Volume 2 of 2

Draft Feasibility Report Technical Appendixes

Rio Salado Oeste

Salt River-Phoenix, Arizona

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Los Angeles District

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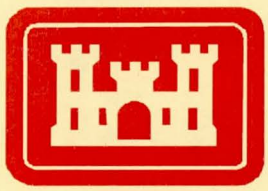

US Army Corps of Engineers
Los Angeles District

Rio Salado Oeste
Feasibility Study

Appendix A

Hydrology and Hydraulics

02/15/06

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INTRODUCTION

Purpose

The purpose of this appendix is to document the hydrologic and hydraulic analyses completed in support of the Rio Salado Oeste Feasibility Study. The goals of the hydraulic analysis were to develop a one-dimensional model of the Salt River study area and model the conditions associated with the Existing Condition, Future Without Project Condition and the conditions associated with selected With Project alternative.

Description of Study Area

The Rio Salado Oeste study area is located within Maricopa County in central Arizona, the area has a general east to west orientation. The study area includes the section of the Salt River that begins at 19th Ave on the east side of the study area and extends downstream to the west for a distance of approximately 9 miles as show on Figure 1.

The study area is within the jurisdiction of the City of Phoenix, Maricopa County, Arizona.

The channel of the Salt River within the study area contains several active and historic sand and gravel mining pits. There are active and inactive landfills along the north bank and there are storm drains and irrigation drains that discharge to the channel

The Salt River was a perennial stream until the construction of upstream dams, with associated reservoirs, regulated the flow. There are four dams on the Salt River and two dams on the Verde River, a tributary to the Salt River. These structures have changed the hydrologic condition of the Salt River below Granite Reef Dam into an ephemeral river. Granite Reef Dam is a diversion structure, not a water storage or flood control structure. This dam diverts the flow in the Salt River into two major irrigation canals. The flood flows vary in duration, quantity and magnitude depending on the nature of the flood

DISCHARGE-FREQUENCY ANALYSIS

The Salt River is characterized by infrequent events, spilling over, on average, once every three years. The maximum rate of flow for each event was determined based upon a water control plan developed for the flood control pool at Modified Theodore Roosevelt Dam. The analysis is described in Corps of Engineers report prepared by the Los Angeles District, (USACE, 1996a). The following table shows the maximum discharge simulated for historic flow events from 1914 to present.

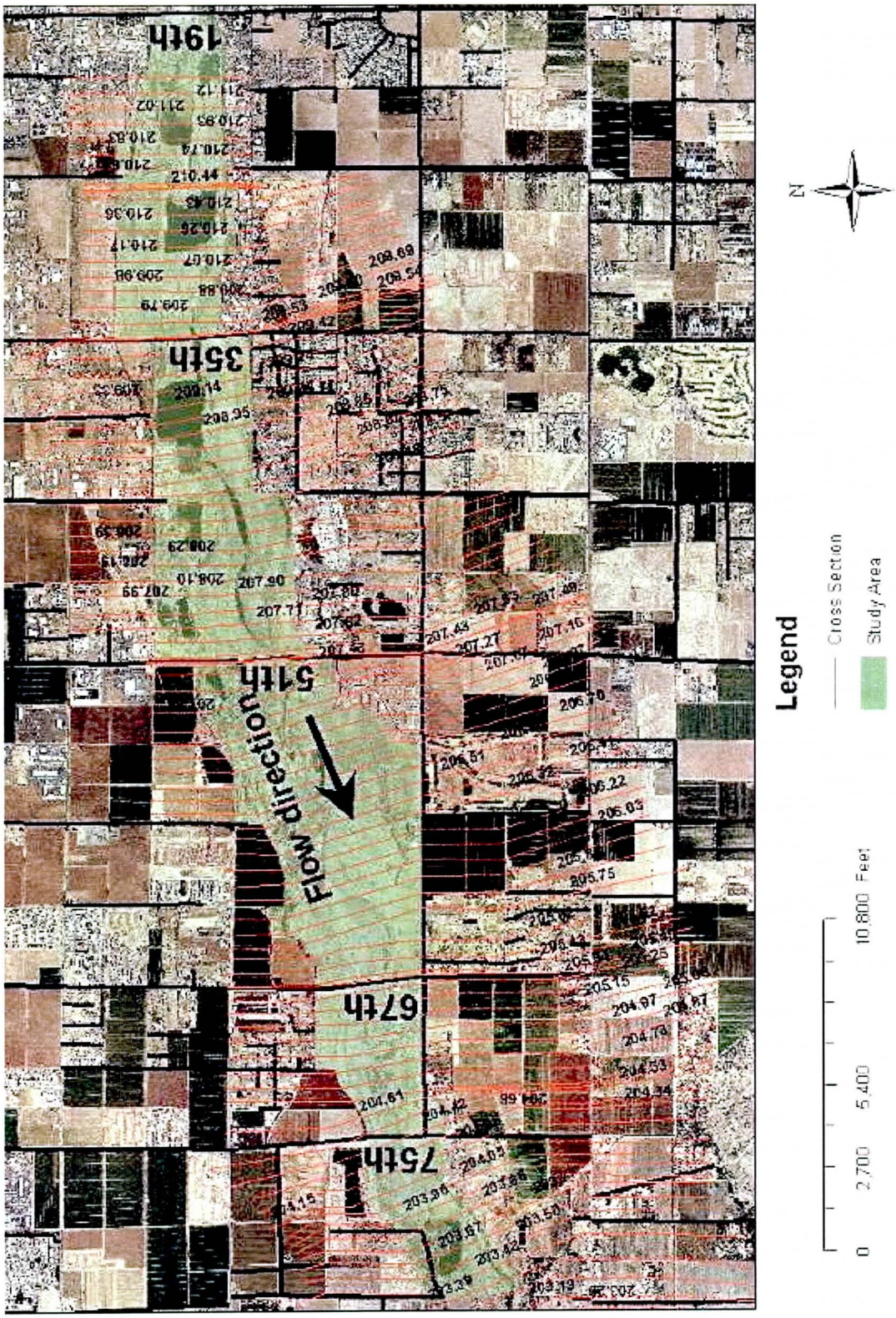

Figure 1: Study Area

Table 1: Summary of Simulated Salt River Flows.

Period of Flow Start Date	Period of Flow End Date	Flow Event Maximum Daily Average Flow (cfs)
2/7/1914	7/2/1914	15,800
1/29/1915	8/18/1915	18,700
1/15/1916	5/15/1916	79,100
9/8/1916	2/4/1917	21,100
4/17/1917	5/15/1917	23,400
3/7/1918	3/26/2018	28,400
11/25/1919	13/14/1919	46,200
1/4/1920	4/25/1920	87,800
12/26/1921	1/9/1922	24,100
2/8/1922	2/18/1922	10,000
3/16/1922	4/10/1922	18,000
9/18/1923	9/22/1923	24,100
12/26/1923	1/8/1924	42,800
3/31/1926	4/16/1926	28,800
2/14/1927	3/19/1927	49,800
9/12/1927	9/20/1927	16,200
4/4/1929	4/19/1929	17,200
2/12/1931	2/20/1931	22,900
2/9/1932	3/29/1932	48,700
2/6/1937	3/25/1937	36,981
2/28/1939	3/17/1939	58,739
2/5/1941	5/25/1941	32,206
12/21/1965	1/12/1966	64,000
2/20/1973	6/5/1973	22,273
2/28/1978	4/11/1978	95,800
12/16/1978	4/19/1979	110,000
1/29/1980	6/3/1980	137,725
2/2/1983	6/17/1983	30,000
9/27/1983	10/24/1983	39,878
12/24/1983	1/24/1984	11,200
12/21/1984	6/1/1985	25,604
12/22/1991	6/21/1992	12,898
8/21/1992	9/8/19992	13,615
12/28/1992	6/4/1993	99,396
1/20/1995	5/2/1995	53,316

A flow frequency distribution information set was developed for the Salt River Rio Salado Oeste study reach based on the dammed Modified Theodore Roosevelt operating condition. The following Table 2 summarizes the discharges that were analyzed for this study's hydraulic models. Note, changes in flow between the two river stations are due to storage effects within the effected floodplain.

Table 2: Flow Frequency for Salt River.

Return Period	Upstream limit at River Station 211.52 (cfs)	River Station 205.52 (cfs)
5 –Year	20200	20000
10 - Year	53000	87000
20 - Year	87000	84000
50 - Year	135000	132000
100 - Year	166000	164000
200 - Year	202000	200000
500 - Year	240000	237000

The average rainfall for the Phoenix area is summarized in the following Table. 3. The information for this rainfall data was extracted from rainfall recorded at the Phoenix Sky Harbor Airport located seven miles east of the downstream section of the study area. However, its important to note that summer thunderstorms can produce local precipitation that exceeds the monthly average which can result in local flooding of streets, drainage channels and washes. The intensity and duration of the precipitation varies depending on the location of the individual storm cells. Therefore, a maximum amount of rainfall at Sky Harbor from a storm may be greater or less than the amount that occurs within the project area.

Table 3: Rainfall Pattern for the Phoenix Area

Month	Rainfall in Inches
January	0.67
February	0.68
March	0.88
April	0.22
May	0.12
June	0.13
July	0.83
August	0.96
September	0.86
October	0.65
November	0.66
December	1.00
Annual Total	7.66

RUNOFF DISCUSSION

The winter months are typically when large regional storms or series of storms occur. These storms may include an accumulation and subsequent melt of the snow pack in the Salt River and Verde River watersheds and result in the releases of water into the Salt River system that can flow over Granite Reef Dam into the study area. While the river stages may be high for an extended period, the quantity and intensity of accompanying storm precipitation is generally reduced in the lower elevations, including the study area.

During the middle to late summer months the monsoon storm pattern is typical. These storms produce intense, short-duration thunderstorms with significant precipitation. During these storms the river stages are low because the storms are localized and because the upstream reservoirs usually have the capacity to store the local runoff from the watershed.

Interior drainage is an assessment of the storm water runoff that accumulated on the up gradient side of levees. But, since the Rio Salado Oeste study reach does not have any significant levees or flood control structures, there are no interior drainage conditions to address. However, there are side drains that outfall into the Salt River within the study area. These drains were evaluated in terms of location and estimated discharge quantity and a more detailed discussion of this topic is presented in the Water Balance Section of these Appendixes.

Table 4 below illustrates an example of typical hydraulic flow conditions at selected locations within the study reach. This pertinent hydraulic information was extracted from the Baseline Without Project 100-Year flood frequency event condition.

Table 4: Selected Cross Section Pertinent Hydraulic Information Data for Baseline Without Project 100-Year Frequency Event Condition

Location Description	River Station In Miles	Min.Channel Elevation (ft)	Water Surface Elevation (ft)	Critical Water Surface (ft)	Slope (ft/ft)	Velocity Channel (ft/s)
19th Ave	211.51	1021.8	1043.8	1037.9	0.002129	15.6
27th Ave	210.44	1017.6	1040.7	1028.8	0.000521	7.4
35th Ave	209.54	1019.6	1036.6	1035.9	0.003416	13.9
43rd Ave	208.48	1007.6	1021.3	1017.8	0.001756	8.4
51st Ave	207.53	999.2	1012.6	1008.1	0.001041	7.5
59th Ave	206.51	990.2	1002.1	999.9	0.002356	10.4
67th Ave	205.52	975.9	994.0	987.0	0.000516	5.7
75th Ave	204.42	971.4	985.5	982.8	0.002884	9.6
83rd Ave	203.48	962.1	975.8	972.0	0.001186	6.5

STUDY METHODOLOGY

Analysis Tool

The HEC River Analysis System (HEC-RAS), Version 3.1.1, was used for the modeling (USACE, 1998a). A series of eight flow profiles were developed for each model based on the 3.1, 5, 10, 20, 50, 100, 200 and 500 –Year Flood Frequency Events.

Determination of Manning's Roughness Coefficient

All "n" values were based on similar vegetation and channel conditions that were used in Tres Rio (down stream), Rio Salado (upstream), and Va Shly'ay (upstream) studies since they have similarities hydraulic "n" value characteristics.

Environmental Features

The Rio Salado Oeste study area has locations where there is existing vegetation supported by precipitation, seepage, periodic flood flows, stormwater runoff. The USACE project design developed three alternatives in support of the Feasibility Study F4 Milestone. The goals of these three alternatives were to: 1) increase the native riparian vegetation: 2) increase the vegetation connectivity; and 3) stabilize bank sections where needed. A mixture of four environmental features was incorporated into these With Project alternatives. These four principle environmental features are classified and denoted as Cottonwood/Willow, Mesquite, Wetlands, and River Bottom.

Cottonwood/Willow (CW). The existing CW stands are located near saturated soil conditions near river overbank areas. CW a water table within 25 feet of the land surface or supplemental irrigation will be required to support the vegetation. Initial plantings will require irrigation to achieve a high survival rate. Once established, CW areas will need drip irrigation or water from the Surface Braided Irrigation Network (SBIN) to supply water. Uneven grading of the river bottom and overbank areas to create pockets to retain water will help maintain the CW. In the model, the CW areas were assigned an "n" value of 0.098.

Mesquite (MS). The MS vegetation is commonly located about 5 to 20 feet above the river channel. The water table must be within 30 feet of the surface to support established MS. Irrigation will be needed to help the MS get established but then flood irrigation or water from the SBIN will support the vegetation. In the model, MS was assigned an "n" value of 0.073.

Wetlands (WT). The WT areas can include open water, submerged vegetation and muddy shorelines. These features require a high water table at or near the surface or may need to be lined to retain water from other sources. The WT features will require

excavation in the riverbed to construct the basins and this changes the configuration of the channel bed. Some WT features may need both inflow and outflow channels. The WT areas were assigned an "n" value of 0.048.

River Bottom (RB). RB will require some reshaping to fill in large depressions and to create mounds to reduce flood flow impacts to the restoration features. The RB areas may be hydro-seeded with native river bottom shrub and grass species but this vegetation should not impact the hydraulic capacity of the river. The "n" value assigned for RB was 0.03

Structural Features

There are several structural features within the study area that have been identified as bridges, sand and gravel mining operation sites, and a grade control structure.

The principle bridges in the study area are identified at the River Mile stations shown in Table 5 below. Also, there is a single buried grade control structure in the Salt River immediately located downstream of the 19th Avenue Road Bridge.

Table 5: Bridges with the Rio Salado Oeste Study Reach

Bridges Name	River Station
19th Avenue Bridge	211.52
Conveyor Bridge at 27th Avenue	210.43
35th Avenue Bridge	209.53
51st Avenue Bridge	207.48

Finally, there are a number of active sand and gravel mining operations within the Salt River floodplain of the subject study reach. The locations of these operations are largely between 51st and 35th Avenues and are shown in Figure 2 below.

HYDRAULIC ANALYSIS & RESULTS

A hydraulic analysis of the existing and future without project conditions were developed using the HEC-RAS River Analysis System modeling process. The initial hydraulic analyses were based on a digital terrain model generated from aerial survey's completed in December of 2001. But, since active mining has continued to change the basic terrain along the Salt River floodplain after the December 2001 date, the initial Baseline Without Project model did not reflect this revised condition. However, to account for this ongoing projected mining condition, the Baseline Without Project model was modified by adjusting the current and potential sand and gravel impacted areas by assuming a final mined out "footprint" condition. Once the Baseline model had been revised to reflect the future mined condition, then With Project alternatives were subsequently developed. There were three environmental

alternative concepts that were developed by the study team and carried forward in the evaluation process. These three alternatives were assessed in terms of their respective level of habitat value and identified as Alternative "High", Alternative "Medium", and Alternative "Low".

Without Project Modeling

Initially, West consultants completed a hydraulic analysis of the existing without project conditions using HEC-RAS (West, 2002). A 1-dimensional model of the reach was created using HEC-RAS and the HEC-GeoRAS extension in ArcView 3.2a (Environmental Systems Research Institute, Inc). The cross section geometry for this model was obtained from the TIN using the same cut lines utilized in the FEMA Flood Insurance Study (FIS) model prepared originally by Michael Baker Jr., Inc. However, The WEST hydraulic analysis was based on a digital terrain model generated from updated aerial surveys completed in December of 2001. Finally, the results generated from the West existing model are referred too as the Existing Condition Baseline Model (again prior to WEST 2002 work).

Within the study reach, the Baseline Existing Condition HEC-RAS 100-year water surface elevation results are generally lower than the corresponding elevations in the FEMA Flood Insurance Study (FIS) model prepared by Michael Baker Jr., Inc. The difference in the water surface elevation can be attributed to different geometric cross section information. The FIS model geometry was reported to be based upon aerial surveys flown in 1992 and 1993. In WEST's Baseline Existing Condition model, the cross section floodplain geometry was updated between River Mile Stations 211.51 to 216.53 with one-foot contour interval mapping developed from aerial information flown in1998. In general, the comparative channel inverts for the updated cross sections were on the order of three to four feet lower than those contained in the Baker model.

A normal depth stage discharge boundary analysis was preformed at cross section 1, which is approximate 1.6 miles downstream of RM 203.29. Consequently, all water surfaces are noralized and stable at the beginning of the study reach (RM 203.29).

New 35th Avenue Bridge

The City of Phoenix has designed and is planning improvements to the 35th Avenue Bridge crossing the Salt River within the study area. The purpose is to improve the safety and operation of traffic along 35th Avenue between Broadway Road and Lower Buckeye Road and to provide an all-weather crossing over the Salt River. The existing 35th Avenue Bridge across the Salt River was built in 1983 as an emergency repair project to replace a bridge that was washed out by flooding. It was built as a half-bridge and designed to accommodate the 35-year flow event, and planned to be widened and lengthened in the future.
The proposed work includes construction of a new 5-lane, 8-pier, 9-span precast concrete I-girder bridge with cast-in-place concrete deck slab to replace the existing

two-lane bridge. The bridge will be constructed upstream of the current bridge, which will be demolished after traffic is rerouted onto the new bridge. Old fill material on the north and south sides of the river will be excavated and replaced by the new bridge abutments. Rock protection will be placed at the bridge abutments to protect the new bridge. Additional fill will be removed from the river bed to allow the new bridge to convey the 100-year discharge.
Modifications to this bridge have been considered as part of the future without and future with project conditions in planning for the Rio Salado Oeste project. The new structure will be in place prior to construction of any proposal resulting from this feasibility study.

With Project Modeling

Determination of Manning's Roughness Coefficient

The maximum Manning's roughness coefficient (*n* value) that can be used in the environmental restoration area without affecting the channel capacity was determined and was correlated to plant density (or % obstruction across the cross-section). This was accomplished by using normal depth calculations for typical cross-sections along the study reach. Then the *n* value was varied horizontally across each cross-section; i.e., the *n* value was set equal to 0.032 for the low flow channel segment while it was varied for the vegetated area.

Discharge frequency values for with project condition

The 100-year discharge of 166,000 cfs was used to design the With Project Salt River floodway through the study reach. Incorporated in this design phase was the need for a low flow channel feature for 5-year peak events with capable of conveying 20,200 cfs. Details on this latter feature will be discussed under the "Low Flow Channel" section of this appendix.

Structural Features

For the With Project Condition analyses, a number of structural features were incorporated into each of the alternative evaluations. These structural features included to some degree a low flow channel, new 35th Avenue Bridge, a grade control structure, wetland creation, and some type of surface braided irrigation network. The structural descriptions provided are only preliminary and will be developed more thoroughly, if necessary, during the Preliminary Engineering and Design Phase (PED).

Low Flow Channel

Maintenance or restoration of physical aquatic habitat in streams during critical periods can often be accommodated with the development of low flow channels,

designed to concentrate flows and increase channel velocity and depth during low flow periods.

A low flow channel was included in the design along two segments of the Rio Salado Oeste study reach. Specifically, a low flow channel was designed between River Mile Station 203.39 to 207.43 and another segment between River Mile Station 209.53 to 211.52. Essentially, these two low flow segments extend downstream and upstream to the study limits from 51st and 35th Avenues respectively. Both subreaches are shown in Figure 4.

The primary purpose of the low flow channels are to increase overall conveyance within the Salt River floodway to offset the increased roughness caused by new vegetation being proposed in the main channel and to collect excess irrigation water that could be used to irrigate wetland habitat and river bottom areas. The low flow channel was designed to convey 20,200 cfs (approximately a 5-year peak event). Initial channel dimensions were based on the following general constraints: 1) an average bottom width varying between 300 to 800 feet; 2) an average flow depth of 5 to 10 feet; 3) a design slope of 0.14%; 4) constructed side slope of 1 vertical for 3 horizontal; and 5) a channel n value of 0.032. The low flow channel was configured to follow the existing river thalwag, which performed reasonably well in terms of maintaining its current alignment and general invert elevation after experiencing on approximate 40,000 cfs discharge during a February 2005 storm event. Finally, the channel design does not incorporate any lining or low flow guide or containment structures. However, based on the performance of the study reach to date, there is no evidence of any significant lateral channel migration concerns that would carry over into the with project condition.

With Future Mining

The City of Phoenix purchased approximately 250 acres of riverbed between 35th and 51st Avenues. The City has been working on a plan to lease the property for removal of aggregate in a manner that will leave the river cross section suitable for restoration. Future with project conditions assume that modifications to this reach of the river will occur prior to the project.

This area is approximately between River Station 207.62 to 209.24 (about 500 feet downstream from the 35th Avenue Bridge) and is shown in Figure 2 below.

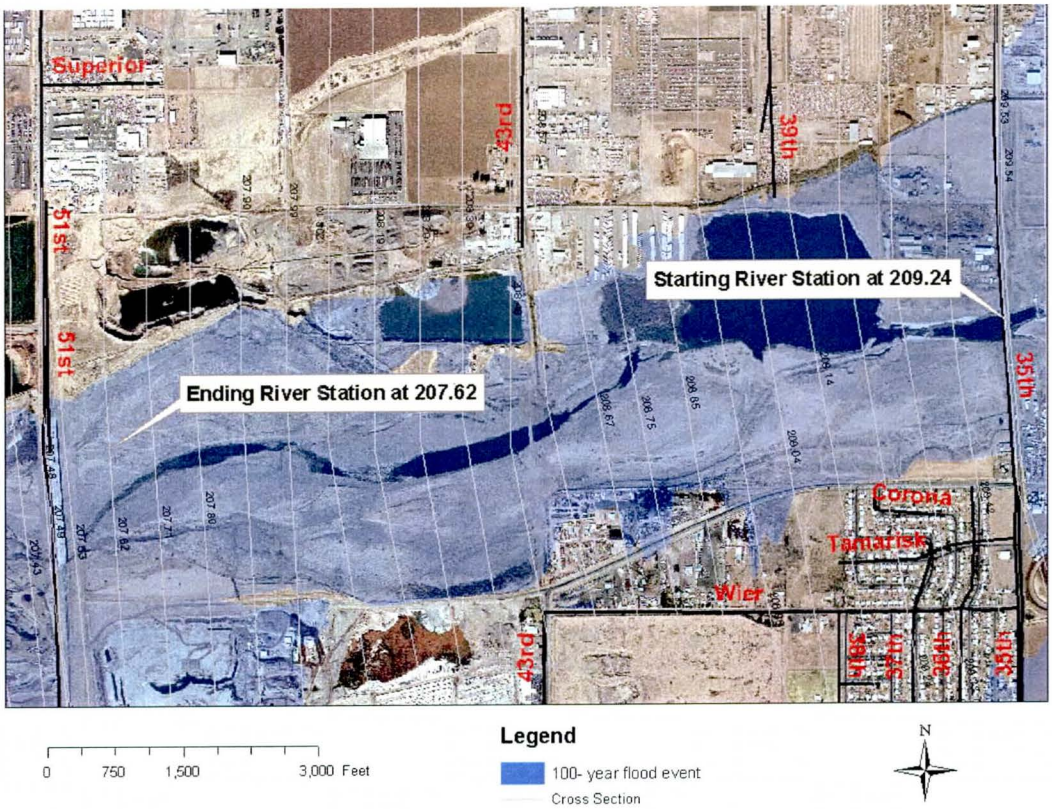

Figure 2: Location of New Mining Operation

The updated revised Existing Condition Baseline model for the Salt River between 51st and 35th Avenues reflects this future mining activity as of target year 2011. These significant channel thalweg depressions can be seen in Figure 3 below.

The associated impact on the channel and overbank in terms of modeled Manning's roughness coefficients ("n" value) were established at 0.035 and 0.043 respectively.

The peak discharges presented in the Discharge Frequency Analysis section of this appendix were used in both the Baseline Conditions and Without Project Condition model simulations.

For the 100-year frequency discharge event, the Future With Project Condition water surface elevations were compared to the original Baseline Without Project model results. The comparative resultant water surface profiles are shown in Figure 3 below.

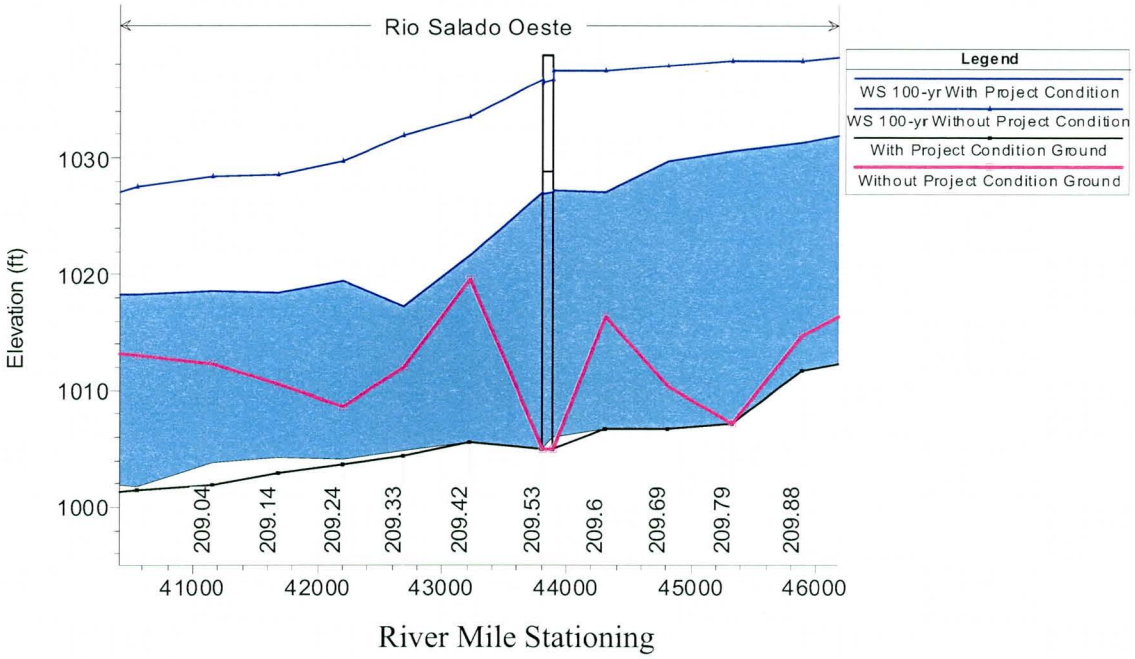

Figure 3: WS 100-yr for Without Project Condition and With Project (Future Mining Operations) Condition between River Mile Stations 209.04 to 209.88.

It was assumed that the channel Manning's roughness coefficient and the ineffective flow areas did not change from the Existing Without Project Baseline Condition or Future With Project Baseline Condition throughout most of the study area.

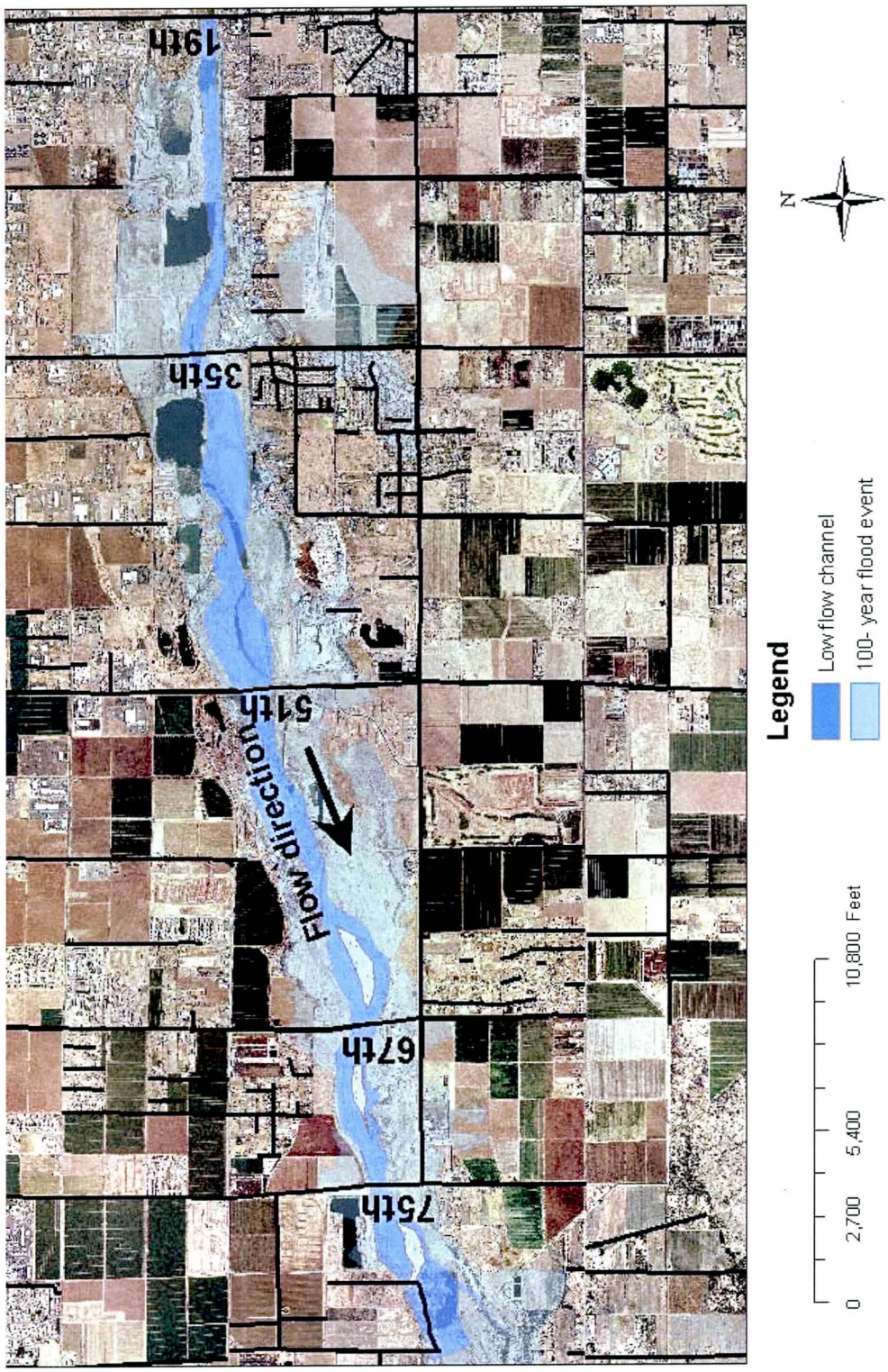

Figure 4: Low Flow Channel

Grade Control Structure

Current and projected mining along the Salt River within the study area has several large depressions. Evidence of a typical depression is identified in Figure 5 below. As expected, these areas have significant flow conveyance and sediment transport impacts within the floodplain. As a minimum, these large depressions alter the hydraulic conditions that translate into riverbed scouring and/or deposition upstream and downstream of their locations and can also potentially induce bank instability concerns as well.

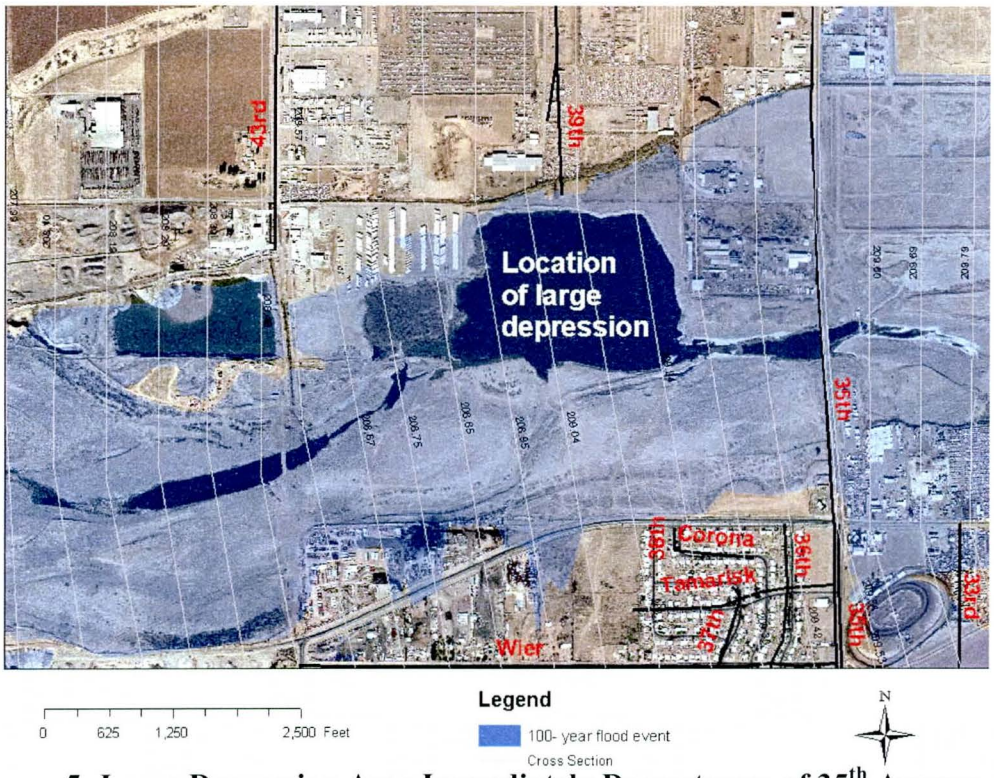

Figure 5: Large Depression Area Immediately Downstream of 35th Avenue

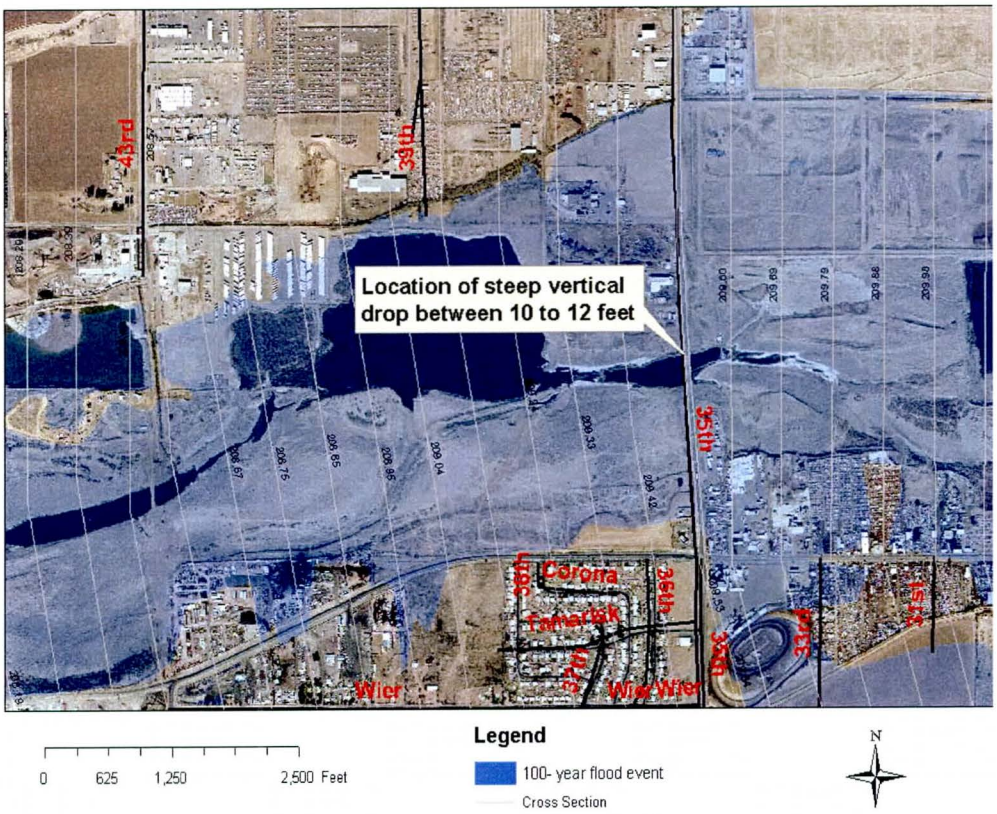

Figure 6: Steep Vertical Drop at 35th Avenue

As a direct result of the large depression and future mining (proposed modification) operation between 35th Avenue and 51th Avenue of downstream of 35th Avenue, there is a 10 to 12 feet thalweg grade break differential. The vicinity of this grade break (future gravel pit mining induced) location is shown in Figure 6 above. And also Figure 3 shows HEC-RAS water surface profile drop, between river stations 209.88 to 209.04, from 10 to 12 feet. In the likelihood that a head will propagate upstream and undermine the 35th Avenue Bridge area, a grade control structure is being recommended to prevent this particular scenario from occurring.

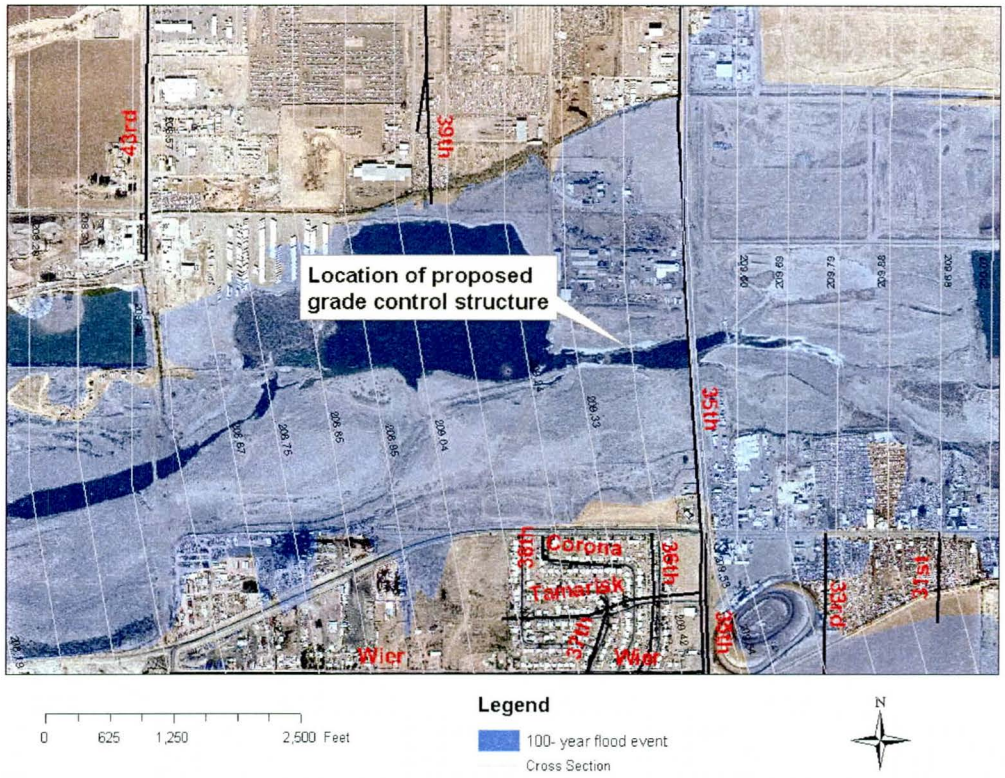

Figure 7: Proposed Location of Grade Control Structure

The proposed grade control structure would be located at approximate River Mile Station 209.42, as shown in Figure 7 above. The proposed grade control structure would extend across the full width of the floodway channel. Preliminary analyses indicate that there would be a requirement for toe protection to extend approximately 27 feet below low flow channel invert.

The grade control structure was designed based on a similar structure used in the upstream Rio Salado Phoenix Project.

Toe-Down Depths
The Veronese equation, as presented by Pemberton and Lara (1984), was used.

$$Ds = 1.32\ \Delta H^{0.225}\ q^{0.54} - y_2$$

Where Ds = depth of scour (ft)
q= unit discharge (cfs/ft)
y_2 = downstream(tailwater) depth(ft)
ΔH=difference in head from upstream reservoir to tailwater(ft)

$$Ds = 1.32 \times 10^{0.225} \times (166000/1250)^{0.54} - 10 = 21.05 \text{ ft}$$

Toe-down Depths = factor of safety x Ds = 1.3 x 21.05 = 27.36 ft

While the low flow channel is designed to convey 20,200 cfs (approximately a 5-year peak event). The grade control structure would be designed to withstand the 100-year frequency flood peak event. Tentatively, the grade control structure would be constructed out of roller compacted concrete (RCC) and would be similar in design that the two structures that are currently incorporated in the Rio Salado Phoenix project immediately upstream.

Project Features

Initially, the principle environmental project feature alternatives were developed by the study manager in close coordination with the local sponsor. These project features evolved into three distinct alternatives that were closely tied to the density level and site specific location of vegetation patterns throughout the study reach. These three unique vegetation alternatives were identified and classified as "High", "Medium", and "Low". As a further refinement and development of a final recommended alternative, the study team elected to proceed exclusively with the "High" Alternative option with its associated project features.

As discussed earlier, a HEC-RAS model was developed to assess the "with project" impacts on the Baseline Future Condition Without Project condition. The vegetation layout plan associated with this "High Alternative" is displayed in Figure 8 below. The vegetation types incorporated in this alternative included Cottonwood/Willow (CW), Emergent Wetlands (WT), and Mesquite (MS).

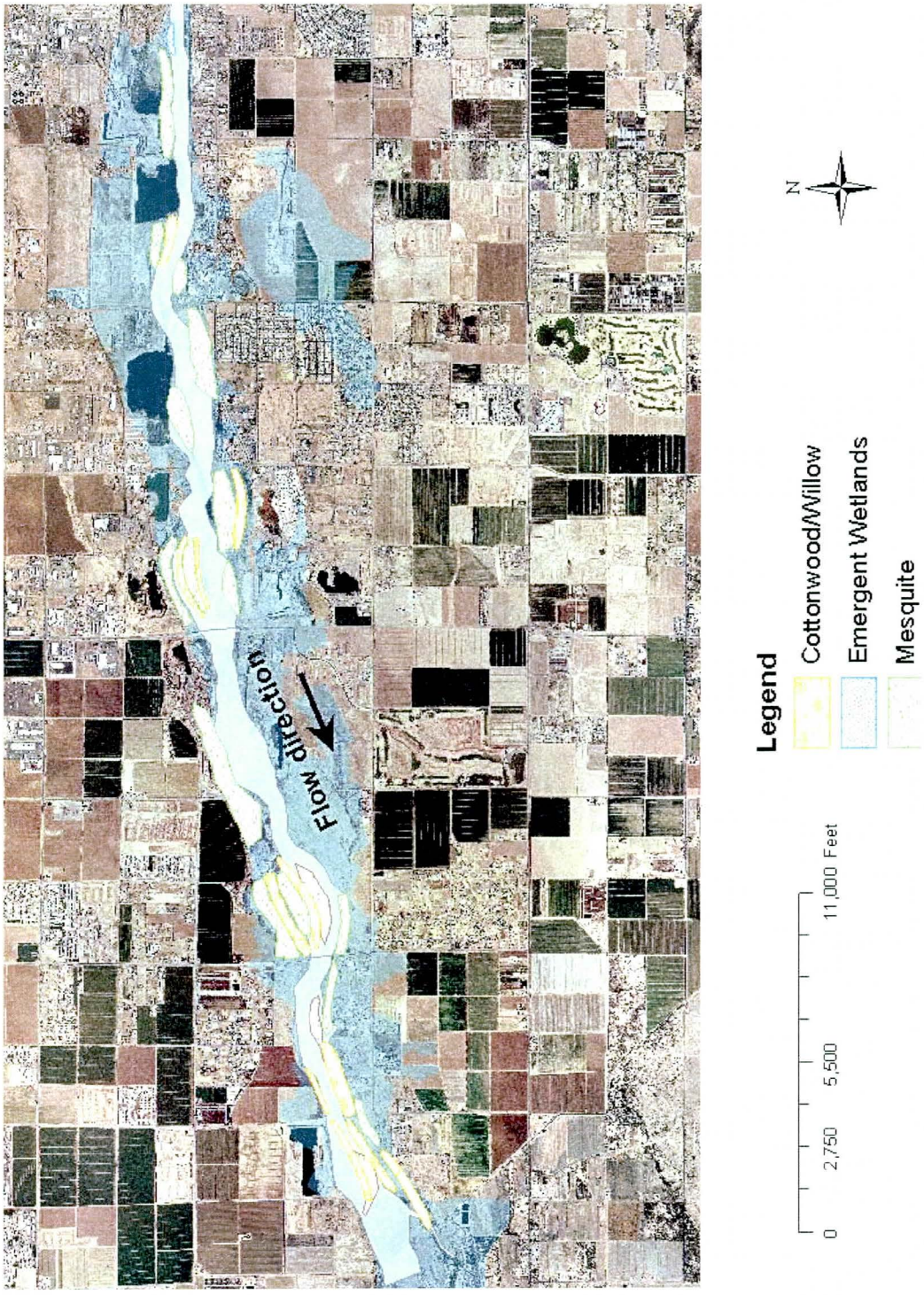

Figure 8: "High Alternative" Environmental Project Features

To properly simulate the with project conditions, several changes had to be made to the Existing Future Without Project Baseline condition model. Essentially, these changes involved modifications to the original model's ineffective flow areas and adjusting the n values where necessary. With respect to this latter item, n value in the channel and overbank on the floodplain terrace were increased to 0.037 and 0.043 respectively. The increases were required to offset the additional roughness associated with greater surface irregularities, channel cross section variation, and more increased vegetation channel obstruction.

With Project Results

Multiple Discharge Analysis

Since the With Project water surface profiles associated with the 3.1-, 5-, 10-, 20-, 50, 100-, 200-, and 500-year frequency flood events are similar to that of the 100-year frequency flood event (with the exception of magnitude), only the 100-year With Project model results were displayed in this document. Figure 9 below captures the With- and Without Future Condition water surface profile for subject study reach.

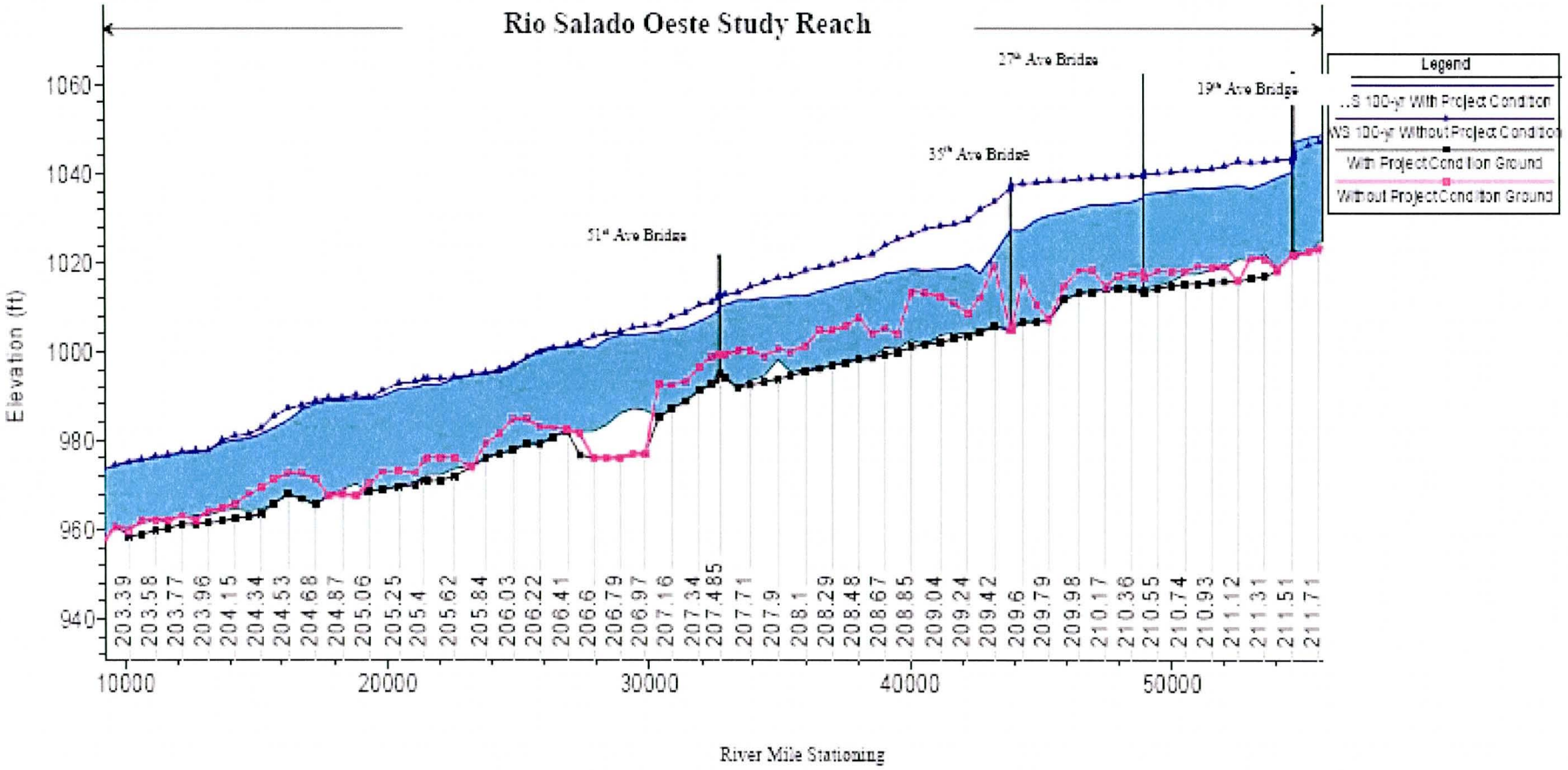

Figure 9: 100-Year Event Water Surface Profile

100-Year Event Discharge Analysis

Corresponding Table 6 below shows pertinent hydraulic 100-year flood frequency event peak discharge information for both With- and Without Project conditions.

Table 6: 100-Year Flood Frequency Event Peak Discharge Analysis for With- and Without Project Conditions

River Station	Q (cfs)	Water Surface Elevation (ft)		Minimum Channel Elevation (ft)		Water Depth (ft)		Average Velocity (ft/s)	
		W/O	W/	W/O	W/	W/O	W/	W/O	W/
211.51	166000	1043.35	1040.29	1021.80	1021.90	21.55	18.39	15.98	22.46
211.41	166000	1043.08	1039.00	1018.30	1018.80	24.78	20.20	13.64	19.08
211.31	166000	1042.54	1037.64	1020.80	1022.20	21.74	15.44	12.61	16.87
211.21	166000	1042.33	1036.74	1021.10	1020.40	21.23	16.34	10.31	13.73
211.12	166000	1042.59	1037.41	1015.67	1020.90	26.92	16.51	7.25	7.58
211.02	166000	1041.67	1036.93	1019.35	1018.90	22.32	18.03	9.46	7.33
210.93	166000	1041.02	1036.78	1018.71	1018.50	22.31	18.28	10.04	6.10
210.83	166000	1040.64	1036.52	1019.14	1017.30	21.50	19.22	9.53	6.14
210.74	166000	1040.56	1036.18	1018.18	1017.40	22.38	18.78	8.11	5.93
210.64	166000	1040.35	1035.84	1017.72	1015.90	22.63	19.94	7.69	6.19
210.55	166000	1040.15	1035.55	1018.02	1014.60	22.13	20.95	7.35	5.43
210.46	166000	1040.03	1035.27	1016.27	1014.30	23.76	20.97	6.80	5.75
210.44	166000	1039.70	1034.82	1017.63	1013.53	22.07	21.29	7.84	7.96
210.43	166000	1039.50	1034.54	1017.52	1013.51	21.98	21.03	7.96	8.00
210.36	166000	1039.29	1033.49	1017.39	1013.92	21.90	19.57	7.19	9.60
210.26	166000	1039.19	1033.28	1016.87	1014.21	22.32	19.07	5.92	7.86
210.17	166000	1039.07	1032.88	1014.74	1013.98	24.33	18.90	5.23	7.54
210.07	166000	1039.05	1032.91	1018.47	1013.50	20.58	19.41	3.98	5.22
209.98	166000	1038.75	1032.31	1018.07	1013.00	20.68	19.31	5.02	6.81
209.88	166000	1038.41	1031.34	1014.72	1011.65	23.69	19.69	5.72	7.71
209.79	166000	1038.28	1030.57	1020.00	1007.14	18.28	23.43	5.27	6.94
209.69	166000	1037.97	1029.71	1019.00	1006.78	18.97	22.93	5.89	7.79
209.6	166000	1037.51	1027.05	1016.38	1006.68	21.13	20.37	7.36	12.71
209.54	166000	1037.47	1027.26	1005.00	1006.00	32.47	21.26	5.27	8.56
209.53	166000	1036.69	1027.05	1005.00	1005.00	31.69	22.05	5.42	8.39
209.42	166000	1033.54	1021.71	1019.56	1005.50	13.98	16.21	13.47	17.49
209.33	166000	1031.92	1017.29	1019.07	1004.80	12.85	12.49	12.55	19.38
209.24	166000	1029.65	1019.51	1017.41	1004.10	12.24	15.41	14.08	6.18
209.14	166000	1028.58	1018.60	1014.45	1004.20	14.13	14.40	11.42	8.61
209.04	166000	1028.34	1018.52	1012.24	1003.80	16.10	14.72	8.72	6.00
208.95	166000	1027.44	1018.35	1013.05	1001.70	14.39	16.65	9.57	5.18
208.85	166000	1026.09	1018.31	1013.35	1002.50	12.74	15.81	9.79	4.25
208.75	166000	1025.17	1017.93	1011.00	1000.70	14.17	17.23	8.92	5.70
208.67	166000	1023.79	1017.37	1010.00	1000.80	13.79	16.57	10.06	7.38
208.57	166000	1021.83	1015.95	1010.00	998.70	11.83	17.25	11.58	10.76
208.48	166000	1021.28	1015.72	1007.62	998.10	13.66	17.62	8.44	9.01

River Station	Q (cfs)	Water Surface Elevation (ft)		Minimum Channel Elevation (ft)		Water Depth (ft)		Average Velocity (ft/s)	
		W/O	W/	W/O	W/	W/O	W/	W/O	W/
208.39	166000	1020.35	1015.17	1005.57	997.50	14.78	17.67	8.58	8.09
208.29	166000	1019.47	1013.97	1004.70	996.79	14.77	17.18	8.13	9.45
208.19	166000	1018.78	1013.55	1004.66	996.10	14.12	17.45	7.40	8.23
208.1	166000	1017.96	1012.33	1001.33	995.80	16.63	16.53	7.23	9.38
207.99	166000	1016.85	1012.39	999.85	995.70	17.00	16.69	7.85	5.55
207.9	166000	1016.26	1012.15	1000.76	998.10	15.50	14.05	6.73	5.04
207.8	166000	1015.28	1011.96	999.08	994.60	16.20	17.36	7.69	4.62
207.71	166000	1014.31	1011.55	1000.34	993.70	13.97	17.85	8.15	5.12
207.62	166000	1012.94	1011.28	1000.23	992.00	12.71	19.28	9.61	5.40
207.53	166000	1012.59	1010.23	999.27	994.37	13.32	15.86	7.48	8.88
207.49	166000	1012.38	1009.97	999.41	994.96	12.97	15.01	7.48	8.70
207.48	166000	1012.05	1009.08	999.23	994.04	12.82	15.04	7.72	9.05
207.43	166000	1011.14	1008.14	999.03	992.99	12.11	15.15	9.33	10.50
207.34	166000	1010.29	1006.54	996.54	991.22	13.75	15.32	9.80	11.75
207.27	166000	1008.74	1005.31	993.27	988.96	15.47	16.35	11.10	11.64
207.16	166000	1007.70	1004.84	992.67	987.06	15.03	17.78	9.58	9.23
207.07	166000	1006.06	1004.22	992.78	985.20	13.28	19.02	11.78	9.07
206.97	166000	1005.79	1003.89	992.70	986.80	13.09	17.09	8.32	7.75
206.88	166000	1005.42	1003.76	992.60	987.00	12.82	16.76	7.69	6.26
206.79	166000	1004.38	1003.53	993.00	986.30	11.38	17.23	9.34	5.89
206.7	166000	1004.10	1002.72	991.20	983.50	12.90	19.22	7.20	7.64
206.6	166000	1003.43	1000.44	990.50	982.10	12.93	18.34	7.88	11.95
206.51	166000	1002.10	1001.39	990.20	982.00	11.90	19.39	10.43	5.04
206.41	166000	1001.20	1001.05	988.80	982.20	12.40	18.85	9.49	6.00
206.32	166000	1000.48	1000.83	987.40	981.00	13.08	19.83	8.09	6.25
206.22	166000	999.54	1000.35	986.00	979.16	13.54	21.19	8.06	6.82
206.13	166000	998.57	998.72	984.62	979.43	13.95	19.29	7.99	9.61
206.03	166000	996.94	996.48	984.67	977.85	12.27	18.63	9.84	11.73
205.94	166000	995.95	995.37	981.52	977.00	14.43	18.37	8.08	7.50
205.84	166000	995.38	995.14	979.54	975.96	15.84	19.18	6.80	4.47
205.75	166000	994.73	994.44	973.88	974.50	20.85	19.94	7.06	6.34
205.62	166000	994.28	993.94	975.97	973.60	18.31	20.34	6.18	4.43
205.52	164000	994.03	992.62	975.91	972.20	18.12	20.42	5.68	7.76
205.43	164000	993.74	992.52	976.08	972.20	17.66	20.32	5.99	6.25
205.4	164000	993.73	992.47	975.49	971.80	18.24	20.67	5.29	5.39
205.34	164000	993.37	992.02	972.70	970.70	20.67	21.32	6.53	6.96
205.25	164000	992.88	991.63	973.42	969.90	19.46	21.73	6.93	6.84
205.15	164000	991.15	989.89	973.07	969.00	18.08	20.89	10.75	10.58
205.06	164000	989.65	989.02	970.41	968.50	19.24	20.52	10.77	10.39
204.97	164000	990.01	989.22	967.59	970.30	22.42	18.92	5.62	6.59
204.87	164000	989.45	988.96	968.08	968.90	21.37	20.06	6.94	6.04
204.78	164000	989.39	988.75	967.60	967.90	21.79	20.85	5.08	4.16
204.68	164000	988.71	988.16	971.32	965.54	17.39	22.62	7.22	5.96
204.61	164000	987.92	986.83	972.56	966.95	15.36	19.88	8.55	7.71
204.53	164000	987.03	984.42	972.73	968.00	14.30	16.42	8.73	10.40
204.42	164000	985.49	982.89	971.40	965.98	14.09	16.91	9.64	10.54

River Station	Q (cfs)	Water Surface Elevation (ft)		Minimum Channel Elevation (ft)		Water Depth (ft)		Average Velocity (ft/s)	
		W/O	W/	W/O	W/	W/O	W/	W/O	W/
204.34	164000	982.74	981.44	969.27	964.50	13.47	16.94	12.19	10.94
204.25	164000	981.35	980.52	967.99	964.10	13.36	16.42	10.54	9.76
204.15	164000	981.23	980.14	965.87	964.70	15.36	15.44	7.14	7.41
204.05	164000	980.23	979.29	964.99	964.10	15.24	15.19	8.49	7.90
203.96	164000	977.57	977.80	964.14	963.20	13.43	14.60	11.99	9.69
203.86	164000	977.66	977.41	962.22	963.40	15.44	14.01	6.92	7.21
203.77	164000	977.24	976.94	963.26	963.70	13.98	13.24	6.50	6.60
203.67	164000	976.81	976.66	962.27	961.40	14.54	15.26	6.47	5.85
203.58	164000	976.33	976.08	962.07	962.10	14.26	13.98	6.54	7.06
203.48	164000	975.83	975.76	962.18	961.30	13.65	14.46	6.48	5.99
203.39	164000	975.18	975.24	959.89	960.60	15.29	14.64	6.57	6.04

W/ -With Project condition
W/O -Without Project condition

Minor Water Surface Anomalies

The only significant changes that occurred when introducing the With Project features on the Without Project Baseline conditions were observed between River Mile Stations 206.13 to 206.32. The water surface profile through this area is displayed in Figure 10 below while the corresponding water surface elevation differentials are shown in Table 7.

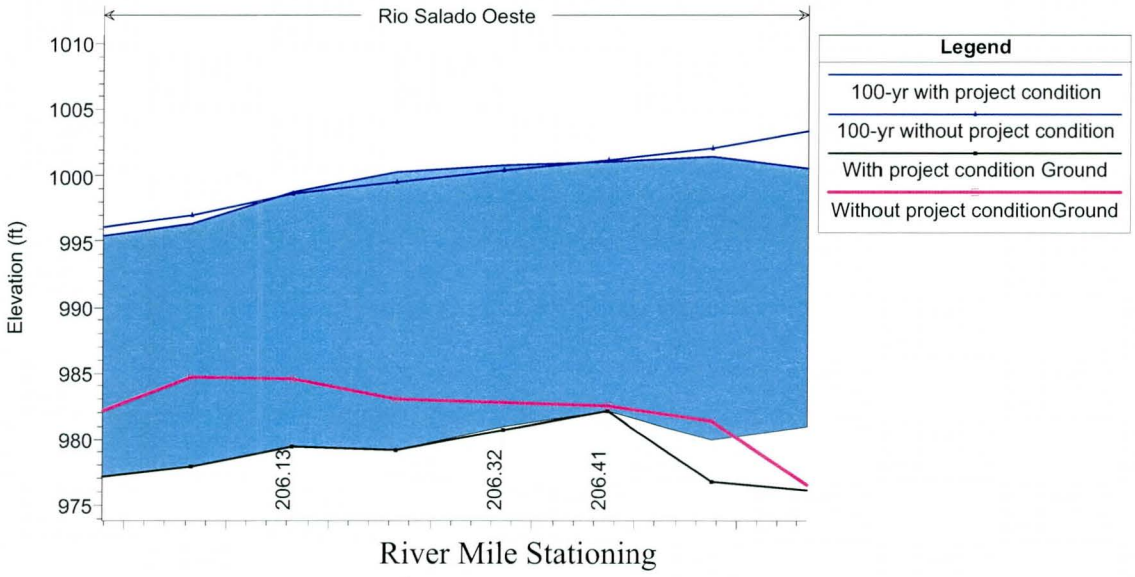

Figure 10: 100-Year Flood Frequency Event Water Surface Profile for River Station between 206.13 and 206.32

Table 7: 100-Year Flood Frequency Event Comparative Water Surface Elevation Differentials Between River Mile Station 206.32 to 206.13

River Station	100- year event discharge (cfs)	Project Condition	Minimum Channel Elevation (ft)	Water Surface Elevation (ft)	Difference in Water Surface between W/ and W/O (ft)
206.32	166000	W/O	987.40	1000.48	
206.32	166000	W/	981.00	1000.83	0.35
206.22	166000	W/O	986.00	999.54	
206.22	166000	W/	979.16	1000.35	0.81
206.13	166000	W/O	984.62	998.57	
206.13	166000	W/	979.43	998.72	0.15

W/ - With Project condition
W/O – Without Project condition

A detailed assessment of the areas in which the With Project water surface elevations are higher than the Without Project Baseline conditions is noted in the accompanying effected River Mile cross sections. Upon a closer examination of Figures 11,12, and 13 below indicate that there would be minimal flood damages since the overbanks are essentially higher in both the With- and Without Project condition.

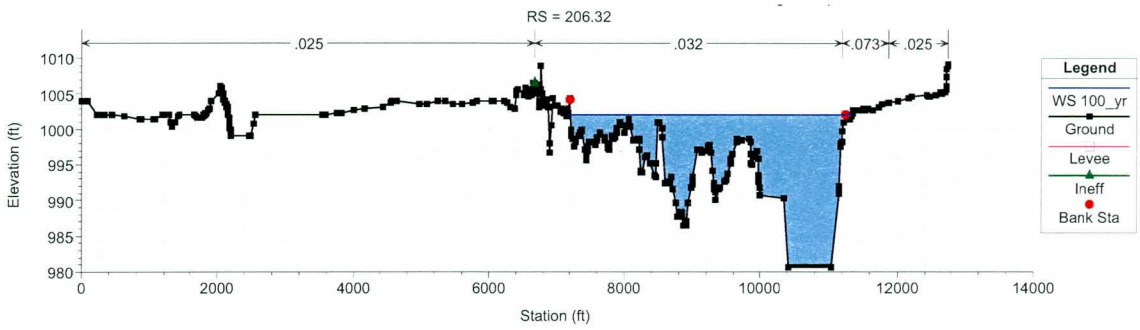

Figure 11: Cross Section at River Mile Station 206.32

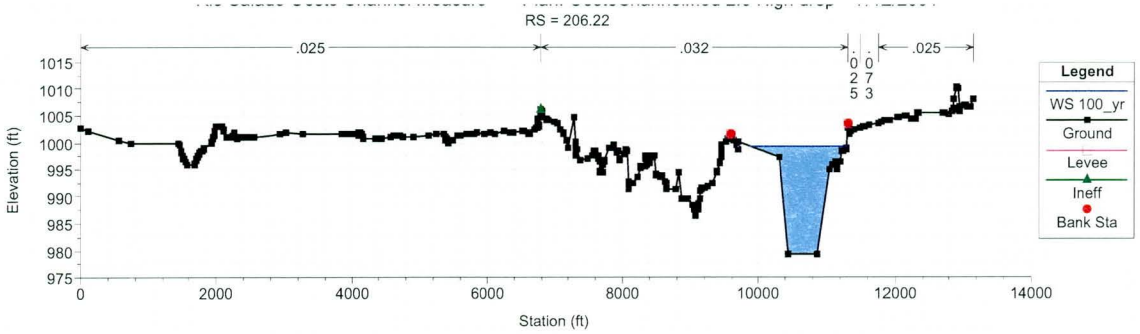

Figure 12: Cross Section at River Mile Station 206.22

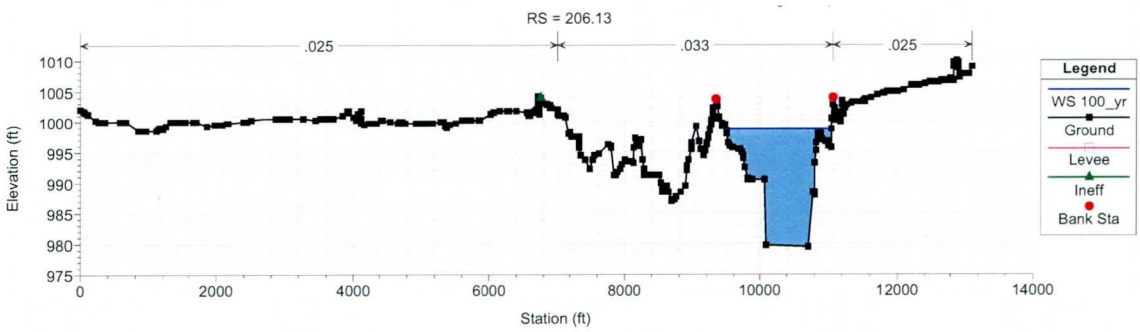

Figure 13: Cross Section at River Mile Station 206.13

However, if flood damages are in fact significantly increased, then further hydraulic modifications will be made during the later feasibility phases to accommodate a more acceptable pre-project condition.

Overall With Project water surface elevations were decreased from River Mile Stations 203.39 to 207.48 and also from River Mile Stations 209.53 to 211.51 as a direct result of the incorporation of a low flow channel feature. Finally, the water surface elevations were also decreased between River Mile Station 207.62 to 209.42 as a direct consequence of channel mining activity.

SEDIMENTATION ANALYSIS

Without Project

A detailed Without Project sediment transport analysis was performed for this study and the results are contained in the F3 Without Project Final Hydraulic Analysis Report. Specifically, the report titled Rio Salado Oeste Study Without Project Final Hydraulic Analysis Report (June 2002) was prepared under contract by WEST Consultants, Inc.

General

The objective of the sediment transport analysis is to identify baseline sediment conditions, which will be used with later alternative conditions studies to identify the preferred project alternatives. A base conditions sediment transport model was created using the geometry from the existing conditions hydraulic model.
The computer program HEC-6T "Sedimentation in Stream Networks", version 5.13.15 of May 24, 2001, was used to conduct the numerical sediment transport modeling in this study. HEC-6T was developed by Mr. William A. Thomas of Mobile Boundary Hydraulics, Clinton, Mississippi.

HEC-RAS Model Conversion

Model Geometry

The geometry of the hydraulic model was converted into a text file with the format required by the HEC-6T program. Roughness coefficients in several cross sections of the hydraulic model vary horizontally with distance in the cross section. HEC-6T does not allow as much horizontal variation of Manning's n, so an alternative method of expressing the roughness coefficient was required. After running the 5-, 10-, 20-, 50-, 100- and 500-year flood events in HEC-RAS, the profile output tables were used to request conveyance weighted Manning's n values for the channel, left and right overbanks for the different discharges. These data were then entered into the HEC-6T input file using NV records. A default value of 0.04 was used to fill blanks when the conveyance in an overbank area was zero. The result was a configuration of roughness coefficients changing in the vertical by discharge rather than in the horizontal by distance.

Conveyance limits defined in HEC-RAS using ineffective flow boundaries were coded using XL records in HEC-6T. The advantage of using XL records is that they allow deposition to occur in the ineffective flow areas. The effect of bridges crossing the river in the study area was accounted for using a single cross section with the pier geometry superimposed as recommended in the HEC-6T manual. Of the two bounding cross sections used to define each bridge in HEC-RAS, only the upstream one was retained in HEC-6T. The two bounding cross sections are very close to each other and keeping both in HEC-6T could cause numerical instabilities.

Fixed Bed Simulation

An elevation-discharge rating curve was developed at the downstream boundary (cross section 1) for starting water surface elevations. Water surface elevations were computed at this location assuming normal depth and a slope of 0.0019 ft/ft, for discharge values ranging from 7,500 cfs to 285,000 cfs, at 7,500 cfs increments (Figure 14).

HEC-6T was then run with a fixed bed using the 5-, 10- and 100-year flood events, and the resulting water surface elevations were compared to the HEC-RAS existing conditions model. In order to guarantee the quality of the sediment model, the water surface elevations computed by HEC-6T for each of the three events were examined at each cross section to ensure that they did not differ from the HEC-RAS results by either 10% of the maximum depth or 1 foot, whichever was less.

Sediment Parameters

The Corps computer program SAMAID was used to select the most appropriate sediment transport relationship. SAMAID results indicated that Madden's 1985 modification of Laursen's equation and Yang's equation were respectively best and second best sediment transport relations for the characteristics of the study reach. Schoklitsch's equation came out in third place. WEST has used Yang's equation in the past on the Salt River upstream and downstream of the project site. In general, this equation performs well for mid sized rivers transporting large amounts of sand,

which is typical of many streams in Arizona. Therefore, the sediment transport equation selected for this study was Yang's unit stream power.

Bed Sediment Characteristics

Nineteen locations were identified for sediment sampling and development of gradation curves. Sampling sites were located approximately 0.5 miles apart, from 19th Avenue to 91st Avenue. Samples were collected from 0 to 2 feet, and laboratory grain-size analyses were performed on the samples. In addition, an in-situ particle count consisting of 100 particles spaced at 1 foot intervals was performed. Bed gradation data were entered into the HEC-6T input file using PF records.

Inflowing Sediment Rating Curve

Recorded information about sediment loads in the Salt River upstream of the study reach is not available. There are however previous studies reporting sediment transport simulations. One of these studies is the Low Flow Channel Design Analysis for Rio Salado (2000) performed by WEST for the Corps. This study presented a sediment transport model of the Salt River from approximately the I-10 Bridge to the 27th Avenue alignment, based on the Toffaleti, Meyer-Peter and Muller combination transport method. The model used an estimated sediment inflow at the upstream end of the reach based on an equilibrium bed material load analysis performed on a 0.5 mile reach upstream of I-10.

The simulated loads from this previous study were not considered appropriate inflow loads to our model because they were not developed using any of the sediment transport equations identified as suitable for the current study (Yang's equation or Madden's 1985 modification of Laursen's equation). If a sediment inflow based on a different equation was used in the current model, depending on the amount of the sediment loads, there is a possibility that it could lead to either unrealistic erosion or deposition in the upstream end of our study reach.

Since we were confronted with a lack of adequate data on inflowing sediment loads into our study reach, an equilibrium bed material load was assumed. The inflowing load at the upstream end of the model was determined on a reach approximately 3 miles long at the upstream end of the study reach (from RM 211.21 to RM 214.14) with the gradation information from the two most upstream sediment sample locations. Equilibrium sediment loads for this reach were determined for a range of discharges from 20 to 200,000 cfs. To determine the equilibrium load, HEC-6T was run using clear water inflow as the initial condition and the recirculation option on ($RE record). The recirculation option instructs the program to use the sediment discharge at the downstream end of the reach as the sediment inflow at the upstream end for the following time step. When equilibrium is attained, sediment load entering the reach is about equal to the load leaving the reach. For discharges between 20 and 50000 cfs, the simulations were run typically for 10 to 100 days with time steps in the

order of 0.01 to 0.1 days. For larger discharges (100,000 to 200,000 cfs), typical durations were between 5 and 10 days with time steps of 0.001 to 0.01 days.

The inflowing sediment loads defined with Yang and Laursen-Madden relationships are shown in Figures 15 and 16. The gradation of the inflowing load from the equilibrium analysis is shown in Figures 17 and 18. This information was entered into the HEC-6T input files using LQ, LT and LF records.

Movable Bed Limits

In general, sediment dynamics tend to be more significant within the active channel, where the bed can either degrade or aggrade in response to erosion or deposition. The overbank areas tend to be more stable and normally are free of erosion, but can experience deposition. HD records were used to specify a bed sediment depth of 20 feet for all cross sections but one. At river mile 211.54 the sediment depth was set to zero to account for the grade control structure located immediately downstream of the 19th Avenue Bridge. Movable bed limits were not identified in the HD records, implying that deposition could occur anywhere in the wetted perimeter. In addition,

HE records were used to limit erosion within the channel bank stations.
In order to develop a sound hydraulic model, the mining pits, in particular those located in the channel, were blocked to ensure a solution with a subcritical water profile along the reach. However, when flooded, the mining pits will likely act as sediment traps. For that reason, the sediment deposited on top of the blocked areas within or next to the channel was removed from the system using the dredging options in HEC-6T. HI records were used to identify the areas where sediment should be removed in the case that deposition took place, and the $DREDGE record was used to instantaneously take away the deposited sediment after each time step. In addition, when mining pits were located in the channel, the HE limits were relocated to exclude the pit from the area of potential erosion.

Hydrology

A continuous 50-year hydrograph consisting of historical flows between 1889 and 1938 was provided by the Corps. This flow series corresponds to the "worst case" continuous 50-year period, in terms of both peak flows and storm volumes, within the 105 years of record, from 1889 to 1993. Discharges less than 20 cfs were removed from the hydrology since no sediment was transported for flows of 20 cfs or less. Simulations were performed with the 50-year hydrograph, with simulation results requested by decade. Figure 19 shows the complete 50-year hydrologic input and identifies the end of each decade.

Results

The sediment transport analysis results are presented in terms of average bed elevation by decade (Figure 20). The average bed elevation corresponding to a 10,000

cfs discharge of very short duration (0.00001 days) was computed in HEC-6T at 10-year intervals. This discharge was selected to generate average bed elevations because, in general, it provided coverage of the channel bottom (HEC-6T computes average bed elevations only from "wetted" points of the cross sections). The 10,000 cfs discharge is used only to generate output, and the short duration minimizes sediment movement.

The results show two distinct areas with respect to sediment dynamics. Downstream of 35th Avenue the reach mainly experiences degradation, with deposition limited to just a few cross sections. One of the depositional areas is defined by cross sections 203.58 to 203.86, and corresponds to an abandoned mining operation. The end result is a channel with a more homogenous bed slope. There are two areas downstream of 35th Avenue where the model predicts severe erosion:

- The first one is defined by cross sections 206.7 to 206.97. This is an area with active mining pits in the channel and a small berm to prevent low flows into the pit. The small flows (the majority in the hydrologic input) are then confined to a channel just about 200 feet wide resulting in severe degradation. Due to the limitations of the model (1-D steady state) it is not possible to simulate the complex interaction that may occur between the mining pit and the channel. The flows could very well breach the berm and enter the pit, limiting degradation in the channel but creating a headcut that would progress upstream.
- The second area corresponds to cross sections 209.24 to 209.54. This is another mined reach with pits on the right overbank and channel in cross sections 209.24 and 209.33. Cross section 209.54 represents the small bridge opening at 35th Avenue. Erosion in this case is associated with the cross sectional area reduction and velocity increase caused by the bridge.

Upstream of the 35th Avenue Bridge the bed slope is milder. That, along with the backwater effect of the bridge, creates the conditions for sediment deposition in most of the cross sections.
In general, average bed elevation changes are more significant in regions of the reach that are currently affected by mining operations in the channel. Where mining is not an issue, average bed changes reach a maximum of 5.8 ft after 50 years of sediment transport, with an average change of 1.9 ft.

During the simulations most of the bed changes took place in the first decade, with minor adjustments occurring in the remaining time. The first decade contained the flow events with the two largest peaks. In addition, it can be seen that the trend observed after the first decade is sometimes reversed after subsequent decades. This is a consequence of both changes in the cross section geometry with time, and changes in sediment dynamics associated with flows of very different magnitudes. Appendix H shows plots comparing the cross sections before and after the sediment transport analysis.

Sensitivity Analysis

The purpose of the analysis was to explore the sensitivity of the sediment transport model to variations in the parameters, in an attempt to determine the appropriateness of the selected values. Sensitivity runs were performed on the base conditions HEC-6T input file to determine the relative effect of changes to Manning's n, inflowing sediment load, and transport equation to the average bed elevation profiles. Results in tabular and graphic format are provided in Appendix I.

Hydraulic Roughness

The sensitivity of the sediment transport model to the hydraulic roughness coefficients was examined. The base conditions sediment transport model results have been compared to simulation outputs resulting from increasing and reducing all Manning's n coefficients in the input file by 25%.

After 50 years of simulating sediment dynamics, the high roughness profile is generally higher than the base condition profile. This is the result of deposition or reduced scour due to reduced flow velocities caused by the higher roughness coefficients. On the other hand, the low roughness profile is generally lower than the base conditions profile because of higher flow velocities. The average bed profile change was 0.7 ft for high roughness and 1.2 ft for low roughness, implying that small errors in the roughness coefficients selected for the base conditions model probably will not have a significant effect on the results.
The largest differences occur in mined reaches, where a 25% increase in Manning's n can reduce erosion by as much as 3.7 ft, and a 25% decrease in Manning's n can augment erosion by as much as 5.9 ft.

Inflowing Sediment Load

The effect of the inflowing sediment load has been assessed by comparing the base conditions sediment transport model with simulation results after increasing and reducing the sediment discharge to twice and half the equilibrium load determined with Yang's equation.

The most important differences can be observed upstream of the 35th Avenue Bridge. In the reach between cross sections 210.07 and 211.34 the double-inflow profile elevation increases an average of 0.6 ft with respect to the base condition, while for the half inflow profile it decreases an average of 0.5 ft. Downstream of 35th Avenue the differences are reduced as the sediment load reaches equilibrium.

Sediment Transport Equation

Simulation results generated with Yang's unit stream power equation have been compared to the simulation results produced with Madden's 1985 modification of Laursen's sediment transport equation.

The two equations yield bed profiles with the same trends in terms of degradational and agradational areas, with slight differences in the depth of eroded or deposited material. The main differences appear at the upstream end of the study reach. The upstream end of the reach is a transition between a narrow segment with levees in both banks and a wider segment severely disturbed by mining operations. It is not surprising that the model results show some instability in this area, until a new equilibrium is reached a little distance downstream. Laursen's equation, as modified by Madden, seems more susceptible to this effect than Yang's equation.

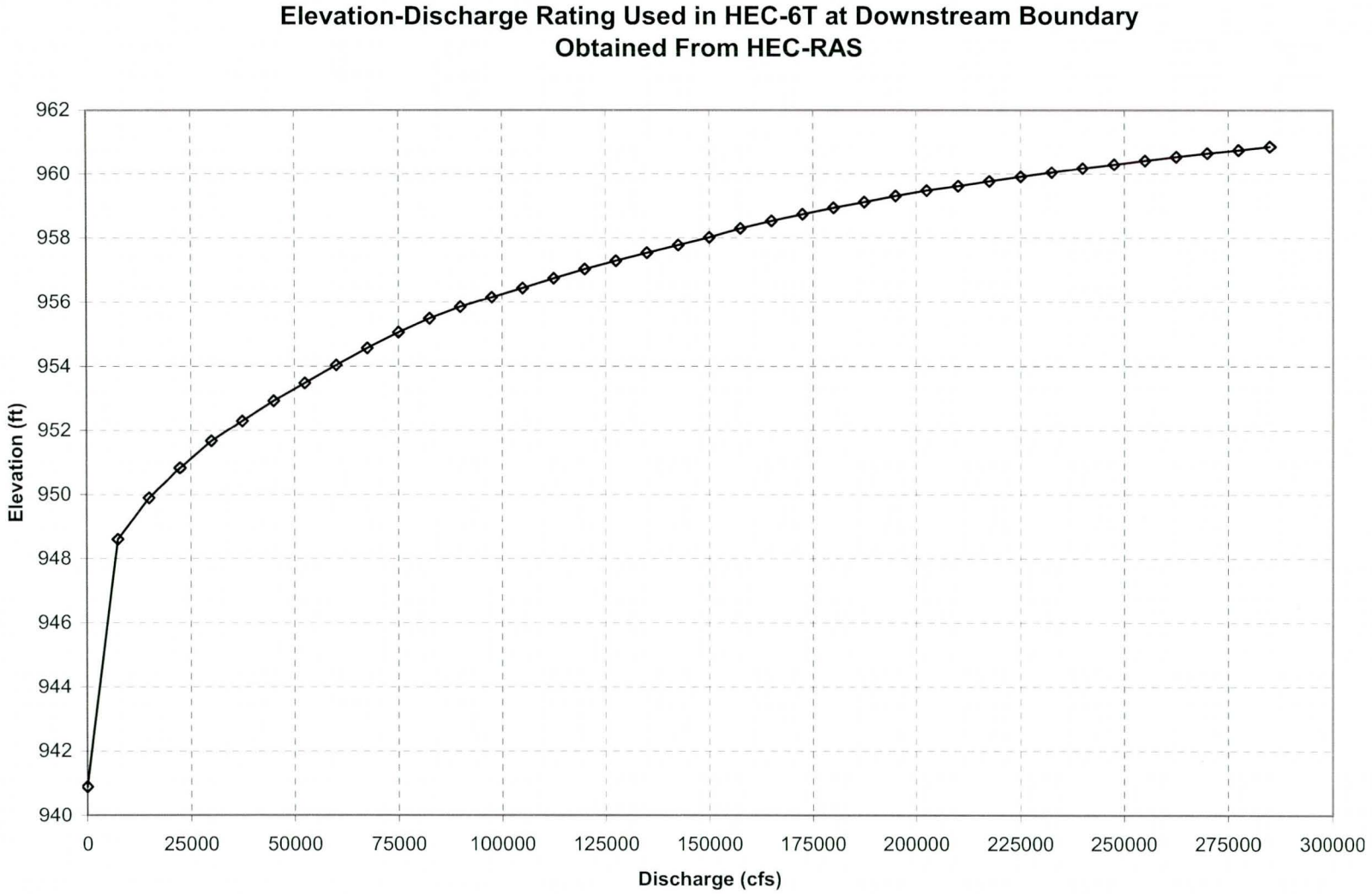

Figure 14: Rating curve at downstream end of sediment transport model.

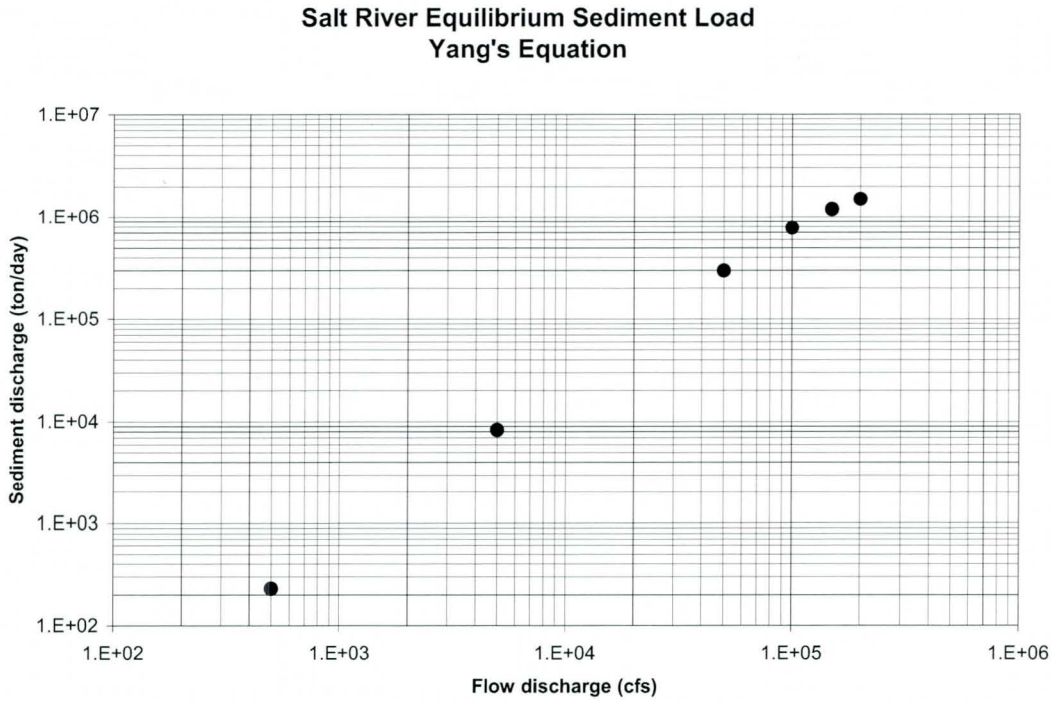

Figure 15: Equilibrium sediment load with Yang's equation.

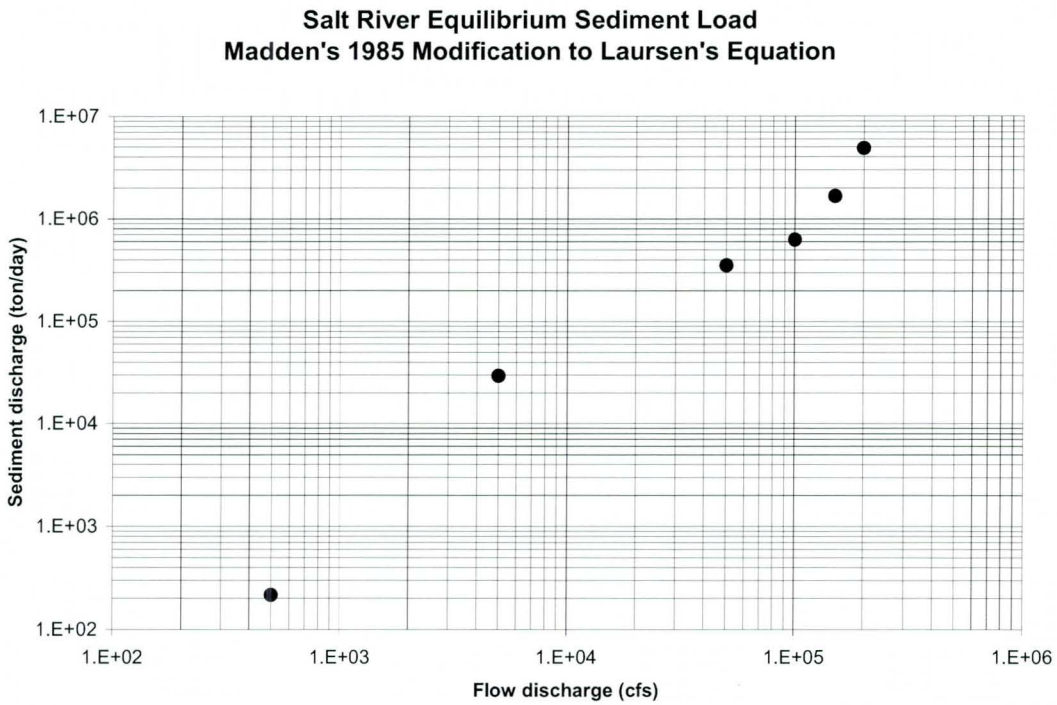

Figure 16: Equilibrium sediment load with Laursen-Madden's relation.

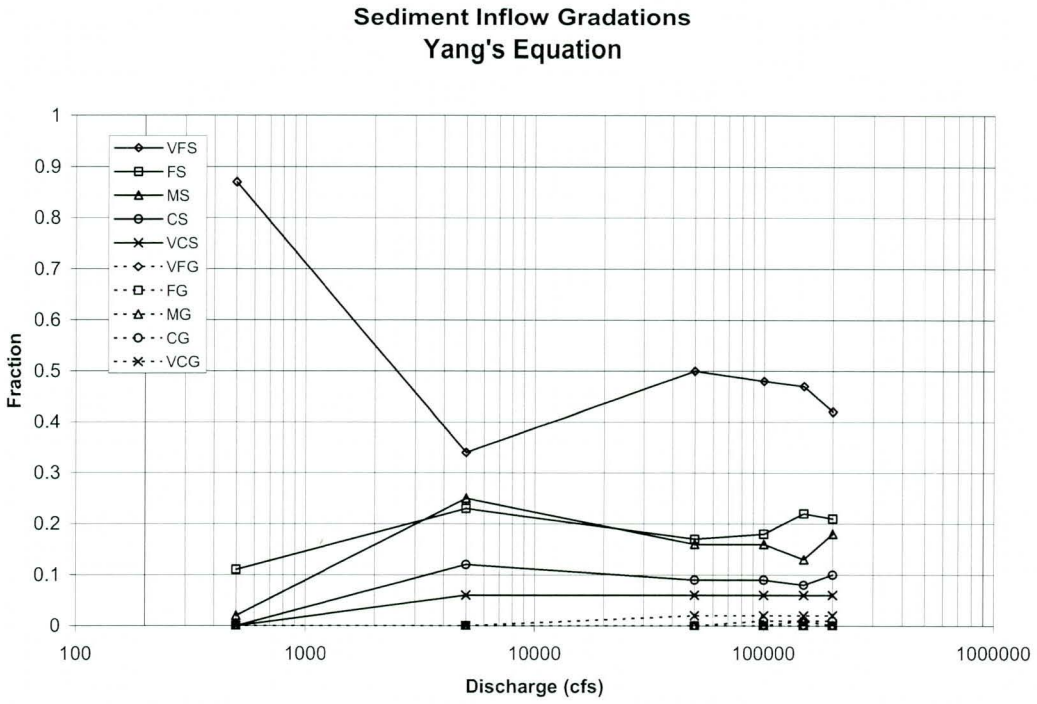

Figure 17: Sediment inflow gradations with Yang's equation.

