DICK [illegible]

PRELIMINARY HYDRAULIC ANALYSIS OF THE SALT RIVER FOR THE EAST PAPAGO FREEWAY AND RED MOUNTAIN INTERCHANGE

sla

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

PRELIMINARY HYDRAULIC ANALYSIS OF THE SALT RIVER FOR THE EAST PAPAGO FREEWAY AND RED MOUNTAIN INTERCHANGE

Submitted to:

Daniel, Mann, Johnson, & Mendenhall
300 West Clarendon Avenue, Suite 400
Phoenix, Arizona 85013-3499

Submitted by:

Simons, Li & Associates, Inc.
4600 South Mill Avenue, Suite 280
Tempe, Arizona 85282

September 1989

Registered Professional Engineer (Civil)
CERTIFICATE NO. 21568
DENNIS RICHARDS
Date Signed 9/8/89
ARIZONA, U.S.A.
Dennis L. Richards

TABLE OF CONTENTS

		Page
PREFACE		iii
I.	INTRODUCTION	1
	1.1 Project Overview	1
	1.2 Work Performed to Date	3
II.	QUALITATIVE ANALYSIS	4
	2.1 Background	4
	2.2 Geomorphic Analysis	5
	2.3 Channel Bed Armoring	7
III.	HYDRAULIC ANALYSIS	9
	3.1 Analyses Procedures	9
	3.2 Data Base	9
	3.3 Discussion of Baseline Conditions	10
	3.4 Concept Hydraulic Analysis	11
	3.5 Hydraulic Parameters by Reach	26
IV.	SEDIMENT-TRANSPORT ANALYSIS	30
	4.1 General	30
	4.2 General Scour/Fill	30
	4.3 Local Scour	32
	4.4 Long-Term Channel Response	37
	4.5 Total Scour Depth	38
V.	MITIGATION MEASURES	40
VI.	SUMMARY	44
REFERENCES		45
APPENDIX A - HEC-2 Cross-Section Locations		

Registered Professional Engineer (Civil)
CERTIFICATE NO. 21560
DENNIS W. RICHARDS
Date Signed 9/8/87
ARIZONA, U.S.A.
Dennis Richards

TABLE OF CONTENTS
(continued)

Page

LIST OF FIGURES

Figure 1. Location Map 2
Figure 2. Invert Profile Comparisons 6
Figure 3. Typical Surface and Subsurface Bed-Material Gradation Curves 8
Figure 4. Water Surface Profiles for Existing, Baseline, and BFE Conditions, 100-Year Event 14
Figure 5. Water Surface Profiles for Baseline and Concept Conditions, 100-Year Event 20
Figure 6. Reach Delineation for Hydraulic and Sediment-Transport Analyses 27
Figure 7. Design Flow Hydrograph, 100-Year Event 31
Figure 8. Initial and Final Bed Profiles 35
Figure 9. Typical Cement Stabilized Alluvium Bank Protection 41
Figure 10. Section Through Grade-Control Structure 43

LIST OF TABLES

Table 1. Peak Discharges from the May, 1982 Central Arizona Water Control Study 10
Table 2. Water Surface Elevation Comparisons for 100-Year Event . . . 12
Table 3. Hydraulic Information for Baseline and Concept Conditions, 10-Year Event 16
Table 4. Hydraulic Information for Baseline and Concept Conditions, 100-Year Event 18
Table 5. Water Surface Elevation and Velocity Comparisons, Concept Minus Baseline Conditions, 100-Year Event 21
Table 6. Water Surface Elevations for Indian Bend Wash, 100-Year Event 23
Table 7. Water Surface Elevations for Salt River Bridge Alternatives, 100-Year Event 25
Table 8. Reach-Averaged Velocity 28
Table 9. Reach-Averaged Topwidth 28
Table 10. Reach-Averaged Hydraulic Depth 29
Table 11. Sediment Routing Results, Concept Conditions 33
Table 12. Estimates of Local Scour at Bridge Piers 36
Table 13. Total Scour Depth Summary 39

PAZ-DMJM-03/PH/IntRep

Registered Professional Engineer (Civil)
CERTIFICATE NO. 21560
DENNIS J. RICHARDS
Date Signed 9/8/89
ARIZONA, U.S.A.

PREFACE

The results presented in this report are based on state-of-the-art techniques for river mechanics and scour analysis. However, the state-of-the-art of river mechanics is such that flow depths on the order of those which exist within the Salt River cannot realistically be predicted more accurately than plus or minus 10%. In addition, the state-of-the-art for scour analysis is such that predictions may vary by as much as 50% to 100%. The results obtained depend on the data base used, assumptions made, engineering computer models utilized, engineering judgement exercised, etc. Some of the assumptions made in conjunction with this study effort include: 1) hydrology (flood peaks) for the Salt River is correct; 2) the 1986 topographic mapping is sufficient to accurately depict topographic conditions; 3) sediment sampling adequately represents the existing sediment distributions in the stream bed; and 4) one-dimensional hydraulic modeling is appropriate to apply to the study reach. Consequently, the results obtained by different investigators could vary widely. Because the results presented within this report are considered to be conservative, based on the assumptions made, they can be used to give a relative measure of the maximum impacts associated with the proposed project. However, the results are only preliminary and not to be used for final design.

I. INTRODUCTION

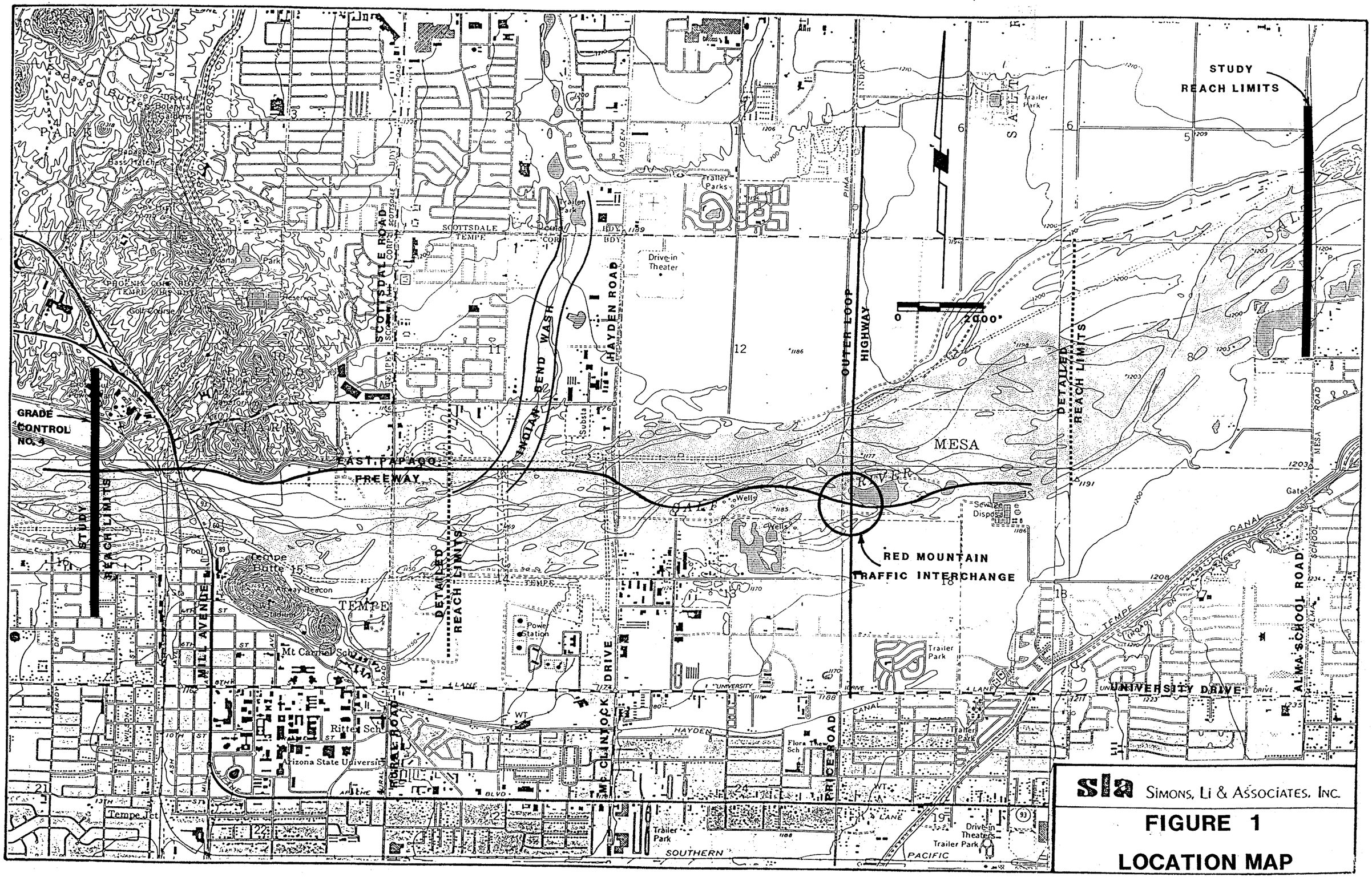
1.1 Project Overview

Simons, Li & Associates, Inc. (SLA) has conducted a preliminary hydraulic and sediment-transport analysis of the Salt River to support the design of the East Papago Freeway and Outer Loop Highway, which will both cross the river corridor. The results will be used to establish the hydraulic conditions for the design of the multiple-bridge crossings near Hayden Road and the Red Mountain Interchange, as well as to establish the location, configuration, and dimensions of bank-stabilization measures. The analysis will also provide sufficient technical documentation to support applications for the necessary 404 permit, water-quality certification, and revisions to flood-insurance rate maps.

The detailed project limits extend from Indian Bend Wash upstream to Dobson Road. However, in order to assess adequately the boundary conditions and the potential upstream and downstream impacts, the hydraulic and sediment-transport analyses extend from Grade Control Structure No. 4, west of the Southern Pacific Railroad bridge, upstream through the detailed study area to Alma School Road. The downstream end of Indian Bend Wash, in the vicinity of the proposed East Papago freeway crossing, is also included in the study. Figure 1 shows the study reach.

A multi-level approach was used to determine project impacts on the river corridor. This approach consisted of a qualitative geomorphic analysis and quantitative analyses using a variety of engineering computer models. The qualitative analysis provides an understanding of the river behavior and a means to predict, in qualitative terms, the potential for impact from the proposed project. The engineering computer models allow for the quantitative prediction of river hydraulics, general scour/fill potential of the channel bed, and local scour effects around bridge piers.

The purpose of this report is to summarize the progress of the project to date. Sufficient progress has been made to support the application for a 404 permit, and to provide initial input into the design of bridge crossings and other hydraulic structures in the study reach. However, the results presented are still preliminary, and subject to change as final design configurations become available.



sla SIMONS, LI & ASSOCIATES, INC.

FIGURE 1

LOCATION MAP

1.2 Work Performed to Date

A geomorphic analysis of the Salt River through the study reach has been conducted. The qualitative and quantitative discussion presented in this report summarizes the results of this analysis and provides insight into the present condition of the Salt River through the study reach; as well as the potential for geomorphic changes due to the implementation of the project.

A preliminary, rigid-boundary hydraulic analysis of the entire study reach from Grade Control Structure No. 4 to Alma School Road has also been completed as a component of this study. The analysis includes a detailed investigation of all existing bridge crossings and a preliminary examination of the proposed East Papago freeway alignment and all proposed bridge crossings. The proposed channelized reach downstream of Grade Control Structure No. 4 was hydraulically modeled using final design plans for the Salt River Channelization (ADOT Project No. RAM-600-3-511) to establish the downstream boundary condition for upstream analyses.

A preliminary sediment-transport analysis of the reach from Grade Control Structure No. 4 to just upstream of the proposed Red Mountain Interchange has also been completed. This sediment-transport analysis includes an estimate of the general scour/fill potential of the channel bed under assumed design conditions, as well as estimates of local scour around bridge piers.

II. QUALITATIVE ANALYSIS

2.1 Background

In 1987, SLA conducted a general qualitative geomorphic analyses of the Salt River through the current study reach as part of the location study and preliminary design for the East Papago and Hohokam Freeways (1). Here a brief summary of the previous work is given, with additional analyses included that are relevant to the present study.

The Salt River in its natural condition was a wide, braided stream of course bed material with a steep channel gradient. The river through the study reach exhibited these characteristics at the time of the aerial photographs taken in 1953. At that time, the stream channel averaged about a mile in width above Hayden Road, narrowing to about a half mile in width through the Tempe Buttes area.

The river was channelized to a bottom width of about 600 feet from Mill Avenue to Scottsdale Road sometime prior to 1975. The channelization was outflanked on the south side by floods during the early 1980's, and was severely eroded at that time.

The present condition of the Salt River through the study reach exhibits significant changes due to man's activities. Encroachments on the river channel have occurred throughout the study area, particularly on the south side, from Scottsdale Road to Dobson Road. The most recent encroachment of significance is the Sun Angel Golf Course, constructed on the south side of the river just downstream of Hayden Road. Extensive gravel mining has occurred in the Salt River from Scottsdale Road to beyond the upstream study limit. Gravel mining is presently active upstream of Hayden Road.

As a result of in-stream sand and gravel mining, the channel invert at Hayden Road has degraded approximately 14 feet since 1962. Immediately upstream of the Hayden Road bridge, the channel invert within existing mining excavations is as much as 35 feet below the 1962 invert elevation.

A study conducted by SLA for the Arizona Transportation Research Center (2) estimated that, between 1962 and 1986, the total production of material for the five-mile reach of the Salt River from Hayden Road to Country Club Drive was

58.5 million tons. The study showed that the amount of channel bed degradation in gravel bed channels is directly proportional to the volume of material extracted from that reach.

2.2 Geomorphic Analysis

The net result of the previously described changes to the Salt River corridor has been a long-term lowering of the channel bed and an overall reduction in topwidth. The most significant changes have resulted from gravel mining activities. Gravel mining induces a response in channel geometry in two important ways: 1) degradation of the downstream channel bed due to a deficit in sediment supply resulting from sediment being trapped in the gravel pits, and 2) a lowering of the upstream channel bed through a physical process known as headcutting. These changes are dramatically illustrated in the bed-profile comparisons given in Figure 2. The Corps of Engineers (COE) invert is taken from the 1983 COE Flood Insurance Study (3), presumably representing conditions prior to the present level of gravel mining. The present profile, taken from a 1986 topographic data base (1), depicts the significant lowering of the channel bed due to the gravel mining. The significance of this illustration, in terms of the present study, is that it graphically demonstrates the potential for continued mining to undermine bridge piers or bank protection within the study reach without the incorporation of appropriate mitigation measures.

Changes to the channel downstream of gravel mining activities can be illustrated using the following qualitative geomorphic relationship (4):

$$Q_s^- \approx b^-, d^+, \lambda^-, S^-, P^+$$

where: Q_s is the bed-load transport rate,
b is the channel topwidth,
d is the channel depth,
λ is the meander wavelength,
S is the channel slope, and
P is the sinuosity.

The + or - sign indicates the direction of change. This relationship shows that scouring associated with a reduction in bedload downstream of gravel pits will, over the long term, result in a channel that is narrower, deeper, less steep, and which has a greater tendency to meander.

