = 560 cfs

Culvert #27



3-Sections

HW = 5.5 HW/D = 5.5/4 = 1.4

Q = 32 cfs/ft

Q_{TOTAL} = 32 x 13 x 3 = 1248 cfs

1 - Section

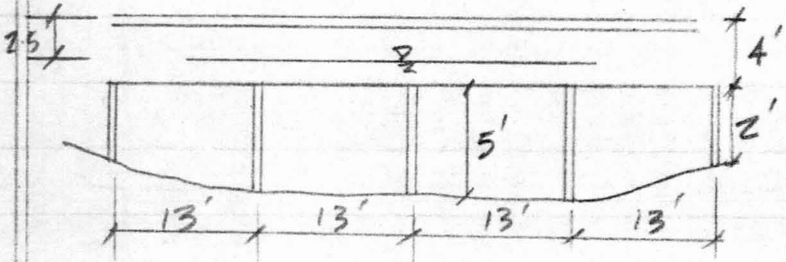
HW = 4 HW/D = 4/2.5 = 1.6 Q = 16 cfs/ft

Av. for section = 16+32/2 = 24 cfs/ft

Q_{TOTAL} = 24 x 13 = 312 cfs

Q_{TOTAL} = 1248 + 312 = 1560 cfs

Culvert #28



Middle section

HW = 6.5' HW/D = 6.5/5 = 1.3

Q = 42 cfs/ft

Q_{TOTAL} = 42 × 13 × 2 = 1092 cfs

End sections

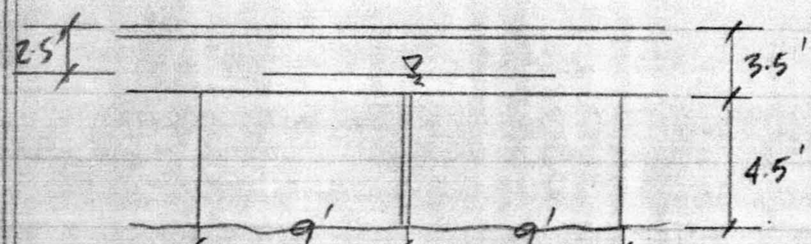
HW = 3.5' HW/D = 3.5/2 = 1.8

Q = 12 cfs/ft Q_{AV} = (12 + 42)/2 = 27 cfs/ft

Q_{TOTAL} = 27 × 13 × 2 = 702 cfs

Q_{TOTAL} = 1092 + 702 = 1794 cfs.

Culvert #29

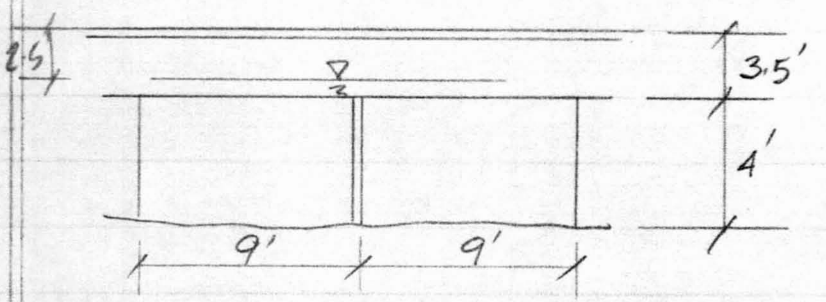


HW = 5.5' HW/D = 5.5/4.5 = 1.2

Q = 32 cfs/ft

Q_{TOTAL} = 32 × 9 × 2 = 576 cfs.

Culvert #30

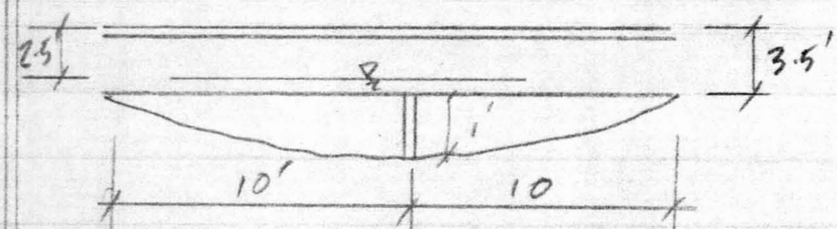


HW = 5'   HW/D = 5/4 = 1.25

Q = 28 cfs/ft

Q_{TOTAL} = 28×9×2 = 504 cfs

Culvert #31

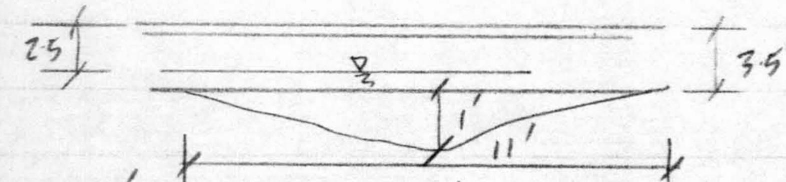


HW = 2'   HW/D = 2/1 = 2

Q = 4.5 cfs/ft

Q_{TOTAL} = 4.5×10×2/2 = 45 cfs

Culvert #32

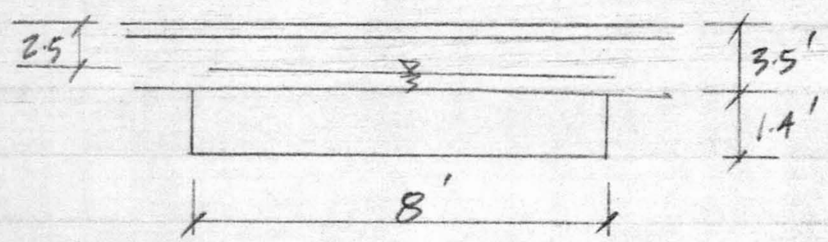


HW = 2'   HW/D = 2/1 = 2

Q = 4.5 cfs/ft

Q_{TOTAL} = 4.5 x 11/2 = 25 cfs

Culvert #33



HW = 2.4'   HW/D = 2.4/1.4 = 1.7

Q = 7 cfs/ft

Q_{TOTAL} = 7 x 8 = 56 cfs

LEGEND

- - - - DRAINAGE BOUNDARY
— · — RIVER COURSE
O USGS GAUGE

SCALE 1:250,000

0 1 2 5 10 MILES

FIGURE 1:
SANTA CRUZ
RIVER SYSTEM

CBA CELLA BARR ASSOCIATES
5062 N. 19th Avenue, Phoenix, Arizona 85015
(602) 242-2999