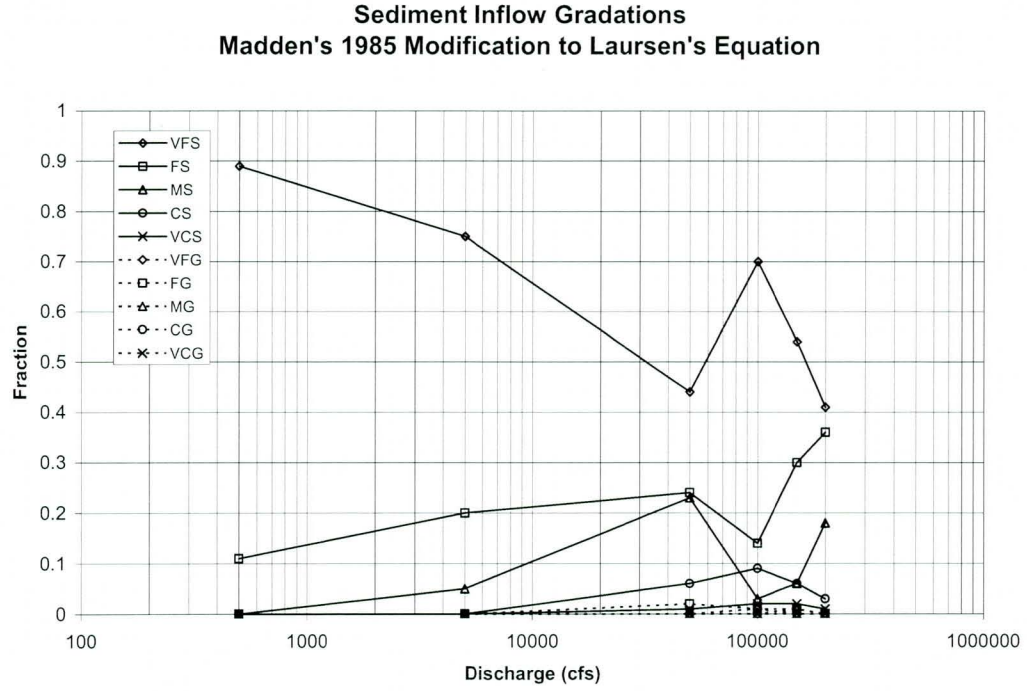

Figure 18: Sediment inflow gradations with Laursen-Madden's relation.

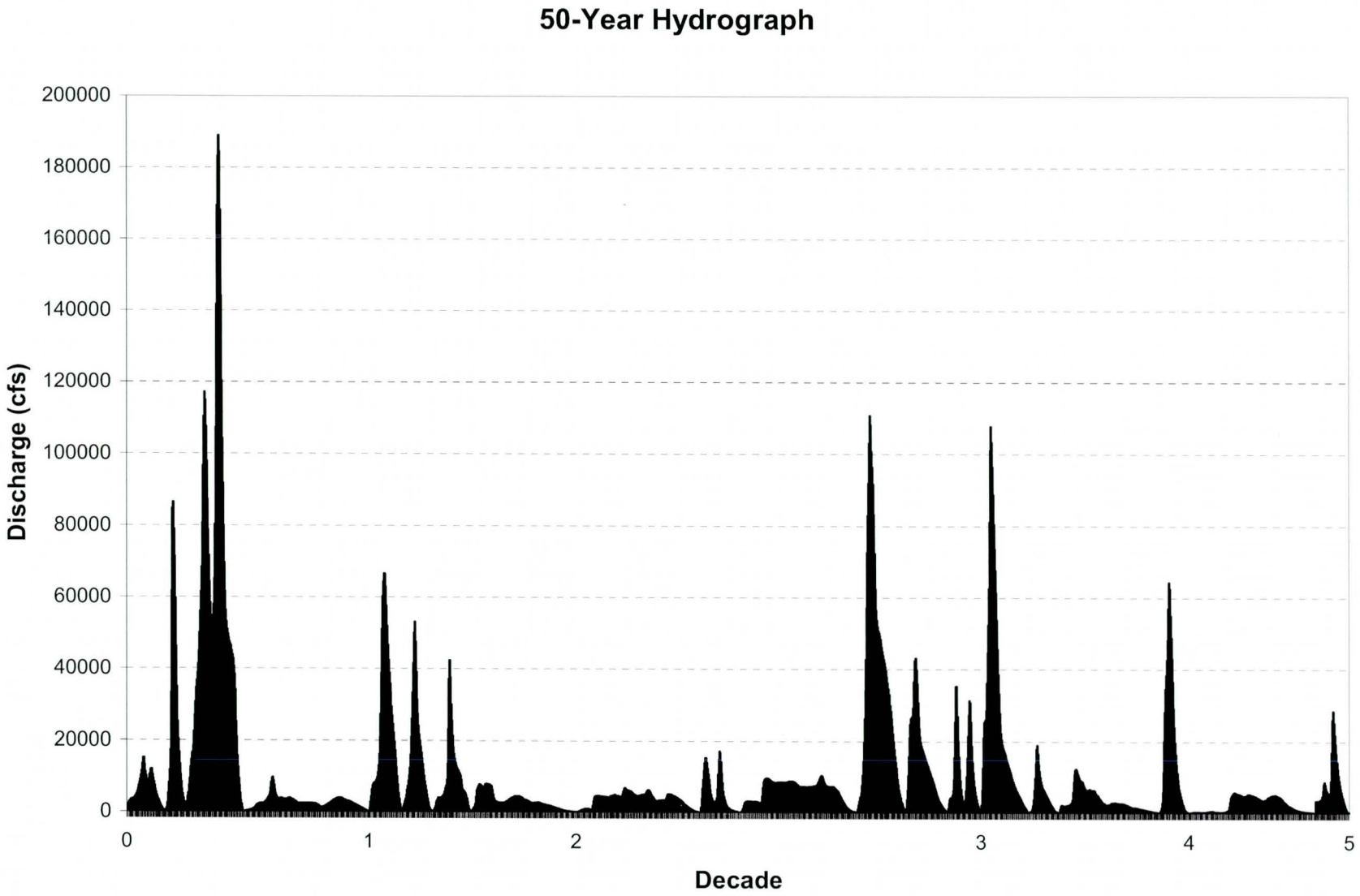

Figure 19: 50-year hydrograph used to run the sediment transport model.

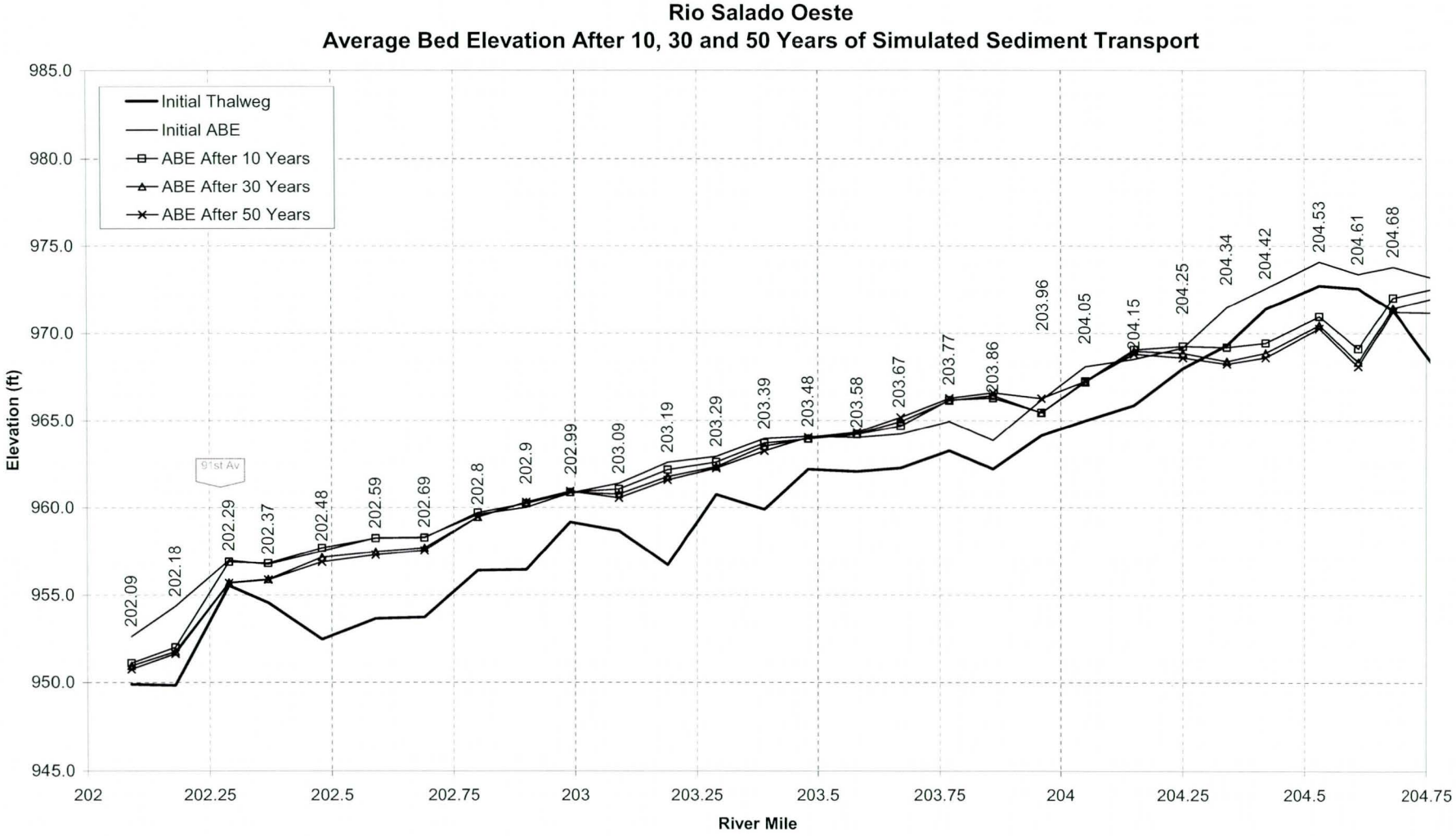

Figure 20: Simulated average bed elevation for selected decades.

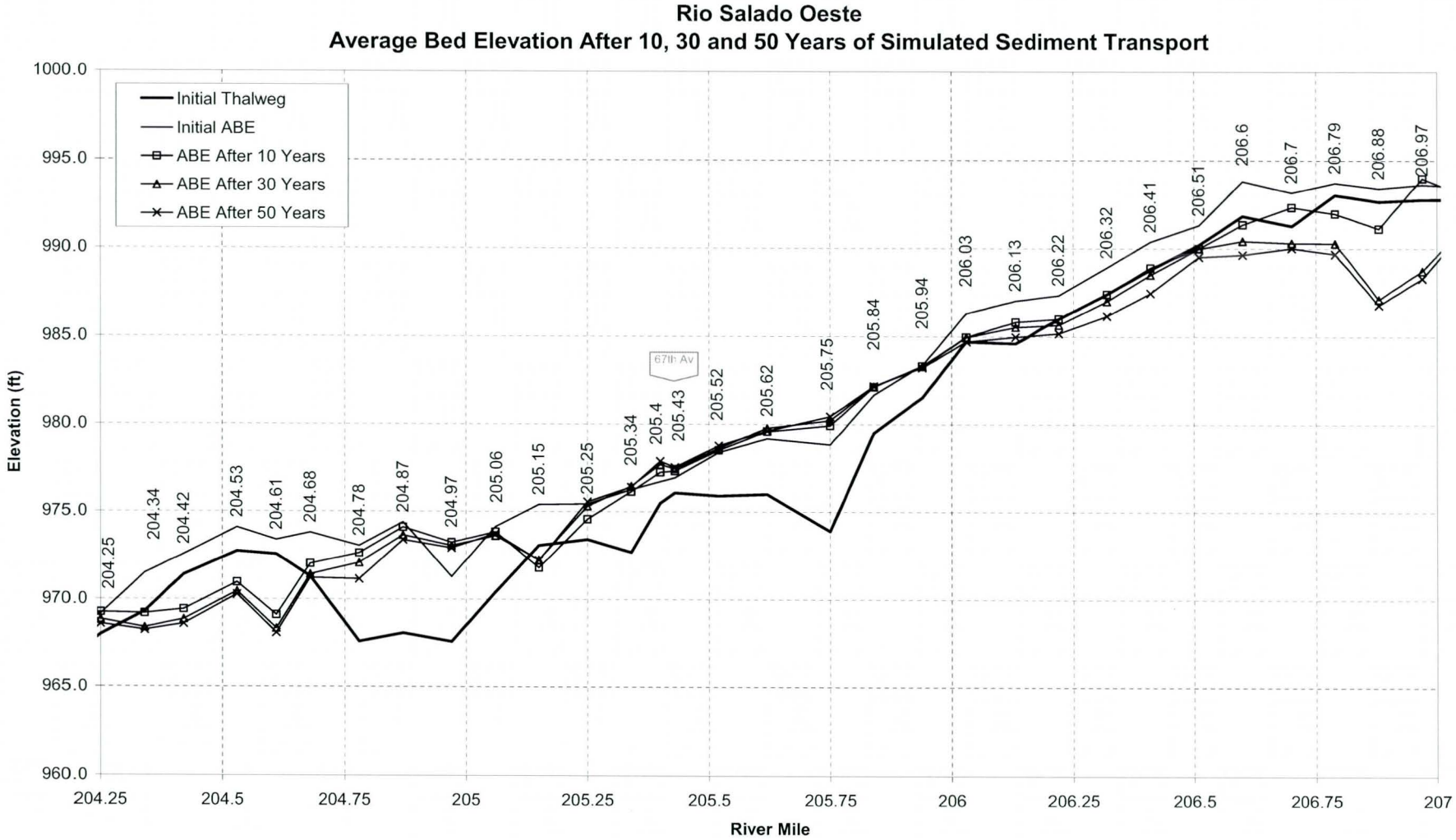

Figure 20: ***Continued.***

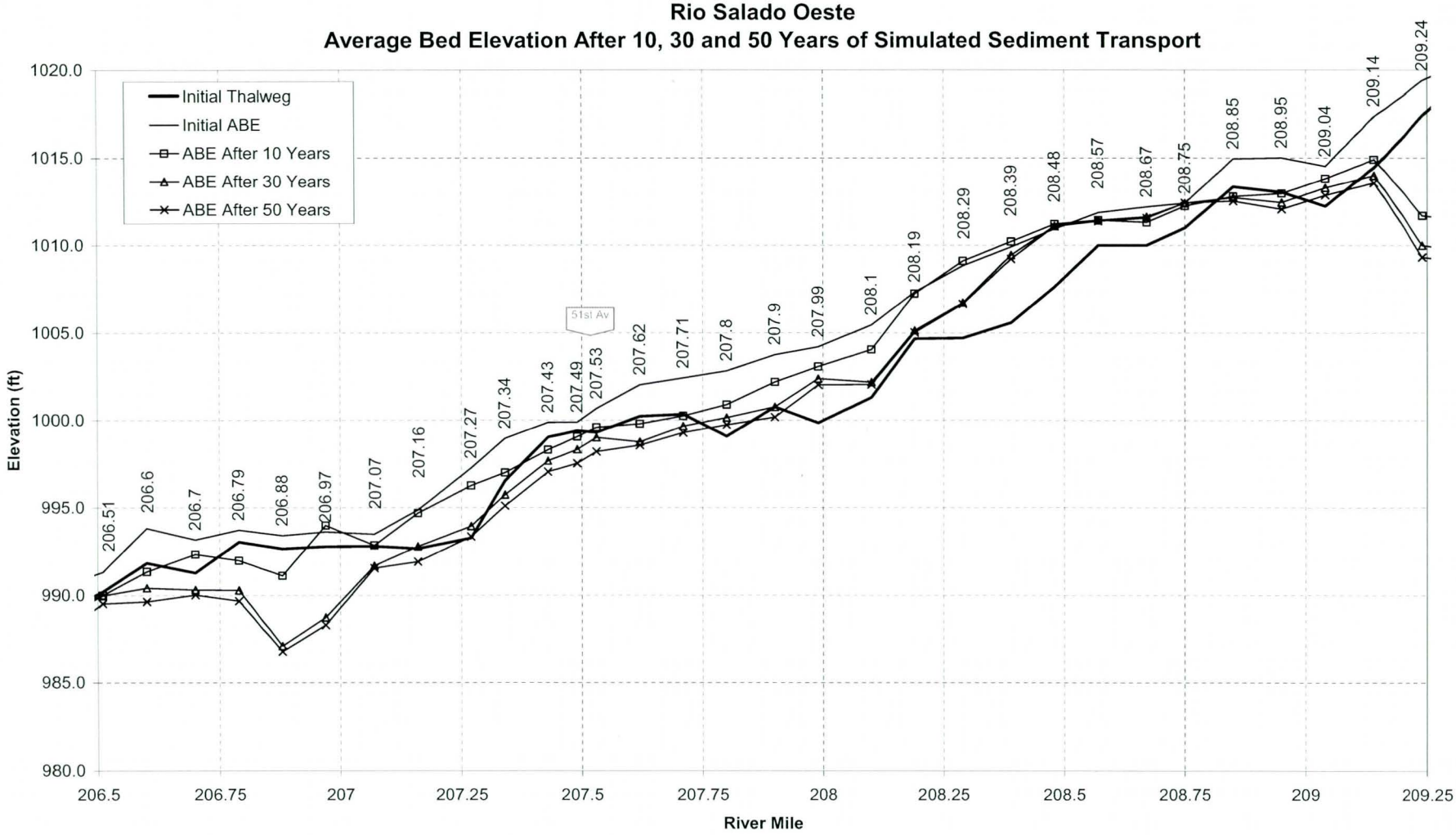

Figure 20: ***Continued.***

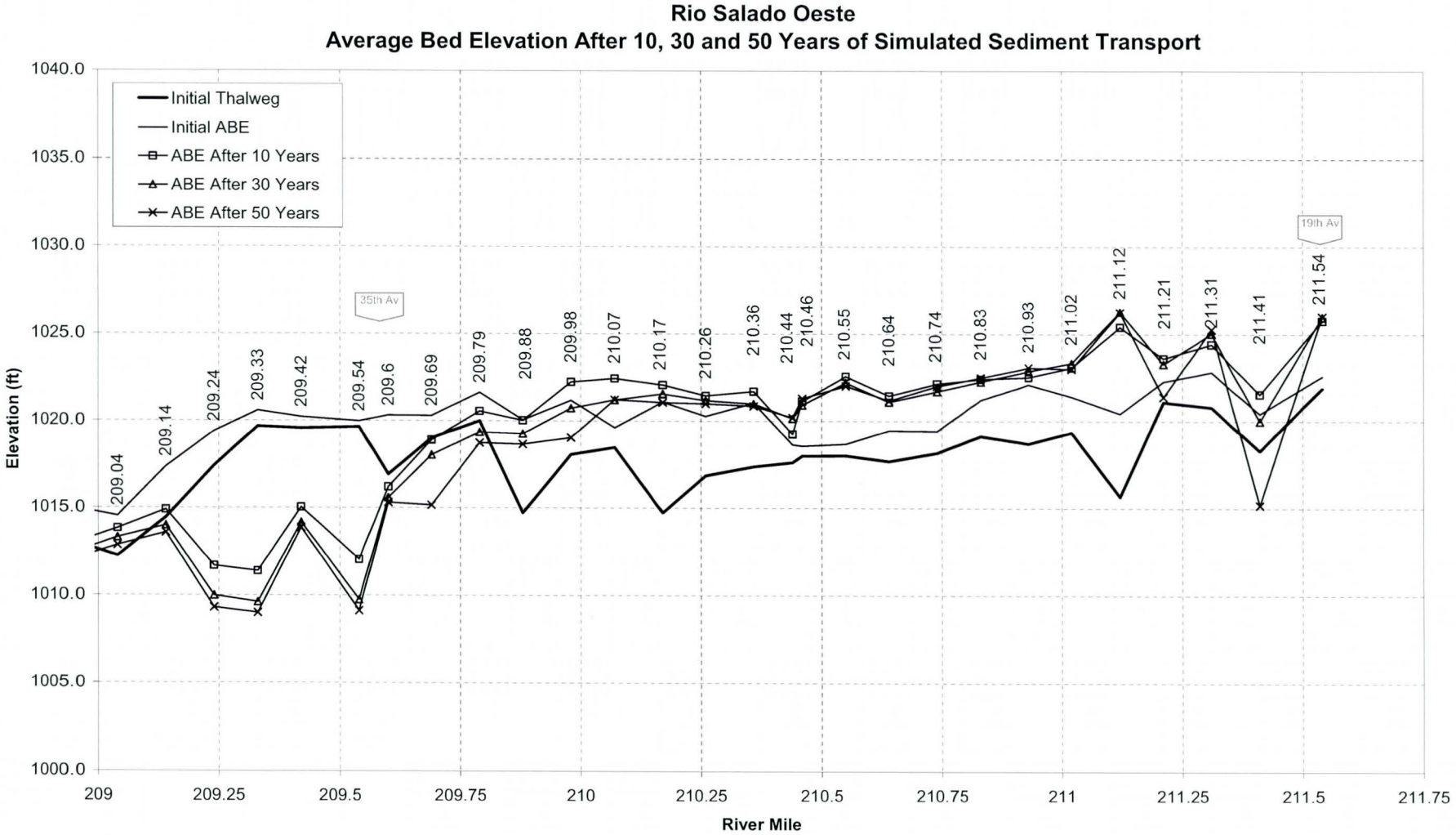

Figure 20: ***Continued.***

Without Project (w/ Proposed 35th Avenue Bridge)

Since the 35th Avenue Bridge will be replaced in the near future by the City of Phoenix Street Transportation Department, the without project sediment transport analysis was modified by replacing the existing 35th Avenue Bridge. The bridge replacement will consist of removing the existing bridge and abutments, widening and deepening the existing channel in the immediate vicinity, and constructing a wider bridge. The existing bridge is approximately 500-ft wide with three groups of 5- to 6-ft wide cylindrical piers. The proposed bridge would be approximately 1100-ft wide with eight groups of 6-ft wide cylindrical piers. It would be expected that this new bridge and widened channel combination would decrease the backwater upstream and consequently affect the sediment routing.

Model Geometry

The without project sediment transport analysis numerical models were modified to reflect the proposed 35th Avenue Bridge by changing cross-section 209.54 in the model. The numerical models were then calibrated with the fixed bed (HEC-RAS) numerical models. Finally, the numerical models were rerun to simulate 50 years of sediment transport.

Results

The sediment transport analysis results are presented in terms of thalweg bed elevation by decade show on Figure 21 and Tables 8 to 10). The existing conditions (with existing 35th Avenue Bridge) results are also presented in Figure 22 and Tables 11 to 13 for comparison. In general, the results of the without project (with the proposed 35th Avenue Bridge) simulation are similar to the without project (with the existing 35th Avenue Bridge) simulation. The main differences are the following.

- A scour hole would develop downstream of the 35th Avenue Bridge. The most probable cause of this scour hole is the initial hole from the proposed bridge construction. During the simulation, this latter hole would fill in, and the resulting clearer water would scour out the channel bed immediately downstream.

- Upstream of the 35th Avenue Bridge, the deposition would be less than if the existing bridge is still in place. This is a result of the wider bridge causing less backwater, and therefore, less deposition upstream.

- Finally, more sediment would leave the study area. After 50 years of simulated sediment transport, approximately 615,000 additional tons of sediment (4 ac-ft/year) would leave the study area with the proposed bridge in place. This indicates that the study area, with the proposed bridge in place, would be more efficient in transporting sediment.

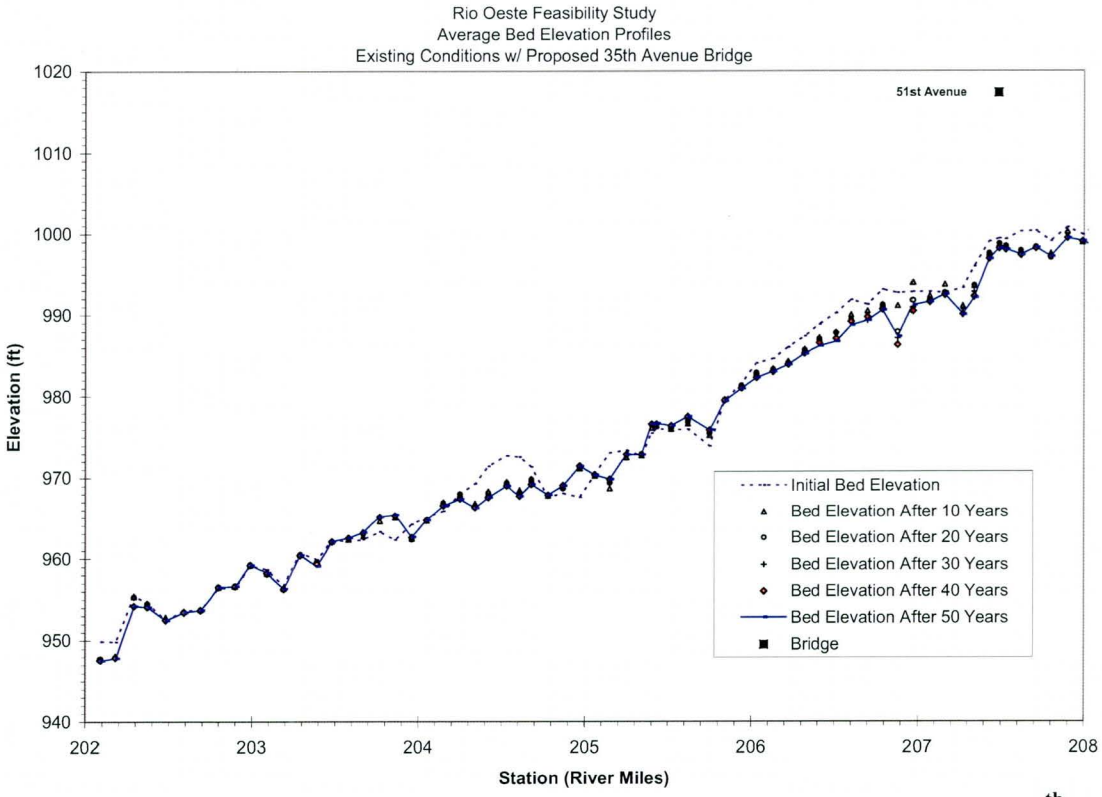

Figure 21: Average bed elevation profiles for existing condition with proposed 35th Avenue Bridge.

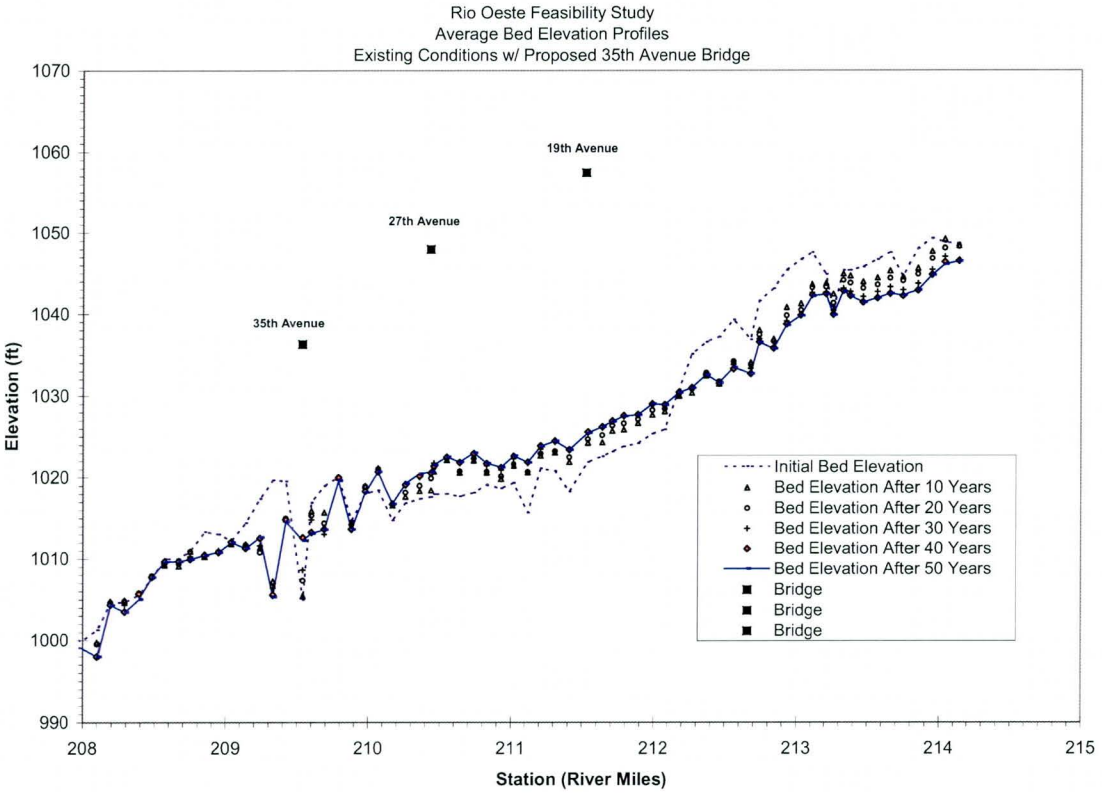

Figure 21: continued

Table 8: Average bed elevation profiles for existing condition with proposed 35th Avenue Bridge.

River Station (miles)	Initial Avg. Bed Elev. (ft)	Avg. Bed Elev. After 10 Years (ft)	Avg. Bed Elev. After 20 Years (ft)	Avg. Bed Elev. After 30 Years (ft)	Avg. Bed Elev. After 40 Years (ft)	Avg. Bed Elev. After 50 Years (ft)
202.1	949.9	947.8	947.8	947.7	947.6	947.5
202.2	949.8	948.1	948.0	947.9	947.9	947.8
202.3	955.5	955.4	955.3	954.2	954.2	954.2
202.4	954.6	954.6	954.5	954.2	954.1	954.1
202.5	952.5	952.8	952.5	952.5	952.5	952.5
202.6	953.7	953.6	953.5	953.5	953.5	953.5
202.7	953.7	953.8	953.7	953.7	953.7	953.7
202.8	956.4	956.5	956.6	956.5	956.5	956.5
202.9	956.5	956.6	956.7	956.7	956.6	956.6
203.0	959.2	959.2	959.3	959.2	959.2	959.2
203.1	958.7	958.2	958.2	958.2	958.2	958.2
203.2	956.7	956.4	956.4	956.3	956.3	956.3
203.3	960.8	960.5	960.5	960.4	960.4	960.5
203.4	959.9	959.6	959.6	959.4	959.4	959.1
203.5	962.2	962.0	962.0	962.0	962.0	962.0
203.6	962.1	962.3	962.4	962.4	962.5	962.5
203.7	962.3	962.7	962.9	963.1	963.1	963.2
203.8	963.3	964.5	965.0	965.0	965.1	965.1
203.9	962.2	965.0	965.2	965.2	965.3	965.3
204.0	964.1	962.4	962.3	962.5	962.6	962.6
204.1	965.0	964.6	964.6	964.6	964.7	964.7
204.1	965.9	967.0	966.9	966.7	966.6	966.5
204.3	968.0	968.0	968.0	967.6	967.4	967.4
204.3	969.3	966.8	966.3	966.5	966.3	966.3
204.4	971.4	968.3	968.1	967.8	967.6	967.6
204.5	972.7	969.5	969.4	969.2	969.0	969.0
204.6	972.6	968.5	968.2	967.9	967.7	967.7
204.7	971.3	969.9	969.8	969.5	969.2	969.2
204.8	967.6	967.8	967.7	967.8	967.9	967.9
204.9	968.1	968.9	968.7	969.0	969.1	969.0
205.0	967.6	971.2	971.2	971.4	971.4	971.4
205.1	970.4	970.3	970.3	970.3	970.4	970.3
205.1	973.1	968.7	969.4	969.4	969.8	969.8
205.3	973.4	972.5	972.8	973.0	972.9	972.9
205.3	972.7	972.7	972.9	973.0	972.9	972.9
205.4	975.5	976.2	976.6	976.6	976.7	976.7
205.4	976.1	976.5	976.6	976.6	976.7	976.7
205.5	975.9	976.0	976.0	976.2	976.5	976.5
205.6	976.0	976.7	976.9	977.2	977.5	977.6
205.8	973.9	975.2	975.4	975.6	975.9	975.9

205.8	979.5	979.6	979.5	979.5	979.5	979.4
205.9	981.5	981.2	981.3	981.0	981.0	980.9
206.0	984.0	982.8	982.9	982.7	982.3	982.3
206.1	984.6	983.4	983.3	983.2	983.0	983.0
206.2	986.0	984.3	984.1	983.9	983.9	983.9
206.3	987.4	985.8	985.7	985.5	985.3	985.2
206.4	988.8	987.2	987.1	986.8	986.5	986.2
206.5	990.2	987.4	987.8	987.9	987.1	986.7
206.6	991.8	990.0	989.4	989.3	989.2	988.7
206.7	991.3	990.5	989.8	989.3	989.7	989.3
206.8	993.0	991.3	991.2	991.0	990.7	990.6
206.9	992.7	991.1	987.9	987.1	986.3	987.4
207.0	992.8	994.0	991.8	990.9	990.5	991.2
207.1	992.8	992.3	991.8	991.5	991.6	991.6
207.2	992.7	993.7	992.7	992.5	992.4	992.5
207.3	993.3	991.1	990.9	990.2	990.0	990.0
207.3	995.9	993.6	993.6	992.8	992.2	992.1
207.4	999.0	997.5	997.5	997.3	996.9	996.9
207.5	999.4	998.7	998.7	998.4	998.2	998.2
207.5	999.3	998.4	998.4	998.2	998.0	998.0
207.6	1000.2	997.9	997.9	997.5	997.3	997.4
207.7	1000.3	998.3	998.3	998.3	998.2	998.3
207.8	999.1	997.5	997.0	997.2	997.1	997.2
207.9	1000.8	1000.2	1000.0	999.5	999.4	999.4
208.0	999.8	998.9	998.9	999.1	999.0	999.1
208.1	1001.3	999.8	999.5	998.0	998.0	998.0
208.2	1004.7	1004.8	1004.7	1004.6	1004.4	1004.3
208.3	1004.7	1004.9	1004.8	1004.4	1003.5	1003.4
208.4	1005.6	1005.8	1005.8	1005.7	1005.7	1005.1
208.5	1007.6	1007.8	1007.9	1007.8	1007.8	1007.7
208.6	1010.0	1009.2	1009.4	1009.6	1009.7	1009.7
208.7	1010.0	1009.1	1009.4	1009.6	1009.7	1009.7
208.8	1011.0	1010.9	1010.9	1010.3	1010.0	1009.9
208.9	1013.3	1010.3	1010.3	1010.4	1010.5	1010.5
208.9	1013.0	1011.0	1010.9	1011.0	1010.8	1010.8
209.0	1012.2	1011.8	1011.8	1012.1	1012.1	1012.1
209.1	1014.5	1011.8	1011.7	1011.8	1011.3	1011.3
209.2	1017.4	1011.4	1010.8	1011.6	1012.6	1012.7
209.3	1019.7	1007.2	1006.6	1006.4	1005.6	1005.3
209.4	1019.6	1014.9	1015.0	1015.0	1014.8	1014.6
209.5	1005.0	1005.4	1007.3	1008.6	1012.6	1012.3
209.6	1016.9	1015.9	1015.3	1014.8	1013.3	1013.2
209.7	1019.0	1015.7	1014.4	1013.1	1013.7	1013.6
209.8	1020.0	1020.0	1020.0	1020.0	1020.0	1019.6
209.9	1014.7	1014.5	1014.2	1013.8	1013.7	1013.6
210.0	1018.1	1019.0	1018.9	1018.4	1018.3	1018.2
210.1	1018.5	1021.2	1021.0	1020.7	1020.7	1020.7
210.2	1014.7	1016.6	1016.7	1016.7	1016.7	1016.8

210.3	1016.9	1017.7	1018.2	1019.1	1019.2	1019.3
210.4	1017.4	1018.4	1019.0	1020.1	1020.2	1020.4
210.4	1017.6	1018.5	1019.9	1020.6	1020.5	1020.7
210.5	1018.0	1020.7	1021.3	1021.8	1021.4	1021.5
210.6	1018.0	1022.1	1022.4	1022.4	1022.5	1022.6
210.6	1017.7	1020.6	1020.7	1021.8	1021.8	1021.9
210.7	1018.2	1022.1	1022.3	1022.8	1023.0	1023.1
210.8	1019.1	1020.6	1020.7	1021.5	1021.7	1021.7
210.9	1018.7	1019.8	1020.1	1020.9	1021.2	1021.3
211.0	1019.3	1021.5	1021.6	1022.3	1022.6	1022.7
211.1	1015.7	1020.6	1020.7	1021.8	1021.9	1021.8
211.2	1021.1	1022.7	1022.9	1023.5	1023.9	1023.9
211.3	1020.8	1023.1	1023.3	1024.4	1024.5	1024.5
211.4	1018.3	1021.9	1022.5	1023.4	1023.4	1023.4
211.5	1021.9	1024.3	1024.7	1025.5	1025.6	1025.5
211.6	1022.6	1024.3	1025.2	1026.1	1026.2	1026.2
211.7	1023.2	1025.8	1026.4	1026.9	1027.0	1026.9
211.8	1023.8	1025.9	1026.6	1027.5	1027.6	1027.5
211.9	1024.2	1026.7	1027.2	1027.7	1027.8	1027.7
212.0	1025.4	1027.7	1028.3	1028.9	1029.1	1029.0
212.1	1025.9	1028.1	1028.5	1028.9	1028.9	1028.9
212.2	1030.8	1030.0	1030.3	1030.5	1030.5	1030.4
212.3	1035.1	1030.4	1030.9	1031.0	1031.0	1031.0
212.4	1036.6	1032.5	1032.8	1032.7	1032.6	1032.6
212.5	1037.2	1031.5	1031.7	1031.6	1031.5	1031.6
212.6	1039.3	1034.1	1034.2	1033.8	1033.3	1033.5
212.7	1036.9	1034.1	1033.8	1033.4	1032.7	1032.7
212.7	1041.6	1038.0	1037.5	1037.0	1036.6	1036.6
212.8	1043.1	1037.0	1036.7	1036.0	1035.8	1035.8
212.9	1045.4	1040.8	1039.8	1039.1	1038.8	1038.6
213.0	1046.7	1041.3	1040.5	1039.9	1039.9	1039.8
213.1	1047.6	1043.7	1043.2	1042.6	1042.3	1042.2
213.2	1044.9	1043.8	1043.3	1042.7	1042.5	1042.4
213.3	1040.4	1042.5	1041.3	1040.4	1040.0	1039.9
213.3	1045.4	1045.0	1044.2	1043.2	1042.9	1042.8
213.4	1045.4	1044.7	1043.8	1042.8	1042.2	1042.2
213.5	1045.8	1044.0	1043.2	1042.1	1041.5	1041.4
213.6	1046.7	1044.5	1043.6	1042.7	1042.0	1042.0
213.7	1047.6	1045.3	1044.4	1043.3	1042.5	1042.5
213.8	1044.6	1044.6	1044.1	1043.0	1042.2	1042.3
213.9	1048.1	1045.6	1044.9	1043.8	1042.9	1043.0
213.9	1049.3	1047.8	1046.8	1045.5	1044.9	1044.8
214.0	1048.8	1049.2	1048.1	1047.1	1046.4	1046.1
214.1	1048.7	1048.5	1048.4	1046.6	1046.6	1046.5

Table 9: Change in average bed elevation with proposed 35th Avenue Bridge.

River Station (miles)	Change in Avg. Bed Elev. After 10 Years (ft)	Change in Avg. Bed Elev. After 20 Years (ft)	Change in Avg. Bed Elev. After 30 Years (ft)	Change in Avg. Bed Elev. After 40 Years (ft)	Change in Avg. Bed Elev. After 50 Years (ft)
202.1	-2.0	-2.1	-2.2	-2.3	-2.3
202.2	-1.7	-1.8	-1.9	-1.9	-2.0
202.3	-0.1	-0.2	-1.3	-1.3	-1.3
202.4	0.0	0.0	-0.3	-0.4	-0.4
202.5	0.4	0.1	0.0	0.0	0.0
202.6	-0.1	-0.2	-0.2	-0.2	-0.2
202.7	0.1	0.0	0.0	0.0	0.0
202.8	0.1	0.2	0.1	0.1	0.1
202.9	0.2	0.3	0.2	0.2	0.2
203.0	0.0	0.1	0.1	0.1	0.1
203.1	-0.5	-0.5	-0.5	-0.5	-0.4
203.2	-0.3	-0.3	-0.5	-0.4	-0.3
203.3	-0.3	-0.3	-0.3	-0.3	-0.3
203.4	-0.3	-0.4	-0.5	-0.5	-0.8
203.5	-0.2	-0.2	-0.2	-0.2	-0.2
203.6	0.2	0.4	0.3	0.4	0.5
203.7	0.4	0.7	0.8	0.9	1.0
203.8	1.3	1.8	1.8	1.9	1.9
203.9	2.8	3.0	3.0	3.1	3.2
204.0	-1.6	-1.7	-1.6	-1.5	-1.4
204.1	-0.4	-0.4	-0.4	-0.4	-0.3
204.1	1.1	1.0	0.8	0.7	0.7
204.3	0.0	0.0	-0.5	-0.7	-0.7
204.3	-2.5	-2.9	-2.9	-2.9	-2.9
204.4	-3.1	-3.2	-3.7	-3.9	-3.9
204.5	-3.2	-3.4	-3.6	-3.7	-3.7
204.6	-4.0	-4.4	-4.8	-4.9	-4.9
204.7	-1.5	-1.6	-1.9	-2.1	-2.1
204.8	0.2	0.2	0.2	0.3	0.3
204.9	0.9	0.6	0.9	1.0	0.9
205.0	3.5	3.5	3.7	3.9	3.8
205.1	-0.1	-0.2	-0.1	0.0	-0.1
205.1	-4.4	-3.8	-3.8	-3.2	-3.3
205.3	-0.9	-0.7	-0.5	-0.6	-0.6
205.3	0.0	0.2	0.2	0.2	0.2
205.4	0.7	1.1	1.1	1.2	1.1
205.4	0.5	0.5	0.5	0.6	0.6
205.5	0.1	0.1	0.3	0.5	0.5
205.6	0.7	0.9	1.2	1.5	1.6

205.8	1.3	1.5	1.8	2.0	2.0
205.8	0.1	0.0	0.0	0.0	-0.1
205.9	-0.3	-0.3	-0.5	-0.5	-0.6
206.0	-1.2	-1.2	-1.5	-1.9	-1.9
206.1	-1.3	-1.4	-1.5	-1.7	-1.7
206.2	-1.5	-1.9	-2.0	-2.1	-2.2
206.3	-1.6	-1.7	-2.0	-2.1	-2.2
206.4	-1.6	-2.1	-2.3	-2.6	-3.0
206.5	-2.7	-2.3	-2.8	-3.3	-3.6
206.6	-2.1	-2.7	-2.9	-2.9	-3.3
206.7	-0.6	-1.5	-2.3	-1.8	-1.9
206.8	-1.8	-1.8	-2.4	-2.5	-2.7
206.9	-2.0	-4.9	-4.9	-5.0	-4.5
207.0	1.1	-1.8	-2.4	-1.6	-1.7
207.1	-0.6	-1.1	-1.5	-1.2	-1.2
207.2	0.5	-0.9	-0.7	-0.7	-0.6
207.3	-2.0	-2.1	-2.7	-2.9	-3.0
207.3	-2.7	-2.7	-3.8	-4.0	-4.2
207.4	-1.5	-1.5	-1.6	-2.1	-2.2
207.5	-0.9	-0.9	-1.6	-1.8	-1.9
207.5	-1.0	-0.9	-1.1	-1.4	-1.4
207.6	-2.6	-2.6	-3.2	-3.3	-3.3
207.7	-2.1	-2.0	-2.0	-2.1	-2.0
207.8	-1.6	-2.2	-2.1	-2.2	-2.2
207.9	-0.6	-0.9	-1.4	-1.4	-1.5
208.0	-1.0	-1.0	-1.0	-1.0	-1.0
208.1	-1.7	-2.1	-3.3	-3.3	-3.3
208.2	0.1	0.0	-0.7	-0.7	-0.7
208.3	0.2	0.1	-0.6	-1.4	-1.5
208.4	0.2	0.2	0.1	-0.6	-1.6
208.5	0.2	0.2	0.2	0.1	0.1
208.6	-0.9	-0.6	-0.5	-0.4	-0.5
208.7	-1.0	-0.7	-0.6	-0.4	-0.5
208.8	-0.2	-0.2	-0.9	-1.1	-1.2
208.9	-3.0	-3.0	-3.1	-3.1	-3.1
208.9	-1.9	-1.9	-1.9	-1.8	-1.9
209.0	-0.9	-0.8	-0.9	-0.9	-0.9
209.1	-2.1	-1.9	-2.0	-2.0	-2.0
209.2	-7.9	-8.1	-8.5	-8.5	-8.5
209.3	-8.3	-8.7	-9.0	-9.1	-9.1
209.4	-6.3	-6.6	-7.1	-7.1	-7.2
209.5	-5.8	-6.3	-6.4	-5.5	-5.5
209.6	-5.1	-5.1	-5.2	-5.2	-5.1
209.7	-2.2	-2.3	-3.0	-3.8	-4.0
209.8	0.0	0.0	-0.1	-0.2	-0.5
209.9	0.1	0.2	1.6	1.4	1.4
210.0	0.7	0.6	1.6	0.7	0.5
210.1	2.8	2.8	4.1	3.7	3.3

210.2	3.1	3.0	3.1	3.0	3.0
210.3	1.9	1.9	2.9	2.5	2.8
210.4	1.9	2.6	4.0	4.0	4.1
210.4	1.3	3.3	4.1	3.7	3.9
210.5	3.5	4.1	4.2	3.9	4.1
210.6	4.7	4.5	5.9	5.8	5.8
210.6	3.2	3.8	4.5	4.2	4.3
210.7	4.5	4.5	5.6	5.9	5.9
210.8	2.1	2.3	3.2	3.1	3.2
210.9	1.7	1.8	2.8	3.0	3.0
211.0	2.8	2.8	4.2	4.5	4.6
211.1	4.9	5.1	5.8	6.1	6.1
211.2	2.4	2.5	3.6	4.2	4.2
211.3	2.5	2.5	3.7	3.8	3.8
211.4	4.4	4.9	6.1	6.1	6.2
211.5	2.6	2.8	3.9	3.7	3.7
211.6	2.5	3.2	4.1	4.4	4.3
211.7	2.8	3.2	3.9	4.0	4.0
211.8	2.5	3.2	4.0	4.3	4.3
211.9	2.6	3.1	3.7	3.9	3.8
212.0	2.6	3.2	3.9	3.9	3.9
212.1	2.4	2.7	3.1	3.3	3.3
212.2	-0.6	-0.4	-0.1	-0.1	-0.1
212.3	-4.5	-4.1	-3.9	-3.8	-3.9
212.4	-4.0	-3.6	-3.7	-3.8	-3.8
212.5	-5.5	-5.3	-5.4	-5.5	-5.4
212.6	-5.1	-5.0	-5.4	-5.8	-5.6
212.7	-2.7	-3.0	-3.4	-4.0	-4.0
212.7	-3.5	-4.0	-4.5	-4.8	-4.8
212.8	-6.1	-6.4	-6.9	-7.1	-7.1
212.9	-4.6	-5.5	-6.1	-6.5	-6.6
213.0	-5.5	-6.2	-6.6	-6.6	-6.6
213.1	-3.7	-4.3	-4.9	-5.1	-5.3
213.2	-0.8	-1.5	-2.1	-2.2	-2.3
213.3	2.1	1.0	0.1	-0.4	-0.4
213.3	-0.5	-1.2	-2.0	-2.3	-2.4
213.4	-0.6	-1.5	-2.6	-3.1	-3.1
213.5	-1.8	-2.7	-3.6	-4.2	-4.2
213.6	-2.2	-3.0	-3.9	-4.6	-4.6
213.7	-2.3	-3.1	-4.2	-5.0	-5.0
213.8	0.0	-0.4	-1.5	-2.3	-2.2
213.9	-2.5	-3.2	-4.3	-5.1	-5.1
213.9	-1.5	-2.4	-3.8	-4.4	-4.4
214.0	0.4	-0.6	-1.7	-2.3	-2.6
214.1	-0.2	-0.3	-2.0	-2.1	-2.1

Table 10: Accumulated sand delivery for with proposed 35th Avenue Bridge.

River Station (miles)	Accumulated Sand Delivery (tons)	Accumulated Sand Delivery (tons/year)	Accumulated Sand Delivery (cy/year)	Accumulated Sand Delivery (ac-ft/year)
202.1	15037569	300751	186020	115.3
202.2	14967304	299346	185151	114.8
202.3	14944806	298896	184873	114.6
202.4	14946462	298929	184893	114.6
202.5	14951205	299024	184952	114.6
202.6	14943625	298873	184858	114.6
202.7	14909069	298181	184431	114.3
202.8	14905746	298115	184390	114.3
202.9	14953643	299073	184982	114.7
203.0	15003490	300070	185599	115.0
203.1	15015896	300318	185752	115.1
203.2	14978741	299575	185293	114.9
203.3	14936465	298729	184770	114.5
203.4	14924907	298498	184627	114.4
203.5	14906192	298124	184395	114.3
203.6	14915493	298310	184510	114.4
203.7	14945329	298907	184879	114.6
203.8	15029182	300584	185917	115.2
203.9	15144626	302893	187345	116.1
204.0	15285842	305717	189092	117.2
204.1	15222140	304443	188304	116.7
204.1	15225308	304506	188343	116.7
204.3	15296343	305927	189221	117.3
204.3	15272909	305458	188932	117.1
204.4	15193313	303866	187947	116.5
204.5	15096844	301937	186754	115.8
204.6	15019508	300390	185797	115.2
204.7	14932123	298642	184716	114.5
204.8	14896353	297927	184273	114.2
204.9	14930478	298610	184696	114.5
205.0	14973850	299477	185232	114.8
205.1	15071792	301436	186444	115.6
205.1	15061388	301228	186315	115.5
205.3	15048621	300972	186157	115.4
205.3	15088853	301777	186655	115.7
205.4	15107140	302143	186881	115.8
205.4	15167595	303352	187629	116.3
205.5	15205258	304105	188095	116.6
205.6	15259522	305190	188766	117.0
205.8	15355878	307118	189958	117.7
205.8	15451985	309040	191147	118.5

205.9	15553847	311077	192407	119.3
206.0	15629758	312595	193346	119.8
206.1	15621629	312433	193245	119.8
206.2	15623828	312477	193273	119.8
206.3	15626949	312539	193311	119.8
206.4	15620117	312402	193227	119.8
206.5	15557389	311148	192451	119.3
206.6	15511074	310221	191878	118.9
206.7	15549149	310983	192349	119.2
206.8	15711058	314221	194352	120.5
206.9	15884286	317686	196495	121.8
207.0	16281333	325627	201406	124.8
207.1	16656015	333120	206041	127.7
207.2	16635213	332704	205784	127.6
207.3	16587300	331746	205191	127.2
207.3	16506229	330125	204188	126.6
207.4	16449965	328999	203492	126.1
207.5	16421358	328427	203138	125.9
207.5	16420542	328411	203128	125.9
207.6	16427266	328545	203211	126.0
207.7	16335306	326706	202074	125.3
207.8	16233476	324670	200814	124.5
207.9	16148249	322965	199760	123.8
208.0	16121743	322435	199432	123.6
208.1	16109035	322181	199275	123.5
208.2	16100372	322007	199168	123.5
208.3	16153297	323066	199822	123.9
208.4	16166333	323327	199984	124.0
208.5	16233848	324677	200819	124.5
208.6	16297963	325959	201612	125.0
208.7	16327028	326541	201971	125.2
208.8	16364057	327281	202429	125.5
208.9	16393665	327873	202796	125.7
208.9	16370831	327417	202513	125.5
209.0	16398309	327966	202853	125.7
209.1	16547624	330952	204700	126.9
209.2	16629587	332592	205714	127.5
209.3	16698455	333969	206566	128.0
209.4	16736727	334735	207040	128.3
209.54	16708192	334164	206687	128.1
209.6	16920108	338402	209308	129.7
209.69	16917886	338358	209281	129.7
209.79	16929810	338596	209428	129.8
209.88	17110826	342217	211667	131.2
209.98	17120436	342409	211786	131.3
210.07	17273856	345477	213684	132.4
210.17	17559752	351195	217221	134.6
210.26	17779852	355597	219943	136.3

210.36	17942596	358852	221957	137.6
210.44	18049232	360985	223276	138.4
210.46	18115474	362309	224095	138.9
210.55	18264508	365290	225939	140.0
210.64	18715186	374304	231514	143.5
210.74	19110600	382212	236405	146.5
210.83	19540114	390802	241718	149.8
210.93	19837184	396744	245393	152.1
211.02	20197370	403947	249849	154.9
211.12	20580582	411612	254589	157.8
211.21	20923114	418462	258827	160.4
211.31	20996336	419927	259732	161.0
211.41	21043660	420873	260318	161.4
211.54	21114384	422288	261193	161.9
211.64	21206044	424121	262327	162.6
211.71	21254220	425084	262923	163.0
211.79	21298988	425980	263476	163.3
211.89	21366950	427339	264317	163.8
211.99	21433396	428668	265139	164.3
212.08	21649204	432984	267809	166.0
212.18	21943948	438879	271455	168.3
212.27	22131948	442639	273780	169.7
212.37	22442508	448850	277622	172.1
212.46	22686196	453724	280637	173.9
212.56	22704850	454097	280867	174.1
212.68	22643656	452873	280110	173.6
212.74	22594456	451889	279502	173.2
212.84	22540922	450818	278840	172.8
212.93	22435342	448707	277533	172.0
213.03	22326774	446535	276190	171.2
213.11	22205016	444100	274684	170.3
213.21	22102780	442056	273420	169.5
213.26	22075462	441509	273082	169.3
213.33	22069956	441399	273014	169.2
213.38	22044334	440887	272697	169.0
213.47	22004646	440093	272206	168.7
213.57	21940752	438815	271415	168.2
213.66	21870748	437415	270549	167.7
213.75	21807436	436149	269766	167.2
213.85	21772134	435443	269329	166.9
213.95	21750404	435008	269061	166.8
214.04	21696148	433923	268389	166.4
214.14	21660388	433208	267947	166.1

Note: weight of sand = 120 pcf, 1 ton = 16.7 cubic feet
This is a table of the total weight of sand and larger transported past each cross section in the model plotted versus channel station.
Sediment inflow = 166 ac-ft/year

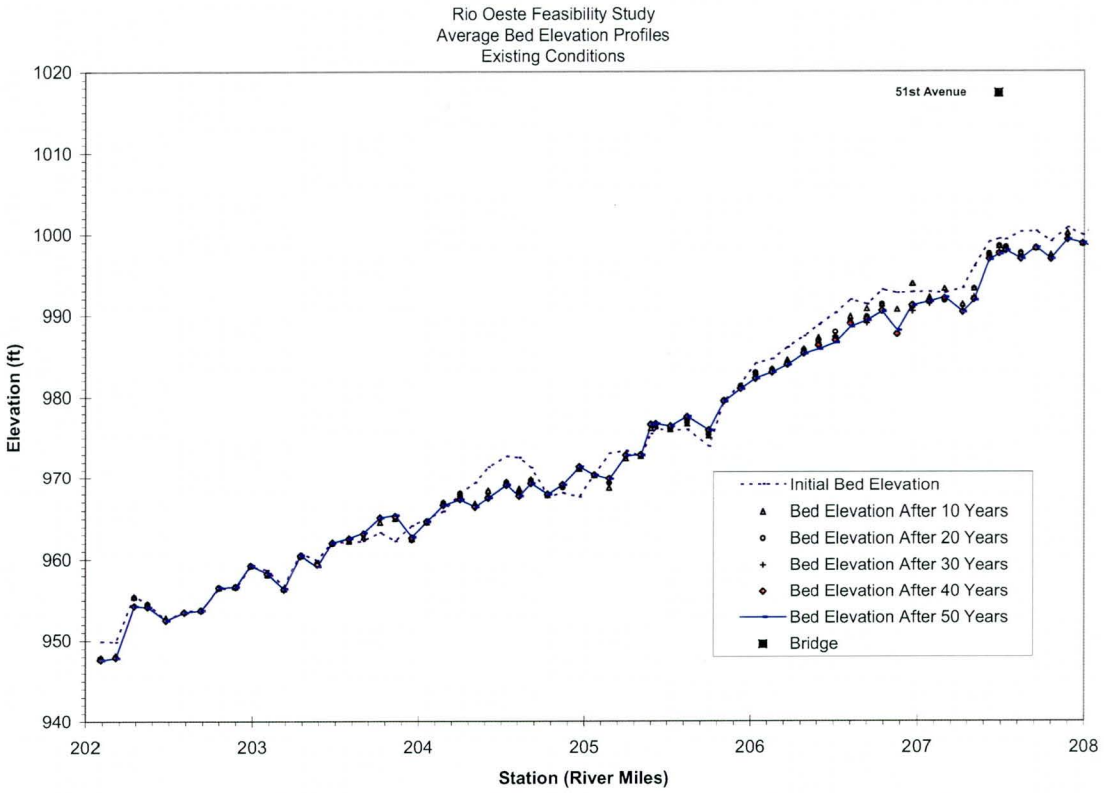

Figure 22: Average bed elevation profiles for with existing 35th Avenue Bridge.

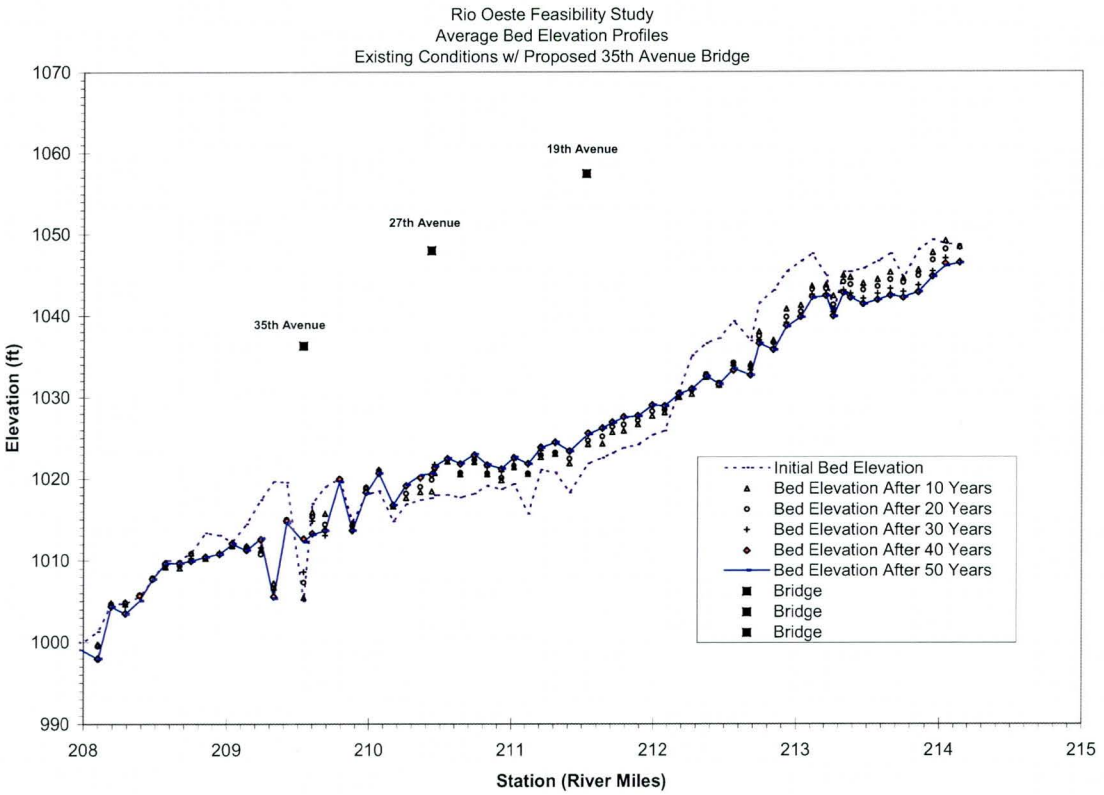

Figure 22: continued

Table 11: Average bed elevation profiles for with existing 35th Avenue Bridge.

River Station (miles)	Initial Avg. Bed Elev. (ft)	Avg. Bed Elev. After 10 Years (ft)	Avg. Bed Elev. After 20 Years (ft)	Avg. Bed Elev. After 30 Years (ft)	Avg. Bed Elev. After 40 Years (ft)	Avg. Bed Elev. After 50 Years (ft)
202.1	949.9	947.9	947.8	947.7	947.6	947.6
202.2	949.8	948.2	948.0	947.9	947.9	947.8
202.3	955.5	955.4	955.4	954.3	954.3	954.3
202.4	954.6	954.6	954.5	954.3	954.2	954.1
202.5	952.5	952.8	952.6	952.5	952.5	952.5
202.6	953.7	953.6	953.5	953.5	953.5	953.5
202.7	953.7	953.8	953.8	953.7	953.7	953.7
202.8	956.4	956.5	956.6	956.5	956.5	956.5
202.9	956.5	956.6	956.7	956.7	956.6	956.6
203.0	959.2	959.2	959.3	959.2	959.2	959.2
203.1	958.7	958.2	958.2	958.2	958.2	958.3
203.2	956.7	956.4	956.4	956.3	956.3	956.4
203.3	960.8	960.5	960.5	960.4	960.4	960.5
203.4	959.9	959.6	959.5	959.4	959.4	959.1
203.5	962.2	962.0	962.0	962.0	962.0	962.0
203.6	962.1	962.3	962.5	962.4	962.5	962.5
203.7	962.3	962.7	963.0	963.1	963.2	963.2
203.8	963.3	964.6	965.1	965.0	965.1	965.1
203.9	962.2	965.0	965.2	965.2	965.3	965.4
204.0	964.1	962.5	962.4	962.5	962.6	962.7
204.1	965.0	964.6	964.6	964.6	964.6	964.7
204.1	965.9	966.9	966.9	966.6	966.6	966.6
204.3	968.0	968.0	968.0	967.5	967.3	967.3
204.3	969.3	966.8	966.4	966.4	966.4	966.4
204.4	971.4	968.3	968.2	967.7	967.5	967.5
204.5	972.7	969.5	969.4	969.1	969.0	969.0
204.6	972.6	968.6	968.1	967.8	967.7	967.7
204.7	971.3	969.8	969.7	969.4	969.2	969.2
204.8	967.6	967.8	967.8	967.8	967.9	967.9
204.9	968.1	969.0	968.7	968.9	969.1	969.0
205.0	967.6	971.1	971.1	971.3	971.4	971.4
205.1	970.4	970.3	970.3	970.3	970.4	970.4
205.1	973.1	968.7	969.3	969.3	969.9	969.8
205.3	973.4	972.5	972.8	972.9	972.9	972.8
205.3	972.7	972.7	972.9	972.9	972.9	972.9
205.4	975.5	976.2	976.5	976.6	976.7	976.6
205.4	976.1	976.5	976.6	976.6	976.7	976.7
205.5	975.9	976.0	976.0	976.2	976.4	976.4
205.6	976.0	976.7	976.9	977.2	977.5	977.6

205.8	973.9	975.2	975.4	975.7	975.9	975.9
205.8	979.5	979.6	979.5	979.5	979.5	979.4
205.9	981.5	981.2	981.3	981.0	981.0	980.9
206.0	984.0	982.9	982.9	982.6	982.2	982.2
206.1	984.6	983.3	983.2	983.1	982.9	982.9
206.2	986.0	984.5	984.1	984.0	983.9	983.8
206.3	987.4	985.8	985.7	985.4	985.3	985.2
206.4	988.8	987.2	986.7	986.5	986.2	985.8
206.5	990.2	987.5	987.9	987.4	986.9	986.6
206.6	991.8	989.8	989.1	988.9	989.0	988.6
206.7	991.3	990.7	989.7	989.0	989.5	989.3
206.8	993.0	991.3	991.3	990.6	990.5	990.4
206.9	992.7	990.6	987.7	987.8	987.6	988.1
207.0	992.8	993.8	991.0	990.4	991.2	991.1
207.1	992.8	992.2	991.7	991.3	991.6	991.6
207.2	992.7	993.2	991.7	991.9	992.0	992.1
207.3	993.3	991.3	991.1	990.6	990.3	990.3
207.3	995.9	993.2	993.2	992.2	991.9	991.8
207.4	999.0	997.5	997.6	997.4	996.9	996.8
207.5	999.4	998.5	998.5	997.8	997.6	997.5
207.5	999.3	998.3	998.4	998.2	997.9	997.9
207.6	1000.2	997.7	997.6	997.0	996.9	996.9
207.7	1000.3	998.2	998.3	998.3	998.2	998.3
207.8	999.1	997.4	996.8	996.9	996.9	996.9
207.9	1000.8	1000.2	999.9	999.4	999.3	999.3
208.0	999.8	998.8	998.8	998.9	998.8	998.9
208.1	1001.3	999.6	999.2	998.0	998.0	998.0
208.2	1004.7	1004.8	1004.6	1004.0	1004.0	1004.0
208.3	1004.7	1004.9	1004.8	1004.1	1003.3	1003.2
208.4	1005.6	1005.8	1005.7	1005.6	1005.0	1004.0
208.5	1007.6	1007.8	1007.8	1007.8	1007.7	1007.7
208.6	1010.0	1009.1	1009.4	1009.5	1009.6	1009.5
208.7	1010.0	1009.0	1009.3	1009.4	1009.6	1009.5
208.8	1011.0	1010.8	1010.8	1010.1	1009.9	1009.8
208.9	1013.3	1010.3	1010.3	1010.3	1010.3	1010.3
208.9	1013.0	1011.1	1011.2	1011.2	1011.3	1011.2
209.0	1012.2	1011.4	1011.4	1011.4	1011.3	1011.3
209.1	1014.5	1012.4	1012.5	1012.4	1012.5	1012.4
209.2	1017.4	1009.5	1009.3	1008.9	1008.9	1008.9
209.3	1019.7	1011.4	1011.0	1010.7	1010.5	1010.6
209.4	1019.6	1013.3	1013.0	1012.4	1012.5	1012.4
209.5	1019.6	1013.8	1013.3	1013.2	1014.2	1014.1
209.6	1016.9	1011.8	1011.8	1011.8	1011.8	1011.8
209.7	1019.0	1016.8	1016.7	1016.0	1015.2	1015.0
209.8	1020.0	1020.0	1020.0	1019.9	1019.8	1019.5
209.9	1014.7	1014.8	1014.9	1016.3	1016.2	1016.1
210.0	1018.1	1018.7	1018.7	1019.6	1018.7	1018.6
210.1	1018.5	1021.3	1021.3	1022.6	1022.2	1021.8

210.2	1014.7	1017.8	1017.7	1017.8	1017.7	1017.8
210.3	1016.9	1018.7	1018.8	1019.7	1019.4	1019.7
210.4	1017.4	1019.3	1020.0	1021.4	1021.4	1021.5
210.4	1017.6	1018.9	1020.9	1021.7	1021.3	1021.6
210.5	1018.0	1021.5	1022.1	1022.2	1021.9	1022.1
210.6	1018.0	1022.7	1022.6	1023.9	1023.8	1023.8
210.6	1017.7	1020.9	1021.5	1022.2	1021.9	1022.0
210.7	1018.2	1022.7	1022.6	1023.8	1024.1	1024.1
210.8	1019.1	1021.2	1021.4	1022.3	1022.2	1022.3
210.9	1018.7	1020.4	1020.5	1021.5	1021.7	1021.7
211.0	1019.3	1022.1	1022.2	1023.5	1023.9	1023.9
211.1	1015.7	1020.6	1020.8	1021.5	1021.8	1021.8
211.2	1021.1	1023.5	1023.6	1024.7	1025.3	1025.3
211.3	1020.8	1023.3	1023.3	1024.5	1024.6	1024.6
211.4	1018.3	1022.7	1023.2	1024.4	1024.4	1024.5
211.5	1021.9	1024.5	1024.7	1025.8	1025.6	1025.6
211.6	1022.6	1025.1	1025.8	1026.7	1026.9	1026.9
211.7	1023.2	1026.0	1026.4	1027.1	1027.2	1027.2
211.8	1023.8	1026.3	1027.1	1027.8	1028.1	1028.1
211.9	1024.2	1026.8	1027.3	1027.9	1028.1	1028.0
212.0	1025.4	1028.0	1028.6	1029.3	1029.3	1029.3
212.1	1025.9	1028.3	1028.6	1029.0	1029.2	1029.2
212.2	1030.8	1030.2	1030.4	1030.7	1030.7	1030.7
212.3	1035.1	1030.6	1031.0	1031.2	1031.3	1031.2
212.4	1036.6	1032.6	1033.0	1032.9	1032.8	1032.8
212.5	1037.2	1031.7	1031.9	1031.8	1031.7	1031.8
212.6	1039.3	1034.2	1034.3	1033.9	1033.5	1033.7
212.7	1036.9	1034.2	1033.9	1033.5	1032.9	1032.9
212.7	1041.6	1038.1	1037.6	1037.1	1036.8	1036.8
212.8	1043.1	1037.0	1036.7	1036.2	1036.0	1036.0
212.9	1045.4	1040.8	1039.9	1039.3	1038.9	1038.8
213.0	1046.7	1041.2	1040.5	1040.1	1040.1	1040.1
213.1	1047.6	1043.9	1043.3	1042.7	1042.5	1042.3
213.2	1044.9	1044.1	1043.4	1042.8	1042.7	1042.6
213.3	1040.4	1042.5	1041.4	1040.5	1040.0	1040.0
213.3	1045.4	1044.9	1044.2	1043.4	1043.1	1043.0
213.4	1045.4	1044.8	1043.9	1042.8	1042.3	1042.3
213.5	1045.8	1044.0	1043.1	1042.2	1041.6	1041.6
213.6	1046.7	1044.5	1043.7	1042.8	1042.1	1042.1
213.7	1047.6	1045.3	1044.5	1043.4	1042.6	1042.6
213.8	1044.6	1044.6	1044.2	1043.1	1042.3	1042.4
213.9	1048.1	1045.6	1044.9	1043.8	1043.0	1043.0
213.9	1049.3	1047.8	1046.9	1045.5	1044.9	1044.9
214.0	1048.8	1049.2	1048.2	1047.1	1046.5	1046.2
214.1	1048.7	1048.5	1048.4	1046.7	1046.6	1046.6

Table 12: Change in average bed elevation for with existing 35th Avenue Bridge.

River Station (miles)	Change in Avg. Bed Elev. After 10 Years (ft)	Change in Avg. Bed Elev. After 20 Years (ft)	Change in Avg. Bed Elev. After 30 Years (ft)	Change in Avg. Bed Elev. After 40 Years (ft)	Change in Avg. Bed Elev. After 50 Years (ft)
202.1	-2.0	-2.1	-2.2	-2.3	-2.3
202.2	-1.7	-1.8	-1.9	-1.9	-2.0
202.3	-0.1	-0.2	-1.3	-1.3	-1.3
202.4	0.0	0.0	-0.3	-0.4	-0.4
202.5	0.4	0.1	0.0	0.0	0.0
202.6	-0.1	-0.2	-0.2	-0.2	-0.2
202.7	0.1	0.0	0.0	0.0	0.0
202.8	0.1	0.2	0.1	0.1	0.1
202.9	0.2	0.3	0.2	0.2	0.2
203.0	0.0	0.1	0.1	0.1	0.1
203.1	-0.5	-0.5	-0.5	-0.5	-0.4
203.2	-0.3	-0.3	-0.5	-0.4	-0.3
203.3	-0.3	-0.3	-0.3	-0.3	-0.3
203.4	-0.3	-0.4	-0.5	-0.5	-0.8
203.5	-0.2	-0.2	-0.2	-0.2	-0.2
203.6	0.2	0.4	0.3	0.4	0.5
203.7	0.4	0.7	0.8	0.9	1.0
203.8	1.3	1.8	1.8	1.9	1.9
203.9	2.8	3.0	3.0	3.1	3.2
204.0	-1.6	-1.7	-1.6	-1.5	-1.4
204.1	-0.4	-0.4	-0.4	-0.4	-0.3
204.1	1.1	1.0	0.8	0.7	0.7
204.3	0.0	0.0	-0.5	-0.7	-0.7
204.3	-2.5	-2.9	-2.9	-2.9	-2.9
204.4	-3.1	-3.2	-3.7	-3.9	-3.9
204.5	-3.2	-3.4	-3.6	-3.7	-3.7
204.6	-4.0	-4.4	-4.8	-4.9	-4.9
204.7	-1.5	-1.6	-1.9	-2.1	-2.1
204.8	0.2	0.2	0.2	0.3	0.3
204.9	0.9	0.6	0.9	1.0	0.9
205.0	3.5	3.5	3.7	3.9	3.8
205.1	-0.1	-0.2	-0.1	0.0	-0.1
205.1	-4.4	-3.8	-3.8	-3.2	-3.3
205.3	-0.9	-0.7	-0.5	-0.6	-0.6
205.3	0.0	0.2	0.2	0.2	0.2
205.4	0.7	1.1	1.1	1.2	1.1
205.4	0.5	0.5	0.5	0.6	0.6
205.5	0.1	0.1	0.3	0.5	0.5
205.6	0.7	0.9	1.2	1.5	1.6
205.8	1.3	1.5	1.8	2.0	2.0

205.8	0.1	0.0	0.0	0.0	-0.1
205.9	-0.3	-0.3	-0.5	-0.5	-0.6
206.0	-1.2	-1.2	-1.5	-1.9	-1.9
206.1	-1.3	-1.4	-1.5	-1.7	-1.7
206.2	-1.5	-1.9	-2.0	-2.1	-2.2
206.3	-1.6	-1.7	-2.0	-2.1	-2.2
206.4	-1.6	-2.1	-2.3	-2.6	-3.0
206.5	-2.7	-2.3	-2.8	-3.3	-3.6
206.6	-2.1	-2.7	-2.9	-2.9	-3.3
206.7	-0.6	-1.5	-2.3	-1.8	-1.9
206.8	-1.8	-1.8	-2.4	-2.5	-2.7
206.9	-2.0	-4.9	-4.9	-5.0	-4.5
207.0	1.1	-1.8	-2.4	-1.6	-1.7
207.1	-0.6	-1.1	-1.5	-1.2	-1.2
207.2	0.5	-0.9	-0.7	-0.7	-0.6
207.3	-2.0	-2.1	-2.7	-2.9	-3.0
207.3	-2.7	-2.7	-3.8	-4.0	-4.2
207.4	-1.5	-1.5	-1.6	-2.1	-2.2
207.5	-0.9	-0.9	-1.6	-1.8	-1.9
207.5	-1.0	-0.9	-1.1	-1.4	-1.4
207.6	-2.6	-2.6	-3.2	-3.3	-3.3
207.7	-2.1	-2.0	-2.0	-2.1	-2.0
207.8	-1.6	-2.2	-2.1	-2.2	-2.2
207.9	-0.6	-0.9	-1.4	-1.4	-1.5
208.0	-1.0	-1.0	-1.0	-1.0	-1.0
208.1	-1.7	-2.1	-3.3	-3.3	-3.3
208.2	0.1	0.0	-0.7	-0.7	-0.7
208.3	0.2	0.1	-0.6	-1.4	-1.5
208.4	0.2	0.2	0.1	-0.6	-1.6
208.5	0.2	0.2	0.2	0.1	0.1
208.6	-0.9	-0.6	-0.5	-0.4	-0.5
208.7	-1.0	-0.7	-0.6	-0.4	-0.5
208.8	-0.2	-0.2	-0.9	-1.1	-1.2
208.9	-3.0	-3.0	-3.1	-3.1	-3.1
208.9	-1.9	-1.9	-1.9	-1.8	-1.9
209.0	-0.9	-0.8	-0.9	-0.9	-0.9
209.1	-2.1	-1.9	-2.0	-2.0	-2.0
209.2	-7.9	-8.1	-8.5	-8.5	-8.5
209.3	-8.3	-8.7	-9.0	-9.1	-9.1
209.4	-6.3	-6.6	-7.1	-7.1	-7.2
209.5	-5.8	-6.3	-6.4	-5.5	-5.5
209.6	-5.1	-5.1	-5.2	-5.2	-5.1
209.7	-2.2	-2.3	-3.0	-3.8	-4.0
209.8	0.0	0.0	-0.1	-0.2	-0.5
209.9	0.1	0.2	1.6	1.4	1.4
210.0	0.7	0.6	1.6	0.7	0.5
210.1	2.8	2.8	4.1	3.7	3.3
210.2	3.1	3.0	3.1	3.0	3.0

210.3	1.9	1.9	2.9	2.5	2.8
210.4	1.9	2.6	4.0	4.0	4.1
210.4	1.3	3.3	4.1	3.7	3.9
210.5	3.5	4.1	4.2	3.9	4.1
210.6	4.7	4.5	5.9	5.8	5.8
210.6	3.2	3.8	4.5	4.2	4.3
210.7	4.5	4.5	5.6	5.9	5.9
210.8	2.1	2.3	3.2	3.1	3.2
210.9	1.7	1.8	2.8	3.0	3.0
211.0	2.8	2.8	4.2	4.5	4.6
211.1	4.9	5.1	5.8	6.1	6.1
211.2	2.4	2.5	3.6	4.2	4.2
211.3	2.5	2.5	3.7	3.8	3.8
211.4	4.4	4.9	6.1	6.1	6.2
211.5	2.6	2.8	3.9	3.7	3.7
211.6	2.5	3.2	4.1	4.4	4.3
211.7	2.8	3.2	3.9	4.0	4.0
211.8	2.5	3.2	4.0	4.3	4.3
211.9	2.6	3.1	3.7	3.9	3.8
212.0	2.6	3.2	3.9	3.9	3.9
212.1	2.4	2.7	3.1	3.3	3.3
212.2	-0.6	-0.4	-0.1	-0.1	-0.1
212.3	-4.5	-4.1	-3.9	-3.8	-3.9
212.4	-4.0	-3.6	-3.7	-3.8	-3.8
212.5	-5.5	-5.3	-5.4	-5.5	-5.4
212.6	-5.1	-5.0	-5.4	-5.8	-5.6
212.7	-2.7	-3.0	-3.4	-4.0	-4.0
212.7	-3.5	-4.0	-4.5	-4.8	-4.8
212.8	-6.1	-6.4	-6.9	-7.1	-7.1
212.9	-4.6	-5.5	-6.1	-6.5	-6.6
213.0	-5.5	-6.2	-6.6	-6.6	-6.6
213.1	-3.7	-4.3	-4.9	-5.1	-5.3
213.2	-0.8	-1.5	-2.1	-2.2	-2.3
213.3	2.1	1.0	0.1	-0.4	-0.4
213.3	-0.5	-1.2	-2.0	-2.3	-2.4
213.4	-0.6	-1.5	-2.6	-3.1	-3.1
213.5	-1.8	-2.7	-3.6	-4.2	-4.2
213.6	-2.2	-3.0	-3.9	-4.6	-4.6
213.7	-2.3	-3.1	-4.2	-5.0	-5.0
213.8	0.0	-0.4	-1.5	-2.3	-2.2
213.9	-2.5	-3.2	-4.3	-5.1	-5.1
213.9	-1.5	-2.4	-3.8	-4.4	-4.4
214.0	0.4	-0.6	-1.7	-2.3	-2.6
214.1	-0.2	-0.3	-2.0	-2.1	-2.1

Table 13: Accumulated sand delivery for with existing 35th Ave Bridge.

River Station (miles)	Accumulated Sand Delivery (tons)	Accumulated Sand Delivery (tons/year)	Accumulated Sand Delivery (cy/year)	Accumulated Sand Delivery (ac-ft/year)
202.1	14422208	288444	178408	110.6
202.2	14352047	287041	177540	110.0
202.3	14329823	286596	177265	109.9
202.4	14333327	286667	177309	109.9
202.5	14339765	286795	177388	110.0
202.6	14331662	286633	177288	109.9
202.7	14295841	285917	176845	109.6
202.8	14291759	285835	176794	109.6
202.9	14340572	286811	177398	110.0
203.0	14390974	287819	178022	110.3
203.1	14404236	288085	178186	110.4
203.2	14368498	287370	177744	110.2
203.3	14325232	286505	177208	109.8
203.4	14312941	286259	177056	109.7
203.5	14293714	285874	176819	109.6
203.6	14302732	286055	176930	109.7
203.7	14333628	286673	177312	109.9
203.8	14416945	288339	178343	110.5
203.9	14533425	290669	179784	111.4
204.0	14675276	293506	181539	112.5
204.1	14611829	292237	180754	112.0
204.1	14612501	292250	180762	112.0
204.3	14685253	293705	181662	112.6
204.3	14658035	293161	181325	112.4
204.4	14572993	291460	180273	111.7
204.5	14469595	289392	178994	110.9
204.6	14385128	287703	177949	110.3
204.7	14293674	285873	176818	109.6
204.8	14252748	285055	176312	109.3
204.9	14285831	285717	176721	109.5
205.0	14328664	286573	177251	109.9
205.1	14426900	288538	178466	110.6
205.1	14417327	288347	178348	110.5
205.3	14394932	287899	178071	110.4
205.3	14432187	288644	178531	110.7
205.4	14446262	288925	178706	110.8
205.4	14498503	289970	179352	111.2
205.5	14531543	290631	179761	111.4
205.6	14579293	291586	180351	111.8
205.8	14668813	293376	181459	112.5
205.8	14758751	295175	182571	113.2

205.9	14857138	297143	183788	113.9
206.0	14929605	298592	184685	114.5
206.1	14909628	298193	184438	114.3
206.2	14911000	298220	184455	114.3
206.3	14905861	298117	184391	114.3
206.4	14898132	297963	184295	114.2
206.5	14824492	296490	183384	113.7
206.6	14777841	295557	182807	113.3
206.7	14810993	296220	183217	113.6
206.8	14957615	299152	185031	114.7
206.9	15118055	302361	187016	115.9
207.0	15454313	309086	191176	118.5
207.1	15757776	315156	194930	120.8
207.2	15722182	314444	194489	120.6
207.3	15661582	313232	193740	120.1
207.3	15573266	311465	192647	119.4
207.4	15491502	309830	191636	118.8
207.5	15453835	309077	191170	118.5
207.5	15438854	308777	190984	118.4
207.6	15428208	308564	190853	118.3
207.7	15327505	306550	189607	117.5
207.8	15229600	304592	188396	116.8
207.9	15132987	302660	187201	116.0
208.0	15103263	302065	186833	115.8
208.1	15077987	301560	186520	115.6
208.2	15064528	301291	186354	115.5
208.3	15111648	302233	186937	115.9
208.4	15121992	302440	187065	115.9
208.5	15172666	303453	187691	116.3
208.6	15229482	304590	188394	116.8
208.7	15257794	305156	188745	117.0
208.8	15278637	305573	189002	117.2
208.9	15305602	306112	189336	117.4
208.9	15263395	305268	188814	117.0
209.0	15296104	305922	189218	117.3
209.1	15410151	308203	190629	118.2
209.2	15534060	310681	192162	119.1
209.3	15550754	311015	192369	119.2
209.4	15549481	310990	192353	119.2
209.54	15322105	306442	189540	117.5
209.6	15296562	305931	189224	117.3
209.69	15262057	305241	188797	117.0
209.79	15561085	311222	192496	119.3
209.88	15868319	317366	196297	121.7
209.98	16038306	320766	198400	123.0
210.07	16310772	326215	201770	125.1
210.17	16749400	334988	207196	128.4
210.26	17124292	342486	211834	131.3

210.36	17352282	347046	214654	133.1
210.44	17525652	350513	216799	134.4
210.46	17593666	351873	217640	134.9
210.55	17748626	354973	219557	136.1
210.64	18237946	364759	225610	139.8
210.74	18689042	373781	231190	143.3
210.83	19202294	384046	237539	147.2
210.93	19585068	391701	242275	150.2
211.02	19995070	399901	247346	153.3
211.12	20396388	407928	252311	156.4
211.21	20760274	415205	256812	159.2
211.31	20863642	417273	258091	160.0
211.41	20913878	418278	258712	160.4
211.54	20998620	419972	259761	161.0
211.64	21089320	421786	260883	161.7
211.71	21147284	422946	261600	162.1
211.79	21213886	424278	262424	162.7
211.89	21289324	425786	263357	163.2
211.99	21363218	427264	264271	163.8
212.08	21587200	431744	267042	165.5
212.18	21911450	438229	271053	168.0
212.27	22148280	442966	273982	169.8
212.37	22396204	447924	277049	171.7
212.46	22641114	452822	280079	173.6
212.56	22660454	453209	280318	173.8
212.68	22603146	452063	279609	173.3
212.74	22555978	451120	279026	172.9
212.84	22504458	450089	278388	172.6
212.93	22401770	448035	277118	171.8
213.03	22296008	445920	275810	171.0
213.11	22178918	443578	274361	170.1
213.21	22079558	441591	273132	169.3
213.26	22059252	441185	272881	169.1
213.33	22055918	441118	272840	169.1
213.38	22033092	440662	272558	168.9
213.47	21993772	439875	272071	168.6
213.57	21931304	438626	271298	168.2
213.66	21863528	437271	270460	167.6
213.75	21801168	436023	269689	167.2
213.85	21767034	435341	269266	166.9
213.95	21747616	434952	269026	166.8
214.04	21694544	433891	268370	166.3
214.14	21659744	433195	267939	166.1

Note: weight of sand = 120 pcf, 1 ton = 16.7 cubic feet
This is a table of the total weight of sand and larger transported past each cross section in the model plotted versus channel station.
Sediment inflow = 166 ac-ft/year

With Project

The without project sediment transport analysis numerical models were modified to reflect the with project conditions. The proposed project would consist of a trapezoidal low flow channel approximately 300- to 800-ft wide and up to 15-ft deep. The low flow channel excavation would extend from approximately River Mile 203.5 to 211.5.

Model Geometry

The without project sediment transport analysis numerical models were modified to reflect the proposed geometry changes. The modification consisted mainly of excavating the low flow channel within the existing channel bed. The numerical models were then calibrated with the fixed bed (HEC-RAS) numerical models. Finally, the numerical models were rerun to simulate 50 years of sediment transport.

Results

The sediment transport analysis results are presented in terms of thalweg bed elevation by decade show on Figure 23 and Tables 14 to 16. The significant results are discussed below.

- In general, the end result of the simulation is a channel with a more homogeneous bed slope. The bed slope tends to parallel the proposed bed slope of the low flow channel.

- The channel reach between the 19th to the 27th Avenue Bridges would experience up to 5 ft of deposition. This is similar to what would occur for without project conditions.

- An area from the 27th to the 35th Avenue Bridges would have up to 6 ft of scour. This is most likely due to the deposition that occurred upstream and from the channel bed trying to obtain a stable slope.

- Downstream of the 35th Avenue Bridge up to River Mile 208, the channel would be generally stable with scattered areas of minor erosion and deposition.

- From River Mile 208 to the 51st Avenue Bridge, up to 5 ft of deposition would occur. Downstream from the bridge to River Mile 207, up to 8 ft of scour would occur.

- Downstream of River Mile 206, the channel would be generally stable with scattered areas of minor erosion and deposition.

- More sediment would leave the study area. After 50 years of simulated sediment transport, approximately 2,591,000 additional tons of sediment (20 ac-ft/year) would leave the study area, as compared to the without project conditions. This indicates that the study area, with the proposed low flow channel in place, would be more efficient in transporting sediment.

- During the simulations most of the bed changes took place in the first decade, with minor adjustments occurring in the remaining time. The first decade contained the flow events with the two largest peaks. In addition, it can be seen that the trend observed after the first decade is sometimes reversed after subsequent decades. This is a consequence of both changes in the cross section geometry with time, and changes in sediment dynamics associated with flows of very different magnitudes.

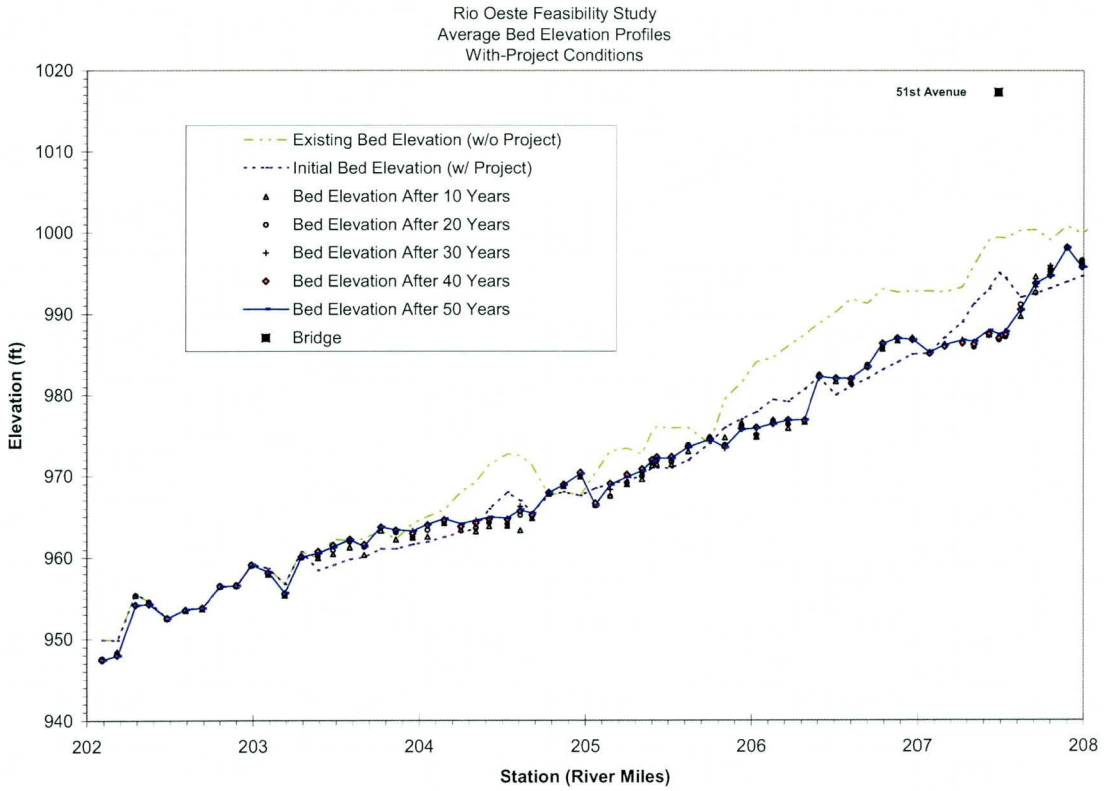

Figure 23: Average bed elevation profiles for with project condition.