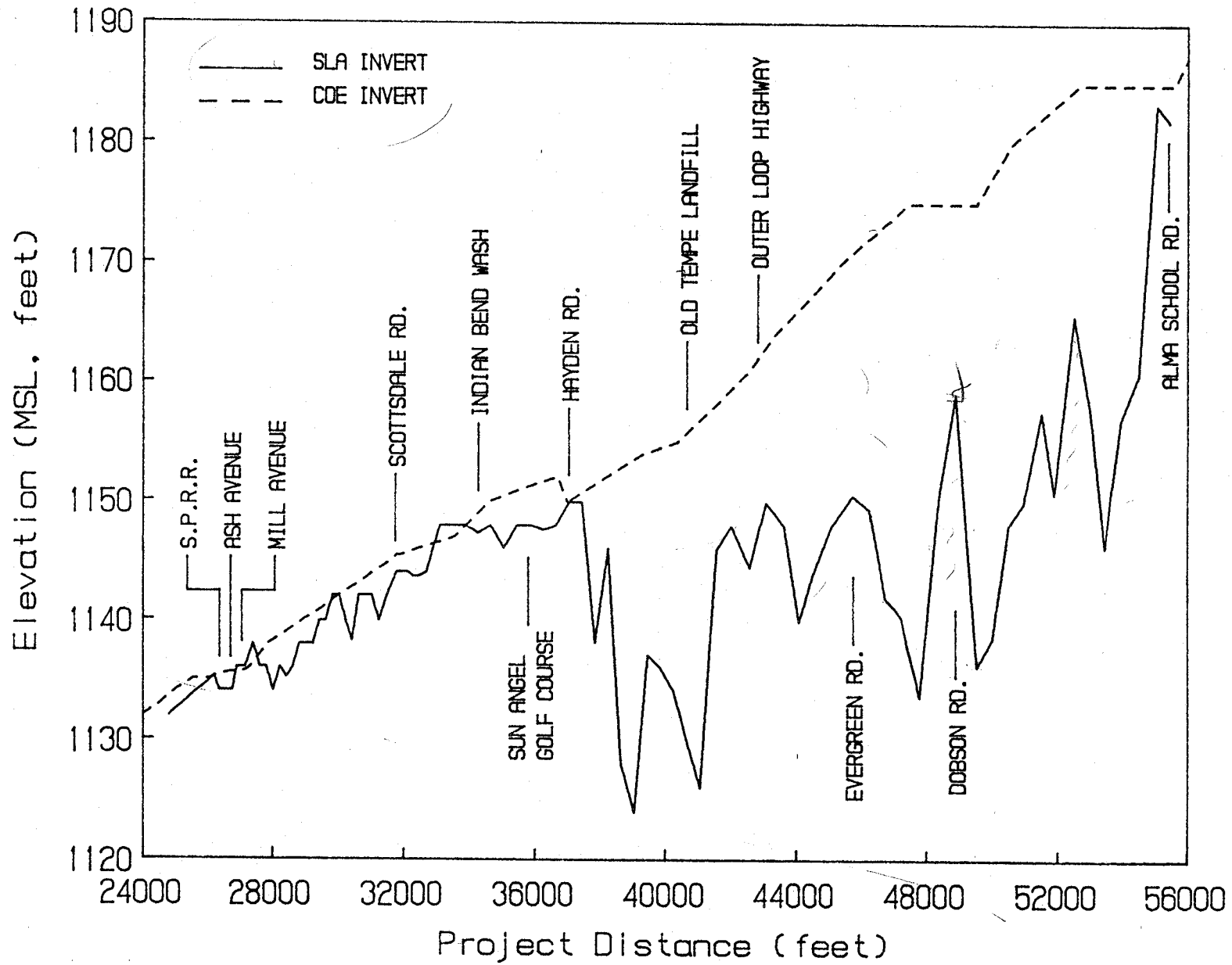


Figure 2. Invert Profile Comparisons

Over the long term, encroachments into the channel can also create conditions for potential channel instability. This is due to the fact that the sediment-transport rate in an encroached area is generally increased due to increased velocity, which is the most important hydraulic parameter in terms of sediment-transport. This results in the potential for degradation and bank instability in the encroached reach, and aggradation downstream due to the increased sediment loading from the encroachment area. Changes in a channel resulting from increased bed material load under these conditions can be illustrated by the following geomorphic relationship (4):

$$Q_s^+ \approx b^+,\ d^-, \lambda^+,\ S^+,\ P^-$$

In this case, the increased bed material load will, over the long term, result in a channel that will tend to be wider, shallower, steeper, and less sinuous. The channel in the constricted reach will adjust by not only scouring, but also will tend to regain its equilibrium by widening. Aggradation in the downstream channel will create the potential for bank instability as the channel tries to widen to reach equilibrium with the increased bed load.

2.3 Channel Bed Armoring

Long-term degradation in the Salt River is limited by bed armoring, where a sorting of the bed material during the degradation process results in the development of a layer of coarser material on the bed surface which retards further degradation. Armoring is clearly evident in the channel bed through the study reach. However, due to the disturbance by gravel mining operations within the study reach, a quantitative prediction of the long-term armoring process through this reach of the Salt River is complex. Figure 3 shows typical gradation curves developed for surface and subsurface sediment layers in the study reach. The curves clearly illustrate the armor layer, with the surface layer being much coarser than the subsurface layer. The sediment-transport modeling conducted for this study takes the armoring process into account.

The qualitative discussion of this section provides insight into the present condition of the Salt River through the study reach, and the potential for changes due to the implementation of the project. The following sections discuss the analyses performed to quantify the project impacts.

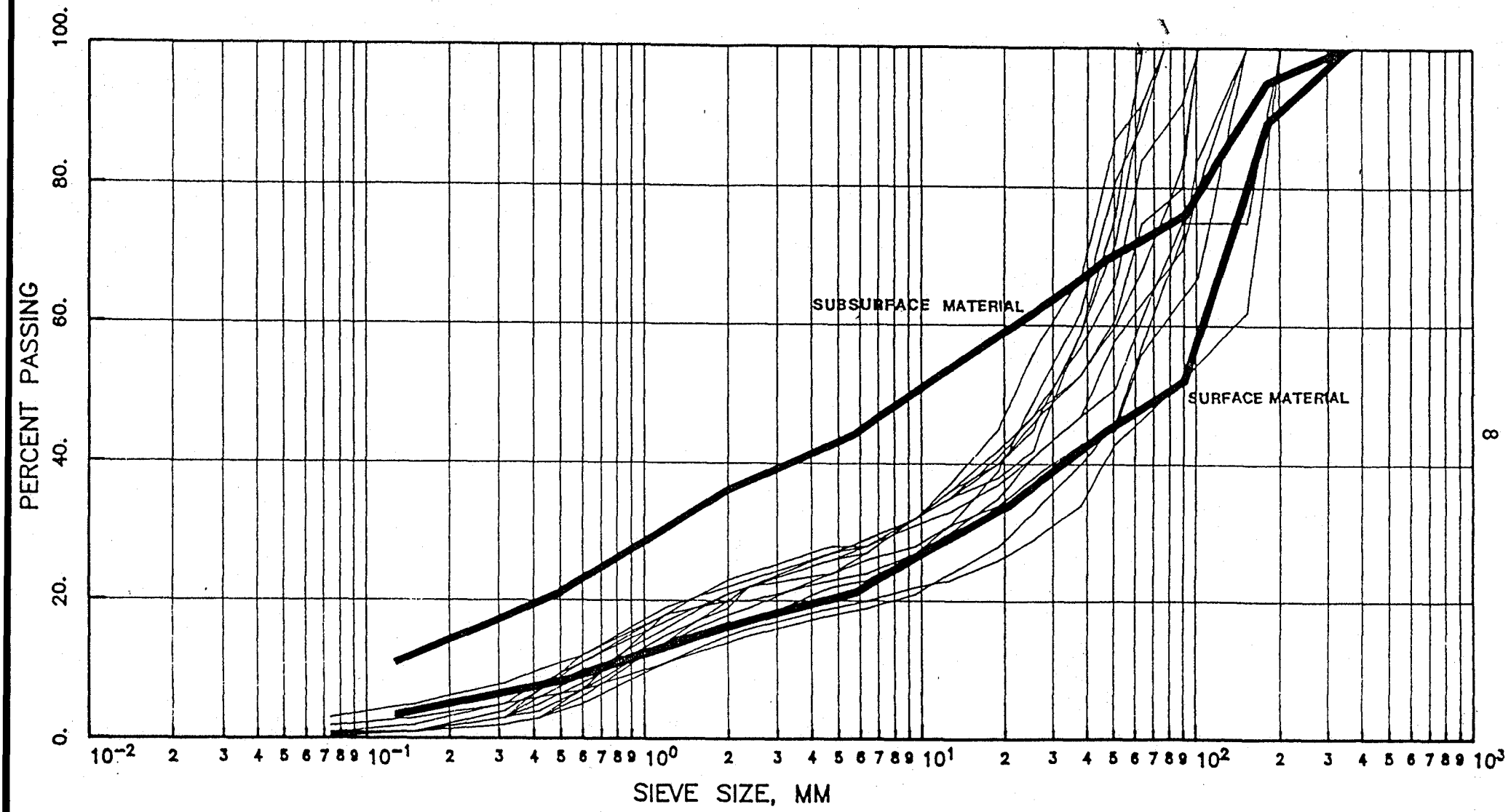


Figure 3. Typical Surface and Subsurface Bed Material Gradation Curves

III. HYDRAULIC ANALYSIS

3.1 Analyses Procedures

The U.S. Army Corps of Engineers (COE) HEC-2 Water Surface Profile Program (5) was used to perform the rigid-boundary hydraulic analysis. Bridge-loss calculations were performed using either the HEC-2 normal-bridge or special-bridge routines. The choice between bridge routines was site specific, and based on the method which would most accurately model field conditions.

3.2 Data Base

Topographic mapping used for the study reach was that produced in 1986 for the Arizona Department of Transportation (ADOT) East Papago and Hohokam Freeway alignment study (1). This mapping was used to develop the input cross sections for the HEC-2 model. The mapping was supplemented with surveyed cross sections of the recently constructed Sun Angel Golf Course (6,7) and all available bridge plans. Cross sections for project concept conditions were developed by superimposing the highway encroachments onto the baseline cross sections. Proposed bridges were analyzed by assuming different pier configurations, with the bridge low-chord above the water-surface elevation for the design flood. Plate 1 of Appendix A shows the proposed highway alignment and the cross-section locations.

Manning's roughness values for the main channel were set equal to 0.035 for the channelized reach downstream of the Southern Pacific Railroad bridge, and 0.040 at all upstream locations. Overbank values were set equal to 0.050. Supporting documentation for the channel roughness values is provided in a previous studies prepared by SLA of the Salt River (1,8). These values were based on flow measurements taken by the U.S. Geological Survey. Analysis of the flow measurements indicated n-values in the range of 0.035 to 0.045 for large magnitude floods, with most values falling near 0.040. Expansion and contraction coefficients were set equal to 0.3 and 0.1, respectively, for reaches between bridges; and 0.5 and 0.3, respectively, for analysis through bridges.

Discharges used in the hydraulic analysis are based on values presented in the May 1982 Central Arizona Water Control Study (CAWCS) (9). A summary of peak discharges from this study are given in Table 1. Discharges used for the

study reach were determined from interpolation of values given in the CAWCS study at Mill Avenue and Gilbert Road.

TABLE 1. Peak Discharges from the May, 1982 Central Arizona Water Control Study

Location	Peak Discharge (cfs) 10-year	100-year
Mill Avenue	93,000	215,000
Gilbert Road	100,000	230,000

3.3 Discussion of Baseline Conditions

Information presented in previous sections of this report reveal that the present condition of the Salt River through the study reach exhibits significant changes due to man's activities. Encroachments on the river channel have occurred throughout the study area, and gravel mining is presently active upstream of Hayden Road. Due to the changes that have occurred in the past, as well as those that are presently occurring, it is difficult to define the baseline condition for analyzing project impacts.

Two conditions were analyzed to determine the most appropriate baseline condition for the subject reach of the Salt River. These two conditions were referred to as 1) existing conditions and 2) modified baseline conditions. The analysis referred to as existing conditions was based on the 1986 topographic mapping, and was supplemented with surveyed cross sections of the recently constructed Sun Angel Golf Course. The input cross sections for the HEC-2 model included the effects of gravel pits upstream of Hayden Road. The analysis referred to as modified baseline conditions was identical to existing conditions, except the effects of gravel pits in the study reach were removed by raising the channel bed in the gravel pits to a smooth channel invert. This was done

to provide an estimate of water-surface elevations that would result if the gravel pits were filled in with water and/or sediment during future flood events. It also provided a comparison to Base Flood Elevations (BFE's) established in the latest Flood Insurance Study for the reach (3), which do not include the effects of the gravel pits.

Water-surface profiles were computed for the 100-year peak discharges for both the existing and the modified baseline condition. Water-surface elevations are presented in Table 2 along with BFE's established by the COE in 1983. In the reach between Grade Control Structure No. 4 and Indian Bend Wash, results are the same for existing and modified baseline conditions since there are no gravel pits in this reach. Figure 4 is a plot of the water-surface profiles. The figure shows areas where the BFE's are both above and below the existing and modified baseline results. Some of these changes are due to the way bridges were modeled, most significantly at Mill Avenue and Hayden Road. Other changes are due to the effects of gravel mining, which has changed the river geometry significantly.

With the effects of the gravel pits removed, a conservative estimate of water-surface elevations and impacts resulting from the project was obtained. Therefore, the modified baseline conditions were used as the project baseline conditions.

3.4 Concept Hydraulic Analysis

Concept conditions are the best estimate of conditions resulting from the proposed highway alignment and an estimate of the final bridge configurations. The effects of gravel pits were removed for concept conditions, as in the (modified) baseline condition, to provide a conservative estimate of impacts resulting from the project. Concept conditions were analyzed and compared to the baseline conditions. The proposed highway alignment and bridge locations are shown on Plate 1 of Appendix A.

Proposed bridges for both the East Papago and Outer Loop crossings of the Salt River, as well as the East Papago crossing of Indian Bend Wash, were analyzed assuming 130-foot spans and piers with 6-foot diameter columns, 3 columns per structure. Due to the large skew of the East Papago crossing of

FEMA

TABLE 2. Water Surface Elevation Comparison, 100-Year Event

PROJECT STATION (ft)	CROSS-SECTION NUMBER	WATER SURFACE ELEVATIONS (ft) EXISTING CONDITION	MODIFIED BASELINE CONDITION	COE BFE	PHYSICAL FEATURE
24800	24800	1151.5	1151.5	1154.3	Grade Control No. 4
25000	25000	1151.7	1151.7	1154.4	
25200	25200	1153.1	1153.1	1154.7	
25400	25400	1154.1	1154.1	1154.9	
25600	25600	1154.8	1154.8	1155.1	
25800	25800	1155.3	1155.3	1155.2	
26000	26000	1155.7	1155.7	1155.2	
26200	26200	1155.8	1155.8	1155.3	
26380	182.10	1156.1	1156.1	1155.3	S.P.R.R. Bridge
26396	182.20	1156.3	1156.3	1155.3	
26575	183.50	1156.5	1156.5	1155.6	
26750	184.10	1156.8	1156.8	1155.8	Ash Ave. Bridge
26770	184.20	1157.5	1157.5	1156.0	
26930	185.50	1157.6	1157.6	1156.6	
27090	186.10	1158.0	1158.0	1156.9	Mill Ave. Bridge
27138	186.20	1159.5	1159.5	1157.0	
27418	188.00	1159.8	1159.8	1157.0	
27613	189.00	1160.2	1160.2	1157.1	
27814	190.00	1160.6	1160.6	1157.2	
28014	191.00	1160.8	1160.8	1157.5	
28215	192.00	1161.0	1161.0	1157.9	
28410	193.00	1161.2	1161.2	1158.2	
28610	194.00	1161.4	1161.4	1158.4	
28830	195.00	1161.6	1161.6	1158.7	
29022	196.00	1161.9	1161.9	1159.0	
29233	197.00	1162.2	1162.2	1159.5	
29438	198.00	1162.3	1162.3	1159.9	
29631	199.00	1162.5	1162.5	1160.0	
29836	200.00	1162.6	1162.6	1160.1	
30035	201.00	1162.8	1162.8	1160.1	
30236	202.00	1162.9	1162.9	1160.2	Sun Devil Stadium
30437	203.00	1163.1	1163.1	1160.3	
30633	204.00	1163.4	1163.4	1160.6	
30830	205.00	1163.9	1163.9	1161.1	
31035	206.00	1164.2	1164.2	1161.6	
31241	207.00	1164.4	1164.4	1162.0	
31471	208.00	1164.6	1164.6	1162.3	
31756	210.00	1164.8	1164.8	1162.5	
31766	210.10	1164.8	1164.8	1162.5	Scottsdale Rd. Bridge
31861	211.00	1165.0	1165.0	1162.8	
31871	211.10	1165.0	1165.0	1162.9	
32051	212.00	1165.1	1165.1	1163.0	
32261	213.00	1165.3	1165.3	1163.2	
32461	214.00	1165.6	1165.6	1163.4	
32656	215.00	1165.7	1165.7	1163.7	
32856	216.00	1165.8	1165.8	1164.0	
33057	217.00	1166.3	1166.3	1164.3	
33455	218.00	1166.6	1166.6	1164.8	
33855	219.00	1167.2	1167.2	1165.4	
34255	220.00	1167.7	1167.7	1166.0	Indian Bend Wash
34658	221.00	1168.1	1168.1	1166.7	
35058	222.00	1168.6	1168.6	1167.9	
35457	223.00	1168.6	1168.6	1169.1	
35856	224.00	1169.9	1169.9	1170.2	Sun Angel Golf Course
36263	225.00	1170.5	1170.5	1171.0	

TABLE 2. (Continued)

PROJECT STATION (ft)	CROSS-SECTION NUMBER	WATER SURFACE ELEVATIONS (ft) EXISTING CONDITION	MODIFIED BASELINE CONDITION	COE BFE	PHYSICAL FEATURE
36660	226.00	1171.3	1171.3	1171.8	
37027	227.10	1171.8	1171.8	1172.5	Hayden Road Bridge
37116	227.40	1171.8	1171.8	1172.6	
37436	228.00	1173.8	1173.8	1172.8	
37836	229.00	1175.1	1174.9	1173.2	
38236	230.00	1175.1	1175.0	1173.5	
38635	231.00	1175.0	1175.0	1173.8	
39042	232.00	1175.2	1175.4	1174.1	
39444	233.00	1175.8	1177.3	1175.0	
39840	234.00	1175.8	1177.3	1176.7	
40246	235.00	1177.4	1179.4	1178.3	
40647	236.00	1178.2	1180.1	1179.5	Old Tempe Landfill
41043	237.00	1178.6	1180.4	1180.3	
41553	238.00	1178.7	1180.9	1181.3	
42018	239.00	1178.7	1181.0	1181.8	
42568	240.00	1179.3	1181.5	1182.3	Outer Loop Highway
43073	241.00	1179.8	1182.0	1182.6	
43588	242.00	1180.4	1182.5	1183.1	
44058	243.00	1180.7	1182.7	1183.5	
44528	244.00	1180.7	1182.7	1184.0	
45078	245.00	1180.9	1182.9	1184.5	
45693	246.00	1181.2	1183.1	1185.4	Evergreen Road
46197	247.00	1181.2	1183.1	1186.4	
46736	248.00	1182.0	1183.7	1187.6	
47237	249.00	1182.1	1183.8	1188.6	
47757	250.00	1182.2	1183.9	1189.6	
48364	251.00	1182.2	1183.9	1190.8	
48862	252.00	1182.8	1184.5	1191.6	Dobson Road
49506	253.00	1184.7	1185.8	1192.6	
49980	254.00	1184.7	1185.9	1193.3	
50487	255.00	1187.2	1189.7	1194.0	
50957	256.00	1189.1	1191.5	1194.5	
51491	257.00	1189.1	1191.5	1195.0	
51910	258.00	1190.7	1192.6	1195.9	
52496	259.00	1192.2	1194.3	1197.3	
53001	260.00	1193.8	1195.3	1198.8	
53445	261.00	1194.4	1195.9	1200.2	
53954	262.00	1194.4	1195.9	1201.3	
54478	263.00	1194.2	1196.9	1201.8	
55034	264.00	1195.5	1198.2	1202.3	
55471	265.00	1198.9	1199.6	1202.6	Alma School Road