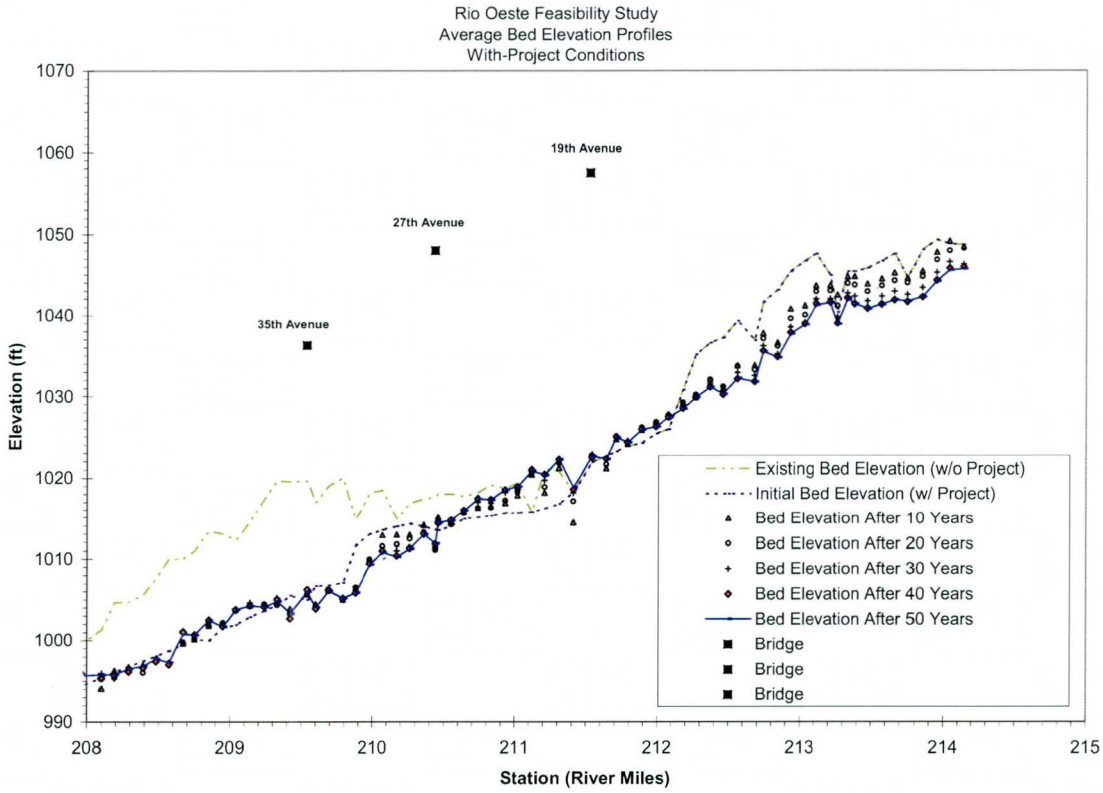

Figure 23: continued

Table 14: Average bed elevation profiles for with project condition.

River Station (miles)	Initial Avg. Bed Elev. (ft)	Avg. Bed Elev. After 10 Years (ft)	Avg. Bed Elev. After 20 Years (ft)	Avg. Bed Elev. After 30 Years (ft)	Avg. Bed Elev. After 40 Years (ft)	Avg. Bed Elev. After 50 Years (ft)
202.1	949.9	947.6	947.5	947.5	947.4	947.4
202.2	949.8	948.4	948.3	948.1	948.0	948.0
202.3	955.5	955.4	955.3	954.2	954.2	954.1
202.4	954.6	954.5	954.5	954.4	954.3	954.3
202.5	952.5	952.6	952.6	952.5	952.5	952.5
202.6	953.7	953.5	953.5	953.5	953.6	953.6
202.7	953.7	953.7	953.8	953.8	953.8	953.8
202.8	956.4	956.5	956.6	956.5	956.5	956.5
202.9	956.5	956.6	956.7	956.6	956.6	956.5
203.0	959.2	959.1	959.1	959.1	959.1	959.1
203.1	958.7	957.9	958.0	958.1	958.1	958.2
203.2	956.7	955.3	955.3	955.6	955.6	955.6
203.3	960.8	960.1	960.1	960.1	960.1	960.1
203.4	958.4	959.9	960.2	960.8	960.8	960.6
203.5	959.0	960.5	960.9	961.5	961.5	961.3

203.6	959.8	961.3	961.9	962.2	962.2	962.1
203.7	960.1	960.3	961.3	961.6	961.6	961.4
203.8	961.1	963.3	963.6	963.8	963.7	963.7
203.9	961.1	962.2	963.1	963.4	963.3	963.4
204.0	961.6	962.4	962.5	963.2	962.9	963.2
204.1	961.9	962.5	963.3	963.9	964.0	964.1
204.1	962.5	964.2	964.3	964.7	964.6	964.7
204.3	963.0	963.4	963.7	963.9	963.8	964.1
204.3	963.5	963.2	963.6	964.5	964.2	964.5
204.4	966.0	963.8	964.3	964.8	964.7	964.9
204.5	968.0	963.9	964.1	964.6	964.7	964.8
204.6	967.0	963.3	965.2	966.3	965.7	965.8
204.7	965.5	964.8	965.0	965.2	965.2	965.4
204.8	967.6	967.8	967.9	967.9	968.0	967.9
204.9	968.0	968.7	968.8	968.9	969.0	968.9
205.0	967.6	970.0	970.1	970.2	970.5	970.3
205.1	968.5	966.5	966.4	966.5	966.6	966.4
205.1	969.0	967.6	967.5	968.3	969.1	968.9
205.3	969.5	969.0	969.2	969.9	970.2	969.9
205.3	970.0	969.6	970.0	970.4	970.9	970.7
205.4	971.0	971.3	971.6	971.8	972.0	971.8
205.4	971.0	971.5	971.9	972.0	972.4	972.2
205.5	971.0	971.5	971.7	972.0	972.4	972.2
205.6	971.9	973.1	973.8	973.5	973.6	973.6
205.8	974.0	974.8	974.7	974.6	974.6	974.5
205.8	976.0	974.8	973.8	973.4	973.7	973.6
205.9	977.0	976.6	976.2	976.0	975.9	975.8
206.0	977.8	974.8	975.1	975.2	976.0	975.9
206.1	979.4	976.9	976.8	976.6	976.5	976.4
206.2	979.2	975.9	976.4	976.4	976.9	976.9
206.3	980.7	976.7	976.8	976.8	976.9	976.9
206.4	982.2	982.5	982.4	982.0	982.3	982.2
206.5	980.0	981.7	982.0	982.0	982.1	982.0
206.6	981.0	981.7	981.4	981.5	982.0	982.1
206.7	982.0	983.6	983.7	983.5	983.4	983.5
206.8	983.1	985.7	985.8	986.1	986.3	986.3
206.9	984.0	986.7	987.0	986.9	987.0	987.0
207.0	985.0	987.0	986.9	986.8	986.8	986.8
207.1	985.1	985.3	985.1	985.1	985.1	985.2
207.2	987.1	986.3	986.1	986.0	986.0	986.2
207.3	989.0	986.8	986.3	986.3	986.4	986.7
207.3	991.2	986.5	985.9	985.9	986.2	986.6
207.4	993.0	987.4	987.3	987.4	987.5	988.0
207.5	995.0	987.3	986.8	986.8	987.0	987.5
207.5	994.4	987.8	987.1	987.5	987.4	987.8
207.6	992.0	989.7	991.1	990.5	990.5	990.5
207.7	992.5	994.5	992.6	993.3	993.7	993.7
207.8	993.1	995.4	995.5	995.9	994.7	994.6

207.9	993.9	998.1	998.2	998.2	998.1	998.1
208.0	994.6	996.5	996.5	996.0	995.7	995.7
208.1	995.4	994.1	995.3	996.0	995.4	995.8
208.2	996.1	996.3	995.5	995.4	995.7	995.8
208.3	996.8	996.8	996.3	996.7	996.2	996.5
208.4	997.5	997.0	996.1	996.7	996.6	996.9
208.5	998.1	997.8	997.5	997.6	997.4	997.8
208.6	998.7	997.3	997.0	997.0	997.0	997.3
208.7	999.4	999.6	999.8	1001.2	1001.0	1000.8
208.8	1000.1	1000.2	1000.2	1000.3	1000.7	1000.7
208.9	1000.0	1001.8	1001.8	1002.2	1002.5	1002.5
208.9	1001.5	1002.2	1002.1	1002.1	1001.7	1001.7
209.0	1001.9	1003.8	1003.7	1003.8	1003.8	1003.8
209.1	1002.9	1004.3	1004.4	1004.6	1004.3	1004.2
209.2	1003.6	1004.4	1004.5	1004.4	1004.1	1004.1
209.3	1004.3	1004.7	1004.3	1005.2	1005.0	1004.8
209.4	1005.5	1003.9	1003.3	1003.2	1002.7	1003.3
209.5	1005.0	1005.7	1005.7	1006.2	1006.2	1006.0
209.6	1006.7	1004.5	1004.2	1004.2	1003.9	1004.0
209.7	1006.8	1006.1	1006.3	1006.4	1006.2	1006.1
209.8	1007.1	1005.0	1005.0	1005.2	1005.2	1005.2
209.9	1011.7	1006.5	1006.5	1006.2	1005.9	1005.9
210.0	1013.0	1009.7	1009.9	1009.7	1009.4	1009.3
210.1	1013.5	1012.9	1011.5	1011.1	1011.0	1010.8
210.2	1013.9	1012.9	1011.7	1011.0	1010.4	1010.3
210.3	1014.2	1012.9	1012.4	1011.3	1011.3	1011.2
210.4	1013.9	1014.1	1013.2	1012.9	1013.0	1013.0
210.4	1013.5	1011.7	1011.1	1011.3	1011.8	1011.8
210.5	1013.5	1015.0	1014.5	1014.1	1014.3	1014.3
210.6	1013.9	1014.3	1014.2	1014.4	1014.7	1014.6
210.6	1014.8	1015.7	1015.5	1015.6	1016.0	1015.9
210.7	1015.0	1016.2	1016.3	1017.0	1017.4	1017.4
210.8	1015.2	1016.5	1016.3	1016.9	1017.3	1017.3
210.9	1015.6	1016.9	1017.2	1018.2	1018.5	1018.5
211.0	1015.6	1017.8	1018.2	1018.6	1018.9	1018.9
211.1	1015.7	1020.4	1020.6	1020.8	1021.0	1020.9
211.2	1016.2	1018.1	1018.9	1019.7	1020.4	1020.4
211.3	1016.8	1021.2	1021.8	1022.1	1022.2	1022.2
211.4	1018.2	1014.3	1017.1	1018.1	1018.5	1018.8
211.5	1021.9	1022.6	1022.7	1022.8	1022.5	1022.6
211.6	1022.6	1021.2	1021.6	1022.3	1022.3	1022.3
211.7	1023.2	1024.7	1025.0	1025.1	1025.0	1024.9
211.8	1023.8	1024.1	1024.2	1024.5	1024.3	1024.3
211.9	1024.2	1025.8	1026.1	1026.1	1025.9	1025.9
212.0	1025.4	1026.7	1026.8	1026.6	1026.2	1026.2
212.1	1025.9	1027.5	1027.6	1027.7	1027.4	1027.4
212.2	1030.8	1029.2	1029.2	1028.7	1028.5	1028.4
212.3	1035.1	1029.9	1030.2	1030.0	1029.9	1029.9

212.4	1036.6	1032.1	1032.0	1031.5	1031.1	1031.1
212.5	1037.2	1031.0	1031.2	1030.6	1030.2	1030.3
212.6	1039.3	1033.8	1033.7	1032.9	1032.2	1032.2
212.7	1036.9	1033.8	1033.3	1032.5	1031.8	1031.8
212.7	1041.6	1037.8	1037.1	1036.2	1035.6	1035.5
212.8	1043.1	1036.6	1036.2	1035.2	1034.9	1034.8
212.9	1045.4	1040.8	1039.6	1038.5	1037.8	1037.7
213.0	1046.7	1041.2	1040.0	1039.1	1038.9	1038.8
213.1	1047.6	1043.6	1042.9	1041.9	1041.4	1041.2
213.2	1044.9	1043.7	1043.0	1042.0	1041.6	1041.5
213.3	1040.4	1042.5	1041.1	1039.8	1039.0	1038.9
213.3	1045.4	1044.7	1043.9	1042.7	1042.1	1042.0
213.4	1045.4	1044.8	1043.7	1042.3	1041.4	1041.4
213.5	1045.8	1043.9	1042.9	1041.7	1040.8	1040.8
213.6	1046.7	1044.5	1043.6	1042.3	1041.3	1041.3
213.7	1047.6	1045.2	1044.3	1042.9	1041.8	1041.9
213.8	1044.6	1044.5	1044.0	1042.6	1041.7	1041.7
213.9	1048.1	1045.4	1044.8	1043.4	1042.2	1042.2
213.9	1049.3	1047.8	1046.8	1045.3	1044.3	1044.2
214.0	1048.8	1049.2	1048.0	1046.6	1045.8	1045.5
214.1	1048.7	1048.5	1048.3	1046.3	1046.0	1045.7

Table 15: Change in average bed elevation profiles for with project condition.

River Station (miles)	Change in Avg. Bed Elev. After 10 Years (ft)	Change in Avg. Bed Elev. After 20 Years (ft)	Change in Avg. Bed Elev. After 30 Years (ft)	Change in Avg. Bed Elev. After 40 Years (ft)	Change in Avg. Bed Elev. After 50 Years (ft)
202.1	-2.0	-2.1	-2.2	-2.3	-2.3
202.2	-1.7	-1.8	-1.9	-1.9	-2.0
202.3	-0.1	-0.2	-1.3	-1.3	-1.3
202.4	0.0	0.0	-0.3	-0.4	-0.4
202.5	0.4	0.1	0.0	0.0	0.0
202.6	-0.1	-0.2	-0.2	-0.2	-0.2
202.7	0.1	0.0	0.0	0.0	0.0
202.8	0.1	0.2	0.1	0.1	0.1
202.9	0.2	0.3	0.2	0.2	0.2
203.0	0.0	0.1	0.1	0.1	0.1
203.1	-0.5	-0.5	-0.5	-0.5	-0.4
203.2	-0.3	-0.3	-0.5	-0.4	-0.3
203.3	-0.3	-0.3	-0.3	-0.3	-0.3
203.4	-0.3	-0.4	-0.5	-0.5	-0.8
203.5	-0.2	-0.2	-0.2	-0.2	-0.2

203.6	0.2	0.4	0.3	0.4	0.5
203.7	0.4	0.7	0.8	0.9	1.0
203.8	1.3	1.8	1.8	1.9	1.9
203.9	2.8	3.0	3.0	3.1	3.2
204.0	-1.6	-1.7	-1.6	-1.5	-1.4
204.1	-0.4	-0.4	-0.4	-0.4	-0.3
204.1	1.1	1.0	0.8	0.7	0.7
204.3	0.0	0.0	-0.5	-0.7	-0.7
204.3	-2.5	-2.9	-2.9	-2.9	-2.9
204.4	-3.1	-3.2	-3.7	-3.9	-3.9
204.5	-3.2	-3.4	-3.6	-3.7	-3.7
204.6	-4.0	-4.4	-4.8	-4.9	-4.9
204.7	-1.5	-1.6	-1.9	-2.1	-2.1
204.8	0.2	0.2	0.2	0.3	0.3
204.9	0.9	0.6	0.9	1.0	0.9
205.0	3.5	3.5	3.7	3.9	3.8
205.1	-0.1	-0.2	-0.1	0.0	-0.1
205.1	-4.4	-3.8	-3.8	-3.2	-3.3
205.3	-0.9	-0.7	-0.5	-0.6	-0.6
205.3	0.0	0.2	0.2	0.2	0.2
205.4	0.7	1.1	1.1	1.2	1.1
205.4	0.5	0.5	0.5	0.6	0.6
205.5	0.1	0.1	0.3	0.5	0.5
205.6	0.7	0.9	1.2	1.5	1.6
205.8	1.3	1.5	1.8	2.0	2.0
205.8	0.1	0.0	0.0	0.0	-0.1
205.9	-0.3	-0.3	-0.5	-0.5	-0.6
206.0	-1.2	-1.2	-1.5	-1.9	-1.9
206.1	-1.3	-1.4	-1.5	-1.7	-1.7
206.2	-1.5	-1.9	-2.0	-2.1	-2.2
206.3	-1.6	-1.7	-2.0	-2.1	-2.2
206.4	-1.6	-2.1	-2.3	-2.6	-3.0
206.5	-2.7	-2.3	-2.8	-3.3	-3.6
206.6	-2.1	-2.7	-2.9	-2.9	-3.3
206.7	-0.6	-1.5	-2.3	-1.8	-1.9
206.8	-1.8	-1.8	-2.4	-2.5	-2.7
206.9	-2.0	-4.9	-4.9	-5.0	-4.5
207.0	1.1	-1.8	-2.4	-1.6	-1.7
207.1	-0.6	-1.1	-1.5	-1.2	-1.2
207.2	0.5	-0.9	-0.7	-0.7	-0.6
207.3	-2.0	-2.1	-2.7	-2.9	-3.0
207.3	-2.7	-2.7	-3.8	-4.0	-4.2
207.4	-1.5	-1.5	-1.6	-2.1	-2.2
207.5	-0.9	-0.9	-1.6	-1.8	-1.9
207.5	-1.0	-0.9	-1.1	-1.4	-1.4
207.6	-2.6	-2.6	-3.2	-3.3	-3.3
207.7	-2.1	-2.0	-2.0	-2.1	-2.0
207.8	-1.6	-2.2	-2.1	-2.2	-2.2

207.9	-0.6	-0.9	-1.4	-1.4	-1.5
208.0	-1.0	-1.0	-1.0	-1.0	-1.0
208.1	-1.7	-2.1	-3.3	-3.3	-3.3
208.2	0.1	0.0	-0.7	-0.7	-0.7
208.3	0.2	0.1	-0.6	-1.4	-1.5
208.4	0.2	0.2	0.1	-0.6	-1.6
208.5	0.2	0.2	0.2	0.1	0.1
208.6	-0.9	-0.6	-0.5	-0.4	-0.5
208.7	-1.0	-0.7	-0.6	-0.4	-0.5
208.8	-0.2	-0.2	-0.9	-1.1	-1.2
208.9	-3.0	-3.0	-3.1	-3.1	-3.1
208.9	-1.9	-1.9	-1.9	-1.8	-1.9
209.0	-0.9	-0.8	-0.9	-0.9	-0.9
209.1	-2.1	-1.9	-2.0	-2.0	-2.0
209.2	-7.9	-8.1	-8.5	-8.5	-8.5
209.3	-8.3	-8.7	-9.0	-9.1	-9.1
209.4	-6.3	-6.6	-7.1	-7.1	-7.2
209.5	-5.8	-6.3	-6.4	-5.5	-5.5
209.6	-5.1	-5.1	-5.2	-5.2	-5.1
209.7	-2.2	-2.3	-3.0	-3.8	-4.0
209.8	0.0	0.0	-0.1	-0.2	-0.5
209.9	0.1	0.2	1.6	1.4	1.4
210.0	0.7	0.6	1.6	0.7	0.5
210.1	2.8	2.8	4.1	3.7	3.3
210.2	3.1	3.0	3.1	3.0	3.0
210.3	1.9	1.9	2.9	2.5	2.8
210.4	1.9	2.6	4.0	4.0	4.1
210.4	1.3	3.3	4.1	3.7	3.9
210.5	3.5	4.1	4.2	3.9	4.1
210.6	4.7	4.5	5.9	5.8	5.8
210.6	3.2	3.8	4.5	4.2	4.3
210.7	4.5	4.5	5.6	5.9	5.9
210.8	2.1	2.3	3.2	3.1	3.2
210.9	1.7	1.8	2.8	3.0	3.0
211.0	2.8	2.8	4.2	4.5	4.6
211.1	4.9	5.1	5.8	6.1	6.1
211.2	2.4	2.5	3.6	4.2	4.2
211.3	2.5	2.5	3.7	3.8	3.8
211.4	4.4	4.9	6.1	6.1	6.2
211.5	2.6	2.8	3.9	3.7	3.7
211.6	2.5	3.2	4.1	4.4	4.3
211.7	2.8	3.2	3.9	4.0	4.0
211.8	2.5	3.2	4.0	4.3	4.3
211.9	2.6	3.1	3.7	3.9	3.8
212.0	2.6	3.2	3.9	3.9	3.9
212.1	2.4	2.7	3.1	3.3	3.3
212.2	-0.6	-0.4	-0.1	-0.1	-0.1
212.3	-4.5	-4.1	-3.9	-3.8	-3.9

212.4	-4.0	-3.6	-3.7	-3.8	-3.8
212.5	-5.5	-5.3	-5.4	-5.5	-5.4
212.6	-5.1	-5.0	-5.4	-5.8	-5.6
212.7	-2.7	-3.0	-3.4	-4.0	-4.0
212.7	-3.5	-4.0	-4.5	-4.8	-4.8
212.8	-6.1	-6.4	-6.9	-7.1	-7.1
212.9	-4.6	-5.5	-6.1	-6.5	-6.6
213.0	-5.5	-6.2	-6.6	-6.6	-6.6
213.1	-3.7	-4.3	-4.9	-5.1	-5.3
213.2	-0.8	-1.5	-2.1	-2.2	-2.3
213.3	2.1	1.0	0.1	-0.4	-0.4
213.3	-0.5	-1.2	-2.0	-2.3	-2.4
213.4	-0.6	-1.5	-2.6	-3.1	-3.1
213.5	-1.8	-2.7	-3.6	-4.2	-4.2
213.6	-2.2	-3.0	-3.9	-4.6	-4.6
213.7	-2.3	-3.1	-4.2	-5.0	-5.0
213.8	0.0	-0.4	-1.5	-2.3	-2.2
213.9	-2.5	-3.2	-4.3	-5.1	-5.1
213.9	-1.5	-2.4	-3.8	-4.4	-4.4
214.0	0.4	-0.6	-1.7	-2.3	-2.6
214.1	-0.2	-0.3	-2.0	-2.1	-2.1

Table 16: Accumulated sand delivery for with project condition.

River Station (miles)	Accumulated Sand Delivery (tons)	Accumulated Sand Delivery (tons/year)	Accumulated Sand Delivery (cy/year)	Accumulated Sand Delivery (ac-ft/year)
202.1	17628630	352573	218073	135.2
202.2	17566704	351334	217307	134.7
202.3	17578326	351567	217450	134.8
202.4	17616204	352324	217919	135.1
202.5	17641616	352832	218233	135.3
202.6	17647478	352950	218306	135.3
202.7	17618552	352371	217948	135.1
202.8	17627956	352559	218064	135.2
202.9	17697854	353957	218929	135.7
203.0	17759152	355183	219687	136.2
203.1	17770982	355420	219834	136.3
203.2	17728772	354575	219311	135.9
203.3	17656010	353120	218411	135.4
203.4	17634948	352699	218151	135.2
203.5	17634116	352682	218141	135.2
203.6	17660976	353220	218473	135.4

203.7	17725830	354517	219275	135.9
203.8	17802298	356046	220221	136.5
203.9	17930276	358606	221804	137.5
204.0	17992160	359843	222570	138.0
204.1	17961880	359238	222195	137.7
204.1	18007294	360146	222757	138.1
204.3	18089458	361789	223773	138.7
204.3	18094522	361890	223836	138.7
204.4	18063454	361269	223452	138.5
204.5	18012190	360244	222817	138.1
204.6	17959644	359193	222167	137.7
204.7	17943648	358873	221970	137.6
204.8	17952666	359053	222081	137.7
204.9	18016020	360320	222865	138.1
205.0	18068326	361367	223512	138.5
205.1	18166800	363336	224730	139.3
205.1	18115050	362301	224090	138.9
205.3	18132840	362657	224310	139.0
205.3	18123232	362465	224191	139.0
205.4	18133152	362663	224314	139.0
205.4	18173510	363470	224813	139.3
205.5	18221230	364425	225403	139.7
205.6	18251780	365036	225781	139.9
205.8	18358150	367163	227097	140.8
205.8	18409544	368191	227733	141.2
205.9	18495754	369915	228799	141.8
206.0	18502134	370043	228878	141.9
206.1	18574610	371492	229775	142.4
206.2	18522596	370452	229131	142.0
206.3	18488262	369765	228707	141.8
206.4	18405322	368106	227681	141.1
206.5	18466258	369325	228434	141.6
206.6	18592264	371845	229993	142.6
206.7	18609980	372200	230212	142.7
206.8	18645066	372901	230646	143.0
206.9	18768976	375380	232179	143.9
207.0	18877108	377542	233517	144.7
207.1	18929182	378584	234161	145.1
207.2	18928294	378566	234150	145.1
207.3	18889876	377798	233675	144.8
207.3	18824338	376487	232864	144.3
207.4	18693176	373864	231242	143.3
207.5	18588570	371771	229947	142.5
207.5	18503374	370067	228894	141.9

207.6	18391202	367824	227506	141.0
207.7	18369146	367383	227233	140.8
207.8	18444202	368884	228162	141.4
207.9	18537142	370743	229311	142.1
208.0	18759652	375193	232064	143.8
208.1	18802348	376047	232592	144.2
208.2	18735716	374714	231768	143.7
208.3	18647152	372943	230672	143.0
208.4	18573832	371477	229765	142.4
208.5	18527040	370541	229186	142.1
208.6	18469774	369395	228478	141.6
208.7	18428648	368573	227969	141.3
208.8	18478280	369566	228583	141.7
208.9	18626658	372533	230419	142.8
208.9	18951092	379022	234432	145.3
209.0	19214994	384300	237697	147.3
209.1	19456122	389122	240679	149.2
209.2	19632624	392652	242863	150.5
209.3	19849070	396981	245540	152.2
209.4	19925544	398511	246486	152.8
209.54	19873520	397470	245843	152.4
209.6	19874018	397480	245849	152.4
209.69	19833710	396674	245350	152.1
209.79	19794046	395881	244860	151.8
209.88	19752222	395044	244342	151.5
209.98	19622552	392451	242738	150.5
210.07	19571026	391421	242101	150.1
210.17	19576600	391532	242170	150.1
210.26	19531080	390622	241607	149.8
210.36	19448810	388976	240589	149.1
210.44	19405058	388101	240048	148.8
210.46	19420082	388402	240234	148.9
210.55	19501814	390036	241245	149.5
210.64	19809372	396187	245049	151.9
210.74	20186708	403734	249717	154.8
210.83	20518542	410371	253822	157.3
210.93	20779750	415595	257053	159.3
211.02	21083192	421664	260807	161.7
211.12	21352598	427052	264140	163.7
211.21	21617646	432353	267418	165.8
211.31	21699780	433996	268434	166.4
211.41	21768300	435366	269282	166.9
211.54	21772100	435442	269329	166.9
211.64	21826002	436520	269996	167.4

211.71	21832558	436651	270077	167.4
211.79	21856348	437127	270371	167.6
211.89	21872180	437444	270567	167.7
211.99	21908828	438177	271020	168.0
212.08	22045154	440903	272707	169.0
212.18	22282030	445641	275637	170.8
212.27	22356534	447131	276559	171.4
212.37	22673536	453471	280480	173.9
212.46	22922546	458451	283560	175.8
212.56	22917512	458350	283498	175.7
212.68	22838462	456769	282520	175.1
212.74	22778198	455564	281775	174.7
212.84	22713836	454277	280979	174.2
212.93	22593486	451870	279490	173.2
213.03	22468946	449379	277949	172.3
213.11	22329284	446586	276222	171.2
213.21	22206750	444135	274706	170.3
213.26	22170514	443410	274257	170.0
213.33	22156638	443133	274086	169.9
213.38	22122092	442442	273658	169.6
213.47	22071350	441427	273031	169.2
213.57	21995908	439918	272098	168.7
213.66	21919336	438387	271150	168.1
213.75	21848124	436962	270269	167.5
213.85	21804714	436094	269732	167.2
213.95	21773480	435470	269346	167.0
214.04	21710996	434220	268573	166.5
214.14	21666602	433332	268024	166.1

Note: weight of sand = 120 pcf, 1 ton = 16.7 cubic feet
This is a table of the total weight of sand and larger transported past each cross section in the model plotted versus channel station.
Sediment inflow = 166 ac-ft/year

GEOMORPHOLOGY DISCUSSION

Historic records indicate an increase in human influences on the Salt River exemplified by the encroachment of urban, commercial and gravel mining areas. Long-term channel responses are entirely dependent on future development in and around the channel. If there is no additional gravel mining, the channel will reach a state of equilibrium but only after all the gravel pits have reached a sediment transport balance through the natural migration of the river system or restoration activities have been conducted (West, 2002).

A significant concern on the stability of the river is the influence of gravel mining on the erosion and planform evolution of the channel. Gravel pits in the channel act as a reach of zero slope and serve to trap sediment. Downstream of the gravel pits, sediment supply to the channel is reduced due to the trapping of sediments within the pits. In order to meet sediment transport capacity, the downstream channel may erode its bed to reduce its slope and corresponding sediment transport capacity. According to Lane (1957), as the slope is reduced the channel would transition form a braided to intermediate planform condition

Existing vegetation

No detail analysis was performed for any significant vegetation impacts on flood flows. As in the immediate upstream Rio Salado Phoenix and Va Shly'ay studies, major floods are expected to remove almost all the vegetation from the floodplain.

Erosion

Because of the complexity of estimating erosion and future erosion conditions it was decided that another approach would be to compare flow conditions at Rio Salado to the entire study reach for the100-Year event. Baseline Conditions average channel velocity in this area ranges from 6 to 10 ft/s for the 100-Year event. This range is comparable to the other areas along the Salt River.

For the Future Without Project condition the average channel velocity remains relatively the same. With project conditions shows equal or lower channel velocity conditions, refer to alternative model results. Thus, for the Rio Salado area bank erosion was not a concern based on the feasibility analysis and no bank stabilization was proposed for this area.

RISK AND UNCERTAINTY ANALYSIS

Selection of index points

Reaches were developed through coordination with Econ to account primarily for differences in channel hydrology and hydraulics. A representative index location for each reach was selected. Table 17 is summarizes the different hydraulically similar reaches within the study area.

Table 17: Summarizes the different hydraulically similar reaches within the study area.

Reach	Index Station	Station Limits
1	203.29	202.09 to 204.25
2	204.78	204.34 to 205.34
3	205.75	205.40 to 207.07
4	207.90	207.16 to 208.29
5	209.14	208.39 to 209.42
6	209.88	209.53 to 210.36
7	210.64	210.43 to 211.02

Risk and Uncertainty Analysis

Procedures outlined in EM 1110-2-1619 "The determination of stage-discharge uncertainty requires accounting for the uncertainty associated with factors affecting the stage-discharge relationship. These factors include bed forms, water temperature, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, changes in channel shape during or as a result of flood events, as well as other factors." The HEC-RAS program should be run with variations in roughness, bed forms if applicable, bridge scour, debris on piers, gravel mining, etc. to estimate the stage uncertainty.

For each modeled subset, two HEC-RAS models were developed for 500-, 200-, 100-, 50-, 20-, 10-, 5- and 3.1-year events, a "Lower Bound" model and an "Upper Bound" model. The range between the water surface elevations for the models is used to estimate standard deviation of stage uncertainty. In accordance with EM 1110-2-1619, the standard deviation is calculated as:

$$STDDEV = E_{mean} / 4$$

Where:
E_{mean}=mean stage difference between the "Upper Bound" and "Lower Bound" models.

Sensitivity to Manning's Roughness Coefficient

The selection of the roughness coefficients has been detail in previous sections. The selections are based on published data, calculation, and field observations, all subjective to engineering judgment. In the risk and uncertainty analysis, the "Lower Bound" models were developed using Manning's roughness values that were 20-percent lower than those contained in the base model. The "Lower Bound" model

was configured with no debris loading on the bridges piers but incorporated the effects of long term bed scour conditions. However, the "Upper Bound" model was constructed using a Manning's roughness values that were approximate 20-percent higher than the value in the base model. The "Upper Bound" model also incorporated debris loading on the bridges and long term bed aggradations in the channel. Finally, since the standard deviation for all reaches was determined to be 0.5 or less, (from Table 18 and Figure 9) the results were considered to be reasonable based on the designs guidance criteria found in EM1110-1619 Table 5-2 Minimum Standard Deviation of Error in Stage.

Figure 24 shows the results of this portion of the sensitivity analysis. Averages values and standard deviation values have been calculated by sub-reach.

A summary of the uncertainty analysis for the different alternatives at the index locations is presented in Table 18. The standard deviation for each alternative is tabulated under the column heading "Standard Deviation"

Table 18: Risk Analysis Standard Deviation

Reach	Frequency	Q (cfs)	High Bound Model	Low Bound Model	E mean	Standard Deviation
Reach 1 Cross Section 203.29 202.09 to 204.25	500	237000	977.10	975.24	1.86	0.5
	200	200000	975.99	974.35	1.64	0.4
	100	164000	974.92	973.38	1.54	0.4
	50	132000	973.87	972.45	1.42	0.4
	20	84000	971.99	970.72	1.27	0.3
	10	51000	970.16	969.07	1.09	0.3
	5	20000	967.51	966.68	0.83	0.2
	3.1	1	960.81	960.81	0.00	0.0
Reach 2 Cross Section 204.78 204.34 to 205.34	500	237000	991.42	990.33	1.09	0.3
	200	200000	990.44	989.40	1.04	0.3
	100	164000	989.25	988.20	1.05	0.3
	50	132000	987.80	986.72	1.08	0.3
	20	84000	984.76	983.65	1.11	0.3
	10	51000	981.29	980.41	0.88	0.2
	5	20000	976.48	975.84	0.64	0.2
	3.1	1	968.03	968.03	0.00	0.0
Reach 3 Cross Section 205.75 205.40 to 207.07	500	240000	997.64	996.17	1.47	0.4
	200	202000	996.43	994.99	1.44	0.4
	100	166000	995.12	993.57	1.55	0.4
	50	135000	993.57	991.85	1.72	0.4
	20	87000	990.24	988.53	1.71	0.4
	10	53000	987.18	985.89	1.29	0.3
	5	20200	982.47	981.53	0.94	0.2
	3.1	1	974.53	974.53	0.00	0.0
Reach 4	500	240000	1015.63	1014.49	1.14	0.3
	200	202000	1014.41	1013.39	1.02	0.3

Cross Section 207.9 207.16 to 208.29	100	166000	1012.93	1011.82	1.11	0.3
	50	135000	1011.42	1010.25	1.17	0.3
	20	87000	1008.48	1007.71	0.77	0.2
	10	53000	1005.87	1005.17	0.70	0.2
	5	20200	1002.04	1001.54	0.50	0.1
	3.1	1	998.13	998.13	0.00	0.0
Reach 5 Cross Section 209.14 208.39 to 209.42	500	240000	1022.31	1020.91	1.40	0.3
	200	202000	1020.74	1019.41	1.33	0.3
	100	166000	1019.09	1017.87	1.22	0.3
	50	135000	1017.57	1016.45	1.12	0.3
	20	87000	1014.67	1013.66	1.01	0.3
	10	53000	1011.90	1010.84	1.06	0.3
	5	20200	1008.50	1007.79	0.71	0.2
	3.1	1	1004.22	1004.22	0.00	0.0
Reach 6 Cross Section 209.88 209.53 to 210.36	500	240000	1036.02	1034.85	1.17	0.3
	200	202000	1033.95	1032.84	1.11	0.3
	100	166000	1031.75	1030.91	0.84	0.2
	50	135000	1029.83	1029.06	0.77	0.2
	20	87000	1026.31	1025.74	0.57	0.1
	10	53000	1023.02	1022.46	0.56	0.1
	5	20200	1017.97	1017.28	0.69	0.2
	3.1	1	1011.67	1011.67	0.00	0.0
Reach 7 Cross Section 210.64 210.43 to 211.02	500	240000	1041.38	1039.32	2.06	0.5
	200	202000	1039.33	1037.35	1.98	0.5
	100	166000	1037.22	1035.39	1.83	0.5
	50	135000	1035.31	1033.57	1.74	0.4
	20	87000	1032.13	1030.32	1.81	0.5
	10	53000	1028.97	1027.38	1.59	0.4
	5	20200	1024.26	1022.91	1.35	0.3
	3.1	1	1015.92	1015.92	0.00	0.0

Figure 24: Risk and Uncertainty Analysis – Roughness Coefficient

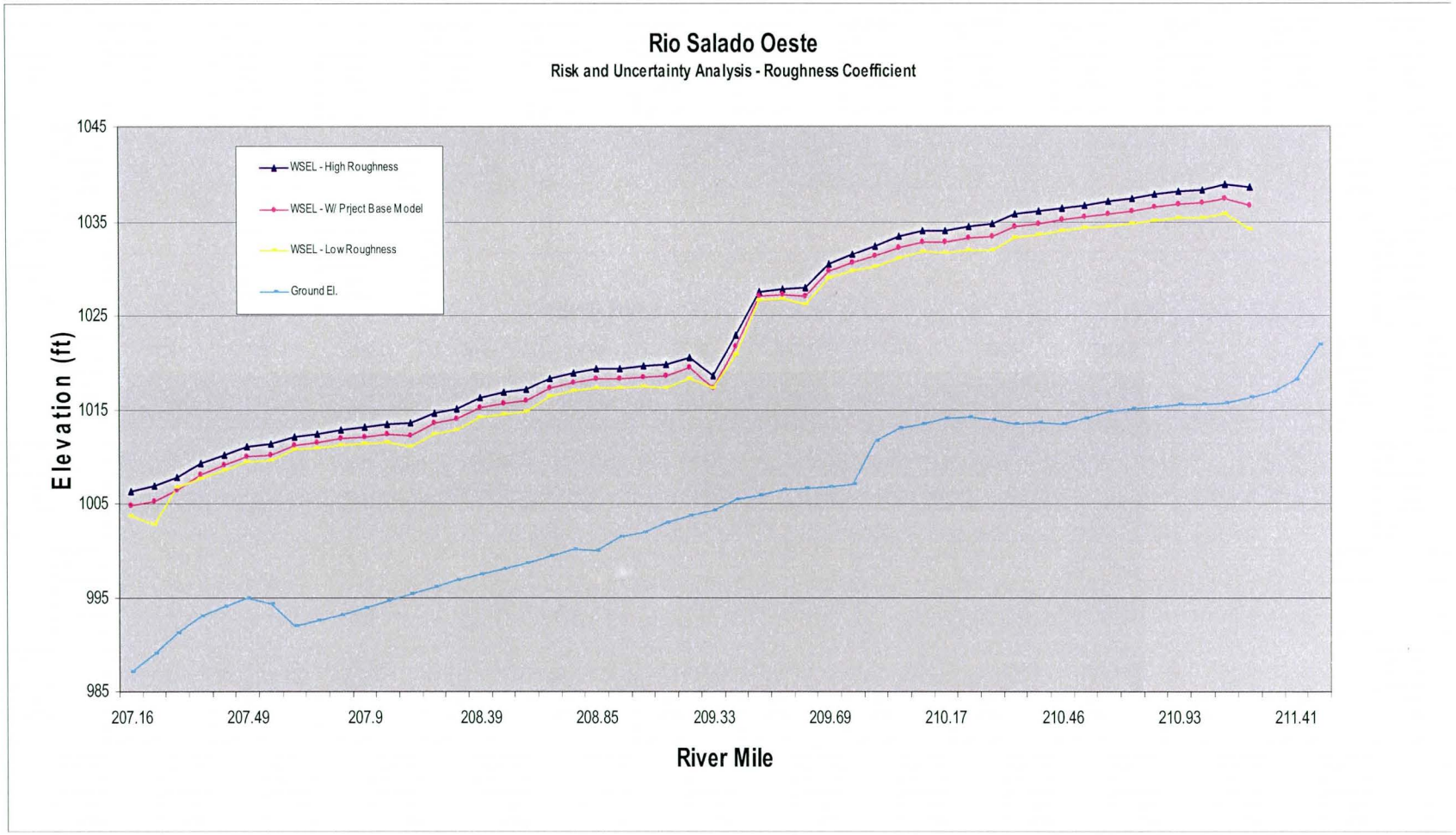

Figure 24: ***Continued***

OPERATION AND MAINTENANCE

The Baseline Without Project Condition and With Project hydraulic results and the Without Project sedimentation results were used to assess the operation and maintenance concerns for this project. During this F4 phase of the study, the With Project sediment analysis was not undertaken. Instead, results from the With Project hydraulic analysis and Without Project sediment analysis (West, 2002) were used to estimate the frequency that environmental features are damaged in each alternative. The method of analysis was to compare the Baseline Condition area of inundation for the 5- and 10-Year events to the vegetated area. It was assumed that the Baseline Condition 5 and 10-Year area of inundation represented the area of highest velocities. Because the alternatives did not significantly alter the existing flow path, it was assumed that the Baseline Condition area of inundation would be sufficient to complete the With Project damage assessment. Damage due to duration of inundation was not taken into account in this analysis. Note that the frequency of vegetation replacement was not analyzed in this study.

Maintenance Considerations

As stated above, the With Project low flow channel was designed between River Mile Stations 203.39 to 207.43 and River Mile Stations 209.53 to 211.52. Inherent in the design objective to maintain the average channel velocities to a level as to not significantly exceed a maximum permissible velocity. These target velocities were tied to velocities associated with the 10-Year Frequency Event Peak Discharge. It was assumed that velocities resulting from flows higher than this particular discharge figure would disrupt the general channel equilibrium in terms of generating excessive erosion and deposition quantities. Further, since the low flow channel does not contain any bank stabilization features other than a grade control structure downstream of 35th Avenue, the same channel would most likely experience some minor degree of laterally migration. However, this anticipated movement of the low flow channel alignment would also be expected to stay within the historic channel thalweg footprint. Therefore, it is highly possible that there would be a requirement for some maintenance for flood events greater than the 20-Year Frequency event.

Vegetation Damage

The vegetation damage was evaluated using a similar method as was used for the maintenance considerations. For the 5-Year event it was assumed that 50% of the area inundated was damaged. For the 10-Year event, 70 % of the area inundated was damaged. The area damaged for the 20 to 500-Year events corresponds to a percentage of the vegetated area inundated by the 10-Year event. For the 5-Year event it was assumed that 50% of the area inundated was damaged. For the 10-Year event, 70 percent of the area inundated was damaged. For the 20-Year event, 80% of

the area and 90 % for the 50 to 500-Year events. These assumptions are based on engineering judgment applicable for the F4 phase of this investigation.

SUMMARY

Hydraulic

Initially, the Existing Condition Baseline hydraulic model was first modified to account for continuing and future mining activities within the study reach. This updated model was subsequently identified as the Future Condition Baseline model. Additional model simulations were then executed for With Project conditions, which included such features as environmental habitat areas, lakes, grade control structure, and a low flow channel design. The water surface With Project Future Condition was less the existing Without Project Condition model simulations as showing on figure 25.

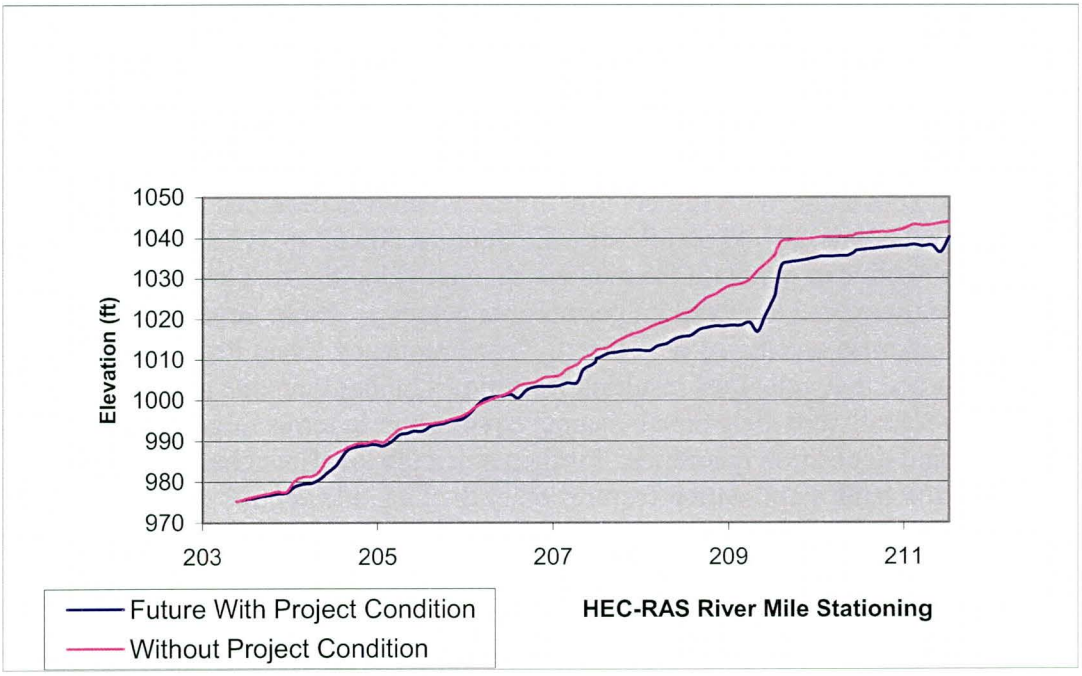

Figure 25: 100-year Water Surface Profile Between Future With Project Condition and Without Project Condition.

As indicated above, the With Project results show minimal water surface elevation variation over the Without Project Baseline condition.

Risk Assessment

As discussed in the text above, the features with the highest risk are associated with those features located in the main channel area, or within the 10-Year area of inundation. However not all vegetation found in this area was or should be assumed to damages during flow events. Because of the complexity of risk assessment to vegetation due to hydraulic and sedimentary conditions, it was assumed that a percentage of vegetation within these limits would be at risk to damage, see Operation and Maintenance, Vegetation Damage Section, for more info. Based on those assumption the at risk area amounts were determined. Of that amount, only a portion is located along the riverbed where the highest stresses are found. Wetlands can be engineered to resist high shear stresses such that vegetation will reestablish after larger flow events. Wetland design will be completed in the PED phase

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WITHOUT PROJECT HYDRAULIC ANALYSIS REPORT

June 2002

Note: Appendixes not included but available upon request

Rio Salado Oeste Study

Without Project Final

Hydraulic Analysis Report

Contract Number: DACW09-00-D-0021

Prepared for:

U.S. Army Corps of Engineers

Los Angeles District

Prepared by:

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1. Introduction

1.1. Purpose

This without-project hydraulic and sedimentation analysis was conducted in support of the Rio Salado Oeste Feasibility – F3 Phase Study.

1.2. Scope

This report documents the hydraulic and sedimentation analysis conducted on a reach of approximately 9.5 miles of the Salt River, within the boundaries of the City of Phoenix, Arizona. The focus of the study was the identification of baseline hydraulic and sediment conditions, which will be used with later alternative condition studies to identify the preferred project alternative(s).

A hydraulic model was created based on "existing conditions", and the inundation boundaries associated with different return periods were delineated. Next, a sediment transport model was developed. Using a 50-year synthetic hydrology, the model was used to simulate long term river processes with results analyzed at 10 year intervals.

1.3. Study Area

The study reach extended from the upstream limit of 19th Avenue down to the lower limit of 91st Avenue. The downstream boundary of the study reach was approximately 2.5 miles upstream of the confluence of the Salt and Gila Rivers. Scattered along the reach were several pits, the result of active and inactive sand and gravel mining operations, both within the channel and in the overbank areas.

2. Existing Conditions Hydraulic Analysis

2.1. General

The objectives of the analysis were to identify an existing conditions hydraulic model, delineate flood inundation boundaries for the 5-, 10-, 20-, 50-, 100-, and 500-year events, and provide the initial geometry for the sediment transport analysis.

2.2. Background

An existing Flood Insurance Study (FIS) HEC-RAS model from the confluence with the Gila River (RM 199.82) to about 12th Street (RM 214.14) was provided by the Flood Control District of Maricopa County (FCD). This model will be referred to as the FEMA model. The FCD also provided aerial photographs from 1993 and 1999, an ArcInfo coverage with contours with a 4-ft interval developed for the Salt/Gila River Master Plan (1992), an ArcInfo coverage with the cut lines of 100 of the FEMA model cross sections, and an ArcInfo TIN (Triangular Irregular Network) of the study area including raw data in point files and breakline format also created for the Salt/Gila River Master Plan (1992). The line coverage included cross sections from RM 202.09 to RM 211.12. Cross section 202.09 is located approximately 1100 ft downstream of 91st Avenue, while cross section 211.12 is about 2150 ft downstream of 19th Avenue.

2.3. Existing Conditions Hydraulic Model

A 1-dimensional model of the reach was created using HEC-RAS and the HEC-GeoRAS extension in ArcView 3.2a (Environmental Systems Research Institute, Inc.). The cross section geometry for this model was obtained from the TIN using the same cut lines utilized in the FEMA model.

First the TIN file, aerial photographs, contours coverage and cross sections coverage (containing the cut lines from the FEMA model) were inspected in ArcView. The cross sections coverage was converted into an ArcView shapefile to facilitate editing the cross sections. Seven new cross section lines were added at the downstream end of the reach (ID numbers 1 through 7). These new cross sections were inserted to prevent the downstream boundary condition from affecting the hydraulics in the project area. In addition, two more cut lines were inserted to model the conveyor bridge in the vicinity of the 27th Avenue alignment. These cross sections were located immediately downstream and upstream of the conveyor bridge, and were identified as River Mile 210.43 and 210.44 respectively.

Using the TIN, the contour coverage and the aerial photographs as reference, new shapefiles were created identifying the location of the bank stations, stream centerline, and flow lines in the channel, left overbank and right overbank.

Using the HEC-GeoRAS extension, a HEC-RAS input data file was generated. The data file contained the geo-referenced stream line and cross section lines, and the cross section station/elevation data. In addition, it included flow lengths in the channel, left overbank and right overbank.

The data file was then imported into HEC-RAS and the cross sections IDs were modified to match those from the FEMA model. Next, cross sections 211.21 through 214.14 from the FEMA model were appended at the upstream end of the reach. Although these cross sections were not geo-referenced they provided the geometry in the vicinity of 19th Avenue (the project's upstream end) and add a 2.5 mile segment at the upstream end of the reach. This segment would not have any effect on the hydraulics of the project area since a subcritical flow regime was expected throughout the reach, but were needed to provide an equilibrium inflowing sediment concentration to the study reach in the sediment transport model.

Next, the cross section geometry was reviewed to ensure proper location of channel bank stations. Roughness coefficients in the FEMA model were evaluated and, based on the field visit and the examination of the aerial photographs, deemed to be acceptable for general use. Some of the n coefficients were adjusted based on inspection of the aerial photographs. The appropriateness of these values for the sediment transport model was further evaluated during a subsequent sensitivity analysis. Typical values used in the model are shown in Table 2.1.

Bridge information and modeling procedures from the FEMA model were reviewed and included with some changes into the current HEC-RAS model. There was a new bridge in place at the 51st Avenue crossing. Plans for this bridge were obtained from the City of Phoenix Engineering Department and used to code the bridge geometry. Plans for the bridges at 19th Avenue and 35th Avenue were also obtained to verify their geometry. Plans for the conveyor bridge near the 27th Avenue alignment were obtained from United Metro Materials.

Contraction/expansion loss coefficients were set to 0.3 and 0.5 respectively in the cross sections near the bridges. The bridges in 35th Avenue, 51st Avenue and 27th Avenue were modeled using the "Multiple Opening Analysis" option in HEC-RAS, with the overbanks modeled as conveyance areas. This selection prevented the use of the weir equation to compute flow on the overbanks for the large flood events simulated.

Table 2-1 Manning's *n* values used in the existing conditions hydraulic model.

LAND USE	*n* VALUE
Sand/gravel mine	0.037
Open shrub	0.04 – 0.043
Agricultural	0.025 – 0.037
Urban/industrial	0.043
Disturbed	0.037 – 0.043
Channel open vegetation	0.037
Channel sand/gravel	0.032 – 0.037

Finally, all the cross sections were inspected to identify the location of ineffective flow boundaries. The area occupied by sand and gravel pits was set ineffective for

conveyance calculations or, where this was not possible, the pits were "filled" using blocked obstructions before computing the steady state profiles. This procedure eliminates the excess conveyance in the pit and therefore results in higher water surface elevation, which is a conservative approach for flooding studies. Consideration of in-channel sand and gravel operations is more important in sediment transport studies. Pits can act as sediment traps and induce headcutting in the upstream direction and/or tailcutting downstream.

The discharges used in the hydraulic analysis were obtained from a report by the U.S. Army Corps of Engineers (USACE, 1996), and are shown in Table 2-1. The discharge at Central Avenue was assigned to cross section 214.14, and the discharge at 67th Avenue was assigned to cross section 205.52.

Table 2-2. Discharge frequency values used in the existing conditions model.

LOCATION	RETURN PERIOD					
	5-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Peak Discharges (ft^3/s) in the Salt River at:						
Central Avenue	20,200	53,000	87,000	135,000	166,000	240,000
67th Avenue	20,000	51,000	84,000	132,000	164,000	237,000

The model was run under this configuration and it was observed that several of the cross sections were not able to contain the 500-year flood. In fact, some cross sections could not contain even the 100-year flood. Under these circumstances HEC-RAS extends vertically the end points of the cross section and carries out the flow calculations, but clearly that does not yield the correct water surface elevation.

New elevation data points were needed to extend the terrain model so that the cross sections would be able to contain all floods. The FCD provided additional contour lines (2 ft interval) for the area south of the study reach, between 19th Avenue and 75th Avenue (from Laveen ADMP, 1989). Elevation data for other areas was obtained from the USGS 30m resolution DEM (generated from digitized contours from 1/24,000 USGS topographic maps). The area added through this process is primarily in the far overbank areas of the model where the DEM vertical accuracy is not as critical.

The USGS DEM was converted first from grid format to TIN format to remove points that did not add terrain information. The TIN was then converted into a point shapefile which was then clipped to cover only the area that was not covered by the original TIN or the additional contour map. Finally, a new TIN was generated using the original point and breakline files, the additional contour coverage from the FCD, and the new point shapefile obtained from the 30m DEM.

Using the new TIN as a reference, the cross section cut lines were extended in ArcView and a new HEC-RAS input file was created using HEC-GeoRAS. The input file was imported into HEC-RAS and manipulated in the same manner as before. Cross section plots are shown in Appendix A.

The new model was then executed using the six flood events. The results show that the 100-year flood is now contained in all the cross sections, and the 500-year flood is contained in most of them. The majority of the cross sections that do not contain the largest flow are located near the confluence with the Gila River. It was decided not to extend these cross sections farther to the south because then they would become part of the Gila River floodplain. In any case, the end points of the cross sections that do not contain the 500-year flow are located far from the main channel in ineffective flow areas, and therefore have no effect on the computed water surface elevation.

2.4. Floodplain Delineation

The model was executed for the 5-, 10-, 20-, 50-, 100- and 500-year flood events with the discharges from the Corps report shown in Table 2-1 (for post Roosevelt Dam modifications). Water surface elevation profiles are shown in Figure 2-1. Appendix A shows the 10-, 100- and 500-year water surface elevation in the cross section plots. In addition, Appendix B shows some other variables from the hydraulic model output file.

The model results were exported from HEC-RAS into ArcView to automatically delineate the inundation boundaries using HEC-GeoRAS. The resulting inundation boundaries were then inspected and edited to remove spurious polygons and to ensure that all polygons contained other polygons with smaller return period. Existing conditions floodplain delineations are shown in Appendix C.

The resulting 100-year profile from the Existing Conditions (EC) model was compared to the FEMA model (Figure 2-2). Both profiles are practically identical from the downstream end of the study reach up to river mile 204.25, where the cross sections from the two models show some differences in their geometry. At this location the water surface elevation in the EC model is 0.45 ft higher than in the FEMA model. Upstream of this cross section, between river miles 204.34 and 205.15, the differences between the two models increase, with the FEMA profile 0.6 to 2.54 ft higher than the EC profile. The reason for this divergence is the different location of the ineffective flow limits in the two models. The ineffective flow limits are located closer to the main channel in the FEMA model, constricting the conveyance area resulting in a rise in the water surface elevation. The location of the ineffective flow boundaries differs between the two models because they were developed with different purposes. The FEMA model was developed to define the floodplain only for the 100-year flow. On the other hand, the EC model was created to map flow boundaries for flows with return periods between 5 and 500 years, and then converted into a single sediment transport model driven by measured flows which varied between 20 and 200000 cfs. Therefore, the existing conditions geometry needs to be valid for a wide range of discharges.

From river mile 205.25 to 206.51 the differences between the profiles become small again (0.4 ft or less). The reach between river miles 206.6 and 207.07 has mining pits within the channel. The EC model blocked completely these pits, while the FEMA model raised the bottom of the pits up to a lower elevation than the EC model blockage. As a consequence, the profiles show some differences, with the EC profile being 0.53 to 2.07 ft higher than the FEMA profile.

The cross section in river miles 207.34 shows a difference of 0.78 ft (EC higher than FEMA). The cause is a change in cross section geometry and the election of different locations for the ineffective flow limits. The channel bed is lower for the bridge cross sections (207.48 and 207.49) in the FEMA model, but that did not produce significant difference in the profiles. However, at river mile 207.53 (immediately upstream of the 51st Avenue Bridge) the EC profile is again 0.49 ft higher due once more to the different location of the ineffective flow limits.

The disparity between the profiles is minimal between river miles 207.62 and 208.75. From river mile 208.85 to 209.24 there are again mining pits located within the channel and in the overbank area. The geometry of the blocks used to fill the pits and the location of ineffective flow boundaries are responsible once more for differences in water surface elevation between 0.46 and 2.15 ft. The FEMA model does not block the pits in the channel and blocks the pits in the overbanks to a higher elevation.

The remaining part of the study reach (from river mile 209.42 to 211.54) displays a complete divergence of the two model profiles. The cause for this discrepancy can be found after examination of the cross sections in the vicinity of the 35th Avenue Bridge (209.53 and 209.54). This is a bridge with a very narrow opening. At the same time, the bed slope upstream of the bridge is nearly flat. Therefore, backwater due to the bridge obstruction propagates all the way to the upstream end of the study reach. The bridge cross sections in the FEMA model are much deeper (thalweg elevation $\approx$ 993 ft) than in the EC model (thalweg elevation $\approx$ 1020 ft), increasing the conveyance through the bridge opening and producing a lower water surface upstream of the bridge.

The origin of the 35th Avenue Bridge cross section in the FEMA model is not clear. The cross sections in the EC model were extracted from the TIN using the procedure previously described. In general, all the EC cross sections matched well their FEMA counterparts except those bounding the 35th Avenue Bridge. These cross sections are located in an area of the Salt River with permanent water, where no visual verification was possible. Preliminary runs of the sediment transport model revealed that after 50 years of sediment transport the thalweg under the bridge becomes stable at a depth between 1005 and 1010 ft regardless of the initial conditions,. When the sediment transport model was run with river mile 209.54 from the FEMA model (a deep scour hole under bridge), the cross section experienced deposition, and when it was run using river mile 209.54 from the TIN (representing a shallow depth under bridge), the cross section experienced erosion. It is possible that the TIN elevations represent the water surface under the bridge when the mapping was performed but verification would require an on site survey of the area near the bridge.

The TIN river mile 209.54 geometry was selected because it resulted in a more conservative approach for the existing conditions hydraulic analysis but may be overly conservative for a detailed FEMA study. The FEMA study is likely too optimistic in regards to flow area under the bridge based on the sediment results obtained during this study. The future without-project hydraulic analysis results were similar using both geometries so the more conservative initial conditions were used as the basis for this study.

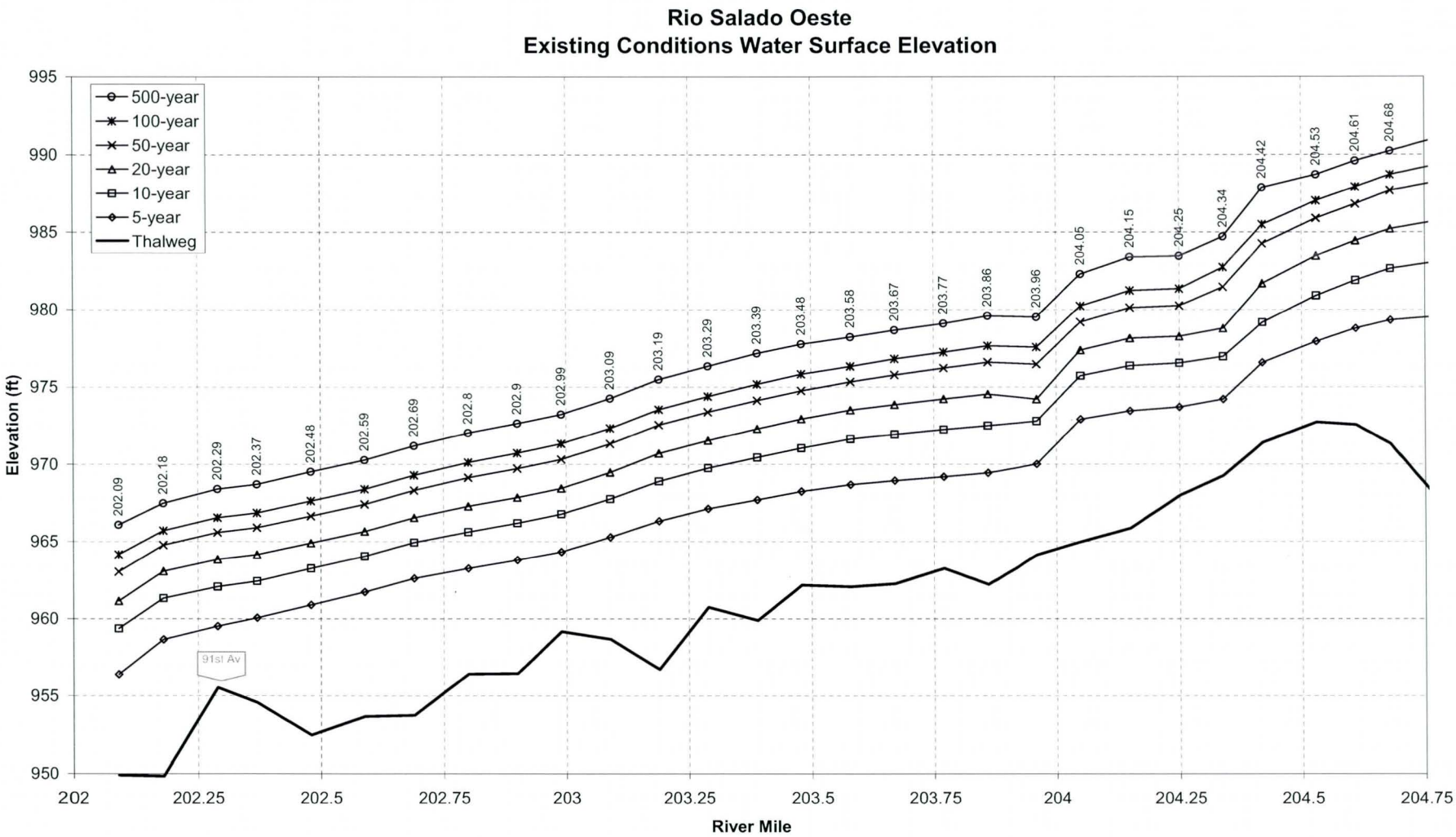
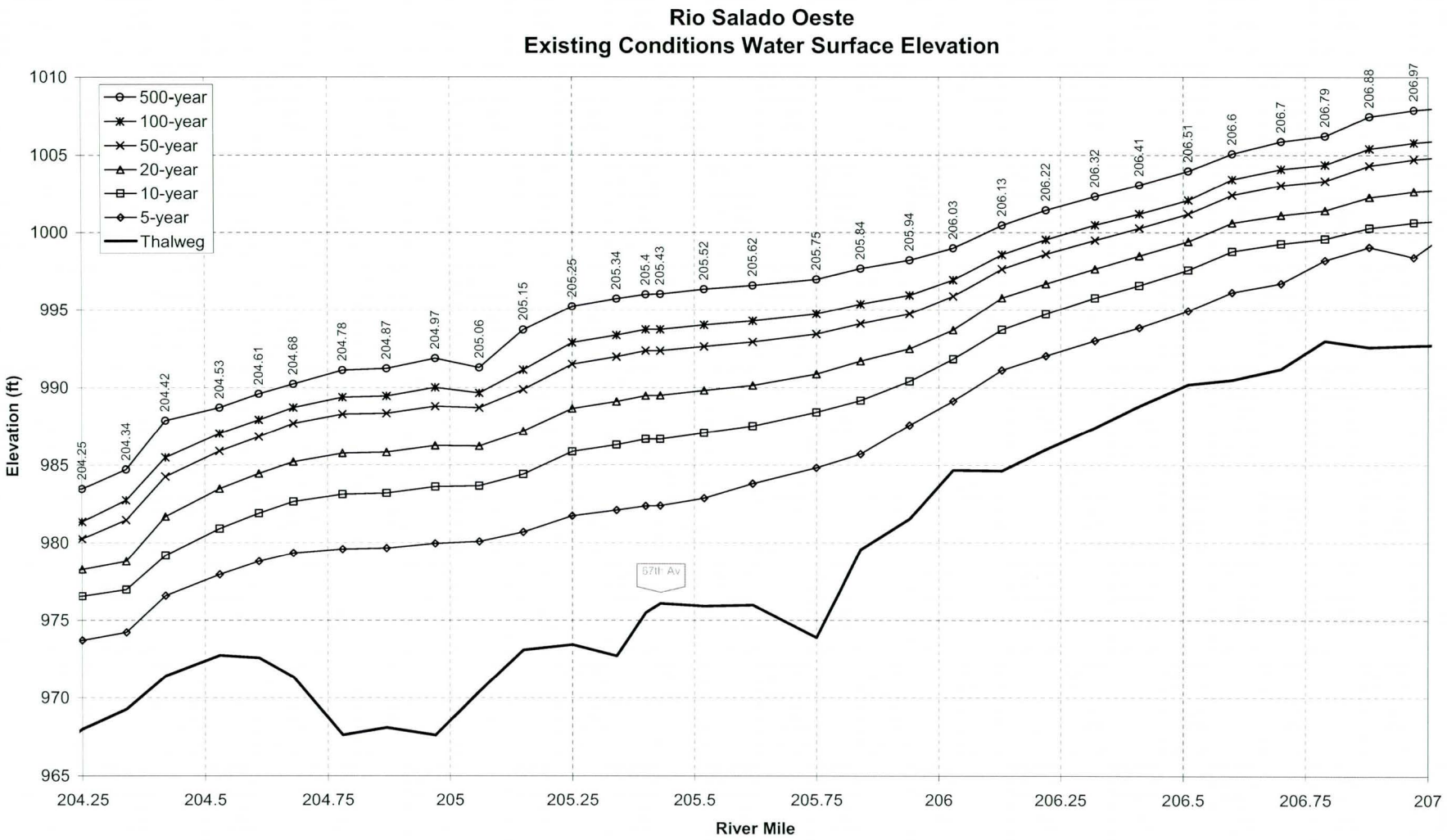


Figure 2-1. Existing conditions water surface elevation profiles.



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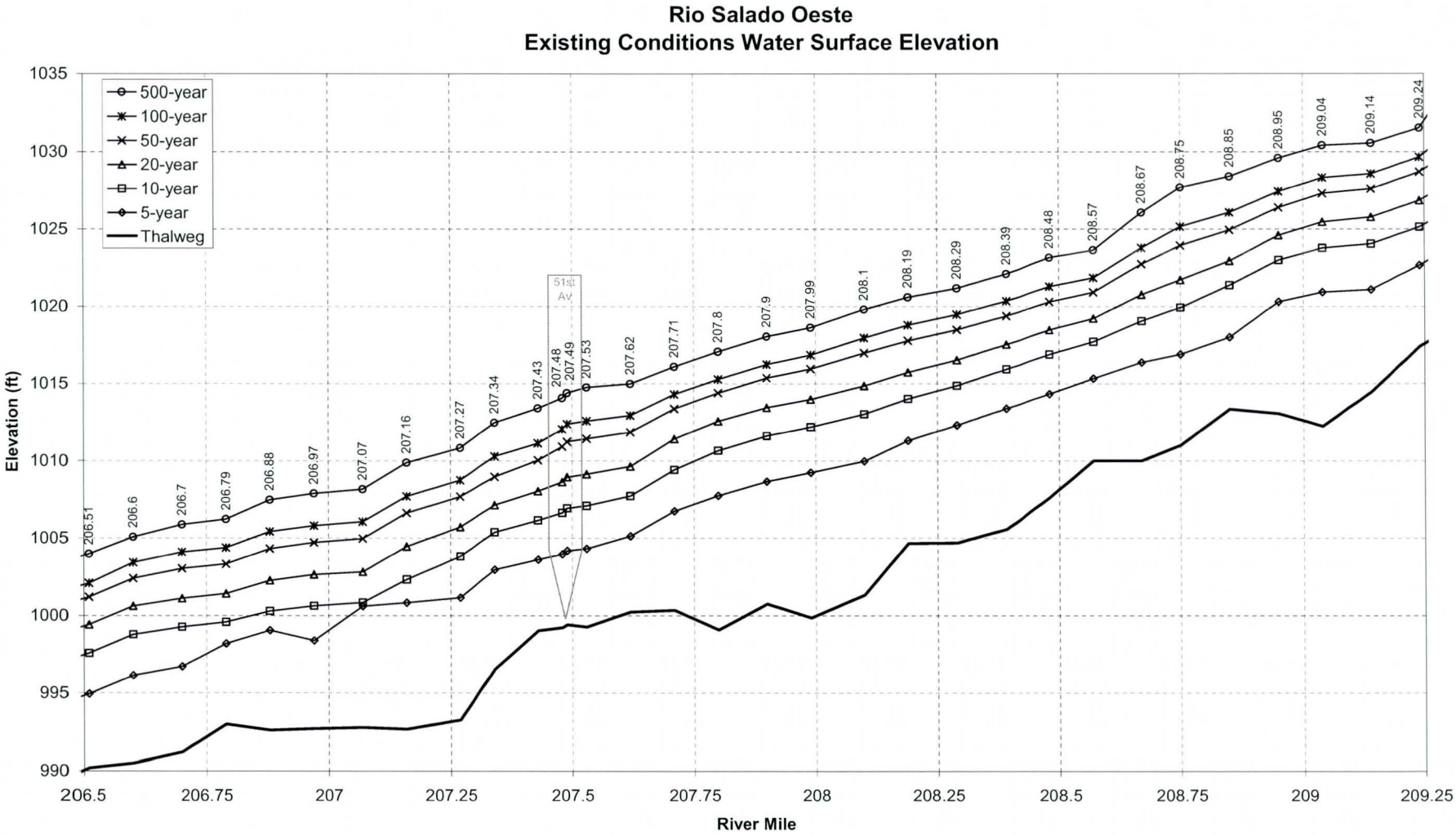

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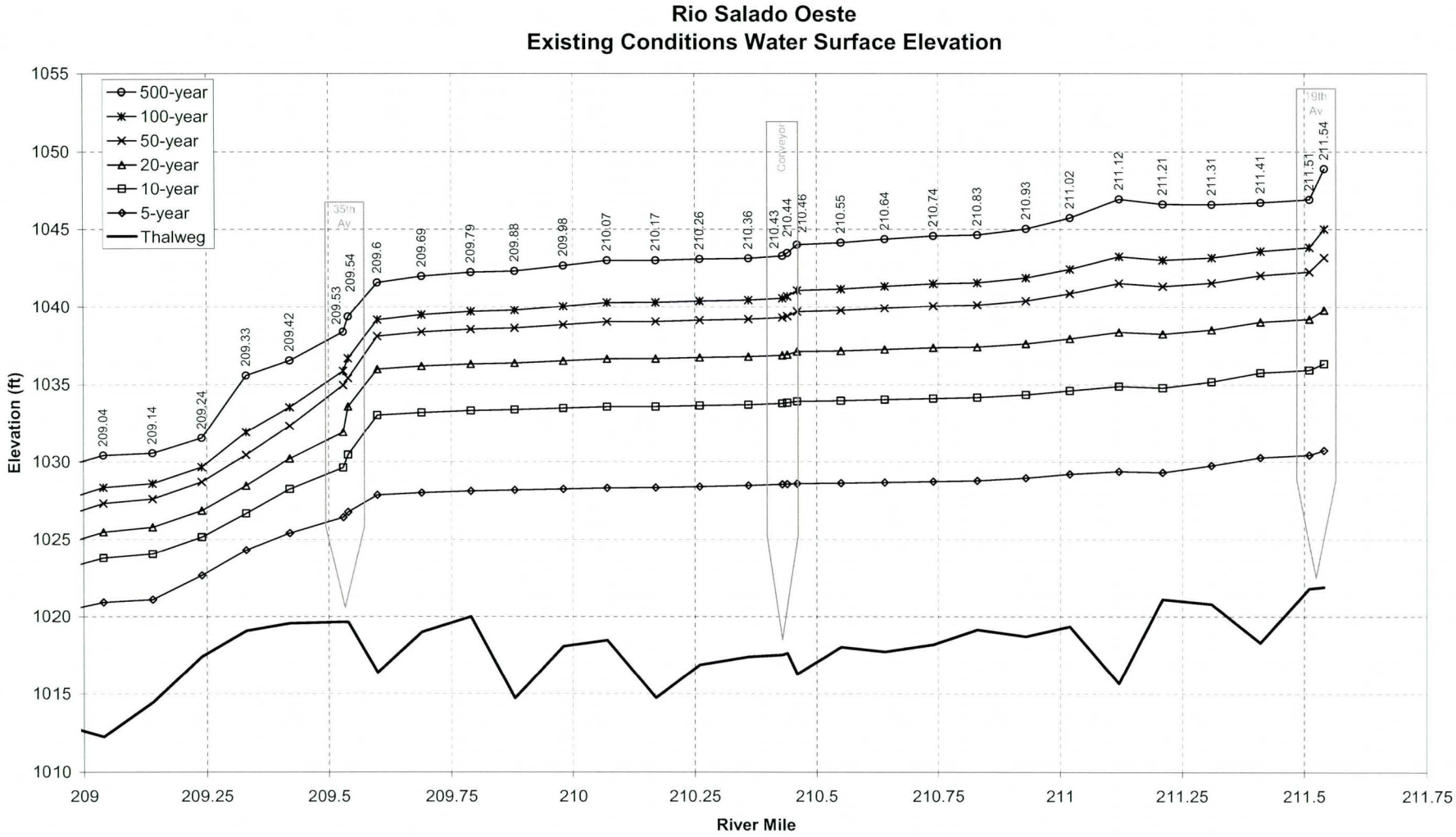

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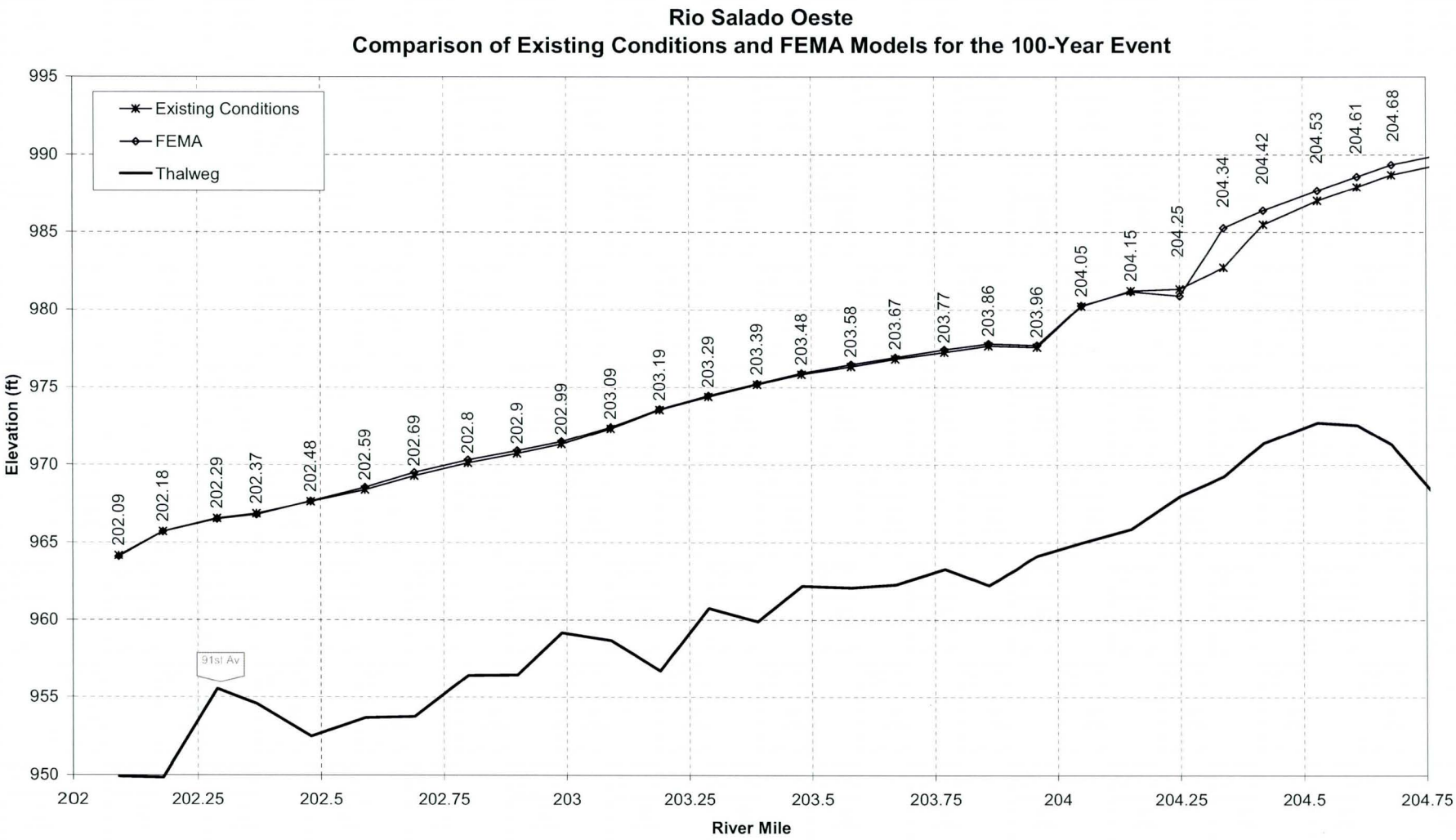


Figure 2-2. Comparison of existing conditions and FEMA models for the 100-year profile.

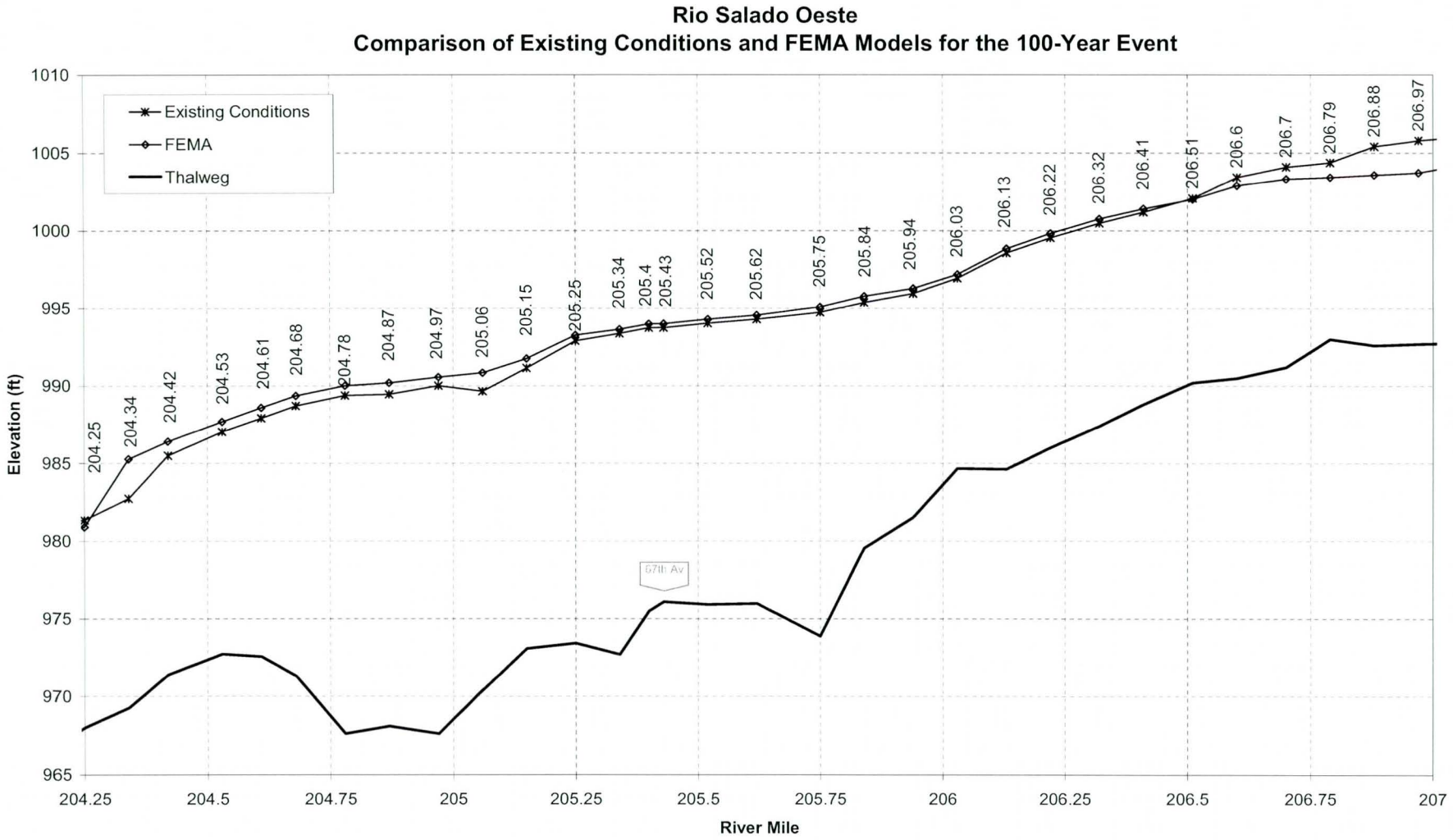
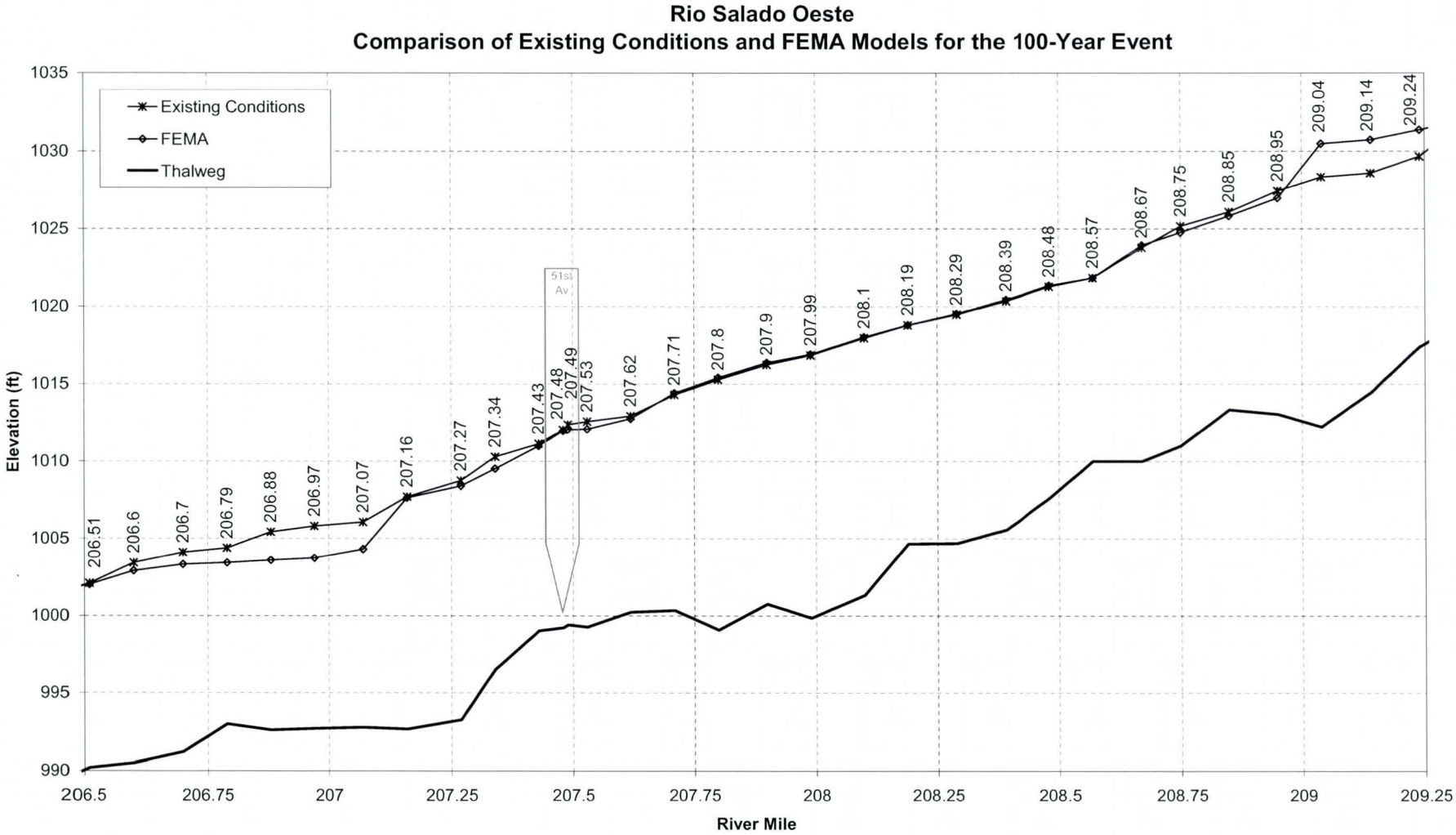


Figure 2-2. *Continued.*



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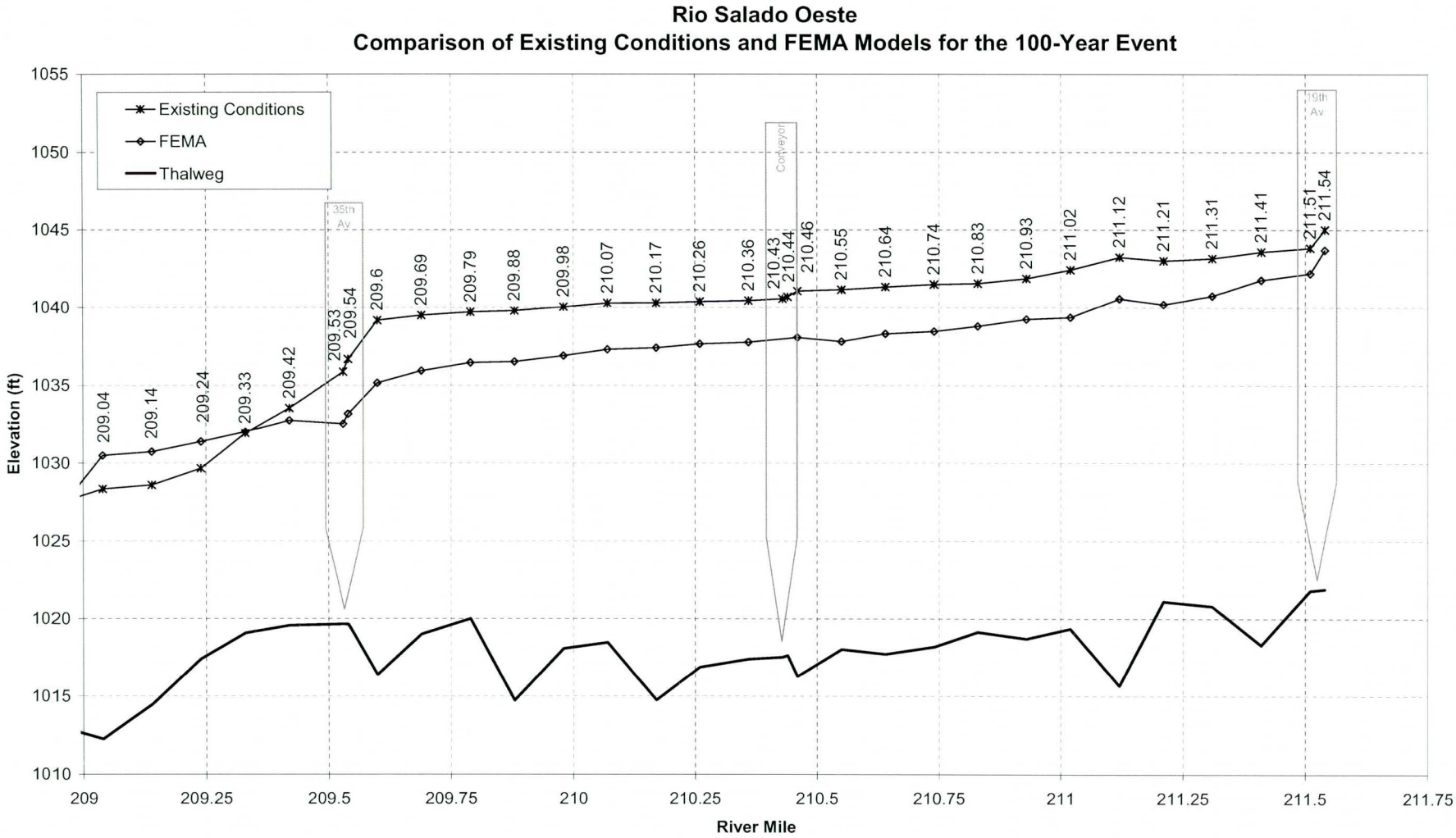


Figure 2-2. ***Continued.***

3. Sediment Transport Analysis

3.1. General

The objective of the sediment transport analysis is to identify baseline sediment conditions, which will be used with later alternative conditions studies to identify the preferred project alternatives. A base conditions sediment transport model was created using the geometry from the existing conditions hydraulic model described in the previous chapter.

The computer program HEC-6T "Sedimentation in Stream Networks", version 5.13.15 of May 24, 2001, was used to conduct the numerical sediment transport modeling in this study. HEC-6T was developed by Mr. William A. Thomas of Mobile Boundary Hydraulics, Clinton, Mississippi.

3.2. HEC-RAS Model Conversion

3.2.1. Model Geometry

The geometry of the hydraulic model was converted into a text file with the format required by the HEC-6T program. Roughness coefficients in several cross sections of the hydraulic model vary horizontally with distance in the cross section. HEC-6T does not allow as much horizontal variation of Manning's n, so an alternative method of expressing the roughness coefficient was required. After running the 5-, 10-, 20-, 50-, 100- and 500-year flood events in HEC-RAS, the profile output tables were used to request conveyance weighted Manning's n values for the channel, left and right overbanks for the different discharges. These data were then entered into the HEC-6T input file using NV records. A default value of 0.04 was used to fill blanks when the conveyance in an overbank area was zero. The result was a configuration of roughness coefficients changing in the vertical by discharge rather than in the horizontal by distance.

Conveyance limits defined in HEC-RAS using ineffective flow boundaries were coded using XL records in HEC-6T. The advantage of using XL records is that they allow deposition to occur in the ineffective flow areas. The effect of bridges crossing the river in the study area was accounted for using a single cross section with the pier geometry superimposed as recommended in the HEC-6T manual. Of the two bounding cross sections used to define each bridge in HEC-RAS, only the upstream one was retained in HEC-6T. The two bounding cross sections are very close to each other and keeping both in HEC-6T could cause numerical instabilities.

3.2.2. Fixed Bed Simulation

An elevation-discharge rating curve was developed at the downstream boundary (cross section 1) for starting water surface elevations. Water surface elevations were computed at this location assuming normal depth and a slope of 0.0019 ft/ft, for discharge values ranging from 7500 cfs to 285000 cfs, at 7500 cfs increments (Figure 3-1).

HEC-6T was then run with a fixed bed using the 5-, 10- and 100-year flood events, and the resulting water surface elevations were compared to the HEC-RAS

existing conditions model. In order to guarantee the quality of the sediment model, the water surface elevations computed by HEC-6T for each of the three events were examined at each cross section to ensure that they did not differ from the HEC-RAS results by either 10% of the maximum depth or 1 foot, whichever was less. The results of this analysis are shown in Appendix D.