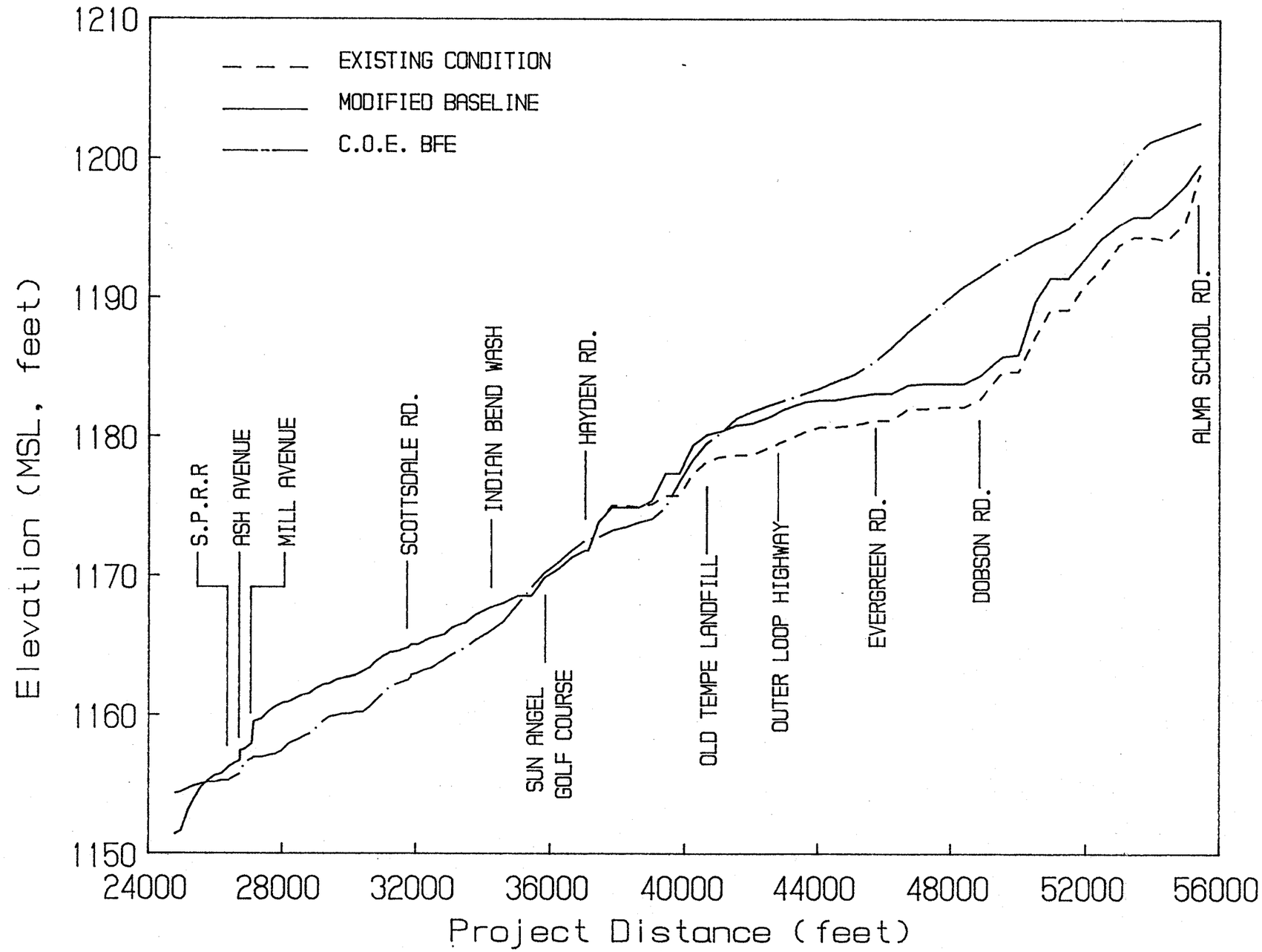


Figure 4. Water Surface Profiles for Existing, Baseline, and BFE Conditions, 100-Year Event

the Salt River, each column was assumed to be exposed to the flow under concept conditions. The effect of skew on the bridge hydraulics at both the East Papago crossing of Indian Bend Wash and the Outer Loop crossing of the Salt River was minimized due to the smaller skew angles at the respective sites. This allowed for the assumption that the piers would be aligned to the flow at these locations.

Water-surface profiles were computed for the 10- and 100-year peak discharges for baseline conditions and concept conditions. The hydraulic results for the study reach are presented in Table 3 for the 10-year event and Table 4 for the 100-year event. The results presented in these tables are for proposed bridges having 130-foot spans and piers with 6-foot diameter columns, 3-columns per structure for both the East Papago and Outer Loop crossing of the Salt River. Figure 5 provides plots of the water-surface profiles for the 100-year event. Computed differences between concept conditions and baseline conditions for both water-surface elevations and average velocities are presented in Table 5 for the 100-year event. The results show a maximum increase in water-surface elevation of 1.9 feet, which occurs at the upstream face of Hayden Road. This increase is due to the assumed configuration of the East Papago freeway crossing, which may be changed in the final design. The increase in water surface is less than 0.1 feet at the next upstream cross section, and obtains a maximum increase of 0.64 feet upstream of this location at cross section 231.00. Upstream of section 231.00, there are actual drops in the water-surface elevation due to some channel improvement that is planned in conjunction with the project. It was assumed that the extent of channel improvement is constrained by the Indian boundary on the north side of the river. The maximum increase in average velocity is 5.8 feet per second which occurs immediately north of the Old Tempe Landfill.

The results of the water-surface-profile calculations for Indian Bend Wash are given in Table 6 for both baseline and concept conditions. The downstream water-surface elevations were set equal to those occurring on the Salt River at peak discharge. Although conservative, the results are almost identical to those that would result if a coincident-peak analysis were performed, since the water-surface elevations for the area of interest are dominated by the effects from the Salt River. In the hydraulic anlaysis used for analyzing pier scour, no contributing flow from the Salt River was used as the downstream condition.

TABLE 3. Hydraulic Information for Baseline and Concept Conditions, 10-Year Event

		----- BASELINE CONDITION -----				----- CONCEPT CONDITION -----				
PROJECT STATION (ft)	CROSS-SECTION NUMBER	CALCULATED WATER SURFACE ELEV. (ft)	HYDRAULIC DEPTH (ft)	CHANNEL VELOCITY (fps)	TOPWIDTH (ft)	CALCULATED WATER SURFACE ELEV. (ft)	HYDRAULIC DEPTH (ft)	CHANNEL VELOCITY (fps)	TOPWIDTH (ft)	PHYSICAL FEATURE
24800	24800	1144.4	10.6	9.9	889	1144.4	10.6	9.9	889	Grade Control No. 4
25000	25000	1144.7	9.3	11.0	908	1144.7	9.3	11.0	908	
25200	25200	1145.7	9.1	9.9	1032	1145.7	9.1	9.9	1032	
25400	25400	1146.6	9.3	8.6	1157	1146.6	9.3	8.6	1157	
25600	25600	1147.2	9.3	7.8	1280	1147.2	9.3	7.8	1280	
25800	25800	1147.7	8.9	7.3	1437	1147.7	8.9	7.3	1437	
26000	26000	1148.1	8.8	6.8	1563	1148.1	8.8	6.8	1563	
26200	26200	1148.3	8.7	7.2	1482	1148.3	8.7	7.2	1482	
26380	182.10	1148.7	8.8	7.2	1460	1148.7	8.8	7.2	1460	S.P.R.R. Bridge
26396	182.20	1148.9	9.0	7.1	1465	1148.9	9.0	7.1	1465	
26575	183.50	1149.2	9.9	7.1	1321	1149.2	9.9	7.1	1321	
26750	184.10	1149.5	10.4	7.1	1259	1149.5	10.4	7.1	1259	Ash Ave. Bridge
26770	184.20	1149.9	10.7	6.8	1272	1149.9	10.7	6.8	1272	
26930	185.50	1150.1	10.1	8.0	1148	1150.1	10.1	8.0	1148	
27090	186.10	1150.6	10.9	7.2	1185	1150.6	10.9	7.2	1185	Mill Ave. Bridge
27138	186.20	1151.5	11.6	6.7	1200	1151.5	11.6	6.7	1200	
27418	188.00	1151.8	11.6	7.5	1072	1151.8	11.6	7.5	1072	
27613	189.00	1152.2	12.2	6.9	1187	1152.2	12.2	6.9	1187	
27814	190.00	1152.5	12.6	6.6	1387	1152.5	12.6	6.6	1387	
28014	191.00	1152.7	12.2	6.6	1362	1152.7	12.2	6.6	1362	
28215	192.00	1153.0	12.0	6.3	1330	1153.0	12.0	6.3	1330	
28410	193.00	1153.2	11.5	6.5	1329	1153.2	11.5	6.5	1329	
28610	194.00	1153.4	11.7	6.3	1265	1153.4	11.7	6.3	1265	
28830	195.00	1153.7	11.6	6.2	1291	1153.7	11.6	6.2	1291	
29022	196.00	1153.9	11.6	6.0	1331	1153.9	11.6	6.0	1331	
29233	197.00	1154.1	10.8	6.0	1440	1154.1	10.8	6.0	1440	
29438	198.00	1154.4	10.3	6.2	1455	1154.4	10.3	6.2	1455	
29631	199.00	1154.6	9.5	6.2	1574	1154.6	9.5	6.2	1574	
29836	200.00	1154.9	9.3	6.4	1569	1154.9	9.3	6.4	1569	
30035	201.00	1155.2	9.4	6.7	1493	1155.2	9.4	6.7	1493	
30236	202.00	1155.4	10.2	7.0	1303	1155.4	10.2	7.0	1303	Sun Devil Stadium
30437	203.00	1155.8	10.3	7.0	1281	1155.8	10.3	7.0	1281	
30633	204.00	1156.1	9.9	7.1	1323	1156.1	9.9	7.1	1323	
30830	205.00	1156.4	9.7	7.2	1388	1156.4	9.7	7.2	1388	
31035	206.00	1156.8	9.8	6.9	1375	1156.8	9.8	6.9	1375	
31241	207.00	1157.3	10.5	6.4	1400	1157.3	10.5	6.4	1400	
31471	208.00	1157.6	10.5	6.2	1422	1157.6	10.5	6.2	1422	
31756	210.00	1158.0	12.6	5.7	1290	1158.0	12.6	5.7	1290	
31766	210.10	1158.0	12.6	6.0	1240	1158.0	12.6	6.0	1240	Scottsdale Rd. Bridge
31861	211.00	1158.1	12.7	5.9	1240	1158.1	12.7	5.9	1240	
31871	211.10	1158.2	12.8	5.6	1291	1158.2	12.8	5.6	1291	
32051	212.00	1158.3	11.4	5.9	1390	1158.3	11.4	5.9	1390	
32261	213.00	1158.5	9.3	6.4	1553	1158.5	9.3	6.4	1553	
32461	214.00	1158.9	10.3	5.8	1566	1158.9	10.3	5.8	1566	
32656	215.00	1159.0	10.7	6.1	1447	1159.0	10.7	6.1	1447	
32856	216.00	1159.2	9.0	7.1	1465	1159.2	9.0	7.1	1465	
33057	217.00	1159.6	8.4	7.1	1569	1159.6	8.4	7.1	1569	
33455	218.00	1160.5	8.7	6.4	1756	1160.5	8.7	6.4	1756	
33855	219.00	1161.2	8.7	6.0	1866	1161.2	8.7	6.0	1866	
34255	220.00	1161.8	8.9	5.5	1892	1161.8	9.0	5.6	1858	Indian Bend Wash
34658	221.00	1162.3	10.4	6.1	2160	1162.2	10.3	6.5	1691	
35058	222.00	1162.7	9.7	6.5	1501	1162.8	9.7	6.5	1502	

TABLE 3. (Continued)

PROJECT STATION (ft)	CROSS-SECTION NUMBER	BASELINE CONDITION: CALCULATED WATER SURFACE ELEV. (ft)	BASELINE CONDITION: HYDRAULIC DEPTH (ft)	BASELINE CONDITION: CHANNEL VELOCITY (fps)	BASELINE CONDITION: TOPWIDTH (ft)	CONCEPT CONDITION: CALCULATED WATER SURFACE ELEV. (ft)	CONCEPT CONDITION: HYDRAULIC DEPTH (ft)	CONCEPT CONDITION: CHANNEL VELOCITY (fps)	CONCEPT CONDITION: TOPWIDTH (ft)	PHYSICAL FEATURE
35457	223.00	1163.2	9.6	7.5	1351	1163.3	9.7	7.5	1351	
35856	224.00	1164.0	11.1	7.2	1630	1164.0	11.1	7.2	1315	Sun Angel Golf Course
36263	225.00	1164.5	11.7	7.7	1277	1164.6	11.7	7.8	1105	
36660	226.00	1165.2	11.6	7.8	1404	1165.3	11.7	8.1	1306	
37027	227.10	1165.9	11.8	7.2	1095	1166.2	15.2	5.6	1097	Hayden Road Bridge
37116	227.40	1166.1	9.3	9.1	1097	1166.3	15.3	5.6	1098	
37436	228.00	1167.3	12.2	7.9	1381	1166.4	15.9	5.3	1106	
37836	229.00	1168.2	16.8	5.1	1095	1167.0	16.5	5.0	1138	
38236	230.00	1168.3	16.3	5.7	995	1167.1	16.7	5.2	1072	
38635	231.00	1168.3	15.8	8.2	720	1167.3	16.7	5.4	1033	
39042	232.00	1168.7	16.3	8.4	680	1167.5	16.7	5.4	1025	
39444	233.00	1169.6	17.9	6.1	858	1167.6	16.6	6.8	830	
39840	234.00	1169.6	14.4	10.8	599	1167.8	15.0	8.2	758	
40246	235.00	1170.9	15.6	7.0	1060	1168.1	15.3	9.6	633	
40647	236.00	1171.4	17.5	5.8	1106	1168.8	14.6	10.3	618	Old Tempe Landfill
41043	237.00	1171.7	17.3	5.5	1158	1169.9	14.7	9.5	669	
41553	238.00	1172.0	18.2	4.8	1140	1171.3	19.1	5.0	1116	
42018	239.00	1172.1	13.2	5.8	1236	1171.5	17.8	5.0	1068	
42568	240.00	1172.5	17.4	5.2	1133	1171.8	20.3	4.0	1187	Outer Loop Highway
43073	241.00	1172.8	14.8	4.7	1391	1171.9	20.3	4.0	1187	
43588	242.00	1173.1	16.6	3.4	1893	1172.1	15.7	3.7	1623	
44058	243.00	1173.2	17.2	2.6	2213	1172.3	16.8	2.8	1997	
44528	244.00	1173.3	12.2	3.4	2283	1172.3	11.7	4.0	2010	
45078	245.00	1173.4	11.6	3.9	2096	1172.5	11.1	4.7	1826	
45693	246.00	1173.7	11.0	3.5	2487	1173.0	11.2	3.7	2291	Evergreen Road
46197	247.00	1173.7	9.9	6.5	1485	1173.0	9.8	7.0	1391	
46736	248.00	1174.6	12.3	3.2	2448	1174.0	11.8	3.3	2444	
47237	249.00	1174.7	12.7	3.2	2321	1174.1	12.6	3.3	2289	
47757	250.00	1174.8	12.3	4.0	1969	1174.2	12.0	4.1	1927	
48364	251.00	1174.8	13.2	7.1	1022	1174.3	12.7	7.4	1013	
48862	252.00	1175.5	8.0	9.0	1336	1175.0	7.7	9.5	1308	Dobson Road
49506	253.00	1178.4	5.9	8.9	1831	1178.4	5.9	8.9	1824	
49980	254.00	1180.2	9.7	11.4	866	1180.2	9.7	11.4	866	
50487	255.00	1182.5	14.6	8.4	778	1182.5	14.6	8.4	778	
50957	256.00	1183.6	14.0	5.4	1259	1183.6	14.0	5.4	1259	
51491	257.00	1183.6	9.0	10.4	1024	1183.6	9.0	10.4	1024	
51910	258.00	1185.4	10.7	8.1	1108	1185.4	10.7	8.1	1108	
52496	259.00	1186.8	9.1	7.4	1433	1186.8	9.1	7.4	1433	
53001	260.00	1187.9	10.9	5.6	1380	1187.9	10.9	5.6	1380	
53445	261.00	1188.3	13.3	4.6	1562	1188.3	13.3	4.6	1562	
53954	262.00	1188.3	9.5	10.7	1179	1188.3	9.5	10.7	1179	
54478	263.00	1190.2	6.7	12.0	1694	1190.2	6.7	12.0	1694	
55034	264.00	1193.5	7.7	9.0	1754	1193.5	7.7	9.0	1754	
55471	265.00	1194.8	8.8	7.8	1716	1194.8	8.8	7.8	1716	Alma School Road