3.3. Sediment Parameters

The Corps computer program SAMAID was used to select the most appropriate sediment transport relationship. SAMAID results indicated that Madden's 1985 modification of Laursen's equation and Yang's equation were respectively best and second best sediment transport relations for the characteristics of the study reach. Schoklitsch's equation came out in third place. WEST has used Yang's equation in the past on the Salt River upstream and downstream of the project site. In general, this equation performs well for mid sized rivers transporting large amounts of sand, which is typical of many streams in Arizona. Therefore, the sediment transport equation selected for this study was Yang's unit stream power.

3.3.1. Bed Sediment Characteristics

Nineteen locations were identified for sediment sampling and development of gradation curves. Sampling sites were located approximately 0.5 miles apart, from 19th Avenue to 91st Avenue. Samples were collected from 0 to 2 feet, and laboratory grain-size analyses were performed on the samples. In addition, an in-situ particle count consisting of 100 particles spaced at 1 foot intervals was performed. Bed gradation data were entered into the HEC-6T input file using PF records. Sediment gradations and sample locations are shown in Appendix E.

3.3.2. Inflowing Sediment Rating Curve

Recorded information about sediment loads in the Salt River upstream of the study reach is not available. There are however previous studies reporting sediment transport simulations. One of these studies is the Low Flow Channel Design Analysis for Rio Salado (2000) performed by WEST for the Corps. This study presented a sediment transport model of the Salt River from approximately the I-10 Bridge to the 27th Avenue alignment, based on the Toffaleti, Meyer-Peter and Muller combination transport method. The model used an estimated sediment inflow at the upstream end of the reach based on an equilibrium bed material load analysis performed on a 0.5 mile reach upstream of I-10.

The simulated loads from this previous study were not considered appropriate inflow loads to our model because they were not developed using any of the sediment transport equations identified as suitable for the current study (Yang's equation or Madden's 1985 modification of Laursen's equation). If a sediment inflow based on a different equation was used in the current model, depending on the amount of the sediment loads, there is a possibility that it could lead to either unrealistic erosion or deposition in the upstream end of our study reach.

Since we were confronted with a lack of adequate data on inflowing sediment loads into our study reach, an equilibrium bed material load was assumed. The inflowing load at the upstream end of the model was determined on a reach approximately 3 miles

long at the upstream end of the study reach (from RM 211.21 to RM 214.14) with the gradation information from the two most upstream sediment sample locations. Equilibrium sediment loads for this reach were determined for a range of discharges from 20 to 200000 cfs. To determine the equilibrium load, HEC-6T was run using clear water inflow as the initial condition and the recirculation option on ($RE record). The recirculation option instructs the program to use the sediment discharge at the downstream end of the reach as the sediment inflow at the upstream end for the following time step. When equilibrium is attained, sediment load entering the reach is about equal to the load leaving the reach. For discharges between 20 and 50000 cfs, the simulations were run typically for 10 to 100 days with time steps in the order of 0.01 to 0.1 days. For larger discharges (100000 to 200000 cfs), typical durations were between 5 and 10 days with time steps of 0.001 to 0.01 days.

The inflowing sediment loads defined with Yang and Laursen-Madden relationships are shown in Figures 3-2 and 3-3. The gradation of the inflowing load from the equilibrium analysis is shown in Figures 3-4 and 3-5. This information was entered into the HEC-6T input files using LQ, LT and LF records.

3.3.3. Movable Bed Limits

In general, sediment dynamics tend to be more significant within the active channel, where the bed can either degrade or aggrade in response to erosion or deposition. The overbank areas tend to be more stable and normally are free of erosion, but can experience deposition. HD records were used to specify a bed sediment depth of 20 feet for all cross sections but one. At river mile 211.54 the sediment depth was set to zero to account for the grade control structure located immediately downstream of the 19th Avenue Bridge. Movable bed limits were not identified in the HD records, implying that deposition could occur anywhere in the wetted perimeter. In addition, HE records were used to limit erosion within the channel bank stations.

In order to develop a sound hydraulic model, the mining pits, in particular those located in the channel, were blocked to ensure a solution with a subcritical water profile along the reach. However, when flooded, the mining pits will likely act as sediment traps. For that reason, the sediment deposited on top of the blocked areas within or next to the channel was removed from the system using the dredging options in HEC-6T. HI records were used to identify the areas where sediment should be removed in the case that deposition took place, and the $DREDGE record was used to instantaneously take away the deposited sediment after each time step. In addition, when mining pits were located in the channel, the HE limits were relocated to exclude the pit from the area of potential erosion.

3.4. Hydrology

A continuous 50-year hydrograph consisting of historical flows between 1889 and 1938 was provided by the Corps. This flow series corresponds to the "worst case" continuous 50-year period, in terms of both peak flows and storm volumes, within the 105 years of record, from 1889 to 1993. Discharges less than 20 cfs were removed from the hydrology since no sediment was transported for flows of 20 cfs or less.

Simulations were performed with the 50-year hydrograph, with simulation results requested by decade. Figure 3-6 shows the complete 50-year hydrologic input and identifies the end of each decade. The individual hydrographs used to compile the 50-year long hydrograph are shown in Appendix F.

3.5. Results

The sediment transport analysis results are presented in terms of average bed elevation by decade (Figure 3-7 and Appendix G). The average bed elevation corresponding to a 10,000 cfs discharge of very short duration (0.00001 days) was computed in HEC-6T at 10-year intervals. This discharge was selected to generate average bed elevations because, in general, it provided coverage of the channel bottom (HEC-6T computes average bed elevations only from "wetted" points of the cross sections). The 10,000 cfs discharge is used only to generate output, and the short duration minimizes sediment movement.

The results show two distinct areas with respect to sediment dynamics. Downstream of 35th Avenue the reach mainly experiences degradation, with deposition limited to just a few cross sections. One of the depositional areas is defined by cross sections 203.58 to 203.86, and corresponds to an abandoned mining operation. The end result is a channel with a more homogenous bed slope. There are two areas downstream of 35th Avenue where the model predicts severe erosion:

- The first one is defined by cross sections 206.7 to 206.97. This is an area with active mining pits in the channel and a small berm to prevent low flows into the pit. The small flows (the majority in the hydrologic input) are then confined to a channel just about 200 feet wide resulting in severe degradation. Due to the limitations of the model (1-D steady state) it is not possible to simulate the complex interaction that may occur between the mining pit and the channel. The flows could very well breach the berm and enter the pit, limiting degradation in the channel but creating a headcut that would progress upstream.

- The second area corresponds to cross sections 209.24 to 209.54. This is another mined reach with pits on the right overbank and channel in cross sections 209.24 and 209.33. Cross section 209.54 represents the small bridge opening at 35th Avenue. Erosion in this case is associated with the cross sectional area reduction and velocity increase caused by the bridge.

Upstream of the 35th Avenue Bridge the bed slope is milder. That, along with the backwater effect of the bridge, creates the conditions for sediment deposition in most of the cross sections.

In general, average bed elevation changes are more significant in regions of the reach that are currently affected by mining operations in the channel. Where mining is not an issue, average bed changes reach a maximum of 5.8 ft after 50 years of sediment transport, with an average change of 1.9 ft.

During the simulations most of the bed changes took place in the first decade, with minor adjustments occurring in the remaining time. The first decade contained the flow events with the two largest peaks. In addition, it can be seen that the trend observed

after the first decade is sometimes reversed after subsequent decades. This is a consequence of both changes in the cross section geometry with time, and changes in sediment dynamics associated with flows of very different magnitudes.

Appendix H shows plots comparing the cross sections before and after the sediment transport analysis.

3.6. Sensitivity Analysis

The purpose of the analysis was to explore the sensitivity of the sediment transport model to variations in the parameters, in an attempt to determine the appropriateness of the selected values. Sensitivity runs were performed on the base conditions HEC-6T input file to determine the relative effect of changes to Manning's n, inflowing sediment load, and transport equation to the average bed elevation profiles. Results in tabular and graphic format are provided in Appendix I.

3.6.1. Hydraulic Roughness

The sensitivity of the sediment transport model to the hydraulic roughness coefficients was examined. The base conditions sediment transport model results have been compared to simulation outputs resulting from increasing and reducing all Manning's n coefficients in the input file by 25%.

After 50 years of simulating sediment dynamics, the high roughness profile is generally higher than the base condition profile. This is the result of deposition or reduced scour due to reduced flow velocities caused by the higher roughness coefficients. On the other hand, the low roughness profile is generally lower than the base conditions profile because of higher flow velocities. The average bed profile change was 0.7 ft for high roughness and 1.2 ft for low roughness, implying that small errors in the roughness coefficients selected for the base conditions model probably will not have a significant effect on the results.

The largest differences occur in mined reaches, where a 25% increase in Manning's n can reduce erosion by as much as 3.7 ft, and a 25% decrease in Manning's n can augment erosion by as much as 5.9 ft.

3.6.2. Inflowing Sediment Load

The effect of the inflowing sediment load has been assessed by comparing the base conditions sediment transport model with simulation results after increasing and reducing the sediment discharge to twice and half the equilibrium load determined with Yang's equation.

The most important differences can be observed upstream of the 35th Avenue Bridge. In the reach between cross sections 210.07 and 211.34 the double-inflow profile elevation increases an average of 0.6 ft with respect to the base condition, while for the half inflow profile it decreases an average of 0.5 ft. Downstream of 35th Avenue the differences are reduced as the sediment load reaches equilibrium.

3.6.3. Sediment Transport Equation

Simulation results generated with Yang's unit stream power equation have been compared to the simulation results produced with Madden's 1985 modification of Laursen's sediment transport equation.

The two equations yield bed profiles with the same trends in terms of degradational and agradational areas, with slight differences in the depth of eroded or deposited material. The main differences appear at the upstream end of the study reach. The upstream end of the reach is a transition between a narrow segment with levees in both banks and a wider segment severely disturbed by mining operations. It is not surprising that the model results show some instability in this area, until a new equilibrium is reached a little distance downstream. Laursen's equation, as modified by Madden, seems more susceptible to this effect than Yang's equation.

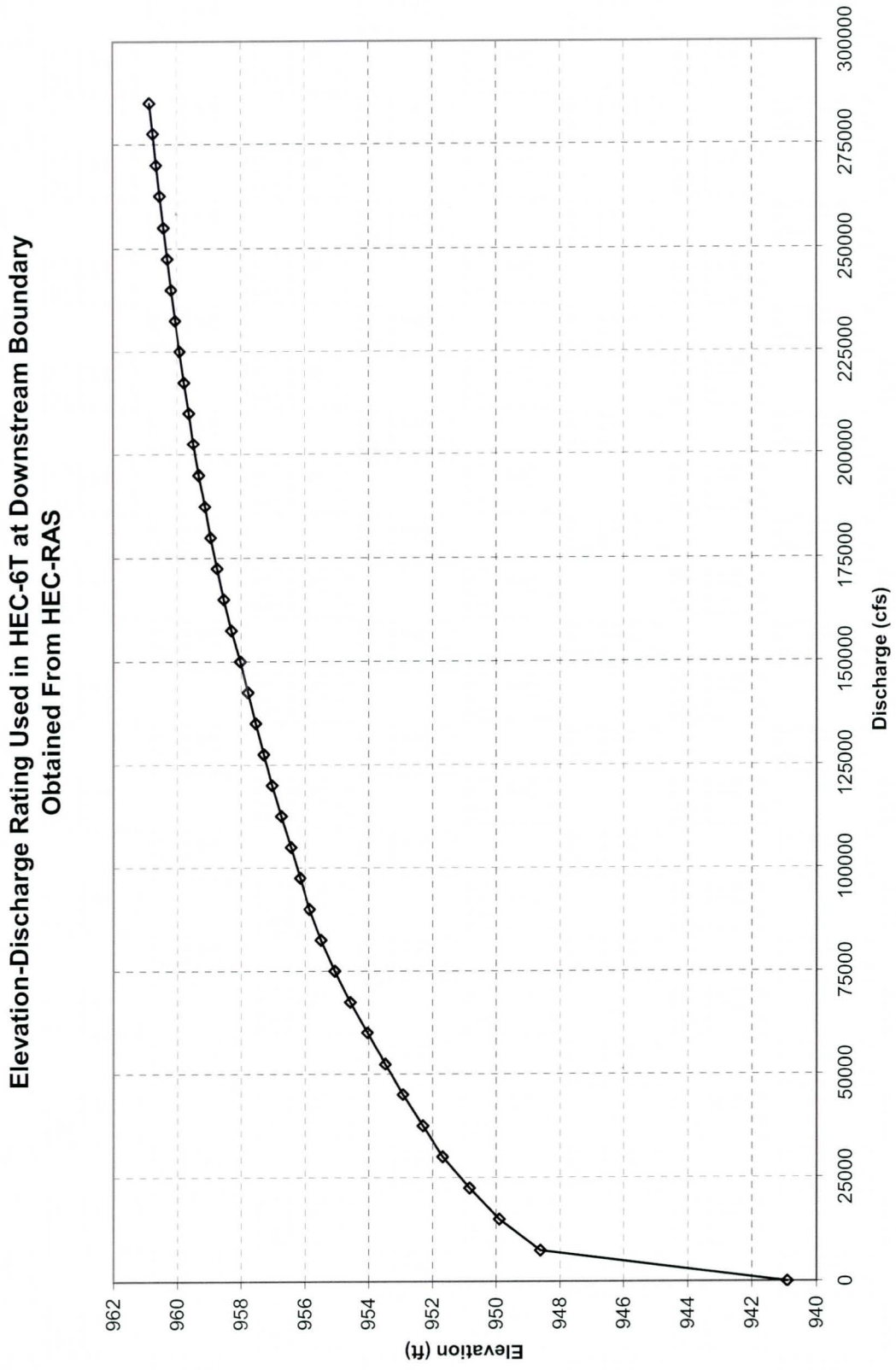


Figure 3-1. Rating curve at downstream end of sediment transport model.

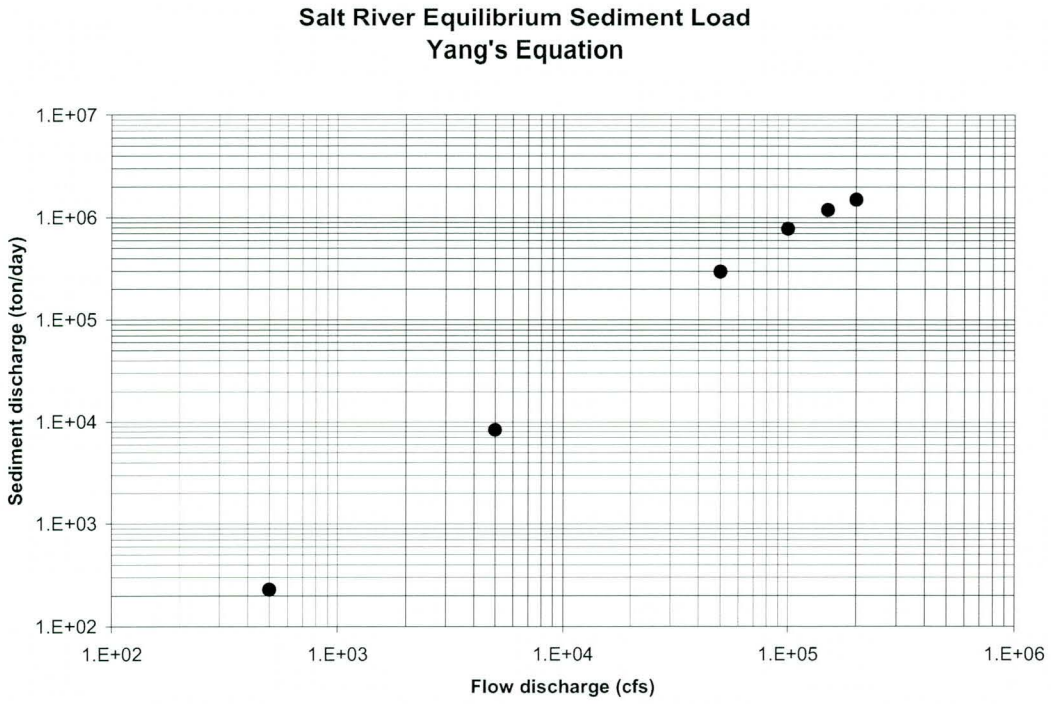


Figure 3-2. Equilibrium sediment load with Yang's equation.

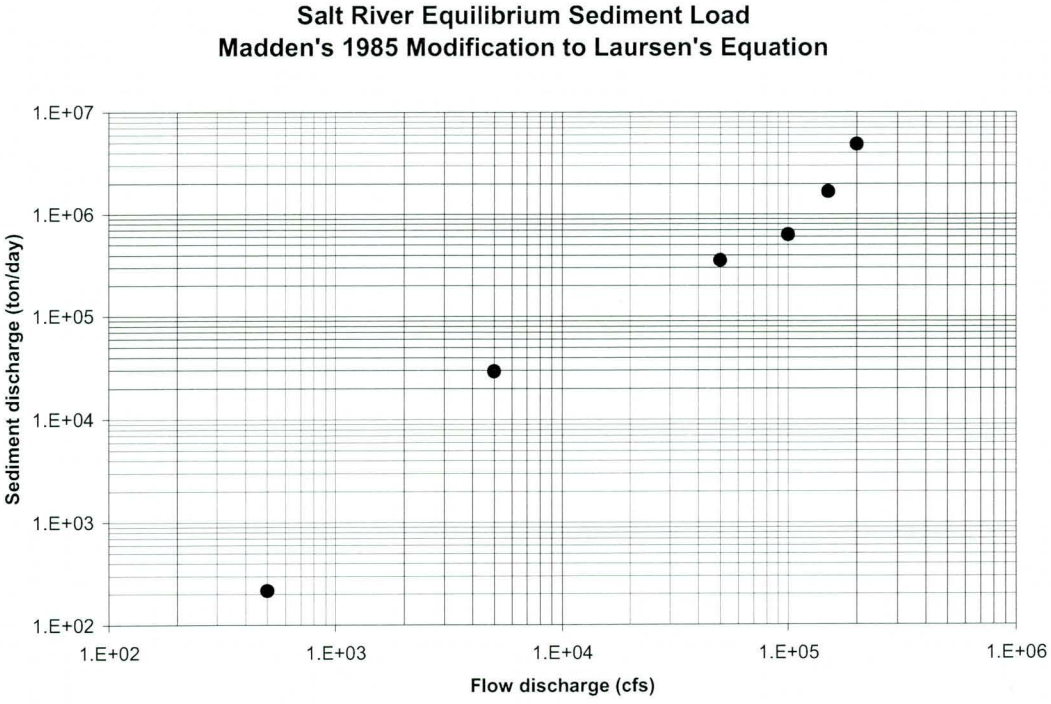


Figure 3-3. Equilibrium sediment load with Laursen-Madden's relation.

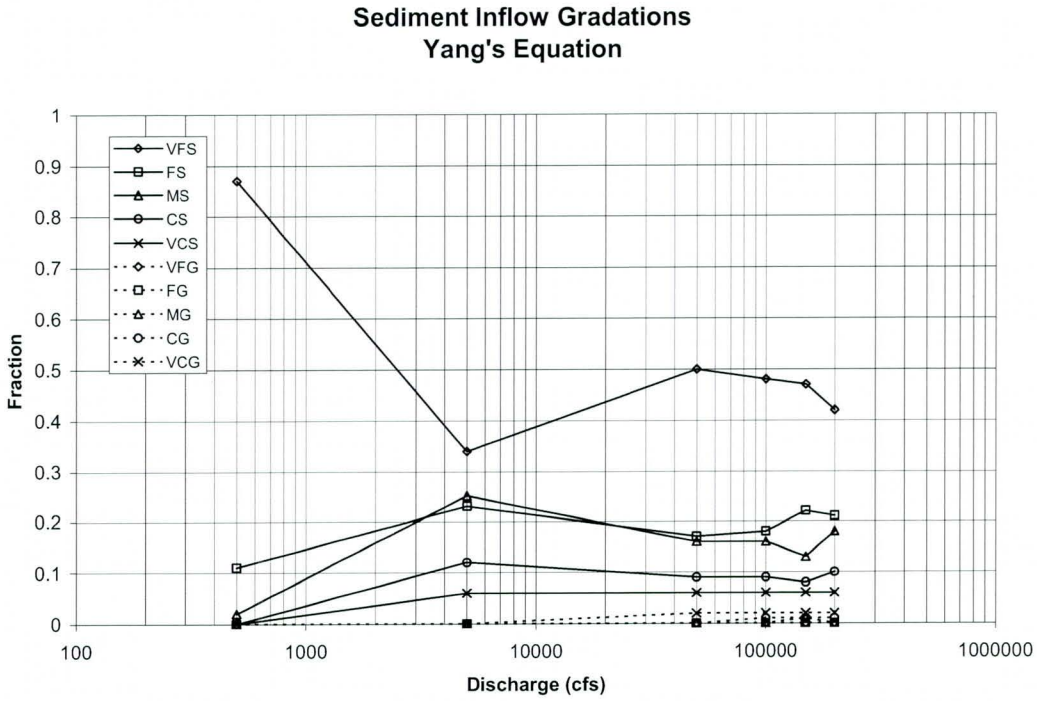


Figure 3-4. Sediment inflow gradations with Yang's equation.

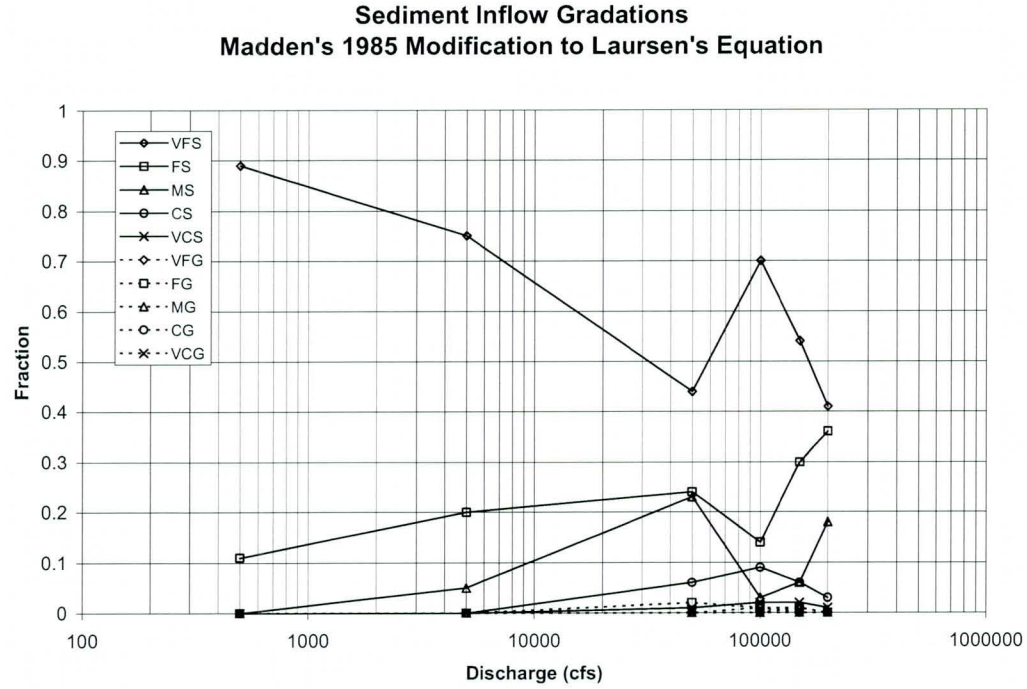


Figure 3-5. Sediment inflow gradations with Laursen-Madden's relation.

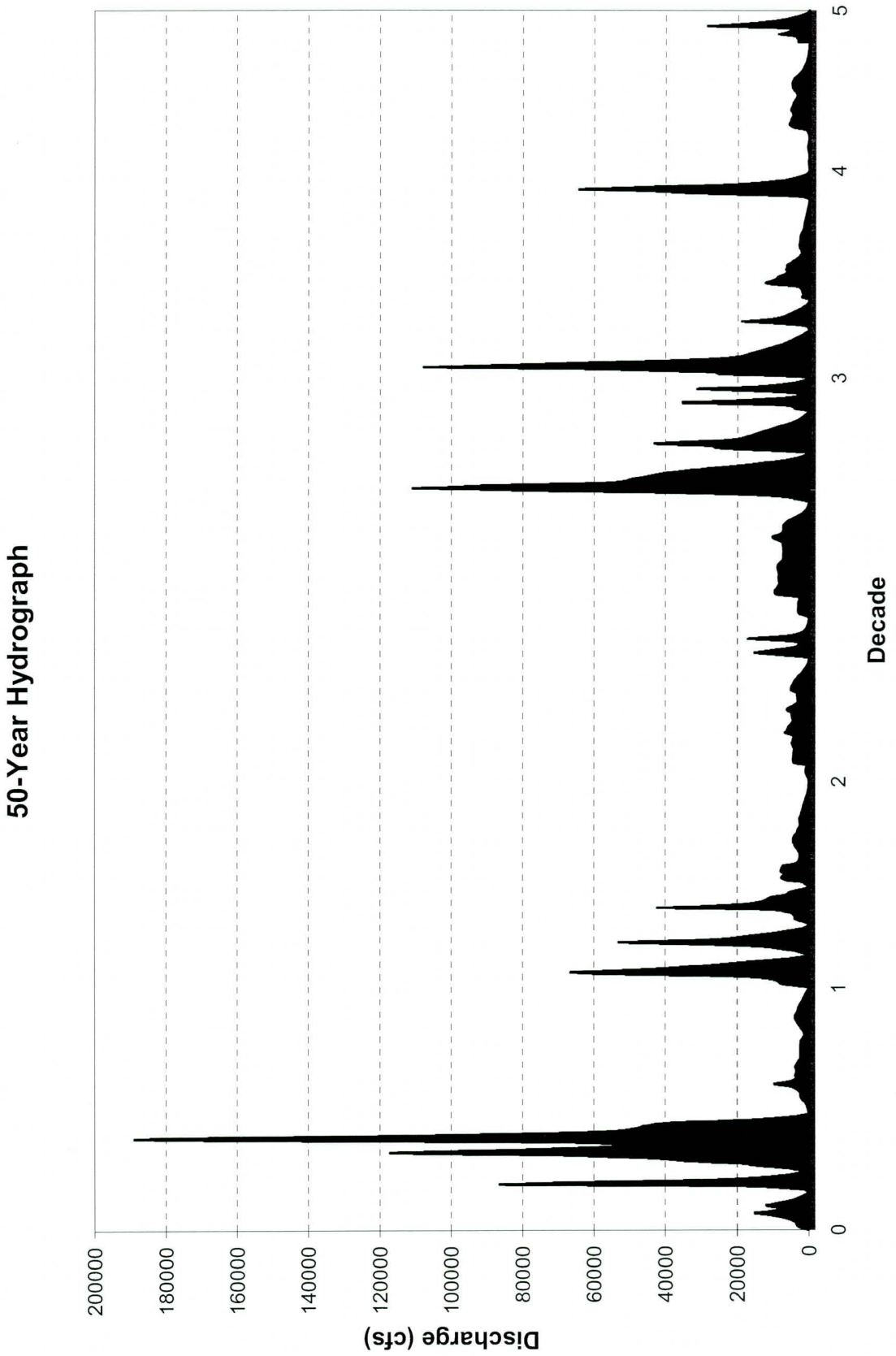


Figure 3-6. 50-year hydrograph used to run the sediment transport model.

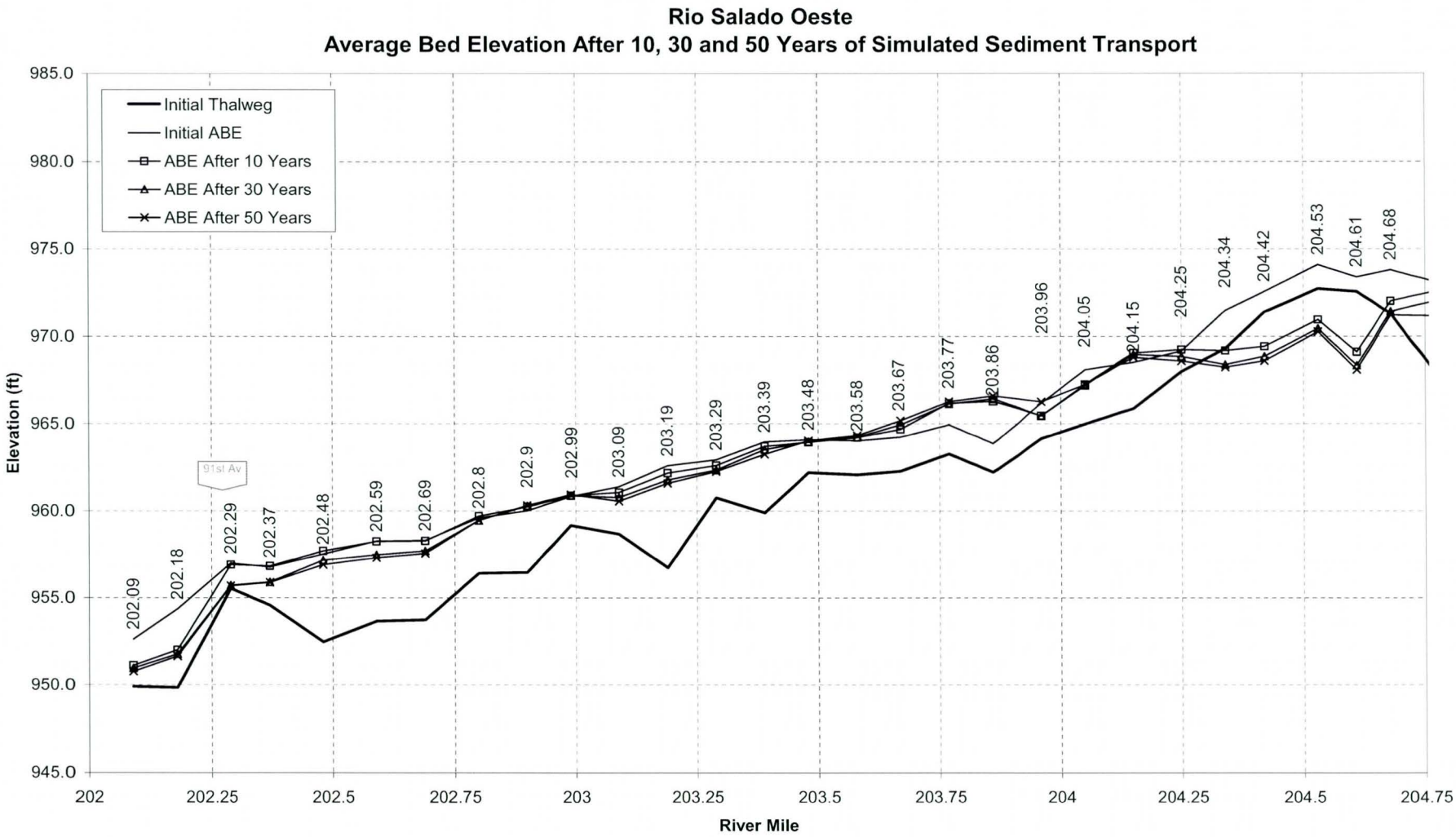


Figure 3-7. Simulated average bed elevation for selected decades.

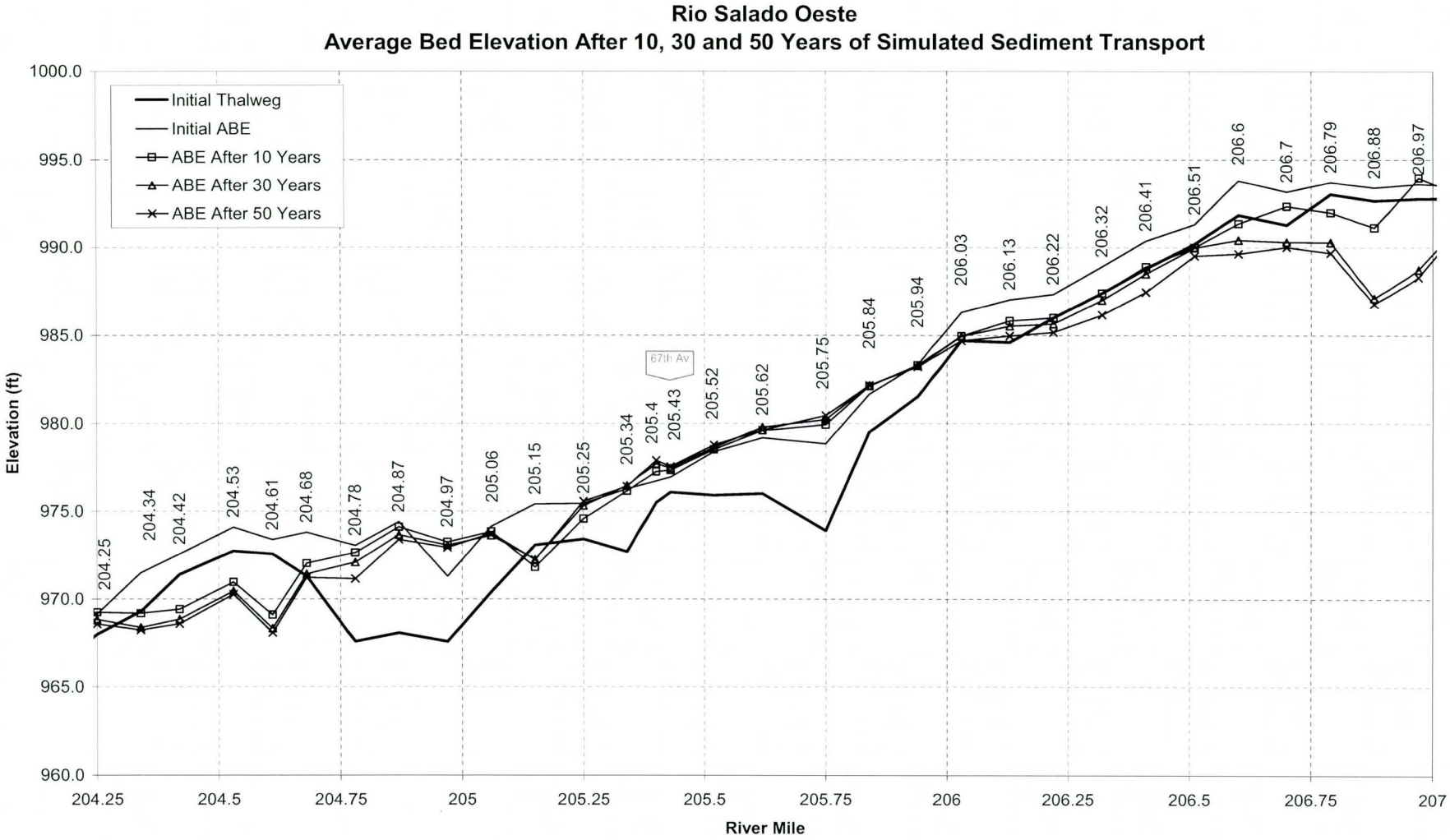


Figure 3-7. ***Continued.***

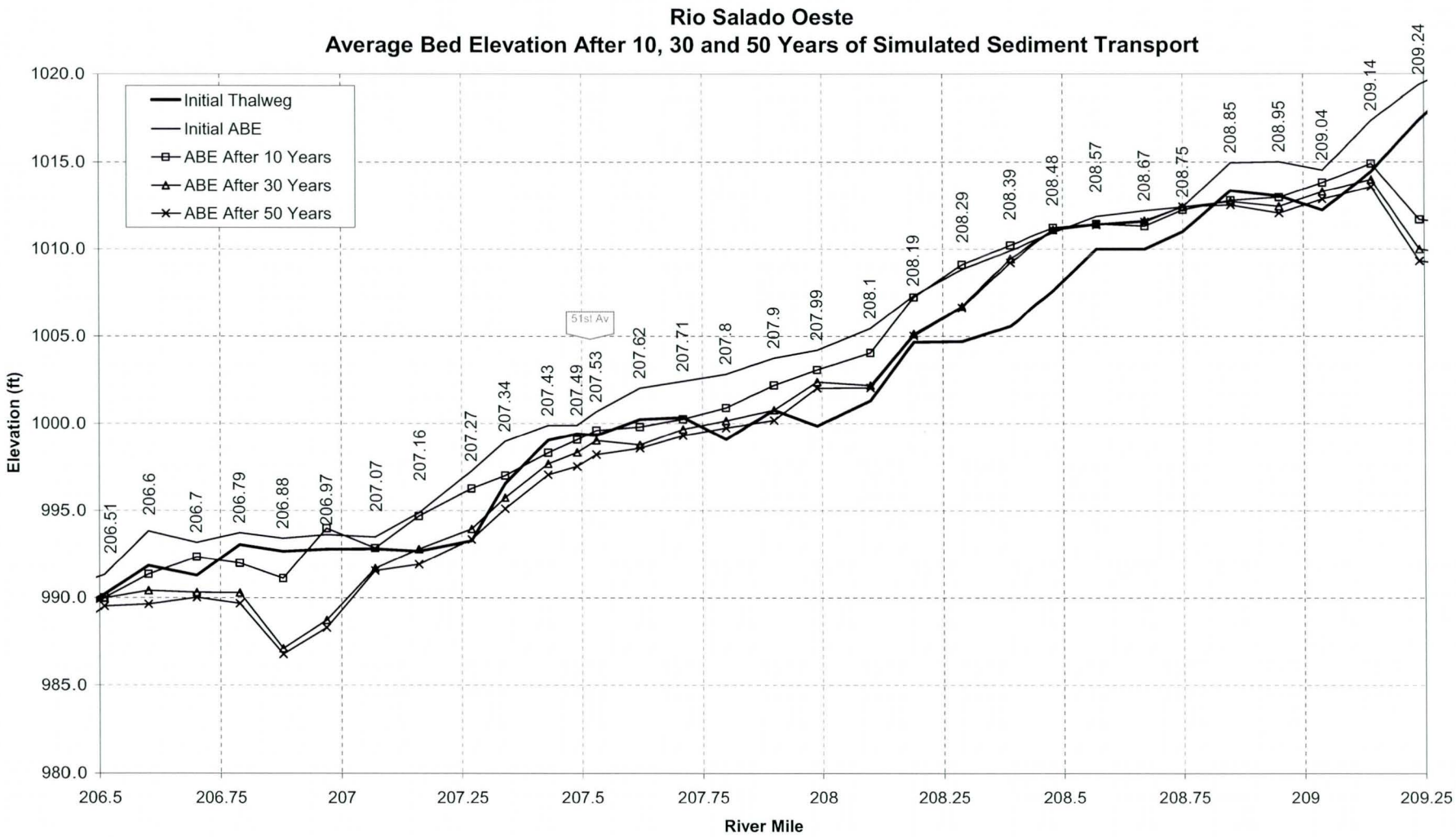


Figure 3-7. ***Continued.***

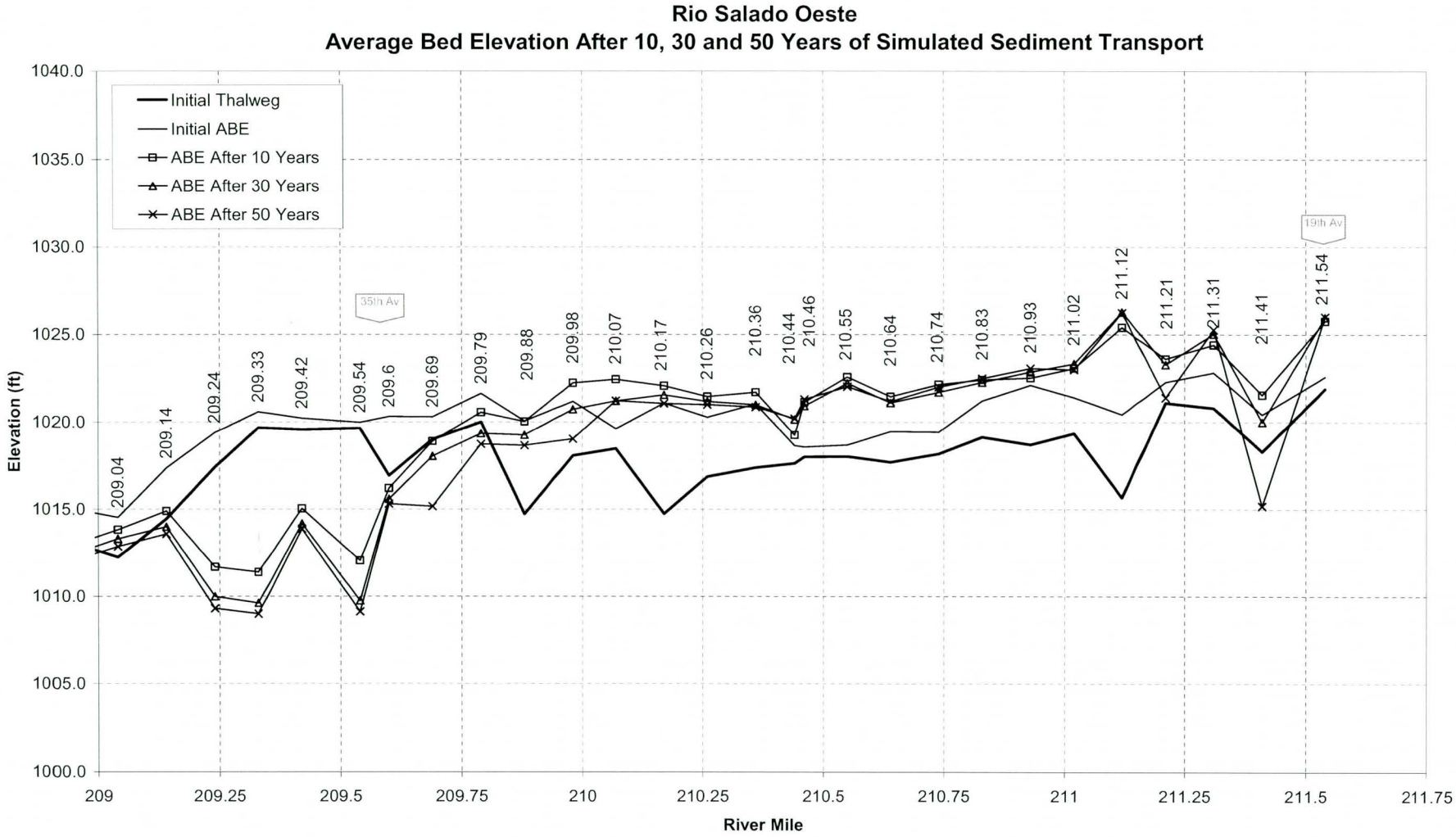


Figure 3-7. ***Continued.***

4. Geomorphic Analysis

The primary goal of the geomorphic analysis is to identify historical behavior of the subject river system by the collection and review of historical aerial photographs and the application of geomorphic relationships. The principle objective is to evaluate lateral channel migration, historical bank lines as well as low flow channel locations and sediment aggradation/degradation potential. A qualitative analysis of historical changes to river morphology is followed by a quantitative analysis for basic geomorphic factors of the subject river system.

4.1. Historical Setting

The Salt River was a perennial stream prior to construction of upstream water supply dams in the period 1908-1930. Historical accounts and photographs indicate that the Salt River was a wide, braided channel that supported significant vegetation but was also prone to major flood events. Since completion of the upstream dams on the Salt and Verde Rivers, the study reach has experienced significant periods of virtually no flow.

4.2. Analysis of Historical Photographs and Maps

WEST obtained historical aerial photographs of the project reach for the years 1937, 1958, 1979, and 1999 (approximately every 20 years). In addition, maps from the original land surveys filed in 1870 showing the outline of the river were obtained. The photos and maps were scanned and geo-referenced so as to be compatible with the recent aerial photographs and GIS coordinates. Based on the map and photographic images, a number of analyses were performed and are described in the following sections.

4.2.1. Bank Lines and Lateral Migration

The historical bank lines and channels were reviewed from 1870 to 1999. The historical bank lines, superimposed on the 1999 aerial photography, are shown in Figure 4-1. The Salt River through this reach has been relatively stable but still the river banks have moved laterally by as much as one-half mile in some locations during the 130 year record. Much of the lands along the south side of the river have been recovered from the active braided channel system during the period of historical photos. Delineating the active channels and banks was made much more complex by the reclamation of fields with active channel scars both upstream and downstream of the new fields as well as expansion of mining pits. Some of the reclaimed areas have subsequently been developed by industrial users.

The lines marked Recent Geologic Banks were determined from reviewing the aerial photos from 1937 to 1999 and viewing the shape of the topographic lines along the river. The boundaries were initially set to include all areas where abandoned meander features were found as well as extending to the areas where the contour lines changed direction from following the regional slopes to being perpendicular to the river channel. This coverage should be fairly close to the maximum historical meander belt for the river in this reach. It varies from approximately two miles in width at 19th Avenue to approximately four miles in width at 91st Avenue.

The river is constrained upstream from 19th Ave by levees constructed as part of earlier projects. The soil cement levees end just downstream from the 19th Ave Bridge and the river is unconstrained by levees until just above the 91st Ave water treatment plant. River alignment is fixed to some extent by bridges located at 35th Ave., 51st Ave. and additional proposed bridges for a future freeway crossing at approximately 61st Ave. The 35th Ave Bridge is very short and provides a significant constriction to flows. The other bridges have much larger openings and provide little, if any, flow constriction.

4.2.2. Low Flow Channel

The historical centerline of the low flow channel, or thalweg, was determined by using the same information previously described. Identification of the main flow channel was sometimes difficult as the system is braided and multiple flow paths can usually be seen at any given time around islands and bars. The thalweg lines from 1870 to 1999 are shown in Figure 4-2. Similar to the bank lines, one can observe that the thalweg consistently shifts its position within the meander belt (compare the thalweg location with the bank lines shown in Figure 4-1). This shifting is typical of braided river systems. The thalweg locations are, however, all within 2000 feet of one another from the downstream boundary of the study at 91st Avenue up to about 35th Avenue. Upstream of this point, the thalweg locations diverge. Available evidence indicates that the river used more northerly channels up until the 1950's, with a shift in the thalweg location to a more southerly location from that time to the present.

4.2.3. Vegetation

Sparse vegetation can still be seen in the 1937 aerial photographs. However, the other sets of aerial photos (1958-1999) show no significant amounts of vegetation in the study reach.

4.2.4. Mining Activities

Mining activities in the Salt River play a significant part in the sediment balance of the river system. In the 1937 photographs, no significant mining activities are seen in or near the river channel. In 1958, two large pits can be seen at the upper end of the study reach (upstream of 35th Avenue). The increase in observable mining activities continues in the 1979 photographs where more pits are observed. These are still located primarily in the upstream part of the study reach. The 1999 photographs show at least 12 pits in and near the river channel more evenly distributed along the reach than in previous years (although still predominantly in the upper portion of the study reach). Since some of these pits are located near the main channel and the river currently flows through some of these pits, they have significant impacts on local flows. These impacts include the redirection of flows through the pits and away from former channel alignments, erosion upstream and downstream from the pits as well as deposition of sediment in the pits.

4.3. Channel Response to Flood Events

To accurately gage the changes wrought by the river to its channel during major flood events, photographs immediately prior to and after the event should be compared. Such a detailed comparison is not part of the present study and photos immediately prior to the floods are not available. However, some information may still be gleaned from the

photos used in this study. For example, in each period in between the dates of the aerial photography (1937-1957, 1958-1979, 1979-1999) a major flood occurred on the Salt River, with the exception of the period 1937-1958. Observing the bank lines and aerial photographs for the period with out large floods reveals that very little change occurred in the channel in the absence of large flood events. During the period between 1973 and 1999 (includes the 1993 Flood) for example the banks in the upstream reach were impacted primarily by gravel mining while areas near 67th Ave and 83rd Avenues widened significantly due to flood events. The widening of selected sections can be seen in comparing the banklines from the various time periods in Figure 4-1.

4.4. Geomorphic Relationships

The current channel geomorphic properties were analyzed in order to quantitatively examine channel stability and potential for lateral migration.

4.4.1. Channel Planform

Leopold, Wolman, and Miller (1964) adopted the sinuosity ratio, defined as the channel (thalweg) length divided by the valley length of the stream, as a criterion which could be used to classify river patterns. Through the observation of several natural river systems, they concluded that systems with a sinuosity greater than or equal to 1.5 would be classified as meandering, while those less than 1.5 would be braided or straight. The average sinuosity for the study reach was approximately 1.4.

Also, Lane (1957) and Leopold & Wolman (1957) developed relationships between channel pattern, channel gradient, and mean discharge based on field data. Figure 4-3 shows these relationships graphically. The significance of this figure is that rivers situated close to the meandering-braided threshold would be expected to experience transitions between one channel form and the other. Utilizing the 5- and 10-year discharges (20,200 and 53,000 cfs, respectively) as indicators of either the mean (Lane) or bankfull (Leopold & Wolman) discharge, error bars are shown for the study reach. The error bar indicates the range of slopes found in geomorphically similar subreaches within the study reach. It can be seen that the study reach plots well into the braided region for both criteria.

4.4.2. Width / Depth Ratio

Width/depth ratios were computed for the study reach using the HEC-RAS model results for both the 5- and 10-year discharges. Results are shown in Table 4-1. It is seen that the channels are very wide and shallow, reflecting the observed braided system (several researchers have defined ratios of 40 or above as "very high", e.g. Rosgen, 1994).

Table 4-1. Width / depth ratios.

	5-Year Flow	10-Year Flow
Maximum	800	561
Minimum	44	31
Average	193	176

4.5. Sediment Aggradation/Degradation Potential

It is common in geomorphic studies to identify "equilibrium" conditions that the channel would experience if inflowing and outflowing amounts of sediment were perfectly in balance. Then areas expected to experience aggradation (deposition) or degradation (erosion) could be identified for areas not conforming to the predicted equilibrium conditions. However, this type of analysis is usually performed either as a precursor to, or in place of, a more detailed sedimentation modeling study. Because such a modeling effort forms part of the current study, and results in predictions of erosional or depositional areas, a separate and more general geomorphic analysis will not be performed here with the exception of a review of recent historical thalweg elevations.

An historic HEC-2 model was obtained from the FCD that contained cross section and thalweg elevations for 1982. This data was compared with the data collected by Baker in 1994 that served as the basis for the current study. These data were also compared with the thalweg from the 50 year simulation as plotted in Figure 4-5. It can be noted that there are some differences between the 1982 (pre-flood) and 1994 (post-flood Baker) data. One of the primary differences is at the 35th Ave bridge where the Baker data shows an extremely deep scour hole under the bridge due to the flood. The 1982 and the future condition thalwegs in this area are nearly in agreement indicating that the channel is relatively stable in this reach for the conditions modeled with large floods scouring deep holes under the bridge to facilitate passage of their high flows.

The channel topography in the TIN supplied for analysis appears to be based on the water level in the river under the bridge rather than the bed elevation as can be seen in Figure 4-6. It was noted, however, that the bed adjusted to the same elevation in the future conditions model regardless of whether the channel elevations from the Baker model (deep scour hole under bridge) or the water surface was used as the initial channel invert.

The 1982 and future thalweg elevations are within approximately 5 ft of each other with most of the larger differences in areas that were mined in prior to the 1982 topography. Differences can be seen at RM 209 and 210.5 for example where mining pits appear to have filled during the 1993 flood.

The correlation between the historical and predicted future conditions again indicates that the river is in a state of dynamic equilibrium and tends to return to its pre-existent state if adequate flow and sediment is available. The impact of gravel mining, at least since 1982, does not appear to have impacted the overall stability of this reach although impacts near the pits are significant.

4.6. Geomorphic Summary

The entire study reach is classified as a braided channel system, conforming to observations in the field and from historical documents and photographs. Braided systems generally have wide main channels in which multiple low flow channels cross, resulting in the braided channel.

Braiding is believed to result primarily from random deposition of materials (sediment) transported during high flows in quantities or sizes too great for continued transport during low flows. Accordingly, as the stream discharge is reduced, larger sediment particles begin to drop to the bed as the stream "sorts" or leaves behind those sizes of the transported sediment (load) which it is unable to transport. The accumulation of these particles on the channel bed initiates the formation of a bar which serves to trap even more sediment particles. Although the depth of flow over the growing bar is gradually decreased, velocity over the bar tends to remain undiminished or even to increase so that some particles moving along the bar are deposited beyond the downstream end where a significant decrease in velocity is associated with the marked increase in depth of flow. Thus, the bar grows by successive addition of sediment particles at its downstream end and some additional growth along its sides. Additional bars will then be propagated through the same process described until the channel obtains its characteristic braided pattern. Growth of the bars will eventually reach a size that will significantly alter the channel conveyance capacity at which time the channel will seek a new equilibrium condition.

The shifting, changing nature of braided channels and the fact that they are often generated by sediment deposition and bed aggradation has led many engineers and river scientists to associate them almost exclusively with disequilibrium in the fluvial system. However, as Leopold et al. (1964) pointed out, braided river systems are a distinct and viable category of dynamically stable planform, along with straight and meandering systems. The recent historical evidence examined here indicates that the project reach is in quasi-equilibrium, although adjustments to bank and thalweg lines within the historical meander belt are possible.

4.7. Lateral Bank Migration Rates

It is extremely difficult to predict bank retreat or lateral migration rates in braided river systems. A braided river system regularly attacks its banks and moves them back as the braided meander patterns shift across and along the river. Once a braid of the river directly attacks a bank it normally will retreat rapidly until the meander shifts and the attack terminates. The rate of bank retreat may thus be several hundred feet for a single event but over the historical record be only a few feet per year. Thus a bank that appears stable can retreat very rapidly while under attack and yet appear stable for long periods of time while the river is attacking the bank in other locations. Other banks are relatively resistant and can withstand a direct impact of a braid with little retreat. The limited number of flows in the Salt River only increases the difficulty of estimating long term rates of retreat.

The fact that a bank has been stable for the historic record may only mean that the full force of the river has not, as yet, been redirected toward that bank. If the historic record of bank lines is reviewed in the context of limits presented in Figure 4-2 as the

Recent Geologic Banks, it can be noted that the river has moved widely on the floodplain over its geologic past. Given the proper flows, meander bends, braid patterns, and bank conditions, the river could again move to its geologic limits or even beyond. Given the exiting constraints the movement of the river to its Recent Geologic Banks is unlikely however.

Notwithstanding the difficulty in the estimation of retreat rates, some estimate of probable bank movement can be made based on current constraints, existing patterns within the river and historical bank lines. Based on the historical record as well as geomorphic principles, it is probable that the river will stay within the limits shown in Figure 4-4 as the Probable Lateral Migration Limits. That is not to say that without protection that the river will stay within these limits indefinitely but only that for flows up to and including the 100 year event the river would not be expected to move dramatically beyond the limits shown in a single or short series of events. These lines take into account the historical bank lines as well as the expected bank attacks during high flows.

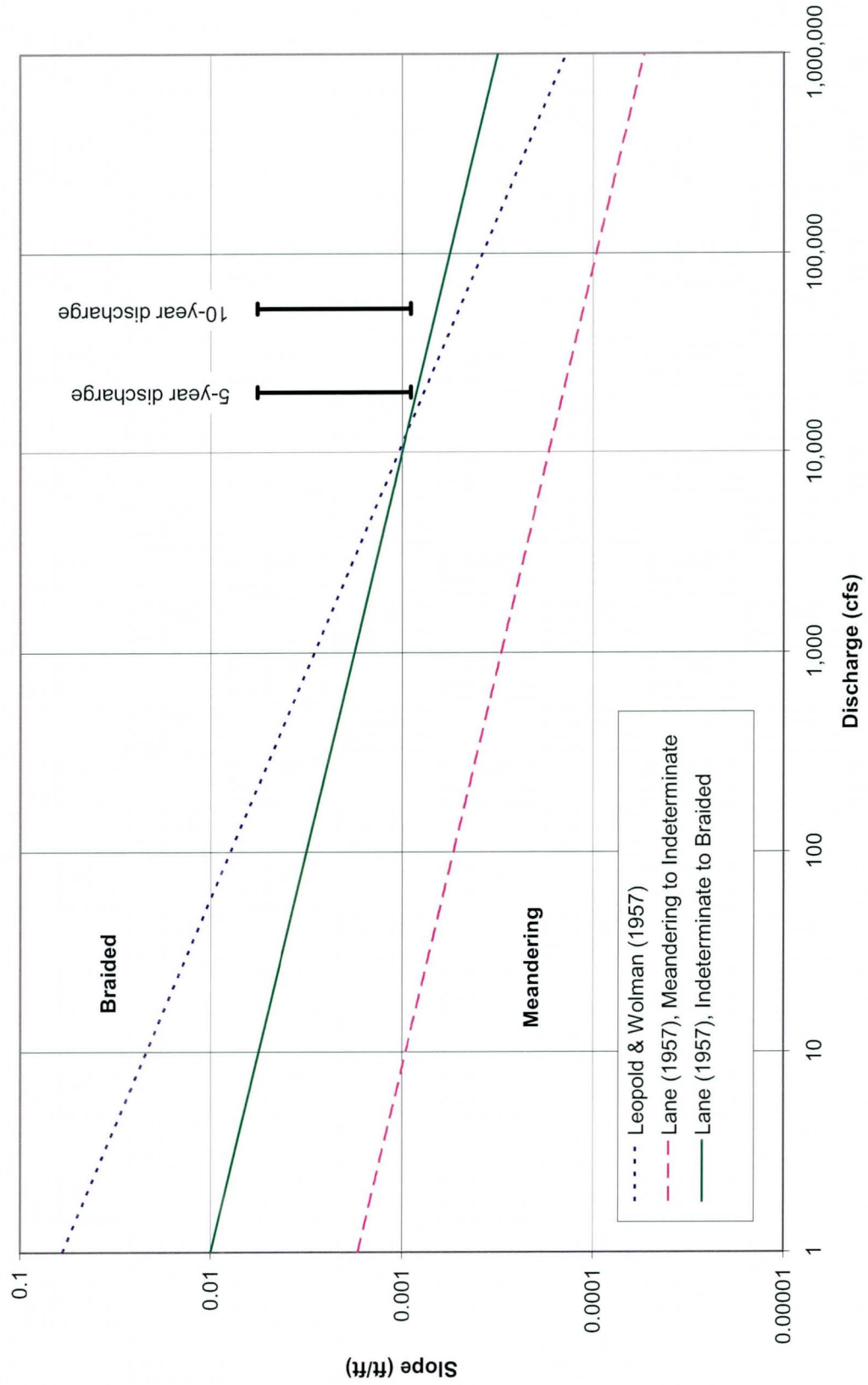


Figure 4-1. Project reach predicted channel form.

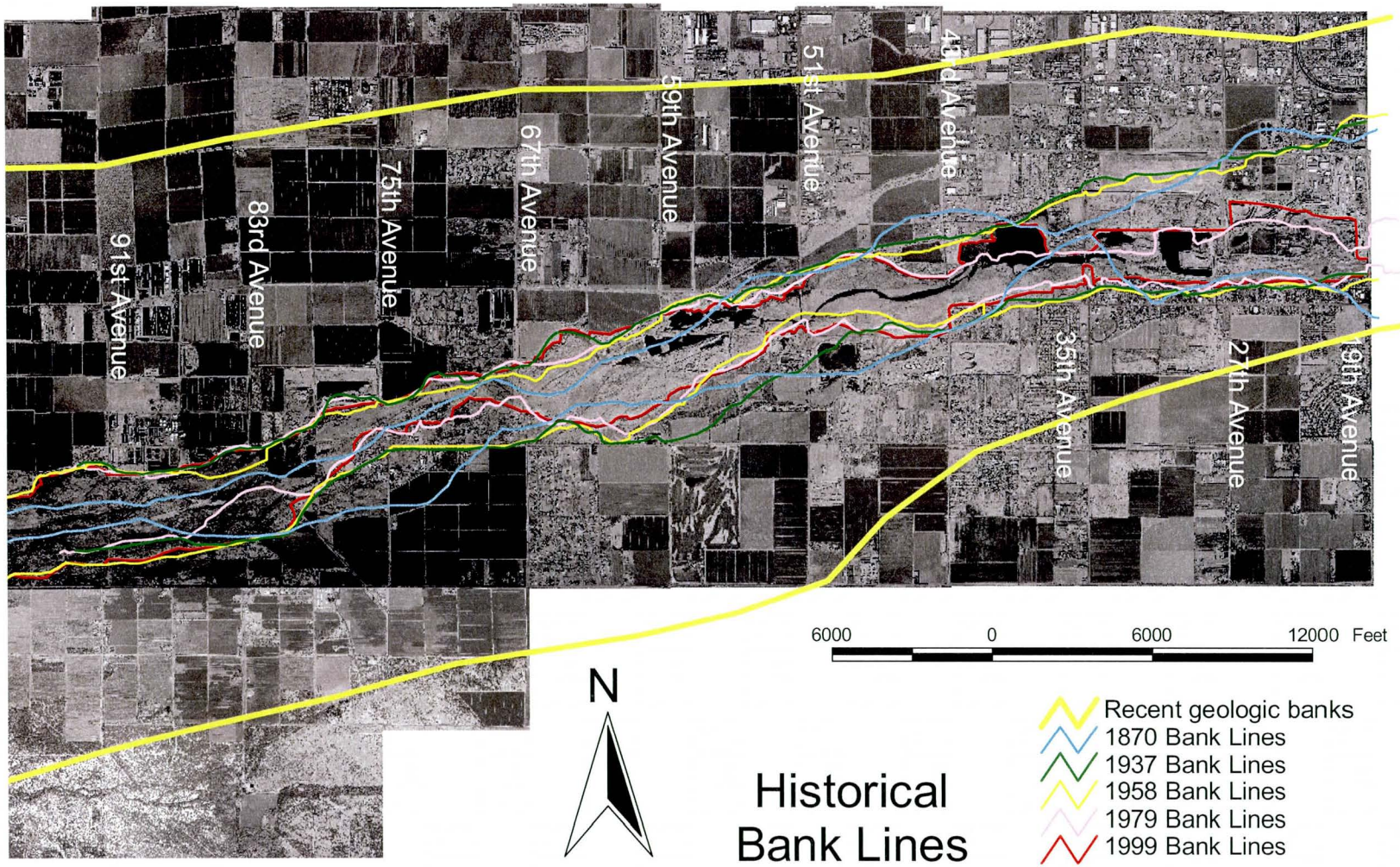
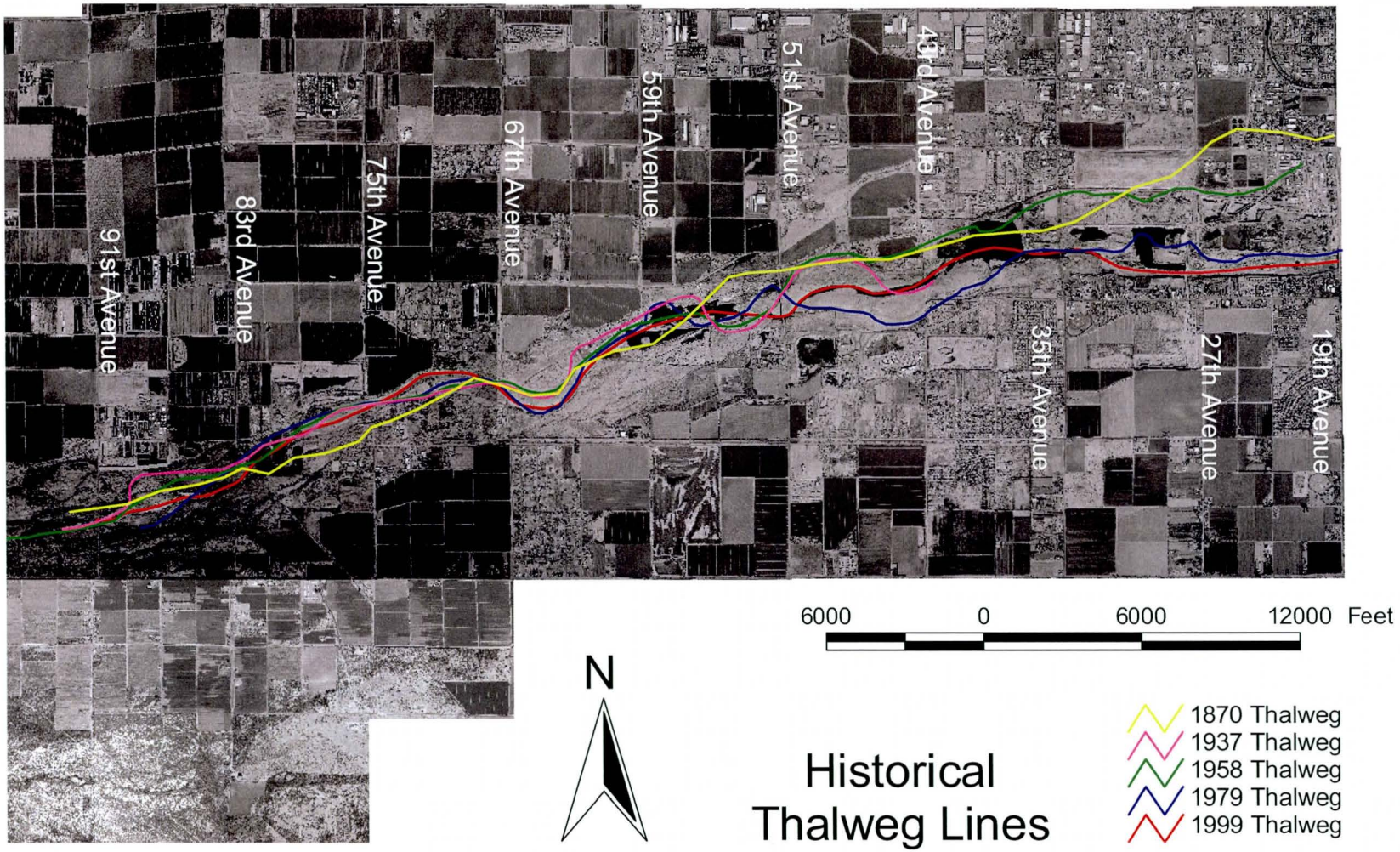


Figure 4-2. Historical bank lines.



Historical thalweg lines.

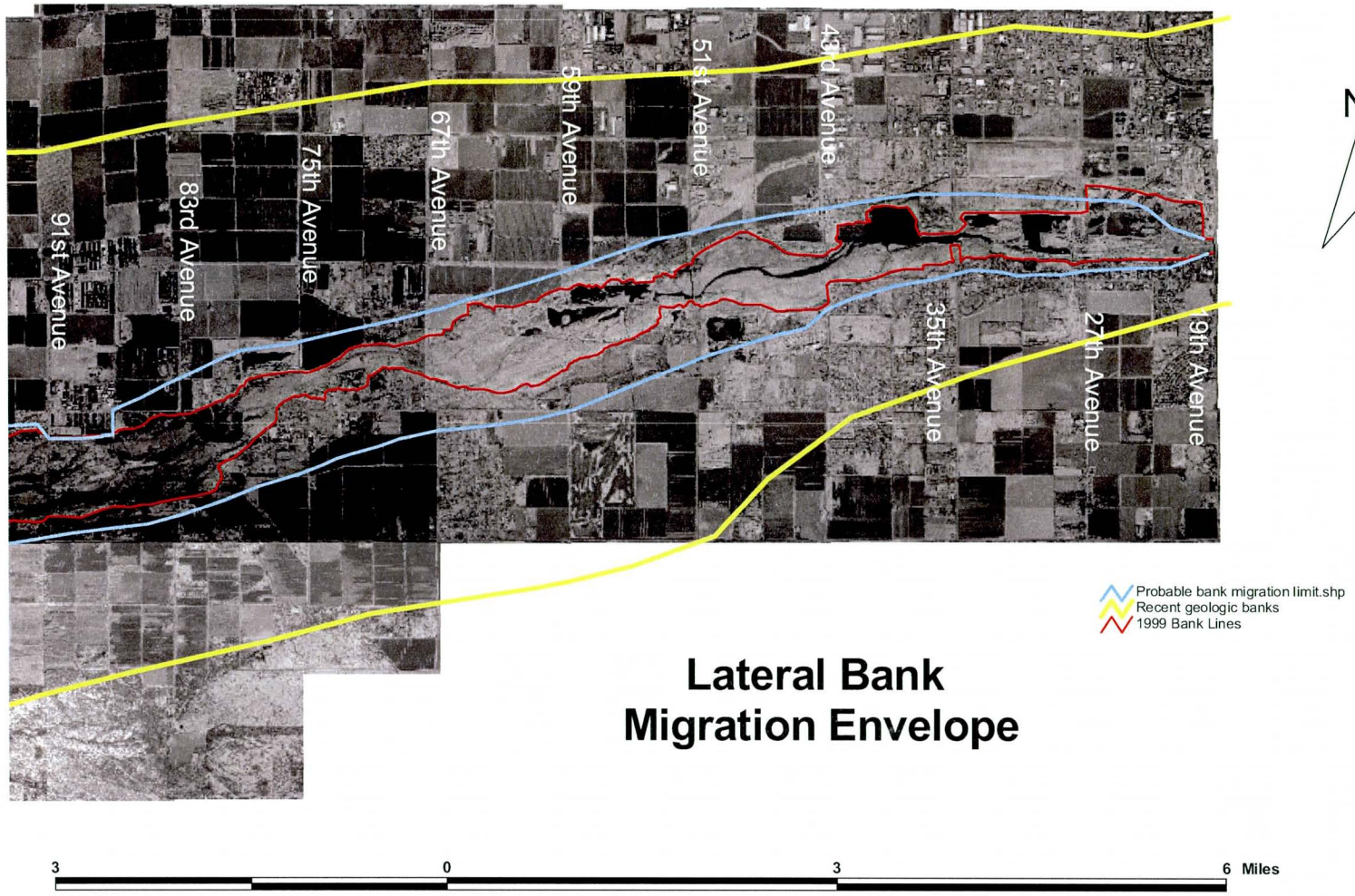


Figure 4-4. Estimated Lateral Bank Migration Limits.

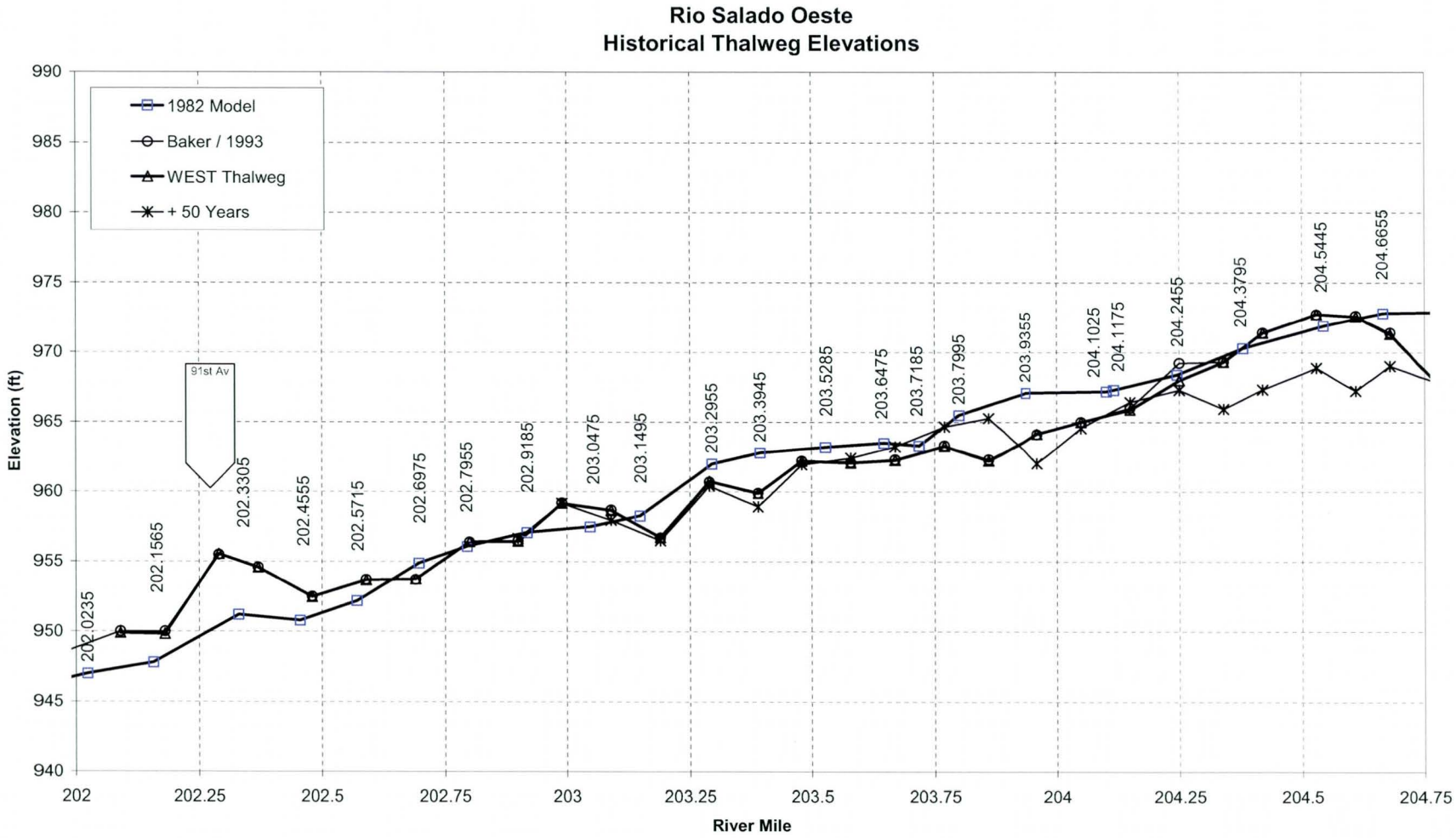
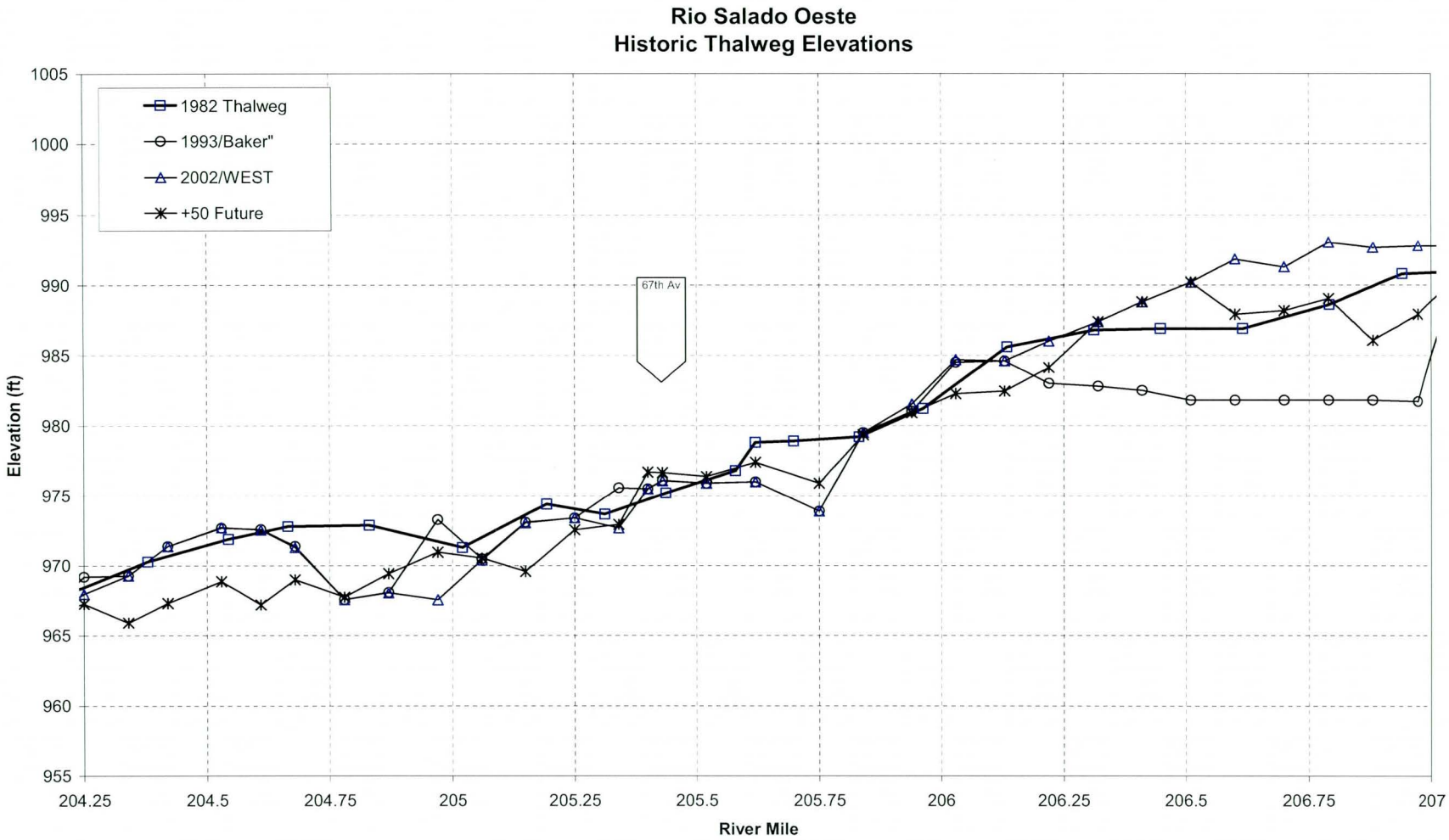


Figure 4-5. Recent Historical Thalweg Elevations of Salt River from 19th Avenue to 91st Avenue.



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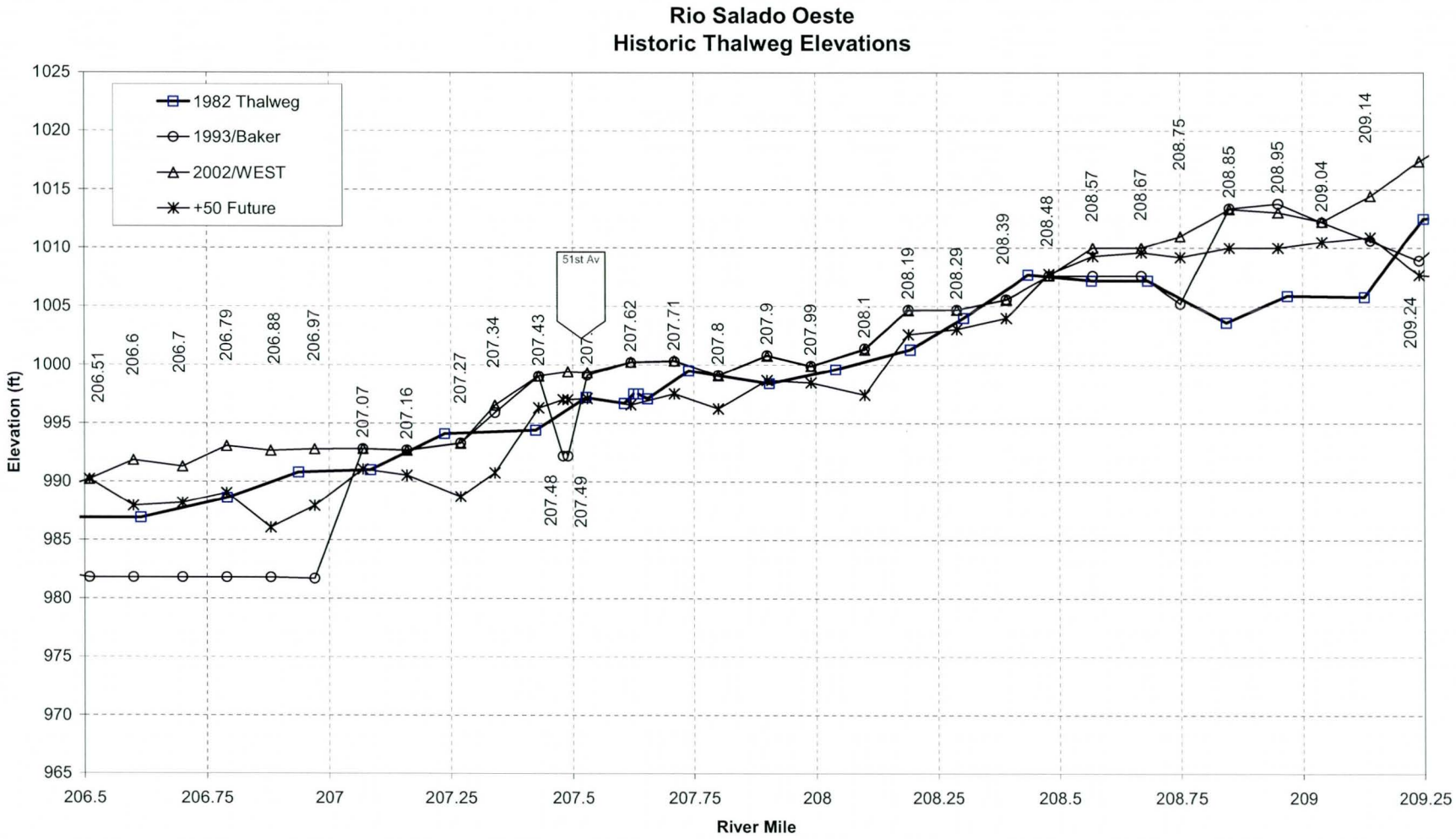

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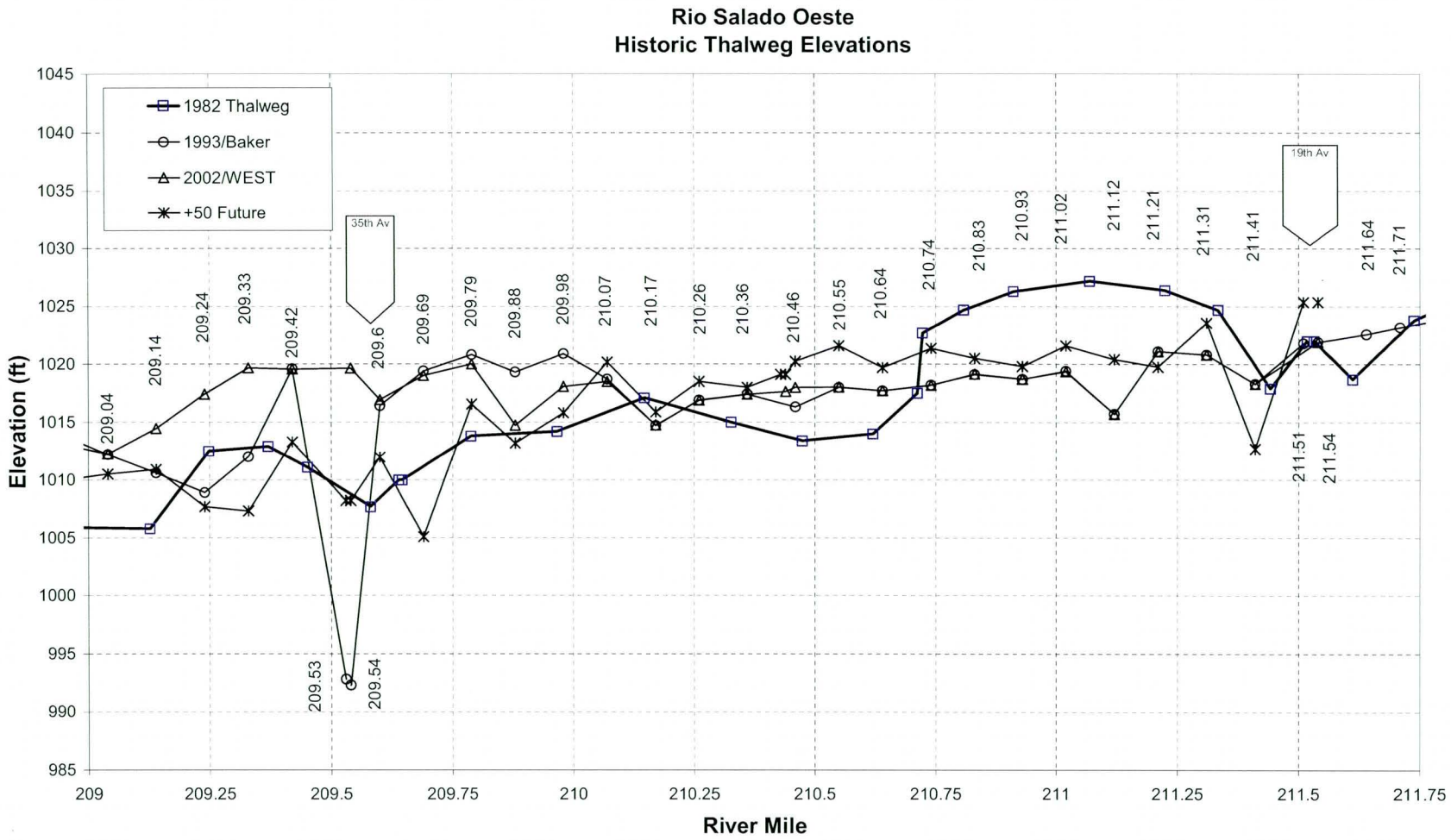


Figure 4-5. *Continued.*

5. Future Without-Project Hydraulic Analysis

HEC-6T generates an output file with the extension T12 where it stores the model geometry at the end of the simulation. The cross section geometry after 10, 20, 30, 40 and 50 years of sediment transport simulation was used to create five new hydraulic models in HEC-RAS. The new cross sections reflect the erosion or deposition that occurred during the sediment transport simulation.

The bridge geometry from the existing conditions model was added to the future conditions model, but first some manipulation of the T12 file was required. HEC-6T uses just one cross section with the superimposed pier geometry to represent each bridge, while HEC-RAS uses two cross sections with bridge geometry specified between the cross sections. Therefore, it was necessary to remove the piers from the bridge cross sections in the T12 file, and a copy of each bridge cross section in the T12 file (with the piers already removed) was placed downstream of each bridge in the HEC-RAS model. The stations of the new downstream cross sections were then adjusted laterally to match the end points and banks of the cross sections downstream of the bridges in the existing conditions model. These new cross sections, placed at the downstream side of the bridges, preserved the distances in the existing conditions model, and the bridge geometry was then imported from the existing conditions HEC-RAS model to complete the future conditions HEC-RAS model.

Hydraulic simulations were performed using the roughness coefficients (Manning's n) in the existing conditions model. Channel and overbank roughness values were then increased 10, 20 and 30% to reflect vegetation growth assuming no clearing is carried out during the 50-year simulation period. Complete simulation results are provided in Appendix J.

Water surface profiles by decade were generated for the 5-, 10-, 20-, 50-, 100- and 500-year discharges in HEC-RAS. Figures 5-1, 5-2 and 5-3 show the water surface profiles for the 10-, 100- and 500-year flood events after 10, 30 and 50 years of sediment transport simulation.

The future conditions water surface profiles are smoother than the existing conditions profiles, as expected for a bed profile with a more homogenous slope. The main differences appear upstream of the 35th Avenue Bridge. The bridge opening in the future conditions model is bigger due to the erosion of the cross section, and therefore the backwater effect diminishes. As a consequence, the inundation boundaries for the future conditions model upstream of 35th Avenue would not extend as far from the channel as for the existing conditions model. If the topography in the TIN shows the water surface under the bridge the initial water surface elevation would be lower and flooding would not be as widespread as indicated in the initial conditions model. A verification of the actual bed elevations should be performed if the bridge is not scheduled for replacement.

The effect of increasing the roughness coefficients to simulate vegetation growth is shown in Table 5-1. The table shows the average increase in water surface elevation caused by an increase of 10, 20 or 30% in Manning's n from the values in the Existing Conditions model.

Table 5-1. Future conditions hydraulic analysis: sensitivity to roughness coefficients.

Flood Event	Average increase in water surface elevation (ft)		
	10% increase in Manning's n	20% increase in Manning's n	30% increase in Manning's n
5-year	0.3	0.5	0.8
10-year	0.4	0.8	1.1
20-year	0.4	0.9	1.3
50-year	0.5	1.0	1.5
100-year	0.5	1.1	1.5
500-year	0.5	1.0	1.5

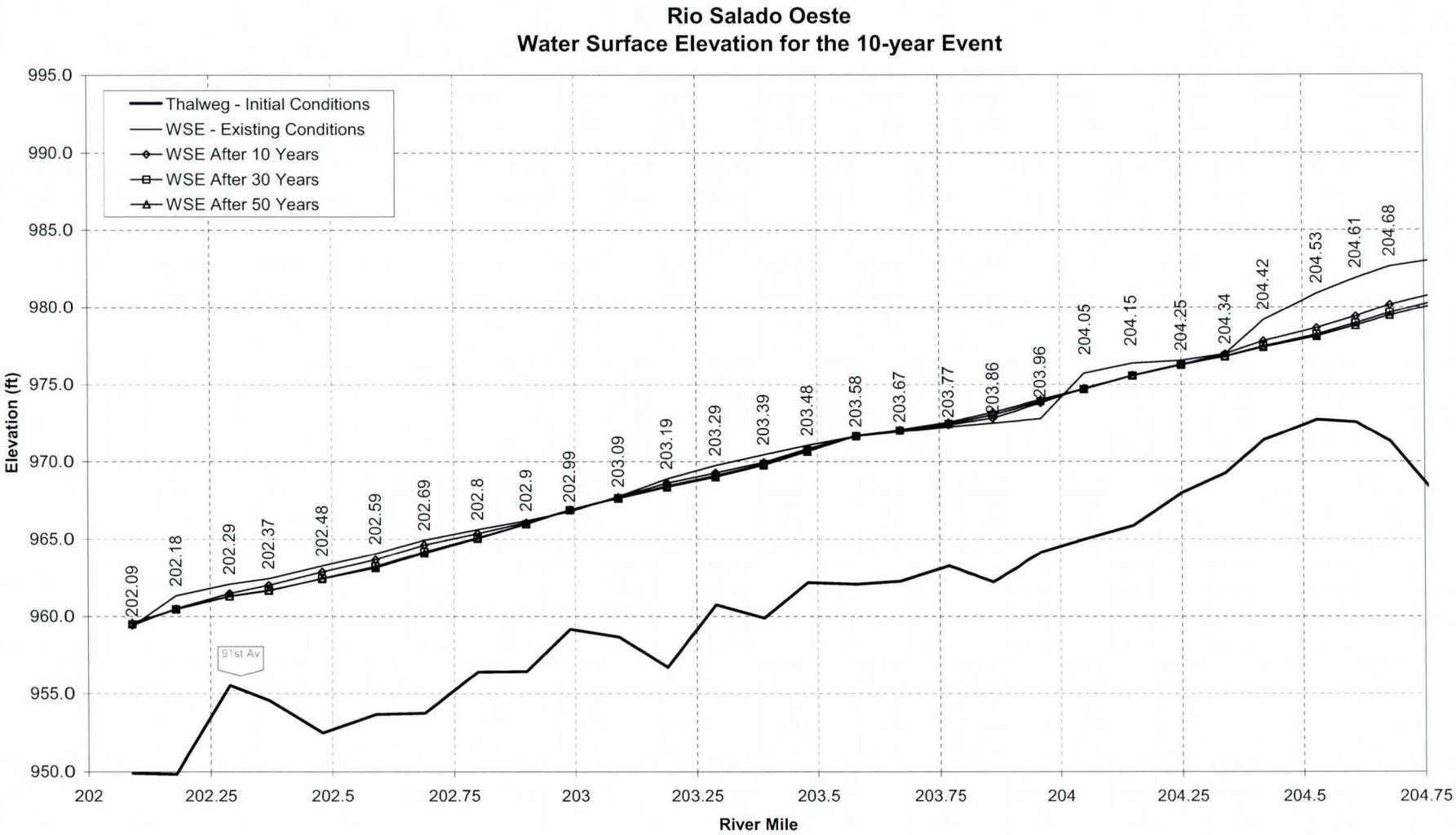
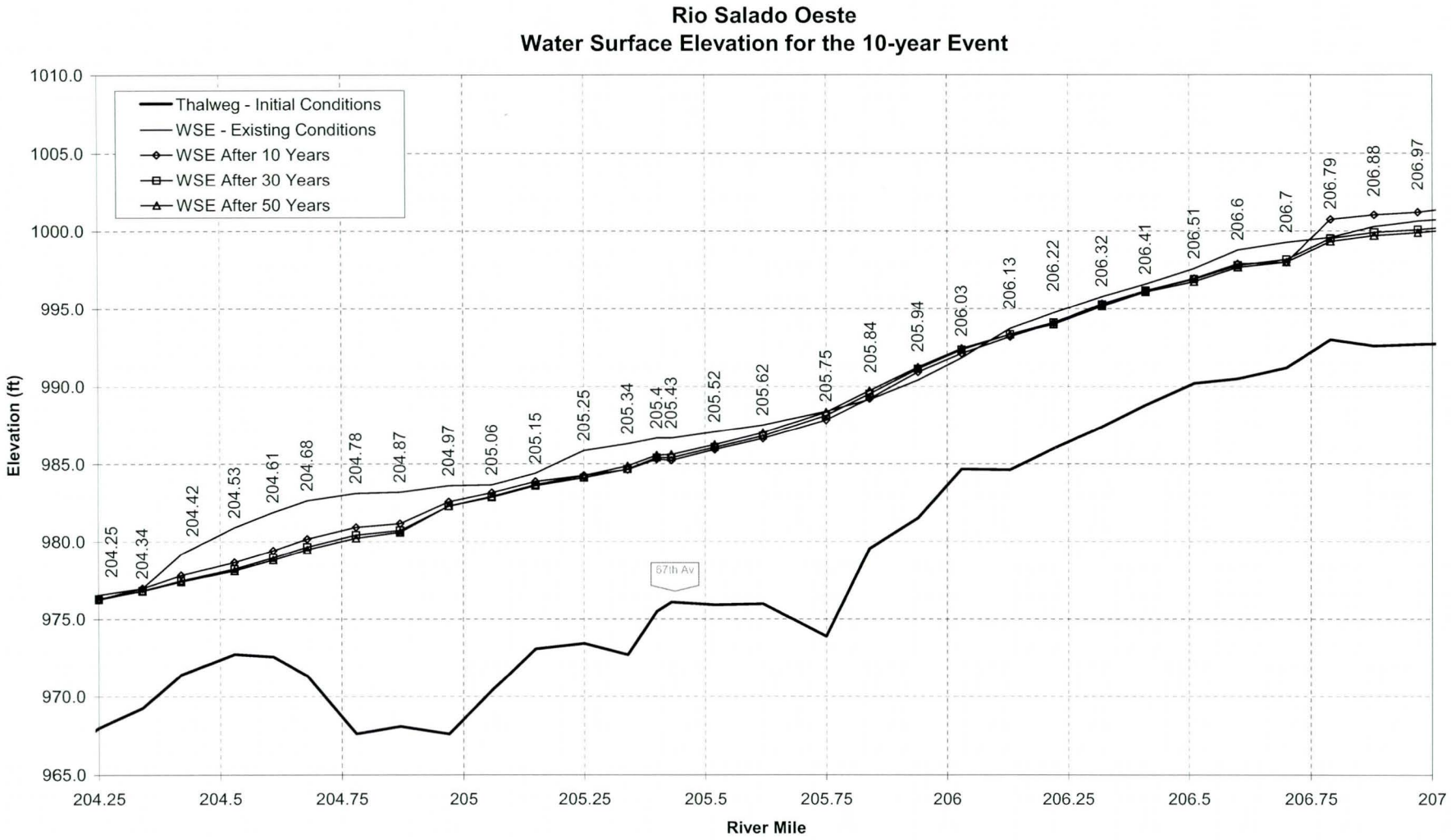


Figure 5-1. Future conditions hydraulic analysis: 10-year flood event.



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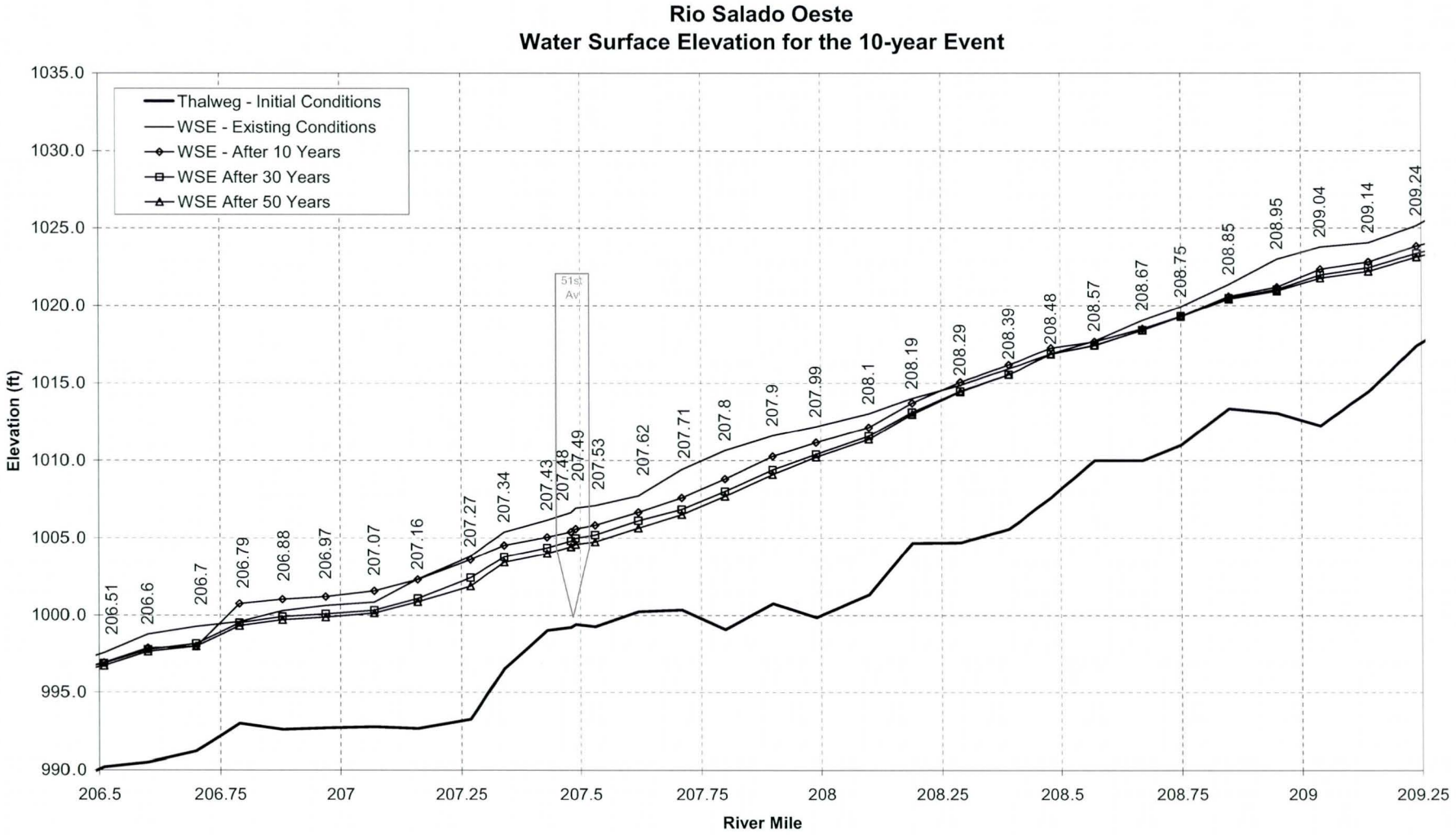

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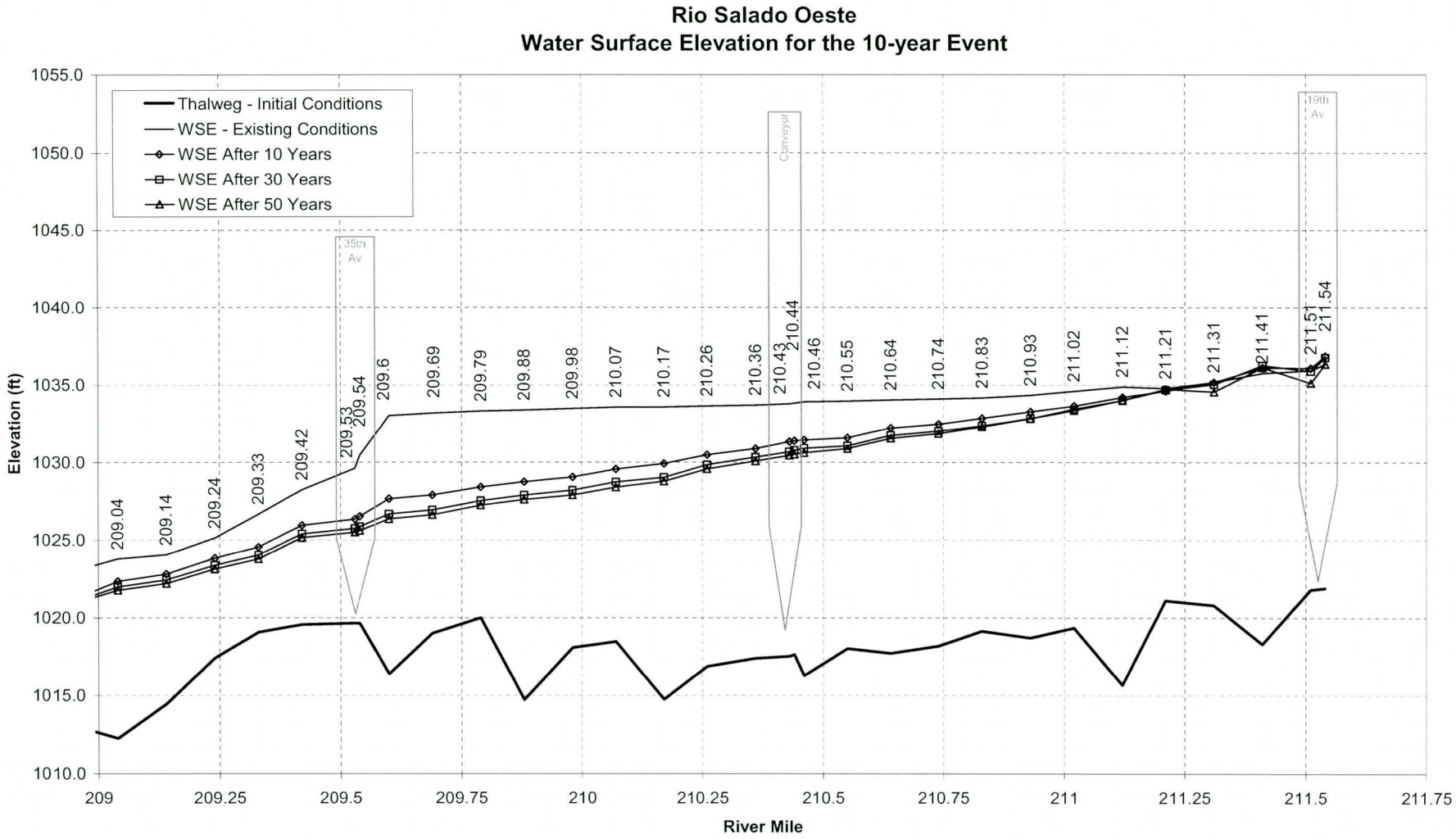

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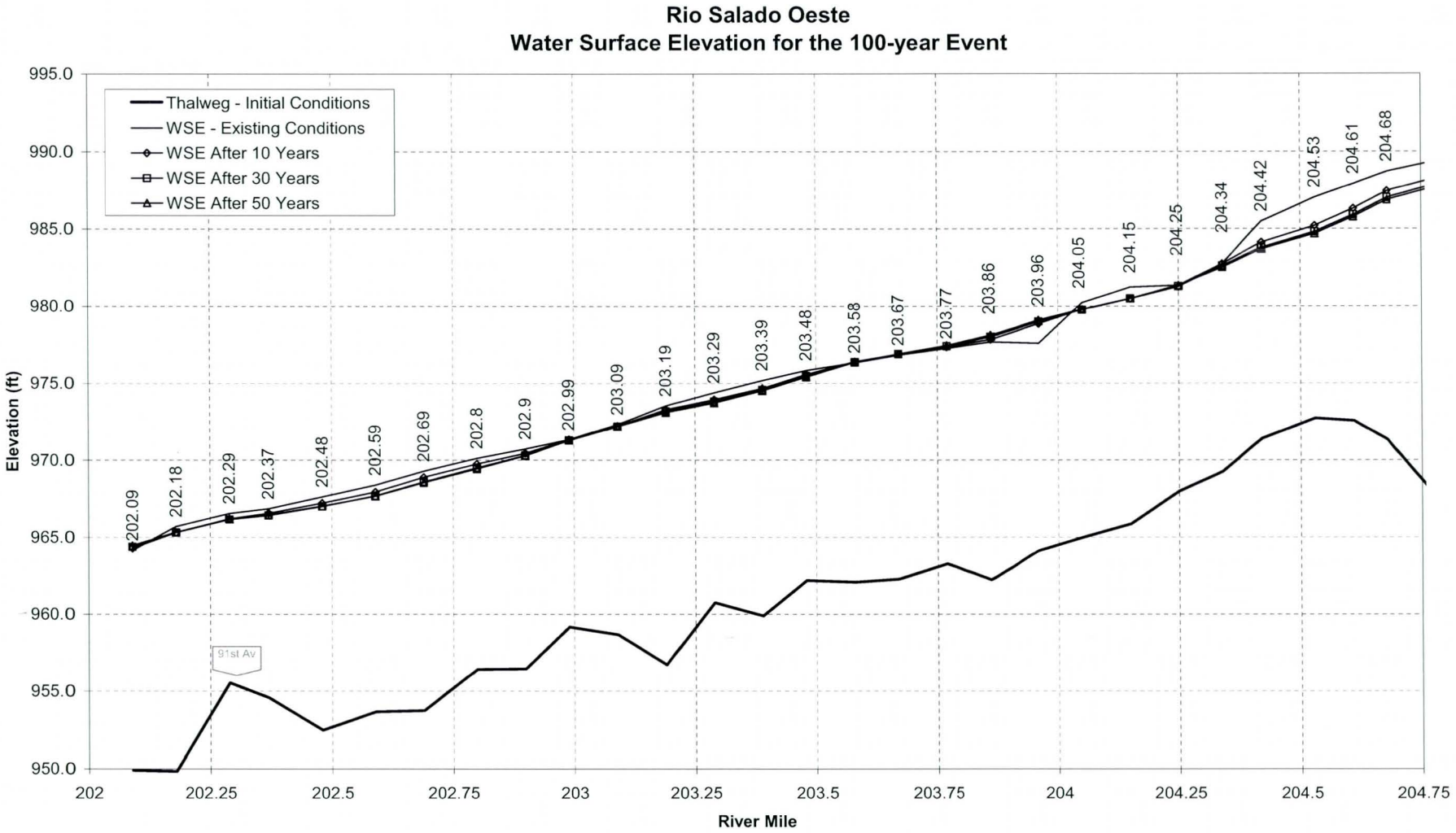
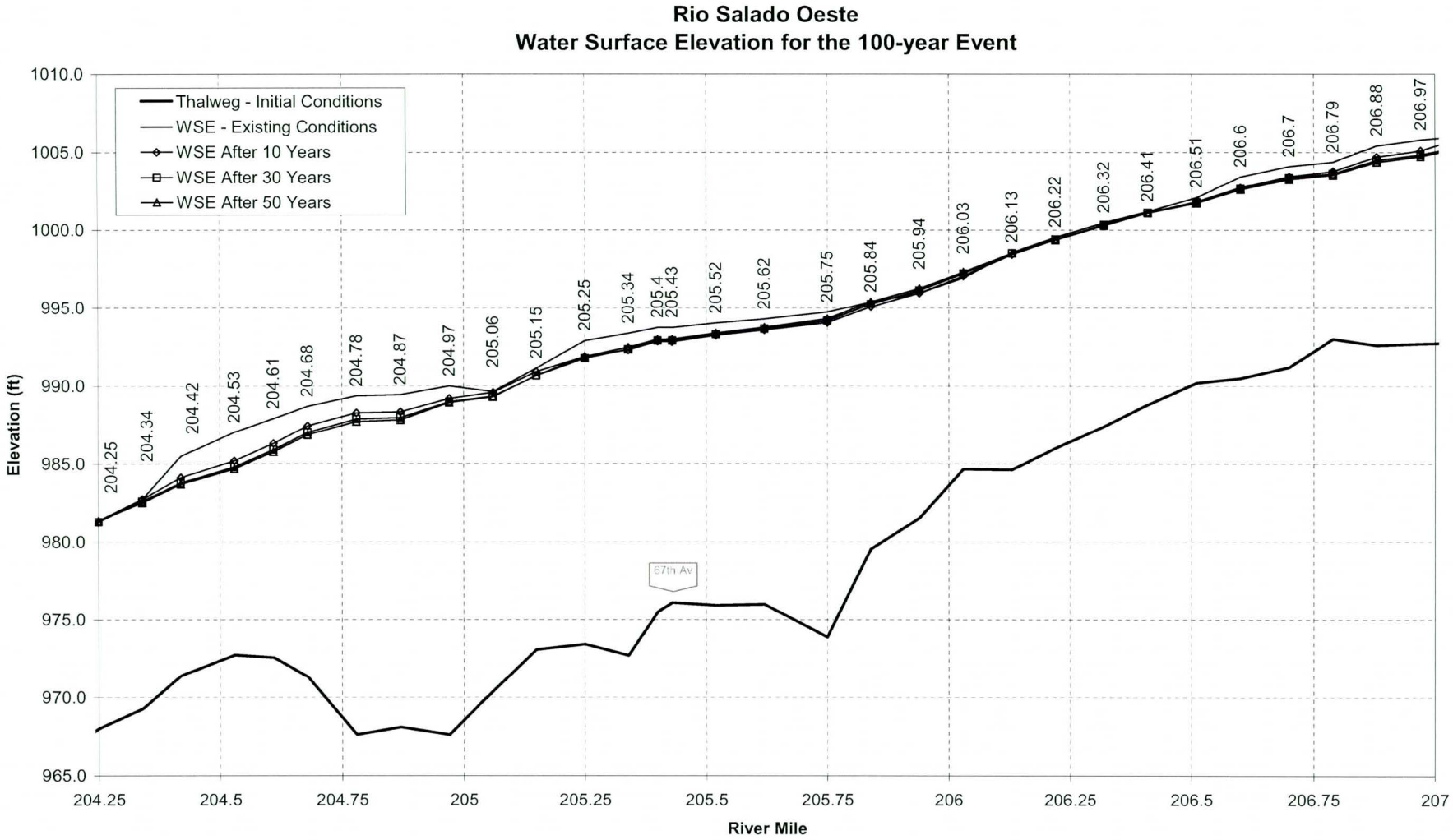


Figure 5-2. Future conditions hydraulic analysis: 100-year flood event.



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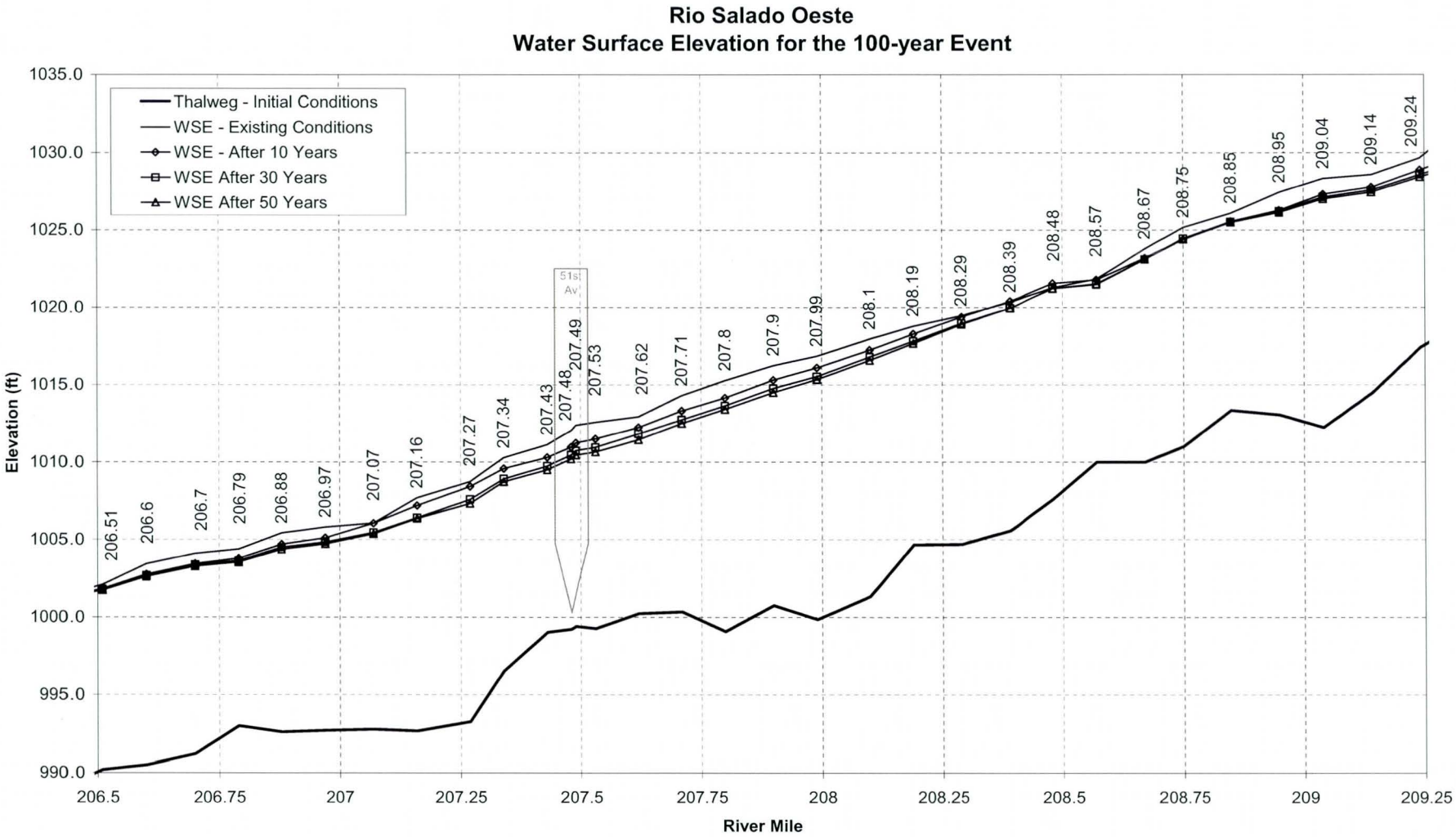

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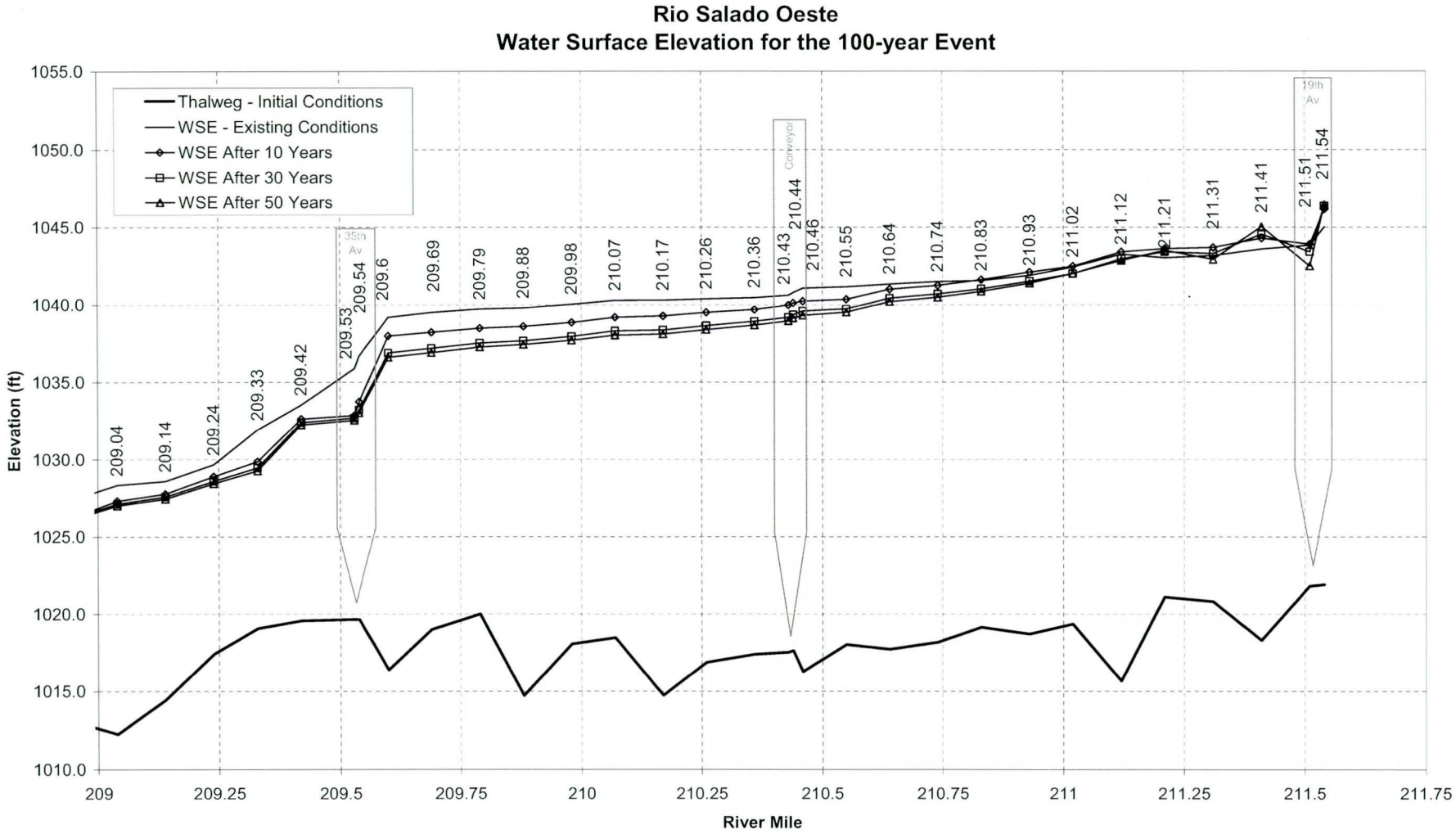

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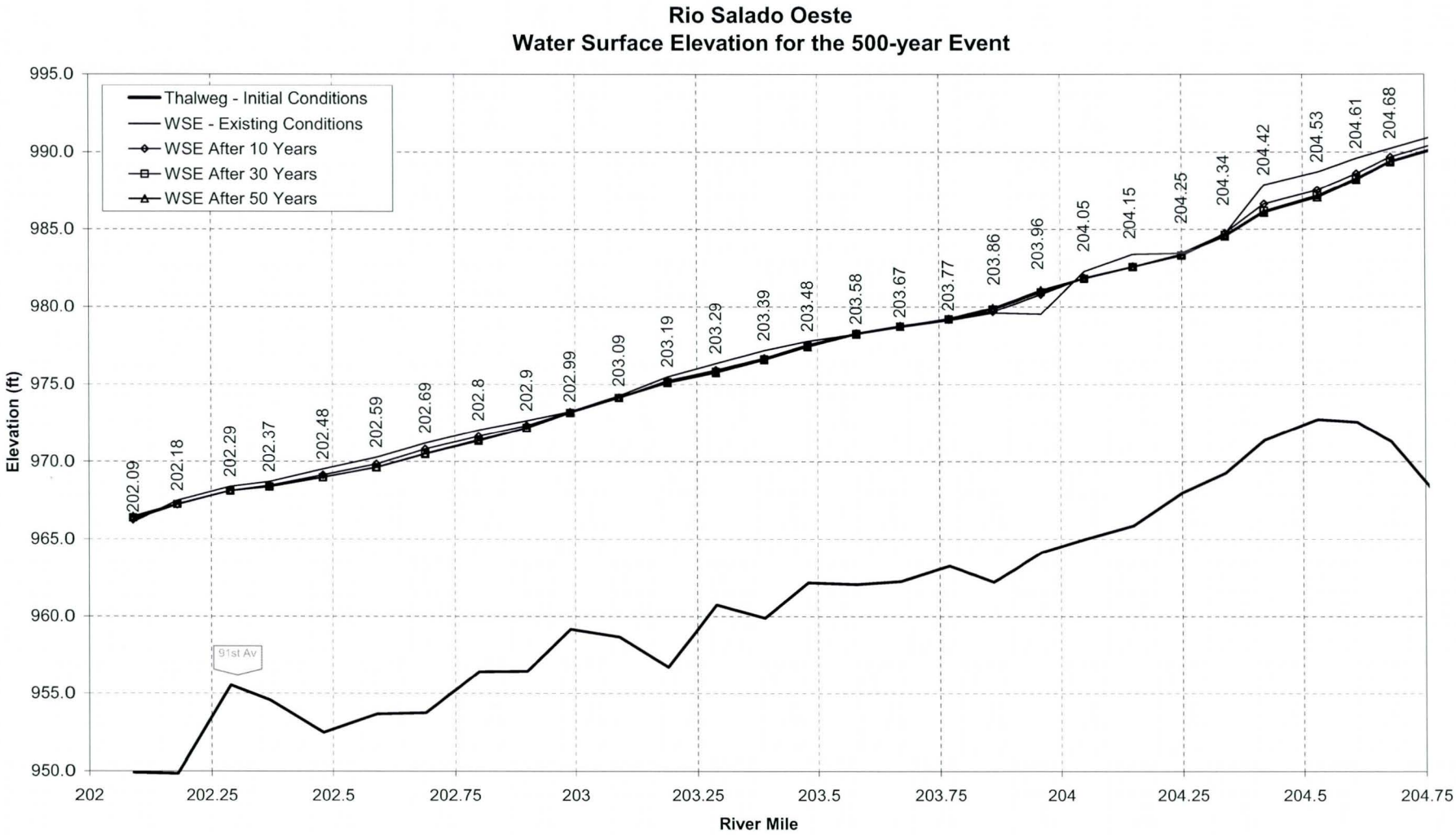
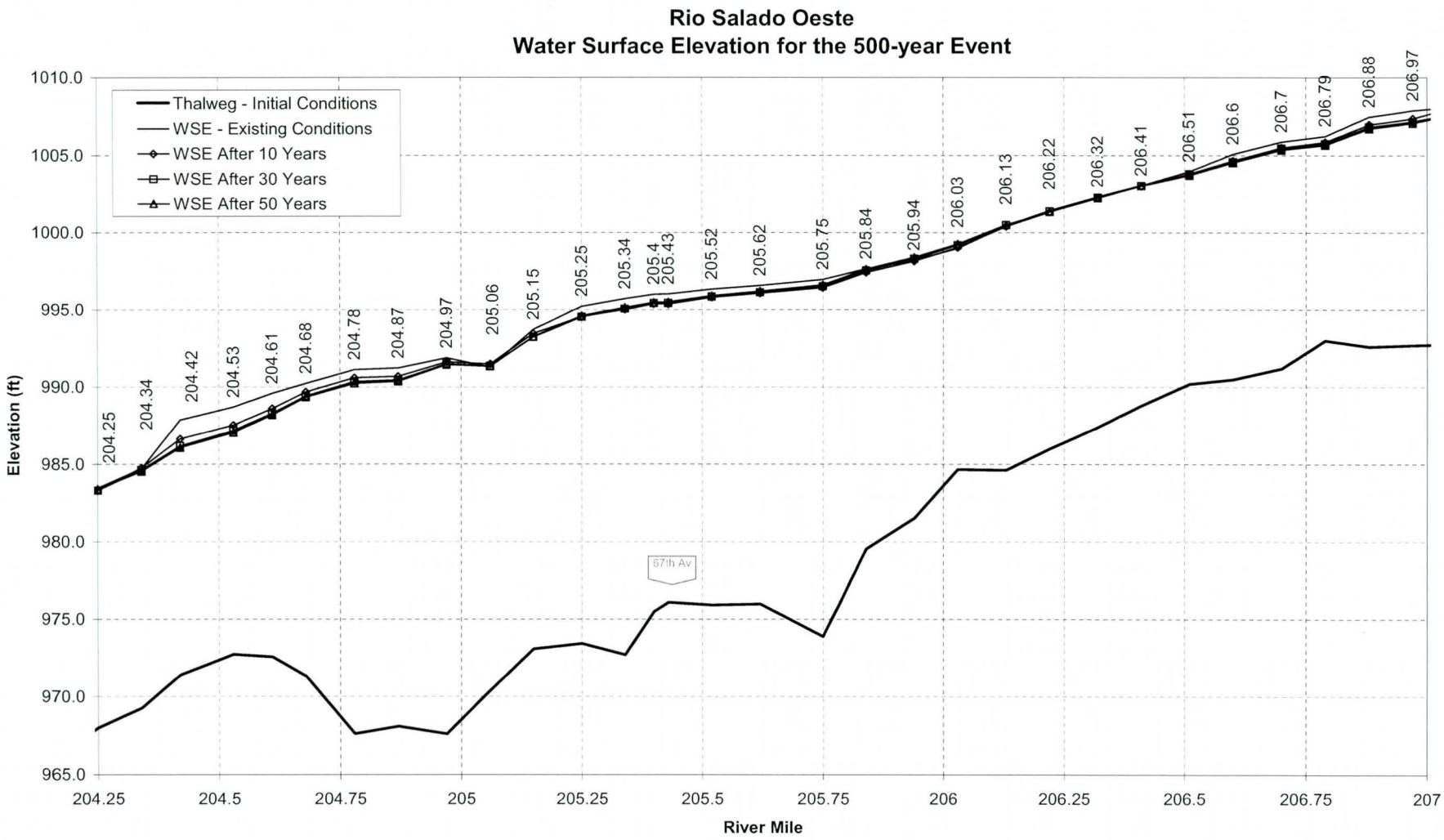


Figure 5-3. Future conditions hydraulic analysis: 500-year flood event.



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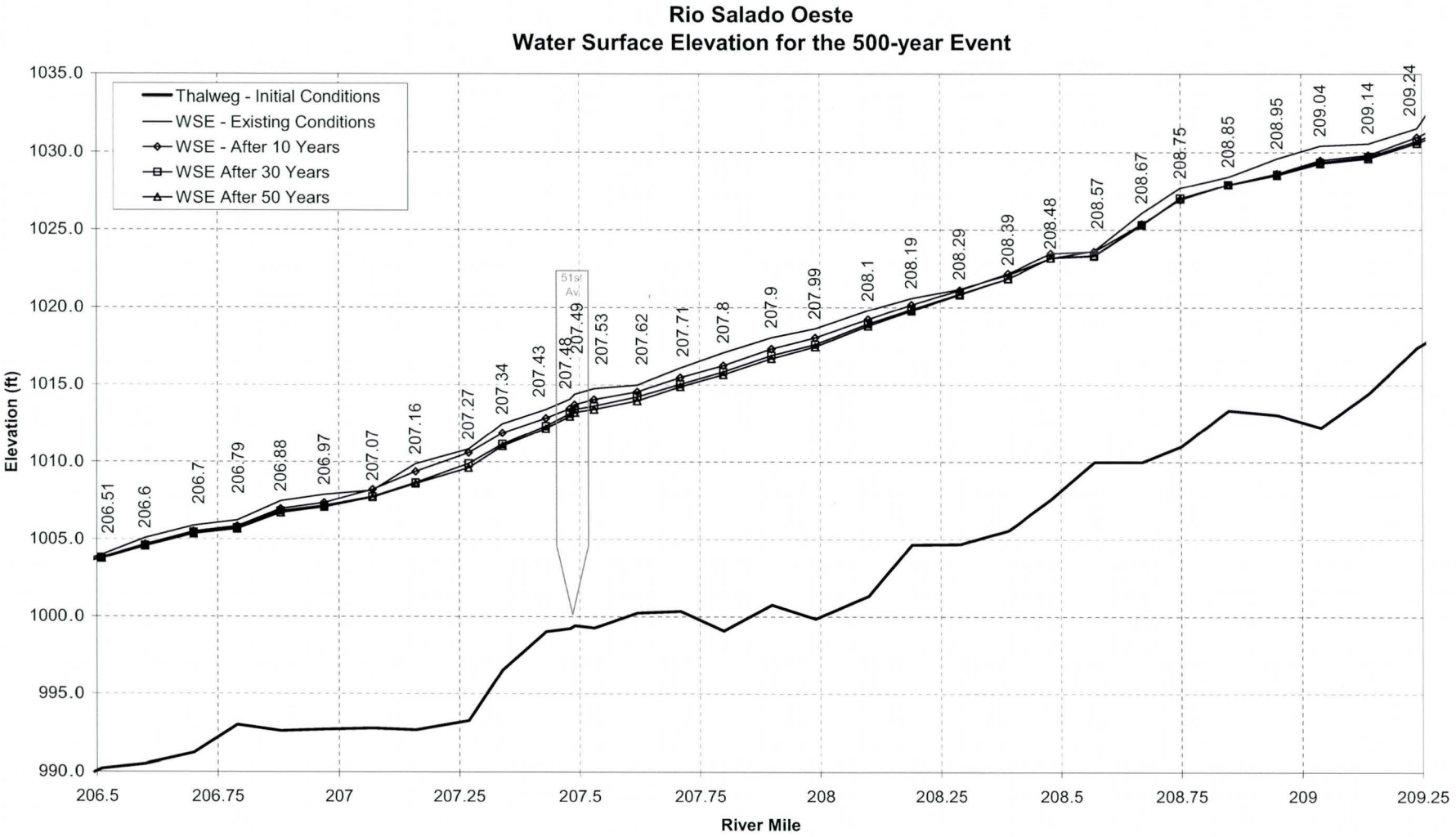

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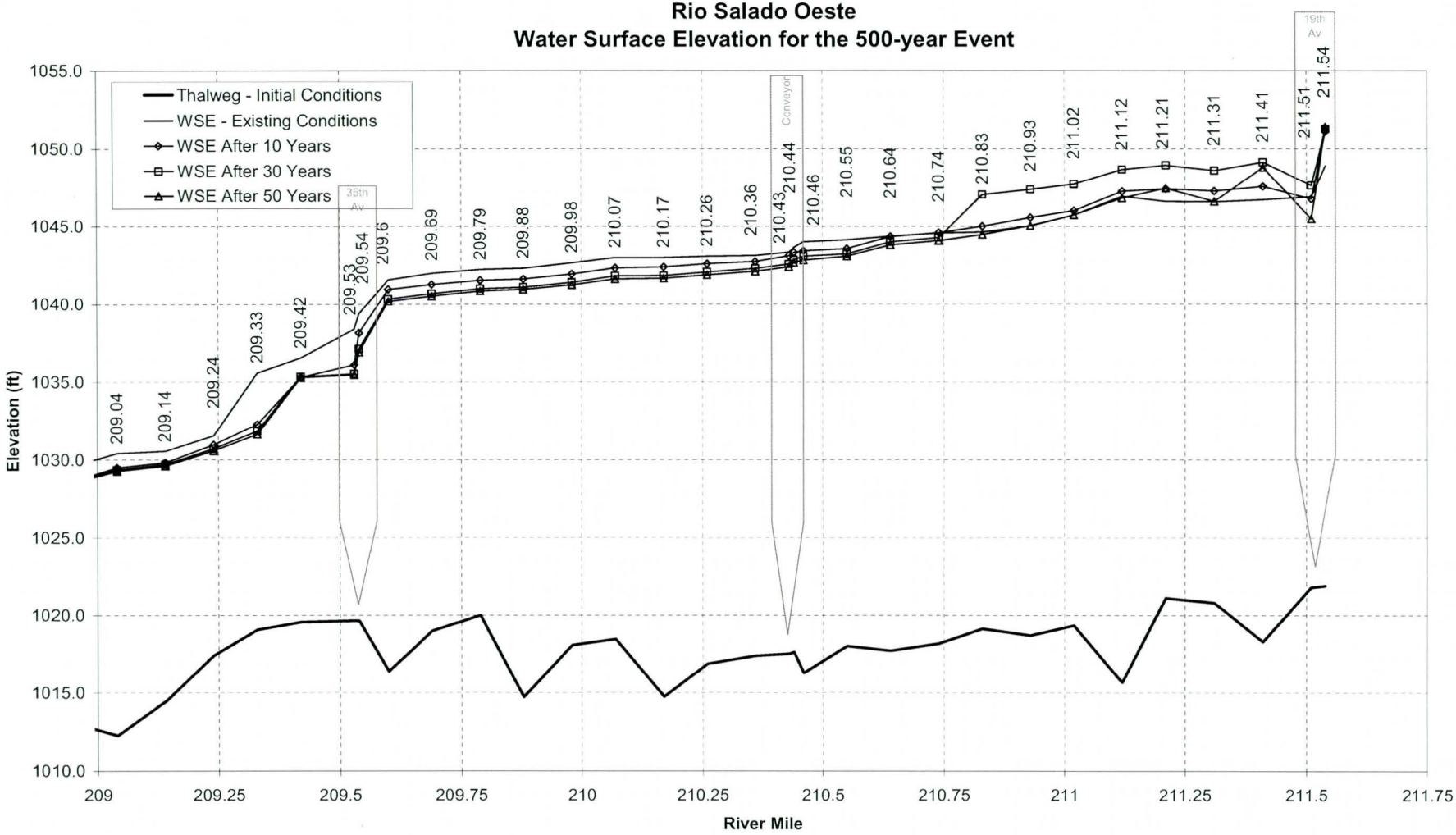

Figure 5-3. ***Continued.***

6. Summary and Conclusions

The results of this hydraulic and sedimentation analysis are intended to support the U.S. Army Corps of Engineers Rio Salado Oeste Feasibility – F3 Phase Study.

A hydraulic model was developed in HEC-RAS to represent existing conditions in the Salt River from 19th Avenue to 91st Avenue. The hydraulic model was used to generate water surface profiles and inundation boundaries for a series of frequency flood events ranging from 5- to 500-year return periods. Small flows are generally contained in the main channel, and only the large flows (100-year and 500-year) occupy significant portions of the floodplains. All the bridges in the study reach but one seem appropriate to pass these large flows without important problems. The exception is the 35th Avenue Bridge, which has a very narrow opening and causes significant backwater and inundation on the overbanks.

The hydraulic model was converted to a sediment transport model in HEC-6T, which was used to simulate sediment dynamics in the study reach during a 50-year time frame. The hydrologic input consisted of flows measured in the Salt River from 1889 through 1938, and corresponds to the "worst case" continuous 50-year period, in terms of both peak flows and storm volumes, in 105 years of record. Results of the sediment transport analysis show that sediment dynamics are more significant in the proximity of mining operations. The study also revealed that downstream of 35th Avenue the reach experienced mainly erosion, while upstream of 35th Avenue the main process was deposition. The bridge cross section suffered severe degradation due to the increase in flow velocity caused by the small size of the bridge opening. In general, most of the changes to the existing conditions geometry took place in the first 10 years of the sediment transport simulation.

The output geometry of the sediment transport model was imported back into HEC-RAS and used to carry out a future conditions without-project hydraulic analysis. The future conditions water surface profiles were then compared to the existing conditions profiles. Results showed the most important differences upstream of the 35th Avenue Bridge. Degradation in the bridge cross section made it possible to increase the conveyance through the bridge opening and reduce the backwater. As a consequence, in the reach upstream of the bridge, the inundation boundaries in the future without-project conditions are expected to stay closer to the channel.

The study includes also a basic geomorphic analysis of the study reach, including historical changes to the river morphology based on the review of historical aerial photographs, and the application of geomorphic relationships. The historical evidence examined here indicates that the project reach is in quasi-equilibrium, although adjustments to bank and thalweg lines within the historical meander belt are possible.

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Maricopa County, Arizona
Feasibility Study

Appendix B

Water Budget and Interior Drainage Report

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532771
LOS ANGELES, CALIFORNIA 90053-2325

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1.0 Introduction and Summary

1.1 Purpose and Scope

The Rio Salado Oeste Restoration Project (Oeste Project) addressed the feasibility of environmental restoration, flood damage reduction, and recreation along the Salt River in Phoenix, Arizona. The success of the Oeste Project is largely dependent on the water budget. The water budget must identify each potential source, quantify the amount and seasonality of flow, and evaluate the quality of the water. The water budget required for this project, however, is more than just an inventory of water sources. It must also identify the water demands and quantify the amount and timing. Restoration projects involve wetlands and riparian vegetation, which have seasonal water demands that are greater in the summer than in the winter. In fact, the water demands vary seasonally. It is necessary to evaluate the water budget on a monthly basis because annual information does not contain sufficient detail to allow consideration of these monthly demands.

The report presents the water budget analysis with project condition for the Oeste Project. Specific objectives of this report are:

1. Collect and research on water use/loss data and plant root zone depth in the project area.
2. Collect water sources information in the project area. Evaluate water sources in term of water quantity, water quality, water rights, availability, and other conditions.
3. Analysis of water budget under the proposed project alternatives. This includes mass balance calculations based on inflow (infiltration and effluent), and plant consumptions (evapotranspiration) for each project alternatives.

1.2 Project Area

The Salt River drains 14,500 square miles of mountains desert terrain in central and eastern Arizona (Figure 1-1) and is the largest tributary to the Gila River. The river rises in the White Mountains of eastern Arizona and flows generally westward to its junction with the Verde River, a northern tributary that drains the edge of the Colorado Plateau near Flagstaff, Arizona. From this junction near the City of Mesa, the Salt River flows westward across the broad Salt River Valley to its confluence with the Gila River, about 14 miles west of the Phoenix Sky Harbor airport. The Phoenix metropolitan area is near the center of the Gila River basin and lies within the lower Salt River Valley. After the junction with the Salt River, the Gila River continues westward and joins the Colorado River near Yuma, Arizona.

Annual average rainfall in the lower Salt River Valley is approximately 8 inches; rainfall at the highest elevations of the watershed ranges up to 14 inches annually (U.S. Geological Survey 1991). Rainfall is less than the evapotranspiration rate in all months of the year. Precipitation is derived primarily from two types of weather systems: summer thunderstorms and regional storms. Summer thunderstorms in July and August develop from the flow of subtropical air masses from the Gulf of Mexico. These two months are responsible for the majority of the total annual rainfall. Regional storms from the Pacific Ocean generate gentle, widespread showers during the fall and winter months. Summers are hot, with daily temperatures exceeding 100° F from mid-June through August. Mean daily temperatures in the summer range from 65° F to 104° F. The relative humidity is low, ranging from approximately 20% to 50%. Winters are mild, with mean daily temperatures ranging from 35° F to 70° F.

The project site is located within the Salt River between 19th Avenue on the east and 83rd Avenue on the west in the City of Phoenix (COP), Maricopa County, Arizona. The north and south study boundaries are located between approximately Durango Street and Southern Avenue for the eastern portion, and Broadway Road and Baseline Road for the western portion. Specifically, the northern and southern boundaries were defined by including all areas between 19th and 83rd Avenues that are within one mile of any segment of the Salt River centerline. Figure 1-1 presents the general study area map. Upstream of the study area is the Phoenix Rio Salado Project area, while downstream of the study area is the Tres Rios Project area. Because the geographic location of these three projects are so close, the water budget related data collected from the Tres Rios and Phoenix Rio Salado Project will be used for the current water budget analysis. Figure 1-2 presents the aerial photo between 19th Avenue and 83rd Avenue and the surface water features. As shown in the map, there are several water ponds along with dry riverbed areas in the study reach of the Salt River.

1.3 Expected Future Without-Project Conditions

Under the Future Without-Project Condition, there will be significant negative changes within the study area. Without agreements to the contrary, there will be insufficient water to support existing areas of riparian and associated floodplain fringe habitats. As development continues throughout the study area and larger Salt River watershed and effluent flows are reallocated, loss of riparian and floodplain fringe habitat is likely to accelerate, and many native species may be increasingly confined to highly isolated pockets. Habitat is expected to decline significantly in both extent and value. The lack of native riparian and associated floodplain fringe habitat will mean the extirpation of many species of native wildlife from the study area.

Flood threats to adjacent unprotected properties are expected to rise as the channel itself becomes more likely to migrate or erode because of reduced vegetation.

1.4 Summary of Future With-Project Conditions

Each of the potential water sources has been evaluated based on the quantity and seasonality of flow, water quality, water rights, and institutional considerations. A few dependable and supplemental sources of water are available to supply the Oeste Project. For some of these, there is sufficient information to quantify the potential supply; however, others will require further monitoring to verify the quantity and seasonality of flow. In addition, the Maricopa County, COP, Salt River Project (SRP), or Central Arizona Project (CAP) could make other water sources available upon institutional commitments. These entities will need to decide if, how much, and when they will commit water to the Oeste Project.

Also, preliminary water demand estimates were calculated for each of alternatives based on hydrologic balance equation with the monthly and annual precipitation, evapotranspiration, evaporation, and infiltration data. A summary of water budget for each restoration alternatives is described below (Table 1-1).

Table 1-1. Summary of Water Budget Analysis

Water Supply Sources	Water Sources (acre-feet/yr)	Water Sources (mgd) (COP)	Water Sources (mgd)
Pumped Groundwater	Pending	1.85	Pending
Stormwater Discharge	~4,503	2	~4.02
Effluent	~17,256	15.1	~15.41
Irrigation Return Flows	~9,905	8	~8.84
Irrigation Drains	~5,320		~4.75
Residual Water Flows from Upstream (Rio Salado Project)	~3,966	3.35	~3.54
Water Demands for Alternatives	**Water Demand (acre-feet/yr)**		**Water Demand (mgd)**
Alt. 2	1,583		1.41
Alt. 3	4,524		4.04
Alt. 4	4,701		4.20
Alt. 5	7,752		6.92
Alt. 5A	9,293		8.30
Alt. 5B	9,234		8.24

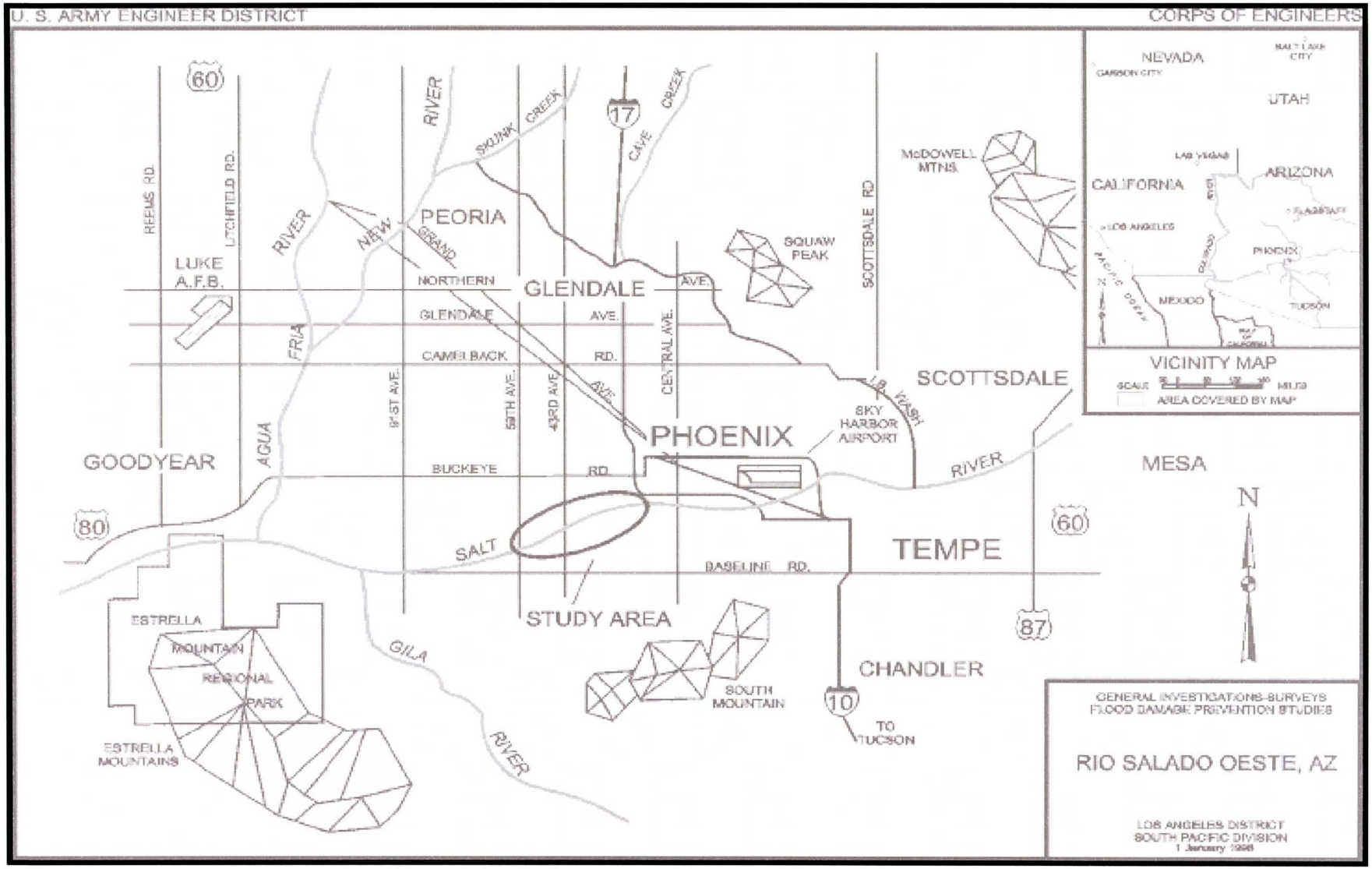


Figure 1-1. Rio Salado Oeste Project General Study Area Map

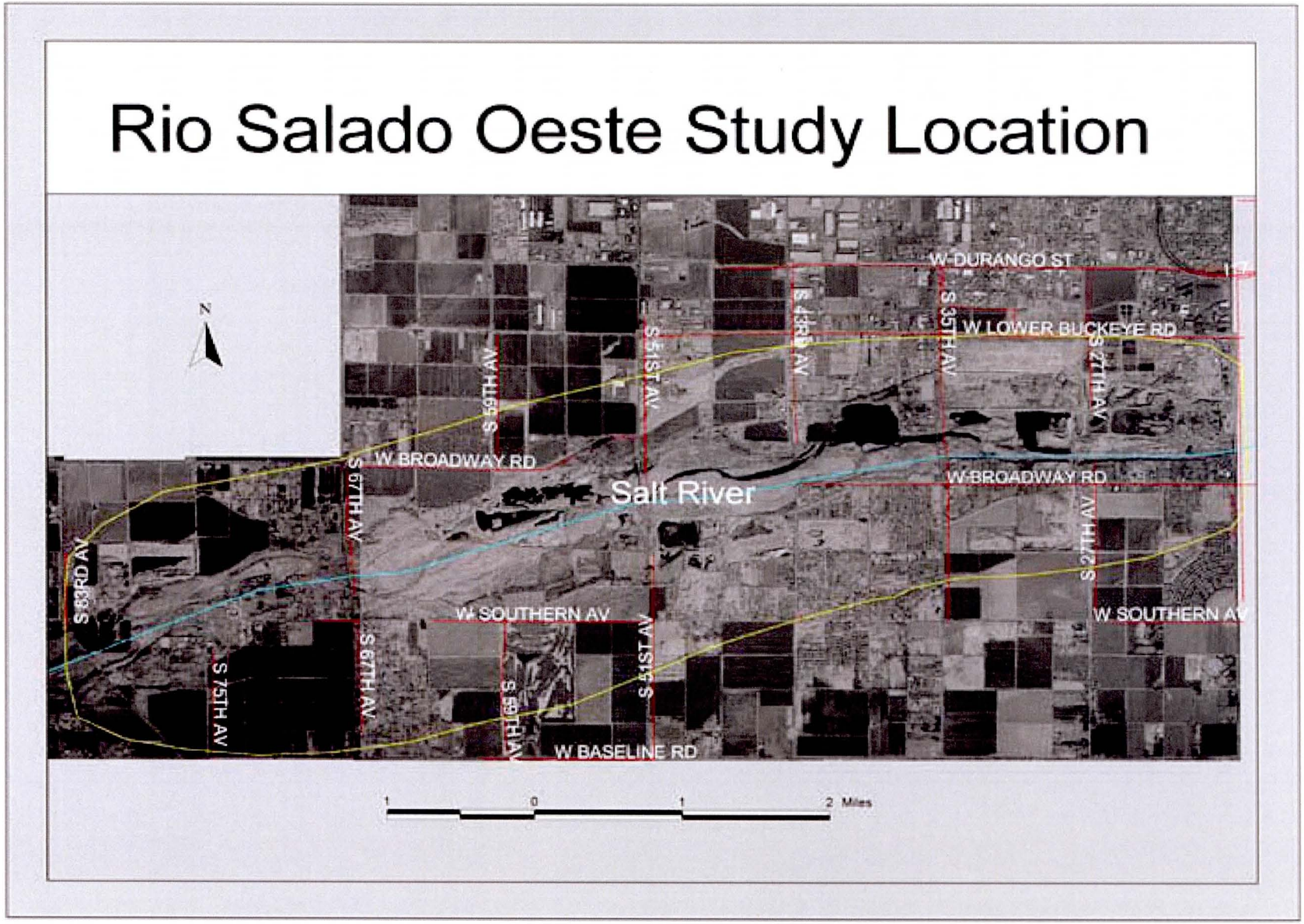


Figure 1-2. Rio Salado Oeste Study Location Aerial Photo

2.0 Water Uses and Plant Root Zone Depth

The hydrologic balance at the Rio Salado Oeste site can be evaluated using the following equation.

$$\mathbf{Q}in + \mathbf{Q}rain = \mathbf{Q}out + \mathbf{Q}evp + \mathbf{Q}eto + \mathbf{Q}inf$$

In the equation, **Q**in and **Q**out are surface water inflow and outflow; **Q**rain is rainfall; **Q**evp is evaporation by the open water; **Q**eto is evapotranspiration by the plant (i.e., the water required by plants for growth, the water that is evaporated by plants, and the evaporation of water from the soil on the immediate area surrounding the plant); and **Q**inf is groundwater infiltration.

As shown in this equation, three primary water demands were identified that are associated with a river restoration project. The monthly and annual water demands were quantified for these water uses as a rate of water used per acre of vegetation or open water. When the project alternatives are finalized, multiplying the per-acre demands by the number of acres for each land use category can project the total demands.

2.1 Evapotranspiration Loss

The water demand of vegetation varies depending on the individual and combination of plant species within a habitat unit. The riparian vegetation in the Salt and Gila River was inventoried as part of the Baseline Ecological Characterization Study (1997). This study, also called the ETI study, inventoried the habitat types and acres of habitat types in the river reach from 67th Avenue on the Salt River downstream to the Buckeye Irrigation Company (BIC) diversion on the Gila River. The ETI study inventoried 4,263 acres within their study area and identified the vegetation communities (Cottonwood-Willow (12.04%), Salt Cedar (32.82%), Marsh (0.38%), Honey Mesquite (3.66%), and Quailbush-Saltbush (5.19%)), desert (3.71%), desert wash (0.14%), open water area (10.39%), and cobble (31.68%, bare riverbed). In the Tres Rios project, the average annual evapotranspiration of river vegetation communities was projected to equal 3.70 acre-feet per acre. This general rate accounted for a mix of vegetation species that is similar to the expected mix for this project (Greeley and Hansen, 2001). The monthly demand is calculated as a percentage of the annual demand and defines the seasonality of the required water supply. Table 2-1 presents the evapotranspiration the Salt River Habitat based on the Tres Rios Project. As shown in Table 2-1, from April through August the plants consume 65% of the annual water usage. The consumptive value shown in Table 2-1 is an average combined value for the Salt River Habitat. The plant evapotranspiration rates associated with the selected vegetation communities are presented on Table 2-2. As shown in Table 2-2, the range of evapotranspiration rate for Marsh is 7.5-16 feet/year and the average evapotranspiration rate for Marsh is 9 feet/year. The average evapotranspiration rates for Cottonwood Willow and Salt Cedar are 6.3 feet/year and 6.1 feet/year respectively.

Table 2-1. Evapotranspiration for Salt River Habitat

Month	Percent of Annual Demand (%)	Evapotranspiration (acre-feet/acre)
January	5	0.185
February	5	0.185
March	5	0.185
April	10	0.370
May	10	0.370
June	15	0.555
July	15	0.555
August	15	0.555
September	5	0.185
October	5	0.185
November	5	0.185
December	5	0.185
Annual	100	3.70

Source: Knight Piesold, Va Shly'ay Akimel Salt River Restoration Project Feasibility Study, Water Budget Report

Table 2-2. Vegetation Evapotranspiration Values

Vegetation Type	Evapotranspiration Range (feet/year)	Evapotranspiration Average (feet/year)
Cottonwood Willow	4.1 – 8.5	8*
Salt Cedar	3 – 9.2	6.1
Honey Mesquite	3	3
Marsh	7.5 – 16	9*
Quailbush-Saltbush	3.2	3.2
Desert	2	2
Desert Wash (Xericriparian)	2	2

Source: Greeley and Hansen, 1998, Tres Rios, Arizona Feasibility Study Salt/Gila Groundwater Analysis
* -COE adjusted for this project.

2.2 Evaporation Loss

The Oeste Project may include open water bodies, constructed wetlands, and marsh areas. In the central Arizona area, the annual evaporation from an open water body averages 72.4 inches or 6.03 feet per year, roughly 6 acre-feet per acre (Table 2-3). However, evaporation is seasonal with the greatest evaporation in the summer months (Cooley, 1970). Constructed wetlands and marshes are open water bodies in which the surface area is shared by water and vegetation. The consumptive use of these areas closely approximates the open water body evaporation rate; thus, the evaporation rate can be used to calculate the water demand for the open water body, constructed wetland, or marsh.

Table 2-3. Evaporation from Open Water

Month	Evaporation (acre-feet/acre)
January	0.183
February	0.258
March	0.417
April	0.550
May	0.750
June	0.825
July	0.825
August	0.750
September	0.575
October	0.442
November	0.275
December	0.183
Annual	6.03

Source: Knight Piesold, Va Shly'ay Akimel Salt River Restoration Project Feasibility Study, Water Budget Report

2.3 Infiltration Loss

The Tres Rios Project included wetland design. Two demonstration wetlands were constructed during the Tres Rios Project, the Cobble Site and Hayfield Site. The long-term average infiltration rates of the Tres Rios Cobble and Hayfield Site wetland cells are shown in Table 2-4. As shown in the table, cell 1 of the Cobble Site is an unlined cell; all other are lined cells use soil liner. The Cobble Site cells are 2.2 acres each and the Hayfield Site cells are 3 acres each. Compared to evaporation, infiltration is a major water loss in the system. The infiltration rates presented in Table 2-4 are long-term average values. Infiltration losses

are solved for from the water balance. At the Hayfield Site Basins, infiltration losses have been extremely stable since startup. This site is characterized by fine sediments deposited during flood events of the Salt River. Long-Term average infiltration loss from Basin H1 = 0.06 ft/d, while Basin H2 = 0.09 ft/d. These rates are very similar to that experienced by the lined Cobble Basin C2 = 0.06 ft/d. The other Cobble Basin (C1), located within the Salt River Floodway and constructed on well-draining sand, gravel, and cobble has behaved differently. In the long-term, C1 has lost an average of 0.74 ft/d to subsurface flow. This was substantiated in April 1997 when subsurface sampling devices were installed by U.S. Geological Survey (USGS) and Tres Rios staff. At that time, the subsurface was saturated to approximately 3 feet below the sediment surface, and then unsaturated to the local groundwater table (approx. 13 feet below ground surface.). Figure 2-1 presents an infiltration rate history from October 1995 to April 1997 for the Tres Rios Cobble Site.

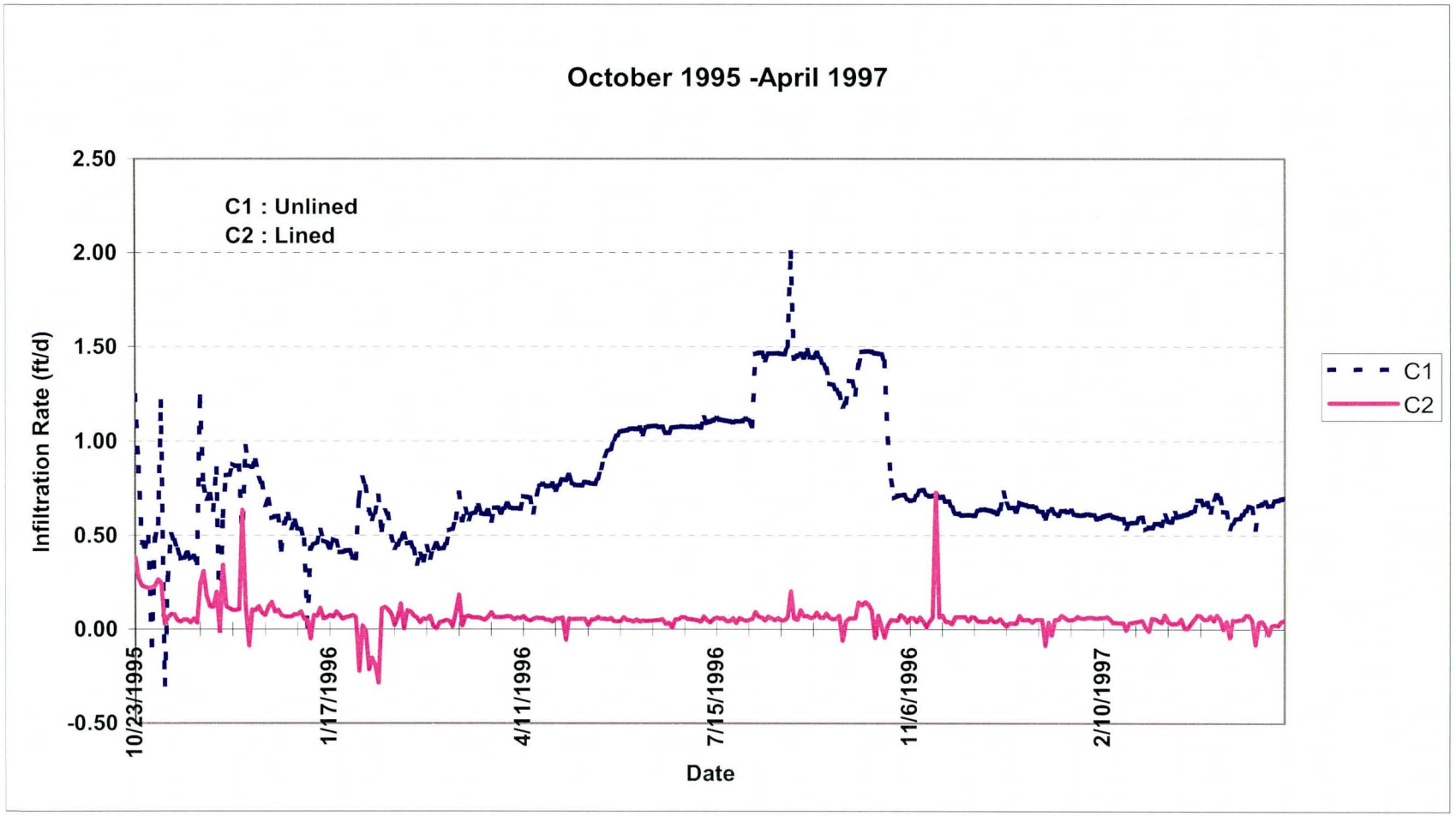
Table 2-4. Infiltration Rates for Tres Rios Demonstration Wetland Cells

	Cobble Site		Hayfield Site	
Cell	C1	C2	H1	H2
Lining	unlined	lined	lined	lined
Size(acre)	2.2	2.2	3.0	3.0
Long Term Average Infiltration Rate (ft/d)	0.74	0.06	0.06	0.09

Source: Tres Rios Demonstration Constructed Wetland Project, 1997

2.4 Plant Root Zone Depth

The root zone depth of vegetation is also an important criterion when assessing the adequacy of water supplies to meet demands. If the roots of plants have access to groundwater, it reduces the irrigation demand. Plants have different water requirements depending on the phase of development; seeding, sapling, and maturity. Table 2-5 (Wass, 2002) presents the root zone depth information for several species common within the Salt River environment. The table also presents the desirable ranges of inundation depth for aquatic plants. These data can be used to assess in-situ groundwater and to calculate irrigation demands during alternative development.



Source: WASS Gerke + Associates, Inc

Figure 2-1. Tres Rios Cobble Site Infiltration Rate History

Table 2-5. Riparian and Constructed Wetland Vegetation Requirements

Vegetation Type		Seedling Establishment	Sapling Growth	Mature Survival
Trees (Groundwater Depth[1] Requirements)				
Cottonwood	Populus freemontii	Moist soils in March/April	0.66 to 6.6 feet	16.5 feet
Willow	Salix gooddingii	Moist soils in April/May	0.66 to 6.6 feet	10 feet
Mesquite	Prospis sp.	< 4 inches	3.3 to 33 feet	< 33 feet
Salt Cedar	Tamarix sp.	Moist soils in May to September	0.66 to 8.2 feet	33 feet
Common Aquatic Plants (Inundation Depth[1] Requirements)				
Shallow Emergent Marsh	Scirpus validus, Scirpus americanus, Scirpus acutus, Sagittaria greggii, Sagittaria latifloa, Alisma triviale, Typha latifola	Saturated soils to 2 inches	Saturated soils	Saturated soils to < 2.6 feet
Deep Emergent Marsh	Typha domingensis, Scirpus californicus, Phragmites australis	Saturated soils to 2 inches	Saturated soils	Saturated soils to < 4.9 feet
Floating Aquatic	Hydrocotyle sp., Ludwegia palustrus, Polygonum hydropeperoides, Potomogeton sp. Rorippa, Nasturtium-aquaticum	Moist soils to 4 inches	Moist soils to 8 inches	Moist soils to 8 inches
Transitional Marsh Plants	Eleocharisparishii, Eleocharis macrostachya, Equisetum laevigatum or similar sp., Cyperus niger, Cyperus laevigatus, Cypeus erythohizos or similar sp., Juncus balticus, Juncus bufonius, Juncius tenurs var. Dudleyi, Juncius inetrior, Juncus torreyi, or similar sp., Heteranthera limosa, Anemopsis californicus	Moist soils to 4 inches	Moist soils to 4 inches	Moist soils to 4 inches

Depth[1]: Depth from ground surface to water table.
Source: WASS Gerke + Associates, Inc.

3.0 Water Sources

The success of a habitat restoration project such as the Oeste Project is largely dependent upon the amount and quality of water that is available to sustain the riparian habitat. A sufficient and reliable supply of suitable water must be developed to support the aquatic, wetland, and upland plant species. Several potential water sources were identified for the Oeste Project area; two relate to groundwater resources and six involve surface water. Groundwater can either be utilized by plant roots in place (in-situ), or it can be pumped to the surface and distributed to the restoration project. These represent the two potential groundwater sources identified. The potential surface water sources identified include Salt River flood flows, stormwater discharges, effluent, irrigation return flows, irrigation drains, and discharges from sand and gravel mining operations. These sources were each evaluated based on the quantity, reliability, and quality of flow available for habitat restoration. In general, the sources were classified into the following four categories.

Dependable source. A source is dependable if it is available on a continuous basis to meet the water demands of the habitat area and has acceptable water quality. Dependable sources constitute the baseline water supply.

Supplemental source. A source may be considered supplemental if it is available to augment the dependable baseline source. This could include infrequent and unreliable flows that can be put to beneficial use when they are available but cannot be relied upon as a dependable base flow. The supplemental flow must also have good water quality.

Problem Source. Problem sources must be accounted for but may not be suitable as a water supply for the Oeste Project. These flows may inhibit the restoration project by potentially damaging restored vegetation or hindering the water quality within the Salt River.

Unacceptable Source. A source is considered unacceptable if it has poor water quality or is not desirable for riparian habitat restoration.

3.1 In-situ Groundwater

3.1.1 Description of Source

In-situ groundwater is defined as groundwater that can be utilized, in place, by riparian vegetation. For this to occur, the groundwater table must be within the root zone depth of the desired plant species. The depth to groundwater (Figure 3-1) as well as the water table fluctuations are important factors for establishing and maintaining riparian habitat.

Historically, the Salt River was a perennial stream and supported riparian and wetland vegetation. However, water storage and diversion projects have depleted the Salt River flows downstream of Granite Reef and, in turn, have decreased the amount of water that gets recharged into the alluvial aquifer. Today static water level is relatively shallow, ranging from 20 to 50 feet below ground surface (bgs) within the Salt River channel to 60 to 80 feet bgs north and south of the river. Data indicate that over the past 25 years groundwater elevations in the study area have decreased approximately 15 to 20 feet. In a few areas the water table is still sufficiently close to the surface so that riparian vegetation can access this water through its root systems. These habitat areas in the Salt River suggest that in-situ groundwater may be a potential source of water for the habitat restoration project.

3.1.2 Quantity Analyses

Depth to groundwater has fluctuated greatly since development of the Salt River Valley began in the late 1890s. Initially, diversion of water from the river for irrigation led to a rise in the water table. Canal seepage locally raised the water table as much as 20 feet above the natural water table.

The City of Phoenix operates the 23rd Avenue Waste Water Treatment Plant (WWTP). Reclaimed water produced by this plant is reused by the Roosevelt Irrigation District (RID), and Peterson Farms for irrigation water. When RID is taking the reclaimed water, there is no flow discharged to the Salt River. RID diversions are seasonal, following the demand for irrigation. During winter, the reclaimed water from the WWTP is discharged into the Salt River. Though Peterson's use is only about 1mgd, approximately 10 mgd must now be diverted via a canal to meet Peterson's demand. The excess water now infiltrates along the canal or is discharged back to the Salt Rivet between 43rd and 51st Avenue. The discharge percolates into the riverbed, but as the discharge season progresses, the flow extends downstream. When hydrologic conditions permit, the flow from the 23rd Avenue WWTP can continue downstream beyond the study area.

These areas receive some groundwater recharge from WWTPs, irrigation seepage, storm drains, irrigation drains, and underflow from the Gila River. The result is that the general groundwater depth beneath the Salt River ranges from 20 to 50 feet below the river channel for the majority of the study area

3.1.3 Quality Analyses

Long-term irrigation practices and landfills within the Salt River Valley have historically influenced water quality in the upper alluvial aquifer. High salinity, chloride, and nitrate concentrations were occasionally found in the shallow groundwater near irrigated or formerly irrigated areas. Also, some landfills have historically caused elevated levels of volatile halocarbons. Since groundwater quality monitoring began in the 1980s, the water quality has significantly improved. Monitoring results from the first quarter of 2002 indicate that there were no exceedences of the maximum contaminant levels for volatile halocarbons in any of the sampled wells (Kenneth D. Schmidt and Associates, 2002). In addition, the concentrations of many volatile halocarbons were the lowest since monitoring commenced.

It should also be noted that there are no superfund sites within the restoration project area. In-situ groundwater is generally suitable for agricultural uses and should be adequate for the habitat restoration project.

3.1.4 Water Rights

Consumptive use of groundwater by vegetation (in-situ groundwater) is not included in state groundwater right categories. There are no water rights to define or restrict the direct use of groundwater by vegetation for habitat restoration projects in central Arizona. In-situ groundwater, when available, can be used as a part of the Oeste Project water supply.

3.1.5 Assessment of In-situ Groundwater

In-situ groundwater can provide a reliable source of water for the open water area formed by effluent and irrigation return water. In this area, seepage from the open water area forms a local perched water table near the surface. Currently, wetland plant species are growing along this reach of the river and extend along the water body. This source of water could be used to restore native riparian vegetation in this area. This local supply is considered a dependable water source for vicinity of open water areas.

The intent of this project is to restore habitat areas for cottonwood, willow, and mesquite trees; these species require that the depth to groundwater be less than approximately 30 feet for survival. Therefore in-situ groundwater is considered to be an unacceptable source of water for areas of the Oeste Project where the depth to groundwater is more than 30 feet.

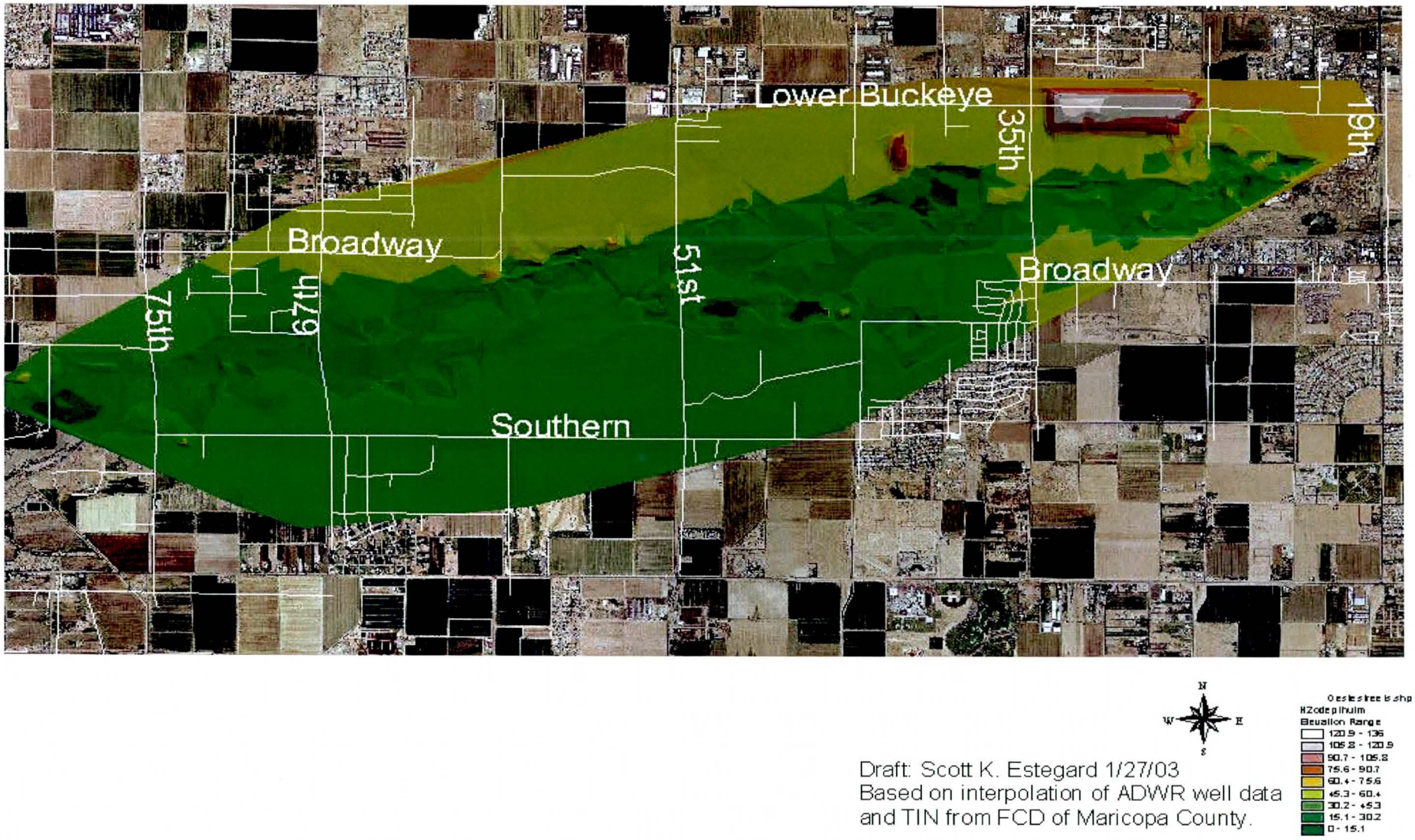


Figure 3-1. Depth to Groundwater

3.2 Pumped Groundwater

3.2.1 Description of Source

Pumped groundwater is groundwater that lies below the root zone of the desired vegetation and must be pumped to the surface to be utilized. After the water is pumped to the surface, a distribution system must be developed to deliver this water to certain areas of the habitat restoration project. There are several legal and institutional implications that pumped groundwater could have on the project.

3.2.2 Quantity Analyses

Groundwater in sufficient quantity to supply water wells is present throughout the majority of the Oeste Project area. This is demonstrated by the location and number of existing wells. Some of these wells are shown on Figure 4 of the Groundwater Quality and Hydrogeology Report (URS, 2002).

Pumped groundwater has been a reliable source of water for many years throughout the Salt River Valley including the Oeste Project area. These wells range in capacity from relatively small wells that produce 10 to 20 gallons per minute (gpm) to large irrigation wells producing more than 6,000 gpm.

Pumped groundwater can be provided using existing wells or new wells. The advantage of using an existing well is that the costs associated with constructing the well have been committed. The constraint is that the location of some wells requires construction of a distribution pipeline and may require a booster pump. The advantage of drilling a new well is that it could be located at a point within the project to minimize distribution pipeline costs. The constraints are the costs associated with constructing a new well and meeting the state regulations.

Pumped groundwater is available on a continuous basis and in sufficient quantity could provide a dependable supply of suitable water for the restoration project. The primary problem associated with using pumped groundwater is the impact that this pumping may have on other nearby groundwater wells.

3.2.3 Quality Analyses

General groundwater quality data were obtained from databases including the Arizona Department of Water Resources (ADWR) Groundwater Site Inventory (GWSI) database, Arizona Department of Environmental Quality (ADEQ) water quality database, and USGS National Water Information System (NWIS) water quality database. Other data were obtained from SRP, RID, the Phase 2 Report, and COP. The locations of wells with groundwater quality data that was useful for this report. For this evaluation, the most recent data available used ranged from 2001 to as far back as 1983.

The above sources provided limited data for nitrates, volatile organic compounds (VOCs), metals, and pesticides. The majorities of these data were below detection levels or detected at concentrations below groundwater quality standards.

The ADWR Well Registry database and Imaged Records database were queried to determine the location, owner, and purpose of monitor wells within the study area. This information was used to identify sites having possible groundwater quality concerns. Further information about sites of particular concern (e.g. landfills, Leaking Underground Storage Tank (LUST) sites, etc.) was obtained from the well owners and ADEQ.

Groundwater conductivity within the study area ranges from about 1,000 to 3,500 micromhos per centimeter (μmhos/cm), which corresponds with an estimated range in TDS of 600 to 2,500 parts per million (ppm). Based on data from wells screened in the Upper Alluvial Unit (UAU) and part of the Middle Fine-Grained Unit (MFU), there is a general trend of increasing conductivity from roughly 1,200 μmhos/cm in the northeast to over 3,000 μmhos/cm in the southwest part of the study area.

Nitrate concentrations are generally less than 10 milligrams per liter (mg/L), with the exception of wells located in the southwestern part of the study area where concentrations are as high as 13.8 mg/L. There is no apparent difference in the concentration of nitrate in the shallow wells versus the deeper wells. Quarterly data from the 23rd Avenue WWTP and the 27th Avenue Landfill monitor wells show that the nitrate concentrations can vary by as much as 4 ppm from quarter to quarter. The changes in nitrate concentration do not appear to be seasonal.

As stated above for in-situ groundwater, groundwater from all alluvial units is generally suitable for agricultural purposes and is expected to be adequate for this habitat restoration project.

3.2.4 Water Rights

The use of groundwater needs to be permitted by the state. Irrigation Grandfather Rights establish the right to pump and use groundwater for the growing of food and forage crops. These rights were established in 1980 on lands that were irrigated before that time and are tied to the specific parcels of land. The water pumped pursuant to the Irrigation Grandfather Right must be used on the land that was originally decreed for that right. The water cannot be used for irrigation on other lands. The lands within the Salt River channel do not fall into the Irrigation Grandfather Right category. Therefore, groundwater pumped pursuant to an Irrigation Grandfather Right is not applicable to the Oeste Project.

COP can pump groundwater pursuant to a Service Area Right. This type of groundwater right is issued to public supply water providers. It allows the water provider to pump the quantity of water needed to meet a given demand, subject to water conservation requirements. The Arizona Groundwater Code dictates that, except in times of surface water drought, all groundwater pumped by an entity, such as COP, with an Assured Water Supply designation must be replenished through the use of long-term storage credits, Irrigation

Grandfather Right extinguishment credits, membership in the Central Arizona Groundwater Replenishment District, annual storage and recovery, or depletion of its groundwater allowance. Groundwater pumped under this right for habitat restoration would count toward COP's annual pumping total and would entail a depletion of their store of credits, making less water available to meet the needs of other current and future water users. Long-term storage credits and Irrigation Grandfather Right extinguishment credits are potential sources of water for the project but require an agreement between the parties to finance their creation.

3.2.5 New Water Well Development

If new wells are to be drilled, permits must be obtained from the ADWR. An impact study is required for all wells with a pump capacity of 500 gpm or greater. The study must demonstrate that the new well will not produce an additional 25 feet of drawdown in existing wells after five years of pumping. If the additional drawdown is less than 10 feet, the permit can be issued. If the drawdown is greater than 10 feet but less than 25 feet, the owner of the new well must obtain a release letter from the owner of each impacted well stating that an agreement has been reached to mitigate the drawdown. This can be a time consuming and expensive process.

Drilling new wells to pump groundwater is feasible and should be considered if there are no existing wells available to supply the project.

3.2.6 Assessment of Source

The water supply and distribution system is critical to the success and sustainability of the Oeste Environmental Restoration Project. A sufficient quantity and adequate quality of water must be available to maintain the viability of the various habitat types that are being considered for Oeste. The primary water supply for the Oeste project is effluent obtained directly from the 23rd Avenue Water Reclamation Plant. Supplemental water could come from a variety of underground sources including: 1) effluent credits "recovered" (pumped) from within the area of hydrologic impact of the RID Groundwater Savings Facility; 2) incidental recharge credits associated with increased recharge from project implementation; 3) groundwater (based on the City's Assured Water Supply allowance); and 4) recovered credits for Central Arizona Project water (stored by the City). Therefore, it did consider groundwater as a makeup source for the seasonal changes of reclaimed water from the 23rd Ave. Water Reclaimed Plant.

The use of pumped water (rather than direct effluent) has several limitations. One of these relates to the City's ability to comply with state mandated water conservation requirements. When the physical availability of pumped groundwater is considered, it is a dependable or supplemental water supply. There are no projections that the aquifer will be depleted, and water rights do not prevent its use for the Oeste Project. However, institutional commitments by COP, or SRP must be made to allow groundwater pumping. These considerations must be resolved before finalizing the design of the pump and delivery system.

3.3 Salt River Flood Flows

3.3.1 Description of Source

The Oeste Project is below the confluence of the Salt River and the Verde River. In the past, both rivers were perennial with consistent flow rates. The construction of dams with water storage reservoirs upstream allowed for the development of water resources to supply water for irrigation and urban use in the Phoenix Valley. Most of the time, all of the flow in the Salt River is diverted at Granite Reef, low-head dam, into the Arizona Canal and Southern Canal. The riverbed downstream is typically dry.

The river, however, is still subject to uncontrolled floods because the reservoirs on the Verde River have no dedicated flood capacity, and only one of the four reservoirs on the Salt River has flood capacity. Due to the design of the dams, only limited flows can be released in anticipation of floods. When the water level exceeds the diversion capacity at Granite Reef, the excess will overflow the spillway to the downstream reaches of the Salt River to flood.

3.3.2 Quantity Analyses

The Salt River is dry the majority of the time due to the upstream dams that were constructed for water supply and hydropower to agriculture and the Phoenix valley. For example, the Salt River flooded in 1941 and then was dry until it flooded again in 1966. The next flood occurred in 1973. The periods from 1978 to 1984 and from 1991 to 1995 were wet periods. Since 1995, there have been no flood releases. Table 3-1 summarizes historic releases at Granite Reef (Tres Rios River Management Plan Water Supply Technical Committee, 1997). This information demonstrates that, in the past, flood flows were more frequent and with less magnitude. Changes in the watershed and construction of additional dams have changed the pattern of flooding. Most of the largest recorded floods have occurred since 1978. Table 3-1 also demonstrates that there is no pattern to the frequency, duration, or magnitude of the flood flows.

Discharge-frequency values are provided in Table 3-2 and more detailed information on flood flows can be found in Appendix A-Hydrology and Hydraulics of Rio Salado Oeste Interim Feasibility Report 2002. While not necessarily a likely preferred source for delivery of water and implementation of restoration measures flood flows need to be considered in plan formulation. On a natural system they provide the necessary dynamics to maintain the ecosystem and are an important factor in seed dispersal. Measures considered in the formulation of plans should account for possible damages resulting from flooding as well as taking advantage of the benefits they may provide to sustaining the project.

Table 3-1. Summary of Historic Salt River Flood Flows

(floods with daily flows greater than 10,000 cfs)

Period of Flow Start Date	Period of Flow End Date	Flow Event Maximum Daily Average Flow (cfs)
2/7/1914	7/2/1914	15,800
1/29/1915	8/18/1915	18,700
1/15/1916	5/15/1916	79,100
9/8/1916	2/4/1917	21,100
4/17/1917	5/15/1917	23,400
3/7/1918	3/26/2018	28,400
11/25/1919	13/14/1919	46,200
1/4/1920	4/25/1920	87,800
12/26/1921	1/9/1922	24,100
2/8/1922	2/18/1922	10,000
3/16/1922	4/10/1922	18,000
9/18/1923	9/22/1923	24,100
12/26/1923	1/8/1924	42,800
3/31/1926	4/16/1926	28,800
2/14/1927	3/19/1927	49,800
9/12/1927	9/20/1927	16,200
4/4/1929	4/19/1929	17,200
2/12/1931	2/20/1931	22,900
2/9/1932	3/29/1932	48,700
2/6/1937	3/25/1937	36,981
2/28/1939	3/17/1939	58,739
2/5/1941	5/25/1941	32,206
12/21/1965	1/12/1966	64,000
2/20/1973	6/5/1973	22,273
2/28/1978	4/11/1978	95,800
12/16/1978	4/19/1979	110,000
1/29/1980	6/3/1980	137,725
2/2/1983	6/17/1983	30,000
9/27/1983	10/24/1983	39,878
12/24/1983	1/24/1984	11,200
12/21/1984	6/1/1985	25,604
12/22/1991	6/21/1992	12,898
8/21/1992	9/8/19992	13,615
12/28/1992	6/4/1993	99,396
1/20/1995	5/2/1995	53,316

Source: Greeley and Hansen, Tres Rios, Arizona Feasibility Study, April 1998

Table 3-2. Discharge frequency values used in the existing conditions model

Location	Return Period					
	5-yr	10-yr	20-yr	50-yr	100-yr	500-yr
Peak Discharges (ft^3/s) in the Salt River at:						
Central Avenue	20,200	53,000	87,000	135,000	166,000	240,000
67th Avenue	20,000	51,000	84,000	132,000	164,000	237,000

3.3.3 Quality Analyses

The Tres Rios River Management Plan Water Quality Technical Committee (1998) reviewed the water quality records for the Salt River. That study found that there were no chemical water quality issues associated with Salt River water. However, during flood periods, sediments represented a water quality problem; the sediment load exceeded the standard established for the designated uses of the river. The problem was not because the sediments represented contamination. The flood flows can contain pollutants of concern derived from tributary stream inflow, erosion of sediments, and landfills. Large quantities of water in flood flows can dilute the concentration and transport the contaminants through the Oeste study area to downstream areas. There is very little information, however, on the chemical constituents in flood flows. There are no known water quality issues that would prevent flood flows from being used as a water source for the Oeste Project.

3.3.4 Water Rights

Salt River floodwater is subject to surface water rights for diversion. A right filed with the state or established by adjudication is required. However, during a flood, all diversion rights are typically fulfilled. Generally, all water demands are diverted into the two canals at Granite Reef; a flood typically represents surplus water.