TABLE 4. Hydraulic Information for Baseline and Concept Conditions, 100-Year Event

		----- BASELINE CONDITION -----				----- CONCEPT CONDITION -----				
PROJECT STATION (ft)	CROSS-SECTION NUMBER	CALCULATED WATER SURFACE ELEV. (ft)	HYDRAULIC DEPTH (ft)	CHANNEL VELOCITY (fps)	TOPWIDTH (ft)	CALCULATED WATER SURFACE ELEV. (ft)	HYDRAULIC DEPTH (ft)	CHANNEL VELOCITY (fps)	TOPWIDTH (ft)	PHYSICAL FEATURE
24800	24800	1151.5	16.9	13.5	943	1151.5	16.9	13.5	943	Grade Control No. 4
25000	25000	1151.7	16.0	14.4	929	1151.7	16.0	14.4	929	
25200	25200	1153.1	16.2	12.6	1054	1153.1	16.2	12.6	1054	
25400	25400	1154.1	16.6	11.0	1179	1154.1	16.6	11.0	1179	
25600	25600	1154.8	16.6	9.9	1302	1154.8	16.6	9.9	1302	
25800	25800	1155.3	16.4	9.1	1448	1155.3	16.4	9.1	1448	
26000	26000	1155.7	16.2	8.4	1585	1155.7	16.2	8.4	1585	
26200	26200	1155.8	15.4	8.6	1619	1155.8	15.4	8.6	1619	
26380	182.10	1156.1	14.8	8.8	1657	1156.1	14.8	8.8	1657	S.P.R.R. Bridge
26396	182.20	1156.3	15.0	8.7	1658	1156.3	15.0	8.7	1658	
26575	183.50	1156.5	15.5	9.0	1538	1156.5	15.5	9.0	1538	
26750	184.10	1156.8	16.4	9.3	1402	1156.8	16.4	9.3	1402	Ash Ave. Bridge
26770	184.20	1157.5	17.1	9.0	1408	1157.5	17.1	9.0	1408	
26930	185.50	1157.6	15.7	10.1	1361	1157.6	15.7	10.1	1361	
27090	186.10	1158.0	17.0	9.8	1298	1158.0	17.0	9.8	1298	Mill Ave. Bridge
27138	186.20	1159.5	18.3	8.9	1318	1159.5	18.3	8.9	1318	
27418	188.00	1159.8	14.8	9.5	1869	1159.8	14.8	9.8	1480	
27613	189.00	1160.2	20.2	9.0	1967	1160.2	20.2	9.2	1550	
27814	190.00	1160.6	20.7	8.6	1780	1160.7	20.8	8.5	1780	
28014	191.00	1160.8	20.3	8.3	2147	1160.9	20.4	8.5	1831	
28215	192.00	1161.0	20.0	8.1	1949	1161.1	20.0	8.3	1664	
28410	193.00	1161.2	19.6	8.2	1944	1161.2	19.6	8.3	1688	
28610	194.00	1161.4	19.4	8.1	1853	1161.4	19.4	8.3	1638	
28830	195.00	1161.6	19.1	8.0	1989	1161.7	19.2	8.1	1729	
29022	196.00	1161.9	19.2	7.7	2236	1161.9	19.3	7.8	1751	
29233	197.00	1162.2	18.6	7.2	2623	1162.2	18.7	7.4	2117	
29438	198.00	1162.3	17.7	7.3	2653	1162.4	17.8	7.5	2189	
29631	199.00	1162.5	16.8	7.3	2615	1162.6	16.8	7.4	2195	
29836	200.00	1162.6	16.2	7.5	2626	1162.7	16.3	7.6	2227	
30035	201.00	1162.8	16.1	7.8	2826	1162.9	16.2	7.8	2446	
30236	202.00	1162.9	16.6	8.3	2999	1163.1	16.8	8.4	2538	Sun Devil Stadium
30437	203.00	1163.1	16.8	8.7	2992	1163.2	16.9	8.7	2545	
30633	204.00	1163.4	17.1	8.6	3729	1163.5	17.1	8.7	2769	
30830	205.00	1163.9	17.2	7.9	4414	1163.9	17.2	8.5	3326	
31035	206.00	1164.2	17.1	7.5	5028	1164.3	17.2	7.7	3872	
31241	207.00	1164.4	16.4	7.3	5207	1164.6	16.6	7.4	4034	
31471	208.00	1164.6	16.6	7.2	5650	1164.8	16.8	7.5	4429	
31756	210.00	1164.8	19.0	7.5	5486	1164.9	19.1	8.0	4034	
31766	210.10	1164.8	18.2	7.6	5439	1164.9	18.3	8.2	3985	Scottsdale Rd. Bridge
31861	211.00	1165.0	18.4	7.4	5489	1165.1	18.5	8.1	4050	
31871	211.10	1165.0	19.1	7.4	5542	1165.2	19.3	7.8	4120	
32051	212.00	1165.1	17.5	7.4	5378	1165.5	17.9	7.5	4039	
32261	213.00	1165.3	15.8	7.5	5318	1165.7	16.1	7.4	4637	
32461	214.00	1165.6	16.6	7.1	5108	1165.9	16.9	7.0	4467	
32656	215.00	1165.7	17.4	7.4	6130	1166.0	17.7	7.6	4629	
32856	216.00	1165.8	15.6	8.2	5485	1166.2	16.0	8.1	4338	
33057	217.00	1166.3	14.3	7.4	5278	1166.6	14.6	7.4	4356	
33455	218.00	1166.6	14.8	8.0	3672	1166.9	15.1	8.1	3020	
33855	219.00	1167.2	14.6	7.8	2961	1167.5	14.9	7.7	2399	
34255	220.00	1167.7	14.6	7.4	2784	1168.0	14.7	7.4	2194	Indian Bend Wash

TABLE 4. (Continued)

PROJECT STATION (ft)	CROSS-SECTION NUMBER	BASELINE CONDITION CALCULATED WATER SURFACE ELEV. (ft)	BASELINE CONDITION HYDRAULIC DEPTH (ft)	BASELINE CONDITION CHANNEL VELOCITY (fps)	BASELINE CONDITION TOPWIDTH (ft)	CONCEPT CONDITION CALCULATED WATER SURFACE ELEV. (ft)	CONCEPT CONDITION HYDRAULIC DEPTH (ft)	CONCEPT CONDITION CHANNEL VELOCITY (fps)	CONCEPT CONDITION TOPWIDTH (ft)	PHYSICAL FEATURE
34658	221.00	1168.1	16.2	8.1	2568	1168.3	16.3	8.9	1963	
35058	222.00	1168.6	15.5	8.1	2382	1168.8	15.6	9.1	1753	
35457	223.00	1168.6	15.0	11.1	1366	1169.2	15.5	10.7	1368	
35856	224.00	1169.9	16.9	10.1	2099	1170.1	17.1	10.5	1364	Sun Angel Golf Course
36263	225.00	1170.5	17.6	10.6	2180	1170.7	17.8	11.2	1231	
36660	226.00	1171.3	17.6	10.7	2252	1171.5	17.9	11.3	1318	
37027	227.10	1171.8	17.1	11.0	1571	1173.0	21.2	8.8	1784	Hayden Road Bridge
37116	227.40	1171.8	14.2	13.2	1496	1173.7	21.9	8.4	1871	
37436	228.00	1173.8	18.7	10.5	2426	1173.8	22.8	8.3	1135	
37836	229.00	1174.9	22.7	7.7	2430	1175.0	24.0	7.7	1170	
38236	230.00	1175.0	22.6	8.7	2655	1175.5	22.4	7.4	2745	
38635	231.00	1175.0	21.3	12.8	2059	1175.7	24.9	8.0	2652	
39042	232.00	1175.4	22.8	13.0	2093	1175.9	24.7	8.0	2688	
39444	233.00	1177.3	15.4	9.1	2311	1175.9	23.9	9.7	1600	
39840	234.00	1177.3	20.2	16.0	1322	1176.0	22.4	11.7	1471	
40246	235.00	1179.4	24.0	9.8	2444	1176.2	23.1	13.9	1390	
40647	236.00	1180.1	26.1	8.5	2730	1177.0	22.0	14.3	1231	Old Tempe Landfill
41043	237.00	1180.4	26.0	8.0	2234	1178.4	22.8	13.1	1163	
41553	238.00	1180.9	26.4	7.4	1497	1180.7	28.4	7.5	1487	
42018	239.00	1181.0	17.2	8.4	1447	1181.0	23.2	7.4	1512	
42568	240.00	1181.5	26.1	7.6	1492	1181.7	21.4	5.5	1885	Outer Loop Highway
43073	241.00	1182.0	23.9	6.5	1855	1181.9	21.5	5.4	1886	
43588	242.00	1182.5	26.0	4.8	2326	1182.1	25.6	5.1	2133	
44058	243.00	1182.7	26.7	3.8	2483	1182.4	26.5	4.0	2245	
44528	244.00	1182.7	20.1	4.3	2536	1182.4	19.9	4.8	2286	
45078	245.00	1182.9	17.0	4.5	2872	1182.6	16.7	5.1	2584	
45693	246.00	1183.1	17.7	3.9	3152	1182.9	17.6	4.0	3149	Evergreen Road
46197	247.00	1183.1	14.3	6.5	2395	1182.9	14.1	6.5	2410	
46736	248.00	1183.7	17.7	3.9	3188	1183.6	17.7	3.9	3184	
47237	249.00	1183.8	20.1	4.2	2603	1183.7	20.4	4.2	2581	
47757	250.00	1183.9	18.3	4.9	2463	1183.8	18.2	4.9	2460	
48364	251.00	1183.9	13.8	8.6	1865	1183.8	13.6	8.7	1864	
48862	252.00	1184.5	15.6	9.0	1562	1184.4	15.5	9.1	1561	Dobson Road
49506	253.00	1185.8	12.2	8.5	2124	1185.7	12.1	8.6	2123	
49980	254.00	1185.9	9.7	14.5	1563	1185.8	9.7	14.6	1555	
50487	255.00	1189.7	12.8	11.1	1541	1189.7	12.8	11.1	1541	
50957	256.00	1191.5	18.4	7.5	1586	1191.5	18.4	7.5	1586	
51491	257.00	1191.5	13.2	11.2	1496	1191.5	13.2	11.2	1496	
51910	258.00	1192.6	17.3	11.0	1162	1192.6	17.2	11.0	1162	
52496	259.00	1194.3	15.5	9.1	1565	1194.3	15.5	9.1	1565	
53001	260.00	1195.3	17.8	8.0	1662	1195.3	17.8	8.0	1662	
53445	261.00	1195.9	20.9	6.9	2069	1195.9	20.9	6.9	2069	
53954	262.00	1195.9	17.2	11.7	1820	1195.9	17.2	11.7	1820	
54478	263.00	1196.9	13.1	11.7	2145	1196.9	13.1	11.7	2144	
55034	264.00	1198.2	12.2	12.2	1871	1198.2	12.2	12.2	1871	
55471	265.00	1199.6	13.4	11.0	2008	1199.6	13.4	11.0	2008	Alma School Road

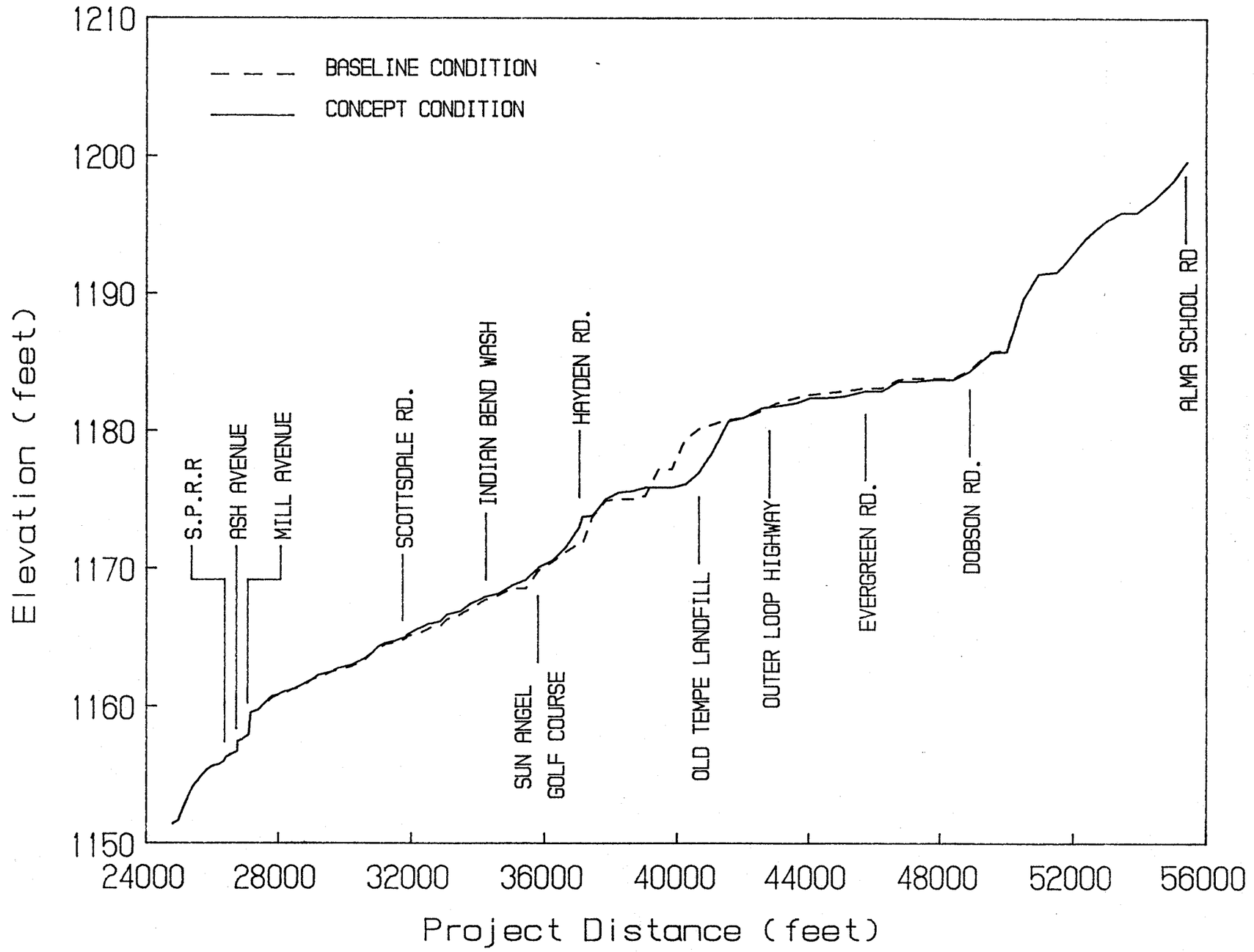


Figure 5. Water Surface Profiles for Baseline and Concept Conditions, 100-Year Event

TABLE 5. Water Surface Elevations and Velocity Comparisons, Concept Minus Baseline Conditions, 100-Year Event

PROJECT STATION (feet)	CROSS-SECTION NUMBER	WATER SURFACE ELEVATION (feet)	CHANNEL VELOCITY (ft/sec)	PHYSICAL FEATURE
24800	24800	.0	.0	Grade Control No. 4
25000	25000	.0	.0	
25200	25200	.0	.0	
25400	25400	.0	.0	
25600	25600	.0	.0	
25800	25800	.0	.0	
26000	26000	.0	.0	
26200	26200	.0	.0	
26380	182.10	.0	.0	S.P.R.R. Bridge
26396	182.20	.0	.0	
26575	183.50	.0	.0	
26750	184.10	.0	.0	Ash Ave. Bridge
26770	184.20	.0	.0	
26930	185.50	.0	.0	
27090	186.10	.0	.0	Mill Ave. Bridge
27138	186.20	.0	.0	
27418	188.00	.0	.3	
27613	189.00	.0	.2	
27814	190.00	.1	-.1	
28014	191.00	.1	.2	
28215	192.00	.1	.2	
28410	193.00	.0	.1	
28610	194.00	.0	.2	
28830	195.00	.1	.1	
29022	196.00	.0	.1	
29233	197.00	.0	.2	
29438	198.00	.1	.2	
29631	199.00	.1	.1	
29836	200.00	.1	.1	
30035	201.00	.1	.0	
30236	202.00	.2	.1	Sun Devil Stadium
30437	203.00	.1	.0	
30633	204.00	.1	.1	
30830	205.00	.0	.6	
31035	206.00	.1	.2	
31241	207.00	.2	.1	
31471	208.00	.2	.3	
31756	210.00	.1	.5	
31766	210.10	.1	.6	Scottsdale Rd. Bridge
31861	211.00	.1	.7	
31871	211.10	.2	.4	
32051	212.00	.4	.1	
32261	213.00	.4	-.1	
32461	214.00	.3	-.1	
32656	215.00	.3	.2	
32856	216.00	.4	-.1	
33057	217.00	.3	.0	
33455	218.00	.3	.1	
33855	219.00	.3	-.1	
34255	220.00	.3	.0	Indian Bend Wash
34658	221.00	.2	.8	