3.3.5 Assessment of Source

Flood flows do not occur on a regular basis or in predictable quantities; therefore, they do not represent a dependable water source. While the water may be available, it may be difficult to incorporate flood flows into the Oeste Project water supply. Flood flows do represent a supplemental source because they recharge the groundwater and replicate historic conditions in the river. Aquifer recharge is an indirect use of flood flows. During or shortly after a flood, it is possible that the water table will rise to the point where the vegetation roots can access it. However, when the flood subsides, the water table will return to depths greater than the root zone.

Flood flows have additional benefits to the natural habitat of the river. Small flows will saturate the soils and spread seeds to encourage the seedling germination and development of cottonwood and willow trees. Moderate flood flows will remove some vegetation and

maintain open areas in the river channel. The removal of vegetation is a natural occurrence in river systems. These flows can also redistribute sediments in the channel and help to replace nutrients in the riverbed soils.

Large floods, on the other hand, represent a problem source. The magnitude of these flows can damage restored habitat areas, degrade the reconstructed channels, and deposit excessive amounts of debris throughout the project. The peak flow during the 1980 flood was 200,000 cfs, which did extensive damage to the Salt River Valley (Va Shly'ay Akimel Salt River Restoration Project, Water Budget Report, Knight Piesold, 2002). Flows of this magnitude are neither predictable nor preventable.

3.4 Stormwater Discharges

3.4.1 Description of Source

Stormwater discharges represent runoff to the Salt River from urban and rural areas due to rainfall events. In general, stormwater can enter the Salt River through defined outfall points from stormwater drainage systems or as overland flow from areas immediately adjacent to the river.

In general, roadside ditches and irrigation canals intercept the majority of storm runoff. These features retain most of this runoff, thus eliminating discharges into the Salt River. There are a few areas down gradient of roadside ditches and irrigation canals where runoff will reach the Salt River. However, these areas are relatively small, and little runoff is projected to occur during most storm events.

Several smaller storm drains exist along the bank of the Salt River. Unfortunately, there are limited flow records for these drains. There are also several areas adjacent to the river where overland flow discharges directly to the river. These areas are generally undeveloped with the exception of the occasional sand and gravel mining operation.

3.4.2 Quantity Analyses

Stormwater flows occur in direct response to precipitation. Most stormwater runoff in the study area is not measured or gaged. The runoff is sheet flow across the land, roadside curb and gutter systems, or ditches that drain to the river channels.

U.S. Army Corps of Engineers (USACE) conducted a site investigation to verify the location of storm drains into the Salt River. It was also observed that wetland plant species were growing in the riverbed near outfalls of the north side of 51st Avenue (SR01) and 67th Avenue (SR49). There are limited flow records for those drains, and the exact drainage area that contributes runoff to the drain is not known. However, the presence of wetland plant species indicates that this runoff is sufficient to maintain this vegetation.

To quantify the average monthly and annual volumes of runoff from ungaged storm drains, the approach used in the Rio Salado project (USACE, 1998) was used to estimate the average annual volume of runoff. To estimate the average monthly volume of runoff, the annual amount was distributed according to the monthly rainfall distribution in the Phoenix area (Schmidli, 1996). This approach is described in detail in the Draft Report for the Interior Drainage Analyses (USACE, 2003). Table 3-3 provides the monthly and annual runoff amounts estimated for these drains.

3.4.3 Quality Analyses

It is important to note that stormwater quality is a function of land use, not the size of the watershed (Greeley and Hansen, 2001). In other words, how a specific section of land is used will impact stormwater quality more so than tract size. Table 3-4 provides the summary statistics for selected event-mean constituent concentrations measured in stormwater and stream by the land use. Stormwater often contains a significant amount of sediment that is washed from undeveloped land and other sources, as well as chemical contaminants or pollutants.

The types of chemical pollutants will vary depending on the land uses within the particular drainage area. Potential water quality impacts associated with runoff from industrial sites are projected to be minimal because the compliance requirements of stormwater National Pollutant Discharge Elimination System (NPDES) permits require each industrial site to have a stormwater pollution prevention plan (SWPPP). Runoff from turf areas has the potential to contain pesticide and fertilizer residuals. Runoff from paved areas can contain hydrocarbon products, metals, and anything spilled on the pavement. The quality of the "first flush" water is generally poor.

In some locations where the farm fields are near river channels, stormwater can flow directly into the river channels. The agricultural stormwater runoff from fields can contain large amounts of sediment because plowing and cultivation break up the soil surface and make the soil susceptible to erosion. The field stormwater runoff can contain pollutants of concern associated with agriculture, such as nitrates (from fertilizers), pesticides, and herbicides. Past irrigation practices often resulted in the application of excess irrigation water, which was drained from fields into drainage canals and released into the rivers. Discharges of excess irrigation water, or tailwater, are not regulated and their quality is not monitored. Water conservation rules restricting irrigation water use have resulted in a substantial reduction in farm field drainage, but have not eliminated it.

Concentrated animal-feeding operations (CAFOs) can produce very poor quality discharges if the site drainage is not controlled. Animal wastes can drain from the site into storm drains or irrigation systems, including both water supply laterals and drainage canals. The principal pollutant of concern from such operations is nitrate. Bacterial pathogens and other microbiological pollutants, biochemical oxygen demand (BOD), total suspended solids, and nutrient loads can also be generated at a CAFO site. CAFO sites are not located within the Salt River channel, however, uncontrolled runoff from CAFO operations can enter the Salt River through canals and storm drainage systems.

As the runoff continues, the water quality improves. The numeric surface water quality standards established by ADEQ for each designated use were compared against the available surface water quality sample data obtained from the various databases. Where an established surface water quality numeric criterion was exceeded, this information was used to compile Table 3-5, Storm Water Quality Summary. In general, based on analysis of available data versus the numeric water quality standards, stormwater is a vehicle by which surface water quality appears to degrade within the Salt River.

3.4.4 Assessment of Source

Rainfall events are infrequent in the Phoenix area, so stormwater runoff would generally not be considered as a dependable water source for a habitat restoration project. However, the 67th Avenue Drain (SR49) has produced sufficient flow to support a small area of wetland plant species; unfortunately, there are no records to further evaluate this flow. The average monthly and annual volumes of water released from some of the interior drains are of sufficient magnitude to be considered as a potential water source. These drains, however, do not flow consistently, and releases into these drains may not be reliable.

The remaining storm drains represent two categories of water supply – problem and supplemental. The first flush runoff generally has poor water quality and may not be suitable to nourish restored vegetation. Additionally, the peak flow rates emanating from these drains during major storm events may damage the habitat areas. These flows are both problem sources. After the first flush, the water quality generally improves. This runoff could be a supplemental source.

3.4.5 Future Drainage Master Plan

The purpose of the Durango Area Drainage Master Plan and Laveen Area Drainage Master Plan (ADMP) are to identify flood control problems and plan for the construction of facilities that will eliminate or minimize flooding problems. There are two major objectives of these studies. The first is to develop a plan to control stormwater runoff to prevent flood damage within the watershed. The second is to mitigate future potential runoff and subsequent ponding and to provide protection to properties from future 100-year flooding damages. Because the existing stormdrain system is not enough to carry the 100-year, 24-hour storm event. The detention basins, channels, and pipes are sized based on the revised 100-year discharges. Detention basins are sized to maximize flow attenuation with the land area available using both off-line and flow-through concepts. The off-line concept uses a perimeter channel to allow low flow to bypass the detention basin. The flow-through concept allows the entire flow to be intercepted by the detention basin. The Drainage Master plans are not going to reduce the volumes of stormwater discharge in terms of low flow discharge but it is going to reduce the peak flow and provide the longer low flow to the Oeste project area after the flooding season instead.

Table 3-3. Storm Drain Average Annual Runoff Volumes

OUTFALL No.	SITE LOCATION	PIPE SIZE (inch)	Drainage Area (acre)	Drainage Area (mi^2)	JAN (AF)	FEB (AF)	MAR (AF)	APR (AF)	MAY (AF)	JUN (AF)	JUL (AF)	AUG (AF)	SEP (AF)	OCT (AF)	NOV (AF)	DEC (AF)	ANNUAL (AF)
SR01[1,2]	51st Avenue and Salt River - North Side	96	2290	3.6	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR02[1,2]	43rd Avenue and Salt River - North Side	90	2290	3.6	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR03[1,2]	35th Avenue and Salt River- North Side	75	1856	2.9	19.5	20.2	25.7	6.5	3.6	3.8	24.2	28.0	25.1	19.0	19.3	29.1	224
SR04[1,2]	27th Avenue and Salt River- North Side	72	2862	4.5	29.6	30.7	39.2	9.9	5.4	5.8	36.8	42.6	38.1	29.0	29.3	44.3	341
SR05[1,2]	25th Avenue and Salt River- North Side	102	1017	1.6	10.9	11.3	14.4	3.6	2.0	2.1	13.5	15.6	14.0	10.6	10.8	16.3	125
SR06[1,2]	22nd Avenue and Salt River- North Side	78	4790	7.5	48.8	50.5	64.5	16.3	9.0	9.5	60.6	70.1	62.8	47.7	48.2	72.9	561
SR07[1,2]	19th Avenue and Salt River- North Side	54	632.77	1.0	6.9	7.1	9.1	2.3	1.3	1.3	8.5	9.9	8.8	6.7	6.8	10.3	79
SR30[1,2]	27th Avenue and Salt River- South Side	108	1620	2.5	17.1	17.7	22.6	5.7	3.1	3.3	21.2	24.5	22.0	16.7	16.9	25.5	196
SR31[1,2]	19th Ave, South Bank	60	1918	3.0	20.1	20.8	26.6	6.7	3.7	3.9	25.0	28.9	25.9	19.6	19.9	30.0	231
SR47[1,2]	51st Avenue and Salt River- North Side 50 feet north of SR01	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR48[1,2]	45th Avenue and Salt River- South Side	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR48a[1,2]	43rd Avenue and Salt River- South Side	N/A	14502	22.66	142.7	147.6	188.6	47.6	26.2	27.9	177.1	205.0	183.7	139.4	141.0	213.2	1640
SR49[1,2]	67th Avenue and Salt River- North Side	96	4762	7.4	48.5	50.2	64.1	16.2	8.9	9.5	60.2	69.7	62.5	47.4	48.0	72.5	558
SR58[1,2]	35th Avenue and Salt River- N/E Side	60	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR59[1,2]	2333 W. Durango (23rd Ave. WWTP east side of 35th Ave. and Salt River) - North Side	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Total																4503

1. Monthly storm water runoff distributions were assumed to follow the monthly pattern of rainfall.
2. Annual runoff volumes were computed from the drainage area vs. average annual runoff relationships developed for the Rio Salado Study.

Table 3-4. Summary statistics for selected event-mean constituent concentrations measured in stormwater and streamflow, Maricopa County, Arizona.

Constituent	Units	# of Samples	# < Detection Limit	Maximum	Minimum	Mean	Std. Dev.	Detection Limit USGS	Detection Limit Phoenix
RESIDENTIAL									
COD	mg/L	13	1	200	< 10	100	50	10	1
Suspended Solids	mg/L	14	1	910	< 1	180	230	1	10
Total Cadmium	µg/L	14	5	3	< 0.2	0.8	0.7	1	0.2
Total Copper	µg/L	11	0	45	5	23	5	1	1
Total Lead	µg/L	14	0	99	5	32	28	1	1
COMMERCIAL									
COD	mg/L	8	0	330	60	150	90	10	1
Suspended Solids	mg/L	8	0	337	20	120	120	1	10
Total Cadmium	µg/L	9	6	0.9	0.6	0.7	0.2	1	0.2
Total Copper	µg/L	9	0	64	8	20	17	1	1
Total Lead	µg/L	9	0	27	3	12	7.7	1	1
HEAVY INDUSTRY									
COD	mg/L	9	0	4300	110	720	90	10	1
Suspended Solids	mg/L	9	0	1480	84	790	530	1	10
Total Cadmium	µg/L	10	1	6	0.9	2.5	1.7	1	0.2
Total Copper	µg/L	8	0	320	50	140	90	1	1
Total Lead	µg/L	10	0	620	31	250	180	1	1
LIGHT INDUSTRY									
COD	mg/L	6	0	300	53	120	1360	10	1
Suspended Solids	mg/L	7	0	680	10	250	260	1	10
Total Cadmium	µg/L	7	4	2	< 1	0.8	0.8	1	0.2
Total Copper	µg/L	5	0	72	10	43	24	1	1
Total Lead	µg/L	7	0	130	11	38	43	1	1
SOUTH MOUNTAIN AND SALT RIVER									
COD	mg/L	8	0	21000	12	2650	7420	10	1
Suspended Solids	mg/L	8	0	3390	3	620	1140	1	10
Total Cadmium	µg/L	8	7	2	< 1	--------	--------	1	0.2
Total Copper	µg/L	8	0	300	2	70	120	1	1
Total Lead	µg/L	8	2	150	< 1	28	50	1	1

(Data for South Mountain and Salt River were combined to represent nonurban sources and include event-mean and instantaneous concentrations. Data from drainage basins with mixed land use were not grouped into any land-use category. <, less than. Dashes indicate that statistics could not be computed.)
Source: USGS

Table 3-5. Rio Salado Oeste Project Storm Water Quality Summary

Site Name	Sample Date	Constituent	Result	Units	Regulatory Limit	Limiting Criteria
19th Ave. Bridge	3/28/1991	TURBIDITY	275	NTU	50	R18-11-109
19th Ave. Bridge	3/28/1991	LEAD, TOTAL	28	UG/L	9.3	A&Wedw*
19th Ave. Bridge	3/28/1991	FECAL STREPTOCOCCI	6400	CFU/100	800	R18-11-109
19th Ave. Bridge	3/28/1991	BERYLLIUM, TOTAL	0.6	UG/L	0.21	FC
19th Ave. Bridge	3/28/1991	COPPER, TOTAL	38	UG/L	24	A&Wedw*
Salt River at 27th Ave.	12/10/1991	FECAL STREPTOCOCCI	22000	CFU/100	800	R18-11-109
Salt River at 27th Ave.	12/10/1991	FECAL COLIFORM	3100	CFU/100	800	R18-11-109
Salt River at 27th Ave.	12/10/1991	FECAL STREPTOCOCCI	22000	CFU/100	4000	PBC
Salt River at 27th Ave.	12/10/1991	FECAL COLIFORM	3100	CFU/100	800	R18-11-109
Salt River at 27th Ave.	12/10/1991	FECAL STREPTOCOCCI	26000	CFU/100	4000	PBC
Salt River at 27th Ave.	12/10/1991	FECAL COLIFORM	11000	CFU/100	4000	PBC
Salt River at 27th Ave.	12/10/1991	DDE	0.14	UG/L	0.0006	FC
Salt River at 27th Ave.	12/10/1991	DDE	0.14	UG/L	0.0006	FC
Salt River at 27th Ave.	12/10/1991	FECAL STREPTOCOCCI	25500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/2/1992	FECAL STREPTOCOCCI	6500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/2/1992	DDT	0.1	UG/L	0.0005	FC
Salt River at 27th Ave.	3/2/1992	DDE	0.67	UG/L	0.0006	FC
Salt River at 27th Ave.	3/2/1992	DDT	0.1	UG/L	0.0006	FC
Salt River at 27th Ave.	3/2/1992	FECAL COLIFORM	5500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/2/1992	PCB SERIES	0.3	UG/L	0.00009	FC
Salt River at 27th Ave.	3/2/1992	PH (STANDARD UNITS)	9.05		9	R18-11-109
Salt River at 27th Ave.	3/2/1992	FECAL COLIFORM	5500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/2/1992	DDE	0.67	UG/L	0.0006	FC
Salt River at 27th Ave.	3/2/1992	FECAL STREPTOCOCCI	6500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/8/1992	FECAL STREPTOCOCCI	6600	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/8/1992	FECAL COLIFORM	5800	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/8/1992	DDE	1.1	UG/L	0.0006	FC
Salt River at 27th Ave.	3/8/1992	PCB SERIES	0.3	UG/L	0.00009	FC
Salt River at 27th Ave.	3/8/1992	DDE	1.1	UG/L	0.0006	FC
Salt River at 27th Ave.	3/8/1992	FECAL STREPTOCOCCI	6600	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/8/1992	FECAL COLIFORM	5800	CFU/100	800	R18-11-109
Salt River at 27th Ave.	3/27/1992	FECAL COLIFORM	9500	CFU/100	4000	PBC
Salt River at 27th Ave.	3/27/1992	FECAL STREPTOCOCCI	8500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	7/11/1992	FECAL COLIFORM	4500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	7/11/1992	FECAL STREPTOCOCCI	9800	CFU/100	800	R18-11-109
Salt River at 27th Ave.	7/11/1992	FECAL STREPTOCOCCI	9800	CFU/100	800	R18-11-109
Salt River at 27th Ave.	7/11/1992	FECAL COLIFORM	4500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	7/11/1992	DDE	0.35	UG/L	0.0006	FC
Salt River at 27th Ave.	7/11/1992	DDE	0.35	UG/L	0.0006	FC
Salt River at 27th Ave.	8/22/1992	FECAL STREPTOCOCCI	4170	CFU/100	800	R18-11-109
Salt River at 27th Ave.	8/22/1992	FECAL COLIFORM	5800	CFU/100	800	R18-11-109
Salt River at 27th Ave.	8/22/1992	FECAL STREPTOCOCCI	4200	CFU/100	800	R18-11-109
Salt River at 27th Ave.	8/22/1992	FECAL COLIFORM	5800	CFU/100	800	R18-11-109

Site Name	Sample Date	Constituent	Result	Units	Regulatory Limit	Limiting Criteria
Salt River at 27th Ave.	12/8/1992	FECAL STREPTOCOCCI	15000	CFU/100	4000	PBC
Salt River at 27th Ave.	12/8/1992	DDT	0.1	UG/L	0.0005	FC
Salt River at 27th Ave.	12/8/1992	FECAL COLIFORM	4500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	12/8/1992	DDE	0.4	UG/L	0.0006	FC
Salt River at 27th Ave.	12/8/1992	DDT	0.1	UG/L	0.0006	FC
Salt River at 27th Ave.	12/8/1992	FECAL STREPTOCOCCI	14700	CFU/100	800	R18-11-109
Salt River at 27th Ave.	12/8/1992	DDE	0.4	UG/L	0.0006	FC
Salt River at 27th Ave.	12/8/1992	FECAL COLIFORM	4500	CFU/100	800	R18-11-109
Salt River at 27th Ave.	1/4/1995	CYANIDE, TOTAL	0.01	MG/L	9.7	A&Wedw
Salt River at 27th Ave.	1/4/1995	CYANIDE, TOTAL	0.01	MG/L	9.7	A&Wedw
Salt River at 27th Ave.	11/1/1995	CYANIDE, TOTAL	0.01	MG/L	9.7	A&Wedw
Salt River at 27th Ave.	11/1/1995	PH (STANDARD UNITS)	9.3		9	R18-11-109
Salt River at 27th Ave.	11/1/1995	CYANIDE, TOTAL	0.01	MG/L	9.7	A&Wedw
Salt River at 27th Ave.	11/1/1995	CYANIDE, TOTAL	0.019	MG/L	9.7	A&Wedw
35th Ave. Bridge	3/29/1991	FECAL STREPTOCOCCI	670	CFU/100	800	R18-11-109
35th Ave. Bridge	3/29/1991	LEAD, TOTAL	18	UG/L	6.3	A&Wedw*
35th Ave. Bridge	3/29/1991	TURBIDITY	108	NTU	50	R18-11-109
35th Ave. Bridge	8/22/1992	FECAL COLIFORM	16000	CFU/100	800	R18-11-109
35th Ave. Bridge	12/5/1994	FECAL STREPTOCOCCI	950	CFU/100	800	R18-11-109
35th Ave. Bridge	12/5/1994	FECAL COLIFORM	1100	CFU/100	800	R18-11-109
35th Ave. Bridge	8/19/1995	FECAL STREPTOCOCCI	1300	CFU/100	800	R18-11-109
35th Ave. Bridge	9/7/1995	FECAL STREPTOCOCCI	1000	CFU/100	800	R18-11-109
35th Ave. Bridge	9/28/1995	FECAL COLIFORM	900	CFU/100	800	R18-11-109
35th Ave. Bridge	3/13/1996	FECAL STREPTOCOCCI	1600	CFU/100	800	R18-11-109
35th Ave. Bridge	7/25/1996	FECAL COLIFORM	9000	CFU/100	800	R18-11-109
35th Ave. Bridge	7/25/1996	FECAL STREPTOCOCCI	16000	CFU/100	800	R18-11-109
35th Ave. Bridge	2/22/1997	CYANIDE, TOTAL	0.03	MG/L	9.7	A&Wedw
35th Ave. Bridge	2/22/1997	FECAL COLIFORM	1600	CFU/100	800	R18-11-109
35th Ave. Bridge	12/22/1997	FECAL STREPTOCOCCI	9000	CFU/100	800	R18-11-109
35th Ave. Bridge	2/4/1998	MERCURY, TOTAL	0.6	UG/L	0.6	FC
35th Ave. Bridge	2/4/1998	FECAL STREPTOCOCCI	90000	CFU/100	800	R18-11-109
51st Ave. Bridge-REW	3/29/1991	FECAL STREPTOCOCCI	1500	CFU/100	800	R18-11-109
51st Ave. Bridge-REW	3/29/1991	TURBIDITY	103	NTU	50	R18-11-109
Salt River at 51st Ave.	4/22/1975	FECAL COLIFORM	360000	CFU/100	800	R18-11-109
Salt River at 51st Ave.	4/28/1975	FECAL COLIFORM	23000	CFU/100	800	R18-11-109
Salt River at 51st Ave.	5/1/1975	FECAL COLIFORM	26000	CFU/100	800	R18-11-109
51st Ave. Bridge	6/1/1982	1,1-DICHLOROETHYLENE	0.0277	MG/L	950	A&Wedw
51st Ave. Bridge	6/1/1982	1,1-DICHLOROETHYLENE	0.0445	MG/L	950	A&Wedw
51st Ave. Bridge	6/1/1982	CARBON TETRACHLORIDE	0.0698	MG/L	5.5	FC
51st Ave. Bridge	6/1/1982	CARBON TETRACHLORIDE	0.1039	MG/L	5.5	FC
51st Ave. Bridge	6/1/1982	TETRACHLOROETHYLENE	0.0622	MG/L	11	FC
51st Ave. Bridge	6/1/1982	TETRACHLOROETHYLENE	0.0274	MG/L	11	FC
51st Ave. Bridge	6/13/1983	LEAD, TOTAL	9.1	UG/L	6	A&Wedw*

A&Wedw*: Calculated value from available hardness data

DDE: p,p'-Dichlorodiphenyldichloroethylene

DDT: p,p'-Dichlorodiphenyltrichloroethane

FC= Fish Consumption

A&Wedw= Aquatic and wildlife (effluent dependent water)

PBC= Partial Body Contact

R18-11-109= Refer to section in Article 1, which is the Numeric Water Quality Standards.

Source: URS, Groundwater Quality and Hydrogeology Report Rio Salado Oeste Project Phoenix, Arizona, 2002

3.5 Effluent

3.5.1 Description of Source

Treated effluent represents a drought tolerant water supply. During water shortage periods, most water conservation measures control the external use of water such as lawn watering, car washing, and landscape irrigation. These uses do not contribute to wastewater flow, so the amount of wastewater will only be reduced slightly during most drought periods.

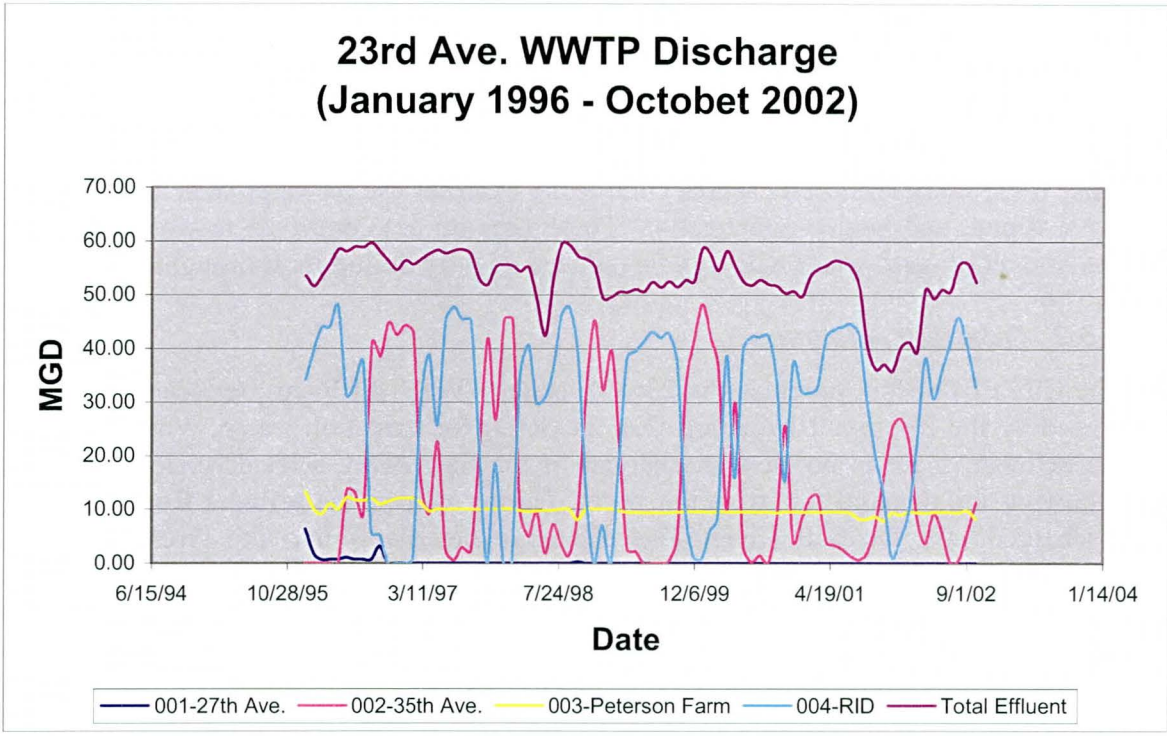
3.5.2 Quantity Analyses

The City of Phoenix operates the 23rd Avenue WWTP. Effluent produced by this plant is reused by the Roosevelt Irrigation District (RID) for irrigation water. When RID is taking the effluent, there is no flow discharged to the Salt River. RID diversions are seasonal, following the demand for irrigation water. During winter, the effluent from the WWTP is discharged into the Salt River. The discharge percolates into the riverbed, but as the discharge season progresses, the flow extends downstream. When hydrologic conditions permit, the flow from the 23rd Avenue WWTP can continue downstream beyond the study area. This occurs during periods when large storm flows or flood flows have saturated the riverbed. Table 3-6 presents the average discharges by month from the 23rd Avenue WWTP. Figure 3-2 also demonstrates the trend of daily discharges (from January 1996 to October 2002) from the 23rd Avenue WWTP.

Table 3-6. 23rd Avenue WWTP Discharge (January 1996 – October 2002)

Source: City of Phoenix

	001 South Gate of discharge structure at 27th Avenue (27th Ave.) Average Flows		002 Pipeline discharge to Salt River at 35th Avenue (35th Ave.) Average Flows		003 West gate of discharge structure at 27th Avenue (Peterson Farm-Irrigation) Average Flows		004 Junction structure on RID pipeline to RID Canal (RID) Average Flows		Total Plant Effluent Average Flows	
	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT
January	0.90	85.94	29.39	2,796.23	10.48	997.23	11.20	1,065.91	51.96	4,942.91
February	0.26	22.57	29.23	2,511.40	10.08	866.29	12.54	1,077.51	52.11	4,477.76
March	0.10	9.07	15.19	1,445.07	9.76	928.90	26.97	2,565.79	52.02	4,948.83
April	0.10	9.25	4.89	450.21	9.72	894.93	40.17	3,698.03	54.87	5,052.07
May	0.10	9.51	10.98	1,044.40	9.65	917.97	33.32	3,169.47	54.03	5,140.13
June	0.15	14.06	4.19	385.85	9.97	917.77	38.38	3,533.85	52.69	4,851.03
July	0.10	9.51	3.26	309.69	9.86	938.38	41.16	3,915.91	54.38	5,173.49
August	0.10	9.51	2.57	244.60	9.72	924.91	43.10	4,100.60	55.46	5,276.42
September	0.10	9.21	7.62	701.87	9.82	903.90	36.36	3,347.79	53.90	4,962.23
October	0.50	47.34	14.21	1,351.75	9.23	878.52	27.50	2,616.47	51.44	4,893.79
November	0.00	0.00	32.39	2,981.60	9.74	896.33	8.67	798.05	50.88	4,684.26
December	0.00	0.00	30.96	2,945.02	10.08	958.91	9.68	920.88	50.76	4,828.74
Annual	0.20	225.15	15.41	17,256.45	9.84	11,025.84	27.42	30,715.91	52.87	59,227.22



Source: City of Phoenix

Figure 3-2. 23rd Avenue WWTP Discharge Rate

3.5.3 Quality Analysis

All WWTPs that discharge to surface waters are required to have NPDES permits that include requirements to monitor the quality of the effluent prior to discharge. There are several WWTPs with discharge permits for the Salt River. Discharges from the Mesa and Tempe Water Reclamation Plants upstream would infiltrate into the Salt River bed before reaching the Oeste study area.

23rd Avenue WWTP

The WWTP is currently active, and effluent water is discharged at the outfall point on the north side of the Salt River near 35th Avenue. There are currently eight monitoring wells surrounding the sludge drying beds and a monitoring well near the outfall point. Groundwater from these wells is sampled and analyzed periodically. The well near the 35th Avenue outfall point is monitored as part of the Aquifer Protection Permit (APP) for the site.

The quality of the effluent from the WWTP meets aquifer recharge standards, surface water quality standards, and NPDES requirements. Having met all three of these authoritative standards, the quality of effluent is suitable for the restoration project.

3.5.4 Water Rights

The producer of effluent retains ownership until it is discharged and no longer under the control of the producer. If effluent is discharged to a river channel, a downstream water user can file for an appropriation to divert the water just like any other surface water source. The water user may be granted the surface water right to divert the effluent; however, this right

does not guarantee that the effluent producer will continue to discharge to the river channel. The producer still has control as to where the effluent is discharged.

Normally, when effluent is discharged to the river, the producer loses control and hence the right to the effluent. However, if the receiving water channel is designated to be a part of the conveyance system, the producer can maintain the right to the flow. This could occur if COP discharged effluent to a receiving channel in the Salt River with the intent to transport the flow to the restoration project.

When COP discharges the effluent to the recharge ponds, they retain control of the effluent and maintain the right to this water. Once the effluent is recharged, COP's right to this effluent is protected pursuant to groundwater recharge legislation statutes.

3.5.5 Assessment of Source

Effluent from the WWTP could be a dependable or supplemental supply for portions of the Oeste Project. The water source is drought tolerant and can meet water quality standards for restoration. However, COP, who controls the right to the effluent flow, must make an institutional decision to commit water to the project. Currently, COP owes a substantial water debt to the Roosevelt Water Conservation District (RWCD). Once the reclaimed water line to the RWCD canal line is in place, COP intends to use the majority of the effluent from the WWTP to fulfill this debt. COP receives long-term storage credits from this delivery as well as from water recharged through the percolation ponds. Therefore, use of reclaimed water for habitat restoration would mean a depletion of the long-term storage credits that COP uses to comply with Assured Water Supply requirements and to meet current and future demands.

Effluent could be used directly downstream of 35th Avenue where gravity flow and the reclaimed water distribution system, the 27th Avenue discharge structure and the 43rd Avenue discharge structure of Peterson Farm, can be used to deliver the effluent. However, indirect use of effluent could be achieved throughout the study area by using recovery wells to pump groundwater accounted for as recharge credits.

3.6 Irrigation Return Flows

3.6.1 Description of Source

The Oeste Project lies adjacent to irrigated agricultural lands so that the potential exists to use irrigation return flows as a water source for the ecosystem and habitat restoration. Irrigation return flows constitute the water delivered to the agricultural areas that is not consumed by crops, evaporated, or infiltrated into the soils. These flows can occur under two scenarios.

The first scenario, termed tailwater, occurs when surplus irrigation water is applied to the fields but is not used by the crops. Irrigation in the project area is typically accomplished through a flood irrigation technique where sufficient water is applied at the top of the field to force water through the furrows to the other end. In some areas, sumps have been constructed to collect the excess water and pump it back to the top of the field or divert it to

another water user. In other areas, the excess water drains from the fields and is either intercepted by irrigation canals, stormwater ditches, other diversion structures, or discharged directly into the Salt River.

The second scenario occurs when surplus irrigation water is delivered to the canals but is not applied to the fields. This excess water then either remains in the canal where it evaporates or infiltrates, is diverted to other users, or is discharged into the Salt River. This scenario can occur if a rainfall event occurs after irrigation water is delivered to a lateral canal; the soils in the irrigated areas may be saturated by rainfall so that the canal water is no longer needed. In other cases, the irrigation canals may intercept stormwater runoff; if this stormwater runoff is significant, water may need to be released from the canal to prevent overflowing the canal banks.

3.6.2 Quantity Analyses

Under the current configuration (Table 3-7), the 23rd Avenue WWTP discharges approximately 11,026 acre-feet of irrigation water to the Peterson Farm annually. Though Peterson's use is only about 1 mgd, approximately 10 mgd must now be diverted via a canal to meet Peter's demand. The excess water now infiltrates along the canal or is discharged back to the Salt River between 43rd and 51st Avenue. Thus, if a pressurized pipeline can be constructed to deliver Peterson 1 mgd, the remaining water, adjusted for losses, can be made available to the Rio Salado Oeste Project.

The amount of additional irrigation return flows, irrigation tailwater, generating from irrigation water users is not currently monitored and is difficult to quantify. The irrigation return flows intercepted from irrigation tailwater are not a potential source of water for restoration project.

3.6.3 Quality Analyses

The quality of the irrigation return flows can meet the needs of the Oeste Project in most cases. The water is Salt River water and, as demonstrated in previous sections of this report, the quality is acceptable. In some locations, irrigation drainage water can be saline, but that problem usually occurs far downstream in the western portions of the SRP service area.

Localized water quality problems could occur if surface runoff drainage enters the irrigation drain canals and transports contaminants from surrounding areas into the drain canals. There are no specific concentrated animal feeding operations in the area that could contribute contaminated runoff into the drainage canal system.

Table 3-7. Irrigation Return Flows from the Peterson Farm

	Discharge from 23rd WWTP to Peterson Farm Average Flows		Peterson's Use (Approximation) Average Flows		Excess Water Average Flows	
	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT
January	10.48	997.23	1.00	95.14	9.48	902.10
February	10.08	866.29	1.00	85.93	9.08	780.36
March	9.76	928.90	1.00	95.14	8.76	833.77
April	9.72	894.93	1.00	92.07	8.72	802.87
May	9.65	917.97	1.00	95.14	8.65	822.83
June	9.97	917.77	1.00	92.07	8.97	825.70
July	9.86	938.38	1.00	95.14	8.86	843.24
August	9.72	924.91	1.00	95.14	8.72	829.78
September	9.82	903.90	1.00	92.07	8.82	811.84
October	9.23	878.52	1.00	95.14	8.23	783.39
November	9.74	896.33	1.00	92.07	8.74	804.27
December	10.08	958.91	1.00	95.14	9.08	863.78
Annual	9.84	11,025.84	1.00	1,120.15	8.84	9,905.70

Source: City of Phoenix

3.6.4 Water Rights

Irrigation return flows discharged to the river become available for use by other water users. If this water is diverted and directed into the Oeste Project, it could be utilized to support the wetland and riparian habitat.

3.6.5 Assessment of Source

Irrigation return flows may provide a supplemental source of water for the habitat restoration. In addition, several factors prohibit irrigation return flows from being a reliable source. Typically, only the amount of water necessary for irrigation is delivered to the fields, which minimizes the tailwater amount. Additionally, storm events that produce significant runoff are rare so that surplus canal water is not available on a regular basis. The irrigation flows that do occur, however, only take place during the irrigation season. When the flows are available, they could be incorporated to supplement the water supply for the Oeste Project.

3.7 Irrigation Drains

3.7.1 Description of Source

Irrigation drains are typically constructed along the irrigation canals and laterals in the area to provide a means to discharge excess water to reduce the possibility of a water-overtopping incident. During storm events, some canals and laterals intercept stormwater runoff; if this stormwater runoff is significant, water may need to be released from the canal to prevent overflowing the canal banks. Additionally, the major canals occasionally collect irrigation tail water. In the event more water is being conveyed than can be handled safely, the drains allow the excess water to be carried to the Salt River. Two significant canal drains were identified within the study area, namely the SRP 67th Avenue Drain, and Maricopa Drain. Each of these canal drains is operated by SRP.

There are also several lateral canals that could ultimately drain into the Salt River. These canals, however, are generally relatively small and rarely have a surplus of water. There are no flow records available for these canals. Given the size and infrequent water surplus of these canals, they are not considered to be a potential water source for the habitat restoration project.

3.7.2 Quantity Analyses

Flow records for the SRP 67th Drain were evaluated for the period from January 1993 through December 2002. These records indicate that, for the SRP 67th Drain, the average monthly volume of flow for this period ranged from 26.1 acre-feet in November to 173.4 acre-feet in September with an average annual total of 1,043.7 acre-feet. Table 3-8 summarizes the average monthly and annual volumes of flow for these drains for the period of record evaluated.

Flow records for the Maricopa Drain were evaluated for the period from January 1994 through December 2002. These records indicated that, for the Maricopa Drain, the average monthly volume of flow for this period ranged from 213.2 acre-feet in November to 574.5 acre-feet in April with an average annual total of 4,276.2 acre-feet. Table 3-9 summarizes the average monthly and annual volumes of flow for these drains for the period of record evaluated.

3.7.3 Quality Analyses

The water discharged from irrigation drains is generally high quality and suitable for the habitat restoration project.

3.7.4 Water Rights

Irrigation return flows discharged to the river become available for use by other water users. If this water is diverted and directed into the Oeste Project, it could be utilized to support the wetland and riparian habitat.

3.7.5 Assessment of Source

Irrigation drains could provide a supplemental source of water for the restoration project. The amount of water released through these drains has historically been relatively consistent from month to month. Although these amounts are sufficient to support some riparian vegetation, the timing of these flows is irregular. These releases are not reliable as the drains have historically been dry for long periods; for example, there were no releases to the SRP 67th Avenue Drain throughout the period from November 1996 through February 1997. The Maricopa Drain flows were historically more frequent and reliable. Future releases to this drain are expected to be less frequent than the historic trend. Most of these releases are controlled by SRP and are not expected to be reliable. Irrigation drains are typically utilized when a surplus of water exists in the major canals. When these releases do occur, however, they could be used to supplement the habitat restoration water supply.

Table 3-8. SRP 67th Avenue Drain Monthly Volume
(Units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1993	0.2	27.8	445.1	504.9	66.0	105.2	140.9	151.7	4.4	17.2	0.0	45.2	1,508.6
1994	174.0	28.1	57.2	42.6	34.7	30.0	16.6	56.3	17.1	23.6	2.5	14.2	496.9
1995	1.6	56.5	137.5	100.6	56.8	109.4	23.1	24.8	21.5	6.6	7.8	7.1	553.3
1996	7.7	89.4	5.6	31.3	36.2	20.8	24.3	42.7	0.2	16.5	0.0	0.0	274.8
1997	0.0	0.0	41.1	31.8	9.5	0.0	0.0	24.4	24.6	25.3	0.0	306.9	463.6
1998	63.5	64.0	399.4	77.1	247.6	85.5	27.1	51.3	1,344.5	1,015.0	45.1	51.3	3,471.2
1999	10.7	12.3	136.7	92.0	56.4	201.7	82.2	156.1	64.0	76.9	6.0	0.5	895.4
2000	31.7	15.8	30.5	63.1	196.4	219.1	34.2	81.8	27.7	92.0	79.4	11.7	883.5
2001	40.5	2.9	189.6	85.8	120.3	91.5	110.7	87.4	137.0	67.9	1.8	15.6	951.0
2002	37.0	5.5	24.2	47.1	80.9	90.7	90.8	168.4	93.0	119.0	118.3	64.2	939.0
Average	36.7	30.2	146.7	107.6	90.5	95.4	55.0	84.5	173.4	146.0	26.1	51.7	1,043.7

Source: SRP

Table 3-9. Maricopa Drain Monthly Volume
(Units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1994	271.5	237.5	296.5	349.7	172.9	431.8	362.2	310.9	1.1	36.2	24.4	366.0	2,860.6
1995	133.7	347.9	338.7	696.7	159.7	357.7	282.7	420.4	78.1	124.2	142.8	173.0	3,255.5
1996	177.9	271.0	482.7	311.1	73.5	287.4	587.8	587.8	191.6	109.0	171.1	271.5	3,522.4
1997	61.0	75.4	315.0	262.7	148.5	189.0	151.6	148.2	170.3	282.0	266.7	366.0	2,436.3
1998	288.7	344.3	481.0	812.2	1,012.8	700.2	1,063.6	682.5	394.8	239.5	241.6	250.5	6,511.7
1999	261.3	376.4	619.8	787.0	692.5	692.4	181.2	439.0	482.1	380.3	210.5	376.4	5,498.9
2000	284.8	341.4	373.8	736.7	711.2	727.3	684.0	574.3	472.2	411.8	296.3	266.3	5,880.1
2001	276.5	236.4	333.9	670.5	597.8	481.7	704.2	205.7	205.7	231.6	363.1	175.6	4,482.8
2002	258.2	273.7	502.6	544.2	518.2	577.0	311.1	33.2	268.6	355.7	202.8	192.4	4,037.5
Average	223.7	278.2	416.0	574.5	454.1	493.8	480.9	378.0	251.6	241.1	213.2	270.8	4,276.2

Source: SRP

3.8 Sand and Gravel Mining Operations Releases

3.8.1 Description of Source

Since the construction of upstream dams began controlling the flows in the Salt River, sand and gravel mining operations moved into the river bed and surrounding flood plain to mine this natural resource. The materials extracted from the river have been used extensively throughout the development of the Phoenix Metropolitan area and have contributed to geomorphic changes to the floodplain and adjacent overbank.

Approximately 1,200 acres within the project area are sand and gravel mining operations. The river between 19th and 35th Avenues is lined with operations and nearly 100% modified. Again South of the river between 43rd Avenue and 51st Avenue are mining operations, which cross the river just downstream of 51st and extend on the North side to near 63rd Avenue. To our knowledge, none of these operations discharge water to the Salt River.

3.8.2 Quantity Analyses

Sand and gravel mining operations use pumped groundwater to sort and wash the aggregate materials. Water is used for processing aggregates and stored in holding ponds when not in use. To our knowledge, no water is being discharged into the Salt River; however, inspection of aerial photography indicated that ponded water exists in the Salt River channel. The origin of this water is unknown.

3.8.3 Quality Analyses

The quality of water discharged from sand and gravel-mining operations is dependant partially on the original water supply. The most significant water quality impairment due to these mining operations is sediment.

These mining operations are usually in the river channels or adjacent to the channels on the riverbanks. Before being pumped for use in these operations, the groundwater flows through materials similar to the mining aggregate. It is therefore expected that the mining will not result in any significant change in the chemical constituent concentrations in the water. Mining can greatly increase the sediment load in the water, however, and mining operations located within waters of the United States are required to have Section 404 permits and Section 401 water quality certification to minimize impacts on water quality. The major water quality impact results when there is an accident that releases water from a mining site or when the site is inundated during flood events in the river and stockpile material is transported downstream. During a flood, any sediment generated by sand and gravel mines is overwhelmed by the sediment transported by the flood flow. Currently, there are active sand and gravel mining operations in the Salt River.

3.8.4 Water Rights

Discharges from sand and gravel-mining operations released to the river become available for use by other water users. If this water is diverted and directed into the Oeste Project, it could be utilized to support the wetland and riparian habitat.

3.8.5 Assessment of Source

Discharges from sand and gravel-mining operations are not considered to be a potential water source for the restoration project. To our knowledge, there are no operations that currently discharge excess water into the Salt River.

3.9 Residual Water from Rio Salado project

3.9.1 Description of Source

The source was to maximize groundwater pumping from the Rio Salado project wells and deliver by either pipe or open channels to Oeste. Rio Saldo drilled five wells into the shallow aquifer and is currently evaluating wellhead treatment for at least two wells to remove volatile organic compounds (VOC).

3.9.2 Quantity Analyses

The Rio Salado wells can yield, if pumped 24 hours a day, 7 days a week, approximately 12.5 mgd. This could provide the Oeste Project with approximately 5.7 mgd to 8mgd if piped or 4.5 mgd to 6.5 mgd if conveyed in open channels (COP). The residual water from Rio Salado project is calculated with given information and assumptions as shown on Table 3-10. The result is shown that the residual water available approximately 3.5 mgd from Rio Salado project.

3.9.3 Quality Analyses

The upper aquifer lies close to the surface and is about 300-400 feet thick. This ground water is under utilized and according to the City's Water Services Department, is not suitable for urban water supplies. It contains varying concentrations of pollutants resulting from agricultural, urban, and adjacent landfill impacts making it available for environmental restoration purposes.

3.9.4 Water Rights

Residual water from the Rio Salado project wells discharge to the river become available for use by other water users. If this water is diverted and directed in the Oeste Project, it could be utilized to support the wetland and riparian habitat.

3.9.5 Assessment of Source

There are concerns however with using the Rio Salado residual water. The main River channel or a low flow channel (LFC) could be used for conveyance reducing construction cost, but a substantial pump would be required in the River to move the water into Oeste's distribution system. Plus, if the water were to be conveyed through open channels, it is

estimated that evaporation and percolation losses would be 20%-30% of the piped amount. These losses could be reduced if the water was piped, but could double the conveyance cost of getting water from Rio Salado to Oeste compared to using an open channel delivery system. Trenching though the overbanks in the Rio Salado involves a high degree of waste removal, over excavation for structural stability, and more expensive construction methods to reduce impacts to existing landfills such as, double containment pipes to capture water that could result from a line break.

Table 3-10. Residual Water Budget from Rio Salado Project for Oeste Project

Month	Days	Precipitation		Stormwater[2]	Groundwater	Water Demand (Average)[1]			Water Demand (Peak)[1]			Residual Water w/ Peak Demand[3]		
		inches	acre-feet per acre	acre-feet	acre-feet	acre-feet	cfs	mgd	acre-feet	cfs	mgd	acre-feet	cfs	mgd
January	31	0.67	0.056	445.12	553.58	269.23	4.38	2.83	432.81	7.04	4.55	343.33	5.58	3.61
February	28	0.68	0.057	451.77	500.01	243.18	4.38	2.83	390.93	7.04	4.55	334.97	6.03	3.90
March	31	0.88	0.073	584.64	553.58	269.23	4.38	2.83	432.81	7.04	4.55	413.09	6.72	4.34
April	30	0.22	0.018	146.16	535.73	260.55	4.38	2.83	418.85	7.04	4.55	189.96	3.19	2.06
May	31	0.12	0.010	79.72	553.58	269.23	4.38	2.83	432.81	7.04	4.55	160.63	2.61	1.69
June	30	0.13	0.011	86.37	535.73	260.55	4.38	2.83	418.85	7.04	4.55	160.06	2.69	1.74
July	31	0.83	0.069	551.42	553.58	269.23	4.38	2.83	432.81	7.04	4.55	396.48	6.45	4.17
August	31	0.96	0.080	637.79	553.58	269.23	4.38	2.83	432.81	7.04	4.55	439.67	7.15	4.62
September	30	0.86	0.072	571.35	535.73	260.55	4.38	2.83	418.85	7.04	4.55	402.55	6.77	4.37
October	31	0.65	0.054	431.83	553.58	269.23	4.38	2.83	432.81	7.04	4.55	336.69	5.48	3.54
November	30	0.66	0.055	438.48	535.73	260.55	4.38	2.83	418.85	7.04	4.55	336.12	5.65	3.65
December	31	1.00	0.083	664.36	553.58	269.23	4.38	2.83	432.81	7.04	4.55	452.95	7.37	4.76
Annual	365	7.66	0.638	5089.00	6518.00	3170.00	4.38	2.83	5096.00	7.04	4.55	3966.50	5.48	3.54
Peak	31		0.083	664.36	553.58	269.23	4.38	2.83	432.81	7.04	4.55	452.95	7.37	4.76

1-Draft Final Conceptual Design Documentation Report, Rio Salado Phoenix, Environmental Restoration Project, Phoenix, Arizona, July 2002, Tables 2-4 and 2-5.

2-Rio Salado Salt River, Arizona, Feasibility Report, Technical Appendice, Appenxix A Hydrology, April 1998, Tables 3-7A and 3-7B.

3-Residual Water w/ Peak Water Demand = 0.5 X Stormwater + Groundwater - Water Demand (Peak).

4 Evaluation of Water Sources

Each of the potential water sources has been evaluated based on the quantity and seasonality of flow, water quality, water rights, and institutional considerations. A few dependable and supplemental sources of water are available to supply the Oeste Project. For some of these, there is sufficient information to quantify the potential supply; however, others will require further monitoring to verify the quantity and seasonality of flow. In addition, the Maricopa County, COP, SRP, or CAP could make other water sources available upon institutional commitments. These entities will need to decide if, how much, and when they will commit water to the Oeste Project. Table 4-1 presents a summary of the analyses.

The water supply and distribution system is critical to the success and sustainability of the Oeste Environmental Restoration Project. A sufficient quantity and adequate quality of water must be available to maintain the viability of the various habitat types that are being considered for Oeste. The primary water supply for the Oeste project is effluent obtained directly from the 23rd Avenue Water Reclamation Plant. Supplemental water could come from a variety of underground sources including: 1) effluent credits "recovered" (pumped) from within the area of hydrologic impact of the RID Groundwater Savings Facility; 2) incidental recharge credits associated with increased recharge from project implementation; 3) groundwater (based on the City's Assured Water Supply allowance); 4) recovered credits for Central Arizona Project water (stored by the City); 5) stormwater discharge; and 6) residual water from Rio Salado Project.

Treated effluent from the City's 23rd Avenue Water Reclamation Plant and one ground water well have been identified as the primary water sources for Oeste. The use of pumped water (rather than direct effluent) has several limitations. One of these relates to the City's ability to comply with state mandated water conservation requirements as discussed above. Secondary influxes of dry weather flows and storm water flows from the network of storm drains that empty into the River, residual Rio Salado flows, and discharges east of 35th Avenue on the north bank from the 23rd Avenue Water Reclamation Plant and at 43rd Avenue on the north bank are also included.

TABLE 4-1

WATER BUDGET MATRIX

Water Source	Description/Location	Quantity Available	Availability	Supply Designation	Discussion/Issues
In-Situ Groundwater					
Regional water table	Throughout the study area	None	Not available	Unacceptable	Regional groundwater is too deep for use by the desired vegetation. Depth exceeds 30 feet, which is the limit for mesquite.
Local or perched water table	River channel between 19th avenue and 83rd avenue	Not measured	Continuous	Dependable	Local supply available at the river channel for majority of the study area.
Pumped Groundwater					
Irrigation Grandfather Rights	Tied to specific parcels of land for growing crops.	Not Available	None	Unacceptable	IGR water must be used on a historically specified parcel of land.
Type I Non-Irrigation Rights	Tied to specific parcels of land for changes in land use.	Not Available	None	Unacceptable	Type I water cannot be used off of the specific land parcel.
Type II Non-Irrigation Rights	Pumping for uses not associated with historic farmland.	Pending	Continuous	Dependable or Supplemental	Requires purchase and transfer of Type II right.
Groundwater Permits	Pumping for new uses.	Not Available	None	Unacceptable	Project can not meet permit requirements and conditions.
Service Area Right	Pumping for public water providers.	Pending	Continuous	Dependable or Supplemental	Pumped water will impact COP's overall water resources unless credits to offset the pumping are purchased or developed.
Salt River Flood Flows					
Direct Use	Flow in the Salt River due to spills over Granite Reef Dam; all reaches	Quantity varies with each flood event	Approximately once every 3 years	Problem	Due to the unpredictable nature of the flood flows, they are not a dependable supply, and may cause damage to restored areas.
Indirect Use	Groundwater recharge due to flood flows in the Salt River; all reaches	Quantity varies with each flood event	During floods and for a short time after	Supplemental	Recharge of groundwater allows for indirect use; and, surface soil saturation will augment seed germination.
Stormwater Discharges					
SR01: 51st Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 274 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR02: 43rd Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 274 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR03: 35th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 224 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR04: 27th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 341 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR05: 25th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 125 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR06: 22nd Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 561 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR07: 19th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 79 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR30: 27th Avenue and Salt River	Storm runoff from COP, outfalls along the south bank side	~ 196 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR31: 19th Avenue and Salt River	Storm runoff from COP, outfalls along the south bank side	~ 231 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR47: 51st Avenue and Salt River - 50 feet north of SR01	Storm runoff from COP, outfalls along the north bank side	Minimal	During or immediately after rainfall events	Problem	Runoff is of insufficient quantity with no dedicated collection system; drainage area is not available.

TABLE 4-1 (CONTINUED)

WATER BUDGET MATRIX

Water Source	Description/Location	Quantity Available	Availability	Supply Designation	Discussion/Issues
Stormwater Discharges (continued)					
SR48: 45th Avenue and Salt River	Storm runoff from COP, outfalls along the south bank side	Minimal	During or immediately after rainfall events	Problem	Runoff is of insufficient quantity with no dedicated collection system; drainage area is not available.
SR48a: 43rd Avenue and Salt River	Storm runoff from COP, outfalls along the south bank side	~ 1,640 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR49: 67th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	~ 558 ac-ft per yr	During or immediately after rainfall events	Unacceptable to Supplemental	First flush is unacceptable due to potential water quality problems, but the remainder of the flow can be a supplemental water source.
SR58: 35th Avenue and Salt River	Storm runoff from COP, outfalls along the north bank side	Minimal	During or immediately after rainfall events	Problem	Runoff is of insufficient quantity with no dedicated collection system; drainage area is not available.
SR59: 2333 W. Drango (23rd Ave. WWTP east side of 35th Ave. and Salt River)	Storm runoff from COP, outfall along the north bank side	Minimal	During or immediately after rainfall events	Problem	Runoff is of insufficient quantity with no dedicated collection system; drainage area is not available.
Effluent					
Direct Use	Effluent from the 23rd Avenue WWTP discharged directly into the 35th Avenue.	averages 15.41MGD (~17,256 ac-ft per yr)	Continuous	Dependable or Supplemental	The quantity and availability of effluent water is subject to an institutional commitment by COP; COP has existing commitments for this effluent.
Indirect Use	Effluent from the 23rd Avenue WWTP recharged into the groundwater	Pending	Continuous	Dependable or Supplemental	COP has incorporated the recharge credits for this effluent into its long-term water plan; it would require a reallocation to the project. Indirect use requires wells to recover the recharged water.
Irrigation Return Flows					
Irrigation Tailwater	Excess water applied to crops within the agricultural area of the Community	Minimal	Irrigation season	Supplemental	Supply only available during irrigation season; unreliable because irrigation practices are designed to reduce the tailwater quantity.
Surplus Irrigation Water	Excess water in Peterson Farm	averages 8.84MGD(~9,905 ac-ft per yr)	Continuous	Supplemental	Supply available during all season based on discharge record; unreliable because irrigation practices are designed to reduce the tailwater quantity.
Irrigation Drains					
SRP 67th Avenue Drain	Allows excess flow in SRP's Lateral 2-19.0 to drain to the Salt River: the north bank of the Salt River on the east side of 67th avenue	averages 1,044 ac-ft per yr	In-frequent	Supplemental	Flow is due to controlled releases by SRP; releases occur irregularly and are not reliable.
SRP Maricopa Drain	Allows excess flows from the ditch known as the Maricopa Drain to flow to the Salt River: the south bank of the Salt River near 77th Avenue	averages 4,276 ac-ft per yr	In-frequent	Supplemental	Flow is due to controlled releases by SRP; releases occur irregularly and are not reliable.
Sand & Gravel Mining Releases					
	Within the Salt River; all reaches	None	Not available	Unacceptable	No known discharges from these operations.
Residual Water Flows from Upstream (Rio Salado Project)					
Ridual Water Flows	Excess water in Rio Salado Project. Resiual Water w/ Peak Water Demand=0.5XStormwater+Groundwater-Water Demand(Peak)	averages ~3,966 ac-ft per yr	Continuous	Supplemental	Supply available during all season based on the water budget of Rio Salado project; unreliable because Rio Salado practices are not fixed.

5 Water Budget for Project Alternatives

Prior to developing restoration alternatives constraints were identified that would affect the plan formulation process. Those constraints were:

- Availability of Water
- Maintenance of Floodway Capacity
- Proximity of Recreation to Restoration
- Endangered Species
- Local Acceptability
- Displacement of People
- Rapid Growth
- Real Estate
- County and City Lands

Water to support restoration was identified as one of the most limiting constraints because of its scarcity and cost. The next greatest limiting factor was land that could be dedicated to restoration. In fact, the last four of the constraints identified deal with land use or land cost issues. Although water and land to support restoration were identified as principal limiting constraints, this analysis determined to evaluate what could be accomplished if significant areas of land and substantial volumes of water were available. This approach allows decision makers to weigh the relative cost of the biologic outputs resulting from commitment of substantial volumes of water when evaluating plans for implementation. Alternatives were developed to focus on varying levels of water supply and varying amounts of available land in order to ensure consideration of the effects of these two resources on plan costs and outputs.

These alternatives include the modification of existing storm-water outfall areas to improve retention and water spreading as well as increasing the existing habitat currently supported by these outfalls and modification and/or restructuring of the primary conveyance channel to a more natural state by grading and terracing the river corridor from 19th avenue to 83rd avenue. Those alternatives also include the features described above and add a supplemental water supply in the form of effluent. At locations identified as suitable throughout the project area cottonwood/willow and mesquite cover types will be restored. These alternatives would also address the management, control and removal of invasive species within the study area. Some of alternatives add restoration of emergent wetlands at the existing gravel pits at 29th and 37th Avenues. The results screened are presented in **Table 5-1**.

Table 5-1. Ecosystem Restoration Alternative Plans

Alternative	Acres	Water Demand (A/F)	Water Demand (mgd)
1. No Action			
2. Storm water and Channel: This alternative includes the modification of existing storm-water outfall areas to improve retention and water spreading as well as increasing the existing habitat currently supported by these outfalls. It also includes modification and/or restructuring of the primary conveyance channel to a more natural state by grading and terracing the river corridor from 19th avenue to 83rd avenue. No additional water source is included in this alternative.	C/W: 66 M: 43 W: 28 + 17 Low flow channel	**1,583**	**1.41**
3. Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive: This alternative includes the features described in alternative 2 and adds a supplemental water supply in the form of effluent. At locations identified as suitable throughout the project area cottonwood/willow and mesquite cover types will be restored. This alternative would also address the management, control and removal of invasive species within the study area.	C/W: 348 M: 409 W: 28 + 34 Low flow channel	**4,524**	**4.04**
4. Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent: This alternative adds restoration of emergent wetlands at the existing lake in the channel immediately downstream of 19th Avenue.	C/W: 348 M: 409 W: 33 + 34 Low flow channel	**4,701**	**4.20**
5. Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent, Lake: Added to this alternative is lake restoration at the existing gravel pits at 29th and 37th Avenues.	C/W: 375 M: 417 W: 76 + 34 Low flow channel O/W: 40	**7,752**	**6.92**
5A. Wetland restoration in lieu of permanent open water and lakes: In lieu of lake restoration this includes regarding of the existing gravel pits to restore them to the floodplain and restoration of emergent wetland and riparian areas.	C/W: 375 M: 417 W: 156 + 34 Low flow channel	**9,293**	**8.30**
5B. This alternative is a hybrid of 5 and 5A: including restoration of one gravel pit to a wetland/riparian complex and the other to include the lake.	C/W: 375 M: 417 W: 136 + 34 Low flow channel O/W: 20	**9,234**	**8.24**

Table 5-2. Water Budget Analysis for Alternative Plans

Functional Assessment Tool Name	PRECIP	OPEN WATER			COVER TYPES						SUB-TOTAL			TOTAL	
	Ann. Avg. Precip.[1] (in/yr)	AREA (acres)	Evapo-ration Loss (ft/yr)	Infiltration Loss (ft/yr)[2]	Mesq. (acres)	Mesq. Water Demand (ft/yr)	CWW (acres)	CWW Water Demand (ft/yr)	Emergent Marsh & Low Flow Channel (acres)	Emergent Marsh Water Demand[3] (ft/yr)	Area (acres)	Water Demand (acre-feet/yr)	Water Demand (mgd)	Water Demand (acre-feet/yr)	Water Demand (mgd)
Alt. 2	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41	1583.15	1.41
Alt. 3	7.66		6.03	27.2	366	3.00	282	8.00		36.20	648	2940.36	2.62	4523.51	4.04
Alt. 3-SW	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41		
Alt. 4	7.66		6.03	27.2	366	3.00	282	8.00	5	36.20	653	3118.17	2.78	4701.32	4.20
Alt. 4-SW	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41		
Alt. 5	7.66	40.00	6.03	27.2	374	3.00	309	8.00	48	36.20	771	6168.65	5.51	7751.79	6.92
Alt. 5-SW	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41		
Alt. 5A	7.66		6.03	27.2	374	3.00	309	8.00	128	36.20	811	7709.91	6.88	9293.06	8.30
Alt. 5A-SW	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41		
Alt. 5B	7.66	20.00	6.03	27.2	374	3.00	309	8.00	108	36.20	811	7650.51	6.83	9233.66	8.24
Alt. 5B-SW	7.66		6.03	27.2	43	3.00	66	8.00	28	36.20	137	1583.15	1.41		

[1]-Source: National Climatic Center, 1995. Phoenix Annual Summary of the Local Climatological Data

[2]-Assume "27.2" with the clay liner for the wetland and lake (Rio Salado, Salt River, Arizona, Hydrology Appendix).

[3]-Assume "36.2" with the clay liner for the wetland and lake (Infiltration Rate (27.2) + Water Demand for Emergent Marsh (9) = 36.2).

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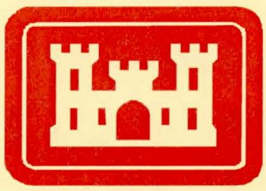

US Army Corps
of Engineers
Los Angeles District

RIO SALADO OESTE

Salt River-Phoenix, Arizona

Interior Drainage Report
(Future Conditions)

June 2004

LOS ANGELES DISTRICT, CORPS OF ENGINEERS
HYDROLOGY AND HYDRAULICS SECTION

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1.0 Introduction and Summary

Interior drains, or side drains, that outfall into Salt River between 19th Avenue on the east and 83rd Avenue on the west may have implications on the Rio Salado Oeste Project (Oeste Project).

Two types of interior drains were identified that outfall into the Salt River within the project study limits – irrigation drains and storm drains. Figure 1-1 presents locations of irrigation drains and storm drains. Irrigation drains are designed to release water from the irrigation facilities and discharge it into the Salt River. These drains are an operational mechanism to restrict flow in the irrigation system. Storm drains are designed to collect runoff generated by rainfall events. These are typically installed in urbanizing areas to protect developments from a design storm of a certain return period.

These have been evaluated to assess the potential damage that frequent inundation or high discharge velocities may cause to the restored habitat and the possibility of utilizing this water to support or nourish the reestablishment of riparian vegetation.

The peak flow rates and discharge velocities from the interior drains are sufficient to create localized damage at the outlet of each drain. However, this damage is not expected to extend beyond the immediate vicinity of the pipe outlet. There is little evidence to suggest that flows from these drains have historically done more than wet the riverbed in the immediate vicinity of the drain outlet. To that regard, there is little advantage to providing extensive protection from the interior drainage discharge.

The interior drains were also evaluated to assess the potential for using these flows as a water source to support and nourish the restored vegetation. For this evaluation, these drains were each evaluated based on the quantity, reliability, and quality of flow that is or may be available for habitat restoration.

Salt River Project (SRP) has maintained the discharge gaging stations of two irrigation drain outfalls within this study area. The irrigation drains, which flow in response to controlled releases, have received occasional flows throughout the record period from 1993 through 2002. The average annual volumes of water released to the Salt River during this period were 1,044 acre-feet (the record period from 1993 through 2002), and 4,276 acre-feet (the record period from 1994 through 2002) for the SRP 67th Avenue Drain, and Maricopa Drain, respectively. Although these amounts are sufficient to support some riparian vegetation, the timing of these flows is irregular. These releases are not reliable as the drains have historically been dry for long periods.

To evaluate the possibility of using storm water as a water sources, the approach used in the Rio Salado study (U.S. Army Corps of Engineers (USACE), 1998) was used to estimate the average annual volume of runoff because there are no gaging stations for the storm drains in this study area. The storm drains flow in response to rainfall events, so the

discharge from these drains is typically infrequent and highly variable. The storm drains provide an average annual volume of water to the Salt River ranging from 79 to 561 acre-feet.

Table 1-1 presents the average monthly and annual volumes of water released through the interior drains. The table shows the interior drains can supply 8,183 acre-feet of water annually to the project area. Although this is a reasonable amount of water supply to the project, it was calculated through regressive analysis and long-term arithmetic average values. As mentioned earlier, the water supply from interior drains is ephemeral. It is not a reliable source of water supply for the habitat restoration project. However, it can be treated as a secondary water supply through a storm and irrigation water collection system.

Localized water quality problems could occur if surface runoff drainage enters the irrigation drains and transports contaminants from surrounding areas into the irrigation drain canals. The water discharged from irrigation drains is generally high quality and suitable for the habitat restoration project.

Stormwater runoff often contains a significant amount of sediment that is washed from undeveloped and developed land, and other sources, as well as chemical contaminants or pollutants. The types of chemical pollutants will vary depending on the land uses within the particular drainage area. Potential water quality impacts associated with runoff from industrial sites are projected to be minimal because the compliance requirements of stormwater National Pollutant Discharge Elimination System (NPDES) permits require each industrial site to have a stormwater pollution prevention plan (SWPPP). The quality of the "first flush" water is generally poor. As the runoff continues, the water quality improves.

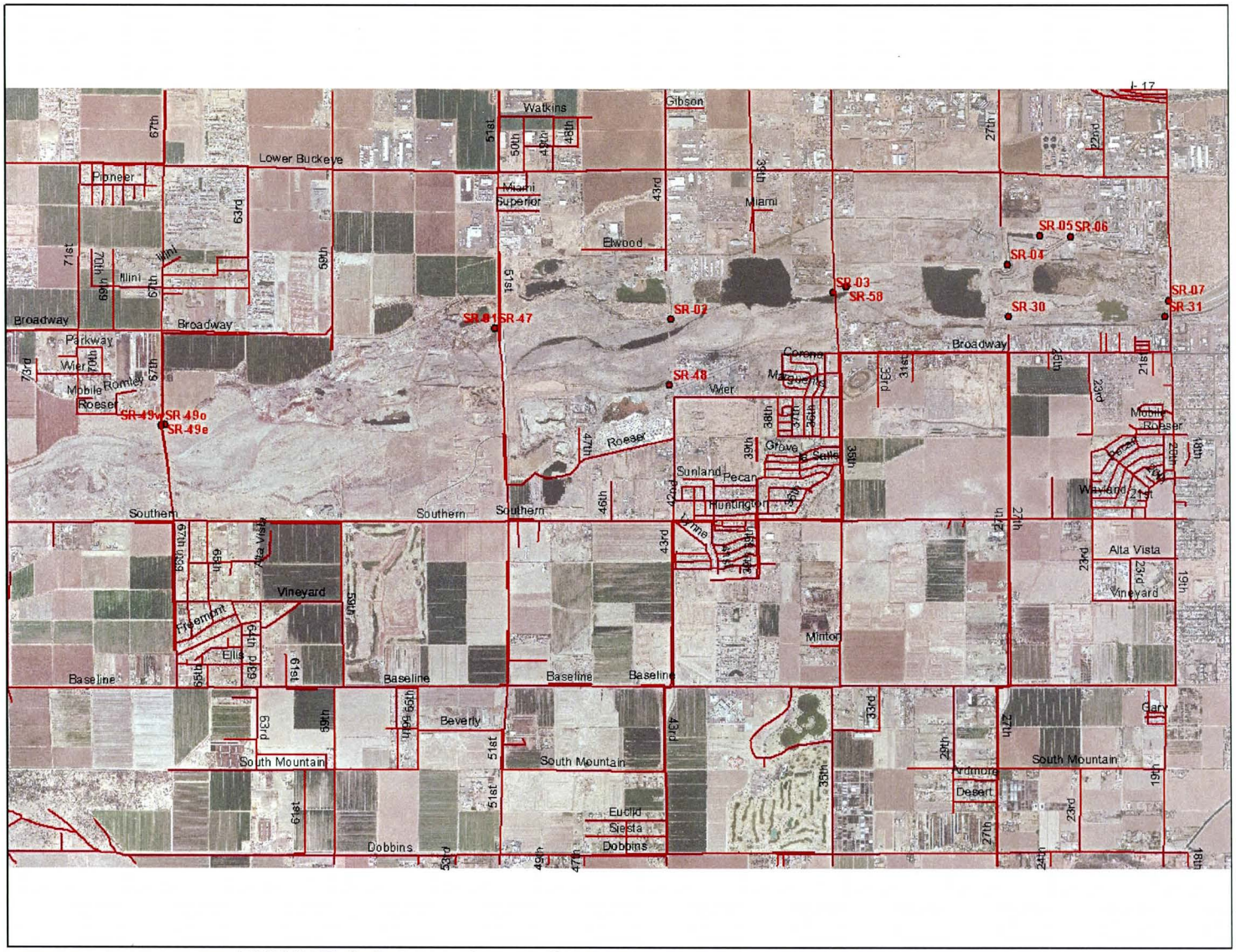


FIGURE 1-1. Locations of Irrigation Drains and Storm Drains

TABLE 1-1. Interior Drains Average Monthly Volume

OUTFALL No.	SITE LOCATION	JAN (AF)	FEB (AF)	MAR (AF)	APR (AF)	MAY (AF)	JUN (AF)	JUL (AF)	AUG (AF)	SEP (AF)	OCT (AF)	NOV (AF)	DEC (AF)	ANNUAL (AF)
	SRP Irrigation Drains													
67th Ave. Drain[1]	67th Ave. and Salt River- North Side	36.7	30.2	146.7	107.6	90.5	95.4	55.0	84.5	173.4	146.0	26.1	51.7	1,044
Maricopa Drain[2]	Near 77th Ave.and Salt River - South Side	223.7	278.2	416.0	574.5	454.1	493.8	480.9	378.0	251.6	241.1	213.2	270.8	4,276
	Storm Drains													
SR01[3,4]	51st Avenue and Salt River - North Side	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR02[3,4]	43rd Avenue and Salt River - North Side	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR03[3,4]	35th Avenue and Salt River- North Side	19.5	20.2	25.7	6.5	3.6	3.8	24.2	28.0	25.1	19.0	19.3	29.1	224
SR04[3,4]	27th Avenue and Salt River- North Side	29.6	30.7	39.2	9.9	5.4	5.8	36.8	42.6	38.1	29.0	29.3	44.3	341
SR05[3,4]	25th Avenue and Salt River- North Side	10.9	11.3	14.4	3.6	2.0	2.1	13.5	15.6	14.0	10.6	10.8	16.3	125
SR06[3,4]	22nd Avenue and Salt River- North Side	48.8	50.5	64.5	16.3	9.0	9.5	60.6	70.1	62.8	47.7	48.2	72.9	561
SR07[3,4]	19th Avenue and Salt River- North Side	6.9	7.1	9.1	2.3	1.3	1.3	8.5	9.9	8.8	6.7	6.8	10.3	79
SR30[3,4]	27th Avenue and Salt River- South Side	17.1	17.7	22.6	5.7	3.1	3.3	21.2	24.5	22.0	16.7	16.9	25.5	196
SR31[3,4]	19th Ave, South Bank	20.1	20.8	26.6	6.7	3.7	3.9	25.0	28.9	25.9	19.6	19.9	30.0	231
SR48a[3,4]	43rd Avenue and Salt River - South Side	142.7	147.6	188.6	47.6	26.2	27.9	177.1	205.0	183.7	139.4	141.0	213.2	1640
SR49[3,4]	67th Avenue and Salt River- North Side	48.5	50.2	64.1	16.2	8.9	9.5	60.2	69.7	62.5	47.4	48.0	72.5	558
	Total													9,823

1. 10-yr statistical average (1993-2002).
2. 9-yr statistical average (1004-2001).
3. Monthly storm water runoff distributions were assumed to follow the monthly pattern of rainfall.
4. Annual runoff volumes were computed from the drainage area vs. average annual runoff relationships developed for the Rio Salado Study.

2.0 Irrigation Drains

Irrigation drains are often constructed along the irrigation canals and laterals in the area to provide a means to discharge excess water from the canal to reduce the possibility of a water-overtopping incident. The drains may be used for a variety of reasons. During storm events, some canals and laterals intercept storm water runoff; if this storm water runoff is significant, water may need to be released from the canal to prevent overflowing the canal banks. Additionally, the major canals occasionally collect irrigation tail water. In the event more water is being conveyed than can be handled safely, the drains allow the excess water to be carried to the Salt River. They also provide a mechanism to empty or lower the water level in the canal to allow for periodic inspection and maintenance or for repairs whenever necessary.

SRP has maintained the discharge data of two outfalls within this study area. The records indicate how many acre-feet per month were discharged at each location. The records do not, however, provide an indication of the instantaneous peak flow rate. SRP 67th Avenue Drain collects and discharges excess water including ordered but unused irrigation water, agricultural return flows, and some street runoff from as far north as Thunderbird Road. The Maricopa Drain collects and discharges excess water including ordered but unused irrigation water, agricultural return flows, and some street runoff from an area as far south as Olney Avenue and as far east as perhaps 16th Street. The average daily flow rates are indicative of the peak flow rates that occur in these canals.

2.1 SRP 67th Avenue Drain

This drain located on the north bank of the Salt River on the east side of 67th Avenue allows excess flows in SRP's Lateral 2-19.0 to drain to the River. Its origin is SRP's Grand Canal near 67th Avenue, just north of Indian School Road. However, it collects and discharges excess water including ordered but unused irrigation water, agricultural return flows, and some street runoff from as far north as Thunderbird Road. The design for the outlet works is detailed on SRP drawing number B-112-405.1. At the point of discharge to the Salt River, it is an open concrete ditch 9.0 feet wide and 3.5 feet deep designed to convey 37.5 cfs.

Flow records for the SRP 67th Avenue Drain were evaluated for the record period from January 1993 through December 2002. These records indicate that the average daily flow rates, on a monthly basis, for this period ranged from 0.87 acre-feet in November to 5.77 acre-feet in September with an average of 2.86 acre-feet. The maximum daily flow rate that occurred during this period was 311.51 acre-feet during October 1998. Table 2-1a and Table 2-1b summarize the average daily and maximum daily flow rates for each month of the period of record evaluated. Although these amounts are sufficient to support some riparian vegetation, these releases are irregular and not reliable since the drains have historically been dry for approximately four months as showed in **Appendix A**. The

average monthly volume of flow for this period ranged from 26.1 acre-feet in November to 173.4 acre-feet in September with an average annual total of 1,043.7 acre-feet. Table 2-2 summarizes the average monthly and annual volumes of flow for the period of record evaluated.

TABLE 2-1a. SRP – 67th Avenue Drain Average Daily Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1993	0.01	0.99	14.36	16.83	2.13	3.51	4.54	4.89	0.15	0.56	0.00	1.46	4.13
1994	5.61	1.00	1.84	1.42	1.12	1.00	0.54	1.82	0.57	0.76	0.08	0.46	1.36
1995	0.05	2.02	4.44	3.35	1.83	3.65	0.74	0.80	0.72	0.21	0.26	0.23	1.52
1996	0.25	3.08	0.18	1.04	1.17	0.69	0.78	1.38	0.01	0.53	0.00	0.00	0.74
1997	0.00	0.00	1.33	1.06	0.31	0.00	0.00	0.79	0.82	0.82	0.00	9.90	1.27
1998	2.05	2.28	12.88	2.57	7.99	2.85	0.88	1.65	44.82	32.74	1.50	1.66	9.51
1999	0.35	0.44	4.41	3.07	1.82	6.72	2.65	5.04	2.07	2.48	0.20	0.01	2.45
2000	1.02	0.54	0.98	2.10	6.34	7.30	1.10	2.64	0.92	2.97	2.65	0.38	2.42
2001	1.31	0.10	6.12	2.86	3.88	3.05	3.57	2.82	4.57	2.19	0.06	0.50	2.61
2002	1.19	0.20	0.78	1.57	2.61	3.02	2.93	5.43	3.10	3.84	3.94	2.07	2.57
Average	1.18	1.07	4.73	3.59	2.92	3.18	1.77	2.73	5.77	4.71	0.87	1.67	2.86

Source: SRP

TABLE 2-1b. SRP – 67th Avenue Drain Maximum Daily Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
1993	0.20	6.33	46.73	48.85	9.14	7.91	14.08	25.75	1.15	5.24	0.00	8.65	48.85
1994	9.14	9.56	12.16	11.17	6.51	5.95	3.69	9.58	3.53	3.23	1.11	3.37	12.16
1995	0.65	16.62	13.92	10.95	6.59	27.79	5.81	5.45	2.78	3.13	3.21	3.53	27.79
1996	2.98	10.95	2.46	4.78	4.22	3.67	6.47	7.12	0.12	5.18	0.00	0.00	10.95
1997	0.00	0.00	5.47	8.57	2.34	0.00	0.00	4.40	8.07	6.94	0.00	30.70	30.70
1998	9.64	11.94	31.34	11.17	32.55	19.00	11.88	17.45	305.94	311.51	19.80	18.70	311.51
1999	3.81	4.09	22.49	14.94	8.35	23.35	11.46	18.45	18.51	10.37	3.47	0.26	23.35
2000	9.32	9.88	10.18	11.03	14.66	14.96	6.98	9.32	5.87	12.89	9.34	2.78	14.96
2001	10.23	2.08	123.45	8.39	11.58	11.11	9.28	10.79	10.87	7.72	0.65	4.72	123.45
2002	2.34	0.69	5.79	7.14	13.59	12.38	16.62	9.26	10.45	18.82	18.88	2.24	18.88
Maximum	10.23	16.62	123.45	48.85	32.55	27.79	16.62	25.75	305.94	311.51	19.80	30.70	311.51

Source: SRP

TABLE 2-2. SRP – 67th Avenue Drain Monthly Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1993	0.2	27.8	445.1	504.9	66.0	105.2	140.9	151.7	4.4	17.2	0.0	45.2	1,508.6
1994	174.0	28.1	57.2	42.6	34.7	30.0	16.6	56.3	17.1	23.6	2.5	14.2	496.9
1995	1.6	56.5	137.5	100.6	56.8	109.4	23.1	24.8	21.5	6.6	7.8	7.1	553.3
1996	7.7	89.4	5.6	31.3	36.2	20.8	24.3	42.7	0.2	16.5	0.0	0.0	274.8
1997	0.0	0.0	41.1	31.8	9.5	0.0	0.0	24.4	24.6	25.3	0.0	306.9	463.6
1998	63.5	64.0	399.4	77.1	247.6	85.5	27.1	51.3	1,344.5	1,015.0	45.1	51.3	3,471.2
1999	10.7	12.3	136.7	92.0	56.4	201.7	82.2	156.1	64.0	76.9	6.0	0.5	895.4
2000	31.7	15.8	30.5	63.1	196.4	219.1	34.2	81.8	27.7	92.0	79.4	11.7	883.5
2001	40.5	2.9	189.6	85.8	120.3	91.5	110.7	87.4	137.0	67.9	1.8	15.6	951.0
2002	37.0	5.5	24.2	47.1	80.9	90.7	90.8	168.4	93.0	119.0	118.3	64.2	939.0
Average	36.7	30.2	146.7	107.6	90.5	95.4	55.0	84.5	173.4	146.0	26.1	51.7	1,043.7

Source: SRP

2.2 SRP Maricopa Drain

This drain, located on the south bank of the Salt River near 77th Avenue allows excess flows from the ditch known as the Maricopa Drain to flow to the River. Its origin is near 23rd Avenue and Roeser Road. However, it collects and discharges excess water including ordered but unused irrigation water, agricultural return flows, and some street runoff from an area as far south as Olney Avenue and as far east as perhaps 16th Street. It also includes excess flows from the Peninsula and Horowitz (P&H) Irrigation service area roughly north of Baseline Road and west of 43rd Avenue. It was historically known as many names including the "Drainage Ditch of the Maricopa County Drainage District No. 5", circa 1930. In addition to carrying excess flows to the Salt River, SRP also uses the facility to transport up to 10 cfs of contracted irrigation water to the Gila River Indian Community, which is diverted from the ditch near 75th Avenue and Baseline. The Flood Control District of Maricopa County plans to convert the western half of the Maricopa Drain to the Laveen Area Conveyance Channel (LACC) sometime in the near future. The capacity of the existing Maricopa Drain northeast of 75th Avenue is approximately 75 cfs and when it's converted to the LACC the updated capacity will be about 2880 cfs. The LACC will carry the normal flows of the existing Maricopa Drain within the LACC's low flow channel.

Flow records for the Maricopa Drain were evaluated for the period from January 1994 through December 2002. These records indicate that the average daily flow rates, on a monthly basis, for this period ranged from 7.11 acre-feet in November to 19.15 acre-feet in April with an average of 11.62 acre-feet. The maximum daily flow rate that occurred during this period was 78.80 acre-feet during May 1995. Table 2-3a and Table 2-3b summarize the average daily and maximum daily flow rates for each month of the period of record evaluated. Although these amounts are sufficient to support some riparian vegetation, these releases are irregular and not reliable since the drains have historically been dry for approximately a month as showed in **Appendix B**.

The average monthly volume of flow for this period ranged from 213.2 acre-feet in November to 574.5 acre-feet in April with an average annual total of 4,276.2 acre-feet. Table 2-4 summarizes the average monthly and annual volumes of flow for the period of record evaluated.

TABLE 2-3a. Maricopa Drain Average Daily Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1994	8.76	8.48	9.56	11.66	5.58	14.39	11.68	10.03	0.04	1.17	0.81	3.08	7.10
1995	4.31	12.42	10.93	23.22	5.15	11.92	9.12	13.56	2.60	4.01	4.76	5.58	8.92
1996	5.74	9.35	15.57	10.37	2.37	9.58	18.96	18.96	6.39	3.52	5.70	8.76	9.62
1997	1.97	2.69	10.16	8.76	4.79	6.30	4.89	4.78	5.68	9.10	8.89	11.80	6.67
1998	9.31	12.30	15.52	27.07	32.67	23.34	34.31	22.02	13.16	7.73	8.05	8.08	17.84
1999	8.43	13.44	19.99	26.23	22.34	23.08	5.84	14.16	15.55	12.27	7.02	12.14	15.02
2000	9.19	11.77	12.06	24.56	22.94	24.24	22.06	18.53	15.74	13.28	9.88	8.59	16.08
2001	8.92	8.44	10.77	22.35	19.28	16.06	22.72	6.64	6.86	7.47	12.10	5.67	12.28
2002	8.33	9.77	16.21	18.14	16.72	19.23	10.04	1.07	8.95	11.47	6.76	6.21	11.06
Average	7.22	9.85	13.42	19.15	14.65	16.46	15.51	12.19	8.33	7.78	7.11	7.77	11.62

Source: SRP

TABLE 2-3b. Maricopa Drain Maximum Daily Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
1994	15.81	19.22	33.68	22.08	18.82	24.54	31.34	18.55	1.09	5.59	6.51	9.94	33.68
1995	12.97	19.36	28.90	32.01	78.80	25.73	26.44	78.76	15.59	11.90	31.54	11.94	78.80
1996	22.71	18.29	26.50	24.42	12.89	23.29	31.87	31.87	16.32	17.79	12.00	15.99	31.87
1997	13.23	13.07	23.72	26.26	27.17	20.73	16.64	27.21	12.48	14.06	12.85	22.67	27.21
1998	17.47	26.48	41.89	36.18	57.28	49.75	60.79	38.08	25.83	20.75	17.14	15.03	60.79
1999	14.00	20.89	35.90	52.78	28.44	34.49	27.77	18.98	18.51	27.09	13.73	24.22	52.78
2000	16.68	20.37	33.72	32.41	30.76	34.26	30.59	28.88	24.12	32.05	20.11	24.62	34.26
2001	20.39	17.12	20.01	39.81	29.00	57.36	39.04	19.08	19.08	22.47	21.22	19.80	57.36
2002	12.95	16.72	26.96	27.93	27.07	37.27	20.03	2.18	16.26	37.29	13.69	20.43	37.29
Maximum	22.71	26.48	41.89	52.78	78.80	57.36	60.79	78.76	25.83	37.29	31.54	24.62	78.80

Source: SRP

TABLE 2-4. Maricopa Drain Monthly Volume

(units are in acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1994	271.5	237.5	296.5	349.7	172.9	431.8	362.2	310.9	1.1	36.2	24.4	366.0	2,860.6
1995	133.7	347.9	338.7	696.7	159.7	357.7	282.7	420.4	78.1	124.2	142.8	173.0	3,255.5
1996	177.9	271.0	482.7	311.1	73.5	287.4	587.8	587.8	191.6	109.0	171.1	271.5	3,522.4
1997	61.0	75.4	315.0	262.7	148.5	189.0	151.6	148.2	170.3	282.0	266.7	366.0	2,436.3
1998	288.7	344.3	481.0	812.2	1,012.8	700.2	1,063.6	682.5	394.8	239.5	241.6	250.5	6,511.7
1999	261.3	376.4	619.8	787.0	692.5	692.4	181.2	439.0	482.1	380.3	210.5	376.4	5,498.9
2000	284.8	341.4	373.8	736.7	711.2	727.3	684.0	574.3	472.2	411.8	296.3	266.3	5,880.1
2001	276.5	236.4	333.9	670.5	597.8	481.7	704.2	205.7	205.7	231.6	363.1	175.6	4,482.8
2002	258.2	273.7	502.6	544.2	518.2	577.0	311.1	33.2	268.6	355.7	202.8	192.4	4,037.5
Average	223.7	278.2	416.0	574.5	454.1	493.8	480.9	378.0	251.6	241.1	213.2	270.8	4,276.2

Source: SRP

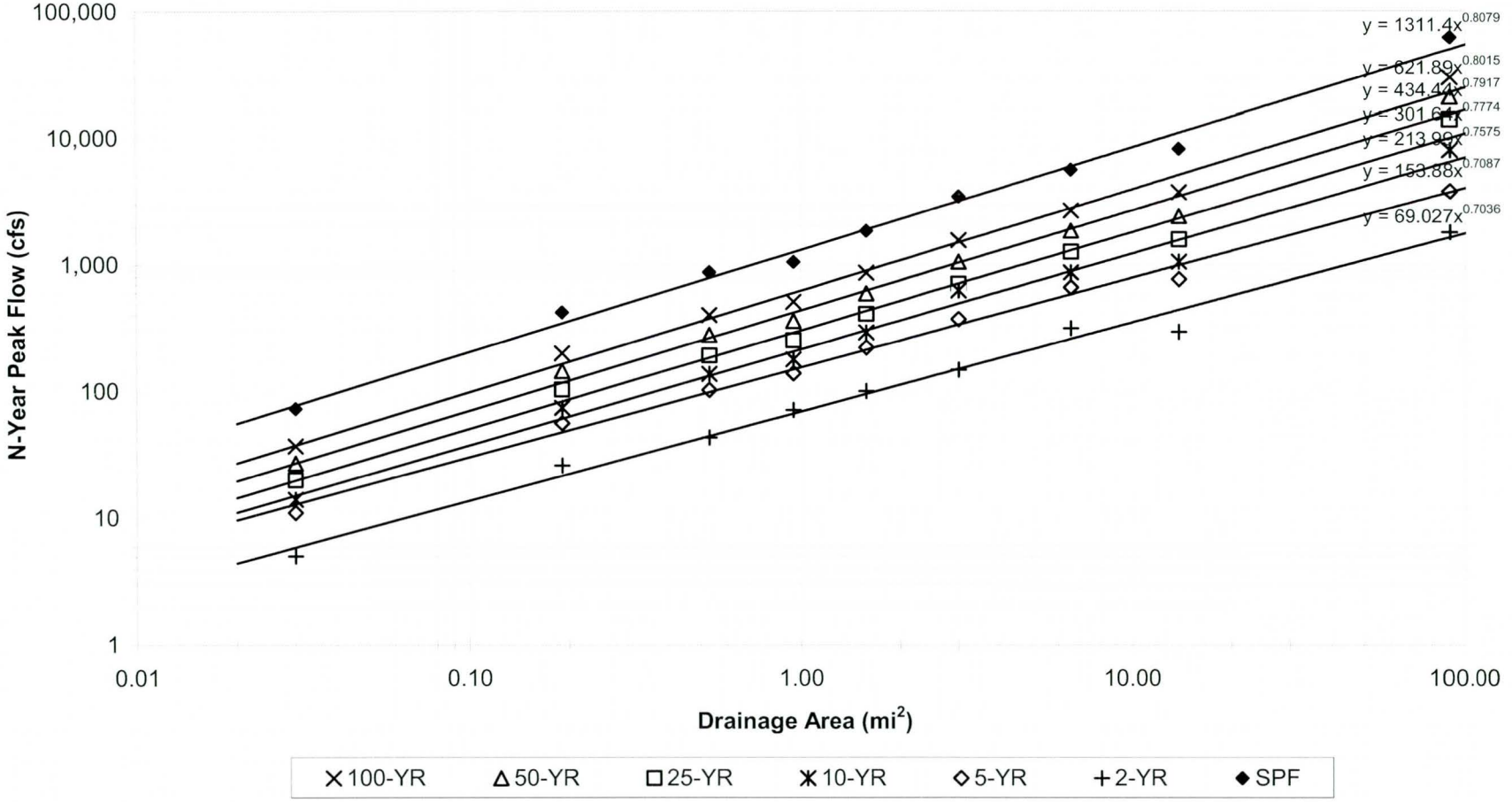
3.0 Storm Drains

Storm drains were evaluated with regard to the potential damage that peak flow rates might have on the restored habitat areas as well as to the possibility of using storm water runoff as a water source. Storm drains are often constructed in urban areas to collect and convey storm water runoff safely through developed or urbanized areas. With increased urbanization, the overall imperviousness of the land generally increases, thus increasing both the peak flow rate and volume of storm water runoff. This storm water runoff can be conveyed through a network of open channels or storm drains to a designated outfall point.

To quantify the potential damage that storm drains may cause to the habitat restoration project, the peak flow rates that occur during or immediately after storm events were examined. Unfortunately, very little information is available from which reasonable peak flow rates can be quantified. Estimates of peak flows were made, however, using the approach developed for the Rio Salado project (USACE, 1998). The Rio Salado project is a similar habitat restoration project within the Salt River. The drainage areas within the Rio Salado study area are similar to those within the Oeste project area. In the Rio Salado project, a series of storm drains were evaluated in which sufficient data were available to model storm runoff using computer modeling techniques. In the Va Shly'ay Akimel Project, a set of N-year peak discharge/drainage area curves was generated by the linear regression analysis to estimate peak flows with only 8-sample drain data without Indian Band Wash (IBW) values. That is a main reason that peak flow rates of Va Shly'ay Akimel project are smaller than peak flow rates of Rio Salado Project. Originally Rio Salado project also included IBW values to aid in providing a consistent set of relationships and to enhance the range established. To keep the consistency for all outfalls to the Salt River, the 8-sample drain sample data and IBW values were then used to generate a series of linear regression curves representing the relationship between peak flow rate and drainage area for this Oeste project. Curves were developed for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events. These curves are shown on Figure 3-1.