TABLE 5. (Continued)

PROJECT STATION (feet)	CROSS-SECTION NUMBER	WATER SURFACE ELEVATION (feet)	CHANNEL VELOCITY (ft/sec)	PHYSICAL FEATURE
35058	222.00	.2	1.0	
35457	223.00	.6	-.4	
35856	224.00	.2	.4	Sun Angel Golf Course
36263	225.00	.2	.6	
36660	226.00	.2	.6	
37027	227.10	1.2	-2.2	Hayden Road Bridge
37116	227.40	1.9	-4.8	
37436	228.00	.0	-2.2	
37836	229.00	.1	.0	
38236	230.00	.5	-1.3	
38635	231.00	.7	-4.8	
39042	232.00	.5	-5.0	
39444	233.00	-1.4	.6	
39840	234.00	-1.3	-4.3	
40246	235.00	-3.2	4.1	
40647	236.00	-3.1	5.8	Old Tempe Landfill
41043	237.00	-2.0	5.1	
41553	238.00	-.2	.1	
42018	239.00	.0	-1.0	
42568	240.00	.2	-2.1	Outer Loop Highway
43073	241.00	-.1	-1.1	
43588	242.00	-.4	.3	
44058	243.00	-.3	.2	
44528	244.00	-.3	.5	
45078	245.00	-.3	.6	
45693	246.00	-.2	.1	Evergreen Road
46197	247.00	-.2	.0	
46736	248.00	-.1	.0	
47237	249.00	-.1	.0	
47757	250.00	-.1	.0	
48364	251.00	-.1	.1	
48862	252.00	-.1	.1	Dobson Road
49506	253.00	-.1	.1	
49980	254.00	-.1	.1	
50487	255.00	.0	.0	
50957	256.00	.0	.0	
51491	257.00	.0	.0	
51910	258.00	.0	.0	
52496	259.00	.0	.0	
53001	260.00	.0	.0	
53445	261.00	.0	.0	
53954	262.00	.0	.0	
54478	263.00	.0	.0	
55034	264.00	.0	.0	
55471	265.00	.0	.0	Alma School Road

TABLE 6. Water Surface Elevations for Indian Bend Wash, 100-Year Event

Cross-Section Number	Project Distance[1] (ft)	Calculated Water Surface Elevation (ft) Baseline	Concept
100.000	0.	1167.7	1168.0
200.000	360.	1167.8	1168.1
201.000	570.	1168.0	1168.1
300.000	930.	1168.3	1168.4

1 Project distance 0.0 is the confluence of the Salt River and Indian Bend Wash. Cross-sections 200 and 201 are the upstream and downstream faces of the modeled structure, respectively.

To aid in the bridge design selection, alternative bridge configurations were analyzed for the East Papago crossing of the Salt River. The alternatives analyzed were as follows:

1. 130-foot spans and piers with 6-foot diameter columns, 3-columns per structure. Piers aligned to flow.
2. 130-foot spans and piers with 6-foot diameter columns, 3-columns per structure. Each column exposed to flow.
3. 200-foot spans and piers with 6-foot diameter columns, 3-columns per structure. Each column exposed to flow.
4. 200-foot spans and piers with 8-foot diameter columns, 2-columns per structure. Each column exposed to flow.
5. 200-foot spans and piers with 10-foot diameter columns, 2-columns per structure. Each column exposed to flow.
6. 200-foot spans and piers with 15-foot diameter columns, 1-column per structure. Each column exposed to flow.
7. 245-foot span over Hayden Road and piers with 10-foot diameter columns, 2-columns per structure; 200-foot spans on each end of 245-foot span and piers with 8-foot columns, 2-columns per structure; and 130-foot spans for the remaining spans and piers with 6-foot diameter columns, 3-columns per structure. Each column exposed to flow.

For the alternatives having 130-foot spans and piers with 6-foot diameter columns, analyses were conducted for aligning the bridge piers to the flow at both the East Papago and Outer Loop bridge crossings (alternative 1) and for skewing the piers sufficiently to expose each column to the flow at both crossings (alternative 2). The Outer Loop bridge was assumed to have 130-foot spans and piers with 6-foot diameter columns, 3-columns per structure in each case. Except for alternative 2, the bridge piers for the Outer Loop bridge were assumed to be aligned to flow.

The 100-year water surface elevations for the seven alternative bridge configurations described above are presented in Table 7. The computed elevations are given in hundredths of a foot only to provide a relative comparison of the various alternatives.

TABLE 7. Water Surface Elevations for Salt River Bridge Alternatives, 100-Year Event

PROJECT STATION (feet)	CROSS-SECTION NUMBER	WATER SURFACE ELEVATIONS (ft) ---------- ALTERNATIVE NUMBER ---------- 1	2	3	4	5	6	7	PHYSICAL FEATURE
36263	225.00	1170.65	1170.65	1170.65	1170.65	1170.65	1170.65	1170.65	
36660	226.00	1171.52	1171.52	1171.52	1171.52	1171.52	1171.52	1171.52	
37027	227.10	1172.68	1172.97	1172.94	1172.91	1172.97	1172.90	1172.96	Hayden Road Bridge
37116	227.40	1173.47	1173.73	1173.70	1173.67	1173.72	1173.66	1173.72	
37436	228.00	1173.56	1173.80	1174.42	1174.38	1174.46	1174.36	1174.26	
37836	229.00	1174.32	1175.03	1174.94	1174.88	1175.00	1174.85	1174.96	
38236	230.00	1174.68	1175.51	1175.35	1175.28	1175.42	1175.25	1175.32	
38635	231.00	1174.86	1175.66	1175.50	1175.43	1175.57	1175.40	1175.48	
39042	232.00	1175.16	1175.92	1175.77	1175.71	1175.84	1175.67	1175.75	
39444	233.00	1175.19	1175.93	1175.78	1175.72	1175.85	1175.69	1175.76	
39840	234.00	1175.25	1175.96	1175.82	1175.76	1175.88	1175.73	1175.80	
40246	235.00	1175.49	1176.15	1176.02	1175.96	1176.08	1175.93	1176.00	
40647	236.00	1176.45	1176.99	1176.89	1176.84	1176.93	1176.82	1176.87	Old Tempe Landfill
41043	237.00	1178.04	1178.40	1178.33	1178.29	1178.36	1178.28	1178.31	
41553	238.00	1180.45	1180.69	1180.64	1180.62	1180.67	1180.61	1180.64	
42018	239.00	1180.74	1180.97	1180.92	1180.90	1180.94	1180.89	1180.92	
42568	240.00	1181.44	1181.66	1181.61	1181.60	1181.63	1181.59	1181.61	Outer Loop Highway
43073	241.00	1181.64	1182.13	1181.81	1181.79	1181.83	1181.78	1181.80	
43588	242.00	1181.89	1182.49	1182.06	1182.04	1182.07	1182.03	1182.05	
44058	243.00	1182.15	1182.73	1182.30	1182.29	1182.32	1182.28	1182.30	
44528	244.00	1182.17	1182.75	1182.33	1182.31	1182.35	1182.30	1182.32	
45078	245.00	1182.36	1182.92	1182.51	1182.50	1182.53	1182.49	1182.51	
45693	246.00	1182.76	1183.29	1182.91	1182.89	1182.92	1182.88	1182.90	Evergreen Road
46197	247.00	1182.76	1183.29	1182.84	1182.83	1182.86	1182.82	1182.84	
46736	248.00	1183.41	1183.88	1183.54	1183.52	1183.55	1183.52	1183.53	
47237	249.00	1183.51	1183.97	1183.64	1183.62	1183.65	1183.61	1183.63	
47757	250.00	1183.60	1184.04	1183.72	1183.70	1183.73	1183.70	1183.71	
48364	251.00	1183.60	1184.04	1183.59	1183.57	1183.60	1183.57	1183.58	
48862	252.00	1184.24	1184.61	1184.34	1184.33	1184.35	1184.32	1184.33	Dobson Road
49506	253.00	1185.57	1185.84	1185.64	1185.64	1185.65	1185.63	1185.64	
49980	254.00	1185.69	1185.93	1185.75	1185.75	1185.76	1185.74	1185.75	
50487	255.00	1189.66	1189.65	1189.66	1189.66	1189.66	1189.66	1189.66	
50957	256.00	1191.50	1191.50	1191.50	1191.50	1191.50	1191.50	1191.50	
51491	257.00	1191.54	1191.54	1191.54	1191.54	1191.54	1191.54	1191.54	
51910	258.00	1192.60	1192.60	1192.60	1192.60	1192.60	1192.60	1192.60	
52496	259.00	1194.29	1194.29	1194.29	1194.29	1194.29	1194.29	1194.29	
53001	260.00	1195.32	1195.32	1195.32	1195.32	1195.32	1195.32	1195.32	
53445	261.00	1195.94	1195.94	1195.94	1195.94	1195.94	1195.94	1195.94	
53954	262.00	1195.94	1195.94	1195.56	1195.56	1195.56	1195.56	1195.56	
54478	263.00	1196.87	1196.87	1196.87	1196.87	1196.87	1196.87	1196.87	
55034	264.00	1198.20	1198.20	1198.20	1198.20	1198.20	1198.20	1198.20	
55471	265.00	1199.64	1199.64	1199.64	1199.64	1199.64	1199.64	1199.64	Alma School Road

3.5 Hydraulic Parameters by Reach

In addition to changes in water-surface elevations, the proposed project will impact other hydraulic characteristics of the river. Changes in these hydraulic parameters directly effect the sediment-transport of the study reach, and hence channel stability. The following section summarizes the impacts of the proposed project upon the sediment-transport characteristics of the reach.

Hydraulic parameters which strongly effect sediment-transport are main channel velocity, hydraulic depth (area/topwidth), and topwidth. Since sediment-transport calculations are performed on a reach-by-reach basis, average values of the hydraulic parameters were computed for specified reaches. Cross-sections within a given reach are grouped on the basis of similar hydraulic and sediment-transport characteristics. The reach designation used in this study is shown in Figure 6. The reaches defined in Figure 6 cover the river from Mill Avenue to just upstream of the proposed Outer Loop Highway crossing, the same area analyzed in the sediment-transport analysis.

The most important hydraulic parameter in terms of sediment-transport is velocity. Reach-averaged main-channel velocities for both baseline and concept conditions are presented in Table 8. Comparison of reach-averaged velocities between concept and baseline conditions illustrates the impacts resulting from the project. The most significant difference occurs in Reach 3, where the reach-averaged velocity increases from 10.3 to 12.7 feet per second. This large increase is due to the encroachment caused by the East Papago freeway alignment around the Old Tempe Landfill (see Plate 1). This increase in velocity will result in a greater sediment-transport capacity in this area, which could result in channel stability problems. This potential is analyzed in the Section IV. Other reaches showing increased average velocities under concept conditions are Reaches 6 through 9, such increase again being due to the freeway alignment.

Reach-averaged main-channel topwidths are presented in Table 9. The most significant thing of note in this table is the reduction in topwidth in Reach 3 under concept conditions due to the freeway encroachment around the Old Tempe landfill. Slight increases occur in Reaches 2, 4, and 5, due mostly to the channel modifications in these areas.

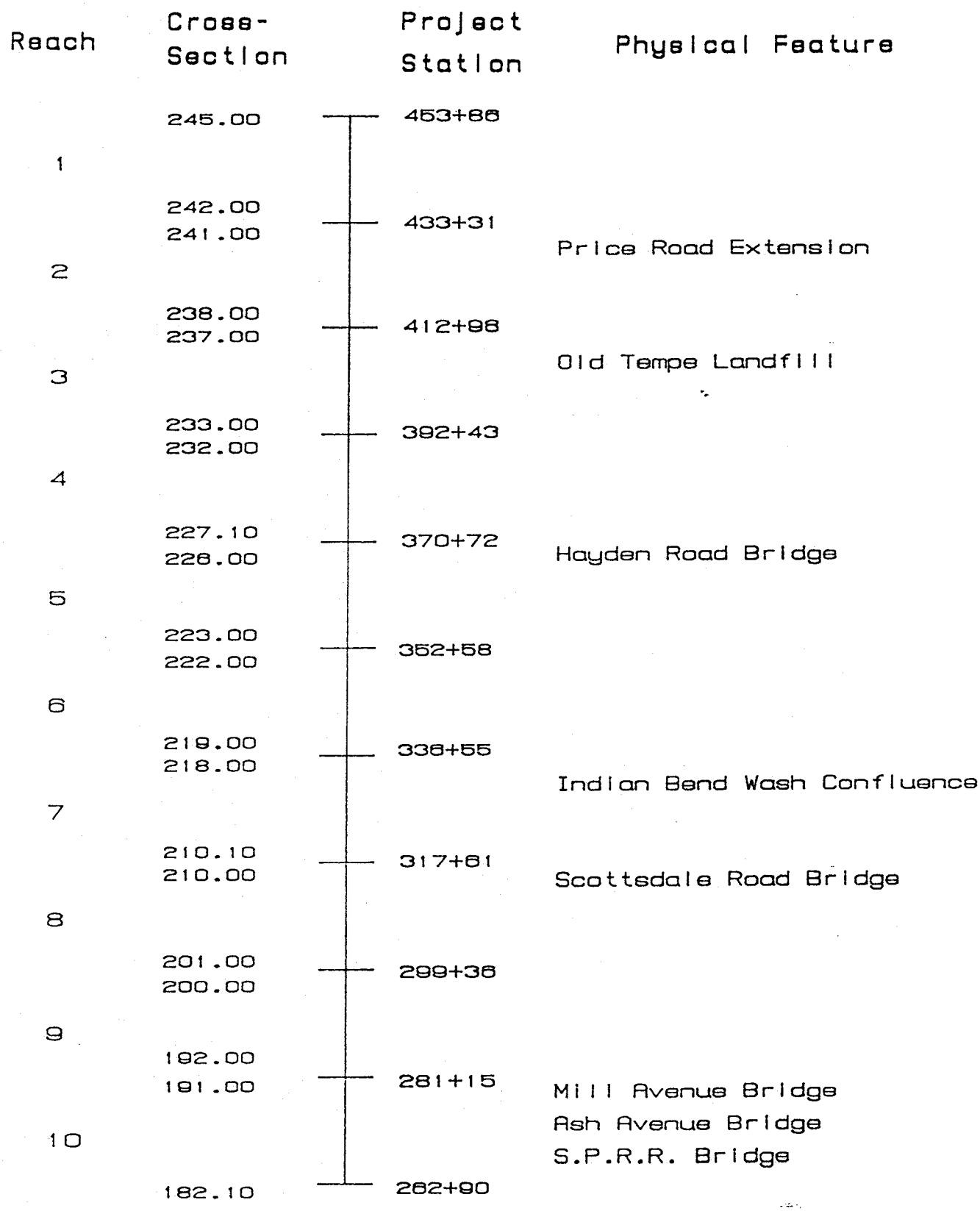


Figure 6. Reach Delineation for Hydraulic and Sediment-Transport Analysis

TABLE 8. Reach-Averaged Velocity, 100-Year Event

Reach	Reach-Averaged Velocity (ft/sec) Baseline	Concept
1	4.4	4.7
2	7.5	5.8
3	10.3	12.7
4	11.0	7.8
5	10.7	9.6
6	7.8	8.3
7	7.5	7.7
8	7.9	8.1
9	7.7	7.9
10	9.1	9.1

TABLE 9. Reach-Averaged Topwidth, 100-Year Event

Reach	Reach-Averaged Topwidth (ft) Baseline	Concept
1	2270	2135
2	1236	1730
3	960	728
4	950	1165
5	1041	1083
6	1609	1609
7	1494	1494
8	1433	1433
9	1426	1426
10	1371	1371

Reach-averaged hydraulic depths are presented in Table 10. Comparison of hydraulic depths between concept and baseline conditions shows consistently higher hydraulic depths under concept conditions due to the freeway encroachment.

TABLE 10. Reach-Averaged Hydraulic Depth, 100-Year Event

Reach	Reach-Averaged Hydraulic Depth (ft) Baseline	Concept
1	22.4	22.4
2	23.4	22.5
3	22.3	22.4
4	20.4	23.5
5	16.8	20.0
6	15.2	15.4
7	16.8	17.0
8	17.0	17.1
9	18.5	18.6
10	17.1	17.2

IV. SEDIMENT-TRANSPORT ANALYSIS

4.1 General

The primary purpose of the sediment-transport analysis is to quantify the upstream and downstream impacts from the project, and identify any need for mitigation measures in these reaches. This analysis also assists in identifying the size and type of stabilization measures required for the freeway embankments and bridge crossings.

4.2 General Scour/Fill

QUASED, a quasi-dynamic computer sediment-routing program developed by SLA, which uses hydraulic data determined with HEC-2, was used to assess the general scour/fill potential of the study reach under concept conditions. The limits of the computer sediment-routing model extend from Mill Avenue on the downstream end to just upstream of the proposed Outer Loop highway crossing on the upstream end. The analysis was performed using the 100-year-design flood event.

Input to QUASED consists of the HEC-2 input file for concept conditions, sediment size distributions, reach designations, inflow hydrographs, and sediment supply. The HEC-2 input file for concept conditions was modified slightly by lowering Manning's n-values from 0.04 to 0.035 to provide a conservative estimate of the general scour/fill potential of the study reach under concept conditions. Lowering n-values increases velocities, resulting in higher sediment-transport rates. Sediment size distributions for the channel bed were developed with data collected from previous SLA studies (8). The size distributions used in the model to represent surface and subsurface sediment layers are those shown in Figure 3 of Section 2.3. The reach designations are the same as those used in the hydraulic analysis and shown in Figure 6. The reaches were developed to ensure similar hydraulic and sediment transport characteristics in each reach and stability in the numerical sediment-routing scheme.

The upstream inflow hydrograph was developed by normalizing the recorded hydrographs at Granite Reef Dam to match flood volumes and peak-flow estimates given in the 1982 CAWCS report (9). The design-flow hydrograph representing the 100-year event is shown in Figure 7. Upstream sediment inflow was set equal to zero for the entire simulation. This provides a conservative estimate of general

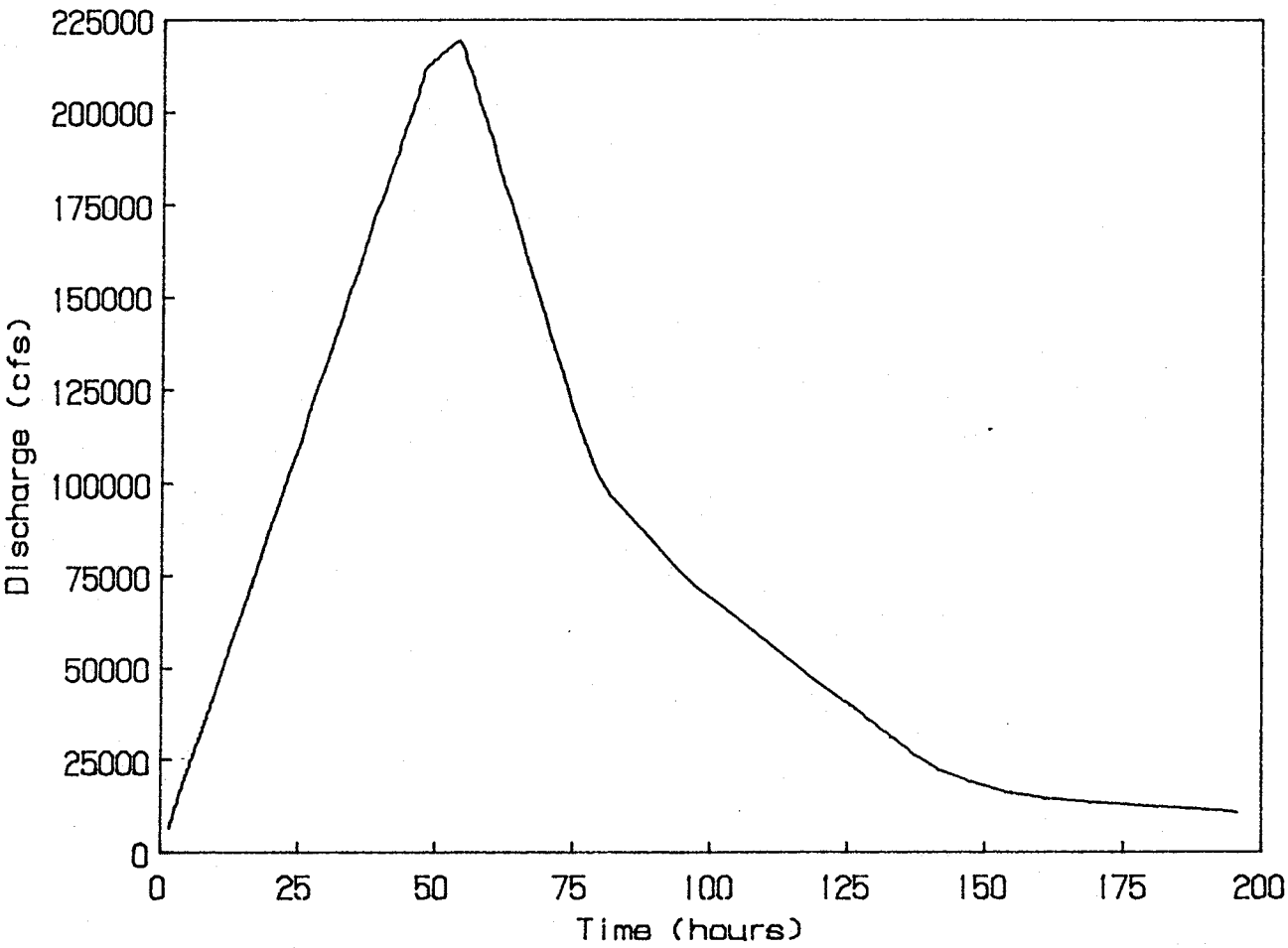


Figure 7. Design Flow Hydrograph, 100-Year Event

scour in the downstream channel; and is probably representative of actual conditions anyway, since gravel pits at the upstream end of the model will trap most of the incoming bedload.

The results of the sediment-routing simulation for the 100-year design storm are given in Table 11, where initial, minimum, maximum, and final bed elevations are given for each cross-section location. Additionally, the maximum computed scour is provided for each cross-section location.

Figure 8 shows the initial and final bed profiles for the simulation. The plot shows that the overall reach is subject to general scour. This is due primarily to the deficit in sediment supply created by the upstream gravel pits. The areas with greatest general scour are the reach near the Old Tempe Landfill and the area just downstream of Hayden Road. The general scour near the Old Tempe Landfill is due primarily to the constriction caused by the freeway alignment around the landfill. The maximum general scour depth computed for this area is 3.2 feet. The general scour just downstream of Hayden Road is likely due in part to the constriction caused by the Sun Angel Golf Course. An area of slight general fill occurs in the area between Hayden Road and the Old Tempe Landfill. This is due to the excess sediment supply created by the constriction upstream.

A sediment-routing analysis of the downstream end of Indian Bend Wash was not performed, since general scour/fill in this reach is controlled by the response of the Salt River bed. For design purposes, the general scour depths of the Salt River bed at the mouth of Indian Bend Wash can be used at the East Papago crossing of Indian Bend Wash.

The results presented in this section indicate that general scour of the channel bed is a component that will have to be considered in the design aspects of the project. In addition to general scour of the bed, there is some potential for bank instability as the channel tries to re-adjust its geometry to reach a new equilibrium.

4.3 Local Scour

To assess the total scour potential of the channel bed for purposes of designing hydraulic structures, local scour due to the presence of structures and debris in the flow field must be considered. Bridge piers and abutments are

TABLE 11. Sediment Routing Results, Concept Conditions

Project Distance (ft)	Cross-Section Number	Initial Elevation (ft)	Minimum Elevation (ft)	Maximum Elevation (ft)	Final Elevation (ft)	Maximum Scour (ft)	Physical Feature
26380	182.10	1134.00	1133.60	1134.04	1133.62	0.40	S.P.R.R. Bridge
26396	182.20	1134.00	1133.61	1134.04	1133.63	0.39	
26575	183.50	1134.00	1133.57	1134.03	1133.60	0.43	
26750	184.10	1134.00	1133.55	1134.04	1133.60	0.45	Ash Ave. Bridge
26770	184.20	1134.00	1133.57	1134.04	1133.61	0.43	
26930	185.50	1136.00	1135.53	1136.04	1135.58	0.47	
27090	186.10	1136.00	1135.58	1136.04	1135.61	0.42	Mill Ave. Bridge
27138	186.20	1136.00	1135.58	1136.04	1135.60	0.42	
27418	188.00	1138.00	1137.52	1138.04	1137.59	0.48	
27613	189.00	1136.00	1135.46	1136.04	1135.54	0.54	
27814	190.00	1136.00	1135.47	1136.04	1135.55	0.53	
28014	191.00	1134.00	1133.49	1134.04	1133.57	0.51	
28215	192.00	1136.00	1135.58	1136.10	1135.58	0.42	
28410	193.00	1135.20	1134.77	1135.28	1134.77	0.43	
28610	194.00	1136.00	1135.57	1136.06	1135.57	0.43	
28830	195.00	1138.00	1137.58	1138.07	1137.58	0.42	
29022	196.00	1138.00	1137.57	1138.06	1137.57	0.43	
29233	197.00	1138.00	1137.58	1138.05	1137.58	0.42	
29438	198.00	1140.00	1139.56	1140.03	1139.56	0.44	
29631	199.00	1140.00	1139.58	1140.03	1139.58	0.42	
29836	200.00	1142.00	1141.57	1142.03	1141.57	0.43	
30035	201.00	1142.00	1141.47	1142.02	1141.47	0.53	
30236	202.00	1140.00	1139.42	1140.02	1139.42	0.58	Sun Devil Stadium
30437	203.00	1138.30	1137.72	1138.33	1137.72	0.58	
30633	204.00	1142.00	1141.41	1142.02	1141.41	0.59	
30830	205.00	1142.00	1141.42	1142.03	1141.42	0.58	
31035	206.00	1142.00	1141.44	1142.04	1141.44	0.56	
31241	207.00	1140.00	1139.47	1140.03	1139.47	0.53	
31471	208.00	1142.00	1141.46	1142.02	1141.46	0.54	
31756	210.00	1144.00	1143.41	1144.01	1143.41	0.59	
31766	210.10	1144.00	1143.19	1144.00	1143.19	0.81	Scottsdale Rd. Bridge
31861	211.00	1144.00	1143.19	1144.00	1143.19	0.81	
31871	211.10	1144.00	1143.20	1144.00	1143.20	0.80	
32051	212.00	1144.00	1143.24	1144.00	1143.24	0.76	
32261	213.00	1143.60	1142.91	1143.60	1142.91	0.69	
32461	214.00	1143.70	1143.02	1143.70	1143.02	0.68	
32656	215.00	1144.00	1143.26	1144.00	1143.26	0.74	
32856	216.00	1146.00	1145.21	1146.00	1145.21	0.79	
33057	217.00	1148.00	1147.29	1148.00	1147.29	0.71	
33455	218.00	1148.00	1147.39	1148.00	1147.39	0.61	
33855	219.00	1148.00	1147.48	1148.00	1147.48	0.52	
34255	220.00	1147.30	1146.80	1147.30	1146.80	0.50	Indian Bend Wash
34658	221.00	1148.00	1147.15	1148.00	1147.15	0.85	
35058	222.00	1146.00	1145.32	1146.00	1145.32	0.68	
35457	223.00	1148.00	1146.62	1148.00	1146.62	1.38	
35856	224.00	1148.00	1146.47	1148.00	1146.47	1.53	Sun Angel Golf Course
36263	225.00	1147.60	1145.88	1147.60	1145.88	1.72	
36660	226.00	1148.00	1146.14	1148.00	1146.14	1.86	
37027	227.10	1150.00	1148.45	1150.00	1148.45	1.55	Hayden Road Bridge
37116	227.40	1150.00	1150.00	1150.32	1150.08	0.00	
37436	228.00	1150.00	1150.00	1150.30	1150.09	0.00	
37836	229.00	1150.00	1150.00	1150.29	1150.09	0.00	
38236	230.00	1150.00	1150.00	1150.33	1150.20	0.00	
38635	231.00	1150.00	1150.00	1150.43	1150.17	0.00	
39042	232.00	1150.00	1150.00	1150.64	1150.38	0.00	
39444	233.00	1150.00	1148.08	1150.40	1148.08	2.32	

TABLE 11. (continued)

Project Distance (ft)	Cross-Section Number	Initial Elevation (ft)	Minimum Elevation (ft)	Maximum Elevation (ft)	Final Elevation (ft)	Maximum Scour (ft)	Physical Feature
39840	234.00	1150.00	1147.97	1150.50	1147.97	2.53	
40246	235.00	1150.00	1147.46	1150.60	1147.46	3.14	
40647	236.00	1150.00	1147.59	1150.80	1147.59	3.21	Old Tempe Landfill
41043	237.00	1150.00	1147.94	1150.90	1147.94	2.96	
41553	238.00	1150.00	1149.36	1150.04	1149.36	0.64	
42018	239.00	1150.00	1149.53	1150.04	1149.53	0.47	
42568	240.00	1151.40	1151.22	1151.44	1151.22	0.18	Outer Loop Highway
43073	241.00	1151.50	1151.32	1151.54	1151.32	0.18	
43588	242.00	1152.00	1151.55	1152.00	1151.55	0.45	
44058	243.00	1152.00	1151.74	1152.00	1151.74	0.26	
44528	244.00	1152.00	1151.62	1152.00	1151.62	0.38	
45078	245.00	1154.00	1153.51	1154.00	1153.51	0.49	

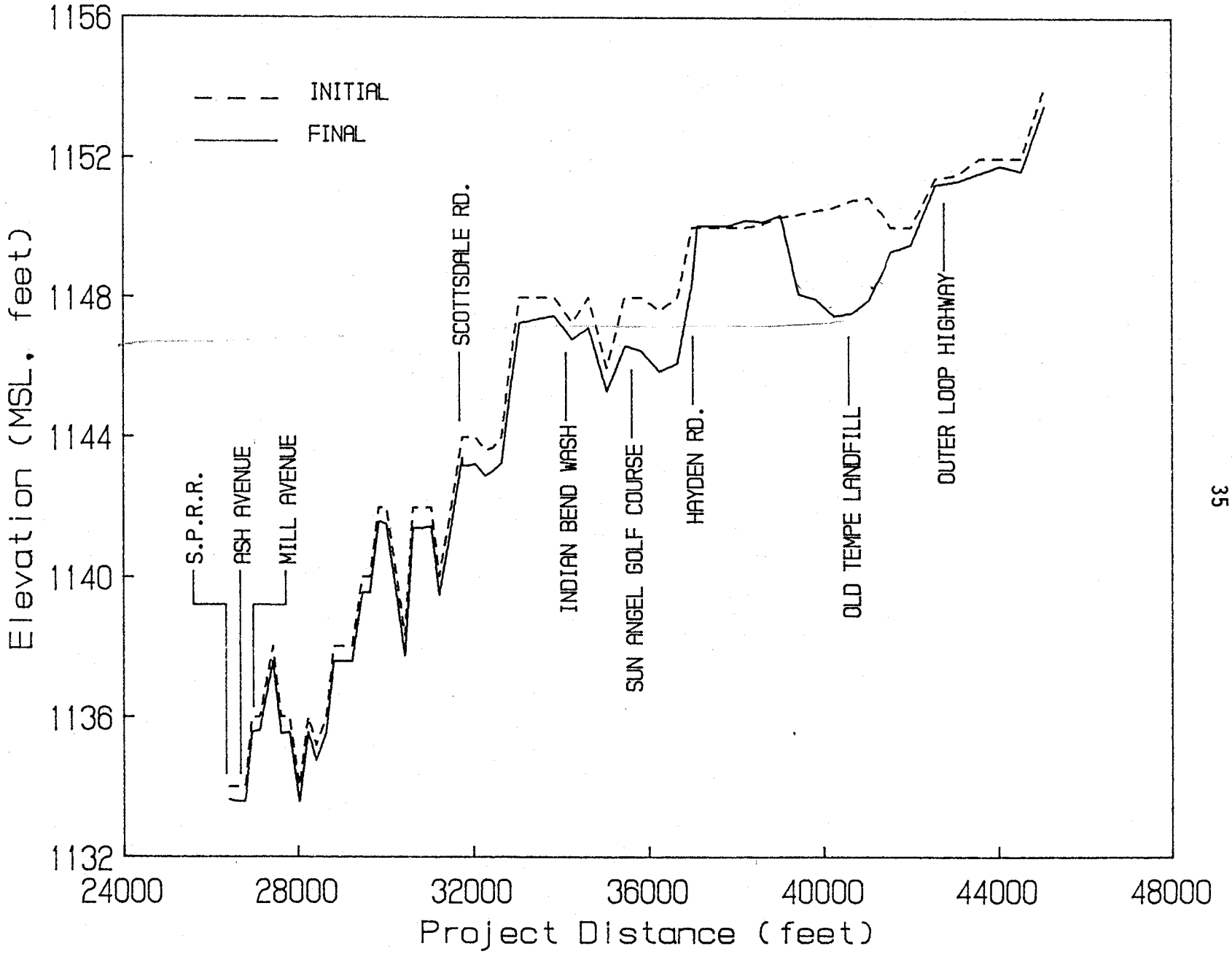


Figure 8. Initial and Final Bed Profiles

the only hydraulic structures proposed at this time that will induce local scour. Scour at the bridge abutments has not been quantified, due to the fact that the bridge selection process has not yet been completed. During the design phases of this project, abutment scour will have to be addressed as a local scour component. If during later stages of the analysis grade-control structures are seen as necessary, local scour will have to be considered for these structures as well.

For the assumed configurations of the bridges under concept conditions, local scour was computed for the 100-year design flood. The computations were based on several pier scour equations reported in the literature, and the most conservative result was adopted. Additional scour calculations were also performed with pier widths increased by 6-feet to account for potential debris blockage. The local scour results for each bridge crossing, both with and without considerations for debris, are presented in Table 12.