In many cases, the storm water runoff is conveyed to retention or detention basins. Retention basins are designed to completely capture the storm water runoff, thus eliminating flow to the outfall point. Detention basins are designed to temporarily capture storm water runoff in order to reduce the peak flow rate to a value that meets local drainage criteria. The detained storm water is then released gradually to the outfall point. The capacity of the outlet pipe is often used to control the rate at which water is released from the detention facilities. For these areas, the peak flow rate that can be discharged into the Salt River is governed by the capacity of the outlet pipe. The full-flow capacities for several pipe sizes were determined for a range of longitudinal slopes. These relationships are presented on Figure 3-2. For this analysis, some of longitudinal pipe slopes were surveyed or found in As-Built drawing by the City of Phoenix (COP) but if the existing slope is unable to figure, a longitudinal slope of 0.0015 was assumed as average value of known value.

To evaluate the possibility of using storm water as a water source, the approach used in the Rio Salado study (USACE, 1998) was used to estimate the average annual volume of runoff. Curves similar to those developed that relate peak flow to drainage area were developed to represent the relationship between the average annual volume of runoff and drainage area. These curves are shown in Figure 3-3. To estimate the average monthly volume of runoff, the annual amount was distributed according to the monthly rainfall distribution in the Phoenix area (Schmidli, 1996). The monthly pattern of rainfall is shown in Table 3-1.



SPF: Standard Project Flood
Data Source: USACE Rio Salado Project

FIGURE 3-1. Peak Flow Relationships for Various Return Periods

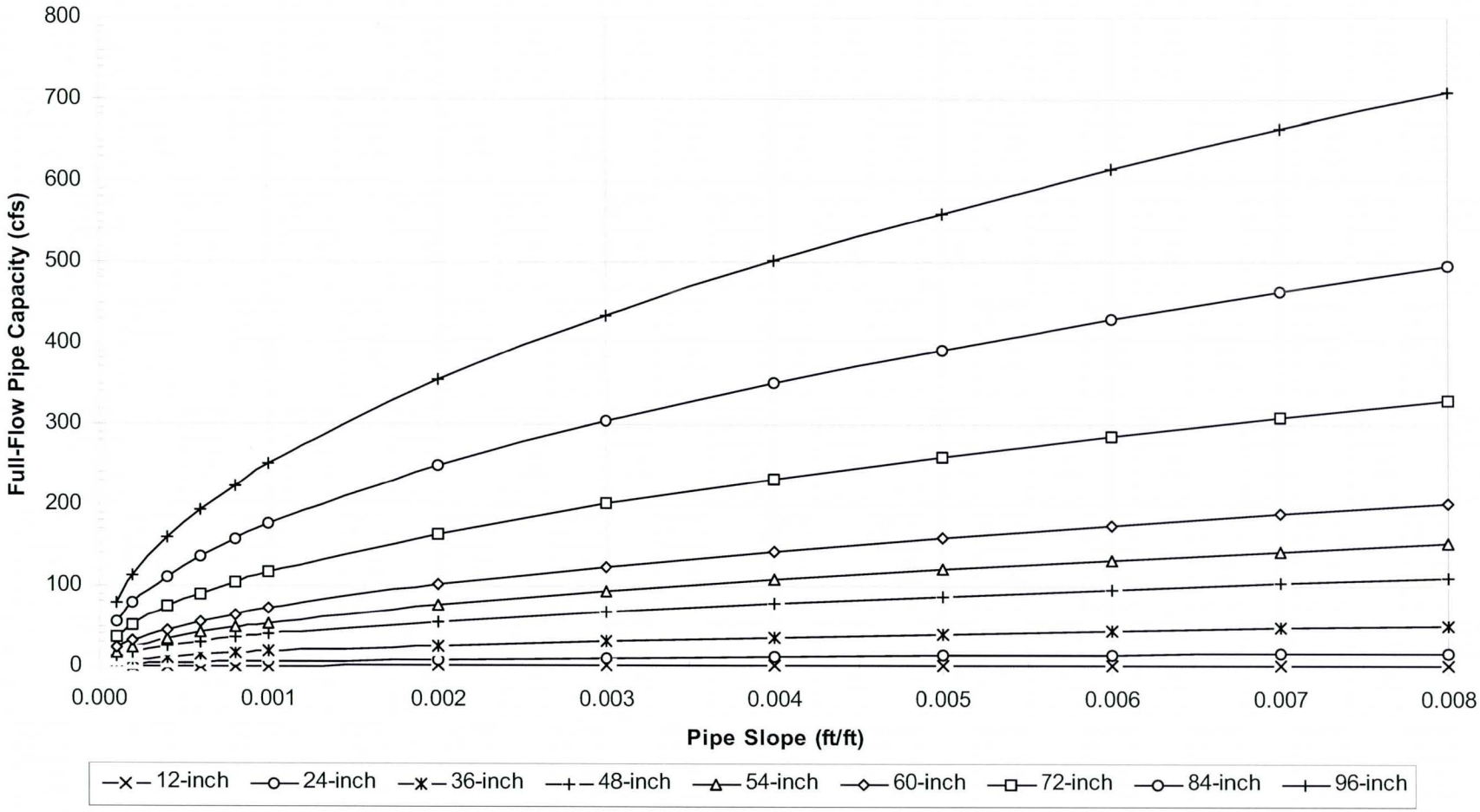
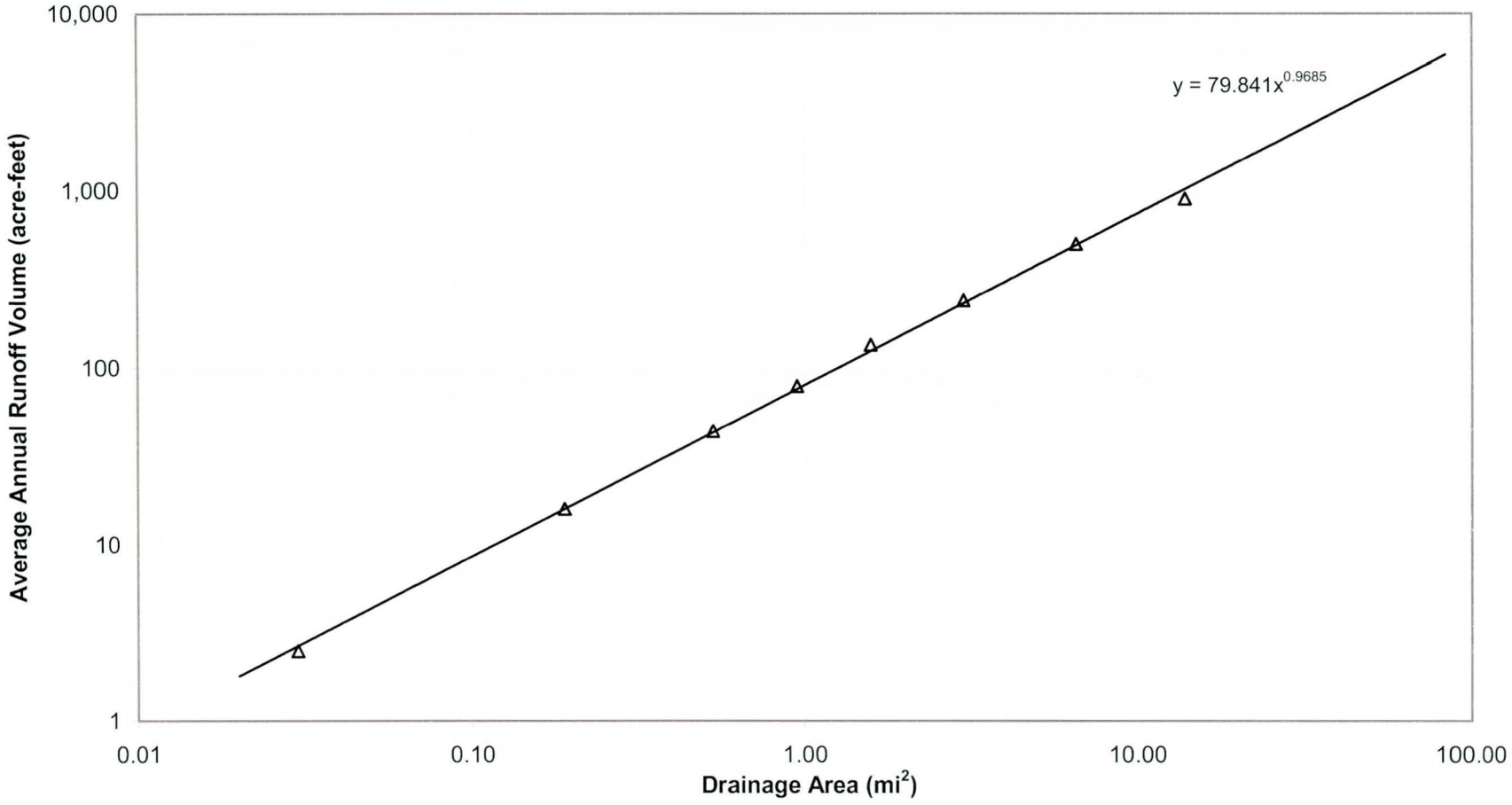


FIGURE 3-2. Typical Full-Flow Storm Drain Pipe Capacity



Source: USACE Rio Salado Project

FIGURE 3-3. Average Annual Storm Drain Runoff for the Phoenix Metro Area

TABLE 3-1. Rainfall Pattern for the Phoenix Area

Month	Rainfall Amount (inches)	Percent of Annual Amount
January	0.67	8.7
February	0.68	9.0
March	0.88	11.5
April	0.22	2.9
May	0.12	1.6
June	0.13	1.7
July	0.83	10.8
August	0.96	12.5
September	0.86	11.2
October	0.65	8.5
November	0.66	8.6
December	1.00	13.0
Annual Total	7.66	100.0

Source: Schmidli, 1996

3.1 SR01: 51st Avenue and Salt River – North Side

The SR01 Storm Drain is located at 51st Avenue of north side bank. A 96-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 3.6 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 1,728 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 96-inch pipe is approximately 177 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 177 cfs would produce a maximum velocity of approximately 3.5 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 274 acre-feet.

3.2 SR02: 43rd Avenue and Salt River – North Side

The SR02 Storm Drain is located at 43rd Avenue of north side bank. A 90-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 3.6 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 1,728 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 90-inch pipe is approximately 221 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 221 cfs would produce a maximum velocity of approximately 5.0 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 274 acre-feet.

3.3 SR03: 35th Avenue and Salt River – North Side

The SR03 Storm Drain is located at 35th Avenue of north side bank. A 75-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 2.9 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 1,460 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 75-inch pipe is approximately 123 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 123 cfs would produce a maximum velocity of approximately 4.0 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 224 acre-feet.

3.4 SR04: 27th Avenue and Salt River – North Side

The SR04 Storm Drain is located at 27th Avenue of north side bank. A 72-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 4.5 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 2,066 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 72-inch pipe is approximately 235 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 235 cfs would produce a maximum velocity of approximately 8.3 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 341 acre-feet.

3.5 SR05: 25th Avenue and Salt River – North Side

The SR05 Storm Drain is located at 25th Avenue of north side bank. A 102-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 1.6 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 901 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 102-inch pipe is approximately 342 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 342 cfs would produce a maximum velocity of approximately 6.0 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 125 acre-feet.

3.6 SR06: 22nd Avenue and Salt River – North Side

The SR06 Storm Drain is located at 22nd Avenue of north side bank. A 78-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 7.5 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 3,121 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 78-inch pipe is approximately 112 cfs. Thus, the peak flow that can

realistically discharge from this drain is governed by the pipe size. A peak flow rate of 112 cfs would produce a maximum velocity of approximately 3.4 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 561 acre-feet.

3.7 SR07: 19th Avenue and Salt River – North Side

The SR07 Storm Drain is located at 19th Avenue of north side bank. A 54-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 1.0 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 622 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 54-inch pipe is approximately 66 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 66 cfs would produce a maximum velocity of approximately 4.1 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 79 acre-feet.

3.8 SR30: 27th Avenue and Salt River – South Side

The SR30 Storm Drain is located at 27th Avenue of south side bank. A 108-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 2.5 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 1,309 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 108-inch pipe is approximately 447 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 447 cfs would produce a maximum velocity of approximately 7.0 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 196 acre-feet.

3.9 SR31: 19th Avenue and Salt River – South Side

The SR31 Storm Drain is located at 19th Avenue of south side bank. A 60-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 3.0 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 1,499 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 60-inch pipe is approximately 88 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 88 cfs would produce a maximum velocity of approximately 4.5 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 231 acre-feet.

3.10 SR48a: 43rd Avenue and Salt River – South Side

The SR48a Storm Drain is located at 43rd Avenue of south side bank. A 96-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 22.66 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 3,107 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 96-inch pipe is approximately 336 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 336 cfs would produce a maximum velocity of approximately 6.7 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in

Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 1640 acre-feet.

3.11 SR49: 67th Avenue and Salt River – North Side

The SR49 Storm Drain is located at 67th Avenue of north side bank. A 96-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a drainage area of approximately 7.4 mi^2. There are no flow records available for this drain.

Figure 3-1 was used to estimate the peak flow rates for a series of storm events. These results are provided in Table 3-2. A peak flow rate of approximately 3,107 cfs was estimated for the 100-year storm event. However, Figure 3-2 indicates that the maximum capacity of a 96-inch pipe is approximately 336 cfs. Thus, the peak flow that can realistically discharge from this drain is governed by the pipe size. A peak flow rate of 336 cfs would produce a maximum velocity of approximately 6.7 ft/sec at the outfall to the Salt River.

Figure 3-3 was used to estimate the average annual volume of storm runoff. The average annual volume of runoff and the monthly distribution of annual runoff are provided in Table 3-3. Using this approach, the average annual volume of storm runoff was estimated to be approximately 558 acre-feet.

3.12 Supplementary

The SR47 Storm Drain is located at 51st Avenue of north side 50 feet north of SR01outfall. A 48-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a probably small drainage area. The drainage area is not well defined; however, it is not expected to generate significant amounts of storm runoff. These are not expected to have implications on the habitat restoration project.

The SR48 Storm Drain is located at 45th Avenue of south side bank. A 48-inch storm drain conveys runoff into the Salt River. This drain collects runoff from a probably small drainage area. The drainage area is not well defined; however, it is not expected to generate significant amounts of storm runoff. These are not expected to have implications on the habitat restoration project.

The SR58 Storm Drain is located at 35th Avenue of northeast side bank. A 60-inch storm drain conveys runoff into the Salt River. This drain discharges runoff from a 23rd Avenue Waste Water Treatment Plant (WWTP). The flow records of this outfall are available in the Water Budget Draft Report.

The SR59 Storm Drain is located at 2333 W. Durango (23rd Ave. WWTP east side of 35th Avenue and Salt River) of north side bank. A 48-inch storm drain conveys runoff into the Salt River. This drain is a part of SR05 conveyance system. The drainage area is not well defined; however, it is not expected to generate significant amounts of storm runoff. These are not expected to have implications on the habitat restoration project.

3.13 Natural Surface Drainage

Natural surface drainage ways, west of 67th Avenue from north bank side and west of 27th Avenue from south bank side, ultimately discharge into the Salt River. The SRP canal intercepts a part of runoff from the areas south of the canal. Because runoff from these areas in not confined to a well-defined drainage ways, storm events will not generate significant flow rates at any location. These areas are not expected to have implications on the habitat restoration project.

TABLE 3-2. Storm Drain N-Year Peak Flow

OUTFALL No.	SITE LOCATION	PIPE SIZE (inch)	Drainage Area[1] (AF)	Pipe Slope (ft/ft)	Drainage Area (mi^2)	N-Year Peak Flow[2] (AF)						CAPACITY[3] (CFS)
						2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	
SR01	51st Avenue and Salt River - North Side	96	2290	0.0005	3.58	169	380	562	813	1192	1728	177
SR02	43rd Avenue and Salt River - North Side	90	2290	0.0011	3.58	169	380	562	813	1192	1728	221
SR03	35th Avenue and Salt River- North Side	75	1856	0.0009	2.90	146	327	479	690	1009	1460	123
SR04	27th Avenue and Salt River- North Side	72	2862	0.00409	4.47	198	445	665	966	1422	2066	235
SR05	25th Avenue and Salt River- North Side	102	1017	0.00135	1.59	96	214	304	432	627	901	342
SR06	22nd Avenue and Salt River- North Side	78	4790	0.0006	7.48	284	641	983	1442	2138	3121	112
SR07	19th Avenue and Salt River- North Side	54		0.0015[4]	1.00	69	154	214	302	434	622	66
SR30	27th Avenue and Salt River- South Side	108	1620	0.0017	2.53	133	297	432	621	906	1309	447
SR31	19th Ave, South Bank	60	1918	0.0015[4]	3.00	149	335	491	708	1036	1499	88
SR47	51st Avenue and Salt River- North Side 50 feet north of SR01	48	unknown	0.0015[4]	unknown	N/A	N/A	N/A	N/A	N/A	N/A	48
SR48	45th Avenue and Salt River- South Side	48	unknown	0.0015[4]	unknown	N/A	N/A	N/A	N/A	N/A	N/A	48
SR49	67th Avenue and Salt River- North Side	96	4762	0.0018	7.44	283	638	979	1436	2128	3107	336
SR58	35th Avenue and Salt River- N/E Side	60	unknown	0.0015[4]	unknown	N/A	N/A	N/A	N/A	N/A	N/A	88
SR59	2333 W. Durango (23rd Ave. WWTP east side of 35th Ave. and Salt River) - North Side	48	unknown	0.0015[4]	unknown	N/A	N/A	N/A	N/A	N/A	N/A	48

1. Drainage areas were provided by COP.

2. N-Year peak flow rates were computed from the drainage area vs. peak flow relationships developed for the Rio Salado Study.

3. A Manning's N-values of 0.015 pipe was assumed for the storm drain capacity estimates.

4. A longitudinal slope of 0.0015 was assumed as average value of known value for the storm drain capacity estimates if the existing slope is unknown.

TABLE 3-3. Storm Drain Average Annual Runoff Volumes

OUTFALL No.	SITE LOCATION	PIPE SIZE (inch)	Drainage Area (acre)	Drainage Area (mi^2)	JAN (AF)	FEB (AF)	MAR (AF)	APR (AF)	MAY (AF)	JUN (AF)	JUL (AF)	AUG (AF)	SEP (AF)	OCT (AF)	NOV (AF)	DEC (AF)	ANNUAL (AF)
SR01[1,2]	51st Avenue and Salt River - North Side	96	2290	3.6	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR02[1,2]	43rd Avenue and Salt River - North Side	90	2290	3.6	23.9	24.7	31.6	8.0	4.4	4.7	29.6	34.3	30.7	23.3	23.6	35.7	274
SR03[1,2]	35th Avenue and Salt River- North Side	75	1856	2.9	19.5	20.2	25.7	6.5	3.6	3.8	24.2	28.0	25.1	19.0	19.3	29.1	224
SR04[1,2]	27th Avenue and Salt River- North Side	72	2862	4.5	29.6	30.7	39.2	9.9	5.4	5.8	36.8	42.6	38.1	29.0	29.3	44.3	341
SR05[1,2]	25th Avenue and Salt River- North Side	102	1017	1.6	10.9	11.3	14.4	3.6	2.0	2.1	13.5	15.6	14.0	10.6	10.8	16.3	125
SR06[1,2]	22nd Avenue and Salt River- North Side	78	4790	7.5	48.8	50.5	64.5	16.3	9.0	9.5	60.6	70.1	62.8	47.7	48.2	72.9	561
SR07[1,2]	19th Avenue and Salt River- North Side	54	632.77	1.0	6.9	7.1	9.1	2.3	1.3	1.3	8.5	9.9	8.8	6.7	6.8	10.3	79
SR30[1,2]	27th Avenue and Salt River- South Side	108	1620	2.5	17.1	17.7	22.6	5.7	3.1	3.3	21.2	24.5	22.0	16.7	16.9	25.5	196
SR31[1,2]	19th Ave, South Bank	60	1918	3.0	20.1	20.8	26.6	6.7	3.7	3.9	25.0	28.9	25.9	19.6	19.9	30.0	231
SR47[1,2]	51st Avenue and Salt River- North Side 50 feet north of SR01	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR48[1,2]	45th Avenue and Salt River- South Side	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR48a[1,2]	43rd Avenue and Salt River- South Side	N/A	14502	22.66	142.7	147.6	188.6	47.6	26.2	27.9	177.1	205.0	183.7	139.4	141.0	213.2	1640
SR49[1,2]	67th Avenue and Salt River- North Side	96	4762	7.4	48.5	50.2	64.1	16.2	8.9	9.5	60.2	69.7	62.5	47.4	48.0	72.5	558
SR58[1,2]	35th Avenue and Salt River- N/E Side	60	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SR59[1,2]	2333 W. Durango (23rd Ave. WWTP east side of 35th Ave. and Salt River) - North Side	48	unknown	unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Total																4503

1. Monthly storm water runoff distributions were assumed to follow the monthly pattern of rainfall.
2. Annual runoff volumes were computed from the drainage area vs. average annual runoff relationships developed for the Rio Salado Study.

4.0 Water Quality Analyses

The water quality of the irrigation drains can meet the needs of the Oeste Project in most cases. Localized water quality problems could occur if surface runoff enters the irrigation drains and transports contaminants from surrounding areas into the drain canals. There are no concentrated animal feeding operations in the area that could contribute contaminated runoff into the irrigation drains system.

It is important to note that storm water quality is a function of land use, not the size of the watershed (Greeley and Hansen, 2001). Stormwater runoff often contains a significant amount of sediment that is washed from undeveloped land and other sources, as well as chemical contaminants or pollutants. The types of chemical pollutants will vary depending on the land uses within the particular drainage area. Potential water quality impacts associated with runoff from industrial sites are projected to be minimal because the compliance requirements of stormwater NPDES permits require each industrial site to have a stormwater pollution prevention plan (SWPPP). Runoff from turf areas has the potential to contain pesticide and fertilizer residuals. Runoff from paved areas can contain hydrocarbon products, metals, and anything spilled on the pavement. The quality of the "first flush" water is generally poor. As the runoff continues, the water quality improves. In general, based on analysis of available data versus the numeric water quality standards, stormwater is a vehicle by which surface water quality appears to degrade within the Salt River.

5.0 Evaluation of Interior Drainage System

Two types of interior drains were evaluated that outfall into the Salt River within the Oeste project study limits – irrigation drains and storm drains. The interior drains were evaluated to assess the potential damage that their flows may have on the habitat restoration project. The interior drains were also evaluated to assess the potential for using these flows as a water source to support and nourish the restored vegetation. For this evaluation, these drains were each evaluated based on the quantity, reliability, and quality of flow that is or may be available for habitat restoration. The water source analyses are described in further detail in the Water Budget
Report.

5.1 Damage to Restored Habitat

The irrigation drains flow in response to controlled releases by SRP. These releases are relatively consistent throughout the day and do not have instantaneous peak flow rates considerably greater than the average daily rate. Flow records for these drains indicate that the maximum daily flow rates recorded for these canals were 311.51 acre-feet, and 78.80 acre-feet for the SRP 67th Avenue Drain, and Maricopa Drain, respectively.

The storm drains flow in response to rainfall events. The two major storm drains identified are the SR06 and SR49. For this study, the peak flow rate associated with the 100-year storm was assumed to represent the upper bound possible condition. The peak 100-year flow rates for these drains were estimated to be approximately 3,121 cfs and 3,107 cfs. However, the maximum capacity of the SR06 is considerably less. The peak flow rates that could realistically discharge from these drains are 112 cfs and 336 cfs, which would generate discharge velocities of 3.4 ft/sec and 6.7 ft/sec, respectively.

The remaining storm drains within the project area could discharge peak flow rates as high as 447 cfs with velocities as high as of 7.0 ft/sec into the Salt River. The peak flow rates generated by the drainage areas for these drains may be considerably greater; however, detention facilities or the maximum capacity of the outlet pipes govern the maximum rate at which storm water will be discharged into the restored habitat. A summary of peak flow rates for a series of storm events and the maximum capacities of each outlet is provided in Table 3-2.

The peak flow rates and discharge velocities from the interior drains are sufficient to create localized damage at the outlet of each drain. However, this damage is not expected to extend beyond the immediate vicinity of the pipe outlet. There is little evidence to suggest that flows from these drains have historically done more than wet the riverbed in the immediate vicinity of the drain outlet. Additionally, the maximum flow rates that could potentially discharge from these drains are significantly smaller in magnitude than Salt River flood flows. The Salt River is expected to spill over Granite Reef approximately once every three years, and the 5-year peak discharge from these spills is expected to exceed 20,000 cfs (USACE, 1998). To that regard, there is little advantage to providing protection from the interior drainage discharge.

5.2 Water Source

The irrigation drains, which flow in response to controlled releases, have received occasional flows throughout the record period from 1993 through 2002. The average annual volumes of water released to the Salt River during this period were 1,044 acre-feet (the record period from 1993 through 2002), and 4,276 acre-feet (the record period from 1994 through 2002) for the SRP 67th Avenue Drain, and Maricopa Drain, respectively. Although these amounts are sufficient to support some riparian vegetation, the timing of these flows is irregular. These releases are not reliable as the drains have historically been

dry for long periods; for example, there were no releases to the SRP 67th Avenue Drain throughout the period from November 1996 through February 1997. The Maricopa Drain flows were historically more frequent and reliable. Future releases to this drain are expected to be less frequent than the historic trend. Table 2-2, and Table 2-4 summarize the average monthly and annual volumes of water released through the irrigation drains for the period of record evaluation. The water discharged from irrigation drains is generally high quality and suitable for the habitat restoration project.

The storm drains flow in response to rainfall events, so the discharge from these drains is typically infrequent and highly variable. The storm drains provide an average annual volume of water to the Salt River ranging from 79 to 1640 acre-feet. Table 3-3 summarizes the average monthly and annual volumes of water released through the storm drains. Stormwater runoff often contains a significant amount of sediment that is washed from undeveloped land and other sources, as well as chemical contaminants or pollutants. The types of chemical pollutants will vary depending on the land uses within the particular drainage area. The quality or the "first flush" water is generally poor. As the runoff continues, the water quality improves.

The average monthly and annual volumes of water released from some of the interior drains are of sufficient magnitude to be considered as a potential water source. The two irrigation drains have historically supplied a significant amount of water to the Salt River. These drains, however, do not flow consistently, and releases into these drains may not be reliable. The SR06, SR48a, and SR49 Drain have supplied a relatively enough flow to the river based on estimated flow rates. However, long-term records are not available to ascertain this supply. The SR01, SR02, SR03, SR04, SR05, SR06, SR07, SR30, SR31, and SR49 should all be included in the water budget analyses.

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APPENDIX A

SRP 67th Avenue Drain Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1993
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0.08	40.78	2.64	3.71	0.56	0.77	1.15	0	0	0
2	0	0	0.73	33.96	1.35	2.84	2.72	1.63	0.32	0	0	0
3	0	0	0	30.7	4.24	2.72	6.64	2.04	0.32	0	0	0
4	0.2	0	0	33.08	5.97	2.46	8.65	6.19	0.32	0	0	0
5	0	0	0	37.83	4.34	2.34	3.09	1.19	0.32	0	0	0
6	0	0	0	48.85	5.75	2.52	1.88	0.93	0.32	0	0	2.06
7	0	0	1.13	47.98	6.61	3.37	3.51	1.63	0.32	1.53	0	2.56
8	0	0	5.08	39.75	9.14	3.73	4.05	4.5	0.32	5.18	0	0.02
9	0	0	9.32	21.24	6.33	1.88	3.51	3.63	0.2	5.24	0	0
10	0	0	8.73	8.03	0	0.24	2.96	7.68	0	4.22	0	0.02
11	0	0	5.99	15.51	0	0.44	1.75	6.31	0	0	0	0.52
12	0	0	1.11	10.97	0	1.07	3.21	7.8	0	0	0	3.57
13	0	0	0	8.75	0	3.91	5.69	0.61	0	0	0	0
14	0	0	0.42	10.79	1.31	6.37	5.65	0.58	0	0	0	0
15	0	0	9.4	15.65	2.4	7.91	14.08	0.32	0	0	0	0
16	0	0	15.09	12.38	2.96	4.34	9.08	0.32	0	0	0	0
17	0	0	17.42	10.55	2.34	3.45	9.01	0.32	0	0	0	1.33
18	0	0	10.51	8.75	2.34	2.32	4.88	0.32	0	0	0	0.26
19	0	0	10.31	10.55	2.36	2.48	1.9	0.32	0	0	0	0.06
20	0	0	14.96	6.29	2.4	4.92	1.79	0.32	0	0	0	2.62
21	0	0	17.32	0.52	0.18	6.59	4.07	1.79	0	0	0	4.46
22	0	0	15.57	4.88	0	7.54	3.73	4.34	0	0	0	0
23	0	2.22	8.37	13.73	0	7.56	5.18	5.57	0	0	0	0
24	0	4.4	16.03	9.22	0	7.1	5.83	5.08	0	0	0	0
25	0	4.62	40.84	5.45	0	6.33	10.99	19.46	0.83	0	0	0
26	0	6.33	46.1	7.46	0.26	5.02	7.99	25.75	0	0	0	4.88
27	0	4.01	31.28	4.92	1.33	1.37	1.25	13.31	0	0.02	0	5.3
28	0	6.19	27.85	0.71	0.63	0.24	0.32	4.32	0	0.42	0	8.65
29	0		46.73	0.87	0.3	0.24	1.05	12.42	0	0.28	0	5.26
30	0		41.55	4.7	0.3	0.22	2.42	9.62	0	0.3	0	0.89
31	0		43.22		0.52		3.41	2.66		0.04		2.76
Total	0.20	27.77	445.14	504.85	66.00	105.23	140.85	151.73	4.42	17.23	0.00	45.22
Count	1	6	26	30	23	30	31	31	10	9	0	17
Average	0.01	0.99	14.36	16.83	2.13	3.51	4.54	4.89	0.15	0.56	0.00	1.46
Maximum	0.20	6.33	46.73	48.85	9.14	7.91	14.08	25.75	1.15	5.24	0.00	8.65

Minimum	0.00	0.00	0.00	0.52	0.00	0.22	0.32	0.32	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1994
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4.28	0	3.05	2.62	0	0	3.69	0	1.11	0	0	0.48
2	4.58	1.37	4.56	3.11	0	0.06	1.47	0	0	0	0	0.79
3	4.26	3	1.8	3.05	0.5	0	0.75	0	0	0	0	1.11
4	7.91	0	0	0	1.27	3.09	0.06	0	0	0	0	1.23
5	7.99	0	0.16	0	1.43	3	0	3.47	0	0	0	0.12
6	5.06	0	0	0	6.51	0.97	0	9.4	0	0	0.65	0
7	5.1	2.44	5.55	0.16	2.76	0	1.31	5.3	1.79	0.02	0	0
8	5.65	9.56	8.45	5.1	0.3	0	1.79	0	0	0	0	0
9	7.56	2.7	0	11.17	0	0	2.46	0	0	0	0	0.08
10	7.81	8.99	0	3.73	1.55	0	2.22	0	0	0	0	0.26
11	7.28	0.02	0	6.57	2.96	0.63	0.02	0	2.74	0.28	0	0
12	6.17	0	0.02	2.46	1.82	1.13	0	0	2.98	2.64	0	0
13	6.94	0	1.37	2.18	0	1.61	0	0.1	0.5	2.14	0	0
14	7.83	0	0.2	0.4	0.52	0.38	0	0	0	2.2	0	0
15	8.93	0	0	0	0.34	0.4	0	0	0	0.02	0	0
16	7.78	0	0.26	0	0.16	0.14	0	0	0	0	0	0
17	7.32	0	3.09	0	4.74	2.06	0.91	0	0	0	0	0
18	7.44	0	0	0	3.01	5.95	1.96	0	0	0.71	0	0.58
19	4.56	0	0	0	0.89	3.57	0	0	0	2.42	0	0
20	1.09	0	0	0.32	1.79	0.1	0	0	0	3.07	0	0.75
21	5.49	0	0	0.04	0	0	0	0.87	0	3.23	0	1.11
22	9.14	0	0	1.67	0	0	0	9.18	0	1.73	0	0
23	6.39	0	1.41	0	0	0	0	3.91	0.06	0.26	0	3.37
24	4.44	0	8.61	0	0.44	0	0	5.26	3.53	0	0	1.49
25	4.21	0	12.16	0	1.92	0	0	7.85	2.9	0	0	1.33
26	5.87	0	6.37	0	0	0	0	9.58	1.49	0	0	1.47
27	8.35	0.02	0	0	0.02	0	0	0	0	2.76	1.11	0
28	4.56	0	0	0	0	0	0	0	0	2.12	0.04	0
29	0		0	0	0	1.35	0	0	0	0	0.12	0
30	0		0	0	1.8	5.51	0	0	0	0	0.58	0
31	0		0.1		0		0	1.41		0		0
Total	173.99	28.10	57.16	42.58	34.73	29.95	16.64	56.33	17.10	23.60	2.50	14.17
Count	28	8	16	14	20	16	11	11	9	14	5	14

Average	5.61	1.00	1.84	1.42	1.12	1.00	0.54	1.82	0.57	0.76	0.08	0.46
Maximum	9.14	9.56	12.16	11.17	6.51	5.95	3.69	9.58	3.53	3.23	1.11	3.37
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1995
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	1.59	0.04	0	1.11	0	0	0	3.53
2	0	3.27	3.11	1.47	4.05	0.14	0	0.38	0	0	0.2	1.51
3	0	8.57	0.12	4.4	0.04	4.62	0	0.02	0	0	0	0.2
4	0	0.52	0.58	7.56	0	9.18	0	0.52	0	0	0	0
5	0.65	0	3.73	6.57	0.02	10.71	0	1.96	0	0	0	0
6	0	0	7.66	6.49	1.07	4.72	0	5.45	0.93	0	0	0
7	0	0.02	11.33	9.46	4.62	0.77	0	3.39	2.78	0	0	0
8	0	4.84	4.64	10.95	4.44	0.85	0	1.47	1.79	0	0	0
9	0.04	1.31	9.58	5.41	4.07	4.64	0	0	0	0	0	0
10	0.08	3.01	13.45	0	1.13	2.28	0	0.04	0	0	0	0
11	0.16	4.11	9.48	0.28	0	5	0	0	0.71	0	0	0
12	0.58	0.18	1.88	6.61	1.88	27.79	0.02	0.16	0	0	0	0
13	0.12	0	0.06	5.97	6.59	11.9	2.32	0	0.18	0	0	0
14	0	0	1.65	8.57	5.91	2.12	0.65	0	0.16	0	0	0
15	0	11.66	0	2.3	2.34	1.01	2.46	0	0.65	0	0	0
16	0	16.62	0	0.73	0.04	0.2	0	0	1.07	0	0	0
17	0	0	0	3.49	2.02	1.79	0	0	0	0	0	0
18	0	0	0.02	5.36	1.41	4.82	0	0	0	0	0	0
19	0	0	0.42	2.76	0	2.76	0	0.77	0.02	0	0	0
20	0	0	0	0.54	0.22	3.77	0	3.23	0.08	2.14	0	0
21	0	0	0.26	0	0.38	7.52	0	0.69	2.6	3.13	0	0
22	0	0	6.78	0	0.02	2.78	0	0.63	2.5	1.29	0	0
23	0	0.48	12.67	0	0.02	0	0	0	2.42	0	0	0.34
24	0	1.07	5.79	0	0.22	0	0	0	2.2	0	0	0.46
25	0	0.54	13.92	0	0	0	0	0	1.53	0	0	0
26	0	0	7.5	0	0	0	5.81	0	0	0	0	0
27	0	0.28	8.09	0.26	1.63	0	2.62	0.87	0	0	0.02	0.95
28	0	0	3.87	1.84	5.57	0	1.92	1.67	1.67	0	1.92	0.08
29	0		5.43	6.61	5.95	0	2.3	1.63	0.18	0	2.46	0
30	0		5.16	2.98	1.59	0	1.73	0.83	0	0	3.21	0
31	0		0.32		0		3.25	0		0		0

Total	1.63	56.48	137.50	100.61	56.82	109.41	23.08	24.82	21.47	6.56	7.81	7.07
Count	6	15	26	22	25	22	10	18	17	3	5	7
Average	0.05	2.02	4.44	3.35	1.83	3.65	0.74	0.80	0.72	0.21	0.26	0.23
Maximum	0.65	16.62	13.92	10.95	6.59	27.79	5.81	5.45	2.78	3.13	3.21	3.53
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1996
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	4.34	0.77	0	2.52	0.42	0	0	0.12	0	0	0
2	0	7.46	0	0.36	2.76	0.83	0	0	0	0	0	0
3	0	0	0	0	2.8	0.26	0	0.91	0	0	0	0
4	0	0	0	0.18	1.96	0.26	0	2.62	0	0	0	0
5	0	0	0	1.8	4.22	0.26	0	1.03	0	0	0	0
6	0	0	0	2.1	4.22	0.28	0	0.61	0	0	0	0
7	0	0	0.58	0.75	2.82	0.36	0.36	0	0	0	0	0
8	0	0	0.22	0	0.32	1.15	2.86	0	0	0	0	0
9	0	0	0	0	0	2.16	2.8	0	0	0	0	0
10	0	0	0	0.54	0	0.46	0.79	0	0	0.38	0	0
11	0	0	0	0	0.42	0.26	0.28	0	0.12	0.44	0	0
12	0	0	0	0	1.61	0.4	0	0	0	0.46	0	0
13	0.67	0	0.5	0.28	3.49	3.11	0	0	0	3.29	0	0
14	2.98	0	2.46	1.31	0.5	3.67	0	0	0	3	0	0
15	1.86	0	1.05	3.61	0.5	0.26	0	0.65	0	5.18	0	0
16	0	0	0	4.19	0.24	0.26	0.08	1.05	0	0.54	0	0
17	0	0	0	0	0	0.3	0	0.75	0	0.4	0	0
18	0.81	0	0	0	0	0.26	0	1.65	0	1.57	0	0
19	0.4	0	0	0.22	0	0.44	0	2.58	0	1.11	0	0
20	0.1	0	0	0.16	0	1.33	0.04	1.82	0	0	0	0
21	0	2.82	0	0.32	0	0.08	0.97	1.11	0	0	0	0
22	0	7.32	0	0.1	0	0.1	2.78	3.19	0	0	0	0
23	0	9.34	0	0.89	0.18	0	0.83	7.12	0	0	0	0
24	0	10.75	0	2.46	0.46	0	1.57	6.45	0	0	0	0
25	0	10.37	0	0.93	0.85	0	4.48	3.77	0	0	0	0
26	0	10.31	0	0	1.27	0	6.47	1.41	0	0.12	0	0
27	0	10.25	0	0.22	1.35	0	0	1.39	0	0.04	0	0
28	0.12	10.95	0	1.55	1.35	0.38	0	2.4	0	0	0	0
29	0	5.53	0	4.78	1.21	1.57	0	2.18	0	0	0	0
30	0.04		0	4.58	0.77	1.92	0	0.02	0	0	0	0

31	0.73		0		0.34		0	0		0		0
Total	7.71	89.44	5.58	31.33	36.16	20.78	24.31	42.71	0.24	16.53	0.00	0.00
Count	9	11	6	21	23	25	13	20	2	12	0	0
Average	0.25	3.08	0.18	1.04	1.17	0.69	0.78	1.38	0.01	0.53	0.00	0.00
Maximum	2.98	10.95	2.46	4.78	4.22	3.67	6.47	7.12	0.12	5.18	0.00	0.00
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1997
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0.73	1.79	0	1.29
2	0	0	0	0	0	0	0	0	0.3	4.09	0	14.72
3	0	0	0	0	0	0	0	0	0	2.62	0	2
4	0	0	0.87	0	0	0	0	0	0	4.98	0	3.63
5	0	0	0.97	0	0	0	0	0	0	0.18	0	13.45
6	0	0	1.37	0	0	0	0	0	0	0	0	14.44
7	0	0	2.02	0	0	0	0	0	0	0	0	14.44
8	0	0	0.44	0	0	0	0	0	0	0	0	14.44
9	0	0	0	0	0	0	0	0	0	0	0	3.03
10	0	0	0	0	0	0	0	0	0.2	0	0	0
11	0	0	0	0.12	0	0	0	0	4.24	0	0	12.46
12	0	0	0	1.67	0	0	0	0	8.07	0	0	19.46
13	0	0	0	2.08	0	0	0	0	0.06	0	0	18.51
14	0	0	1.84	0	0	0	0	0	0	0	0	13.31
15	0	0	4.74	1.57	0	0	0	0	0	0	0	12.12
16	0	0	5.47	1.37	0	0	0	0	0	0	0	11.8
17	0	0	5.38	1.33	0	0	0	0.3	0	0	0	16.44
18	0	0	2.56	1.19	0	0	0	1.49	0	0	0	17.55
19	0	0	0.04	0.06	0	0	0	2.78	0	0	0	19.56
20	0	0	4.09	1.57	0	0	0	4.38	0.67	0	0	30.7
21	0	0	5.18	8.57	0	0	0	4.4	3.47	0	0	7.66
22	0	0	3.19	2.26	0.1	0	0	4.11	4.01	1.45	0	5.16
23	0	0	2.64	2.42	1.96	0	0	3.95	2.22	3.05	0	2.44
24	0	0	0.14	0.95	1.03	0	0	1.41	0.52	6.94	0	0
25	0	0	0	1.75	2.28	0	0	0.52	0	0.24	0	0
26	0	0	0	2.64	2.34	0	0	0	0	0	0	0
27	0	0	0	2.12	1.63	0	0	0	0	0	0	1.53
28	0	0	0.16	0.12	0	0	0	0	0	0	0	0.63

29	0		0	0	0.16	0	0	0	0	0	0	3.61
30	0		0	0	0	0	0	0.52	0.08	0	0	14.08
31	0		0		0		0	0.58		0		18.41
Total	0.00	0.00	41.10	31.79	9.50	0.00	0.00	24.44	24.57	25.34	0.00	306.87
Count	0	0	17	17	7	0	0	11	12	9	0	27
Average	0.00	0.00	1.33	1.06	0.31	0.00	0.00	0.79	0.82	0.82	0.00	9.90
Maximum	0.00	0.00	5.47	8.57	2.34	0.00	0.00	4.40	8.07	6.94	0.00	30.70
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1998
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	3.45	0	0.34	2.34	1.98	0	0.08	0	21.86	0	2.88	0
2	0.1	0	0	1.23	10.85	0	0.08	0.12	0.08	0	0	0.04
3	0.85	0	4.13	1.17	11.23	0	0.1	0.1	0.14	0	0	0
4	0.02	4.4	3	1.03	10.73	0	0.22	0	0.95	0	0	0
5	1.96	1.92	3.23	0.91	5.91	19	0.08	0.12	0.08	31.12	0	0.44
6	2	0	3.45	1.03	8.53	17.81	0.08	0.18	0.14	51.49	0	3.17
7	6.03	0	13.67	11.17	1.45	0.52	0.14	0.1	0.08	3.47	0	0
8	5.38	1.27	7.26	4.7	1.55	0.71	0.12	0	0.08	0	0.56	0.04
9	1.13	7.93	19.08	6.8	15.87	1.86	0.12	0	0.08	0	19.8	10.37
10	2.14	5.28	22.93	4.58	27.41	6.19	0.08	0	0.08	0	1.19	18.7
11	0.24	3.85	21.58	2.8	10.35	4.78	0.08	1.19	0.08	0	4.76	0
12	0	0	23.8	8.85	20.49	4.98	0.08	4.07	0.08	0	2.32	0
13	0	0	28.98	0.22	32.55	5.55	0.08	5.32	0.08	0	0	0
14	0	0	24.46	0	12.3	1.96	1.23	2.74	0.08	0	0	0
15	0	6.68	23.86	0	8.05	2.72	1.05	0	87.33	0	0	0
16	0.6	0	21.34	0.52	7.54	0.1	1.23	0	32.19	0	0.06	0
17	0.04	11.94	29.77	5.93	0.67	0.12	2.04	2.72	72.16	0	0	0
18	0	10.29	27.89	5.77	0.12	0.12	11.88	0	18.37	0	0	0
19	0	0.79	1.69	1.9	0	0.12	2.1	0	0.08	0	0	0.06
20	0	1.21	0.42	0.73	0	0.34	0.3	0	87.29	0	0	0.87
21	0.26	0.4	3.93	0	0.54	0	0.34	0	189.74	0	0.08	2.62
22	0.22	0	6.68	0.5	2.84	0	0.89	0	269.44	294.15	3	2.4
23	0.48	0	7.46	1.23	0.16	4.94	0.08	0	305.94	311.51	7.24	8.27
24	2.6	4.05	5.16	5.28	5.61	6.49	0.08	0.16	257.56	284.93	1.29	2.6
25	9.64	1.37	2.02	2	10.27	7.12	0.3	0.65	0.08	26.38	1.88	0
26	5.04	0.16	12.44	4.24	10.29	0	0.75	3.53	0.08	5.91	0.02	0

27	6.84	0.97	1.21	0.1	7.74	0	0.91	1.98	0.08	0.12	0	0
28	5.41	1.45	9.86	0.85	10.06	0.04	1.21	3.09	0.08	0	0	0
29	4.5		24.4	0	9.96	0	0.08	6.8	0.08	0.73	0	0.2
30	2.74		31.34	1.17	1.63	0	0.08	17.45	0.08	4.17	0	1.21
31	1.82		13.98		0.87		1.25	0.97		1.03		0.32
Total	63.49	63.96	399.36	77.05	247.55	85.47	27.14	51.29	1,344.47	1,015.01	45.08	51.31
Count	24	17	30	26	29	20	31	18	30	12	13	15
Average	2.05	2.28	12.88	2.57	7.99	2.85	0.88	1.65	44.82	32.74	1.50	1.66
Maximum	9.64	11.94	31.34	11.17	32.55	19.00	11.88	17.45	305.94	311.51	19.80	18.70
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 1999
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1.55	0	0	0.08	0	0	0.54	2.48	3.37	5.81	0	0.04
2	0	0	0.38	14.94	0	0	0.04	1.69	3.99	7.62	0	0
3	0	0	0.5	0	0	0	0.61	0	2.3	6.21	0	0
4	0	0	2.22	0	0.06	5.69	0.73	4.05	0	5.89	0	0
5	0	0	5.83	0.44	0	11.11	2.56	2.48	0	6.49	0	0
6	0	0	15.21	0	0	8.23	0.32	8.85	0	3.53	0	0
7	0	0	3.23	0	0	0.91	10.65	10.31	0	4.24	0	0
8	0	0	0	0	0.56	0	11.46	9.42	0	0	0	0
9	0	0	0	0.06	1.29	0	6.53	3.13	1.9	0	0	0
10	0	0	0	0.08	0	0	7.8	0.91	2.82	0	0	0
11	0	0	0.02	0	4.74	2.48	1.47	0	3.01	0	0	0
12	0	0	3.27	0	1.8	5.67	0.95	0.06	0.95	0	0.08	0
13	0	0	3.37	2.5	0.08	23.35	0.3	5.12	1.79	0.44	0	0
14	0	0	22.49	5.89	0	17.12	5.95	2.68	3.79	2.9	0	0
15	0	0	11.52	5.18	2.28	0	5.1	2.26	2.62	0	0.34	0
16	0	0.63	9.82	8.43	1.03	0	0.99	1.67	2.42	0	0.73	0
17	0	0	10.25	10.47	2.08	13.9	0	2.74	3.35	3.01	1.05	0
18	0	0	10.87	10.71	4.54	15.95	0	3.07	1.09	6.92	3.47	0
19	0	0	6.76	9.3	1.59	21.46	0	5.53	2.56	5.69	0	0.16
20	0.79	0.02	0.12	3.75	1.71	21.03	0	18.21	2.04	7.74	0	0
21	3.81	0	0	3.05	8.35	4.7	0	3.19	0	10.37	0	0
22	3.77	1.07	0	0.56	3.57	7.76	0.18	1.49	0	0	0	0
23	0.61	1.61	2.58	0.61	0.22	9.38	1.23	3.95	0	0	0	0
24	0.18	1.98	3.03	4.26	6.31	7.42	4.01	2.18	0	0	0	0

25	0	2.86	0	7.6	4.62	10.91	2.06	5.22	0	0	0	0
26	0	4.09	2.16	0.36	4.6	3.29	2.62	18.45	0	0	0	0
27	0	0.04	7.16	0	0	11.33	5.59	11.7	0	0	0	0
28	0	0	5.65	0	0	0	9.96	10.31	0	0	0	0
29	0		4.92	0.42	6.39	0	0.18	4.38	3.73	0	0	0
30	0		3.65	3.31	0	0	0	6.33	3.79	0	0.34	0
31	0		1.67		0.54		0.32	4.28	18.51	0		0.26
Total	10.71	12.30	136.68	92.00	56.36	201.69	82.15	156.14	64.03	76.86	6.01	0.46
Count	6	8	24	21	20	19	25	29	18	14	6	3
Average	0.35	0.44	4.41	3.07	1.82	6.72	2.65	5.04	2.07	2.48	0.20	0.01
Maximum	3.81	4.09	22.49	14.94	8.35	23.35	11.46	18.45	18.51	10.37	3.47	0.26
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 2000
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	2.72	0	0.02	4.24	6.07	0.93	0.67	2.92	0.69	4.82	2.78
2	0	0	0	0.48	4.4	9.52	2.06	0	0	1.33	4.94	2.5
3	0	0	0	0	5.1	7.66	0.3	0	0	4.05	5.04	0.16
4	0	0	1.61	0	5.3	9.88	0	0	0.04	1.65	5.99	0.2
5	0	0	4.82	0	2.94	4.8	1.19	0.14	0	0	9.34	0.04
6	0	0	10.18	0	5.02	7.7	0.58	1.37	0	0	4.52	0.87
7	0	0	4.46	0	5.02	12.24	0.67	2.16	0	0	1.79	0
8	0	3.11	0.83	0	4.42	12.48	0.99	9.32	0.26	0	4.07	0.2
9	0	9.88	1.05	0	5.97	9.6	2.04	4.96	0.04	0	3.71	0
10	0	0	1.51	0.4	5.97	6.47	0	2.26	0	12.89	3.61	0
11	9.32	0	2.28	2.14	10.95	5.97	2.16	4.68	0.08	4.28	1.69	0
12	5.71	0	1.29	2.92	10.43	6.09	6.98	8.31	0.14	0	2.4	0
13	5.08	0	1.27	3.53	7.34	14.08	1.71	5.47	0	0.12	7.48	0
14	3.73	0	0	4.48	5.18	8.77	2.6	7.85	0.22	0	0	0
15	0	0	0	7.38	1.73	0.18	2.2	3.81	0	0	0	0
16	0	0	0	3.05	1.45	6.92	0	1.57	1.25	0	0	0
17	0	0	0	1.41	2.7	8.73	0	0.32	5.87	0.06	0	0
18	0	0	0	0	5.3	10.45	0	0	1.15	0	0.06	0
19	0	0	0	0	14.66	14.96	0	0	0.58	0	0.4	1.31
20	0	0	0	0	9.38	6.88	0	0.46	0.81	0	0.32	0.24
21	0	0.04	0	0.4	1.61	3.15	0	1.09	0.08	1.07	2.78	0.04
22	0	0	0.12	0.67	3.89	3.13	0	0	4.56	8.31	5.4	0

23	0	0	0	0	11.01	4.26	0.61	0	2.26	4.76	0	0
24	0	0	0	1.25	5.4	2.84	0.1	1.39	3.65	8.99	2.1	0
25	0	0	0	2.56	6.61	2.62	0	0	2.46	6.39	1.71	0
26	0	0	0	0.61	11.72	11.09	0	1.69	0.97	5.95	1.57	0
27	4.32	0	0	6.96	13.63	9.92	0	6.84	0	7.44	0.63	0.04
28	0	0	0	7.68	12.42	7.66	0	5.12	0	5.53	0	0.5
29	3.55	0	0	11.03	5.24	0.95	0.06	4.28	0	5.85	0	1.65
30	0		0.06	6.11	3.63	4.07	5.71	4.52	0.34	7.34	5.06	0.2
31	0		1.05		3.77		3.31	3.51		5.32		0.99
Total	31.71	15.75	30.53	63.08	196.43	219.14	34.20	81.79	27.68	92.02	79.43	11.72
Count	6	4	13	19	31	30	18	23	19	19	23	15
Average	1.02	0.54	0.98	2.10	6.34	7.30	1.10	2.64	0.92	2.97	2.65	0.38
Maximum	9.32	9.88	10.18	11.03	14.66	14.96	6.98	9.32	5.87	12.89	9.34	2.78
Minimum	0.00	0.00	0.00	0.00	1.45	0.18	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 2001
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	50.46	7.99	1.49	1.77	4.28	10.79	6.53	0.58	0.36	0
2	0	0	123.45	4.68	5.22	2.22	3.67	4.98	9.52	2.32	0.26	0
3	0	0	0	0.95	4.07	2.46	1.13	0.67	8.45	2.14	0	1.8
4	0.6	0	0	1.07	7.95	2.68	2.92	0.1	2.94	0.77	0	3.27
5	0	0	0.04	3.13	7.81	2.36	2	2.7	2.34	0.12	0	4.72
6	4.09	2.08	0.26	8.21	4.8	1.57	0.52	0.81	3.21	4.84	0	4.72
7	5.45	0	1.49	8.39	1.75	2.28	0.3	0.58	3.73	4.76	0	0.04
8	3.23	0.06	0.71	6.78	3.15	5.28	6.49	2.58	5.02	1.86	0	0
9	1.25	0	0.71	0.34	7.04	0.26	4.72	2.82	10.87	0.12	0	0
10	0.04	0	0.6	4.05	6.72	0.28	3.69	3.07	6.29	7.72	0	0
11	0.1	0	0.16	1.69	5.77	0.2	3.77	6.92	4.86	6.15	0	0.24
12	2.34	0	0.52	2.96	9.36	0.12	7.68	0.5	4.01	1.35	0.32	0.1
13	0.04	0	0	3.71	8.21	2.24	2.9	0.42	0.6	0.26	0.65	0
14	0	0	0	2.6	2.12	1.53	1.57	0	2	0.71	0	0
15	0	0	0	0	1.9	1.94	1.43	1.49	1.84	1.07	0	0
16	0	0.77	0	0.22	3.07	2.1	3.99	0	4.74	3.99	0	0
17	0	0	0.06	0.4	1.07	2	9.28	0.58	6.9	4.4	0	0
18	0	0	0	0.46	0.38	3.37	4.15	1.82	3.69	1.88	0	0
19	0	0	0	1.61	0	1.63	3.35	0.75	0.81	4.01	0	0
20	0.61	0	0	2.72	0.4	4.24	3.53	2.24	3.59	3.31	0.1	0

21	0.1	0	0	8.15	0.06	1.03	2.08	3.49	2.96	1.47	0	0
22	0.04	0	0	4.92	0.3	1.13	2.28	2.92	6.96	0.14	0	0
23	0	0	0	0.65	1.59	0.81	2.14	5.16	3.49	0	0	0
24	0.44	0	0.5	0.36	1.41	8.99	3	4.96	1.86	0.46	0	0
25	5.16	0	2.44	0.83	0.95	11.11	6.31	9.8	3.53	0.61	0	0
26	6.19	0	0.63	0.46	1.03	10.31	4.68	4.42	7.3	0.6	0	0.02
27	10.23	0	1.37	0.58	2.4	8.53	6.9	3.55	1.63	0.79	0	0.32
28	0.48	0	1.11	2.3	4.21	5.67	0.44	3.07	1.9	0.65	0	0.38
29	0.1		0.36	3.41	10.95	1.86	2.12	2.34	7.22	3.67	0	0
30	0		0.22	2.14	11.58	1.55	3.75	1.75	8.17	4.66	0.1	0
31	0		4.48		3.55		5.65	2.12		2.52		0
Total	40.49	2.91	189.57	85.76	120.31	91.52	110.72	87.40	136.96	67.93	1.79	15.61
Count	18	3	19	29	30	30	31	29	30	30	6	10
Average	1.31	0.10	6.12	2.86	3.88	3.05	3.57	2.82	4.57	2.19	0.06	0.50
Maximum	10.23	2.08	123.45	8.39	11.58	11.11	9.28	10.79	10.87	7.72	0.65	4.72
Minimum	0.00	0.00	0.00	0.00	0.00	0.12	0.30	0.00	0.60	0.00	0.00	0.00

Source: SRP Daily Flow Records

SRP - 67TH AVE. DRAIN
DAILY FLOW RECORDS - 2002
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0.6	0.52	0	13.59	0	7.48	3.45	2.28	6.64	18.33	2.22
2	0	0.52	0.32	0	5.49	0	8.73	3.55	2.26	8.61	18.88	2.18
3	0.26	0.36	5.79	0	7.62	1.11	16.62	3.45	2.28	2.24	11.33	2.20
4	0.67	0.22	4.24	1.71	4.92	5.81	10.85	3.45	0	0	2.04	2.20
5	0.79	0	4.74	4.96	0.1	4.5	6.07	3.13	9.8	0	2.22	2.20
6	0.77	0	0.97	5.63	0	7.66	5	4.56	10.45	0	2.22	2.20
7	0.5	0.12	0	2.66	0.14	6.27	4.46	5.67	5.93	0	2.22	2.20
8	0.46	0.42	0.18	0.14	0.75	1.55	3.57	7.48	3.15	2.24	2.22	2.20
9	0.77	0.67	0.02	0.24	4.44	12.38	2.96	7.89	2.56	2.24	2.22	1.90
10	0.99	0.69	0	0.52	6.8	2.88	4.13	6.21	2.4	2.24	2.22	1.71
11	0.99	0.61	0.24	0.73	5.08	0.04	4.56	6.57	2.28	2.24	2.2	2.20
12	0.85	0.32	0	0.02	6.19	0	6.05	9.12	2.28	2.24	2.94	2.18
13	0.87	0	0.08	0	0.83	0.02	3.53	4.96	2.2	2.24	5.04	2.18
14	0.99	0	2.9	2.74	0	1.29	3.55	5.26	2.22	2.24	5.87	2.16
15	0.85	0	0	4.09	0.16	3.69	0	7.93	2.32	2.22	5.67	1.47
16	1.07	0	0	5.43	1.11	1.63	0	6.55	2.28	2.24	2.24	1.88
17	0.89	0	0	0.1	1.11	0	0	6.9	0	3.37	2.24	2.20
18	1.21	0	0	0	1.45	0	0	8.45	2.3	2.22	2.24	2.20

19	1.77	0	0.16	0	0	0.46	0	8.73	2.42	2.3	2.24	2.18
20	1.47	0	0.67	0	0	6.51	0	2.32	2.64	3.55	2.24	2.20
21	1.57	0	0.36	0	0	5.91	0	2.24	2.58	2.2	1.77	1.59
22	1.65	0.1	0	0	0	3.19	0	2.3	2.62	2.22	2	1.75
23	2.34	0.61	0	0.3	0	0	0	2.24	2.84	2.22	2.24	2.18
24	2	0.3	0	0	3.07	7.02	0	3.47	2.92	2.22	2.24	2.18
25	2.2	0	0.4	0	7.08	5.14	0	9.26	3.05	2.22	2.2	2.18
26	2.14	0	0.52	0.46	5.67	0.89	0	6.92	2.88	2.3	2.2	2.18
27	2.22	0	0.46	2.9	4.6	0.04	0	2.7	3.69	2.3	2.2	2.16
28	2	0	0.85	0.6	0.34	0.06	0	9.22	2.36	2.22	2.22	1.47
29	1.69		0.73	7.14	0	4.74	0	7.16	4.22	14.66	2.22	2.00
30	1.73		0	6.72	0	7.87	0.61	4.68	3.79	18.82	2.22	2.18
31	1.27		0		0.32		2.6	2.58		18.55		2.24
Total	36.98	5.54	24.15	47.09	80.86	90.66	90.77	168.40	93.00	119.00	118.33	64.21
Count	29	13	19	19	22	24	16	31	28	27	30	31
Average	1.19	0.20	0.78	1.57	2.61	3.02	2.93	5.43	3.10	3.84	3.94	2.07
Maximum	2.34	0.69	5.79	7.14	13.59	12.38	16.62	9.26	10.45	18.82	18.88	2.24
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	0.00	0.00	1.77	1.47

Source: SRP Daily Flow Records

APPENDIX B

SRP Maricopa Drain Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1994
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	7.85	8.27	0.3	22.08	0	7.3	7.28	10.91	0	0.18	6.51	0
2	8.45	6.9	4.66	18.09	0	7.3	7.28	10.91	0	0.32	4.8	0
3	6.8	6.88	12.71	15.35	0	12.65	7.28	9.82	1.09	0.52	1.82	0.81
4	7.26	6.09	2.02	16.58	0	9.5	7.28	9.82	0	0.42	0.08	5.81
5	11.74	9.98	12.58	16.03	0	7.8	7.28	7.64	0	0.36	1.33	1.61
6	12.54	8.53	15.21	12.99	3.03	11.56	7.83	17.45	0	0.28	5.12	7.04
7	11.84	15.67	33.68	10.89	13.31	11.19	10.65	16.36	0	0.04	0.61	1.19
8	9.34	19.22	21.72	16.48	14.76	10.53	11.41	13.09	0	0	0	1.03
9	8.25	9.78	14.62	20.25	7.58	9.14	12.56	6.55	0	0	0	1.51
10	6.09	12.65	8.99	13.27	2.36	6.62	17.12	10.91	0	0.63	0	0.38
11	6.78	6.88	9.06	16.03	0.04	6.7	17.53	12	0	1.31	0	0
12	9.74	7.02	8.51	16.38	0.79	6.7	19.14	12	0	0.18	0	0
13	8.35	12.93	10.23	7.36	2.44	6.03	15.09	9.82	0	0	0.48	0.02
14	11.5	10.31	3.87	1.21	1.69	7	24.06	10.91	0	0	0.04	1.55
15	9.4	8.55	2.68	4.84	4.11	10.97	20.43	15.27	0	0	0	0.26
16	8.31	2.98	2.24	11.41	12.42	10.93	21.6	18.55	0	0	0	0.3
17	9.9	8.99	4.05	10.67	14.72	13.07	30.19	9.82	0	0	0	1.07
18	9.76	5.93	8.65	18.66	18.82	15.77	31.34	10.91	0	0	0	0.91
19	11.56	8.15	11.72	17.85	12.38	13.86	19.26	14.18	0	0	0	0.54
20	6.8	2.9	6.35	19.34	14.3	14.22	12.34	9.82	0	0	0	3.09
21	9.01	3.99	7.2	18.57	15.41	14.12	13.71	9.82	0	0	0	6.92
22	6.59	7.85	6.03	8.63	15.57	22.51	7.7	15.27	0	4.3	0	5.49
23	5.69	4.86	7.95	2.48	14.92	24.54	3.91	9.82	0	4.68	0	9.94
24	8.85	7.44	0.04	14.08	3.09	24.54	4.13	7.64	0	0.79	0	6.66
25	9.8	11.03	8.55	4.8	1.11	24.54	3.81	7.64	0	3.21	0	5.47
26	15.81	9.62	13.69	4.36	0	24.54	3.67	6.55	0	0.26	0.02	9.58
27	8.95	12.95	7.99	10.97	0	24.54	3.67	6.55	0	3.09	0.81	4.17
28	4.36	1.17	8.39	0.02	0	24.54	3.67	8.73	0	5.59	2.04	3.19
29	5.14		10.08	0	0	24.54	3.67	2.18	0	2.22	0.77	7.68

30	6.94		11.56	0	0	24.54	3.67	0	0	2.96	0	6.59
31	8.05		21.16		0		3.67	0		4.86		2.6
Total	271.45	237.52	296.49	349.67	172.85	431.79	362.23	310.94	1.09	36.20	24.43	95.41
Count	31	28	31	28	20	30	31	29	1	20	13	27
Average	8.76	8.48	9.56	11.66	5.58	14.39	11.68	10.03	0.04	1.17	0.81	3.08
Maximum	15.81	19.22	33.68	22.08	18.82	24.54	31.34	18.55	1.09	5.59	6.51	9.94
Minimum	4.36	1.17	0.04	0.00	0.00	6.03	3.67	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1995
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.54	14.58	9.12	19.54	17.95	20.97	26.44	13.9	0	0	5.32	4.22
2	0	17.53	6.21	21.34	14.06	25.73	17.95	12.77	10.31	0	31.54	7.06
3	0	14.16	11.05	21.24	78.8	23.58	17.79	8.21	15.59	0	3.07	6.84
4	3.31	12.08	5.3	19.3	0	20.87	12.26	3.33	10.29	0	5.83	4.74
5	12.6	15.13	12.2	23.52	0	22	13.79	5.67	9.34	0	6.17	3.33
6	3.35	10.53	20.63	23.25	0	12.4	10.51	2.36	8.51	0	6.13	2.64
7	5.02	9.9	4.94	25.19	0	13.69	11.9	6.09	9.48	0	1.45	4.9
8	1.17	9.94	13.41	24.5	3.43	10.43	8.31	3.93	3.59	0	0.16	10.45
9	4.22	10.83	17.36	21.94	0.16	13.51	17.93	2.4	0	0	0	2.26
10	4.9	9.28	12.2	12.2	6.27	13.75	12.04	7.46	5.53	0	0	2.56
11	3.17	9.42	5.32	16.4	4.64	12.77	4.21	11.84	0	0.54	0	0
12	2.8	10.31	13.92	22.83	5.59	16.13	1.05	78.76	0	4.17	0	6.07
13	2.82	15.27	12.34	23.8	8.71	14.62	5.85	76.84	0	6.9	0	9.01
14	2.32	17.02	10.85	19.8	0	11.27	9.24	0	0	3.87	0	6.31
15	4.15	13.63	5.91	18.8	0	9.06	13.63	8.47	0	2.54	1.39	4.15
16	8.93	12.83	7.97	23.46	0	13.9	10.35	10.59	0	8.37	5.99	4.38
17	4.52	11.23	10.75	27.79	0	2.66	4.92	18.43	0	10.1	8.41	3.07
18	0.34	13.47	14.62	25.35	0	0	1.43	18.94	0	10.35	6.43	0.83
19	0.18	18.15	9.46	27.55	0	0	0	15.95	0	9.32	3.99	0
20	3.09	13.15	6.66	19.3	0	3.17	0	7.42	0	11.9	5.12	5.02

21	2	10.16	0	23.82	0	1.75	5.34	2.52	0	10.91	5.36	7.99
22	2.34	7.02	0	30.72	0	5.41	7.6	0	0	8.11	6.11	11.94
23	3.85	10.49	1.33	23.11	0	3.11	8.79	0	0	3.77	8.77	6.17
24	2.84	7.99	11.39	20.75	0	0	3.77	12.4	0	4.24	2.54	6.8
25	2.88	6.59	7.46	18.98	0	9.6	0.34	15.75	0	7.95	6.19	11.25
26	2.86	15.45	5.67	31.02	0	14.36	0	19.46	0	5.95	7.52	5.99
27	6.33	12.38	13.49	32.01	0	8.79	7.22	18.43	0	8.57	7.06	8.81
28	8.27	19.36	12.73	25.11	0	14.36	11.33	15.87	5.47	2.52	3.51	9.62
29	9.28		28.9	23.05	0	15.57	13.01	14.08	0	2.54	1.75	8.47
30	12.6		22.73	30.98	3.49	24.24	11.23	8.55	0	0.26	2.96	8.07
31	12.97		24.79		16.6		14.5	0		1.31		0
Total	133.65	347.88	338.71	696.65	159.70	357.70	282.73	420.42	78.11	124.19	142.77	172.95
Count	29	28	29	30	11	27	28	27	9	21	24	28
Average	4.31	12.42	10.93	23.22	5.15	11.92	9.12	13.56	2.60	4.01	4.76	5.58
Maximum	12.97	19.36	28.90	32.01	78.80	25.73	26.44	78.76	15.59	11.90	31.54	11.94
Minimum	0.00	6.59	0.00	12.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1996
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	6.15	8.79	8.49	0.42	11.37	0.06	14.92	14.92	10.75	0	8.59	5.28
2	6.07	9.84	10.41	0	5.16	0.1	15.09	15.09	10.29	0	9.46	9.16
3	5.61	7.83	14.76	0	0.06	4.24	11.41	11.41	9.28	0	9.36	15.99
4	5.55	13.59	8.59	0	0.34	0	17.99	17.99	12.12	0	5.81	11.82
5	5.1	10.27	9.92	9.26	10.81	0	21.78	21.78	10.69	0	7.48	4.22
6	5.02	9.16	13.19	0.06	0.52	0.42	28.58	28.58	7.93	0	5.02	5.43
7	4.13	9.01	24.18	18.27	0	3.01	29.04	29.04	13.15	0	2.2	7.16
8	4.36	9.64	13.09	20.17	0	4.84	15.35	15.35	10.65	0	9.94	10.45
9	4.42	7.4	13.19	23.37	0	9.16	23.19	23.19	5.22	0	7.87	8.81
10	4.21	11.29	21.4	8.85	2.22	13.82	25.09	25.09	0.06	0	5.34	11.62
11	3.67	13.19	19.46	9.02	9.02	15.15	23.29	23.29	8.61	0	2.72	12.91

12	3.55	6.29	17.51	16.86	12.89	17.77	25.69	25.69	12.14	2.84	1.27	13.98
13	3.23	4.92	16.01	20.17	0.06	10.85	31.87	31.87	2.58	10.25	3.97	13.9
14	3.15	8.85	23.27	24.42	0.06	6.37	24.3	24.3	6.25	13.88	3.97	7.54
15	2.82	15.27	14.44	14.38	0.06	6.82	14.78	14.78	12.87	10.69	4.48	13.23
16	2.6	14.34	12.4	10.49	0.06	0	18.59	18.59	12.14	2.56	8.03	7.32
17	3.25	4.64	5.83	12.58	0.85	0	24.54	24.54	16.32	0.06	5.47	8.53
18	4.03	5.87	7.46	14.52	0.06	0	17.79	17.79	13.55	0.06	1.45	8.93
19	5.14	11.21	7.08	6.39	0.06	0.75	13.21	13.21	12.6	0.06	1.53	11.29
20	7.8	8.99	6.88	11.15	0.06	14.22	16.9	16.9	4.36	0.06	4.98	7.66
21	4.66	4.21	13.51	10.18	1.11	17.99	20.49	20.49	0	4.42	9.68	8.09
22	7.04	0.06	18.09	2.92	5.18	16.88	20.41	20.41	0	7.74	2.58	8.81
23	4.74	11.78	20.23	7.06	6.66	18.57	13.94	13.94	0	0.06	6.37	8.31
24	4.6	10.45	22.81	3.95	4.01	15.81	8.57	8.57	0	0.06	2.92	5.61
25	10.73	12.04	26.5	18.51	2.46	12.87	16.98	16.98	0	0.06	0.71	12.65
26	22.71	18.29	24.4	21.78	0.06	17.81	25.79	25.79	0	0.06	6.17	9.8
27	10.2	10.35	22.2	7.89	0.06	22.75	23.33	23.33	0	17.79	7.78	12
28	4.92	8.61	24.4	3.47	0.06	17.12	23.5	23.5	0	9.94	8.19	5.53
29	6.41	4.86	22.61	7.3	0.06	23.29	16.03	16.03	0	10.23	12	4.01
30	5.71		15.85	7.7	0.06	16.74	5.28	5.28	0	10.14	5.71	1.43
31	6.31		4.58		0.08		0.06	0.06		8.03		0.06
Total	177.89	271.04	482.74	311.14	73.46	287.41	587.78	587.78	191.56	108.99	171.05	271.53
Count	31	29	31	27	28	25	31	31	20	20	30	31
Average	5.74	9.35	15.57	10.37	2.37	9.58	18.96	18.96	6.39	3.52	5.70	8.76
Maximum	22.71	18.29	26.50	24.42	12.89	23.29	31.87	31.87	16.32	17.79	12.00	15.99
Minimum	2.60	0.06	4.58	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.71	0.06

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1997
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0.06	12.06	10.53	8.19	0	3.23	6.43	0.06	10.63	6.23	7.08
2	4.24	3.25	12.26	15.02	18.15	0	10.97	2.62	7.08	8.09	8.33	6.25
3	2.8	1.92	8.83	21.54	4.66	0	8.09	6.23	3.71	5.91	5.43	8.87
4	0	0.06	14.56	20.53	0	1.82	11.82	10.35	0	13.55	12.69	12.69
5	0	0.06	13.69	6.09	0	1.09	11.62	1.8	0	11.92	12.85	14.5
6	0	0.06	12.83	0.06	0	0	14.24	0	0	12.62	11.74	15.43
7	0	0.08	14.48	0.06	0.22	3.59	16.64	0	0	11.84	8.87	13.9
8	0	0.36	14.98	0.06	0.06	14.48	6.59	0	0	9.9	8.43	11.98
9	0	9.6	11.44	0.06	1.71	20.73	0.28	3.65	0	7.95	5.75	10.97
10	0	0.48	5.12	0.95	15.55	18.51	0	0	0.2	10.31	4.82	15.13
11	0	3.89	3.65	1.27	9.52	15.97	0	0	12.18	7.85	12.79	12.2
12	0	13.03	3.31	2.66	3.03	13.84	0	0	11.88	8.99	10.43	10.43
13	0	0.67	0.06	11.41	0	2.68	1.9	0	12.48	6.96	9.92	8.93
14	0	0	12.58	10.08	6.88	3.21	6.92	0	11.56	9.32	8.09	10.02
15	0	0	4.26	2.58	17.87	14.34	7.78	0	11.31	6.78	11.56	4.52
16	0	6.15	23.72	6.86	27.17	9.22	3.45	2.94	10.55	7.18	9.06	8.09
17	0	0.87	9.6	10.81	17.71	14.7	0	7.32	5.65	9.14	7.89	11.05
18	0	0.52	11.7	2.5	3.87	7.83	6.27	27.21	0	9.48	10.43	9.86
19	0	0.06	8.89	0.18	4.8	0.06	0.06	12.75	0	7.6	9.88	10.29
20	0	0.06	9.32	6.31	9.14	0.06	0.06	4.8	0	6.15	5.34	12.73
21	0.44	0.06	11.21	7.76	0	0.06	5.32	6.37	1.33	9.64	4.26	12.02
22	13.23	0.06	1.59	11.42	0	10.12	5.4	12.42	8.55	7.34	8.39	12.32
23	9.38	8.29	20.11	0.06	0	11.41	5.41	10.79	10.95	12.85	10.75	10.73
24	5.61	9.8	13.47	19.38	0	15.79	2.02	12.04	8.15	14.06	11.62	7.74
25	5.1	0.12	13.03	26.26	0	5.38	0.1	8.53	8.55	12.1	7.8	10.41
26	9.52	0.06	10.51	19.3	0	0	7.12	2.86	8.89	9.9	11.66	7.58
27	3.17	2.8	5.51	25.86	0	0	11.23	0.06	10.2	6.98	7.85	17.57
28	0	13.07	0.1	19.68	0	0	3.99	4.07	10.47	8.41	5.79	22.67
29	0		3.05	3.33	0	1.98	0	3.73	6.88	6.92	5.24	19.32
30	0		18.45	0.06	0	2.08	0	0	9.62	5.97	12.81	16.15
31	7.52		10.63		0		1.11	1.23		5.67		14.52
Total	61.01	75.44	315.00	262.67	148.53	188.95	151.62	148.20	170.25	282.01	266.70	365.95
Count	10	26	31	30	16	23	25	21	21	31	30	31

Average	1.97	2.69	10.16	8.76	4.79	6.30	4.89	4.78	5.68	9.10	8.89	11.80
Maximum	13.23	13.07	23.72	26.26	27.17	20.73	16.64	27.21	12.48	14.06	12.85	22.67
Minimum	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.00	5.67	4.26	4.52

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1998
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	8.03	3.21	3.45	15.57	21.34	49.75	15.47	23.78	13.92	3.59	4.22	7.3
2	6.76	6.47	3.97	25.75	20.69	29.63	24.36	21.32	23.31	9.64	7.6	7.46
3	7.83	9.54	6.66	25.86	26.38	7.78	45.22	20.89	25.03	1.98	9.16	5.57
4	12.69	16.09	8.45	30.53	24.79	31.44	60.79	21.32	25.83	11.94	10.37	0.81
5	13.88	13.37	8.87	25.81	28.36	23.19	55.78	19.1	19.12	14.8	10	9.04
6	8.09	7.02	10.35	22.85	43.34	5.83	52.68	17.45	23.82	7.24	7.68	10.71
7	10.81	11.74	9.74	34.04	28.7	20.57	52.09	15.39	20.73	7.48	10.31	6.74
8	11.52	8.51	15.83	35.6	51.57	34.2	48.66	18.05	15.53	0	16.26	3.77
9	8.55	22.04	14.18	27.35	57.28	11.66	31.44	19.2	16.98	3.97	17.14	6.37
10	14.8	3.75	9.06	31.82	47.05	26.64	29.38	27.93	18.37	16.5	6.66	5.63
11	17.47	3.67	5.59	36.18	57.12	35.13	31.93	23.86	18.29	18.82	6.01	7.83
12	11.46	11.13	7.4	31.99	42.15	33.12	27.25	21.28	13.05	10.47	5.79	8.67
13	9.1	5.73	7.83	33.5	40.58	15.25	37.73	22.39	17.49	12.75	3.95	14.38
14	4.92	13.45	7.7	30.19	49.25	9.92	38.38	19.6	11.33	16.32	5.3	11.15
15	4.44	24.85	16.28	23.19	42.43	10.51	41.95	25.37	14.06	0	6.57	5.51
16	5.73	3.79	16.23	32.31	35.78	14.08	36.12	29.65	3.59	0	10.81	0.24
17	10.55	11.98	7.58	22.16	21.7	24.91	39.29	31.36	0	0	7.3	11.13
18	6.29	26.48	6.59	17.73	23.17	22.41	39.99	38.08	2.3	0	5.93	15.03
19	11.01	8.07	10.06	22.04	23.52	28.78	36.34	28.6	4.17	0.99	8.03	12.24
20	13.47	14.74	17.51	26.38	10.2	47.39	24.85	29.49	13.9	0	9.4	9.58
21	4.34	12.2	21.44	24.83	14.4	35.19	21.2	19.46	13.01	2.92	6.13	11.17
22	8.21	20.95	22.99	25.15	7.58	24.93	26.42	23.54	13.71	5.59	4.98	9.16

23	13.17	25.85	21.22	26.58	20.05	22.75	26.24	26.44	11.74	2.14	2.46	10.93
24	6.72	24.58	20.87	25.15	17.36	23.25	20.99	25.25	12.58	18.13	0.06	13.09
25	8.91	9.26	25.75	17.91	24.81	25.05	23.27	24.1	8.21	20.75	1.45	12.28
26	8.85	7.74	28.32	22.51	32.53	7.22	32.29	21.08	2.42	19.82	11.84	3.33
27	7.08	10.25	23.05	28.21	36.2	9.3	35.48	22.27	9.24	13.31	10.22	3.65
28	7.7	7.81	22.61	28.9	32.35	22.97	24.71	20.49	3.01	5.89	15.43	6.88
29	9.98		37.77	32.45	40.6	25.81	30.45	9.1	9.5	2.76	11.78	7.34
30	7.83		41.89	29.69	39.73	21.54	29.67	7.08	10.59	5.95	8.77	7.85
31	8.53		21.76		51.77		23.15	9.62		5.75		5.65
Total	288.72	344.27	481.00	812.23	1,012.78	700.20	1,063.57	682.54	394.83	239.50	241.61	250.49
Count	31	28	31	30	31	30	31	31	29	25	30	31
Average	9.31	12.30	15.52	27.07	32.67	23.34	34.31	22.02	13.16	7.73	8.05	8.08
Maximum	17.47	26.48	41.89	36.18	57.28	49.75	60.79	38.08	25.83	20.75	17.14	15.03
Minimum	4.34	3.21	3.45	15.57	7.58	5.83	15.47	7.08	0.00	0.00	0.06	0.24

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 1999
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	8.33	4.74	10.39	31.78	18.35	17.95	17.91	13.84	18.51	11.72	13.73	7.68
2	5.61	12.75	12.95	52.78	23.58	16.15	22.75	14.04	18.51	11.72	9.48	10.31
3	5.51	12.69	14.76	28.7	19.99	16.03	27.77	14.84	18.51	10.91	6.62	12.28
4	4.34	11.86	12.79	24.4	18.07	18.64	26.88	16.13	18.51	9.04	5.91	17
5	4.84	19.7	19.18	18.07	19.24	21.38	21.01	13.37	18.51	10.04	5.57	16.62
6	4.56	19.2	35.9	18.94	21.98	28.21	18.86	12.95	18.51	8.89	5.38	8.57
7	8.41	14.02	28.58	20.63	22.43	29.28	16.74	12.42	18.51	12.26	6.43	4.28
8	10.47	13.23	27.15	23.6	23.84	25.03	23.17	11.39	18.51	15.53	5.24	9.64
9	14	12.18	25.73	25.57	20.69	30.55	6.07	10.37	18.51	14.56	7.3	11.15
10	6.47	7.54	21.96	32.43	17.55	16.01	0	11.05	18.51	13.23	8.55	10.1

11	7.08	13.35	19.04	32.63	15.05	15.27	0	12.42	16.13	11.68	8.93	10.37
12	8.15	18.35	11.56	31.78	21.3	14.38	0	13.61	16.13	10.93	9.01	10.1
13	8.77	13.75	14.3	38.02	20.53	25.67	0	13.84	16.13	10.08	6.92	9.56
14	11.9	10.97	17.77	35.9	25.17	23.23	0	13.84	16.13	6.9	5.55	8.55
15	5.77	11.07	19.14	29.85	23.07	25.59	0	15.55	16.13	9.62	5.71	7.81
16	5.89	7.95	19.16	28.46	24.16	27.79	0	16.13	16.13	12.08	4.52	10.93
17	12.95	6.59	20.63	30.37	25.39	28.9	0	16.13	16.13	14.06	6.88	9.08
18	8.39	8.93	15.49	28.62	22.95	22.04	0	16.13	16.13	13.13	6.19	11.07
19	9.26	10.2	11.7	24.3	28.44	25.49	0	16.13	16.13	9.22	7.95	13.33
20	11.66	15.17	11.7	30.09	27.51	28.34	0	14.84	16.13	8.69	9.26	15.35
21	7.85	19.08	13.53	18.35	25.47	26.36	0	11.03	11.72	12.71	6.98	17.38
22	10.73	13.75	15.27	22.06	24.71	23.92	0	11.03	11.72	13.47	5.51	13.53
23	10.22	14.52	19.32	28.3	26.78	24.42	0	11.03	11.72	14.72	4.21	12.12
24	9.58	18.9	20.39	26.24	20.73	34.49	0	11.03	11.72	9.72	4.01	10.89
25	8.21	20.89	24.91	15.03	18.92	28.17	0	12.44	11.72	13.55	8.85	3.07
26	10.39	18.66	31.06	15.13	18.53	21.74	0	13.13	11.72	14.4	10.43	10.65
27	10.69	17.34	25.53	14.46	20.53	24.5	0	17.24	11.72	17.77	7.93	18.9
28	6.53	9.06	25.53	16.4	24.62	17.18	0	18.98	11.72	12.46	8.35	13.88
29	7.5		27.09	23.01	24.67	16.54	0	17.69	11.72	10.77	4.03	19.72
30	9.82		23.43	21.14	25.03	19.1	0	17.89	11.72	27.09	5.08	24.22
31	7.46		23.84		23.19		0	18.51	18.51	9.32		18.23
Total	261.34	376.44	619.78	787.04	692.47	692.35	181.16	439.02	482.11	380.27	210.51	376.37
Count	31	28	31	30	31	30	9	31	31	31	30	31
Average	8.43	13.44	19.99	26.23	22.34	23.08	5.84	14.16	15.55	12.27	7.02	12.14
Maximum	14.00	20.89	35.90	52.78	28.44	34.49	27.77	18.98	18.51	27.09	13.73	24.22
Minimum	4.34	4.74	10.39	14.46	15.05	14.38	0.00	10.37	11.72	6.90	4.01	3.07

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 2000
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	7.58	15.67	7.56	21.68	29.93	15.51	19.42	23.09	14.74	13.19	0.42	9.54
2	2.38	14.28	4.03	20.77	30.76	17.36	20.23	20.75	13.23	16.4	11.44	11.15
3	5.87	14.02	6.74	19.32	27.39	14.96	21.56	18.76	14.56	20.91	12.52	12.04
4	7.2	13.53	6.62	26.1	25.85	19.6	16.17	23.15	15.27	17.47	1.65	11.39
5	11.76	12.73	8.49	26.44	20.11	19.12	12.26	18.19	13.03	15.73	0.79	4.46
6	6.51	13.61	33.72	15.95	21.03	19.28	20.07	22.2	10.83	15.93	3.37	3.61
7	6.98	11.76	12.79	13.75	23.21	27.73	21.3	19.82	14.5	23.9	6.61	2.22
8	10.95	16.9	5.1	20.73	21.38	34.26	26.78	21.82	17.75	19.97	6.78	4.62
9	7.18	20.37	7.68	23.9	21.72	29.53	25.79	16.86	12.28	24.12	8.93	7.38
10	7.1	14.12	7.72	23.92	18.9	28.92	30.59	18.8	14.04	14.58	11.11	9.2
11	4.28	14.44	4.3	22.43	25.55	28.54	21.76	16.26	15.47	5.63	10.04	10.75
12	5.2	16.88	5.14	23.56	21.03	26.82	19.48	18.07	10.25	11.68	11.86	4.46
13	6.62	12.87	5.26	25.53	20.61	25.81	25.21	23.64	12.26	9.32	15.03	4.24
14	9.3	12.06	6.27	19.99	21.48	25.09	19.62	21.82	8.01	8.07	12.93	5.61
15	11.56	10.89	8.77	27.39	23.29	17.95	14.8	17.73	21.72	8.63	14.82	4.19
16	8.45	12.85	10.87	27.23	20.19	16.05	19.95	28.88	21.62	10.93	17	6.05
17	6.72	11.66	17.65	26.62	24.2	20.19	22.43	28.8	21.18	10.22	16.6	4.92
18	10.97	13.75	15.69	32.41	21.94	27.41	21.52	20.93	18.41	14.52	14.66	5.02
19	10	9.52	13.94	30.33	23.21	23.86	22.41	19.82	17.93	13.49	9.48	8.05
20	3.23	6.27	16.11	29.91	27.87	27.05	27.55	14.94	15.09	19.89	16.58	6.43
21	3	4.11	16.48	32.35	28.94	31.84	29.36	18.07	14.62	32.05	20.11	2.8
22	12.18	3.11	13.15	27	23.98	27.69	28.68	13.15	16.23	10.81	14.54	4.74
23	9.64	5.77	13.98	24.18	29.81	22.81	26.92	13.49	13.07	11.54	9.08	5.36
24	8.83	7.48	19.8	25.59	21.42	18.8	17.47	14.66	24.12	11.29	10.18	7.97
25	12.3	7.24	10.69	25.86	22.93	27.73	21.2	14.72	16.76	10.73	7.46	8.59
26	15.47	14.68	12.69	28.8	19.7	28.46	19.89	17.38	17.22	21.18	7.93	3.53
27	15.51	15.15	16.21	22.41	21.36	29.57	22.35	15.15	19.89	9.12	3.69	12.5
28	16.68	9.02	18.09	21.12	20.99	24.48	27.55	14.98	19.28	2	5.79	21.28
29	13.9	6.68	13.84	23.72	15.33	24.02	21.68	16.62	14.9	3.95	9.38	24.62
30	14.54		14.96	27.71	20.07	26.86	18.86	12.81	13.96	3.79	5.53	22.87
31	12.93		19.42		17.06		21.12	8.93		0.79		16.68
Total	284.82	341.42	373.76	736.70	711.24	727.30	683.98	574.29	472.22	411.83	296.31	266.27

Count	31	29	31	30	31	30	31	31	30	31	30	31
Average	9.19	11.77	12.06	24.56	22.94	24.24	22.06	18.53	15.74	13.28	9.88	8.59
Maximum	16.68	20.37	33.72	32.41	30.76	34.26	30.59	28.88	24.12	32.05	20.11	24.62
Minimum	2.38	3.11	4.03	13.75	15.33	14.96	12.26	8.93	8.01	0.79	0.42	2.22

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 2001
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	19.7	3.83	5.38	21.66	12.83	24.18	17.04	19.08	19.08	13.05	17.87	6.37
2	12.62	3.93	5.97	26.4	14.64	27.37	22.65	16.64	16.64	2.96	21.22	5.34
3	12.4	4.38	5.45	24.56	17.24	32.03	30.09	17.08	17.08	0	18.96	6.01
4	13.82	8.33	8.61	34.93	20.89	21.54	32.17	9.94	9.94	0	14.3	1.61
5	9.74	10.45	12.06	39.81	23.01	27.19	37.15	0.08	0.08	0	15.05	2.88
6	7.26	7.76	9.26	30.92	23.7	20.63	39.04	15.65	15.65	3.69	8.79	5.02
7	8.69	10.51	16.09	27.71	20.29	2.9	20.71	10.2	10.2	12.83	11.72	1.19
8	8.73	12.2	7.7	21.08	23.29	4.46	16.96	0.3	0.3	6.37	10.71	0.12
9	9.94	11.58	8.31	16.86	15.09	10.16	27.35	13.88	13.88	0	9.5	2.68
10	14.3	4.7	4.94	19.97	21.24	12.75	25.88	8.51	8.51	0.95	11.09	4.28
11	11.33	4.42	6.37	14.34	24.56	9.24	25.81	8.67	8.67	7.78	9.64	2.1
12	7.99	3.27	2.58	17.02	17.71	5.4	25.96	17.08	17.08	2.56	11.62	1.98
13	3.39	11.68	4.54	12.69	15.33	4.01	27.21	6.64	6.64	13.67	5.67	0.44
14	9.36	10.06	5.12	14.24	18.23	0.69	19.36	5.26	5.26	9.86	8.23	1.94
15	8.75	10.73	5.4	18.45	15.23	11.13	16.7	12.67	12.67	2.14	11.07	0
16	4.86	7.95	6.47	19	9.72	6.66	23.01	8.79	8.79	0.6	12.99	0
17	9.64	10.2	10.2	25.59	16.52	6.78	14.3	4.46	4.46	0	15.73	0
18	2.46	11.84	5.85	21.5	18.63	3.41	18.61	2.54	2.54	0	20.35	0
19	10.02	12.2	11.31	23.84	15.67	3.55	16.62	0	0	6.82	10.77	4.24
20	12.71	13.27	15.63	24.1	17.93	8.77	22.51	0	0	4.34	15.05	5.1
21	9.04	17.12	13.01	21.08	19.42	20.55	21.32	0	0	6.53	15.95	4.9
22	6.72	11.41	12.48	21.86	17.38	23.44	24.52	6.31	6.31	13.59	11.13	4.6
23	9.66	7.28	14.5	31.44	13.98	17.77	18.94	9.3	9.3	16.54	11.72	11.35
24	7.4	5.18	15.53	27.81	25.81	19.42	20.05	8.71	8.71	20.47	7.42	8.21
25	6.45	6.39	18.64	20.59	17.85	24.91	20.03	0	0	22.47	7.72	7.64

26	6.98	4.82	14.88	21.72	22.12	24.38	17.43	0	0	9.06	7.28	8.77
27	20.39	5.65	15.77	15.19	29	16.68	12.34	0	0	6.41	10.06	12.18
28	3.51	5.28	19.26	20.97	27.69	17.71	13.81	0	0	9.1	11.78	14.14
29	2.2		17.93	21.8	25.65	16.62	30.86	2.3	2.3	12.42	10.79	13.47
30	2.74		14.6	13.41	17.77	57.36	24.5	1.65	1.65	15.77	8.91	19.8
31	3.73		20.01		19.34		21.26	0		11.58		19.28
Total	276.53	236.42	333.85	670.54	597.76	481.69	704.19	205.74	205.74	231.56	363.09	175.64
Count	31	28	31	30	31	30	31	23	23	25	30	27
Average	8.92	8.44	10.77	22.35	19.28	16.06	22.72	6.64	6.86	7.47	12.10	5.67
Maximum	20.39	17.12	20.01	39.81	29.00	57.36	39.04	19.08	19.08	22.47	21.22	19.80
Minimum	2.20	3.27	2.58	12.69	9.72	0.69	12.34	0.00	0.00	0.00	5.67	0.00

Source: SRP Daily Flow Records

MARICOPA DRAIN
DAILY FLOW RECORDS - 2002
(units are in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	7.46	4.9	12.69	14.36	14.96	14.98	15.09	0.4	3.97	8.13	7.74	1.39
2	2.54	6.7	16.36	11.21	16.24	16.24	12.08	0.6	7.34	12.1	2.98	14.88
3	5.73	9.7	18.8	14.12	12.91	16.7	17.18	1.19	11.9	12.3	3.77	20.43
4	7.8	9.32	17.12	19.04	12.87	14.8	17.22	0.99	8.13	10.12	5.36	16.66
5	7.08	9.68	14.34	23.05	13.17	11.68	17.42	1.19	16.26	6.55	5.95	10.91
6	7.78	10.63	14.7	23.15	12.95	16.46	15.11	1.39	10.12	7.54	10.91	10.91
7	6.11	7.26	9.9	25.94	12.4	15.71	14.66	1.59	10.51	4.36	8.33	12.1
8	2.9	10.67	7.89	27	14.4	15.33	9.9	1.79	15.07	5.16	6.55	8.93
9	8.07	7.72	6.53	27.93	12.77	12.93	10.63	2.18	9.92	9.12	3.17	3.17
10	11.35	9.16	13.31	24.75	11.13	13.01	13.57	1.79	5.75	2.18	1.79	0.2
11	12.81	13.25	18.57	17.36	14	16.38	16.96	1.98	2.58	14.28	0.99	0
12	11.15	13.84	13.88	9.84	21.24	12.75	14.1	1.79	1.79	8.73	6.15	0.2
13	7.64	12.67	16.84	15.69	12.73	18.41	17.42	1.59	4.36	9.92	2.38	2.18
14	8.83	13.07	15.43	22.83	11.64	19.38	20.03	1.19	1.59	10.91	6.15	1.19
15	12.95	11.17	17.55	22.79	15.41	16.92	9.74	0.6	8.13	14.68	3.17	4.96
16	11.6	15.05	12.08	15.03	16.4	18.96	4.07	0.79	10.91	10.71	0.6	5.75
17	8.75	6.05	16.86	18.59	20.79	17.75	2	0.4	7.34	5.16	2.98	0.6
18	3.67	3.91	15.17	18.84	22.39	18.01	7.99	1.19	9.92	2.58	2.38	3.77
19	5.41	8.03	14.08	15.79	20.87	20.25	9.78	1.39	10.71	2.78	3.37	3.37
20	5.3	10.02	14.66	12.97	19.72	24.85	9.4	1.19	10.12	9.52	4.17	7.54
21	5.91	10.81	16.42	20.95	27.07	17.49	8.19	1.39	10.12	17.26	7.14	10.12
22	9.01	9.84	13.81	23.29	25.13	15.13	8.75	0.99	11.7	18.25	8.73	12.89
23	11.11	6.66	22.67	19.04	24.44	31.42	6.88	0.99	3.57	16.66	11.9	7.14
24	11.5	5.22	26.96	8.87	16.07	37.27	5.04	0.6	8.53	17.45	13.69	6.74
25	11.62	13.84	18.8	14.66	17.42	28.88	4.76	0.6	14.88	24.99	13.69	2.98
26	11.8	16.72	17.53	21.48	16.8	16.44	0	0.99	10.12	37.29	6.94	3.57
27	12.65	11.07	23.11	13.86	17.75	20.65	0	0.6	7.54	12.1	13.49	3.97
28	8.13	6.7	20.89	10.83	16.66	28.38	0	0.6	14.68	12.3	13.49	3.97
29	5.28		18.7	12.71	18.61	25.53	0	0.4	8.13	11.11	12.89	4.76
30	7.4		16.86	18.23	14.5	24.26	7.74	0.4	12.89	11.11	11.9	2.38
31	8.87		20.05		14.76		15.43	0.4		10.31		4.76
Total	258.21	273.66	502.56	544.20	518.20	576.95	311.14	33.18	268.58	355.66	202.75	192.42
Count	31	28	31	30	31	30	27	31	30	31	30	30
Average	8.33	9.77	16.21	18.14	16.72	19.23	10.04	1.07	8.95	11.47	6.76	6.21
Maximum	12.95	16.72	26.96	27.93	27.07	37.27	20.03	2.18	16.26	37.29	13.69	20.43
Minimum	2.54	3.91	6.53	8.87	11.13	11.68	0.00	0.40	1.59	2.18	0.60	0.00

Source: SRP Daily Flow Records

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE

Salt River-Phoenix, Arizona

Appendix C
Groundwater Modeling

February 2006

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I. INTRODUCTION

1.1 STUDY AREA AND GROUNDWATER MODELING AREA

The U.S. Army Corps of Engineers (USACE) and the City of Phoenix (COP) have initiated a feasibility study for the Rio Salado Oeste Project to evaluate the design and completion of riparian habitat restoration along the Salt River in Phoenix area. The study area is located along the Salt River, in Phoenix, Arizona, between 19th Avenue and 83rd Avenue. The study area is located in between the authorized Rio Salado Project area and the authorized Tres Rios Project area. The Oeste study area is approximately eight river miles in length. In comparison, the authorized Phoenix reach of the Rio Salado project is five miles long and the Tres Rios study area is about seven miles long. Figure 1 shows the modeling area of the groundwater flow model study. The modeling area is bounded by 40th Street on the East, one mile from 115th Avenue on the West, one mile from Highway I-10 on the North, and Estrella Street on the South. As shown in the figure, the study area is in the central portion of the modeling area and is bounded by 19th Avenue, 83rd Avenue, Buckeye Road, and Baseline Road. The selection of a larger area for groundwater modeling is to avoid the effect from the boundary conditions to the study area.