TABLE 12. Estimates of Local Scour at Bridge Piers

Bridge	Pier Diameter (ft)	Local Scour w/o debris (ft)	Local Scour with debris[1] (ft)
East Papago	6	16	26
	8	19	27
	10	22	30
	15	29	36
Outer Loop	6	18	26
East Papago at Indian Bend Wash	6	18	29

[1] Pier width increased by six feet to account for potential blockage.

4.4 Long-Term Channel Response

The profile of the Salt River is controlled to a large extent by the formation of a surface armor layer. This layer is formed from the subsurface gradation as finer particles are transported downstream, leaving the coarser fraction of sediments behind. The armoring mechanism effectively arrests long-term degradation within the river system. However, over the long term, mining and channel headcutting will have the most significant impact upon the river upstream of Hayden Road. This is due to the fact that mining affects channel response in direct proportion to production within the mined reach. These processes are summarized below in order to quantify the long-term channel response and effects on the proposed project.

Initially, it was assumed the long-term channel response downstream of Hayden Road would be controlled by an equilibrium-slope condition projected upstream from Grade Control No. 4. However, it was subsequently determined that the controlling factor in this portion of the study reach is actually the armoring process. Using four different equations reported in the literature (10), it was found that particles with minimum diameters of 110 mm were necessary to provide armoring for hydraulic conditions during a 100-year flood. Figure 3 of Section 2.3 shows that at least ten percent of the bed material is coarser than the particle diameter necessary to form the armor layer. It is recommended that two times the diameter of the particle size necessary for armoring constitute the thickness of the armor layer (11). This data leads to the conclusion that the armoring process would arrest further degradation of the streambed downstream of the pits after 6.5 feet of material has been transported during a 100-year flood. Alternatively, a sufficient quantity of material is available within the top 6.5 feet of the existing channel invert to form an armor layer which will prevent further degradation during a 100-year flood. Because this 6.5 feet of degradation occurs during a 100-year flood, and all floods of lesser magnitude would exhibit armoring depths less than 6.5 feet, it is felt that this depth is justified to represent the long-term armoring process of the subject reach of the Salt River.

At the time of this analysis, it was not known if mining operations would continue upstream of Hayden Road. Under these conditions, it was assumed that the long-term channel response for the reach upstream of Hayden Road would be

directly proportional to the mining production. A research project performed by SLA for the Arizona Transportation Research Center (ATRC) on the "Effects of In-Stream Mining on Channel Stability" (2) confirms this assumption. This study determined the maximum depth of mining to be on the order of 40 feet, limited by bank stability in the vicinity of the project. Therefore, 40 feet was used as the estimate for long-term degradation upstream of Hayden Road, where the potential for mining exists.

It was assumed that ADOT would not allow sand and gravel operations within the right-of-way of the Outer Loop crossing. This creates the potential for a perched bridge, with pits both upstream and downstream of the Outer Loop crossing. The assumed perched-bridge condition supplies the hydraulic potential for the headcut process, similar to the bridges at Alma School Road. The ATRC study identifies the maximum depth of the headcut process as being one half the pit depth. Therefore, the headcut process provides for a long-term degradation potential at the Outer Loop crossing of 20 feet. The 20-feet of long-term degradation, due to the headcut process, is assumed to be the result of multiple flood events, rather than just a single flood event. Long-term degradation is summarized in the following section as a component of total scour.

4.5 Total Scour Depth

The total scour depth at any given point along the reach of the Salt River under investigation is the sum of the general scour, computed from a sediment-routing analysis; bedform trough depths; local scour; and long-term degradation. A summary of the total scour depths computed for concept conditions are presented in Table 13. The pier scour included in Table 13 is for the 130-foot spans with 6-foot diameter columns and 6-feet of additional pier width included for debris buildup. Use of an alternative pier configuration will require adjustment of the results shown in Table 13 by the respective pier scour component. A safety factor equal to 30 percent of the sum of the above scour components is included to account for the non-uniform flow distribution that is typical of alluvial channels. Once the bridge selection process is completed, a local scour analysis must be performed for the bridge abutments. The final column in Table 13 is the recommended long-term design invert for the concept condition. Mitigation measures for these potential problems are discussed in Section VI of this report.

TABLE 13. Total Scour Depth Summary

Project Station (ft)	Cross-Section Number	General Scour (ft)	Bed-Form Scour (ft)	Pier[1] Scour (ft)	Long-term[2] Degradation (ft)	Safety Factor (ft)	Total Scour (ft)	Long-term[3] Predicted Invert Elevation (ft)	Physical Feature
32656	215.00	0.7	2.0	NA	6.5	2.8	12.0	1132.0	
32856	216.00	0.8	2.0	NA	6.5	2.8	12.1	1133.9	
33057	217.00	0.7	2.0	NA	6.5	2.8	12.0	1136.0	
33455	218.00	0.6	2.0	NA	6.5	2.7	11.8	1136.2	
33855	219.00	0.5	2.0	NA	6.5	2.7	11.7	1136.3	
34255	220.00	0.5	2.0	NA	6.5	2.7	11.7	1135.6	Indian Bend Wash
34658	221.00	0.9	2.0	NA	6.5	2.8	12.2	1135.8	
35058	222.00	0.7	2.0	NA	6.5	2.8	12.0	1134.0	
35457	223.00	1.4	2.0	NA	6.5	3.0	12.9	1135.1	
35856	224.00	1.5	2.0	NA	6.5	3.0	13.0	1135.0	Sun Angel Golf Course
36263	225.00	1.7	2.0	NA	6.5	3.1	13.3	1134.3	
36660	226.00	1.9	2.0	26.0	6.5	10.9	47.3	1100.7	
37027	227.10	1.6	2.0	26.0	6.5	10.8	46.9	1103.1	Hayden Road Bridge
37116	227.40	0.0	2.0	26.0	6.5	10.4	44.9	1105.2	
37436	228.00	0.0	2.0	26.0	6.5	10.4	44.9	1105.2	
37836	229.00	0.0	2.0	26.0	6.5	10.4	44.9	1105.2	
38236	230.00	0.0	2.0	26.0	6.5	10.4	44.9	1105.2	
38635	231.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
39042	232.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
39444	233.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
39840	234.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
40246	235.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
40647	236.00	NA	NA	NA	40.0	12.0	52.0	1098.0	Old Tempe Landfill
41043	237.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
41553	238.00	NA	NA	NA	40.0	12.0	52.0	1098.0	
42018	239.00	NA	NA	26.0	20.0	13.8	59.8	1090.2	
42568	240.00	NA	NA	26.0	20.0	13.8	59.8	1091.6	Outer Loop Highway
43073	241.00	NA	NA	26.0	20.0	13.8	59.8	1091.7	
43588	242.00	NA	NA	26.0	20.0	13.8	59.8	1092.2	
44058	243.00	NA	NA	NA	40.0	12.0	52.0	1100.0	
44528	244.00	NA	NA	NA	40.0	12.0	52.0	1100.0	
45078	245.00	NA	NA	NA	40.0	12.0	52.0	1102.0	

NOTES:

1 Includes consideration for debris buildup.

2 Represents armoring, mining, or headcut component, whichever is the controlling process.

3 Based upon ADOT 1986 topographic mapping.

NA Scour component is not applicable at this cross-section.

V. MITIGATION MEASURES

Mitigation measures for the erosion/sedimentation hazard on the Salt River include bank stabilization, provision of adequate bridge pier depths, and grade-control structures. Detailed analyses of these measures will be provided later in the project. Here, a brief discussion of each is given.

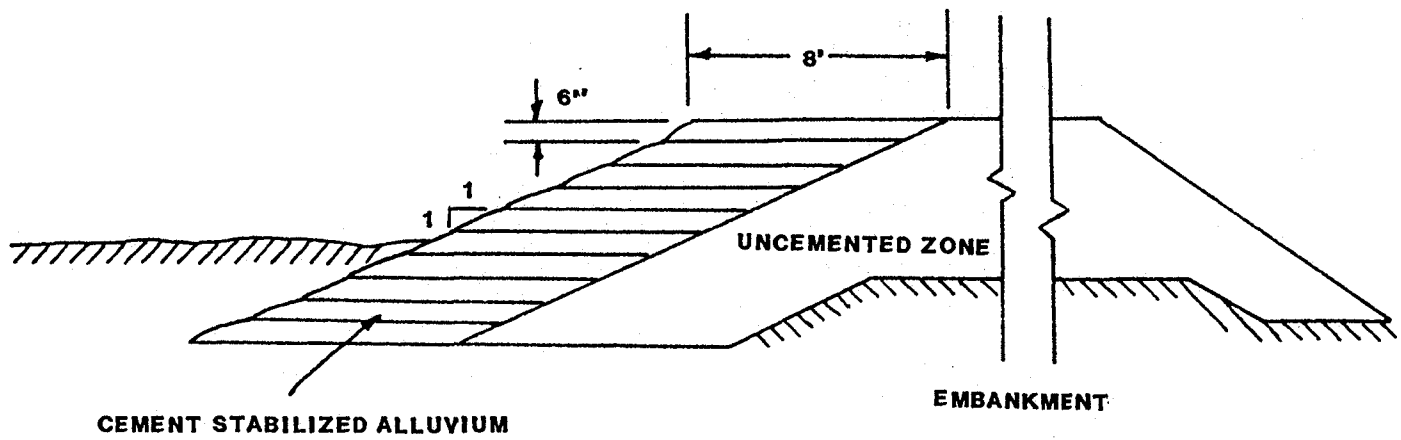
Bank protection will be very important aspect of the design of the freeway crossings of the Salt River corridor. As has been shown in this report, the potential for bank instability is high along the study reach, particularly in areas of channel encroachment. Bank protection is currently planned for the freeway embankment on the south side of the river from Hayden Road to a point upstream of the Red Mountain Interchange, where the protection can be tied into the existing bank adequately. Although the exact location of the upstream extent of this protection has not yet been determined, it is proposed to be in the vicinity of Evergreen Road. The need for bank protection in other areas has also not been determined at this time.

The proposed bank protection system will consist of Cement Stabilized Alluvium (CSA). CSA has been used with success on the Salt River, and on other streams in the arid southwestern United States. Figure 9 shows a typical section of a bank protected with CSA.

As was shown in Section 4.3, the potential for local scour around bridge piers is significant. To mitigate this hazard, bridge piers must be constructed to an adequate depth below the potential scour to ensure structural stability. Coordination is currently under way to ensure that the bridge designers consider the total scour potential (general scour, plus bedform troughs, plus local scour, plus long-term channel response) in the design of any bridge crossings of the subject reach of the Salt River.

Grade-control structures are used to control bed degradation and stabilize the vertical profile of a river bed. Grade-control structures, properly located and designed, can also stop the upstream advance of headcuts that develop as a result of downstream degradation or man induced bed lowering, such as that resulting from gravel mining. The general concept for a grade-control structure is simply to provide a substantial mass of concrete or CSA that extends below

TYPICAL CEMENT STABILIZED ALLUVIUM BANK PROTECTION

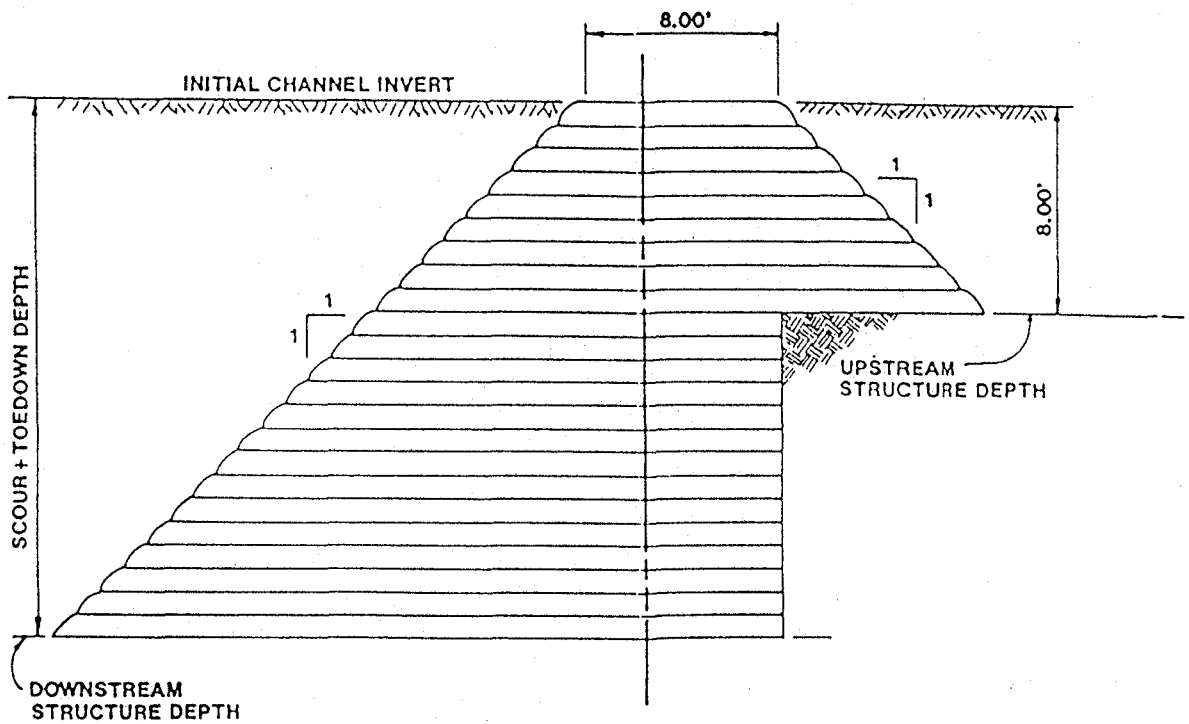


sla Simons, Li & Associates, Inc.

FIGURE 9

the local scour depths, and can resist overturning forces. A typical cross section of a grade-control structure is shown in Figure 10. At this time, the need for grade-control structures has not yet been determined.

SECTION THROUGH GRADE-CONTROL STRUCTURE



sla Simons, Li & Associates, Inc.

FIGURE 10

VI. SUMMARY

Preliminary results of the hydraulic and sediment-transport analysis of the Salt River have been presented in this report. Water-surface profiles were computed for 1) existing conditions; 2) modified baseline conditions existing conditions with gravel pits in the study reach removed); and 3) concept conditions. The results presented as concept conditions are for the best estimate of conditions resulting from the current highway alignment and an estimate of the final bridge configurations. 100-year existing and modified baseline water-surface elevations are compared to Base Flood Elevations (BFE's) established by the COE in the latest Flood Insurance Study for the reach.

A multi-level approach is being used to perform the sediment-transport analysis. This approach consisted of a qualitative geomorphic analysis and quantitative analyses to predict general scour and fill. The geomorphic analysis has been completed; and preliminary estimates of general scour and fill have been made, based on assumed design configurations. Preliminary results indicate general scour of the channel bed is a component that will have to be considered in the overall design aspects of the project.

Preliminary estimates of local scour at bridge piers have been performed, based upon preliminary bridge configurations. Bridge type selection for the East Papago and Outer Loop crossings of the Salt River and the East Papago crossing of Indian Bend Wash is presently ongoing. Close coordination with the bridge design engineers will be maintained to address this component of total scour.

Historically, degradation has been the predominant geomorphic process along the subject reach of the Salt River. As described in a previous section of this report, there has been 14 feet of degradation at Hayden Road since 1962. This process is ongoing due to the presence of active gravel-mining operations, narrowing of the river channel through the years, and other man-induced changes in the river system. This long-term lowering of the channel bed will continue to occur with or without the presence of the project under study.

The results presented in this report, although not final, can be used as a basis for the preliminary design of the East Papago and Outer Loop bridge crossings; and to support the application for a 404 permit. The results presented in this report show that the proposed project will produce some, though no dramatic, changes in the hydraulics of the Salt River.

REFERENCES

1. Simons, Li & Associates, Inc., "River Mechanics and Floodplain Analysis of the Salt River for the East Papago and Hohokam Freeway Alignments". Submitted to John Carollo Engineers, May, 1987.

2. Arizona Department of Transportation, "Effects of In-Stream Mining on Channel Stability", Final Report, June, 1989.

3. U. S. Army Corps of Engineers, Los Angles District, "Salt River Flood Insurance Study, Agua Fria River to Country Club Drive", 1983.

4. Schumm, S.A., The Fluvial System, Wiley-Interscience, New York, New York, 1977.

5. U. S. Army Corps of Engineers, Water Resources Support Center, "HEC-2 Water Surface Profiles", Computer Program 723-X6-L202A, September, 1982.

6. Futura Engineering Inc., "Flood Analysis and Recommendations for the Flood Protection Berm on the Arizona State University Golf Course". Prepared for The Sun Angel Foundation. July, 1988.

7. Futura Engineering Inc., "Base Flood Elevations Resulting from the Existing Hayden Road Bridge and the Flood Protection Berms on the Arizona State University Golf Course". Prepared for The Sun Angel Foundation. September, 1988.

8. Simons, Li & Associates, Inc., "Concept Hydraulic Design Salt River Channelization East Papago Freeway". Submitted to Daniel, Mann, Johnson, & Mendenhall. May, 1988.

9. U. S. Army Corps of Engineers, Los Angeles District, "Gila River and Tributaries Central Arizona Water Control Study, Hydrology Report", May, 1982.

10. U. S. Bureau of Reclamation, "Computing Degradation and Local Scour", Technical Guideline, January, 1984.

11. Simons, Li & Associates, Inc., Engineering Analysis of Fluvial Systems, published by Simons, Li & Associates, printed and bound by Bookcrafters, Inc., Chelsea, Michigan, 1982.

APPENDIX A

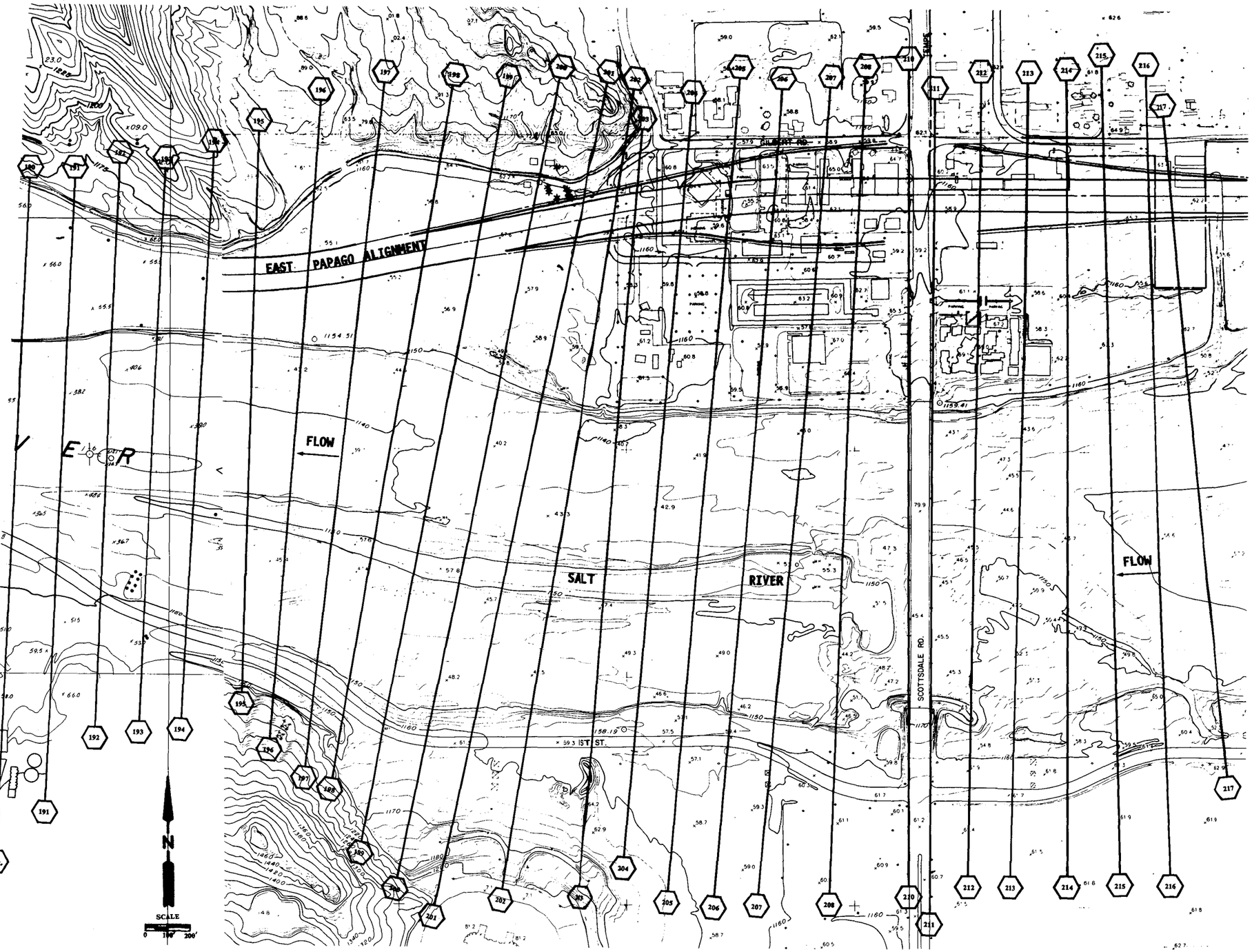
HEC-2 Cross Section Locations

Plate 1
1 of 4

Project No: AZ-DRAIN-05
Date:
Design: JRM
Drawn: JRM
Check:
Revisions:

HEC-2 Cross-Section Locations

sla Simons, Li & Associates, Inc.
Newport Beach, CA., Fort Collins, CO.,
Tucson, AZ., Phoenix, AZ.

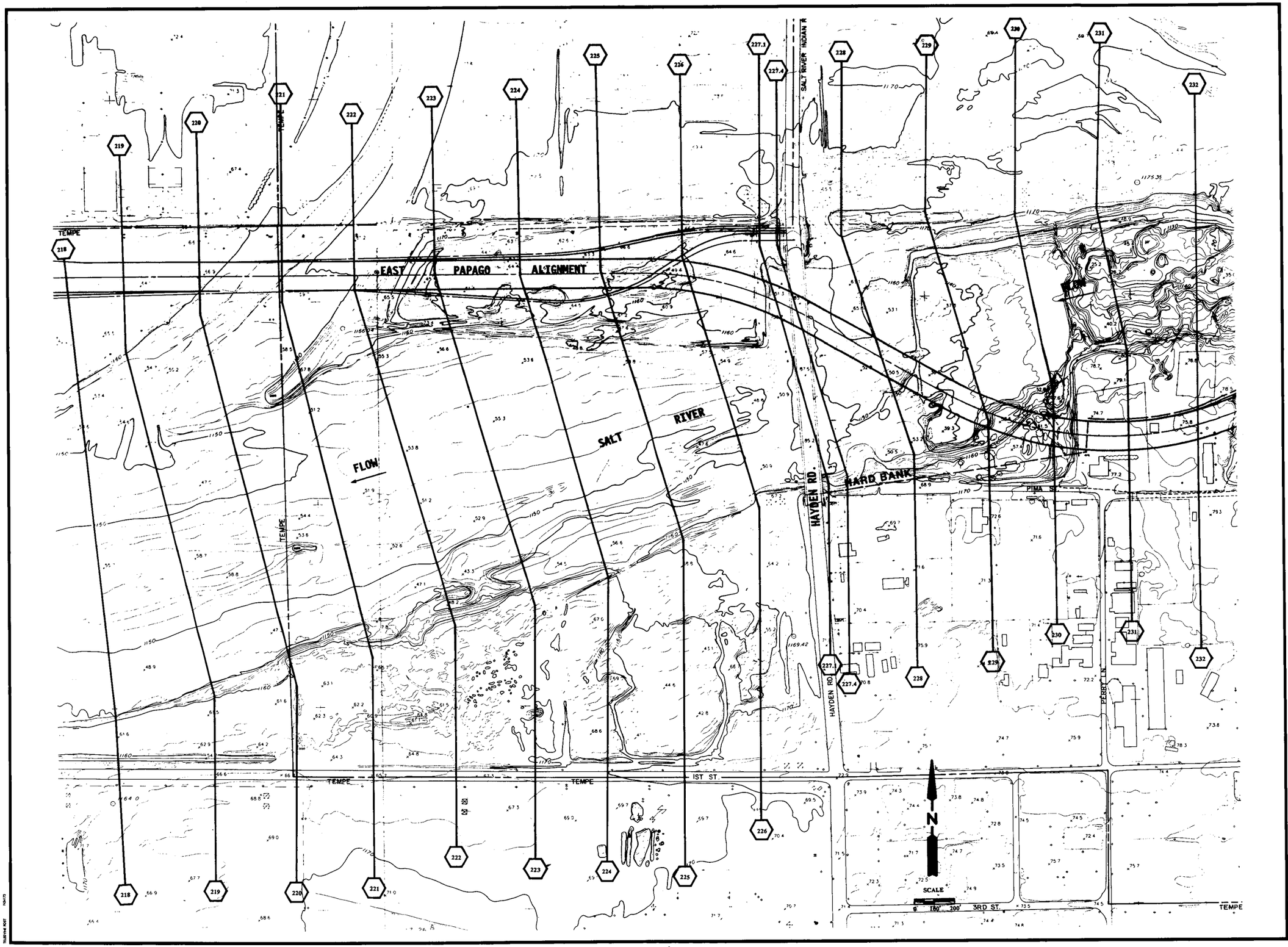


Simons, Li & Associates, Inc.
Newport Beach, CA., Fort Collins, CO.,
Tucson, AZ., Phoenix, AZ.

HEC-2 Cross-Section Locations

Project No.	AZ-DMJM-03
Date:	
Design:	JRM
Drawn:	JRM
Check:	
Revisions:	

Plate 1
2 of 4

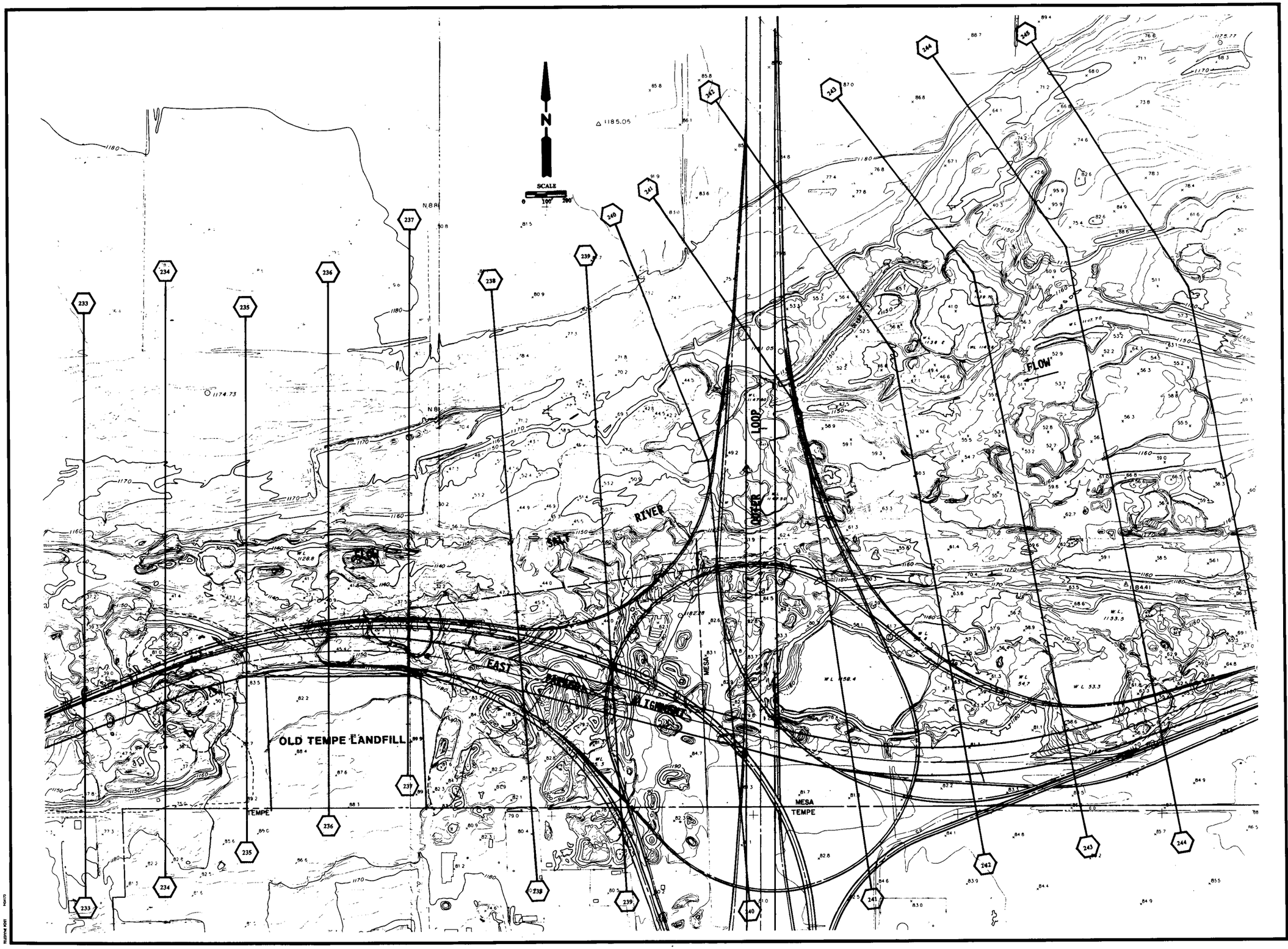


Simons, Li & Associates, Inc.
Newport Beach, CA., Fort Collins, CO., Tucson, AZ., Phoenix, AZ.

HEC-2 Cross-Section Locations

Project No.	AZ-DMJM-03
Date:	
Design:	JRM
Drawn:	JRM
Check:	
Revisions:	

Plate 1
3 of 4

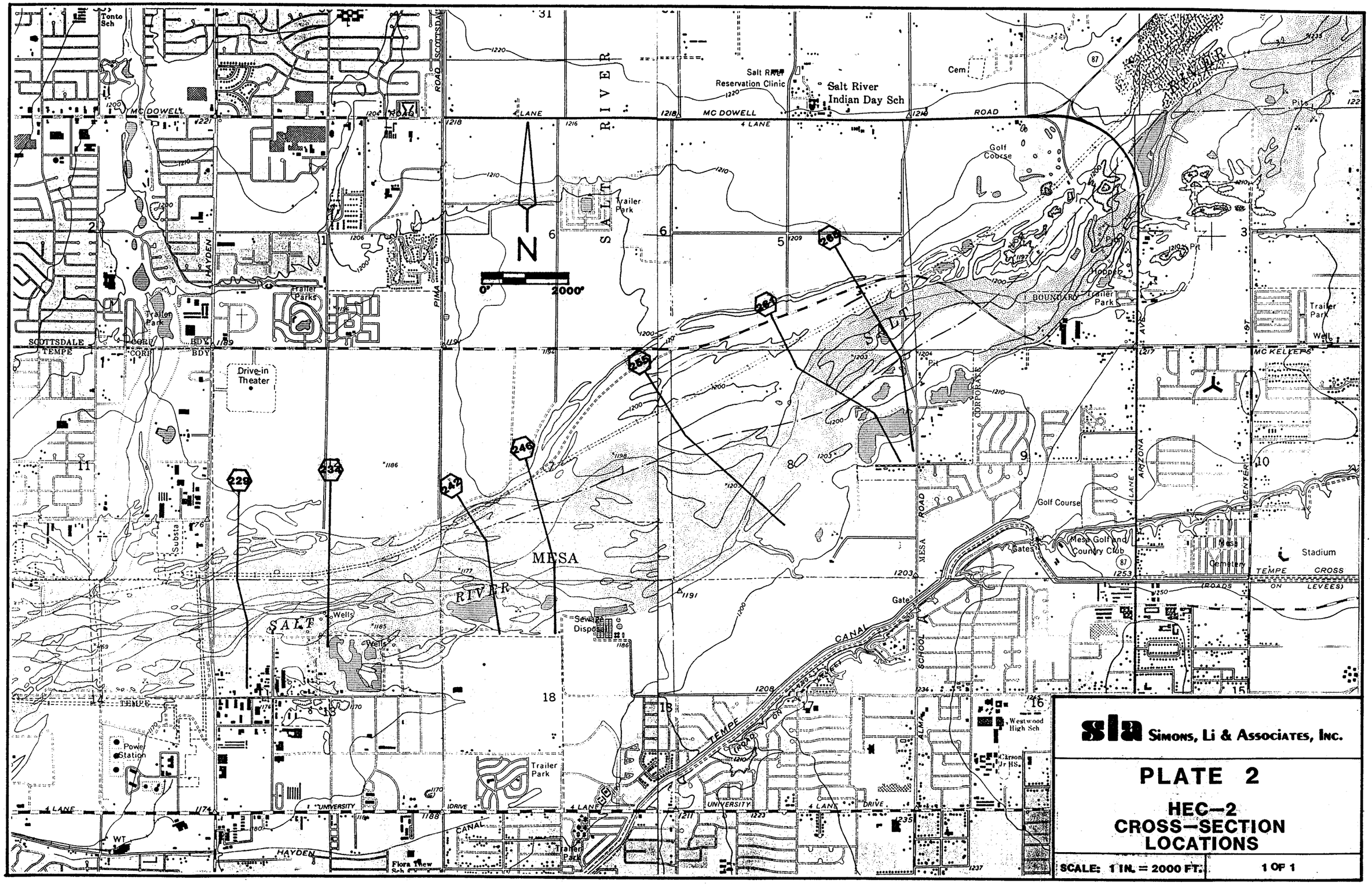


sla Simons, Li & Associates, Inc.
Newport Beach, CA.; Fort Collins, CO.;
Tucson, AZ.; Phoenix, AZ.

HEC-2 Cross-Section Locations

Project No.	AZ-DMJM-03
Date:	
Design:	JRM
Drawn:	JRM
Check:	
Revisions:	

Plate 1
4 of 4



sla Simons, Li & Associates, Inc.

PLATE 2

HEC–2 CROSS–SECTION LOCATIONS

SCALE: 1 IN. = 2000 FT.

1 OF 1