1.2 PURPOSE OF THE GROUNDWATER MODELING TASK

The groundwater modeling task for this study includes a review of previous studies for the Salt River watershed, development of a site-specific groundwater flow model, and evaluation of project alternatives using the groundwater flow model. The regional groundwater flow model for the Salt River Valley developed by Arizona Department of Water Resources (ADWR) is reviewed and is adapted for the model development. Groundwater model is constructed and will be calibrated for baseline conditions. The developed model will be used to evaluate the impact to the local groundwater due to the selected alternatives.

II. HYDROGEOLOGICAL SETTING

The Rio Salado study area is located in the Phoenix Active Management Area (AMA) and is comprised of portions of two distinct but interconnected alluvial groundwater basins. These basins, West Salt River Valley (WSRV) and East Salt River Valley (ESRV), are shown on Figure 2.

The subsurface geologic conditions in the Salt River Valley (SRV) are described by the USBR (1976), the USGS (Laney and Hahn, 1986; Brown and Pool, 1989), and by ADWR (Corkhill, 1993). All three investigations divide the basin-fill sediments into three hydrogeologic units. However, the units have sometimes been defined differently. This report uses the most recent division of hydrogeologic units, as described by ADWR.

There are three hydrogeologic units: the lower alluvial unit (LAU), the Middle Alluvial Unit (MAU), and the Upper Alluvial Unit (UAU). There is also a Red Unit which forms the base of the aquifer beneath parts of the area. The LAU overlies the Red Unit and consists mainly of conglomerate and gravel. The LAU is tapped by many city wells and it is estimated that

approximately 25 percent of the pumpage in the SRV originates from this unit (ADWR, 1993). The LAU may be less than 100 feet thick near the basin margins and several thousands of feet thick in the central areas of the basins. The MAU overlies the LAU and consists mainly of clay, silt, mudstone and some sand and gravel. The unit ranges in thickness from 100 feet to over 1600 feet in the deeper parts of the basin. The MAU is now the primary source of groundwater in the valley. ADWR estimated that about one half of the total pumpage in the valley is from the MAU. The UAU overlies the MAU and consist primarily of gravel, sand and silt. The amount of coarse-grained deposits in this unit is highest near the Salt and Gila Rivers. The thickness of the UAU is relatively uniform and ranges from 200 to 300 feet thick in ESRV and between 300 and 400 feet thick in the WSRV. In the past, the UAU was the primary source of groundwater in the valley, but because of lower water levels (decreased groundwater elevations) and large areas of poor quality water, only about one fourth of groundwater pumped in the valley is from the UAU. Important sources of recharges to groundwater in the valley include infiltration of Salt River flows, mountain recharge along the McDowell and Superstition Mountains, percolation of excess irrigation water, and canal seepage. Figure 3 shows the Salt River Valley generalized geologic cross-section. The location of the cross-section is shown in Figure 2.

The UAU is divided into four subunits within the study area (URS, 2002). These subunits are designated from youngest to oldest as S, A, B, and C. These subunits appear to be essentially horizontal within the study area and no significant geologic structures have been identified.

- **Subunit S** is exposed at the surface near the river and consists of silty sand with clay and gravel. This unit is typically unsaturated in the vicinity of the Salt River.

- **Subunit A** is further subdivided into Subunits A_1 and A_2, and is generally comprised of sandy gravel and cobbles. Subunit A_1 extends to a depth of 90 to 110 feet below ground surface (bgs) and consists of unconsolidated, poorly sorted, coarse sand and gravel. The primary difference between A_1 and A_2 is that Subunit A_2 contains 30 to 40 percent fine to coarse sand versus 5 to 20 percent in Subunit A_1. In addition, Subunit A_2 is typically better sorted than A_1. The contact between these subunits is gradational and is identified by a transition from coarse to medium-sized gravel, increased roundness, and greater amounts of fine sand and silt (Dames & Moore, 1991). In the vicinity of the 19th Avenue Landfill Subunit A_1 was observed to be about 100 feet thick, and Subunit A_2 was observed to be about 90 feet thick.

- **Subunit B** underlies Subunit A_2 and is dominated by coarse to fine sand, silt, clay, and minor gravels. Subunit B is distinguished by its reddish-brown color and finer-grained nature. In the vicinity of the 19th Avenue Landfill Subunit B was observed to be about 40 feet thick.

- **Subunit C** underlies Subunit B and primarily consists of fine to medium sand, angular to subrounded fine gravel, minor silt, and clay. The transition from Subunit B to Subunit C is identified by an increase in grain size and a color change to brown. In the vicinity of the 19th Avenue Landfill Subunit C was observed to be about 150 feet thick.

III. HYDROLOGIC SYSTEM

3.1 PREDEVELOPMENT HYDROLOGIC SYSTEM

The predevelopment hydrologic system of the Salt River Valley is described by the ADWR. Prior to the arrival of non-Indian settlers in the 1860's and 1870's, the hydrologic system in the SRV was in a state of equilibirum. Flows into and out of the SRV were in approximate balance and water levels generally remained constant. The main components of the predevelopment groundwater budget were underflow, stream channel infiltration, mountain front recharge, and evapotranspiration. An approximate predevelopment groundwater budget is presented in Table 1 and the components are described below.

3.2 GROUNDWATER FLOW

In general, groundwater moved east to west through the SRV. Most of the Salt River Valley groundwater moved in a direction towards the lower topographic areas. Substantial groundwater flow underflow moved northwestward along the Gila River and passed through the gap between the South Mountain and the Sierra Estrella.

3.3 STREAM RECHARGE

Prior to development of the valley and construction of upstream reservoirs, the Salt and Gila Rivers were perennial throughout the SRV. The rivers were significant sources of groundwater recharge in some areas and recipients of groundwater discharge in other areas. The reaches of the river can be classified as losing or gaining. The rivers 'lose' water where the groundwater table elevation is lower than the water level in the river channel. Similiarly, the river 'gains' when groundwater is discharged into the river, where the water table is higher than the water level in the channel. ADWR estimated the total recharge from the Agua Fria River, Cave Creek, New River, Skunk Creek, and Queen Creek to be about 20,000 acre-feet per year.

3.4 MOUNTAIN FRONT DISCHARGE

Mountain-front recharge is water that infiltrates into the alluvial material along the interface between mountains and the alluvial groundwater basin. The amount of mountain-front recharge depends on average precipitation. The ADWR estimated that mountain-front recharge in the SRV is only significant along the McDowell and Superstition Mountains.

3.5 EVAPOTRANSPIRATION

Under predevelopment conditions, ADWR identified evapotranspiration as the major source of discharge from the groundwater system in the SRV. Evapotranspiration is the process of evaporation from water surfaces and moist soil and transpiration from vegetation. During the predevelopment period, there were approximately 48,000 acres of phreatophytes along the Salt and Gila Rivers. ADWR used an evapotranspiration rate of 1.6 acre-feet per acre per year to estimate a loss of 76,000 acre-feet per year.

3.6 MODERN HYDROLOGIC SYSTEM

Irrigation was originally developed by diversion of streamflow into canals. By the turn of the century, much of the valley was waterlogged, due to recharge from canal seepage and deep percolation, combined with a lack of groundwater pumping. Beginning in the 1920's and 1930's, substantial groundwater pumpage began for irrigation and to control shallow groundwater levels. Following World War II, extensive pumpage began, primarily for irrigation. This resulted in extensive groundwater overdraft. With the advent of the State Groundwater Management Act, the extent of overdraft has been curtailed through management procedures such as decreased irrigation pumpage, water conservation pratices, and irrigational recharge projects. By the late 1980's, water levels within the Salt River Project had essentially stabilized. Continuing overdraft was present, however, in some off-project areas.

3.7 REGIONAL STATIC GROUNDWATER-LEVEL CONDITIONS

ADWR published "Maps Showing Groundwater Conditions in the Phoenix Active Management Area" in July 1995. The detailed groundwater survey of fall and winter 1991-92 was the first one in which water levels in wells were measured in all seven sub-basins of the Phoenix Active Management Area at about the same time. The vast majority of the more than 2,000 measurements were made during November 1991. Field work continued intermittently in the area through January 1992 in order to obtain additional data to provide acceptable coverage.

On the regional scale groundwater is generally moving laterally toward extensive and deep depressions in some of the main aquifer systems. In the East Salt River sub-basin, major groundwater depressions are centered in the Scottsdale-Paradise Valley area, in east Mesa, and north of the Santan Mountains. A depression in the vicinity of the community of Maricopa in the Pinal Active Management Area is apparently diverting groundwater from the southern part of the East Salt River sub-basin near the Gila River.

Significant water-level or head differences exist in proximate wells within some of the main aquifer systems. During the 1991-92 measurement period, differences exceed 25 ft in several places, and exceeded 400 ft in a small area north of the Santan Mountains in the East Salt River sub-basin. The major areas of these differences are located in the East Salt River sub-basin, and extend from north Scottsdale to south Chandler to the southeast part of the sub-basin. They are separated by the Salt River. Presumably, the higher water levels are mostly the result of fine-grained deposits in the upper basin fill which inhibit downward movement of water. Much of these areas corresponds to areas described as having perched groundwater in the upper unit by Laney and Hahn (1986), and to a regional perched zone described by Schmidt based on work done by the U.S. Bureau of Reclamation and the U.S. Geological Survey in 1972 (1981).

3.8 REGIONAL GROUNDWATER-LEVEL CHANGES

For the time periods extending from the detailed water-level surveys of fall and winter 1981-82 and 1982-83 to that of fall and winter 1991-92, data indicate there were general rises in water levels in the study area. During the respective periods, pumpage was reduced compared to the recent past, and abundant surface water was available in many areas, with much of this surface water becoming incidental recharge. Measurements in 1991-92 were made in approximately

1,150 wells that had also been measured in the earlier survey. Of these, only about 100 wells exhibited declines in water levels during the respective periods.

In the main aquifer system, water level rises of 50 feet or more occurred in many wells in all of the major groundwater depressions mentioned in the previous section except in the south portion of the Hassayampa sub-basin, where maximum rises of about 20 feet occurred over the respective time period. The rises in all of these groundwater depressions were probably due primarily to the combined effect of reduced pumping and migration of groundwater from adjacent areas.

In general, water levels declined during the period in much of the areas near the Salt, Gila, and Agua Fria Rivers in the West Salt River sub-basin. The declines were generally less than 25 feet. An explanation for at least part of these declines could be that when the survey was conducted in 1982-83, water levels near these rivers were still elevated due to the especially large flood flows that began in late 1978 and continued off and on through 1981. Part of the rises in areas adjacent to areas of decline might be explained by lateral groundwater movement away from the rivers, where the groundwater had been introduced as recharge during the flood flows. Similarly, this type of process may explain part of the declines and rises in the vicinity of the Town of Queen Creek, near the course of Queen Creek itself, in the East Salt River sub-basin.

III. CURRENT GROUNDWATER CONDITION IN THE STUDY AREA

URS (April 2002) conducted a groundwater quality and hydrogeology study for the Rio Salado Oeste Project. The current groundwater condition in the study area was presented in the URS study report. According to the URS report, groundwater generally occurs under unconfined conditions within the UAU. Groundwater flow in the eastern third of the study area (east of 39th Avenue) is generally from the south to north-northwest toward the RID well field located along or north of Lower Buckeye Road between 19th and 35th Avenue. The groundwater gradient is steepest to the north with values as high as 0.008 ft/ft in the vicinity of 35th Avenue and Lower Buckeye Road. The groundwater flow direction in the western two thirds of the study area (west of 39th Avenue) ranges from northwest to west. The groundwater gradient flattens to the west with values as low as 0.002 ft/ft. Static water level is relatively shallow, ranging from 20 to 50 feet below ground surface within the Salt River channel to 60 to 80 feet below ground surface north and south of the river.

Fluctuations in static water level can be as much as 20 to 30 feet on an annual basis due to agriculture pumping demands, and have declined as much as 25 feet in the last five years (Dames & Moore, 1991; Parsons Engineering Science, 2001). Hydrographs of selected wells show this decline is most pronounced in the eastern portion of the site near the RID wellfield. The selected wells provided static water levels from both ends of the study area that have the most complete water level records. Contributing factors that may cause the fluctuations are water discharge from the 35th Avenue water treatment plant outfall during winter months that produces groundwater mounding, and related radial flow during periods of discharge and basin-wide groundwater pumping and storm water runoff into the Salt River.

A groundwater contour map of the study area was prepared using ADWR well data from 1997 because it represented the most complete data set available (Figure 4). ADWR collected many water levels from both production and monitoring wells in the month of October, at the end of the pumping season. Water levels represent static values prior to significant precipitation. Some data outside of the Study Area were incorporated while contouring to fill data gaps. The hydrographs were prepared and reviewed to validate whether the contour map is representative of current conditions. In general the selected wells show a consistent water level decline without radical changes in gradient direction. Therefore, while the groundwater elevation has declined approximately 10 to 20 feet since 1997, the current contours are likely to be similar to the 1997 contours (URS, 2002).

IV. DEVELOPMENT OF A GROUNDWATER FLOW MODEL

The Arizona Department of Water Resources (ADWR) has developed a regional groundwater flow model of the Salt River Valley. The goal of the SRV groundwater modeling effort is to provide an analytical tool capable of quantifying the effects of various groundwater management and conservation scenarios on the groundwater supplies within the study area. The SRV groundwater model uses 3D-MODFLOW and has been calibrated under steady state and transient conditions. Based on the SRV groundwater model, a site-specific model along the Rio Salado Oeste study area was developed to assist in the wetland restoration, groundwater infiltration, and drawdown analysis. General model characteristics are presented in this section below.

5.1 MODEL GRID

The site specific model grid is 100 rows by 190 columns, with 3 layers and is aligned with the local baseline and meridian. The north and south boundaries of the model are one mile north of Mc Dowell Road and Estrella Road respectively, while the east and west boundaries are 40th Street and one mile west of 115th Avenue. Model cells are one-tenth mile in length and width. Each model layer corresponds to a single hydrogeologic unit. The active model domain encompasses 190 square miles. Figure 5 presents the model grid.

5.2 MODEL LAYER AND AQUIFER CONDITIONS

Three model layers were used to represent the hydrogeologic system. The uppermost layer, Layer 1, corresponds to the Upper Alluvial Unit (UAU). The UAU is modeled as an unconfined aquifer. The middle layer, Layer 2, corresponds to the Middle Alluvial Unit (MAU). The MAU is modeled as a confined/unconfined aquifer, confined when the overlying UAU is saturated and unconfined when the UAU is dewatered. The bottom layer, Layer 3, corresponds to the Lower Alluvial Unit (LAU). The LAU is also modeled as a confined/unconfined aquifer, confined when the overlying MAU is saturated and unconfined when the MAU is dewatered. The thickness of each model layer is defined by the elevation of each hydrogeologic unit contact.

5.3 BOUNDARY CONDITIONS

The selection of proper model boundary cell types is essential to the accuracy of the model. Boundary cells define the hydrologic conditions along the model borders. General-Head boundaries were applied in this model. The function of the General-Head Boundary Package is mathematically similar to that of the River, Drain, or ET Packages of the MODFLOW model. In the General-Head boundaries, flow into or out of a cell i,j,k, from an external source is provided in proportion to the difference between the head in the cell, $h_{i,j,k}$, and the head assigned to the external source, $H_{i,j,k}$.

5.4 VERTICAL LEAKANCE

The vertical leakance between Layers 1 and 2, and between Layers 2 and 3 was modeled using the VCONT option. MODFLOW requires VCONT to be calculated independently, and input as an array in the Block Centered File (BCF) package. VCONT was calculated by the following equation:

$$VCONT_{1-2} = 1 / (V_1/2K_{v1} + V_2/2K_{v2})$$

Where:

$VCONT_{1-2}$: Vertical leakance between Layers 1 and 2
V_1 : Saturated thickness of Layer 1 (feet)
V_2 : Saturated thickness of Layer 2 (feet)
K_{v1} : Vertical hydraulic conductivity of Layer 1 (feet/day)
K_{v2} : Vertical hydraulic conductivity of Layer 2 (feet/day)
Units : 1/day

The final calibrated ratios of horizontal hydraulic conductivity for Layers 1, 2, and 3 are given below.

Layer 1 Horizontal:Vertical K ratio = 20:1
Layer 2 Horizontal:Vertical K ratio = 100:1
Layer 3 Horizontal:Vertical K ratio = 50:1

5.5 INITIAL WATER LEVEL

The water-level data for the steady-state model simulation was adapted mainly from the depth to water map constructed by Lee (1905), and predevelopment water level maps constructed by Anderson (1968), and by Thomsen and Baldys (1985). The selected water level contours were then digitized and introduced into the model. After introduced into the model, the water levels were further adjusted to the current water levels based on a few measured water levels.

5.6 AQUIFER PARAMETERS

Initial hydraulic conductivity (K) estimates were developed using aquifer test data from groundwater contamination site studies, specific capacity data from GWSI and other sources, and recovery test data from the Salt River Project (SRP). Hydraulic conductivity values of all model layers were adjusted during the calibration of the steady-state model.

5.7 INITIAL MODEL SIMULATION

Model simulation runs were conducted for initial simulations with the COE's Groundwater Modeling System (GMS). Model runs were converged successfully. Figure 6 shows a test run result. Simulated groundwater contours for the modeling area are shown in the figure. The red line enclosed the modeling area is the general-head boundary. The model grids outside the boundary are inactive grids. Further model runs will be conducted to simulate the known static groundwater condition to complete the model calibration.

IV. SUMMARY

The Phoenix Rio Salado Project Report prepared by COE (April, 1998), ADWR Modeling Report No. 6 and No. 8 (A Regional Groundwater Flow Model of the Salt River Valley Phase I and Phase II), and Groundwater Quality and Hydrogeology Report by URS (April, 2002) were reviewed and applied for this study. A site-specific groundwater flow model was developed based on the regional groundwater flow model developed by ADWR. The project site groundwater condition and hydrogeologic data presented by URS were used for the model development. Initial model simulation runs were conducted for the without project condition.

TABLE 1, ESTIMATED PREDEVELOPMENT GROUNDWATER BUDGET FOR SRV

Source of Inflow to SRV	Volume (ac-ft/yr)
Stream Channel Recharge	100,000
Groundwater Inflow	30,000
Mountain Front Recharge	10,000
Total Inflow	140,000
Groundwater Discharge to Stream Channel	60,000
Evapotranspiration	76,000
Total Outflow	140,000

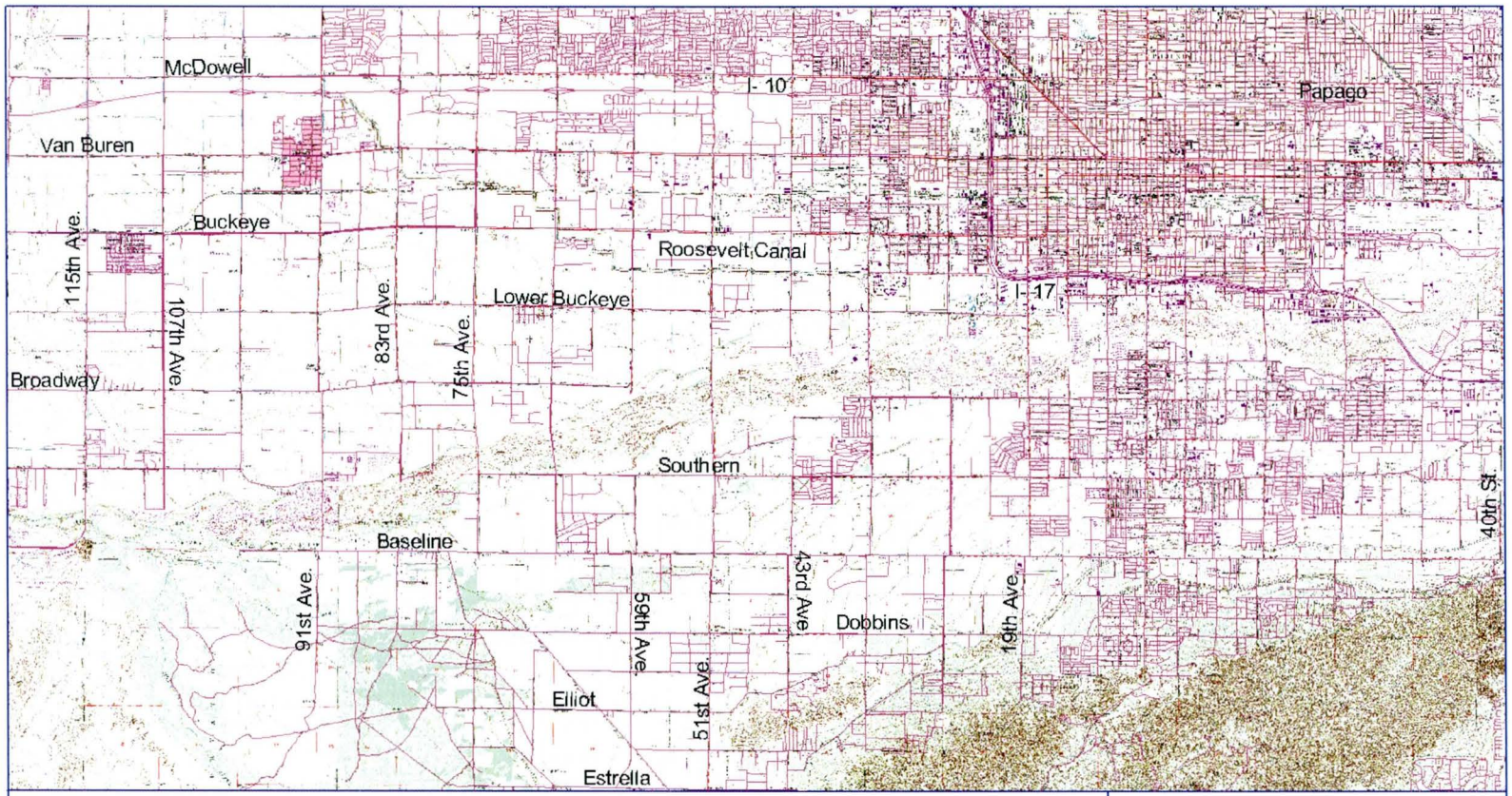
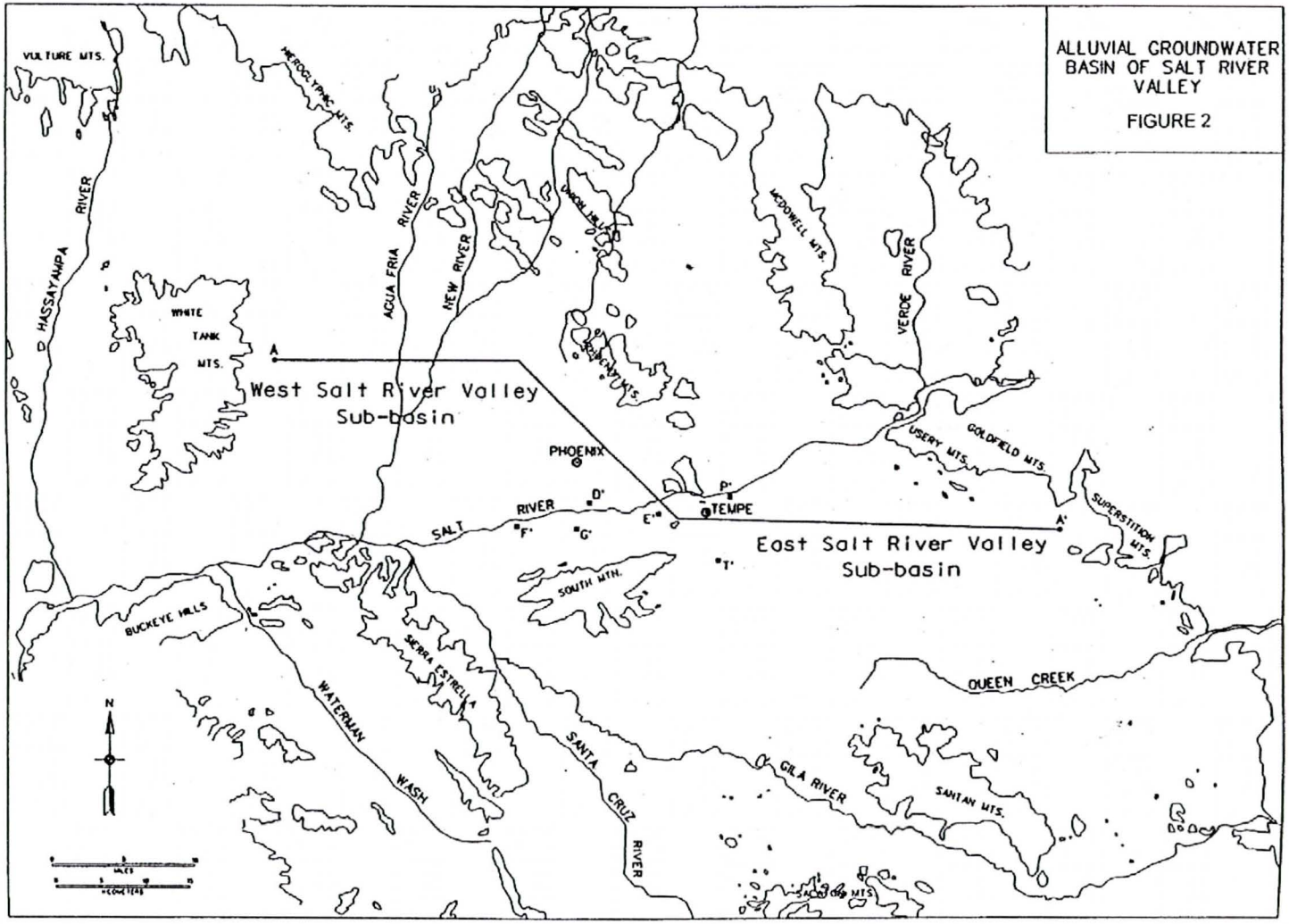
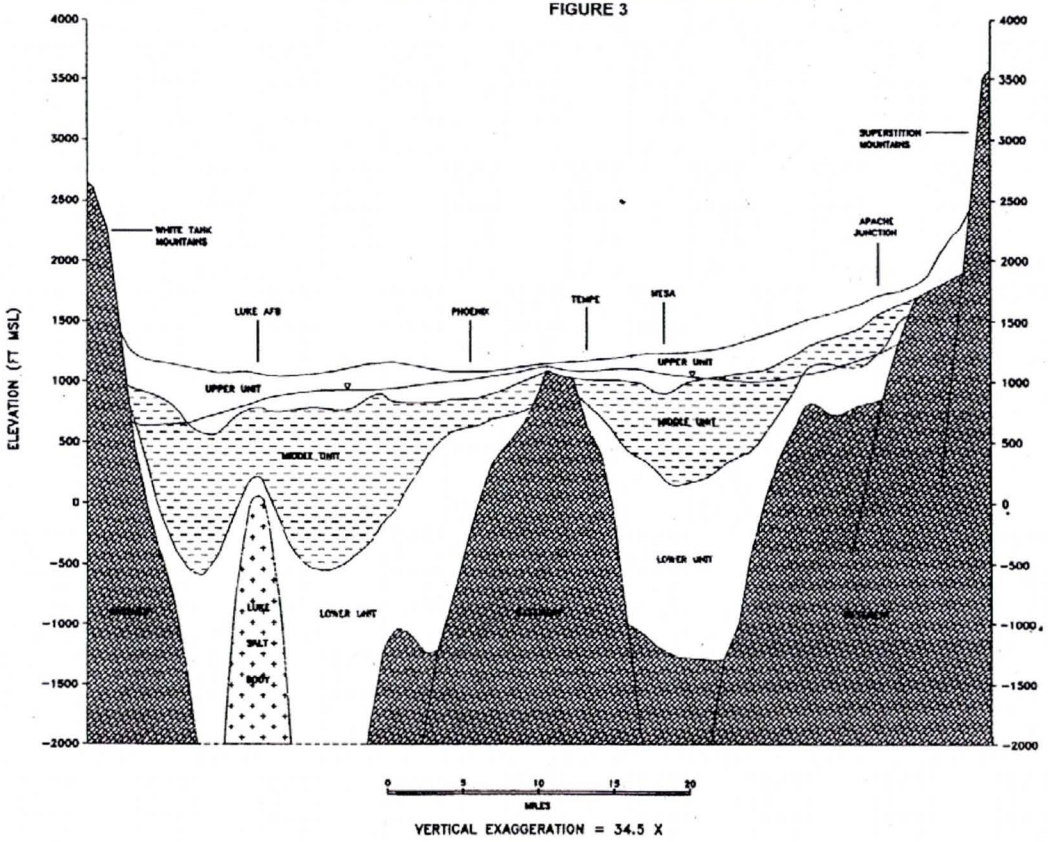


FIGURE 1 GROUNDWATER FLOW MODEL - MODELING AREA

RIO SALADO OESTE STUDY
SALT RIVER
PHOENIX, ARIZONA
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


ALLUVIAL GROUNDWATER BASIN OF SALT RIVER VALLEY
FIGURE 2
VULTURE MTS.
HASSAYAMPA RIVER
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
BRADSHAW MTS.
McDOWELL MTS.
VERDE RIVER
West Salt River Valley Sub-basin
PHOENIX
TEMPE
SALT RIVER
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
East Salt River Valley Sub-basin
SOUTH MTN.
BUCKEYE HILLS
SIERRA ESTRELLA
WATERMAN WASH
SANTA CRUZ RIVER
QUEEN CREEK
GILA RIVER
SANTAN MTS.
SACATON MTS.
A
A'
D'
E'
F'
G'
P'
T'
N

SALT RIVER VALLEY GENERALIZED GEOLOGIC CROSS SECTION
FIGURE 3



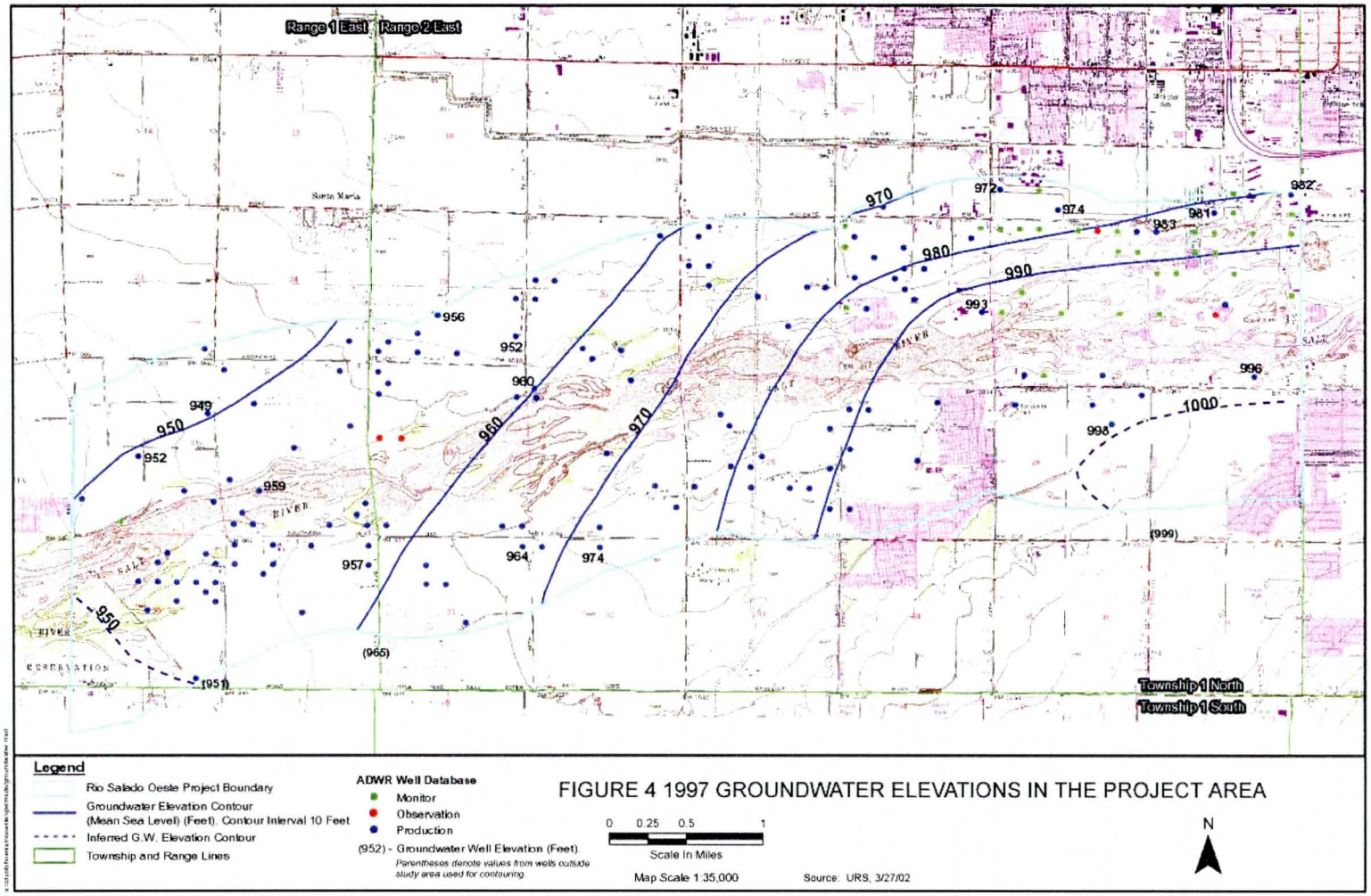
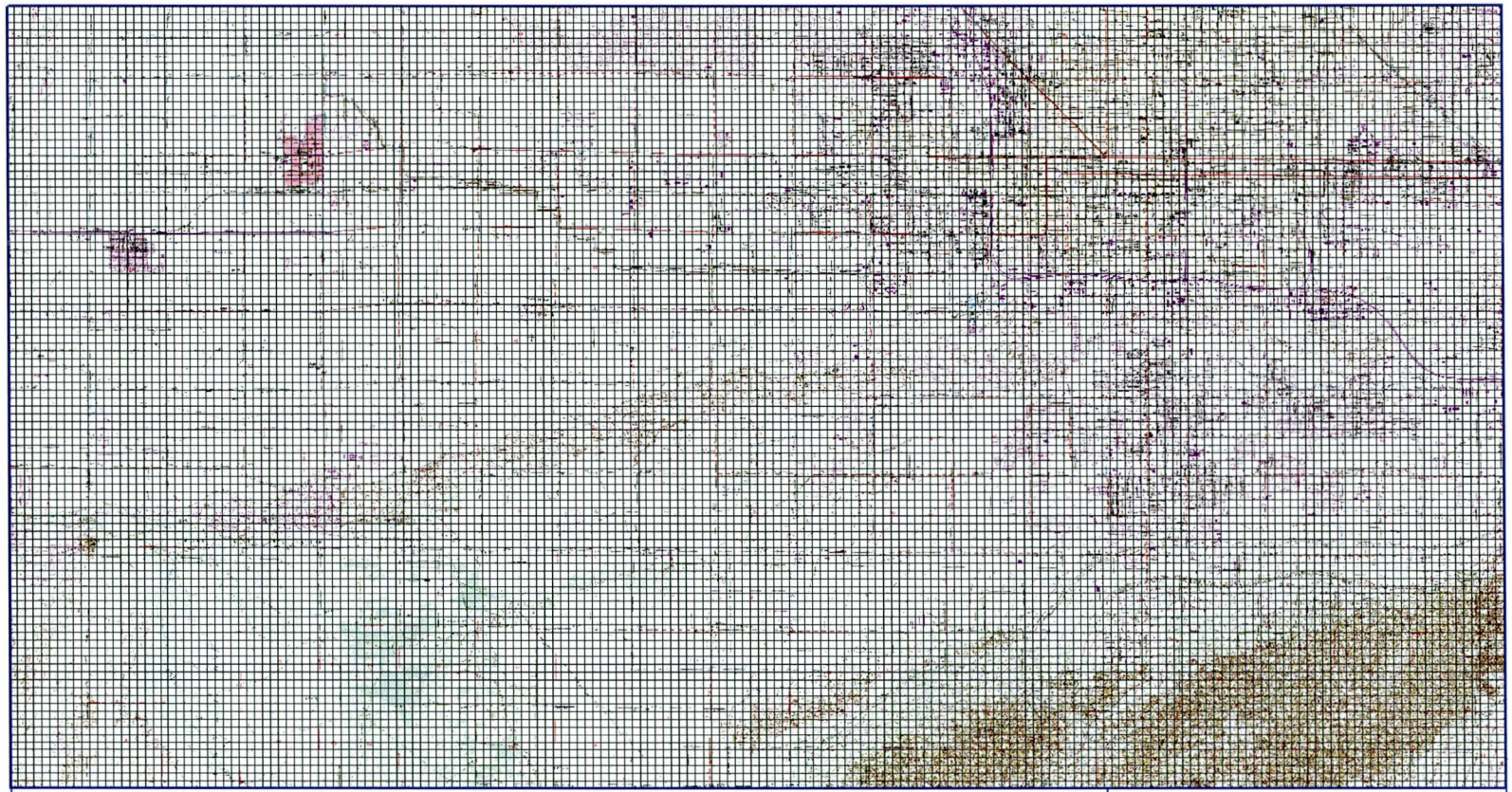


FIGURE 4 1997 GROUNDWATER ELEVATIONS IN THE PROJECT AREA



0 1 2 Miles

N

FIGURE 5 GROUNDWATER FLOW MODEL - MODEL GRID

100 ROWS by 190 COLUMNS

RIO SALADO OESTE STUDY
SALT RIVER
PHOENIX, ARIZONA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

FIGURE 6 INITIAL MODEL SIMULATION RESULT

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE

Salt River-Phoenix, Arizona

Appendix D
Groundwater Quality
and
Hydrogeology Report

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
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A Well Inventory Reports

1.0 INTRODUCTION

The U.S. Army Corp of Engineers (USACE) and the City of Phoenix (COP) have initiated a feasibility study for the Rio Salado Oeste Project (Oeste Project) to evaluate the design and completion of a riparian habitat restoration project. The Oeste Project lies within the Salt River between 19th Avenue on the east and 83rd Avenue on the west. The north and south boundaries are designated to be Durango Street and Southern Avenue, respectively, for the eastern portion; and Broadway Road and Baseline Road, respectively, for the western portion. As part of the feasibility study, the USACE and COP are assessing the various water sources and potential locations and design for the production and monitor wells for the project.

The purpose of this report is to evaluate the existing groundwater and surface water quality, describe the hydrogeology of the project area, and provide information about existing monitor and production wells in tabular format. The hydrogeologic and groundwater data will be used to facilitate the design specifications and future siting of monitor and production wells in the project area.

2.0 SCOPE OF WORK

The scope of work for this project was developed by the COP and during meetings with the USACE. To meet the objectives of this project URS's scope of work included the following tasks:

1. **Provide a Base Map of the Project Area.** URS was tasked to update and delineate the project boundary, major roads, major geographic features, streams, storm water drainages, and existing land use. Major roads and geographic features were derived from URS archives of existing data. Existing land use data were inventoried at 1:35,000 scale. The land use inventory effort resulted in polygon coverage with the following categories: residential, commercial/industrial, landfill, sand/gravel operation, agricultural, recreational, and river bottom/native.

2. **Review "Phase 2 Middle Gila Watershed Study Final Report".** Using the "Phase 2 Middle Gila Watershed Study Final Report" (Phase 2 Report) prepared by Greeley and Hanson (2001), URS provided a general description of the surface water quality in the project area. URS conducted a cursory field reconnaissance along the Salt River to identify discharges of effluent, irrigation return flows, and storm water drainage. The locations of these features were provided on the project base map. Assessing the surface water quality along the Salt River was conducted by researching databases from the COP, U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (EPA) Storage and Retrieval system *STORET,* and Salt River Project (SRP).

3. **Review and Identify Existing Public Records.** This task was to provide a general description of the groundwater chemistry and assess whether water quality should be considered in siting production wells along the Salt River. To accomplish this task, we researched records and files at the Arizona Department of Environmental Quality (ADEQ) and the Arizona Department of Water Resources (ADWR) on existing wells and groundwater investigations. Using the modified base map prepared in Task 1, URS delineated areas of groundwater environmental contamination and identified the potential extent of groundwater contamination where it can be inferred from the available data. URS also delineated areas of high Total Dissolved Solids (TDS), based on conductivity measurements, and nitrate contamination in groundwater, on the project base map.

4. **Describe the Hydrogeology of the Oeste Project.** URS provided a general description of the regional hydrogeology of the project area. We researched available well records,

groundwater modeling reports at ADWR, and the Roosevelt Irrigation District (RID). With the available data, URS calculated and estimated aquifer hydraulic properties such as groundwater gradient, hydraulic conductivity, transmissivity, and storativity. The aquifer property data will be used to provide recommendations for the design specifications and siting for future production wells and monitor wells.

5. **Preparation of the Well Inventory Report.** This task was subdivided into several subtasks and included the following: extraction of ADWR well records, research and compilation of records, database design and form generation, database population, and generation of tabular well inventory reports. The well inventory report tables will be used to facilitate future siting of production and monitor wells for the Oeste Project.

Once this groundwater and hydrogeologic report is completed and finalized, URS will provide a letter report that will provide recommendations on the siting criteria and design specifications for the monitor and production wells that will be required for the habitat restoration project.

3.0 DATA COLLECTION AND COMPILATION METHODS

3.1 DATA SOURCES

URS queried the following databases for groundwater quality, surface water quality, and aquifer properties:

- 1999 and 2002 ADWR well registry database
- ADEQ Water Quality database as of March 2002
- 2002 ADWR Groundwater Site Inventory (GWSI) database
- ADWR Imaged Records database as of March 2002
- EPA *STORET* as of March 2002
- USGS National Water Information System (NWIS) database as of March 2002.

URS collected the following reports to summarize the land use issues, hydrogeology, groundwater quality, and surface water quality of the project area:

- Phase 2 Middle Gila Watershed Study Final Report (Greeley and Hanson, 2001a)
- Salt/Gila Groundwater Analysis Project Summary Report (Greeley and Hansen, 2001b)
- Tres Rios Hydrologic Model Development and Applications Report (Water & Environmental Systems Technology, 2000)
- Del Rio Landfill Report (Dames & Moore, 1991)
- Groundwater Quality Survey, Rio Salado Habitat Restoration Project (Dames & Moore, 1997)
- Draft Well Installation and Data Analysis of Rio Salado Production Well (RSPW-2) (URS, 2002).

URS collected data pertaining to well production capacity, groundwater quality, and surface water features from the various sources:

- SRP
- RID
- Peninsula-Horowitz Irrigation District (P&H)
- COP 23rd Avenue Waste Water Treatment Plant (23rd Avenue WWTP) and 27th Avenue Landfill
- ADEQ Leaking Underground Storage Tank (LUST) files
- Personnel communications with various landowners.

3.2 WELL DATA PROCESSING AND REPORTING

Initially, URS created a suitable reporting format for the well inventory reports, and submitted it to the COP and USACE for approval. Once the format was approved, URS contacted and obtained public files from sources such as the ADWR, ADEQ, COP, SRP, RID, and several private entities, which own wells in the project area. URS then utilized Microsoft Access 2000 to design a relational database with four tables (Sites, Well_Construction, Water_Levels, and Surface_Water_Quality). The compiled electronic as well as hard copy data were then entered into the database. With the database design and population accomplished, URS employed the four (4) tabular reports: Table 1 – Well Locations, Table 2 – Well Construction, Table 3 – Water Levels, and Table 4 – Surface Water Quality. These reports are provided in Appendix A.

4.0 STUDY RESULTS

4.1 SITE DESCRIPTION

The project site is located within the Salt River between 19th Avenue on the east and 83rd Avenue on the west in Phoenix, Maricopa County, Arizona. The north and south study boundaries are located between approximately Durango Street and Southern Avenue for the eastern portion, and Broadway Road and Baseline Road for the western portion. Specifically, the northern and southern boundaries were defined by including all areas between 19th and 83rd Avenues that are within one mile of any segment of the Salt River centerline (Figure 1).

4.2 LAND USE

Land use within the study area was classified into the following seven categories: Residential, Commercial/Industrial, Landfill, Sand/Gravel Operation, Agricultural, Recreational (i.e. public parks), and River Bottom/Native (Figure 1). The project study area was divided into four separate portions of land based on the dominant types of uses; 19th - 35th Avenues, 35th - 51st Avenues, 51st - 67th Avenues, and 67th - 83rd Avenues (Figure 1).

- **19th - 35th Avenues** Sand and gravel operations line the Salt River with no remaining native river bottom. Commercial/industrial properties dominate both north and south of the river with about equal portions of agricultural and sand and gravel operations making up most of the balance

- **35th - 51st Avenues** Major sand and gravel operations exist in and along the Salt River. Almost half the river has remained undisturbed and is designated as native. Large areas of commercial/industrial properties exist primarily north of the river, gravel operations are present along the river, and residential properties are present south of the river

- **51st - 67th Avenues** Sand and gravel operations are present in and along a large portion of the Salt River. Almost half the river has remained undisturbed and is designated as native. Although there are small pockets of residential land north and south of the river, the majority of land is utilized for agricultural purposes

- **67th - 83rd Avenues** Sand and gravel operations are present in and along some areas of the Salt River with a small portion remaining undisturbed. Few commercial/industrial properties are present. While there is a small pocket of residential land north of the river, the majority of land is utilized for agricultural purposes.

4.3 SURFACE WATER

The purpose of this task was to evaluate the data compiled during the Phase 2 Report by Greeley and Hansen (2001) and review that database to identify only those data that are applicable to the Oeste Project area. These data, as well as newly compiled data, were then used to describe the surface water quality within the Oeste Project area and delineate surface water chemical constituents that exceed the Arizona Administrative Code, Title 18, Chapter 11, § 109 A Appendix A, Numeric Water Quality Criteria, September 30, 1996 (A.A.C. R18-11-109.A Appendix A).

4.3.1 Information Sources

Compiling information to provide a general overview of the surface water quality within the Oeste Project area involved three distinct steps. The first step was to conduct cursory field reconnaissance to correlate field data and surface water sources identified within the Phase 2 Report with current project area site conditions, attributes, and narrative water quality standards. Field reconnaissance was conducted on five separate days from March 1 through March 8, 2002. This reconnaissance primarily focused on identifying surface water features, discharge points, and making observations relative to applicable surface water quality narrative standards. In addition, the field work identified commercial and industrial activities that may have the ability to impact surface water quality in the study area.

The second step involved the review of available databases from recognized sources to compile the most recent numeric surface water quality data. Data for the study area were extracted from the Phase 2 Report as well as from those sources known to collect surface water quality data. These additional sources of data include the COP, SRP, ADEQ, ADWR, EPA, and the USGS. All of these sources were able to provide surface water quality data, but not all data were applicable to the Oeste Project area.

The last step in data compilation was to describe the surface water quality within the study area by comparing available surface water quality sample data and field observations with numeric and narrative surface water quality standards, respectively.

4.3.1.1 Field Data

Field reconnaissance was conducted over a period of five days by a two-person field crew. Based on this work, it was concluded that the information presented within the Phase 2 Report was accurate and complete with regard to outfall locations, storm water sampling locations and

commercial and industrial activities. Observations relative to narrative surface water quality standards were also completed.

URS field personnel confirmed that there are a limited number of point-source outfalls impacting the Oeste Project area. These outfalls include the National Pollutant Discharge Elimination System (NPDES) permitted outfalls associated with the 23rd Avenue WWTP operated by the COP. In addition, several point-source, stormwater outfalls were identified and confirmed to be the same as those identified within the Phase 2 Report. A map of surface water features is presented in Figure 2.

It is suspected that there are additional connections to the point-source, stormwater outfalls. These connections are associated with the various canal systems. Irrigation district maps acquired from SRP show irrigation district connections to storm drains at 19th, 27th, 35th, 43rd, and 51st Avenues along the north and south sides of the Salt River. It would require a comprehensive field effort to obtain the necessary authorizations to enter private property and survey the entire project area to identify and assess the extent of these connections. Therefore, although these irrigation-impacted outfalls have been identified, the extent of those connections to the outfalls have not been identified within the scope of this project.

Second, it was confirmed that there is a variety of commercial and industrial activities having the ability to impact the project area via non-point source storm water run-off. Along the south side of the Salt River from 19th Avenue to 43rd Avenue, the land use was predominantly auto-wrecking yards and construction lay-down areas, which can be expected to contribute to the contamination of storm water run-off. The north side of the river was impacted by a larger percentage of commercial and industrial activity between 19th and 43rd Avenues, including the COP transfer station and landfill at 27th Avenue. These sources can be expected to introduce metals, grease, oils and organic contaminants via storm water run-off. Residential impact was minimal. Although a significant amount of agricultural activity was present, most of this activity was not adjacent to the river, but was located along the study area borders. At approximately 51st Avenue, the primary commercial and industrial impact activity transitioned to agricultural use. Sand and gravel mining activities have a significant presence within the Salt River channel. Dewatering from the mining activities has resulted in established riparian segments, although these water features do not meet the ADEQ definition of "surface water" in accordance with A.A.C. R18-11-109.A. Thus, given the variety of commercial and industrial impact activities described above, it is apparent that non-point source storm water run-off has the potential to impact storm water and, thus, surface water quality in the study area. The only exception to this was the COP 27th Avenue Landfill, which has on-site stormwater retention ponds.

Lastly, it was determined that data gaps exist with regard to the quality and impact of irrigation return flows. SRP, RID, and P&H were contacted for available surface water quality information, but they either did not have surface water quality data or they did not have information from within the study area boundaries. SRP did indicate that the return flow networks are complex and the discharge of water empties to multiple sites (personal communication with Gregg Elliott of SRP, March 13, 2002). SRP also indicated that during the early 1980s many former agricultural sites were developed for commercial/industrial use and, in some cases, the canal systems were not removed or disconnected. As a result, storm water from these developed areas would enter the canal system and eventually discharge into the Salt River during a storm event (personal communication with Gregg Elliott of SRP, March 13, 2002). Analysis of canal maps provided by SRP indicates that storm drain connections are present throughout the canal system along the perimeter of the entire project area.

4.3.1.2 Databases

Three databases contained water quality data applicable to the Salt River project area. These databases were part of the original Phase 2 Report and were obtained from:

- EPA STORET,
- SRP, and
- COP.

Several other sources of data were queried for surface water quality data. These sources of data included USGS, ADWR, ADEQ, RID, SRP and P&H. However, surface water quality data from these sources were either: (1) not available, (2) not within the site area boundaries, (3) never delivered from the source, or (4) reported in a format that could not be directly compared to the ADEQ surface water quality standards[1].

EPA STORET

The EPA STORET database is a repository for water quality, biological, and physical data and is used by a variety of local, state and federal agencies. The EPA maintains two data management systems containing water quality information: the Legacy Data Center (LDC) and STORET. The LDC contains historical water quality data from the early part of the 20th Century to the end of

[1] The USGS database reported values to be "less than" a certain quantity. These data could not be directly compared to the ADEQ value to determine if the USGS value exceeded the ADEQ criteria value.

1998. STORET contains data collected beginning in 1999 to the present. Both databases were queried for data applicable to the study area. STORET did contain surface water quality data, but it did not contain any Arizona data from 1997 forward.

SRP

SRP provided flow volume data for the Maricopa Drain, an irrigation drain that discharges to the Salt River in the vicinity of 77th Avenue (Figure 2). Although SRP had previously supplied some surface water quality data for the Phase 2 Report, it was not able to provide any additional surface water quality data for inclusion in this report.

COP

COP provided storm water sampling data and river sampling information as part of the Phase 2 Report. River sampling information pertained to the discharge of the 23rd Avenue WWTP to the Salt River. The data collected by the COP were in response to NPDES permit requirements for both point-source outfalls associated with the 23rd Avenue WWTP and for non-point source impacts (storm water).

4.3.2 Water Quality Standards

Surface water quality standards are comprised of designated uses, associated numeric water quality criteria, and narrative standards. The numeric water quality criteria are established to protect the designated use(s) of the specific reach of a river system, while the narrative standards are to protect all surface waters. Both the designated use and the numeric criteria are prescribed by the ADEQ in accordance with A.A.C. R18-11-109.A Appendix A, and the narrative standards are prescribed in A.A.C. R18-11-108.A and B.

It should be noted that ADEQ is in the process of updating various water quality standards and this update may impact surface water quality standards (personal communication with Samuel Rector of ADEQ, March 2002). Presently, ADEQ has adopted new standards and, although these standards have not been reviewed and approved by the EPA (and thus are not yet applicable as NPDES permit standards), they are considered to be the applicable water quality standards within Arizona. However, a current listing of the revised standards was not yet available from ADEQ. Therefore, those ADEQ numeric standards that have been in effect since 1996 were used in the surface water quality analysis presented herein.

4.3.2.1 Designated Uses

ADEQ separates rivers into specific reaches for the purpose of assigning designated uses. The study area discussed in this report includes Reaches 4 and 5 along the Salt River. Reach 4 extends from the Interstate-10 Bridge at the Salt River to the 23rd Avenue WWTP. Reach 5 extends from the 23rd Avenue WWTP past the 83rd Avenue study area boundary (at the confluence of the Salt and Gila Rivers).

The current associated designated uses for the Salt River (Reaches 4 and 5) are as follows:

- Reach 4 – designated for aquatic life and wildlife – warm water (A&W w), partial body contact – recreation (PBC), and fish consumption (FC)

- Reach 5 – designated for aquatic life and wildlife – effluent dependent water (A&W edw), partial body contact – recreation (PBC), fish consumption (FC), agricultural irrigation (AgI), and agricultural livestock watering (AgL).

4.3.2.2 Numeric Surface Water Quality Standards

For each of the above-designated uses, there are numeric surface water quality criteria established for each established criteria element (A.A.C. R18-11-109.A Appendix A and B). As the numeric standards are used to protect a designated use, a value that exceeds the numeric standard indicates that a particular criteria element is a pollutant that may cause water quality degradation within that Reach. Within this report, data were compared against numeric standards to identify these potential surface water quality pollutants and the source of the pollution.

4.3.2.3 Narrative Surface Water Quality Standards

Narrative water quality standards are established to protect all surface waters. Current standards require that surface water be free from pollutants in accordance with A.A.C. R18-11-108.A and B. In summary, surface water shall be free from pollutants that cause odor, off-taste, undesirable growth, changes in color or contribute to violation of an aquifer water quality standard. Surface water shall also be free from oil, grease, and other pollutants that float as debris, foam or scum.

4.3.3 Water Quality Summary

With respect to the databases discussed in Section 4.3.1.2, the data for the Salt River between 19th Avenue and 83rd Avenue were generally collected prior to 1997. There is a limited amount

of data available for 1999, and no data for this river segment beyond 1999. Also, there is a minor amount of surface water flow in the Salt River between 19th Avenue and 83rd Avenue. As a result, limited water quality sampling information is available for this area. The following sampling location information has been included in this report and was also provided within the Phase 2 Report. The data availability moving downstream through the study area includes the following:

- 23rd Avenue WWTP Outfall (7/92-6/93),
- 35th Avenue Bridge (7/92-6/93),
- 51st Avenue Bridge (7/92- 6/93),
- 59th Avenue and Salt River (4/94-4/95),
- 67th Avenue Bridge (7/92-6/93), and
- SRP Maricopa Drain (1996-1999).

4.3.3.1 Surface Water Sources

The sources of surface water in the study area include: point-source outfalls from the COP 23rd Avenue WWTP, SRP Maricopa Drain, storm water point-source discharges, and irrigation flows. Surface water quality data were available for:

- COP 23rd Avenue WWTP,
- SRP Maricopa Drain, and
- COP storm water outfalls at designated locations.

In 1995, the COP began discharging treated wastewater to the Salt River channel at the 35th Avenue outfall. The COP discharges approximately 45 million gallons per day (MGD) to the river during a 4-month period, generally ranging from mid/late October to mid/late February or March. During the remaining 8 months of the year, treated wastewater is distributed via canals and pipelines to the RID for agricultural use. In addition, approximately 10 MGD of treated effluent is distributed from the 23rd Avenue WWTP continuously throughout the year for other agricultural irrigation allotments (Parsons Engineering Science, 2001).

The SRP Maricopa Drain is an irrigation district discharge point that discharges intermittently dependent upon agricultural needs, system maintenance needs and storm water impacts. It is a drainage ditch that collects unused water from about 27th Avenue west to 75th Avenue.

The COP storm water outfalls provide an intermittent source of surface water to the project area. The average annual rainfall in Phoenix metropolitan area is 7.95 inches per year (Western Regional Climate Center, 2002).

4.3.3.2 Storm Water Data

It is important to note that storm water quality is a function of land use, not the size of the watershed (Greeley and Hansen, 2001). In other words, how a specific section of land is used will impact stormwater quality more so than tract size. Thus, to better manage stormwater data, the Phase 2 Report produced by Greeley and Hansen divided the storm water database into three data sets that are designated as follows:

- In-stream storm water samples from a variety of storm water drainage basins in urbanized areas, including natural runoff and background streamflow.
- Storm water samples at the point of discharge to Waters of the United States (U.S.) that represent storm water from a defined drainage basin and land use mixture.
- Storm water samples from within a municipal storm drain system that represent storm water from a defined drainage basin and land use mixture that are not representative of storm water discharges to Waters of the U.S.

Storm water data were divided into the above files so that data from within the storm drain system are not misunderstood and extrapolated to represent the storm water characteristics at the point of discharge to Waters of the U.S. or in-stream water quality. Greeley and Hansen (2001) strongly caution against the direct comparison of storm water data with water quality standards, particularly those related to acute and chronic toxicity. Storm water data were available from the following in-stream locations within the project area:

- Downstream side of 19th Avenue bridge — In-stream
- Arizona Central District Canal (ACDC) at 43rd Avenue — In-stream
- Downstream side of 51st Avenue bridge over the ACDC — In-stream
- Downstream side of 51st Avenue bridge over Salt River — In-stream

Storm water data were also available for the following point-of-discharge locations:

- Salt River at 27th Avenue – south bank of river — Point-of-Discharge
- Salt River at 35th Avenue – north bank of river — Point-of-Discharge
- 67th Avenue at Salt River — Point-of-Discharge

4.3.3.3 Numeric Surface Water Quality Criteria Summary

The numeric surface water quality standards established by ADEQ for each designated use were compared against the available surface water quality sample data obtained from the various databases. Where an established surface water quality numeric criterion was exceeded, this information was used to compile Table 4, Surface Water Quality Summary (Appendix A). Because the amount of data provided for the study area is rather limited as a whole, and especially limited between 51st Avenue and 83rd Avenue, data from two locations downstream outside of the study area were also included in the analysis. This was done to provide a set of comparison values that may be indicative of the surface water quality of the western portion of the study area and downstream of the study area.

As an overall observation, the A&W edw designated use was frequently problematic for certain metal analytes because the standard requires hardness data for evaluation. Where hardness data were available, all applicable data were evaluated and concentrations greater than the current standard were included in the table. Data from sampling events lacking hardness results were not evaluated as the numeric value for the standard could not be calculated. Additionally, all data that were qualified by the analytical laboratory (e.g. estimates, calibration failure, contamination, etc.) were excluded.

A total of 21 parameters were found to have exceeded numeric surface water quality criteria (Appendix A, Table 4). The parameters included pesticides, metals, chlorinated hydrocarbons, the water quality parameters pH and turbidity, and bacteriological parameters. Approximately 45 percent of the exceedances were elevated bacteria counts, 15 percent of the results were from pesticides, 13 percent of the results were from metals, and 9 percent of the results were chlorinated hydrocarbons. The remainder represents parameters such as pH, dissolved oxygen, and cyanide.

In general, based on analysis of available data versus the numeric water quality standards, stormwater is a vehicle by which surface water quality appears to degrade within the Salt River.

4.3.3.4 Narrative Surface Water Quality Criteria Summary

Based on field observations and the comparison of site data with the narrative water quality standards, stormwater can degrade surface water quality within the Salt River. Point-source stormwater outfalls were observed to be non-compliant with narrative standards as these points tended to accumulate debris, foam, scum and odor.

4.3.4 Data Gaps

In the process of compiling this surface water quality summary, the following data gaps were identified:

- There was a limited amount of surface water quality data for the Salt River study area from 19th to 83rd Avenues (data location gap).
- Based on inquiries, it is believed that additional surface water quality data exists, but it was not delivered timely to URS for inclusion in this summary (data source gaps).
- Older storm water data (from 1992 and 1993) were predominant in the analysis (data date gap). As land use patterns have changed, it is logical to assume that storm water quality has been impacted by these land-use changes and that the older data may no longer be truly reflective of actual site conditions.
- Sample data were not available for the comprehensive list of surface water quality criteria compiled by ADEQ (study parameter data gaps).
- Non-point source storm water run-off is likely a key contributor to the degradation of water quality in the project area, but comprehensive data sets are not available to confirm this supposition.
- Major data gaps include ungaged agricultural drains, impact of concentrated animal feeding operations (CAFO) on water quality, and storm water pollutant loads and RID canals and discharges.
- Gila River Indian Community discharges into the Salt River, just at edge of study area near 83rd Avenue, but no data on these discharges were made available to URS for inclusion in this report.

4.4 HYDROGEOLOGY

The purpose of this task was to evaluate the aquifer characteristics and groundwater use within the study area. Understanding the hydrogeology will help with design and site selection for future monitor and production wells required for habitat restoration project.

4.4.1 Geologic Setting

The Oeste Project is located in the Basin and Range Physiographic Province of Arizona, which is characterized by predominantly north to northwest-trending mountain ranges that are separated by gently sloping alluvial basins. Basin-fill deposits in this region range in thickness from less than 100 feet near the basin margins to over 10,000 feet in the central areas of some basins. Basin-fill deposits consist of intercalated sequences of alluvial sediments and evaporites, and are underlain by basement rocks that consist of Precambrian igneous and metamorphic rocks and Tertiary sedimentary and volcanic rocks (Corkhill, et al., 1993). In the Oeste Project area, unconsolidated basin-fill sediments are approximately 1,000 feet thick at the eastern portion of the study area and thicken to the west to over 3,000 feet.

The clastic sediments are interpreted as alluvial fan, lacustrine, and fluvial deposits formed during development of the Salt River Valley basin and sub-basins. The unconsolidated alluvial and lacustrine deposits have been subdivided into three stratigraphic units from oldest to youngest: the Lower Conglomerate Unit (LCU), the Middle Fine-Grained Unit (MFU), and the Upper Alluvial Unit (UAU). As previously stated, this project focuses on the water quality and water supply potential of the UAU, which is the proposed source of water for the Oeste Project.

The UAU is divided into four subunits within the study area. These subunits are designated from youngest to oldest as S, A, B, and C. These subunits appear to be essentially horizontal within the study area and no significant geologic structures have been identified.

- **Subunit S** is exposed at the surface near the river and consists of silty sand with clay and gravel. This unit is typically unsaturated in the vicinity of the Salt River

- **Subunit A** is further subdivided into Subunits A_1 and A_2, and is generally comprised of sandy gravel and cobbles. Subunit A_1 extends to a depth of 90 to 110 feet below ground surface (bgs) and consists of unconsolidated, poorly sorted, coarse sand and gravel. The primary difference between A_1 and A_2 is that Subunit A_2 contains 30 to 40 percent fine to coarse sand versus 5 to 20 percent in Subunit A_1. In addition, Subunit A_2 is typically better sorted than A_1. The contact between these subunits is gradational and is identified

by a transition from coarse to medium-sized gravel, increased roundness, and greater amounts of fine sand and silt (Dames & Moore, 1991). In the vicinity of the 19th Avenue Landfill Subunit A_1 was observed to be about 100 feet thick and Subunit A_2 was observed to be about 90 feet thick

- **Subunit B** underlies Subunit A_2 and is dominated by coarse to fine sand, silt, clay, and minor gravels. Subunit B is distinguished by its reddish-brown color and finer-grained nature. In the vicinity of the 19th Avenue Landfill Subunit B was observed to be about 40 feet thick

- **Subunit C** underlies Subunit B and primarily consists of fine to medium sand, angular to subrounded fine gravel, minor silt, and clay. The transition from Subunit B to Subunit C is identified by an increase in grain size and a color change to brown. In the vicinity of the 19th Avenue Landfill Subunit C was observed to be about 150 feet thick.

4.4.2 Hydrogeology and Aquifer Properties

Hydrogeologic data and aquifer properties for the UAU were collected from available reports and public database information as described in Section 3.1. URS contacted various owners with a history of groundwater production capacity greater than 500 gallons per minute (gpm), a casing diameter greater than 10 inches, and screen intervals placed in either subunits A, B, or C of the UAU. While many other production and monitor wells were located during the investigation, aquifer properties were based preferentially on data from wells capable of producing significant discharge ($\geq$ 500 gpm) in order to stress the aquifer of the UAU. For wells with limited aquifer property data, but with pumping, drawdown, and well construction information available, a mathematical approximation was used to estimate aquifer characteristics (Razack & Huntley, 1991). ADWR personnel were contacted to obtain the most recent data regarding water levels, aquifer modeling, and recent publications in the study area. ADWR also queried their databases for recent aquifer testing and research done to support submitted Certificates of Assured Water Supply or Water Adequacy Statements, however none were encountered in the study area. The compiled aquifer parameters of the UAU are presented in Table 4.4.2.

TABLE 4.4.2
AQUIFER PROPERTIES OF THE UPPER ALLUVIAL UNIT
RIO SALADO OESTE PROJECT

Sources	Hydrogeologic Units	Transmissivity (ft^2/day)	Storativity (Dimensionless)	Hydraulic Conductivity (K) (ft/day)
161 ARG Site Characterization Report, LUST File Pump Test, (Dames & Moore, 1997)	UAU Unit A	18,048 - 19,519	0.4 – 0.44	27.7 – 338.6
19th Avenue Landfill Modeling, (Dames & Moore, 1997)	UAU Unit A	15,709 - 36,096	NA	NA
19th Avenue Landfill Aquifer Testing, (Dames & Moore, 1997)	UAU Unit A	25,209 (a)	0.11 (a)	30.7
Aquifer Test in Salt River Sediments, Avis Facility at Airport, (Dames & Moore, 1997)	UAU Unit A	25,936	NA	160.4
Salt River Valley Modeling Report No. 8, (Corkhill, et al., 1993)	UAU undifferentiated	NA	0.08 – 0.22	20 – 250
Renovation of Wastewater at the 23rd Avenue Rapid Infiltration Project (Bouwer and Rice, 1984)	UAU Unit A	25,401 (a)	NA	72.6
Well Installation and Data Analysis Report, Rio Salado Production Well No. 2 (RSPW-2), (URS, 2002)	UAU Unit A	21,390	NA	203
Well #55-613468, (personal communication Mr. A. King, 2002)	UAU Unit A	59,927	NA	500
Well #55-605117 (United Metro Materials), (personal communication Mr. A. Shelton, 2002)	UAU Units A, B, and C	27,629	NA	153
Well #55-528969 (Hansen Aggregate), (personal communication Mr. A. Jason, 2002)	UAU Unit C	23,815	NA	297
Well # 55-607697 (SRP 7E-1N), (SRP well database, 3/2002)	UAU Units A, B, and C	32,727	NA	76
Well # 55-607698 (SRP 4.8E-0N), (SRP well database, 3/2002)	UAU Units A, B, and C	23,258	NA	83
Well # 55-608378 (SRP 11.8E-2N), (SRP well database, 3/2002)	UAU Units A, B, and C	26,011	NA	68
Well # 55-578740 (SRP 6E-0.9N), (SRP well database, 3/2002)	UAU Units A, B, and C	19,487	NA	63
Tres Rios Hydrologic Model Development and Applications Report (Water & Environmental Systems Technology Inc., 2000)	UAU Units A, B, and C	NA	0.10-0.15	600-800
Dewatering Investigation Southern Ave. Sewer Line/ Sewage Lift Station #43 (Southwest Groundwater Consultants, Inc., 2000)	UAU Unit A	26,738	0.1	668

ARG= Air Refueling Group
LUST= Leaking Underground Storage Tank
UAU= Upper Alluvial Unit
(a)= averaged calculation
SRP= Salt River Project

Overall, the estimates of transmissivity for the UAU range from 15,000 to 60,000 ft^2/day (112,200 to 448,800 gallons per day per foot [gpd/ft]). However, the average estimate of transmissivity is approximately 27,000 ft^2/day (201,960 gpd/ft). Estimates of storativity ranged

from 0.08 up to 0.44. Hydraulic conductivity values in the study area vary from 20 ft/day to 800 ft/day (150 gpd/ft to 5,984 gpd/ft); the representative estimate of the hydraulic conductivity is 200 ft/day (1,496 gpd/ft).

The range of hydraulic conductivity values result from a combination of three factors: complexity of the fluvial system, well screen constructed across differing hydrogeologic units, and unconfined groundwater conditions in Unit A. Within each of the defined hydrogeologic units some variability in hydraulic conductivity is expected. Lateral changes in grain size or the presence of partial cementation can greatly impact the hydraulic conductivity. Because hydraulic conductivity is the resultant taken from the transmissivity value divided by the thickness of the aquifer, it is sensitive to the thickness of the aquifer. Because many wells in the study area were screened across the subunits A, B, C, of the UAU and sometimes into the MFU, aquifer thickness was estimated to be the length of the screened interval. The consequence of this assumption is that the hydraulic conductivity becomes an average over the entire screened interval for the higher conductivity A and C units as well as the lower conductivity B and MFU units. In general, the presence of low conductivity units within the screened interval decreases the estimated value of hydraulic conductivity. Lastly, inaccurately low hydraulic conductivity values may have resulted from declining water levels or local pumping that dewatered a portion of the screened interval and saturated aquifer, shortening the effective saturated thickness. Where data were available, the hydraulic conductivity estimates were corrected for dewatered screen and aquifer.

4.4.3 Depth to Water and Groundwater Gradient

Groundwater generally occurs under unconfined conditions within the UAU. Groundwater flow in the eastern third of the study area (east of 39th Avenue) is generally from the south to north-northwest toward the RID well field located along or north of Lower Buckeye Road between 19th and 35th Avenues. During winter months when the well field is inactive, the gradient shifts to the west-northwest. The groundwater gradient is steepest to the north with values as high as 0.008 ft/ft in the vicinity of 35th Avenue and Lower Buckeye Road. The groundwater flow direction in the western two thirds of the study area (west of 39th Avenue) ranges from northwest to west. The groundwater gradient flattens to the west with values as low as 0.002 ft/ft. Static water level is relatively shallow, ranging from 20 to 50 feet below ground surface (bgs) within the Salt River channel to 60 to 80 feet bgs north and south of the river (URS, 2002).

Fluctuations in static water level can be as much as 20 to 30 feet on an annual basis due to agricultural pumping demands, and have declined as much as 25 feet in the last five years (Dames & Moore, 1991; Parsons Engineering Science, 2001). Hydrographs of selected wells

(Figure 3) show this decline is most pronounced in the eastern portion of the site near the RID wellfield. The selected wells provided static water levels from both ends of the study area that have the most complete water level records. Contributing factors that may cause the fluctuations are water discharge from the 35th Avenue water treatment plant outfall during winter months that produces groundwater mounding, and related radial flow during periods of discharge and basin-wide groundwater pumping and storm water runoff into the Salt River.

A groundwater contour map of the study area was prepared using ADWR well data from 1997 because it represented the most complete data set available (Figure 4). ADWR collected many water levels from both production and monitoring wells in the month of October, at the end of the pumping season. Water levels represent static values prior to significant precipitation. Some data outside of the Study Area were incorporated while contouring to fill data gaps. Values that materially impacted contours (southern Study Area boundary) are represented as elevations without a well symbol. The hydrographs were prepared and reviewed to validate whether the contour map is representative of current conditions. In general the selected wells show a consistent water level decline without radical changes in gradient direction. Therefore, while the groundwater elevation has declined approximately 10 to 20 feet since 1997, the current contours are likely to be similar to the 1997 contours shown in Figure 4.

4.5 GROUNDWATER QUALITY

General groundwater quality data were obtained from databases including the ADWR GWSI database, ADEQ water quality database, and USGS NWIS water quality database. Other data were obtained from SRP, RID, the Phase 2 Report, and COP. The locations of wells with groundwater quality data that were useful for this report are shown on Figure 4. For this evaluation, the most recent data available used ranged from 2001 to as far back as 1983.

The above sources provided limited data for nitrates, volatile organic compounds (VOCs), metals, and pesticides. The majority of these data were below detection levels or detected at concentrations below groundwater quality standards.

The ADWR Well Registry database and Imaged Records database were queried to determine the location (Figure 4), owner, and purpose of monitor wells within the study area. This information was used to identify sites having possible groundwater quality concerns. Further information about sites of particular concern (e.g. landfills, LUST sites, etc.) was obtained from the well owners and ADEQ.

Groundwater conductivity within the study area ranges from about 1,000 to 3,500 micromhos per centimeter (µmhos/cm), which corresponds with an estimated range in TDS of 600 to 2,500 parts per million (ppm). Based on data from wells screened in the UAU and part of the MFU, there is a general trend of increasing conductivity from roughly 1,200 µmhos/cm in the northeast to over 3,000 µmhos/cm in the southwest part of the study area (Figure 5).

In the vicinity of the 23rd Avenue WWTP and the associated effluent outfalls, there are a number of monitor wells screened only in the uppermost part of Subunit A of the UAU. Groundwater from these wells has a relatively low conductivity—approximately 1,000 ±500 µmhos/cm—compared to groundwater from the deeper wells. The lower conductivity may be due to recharge of effluent water from the WWTP, or the upper UAU may have lower conductivity throughout the study area. Additional data from the upper UAU in other parts of the study area would be required to determine which is the case. There was not sufficient data available to distinguish between Subunit A and Subunit C of the UAU.

Nitrate concentrations are generally less than 10 milligrams per liter (mg/L), with the exception of wells located in the southwestern part of the study area where concentrations are as high as 13.8 mg/L (Figure 5). There is no apparent difference in the concentration of nitrate in the shallow wells versus the deeper wells. Quarterly data from the 23rd Avenue WWTP and the 27th Avenue Landfill monitor wells show that the nitrate concentrations can vary by as much as 4 ppm from quarter to quarter. The changes in nitrate concentration do not appear to be seasonal.

4.6 AREAS WITH GROUNDWATER QUALITY CONCERNS

The locations of sites where the groundwater quality may have been impacted are shown on Figure 6. These sites include landfills, wastewater treatment plants, and LUST sites. In addition, the study area is located in proximity of two Water Quality Assurance Revolving Fund (WQARF) or National Priority List (NPL) sites also known as Superfund sites. Groundwater investigations at the sites within the study area were all limited to Subunit A of the UAU. Monitor wells at these sites ranged in depth from 60 to 110 feet. The following sections give brief descriptions of each site.

4.6.1 WQARF/NPL Sites

19th Avenue Landfill

The 19th Avenue Landfill is located adjacent to the east side of the study area on 19th Avenue between Lower Buckeye Road on the north and the Salt River on the south. The landfill was used for disposal of municipal and local industrial waste. Historically very low concentrations of

VOCs, heavy metals, and beta radiation have been detected in groundwater at the site. Remediation activities at this site have been completed and the site is currently in the operations and maintenance phase (ADEQ, 2001).

In 2001, 1,1-Dichloroethylene (1,1-DCE) was the only compound detected above drinking water standards. Moderate concentrations of 1,1-DCE were detected in two wells located in the study area and associated with the 19th Avenue Landfill NPL Site. One of these wells had a concentration exceeding the ADEQ Aquifer Water Quality Standard (AWQS) of 7 micrograms per liter (µg/L). Based on these data and data from wells east of the study area, the likely extent of groundwater with high concentrations of 1,1-DCE was estimated as shown on Figure 6.

West Van Buren WQARF Site

The WVB site is located between Buckeye Road on the south and Van Buren Street on the north and between 7th Avenue on the east and 83rd Avenue on the west. Part of the Oeste Project study area falls within the one-mile buffer zone of the WVB site. This site has elevated concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) (ADEQ, 2001).

The portion of the study area north of the Salt River and east of 51st Avenue is most likely to be impacted by poor groundwater quality from these sites. However, the study area is located up-gradient, so encroachment of poor quality groundwater from these sites is not anticipated.

4.6.2 Landfills

27th Avenue Landfill

The 27th Avenue Landfill was closed in 1995. It is currently used as a waste transfer station. Monitor wells are located along the edges of the landfill to monitor groundwater quality in the vicinity of the landfill. Quarterly sampling data from these wells indicate that there has been no impact to groundwater quality from the landfill and that groundwater quality in the area is good.

SRP Landfill

This site is located on the east side of 67th Avenue, just north of the Salt River (Point 1 on Figure 5). There are five observation wells registered with ADWR (Registration Nos.: 55-517070 through 55-517074) that are located at this site. These wells were drilled in 1987, and the purpose of these wells listed on the Notices of Intent to Drill a Well (NOIs) is to monitor potential groundwater contamination, "Monitoring program to identify the extent and nature of

any groundwater contamination at SRP landfills." No groundwater quality data were available from SRP for these wells. Site closure was obtained from ADEQ in 2000.

4.6.3 Waste Water Treatment Plants

23rd Avenue WWTP

The WWTP is currently active, and effluent water is discharged at the outfall point on the north side of the Salt River near 35th Avenue. There are currently eight monitoring wells surrounding the sludge drying beds and a monitoring well near the outfall point. Groundwater from these wells is sampled and analyzed periodically. The well near the 35th Avenue outfall point is monitored as part of the Aquifer Protection Permit (APP) for the site.

91st Avenue WWTP

The WWTP is currently active and effluent water is discharged to the Salt River and used as a water source for the Tres Rios Project, a riparian habitat restoration project that is located west of 83rd Avenue. Part of the WWTP's field of sludge drying beds is located within the project boundary. Since the WWTP's effluent outfalls are west of the study area and groundwater flow is to the west in the vicinity of the WWTP, the WWTP will likely have little influence on groundwater quality within the study area.

4.6.4 Leaking Underground Storage Tank Sites

Only LUST sites where monitor wells were installed and registered with ADWR are discussed here. Many of these sites have obtained site closure from ADEQ. In general, LUST site closure requires the following criteria:

- Extent of contamination at the release location was adequately investigated both laterally and vertically;
- Depth to groundwater determined;
- Soil contamination in exceedance of ADEQ's cleanup standard(s) was remediated to concentrations below the standards;
- Soil that remains in place is below ADEQ's cleanup standard(s) per R18-7-205; and
- Groundwater concentrations of contaminants have remained at or below the AWQS for a sufficient period of time.

Contaminants that were commonly detected in the groundwater at sites within the study area include benzene, toluene, ethylbenzene, and xylenes (BTEX) as well as total petroleum hydrocarbons (TPH). The AWQS for the BTEX compounds are as follows: benzene, 5 µg/L; toluene, 1,000 µg/L; ethylbenzene, 700 µg/L; and total xylenes, 10,000 µg/L. An AWQS for TPH has not been established.

Based on the above criteria it is possible for detectable concentrations of contaminants to remain in the soil and groundwater after the site has been closed. It is assumed that concentrations of petroleum hydrocarbons will degrade over time due to natural processes.

19th Avenue Landfill (ADEQ Facility ID: 0-003859)

There are two LUST sites (Leak IDs: 2235.01 and 2728.01) associated with the landfill. The actual locations and the impacts to groundwater at these sites are unknown; the ADEQ files for these sites were not available for review at the time this report was written. Both of these sites were closed in 1993.

27th Avenue Landfill (ADEQ Facility ID: 0-003858)

There is one LUST site (Leak ID: 1787.01) associated with the 27th Avenue Landfill (Point 6 on Figure 5). One monitor well was installed to determine if there was any impact to groundwater. There were minor BTEX detections that did not exceed the ADEQ AWQS. The well was abandoned when the site was closed in 1998.

PCE was also detected at a concentration of 0.4 µg/L. It was reported that the analytical results of the groundwater samples from the monitor well were typical of the ambient groundwater quality of the WVB study area.

USF Bestway Transportation (ADEQ Facility ID: 0-005062)

This site, located at 3045 South 43rd Avenue. (Point 3 on Figure 5), had three diesel and one gasoline USTs. ADEQ was notified about leakage from these tanks in 1988 (Leak ID: 0456.01). Nine monitor wells were installed to characterize the nature and extent of the impact to groundwater. Initially 12 inches of free product was measured in one monitor well, and detectable concentrations of BTEX and TPH were present in four of these wells. Concentrations exceeded the ADEQ AWQS for benzene in three wells with a maximum concentration of 420 µg/L. Remedial activities have been performed at the site and concentrations have been lowered to levels required by ADEQ. Site closure has been requested.

Publicker Ind/Masterveiw Window (ADEQ Facility ID: 0-004800)

This site is located at 3065 South 43rd Avenue (Point 4 on Figure 5). In 1991 an incident report was filed with ADEQ documenting a release of petroleum hydrocarbons discovered during removal of the UST (Leak ID: 1864.01). Six monitor wells were installed to evaluate the degree and extent of the impact to groundwater. In one of the monitor wells, 4.4 inches of free product was measured. Detectable concentrations of BTEX were present in five of the six monitor wells. Only benzene was detected at concentrations exceeding the ADEQ AWQS of 5 µg/L with concentrations as high as 520 µg/L. Concentrations of isopropylbenzene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, n-butylbenzene, and naphthalene were detected in five of the monitor wells. These compounds are typical components of unleaded gasoline and are associated with the hydrocarbon release at the site. The site is currently being remediated.

Other compound detections that are not related to the petroleum release at this site include TCE, chloroform, and dichloromethane (methylene chloride). TCE was detected at concentrations as high as 5.7 µg/L. The source and extent of the TCE contamination is unknown; however, it is believed that the source is off-site (Geraghty and Miller, 1997).

Phoenix Transit System (ADEQ Facility ID: 0-003877)

This site is located at 2225 West Lower Buckeye Road (Point 12 on Figure 5). A petroleum release from leaking USTs was reported to ADEQ in 1995 (Leak ID: 3869.01). Six monitor wells were installed to evaluate the impact to groundwater. Approximately 143 gallons of free product had been removed from one of these wells as of July 2, 1996. Free product was not discovered in any of the other wells. No VOCs were detected in the groundwater in any of the wells. Remedial action was taken and the site was closed in 2000.

City of Phoenix Petroleum Stores (ADEQ Facility ID: 0-003854)

This facility located at 2239 West Lower Buckeye Road (Point 10 on Figure 5) is used for fuel and lubricant storage and distribution. Between September 1987 and March 1989 the facility had four incidents of documented product release or inventory loss (Leak ID: 0350.01). Four monitor wells were installed to evaluate the impact to groundwater. Detectable concentrations of TPH, BTEX, and 1,1-DCE were present in all four of the monitor wells. Benzene was detected in one well at concentrations exceeding ADEQ AWQS levels with concentrations up to 39 µg/L. Remedial action was taken to lower the concentration and the site was closed in 1998.

Phoenix Salt River Service Center (ADEQ Facility ID: 0-003864)

This facility located at 3045 South 22nd Avenue is used as a fueling and maintenance facility (Point 11 on Figure 5). At least eleven USTs were removed from the site. Four monitor wells were installed to evaluate the impact to groundwater due to product released from leaking tanks (Leak IDs: 1102.01 through 1102.06). Detectable concentrations of TPH and BTEX were present in all four wells and 1,1-DCE in one well. Benzene was detected in one well at concentrations exceeding the ADEQ AWQS as high as 53µg/L. Remedial action was taken and the site was closed in 1999.

Phoenix Redi-Mix Co Inc (ADEQ Facility ID: 0-004998)

This site is located at 3635 South 43rd Avenue (Point 5 on Figure 5). No groundwater information was found in the available ADEQ files. However, there are two monitor wells at this location registered with ADWR that were reportedly drilled to investigate a UST petroleum release.

Tanner-United Metro (ADEQ Facility ID: 0-004836)

This facility is located at 3640 South 19th Avenue (Point 15 on Figure 5). A diesel fuel release from a UST system was reported in 1988 (Leak ID: 0476.01). The USTs were removed and eight monitor wells were installed to evaluate the impact to groundwater due to the release. As much as 1.6 feet of free product was measured in two of the wells and TPH concentrations up to 11 mg/L were detected in the groundwater from other monitor wells. Remedial action was taken and the site was closed in 1999. Following closure, six of the monitor wells were abandoned. The ADWR records for other monitor wells installed at the site in 1997 indicate that these wells were drilled to monitor potential contamination from a petroleum hydrocarbon constituent released from a former lube pit and oil/water separator. The status of this investigation is not known at this time.

Salt River Recycling/Smithey (ADEQ Facility ID: 0-003031)

This site is located at 3640 South 35th Avenue (Point 14 on Figure 5). One monitor well was installed to determine if there was any impact to groundwater due to leaking USTs (Leak IDs: 4480.01, 4480.02, 4480.03). No detectable concentrations of BTEX or TPH were present. The site was closed in 2000.

Empire Metals Inc. (ADEQ Facility ID: 0-001930)

This site is located at 2010 West Lower Buckeye Road (Point 13 on Figure 5). Two USTs were removed in 1994. Release of hydrocarbons at this site was reported to ADEQ (Leak IDs: 3466.01 and 3466.02). Three monitor wells were installed to evaluate the impact to groundwater. Detectable BTEX concentrations were discovered in all three wells. However, the concentrations were all below the ADEQ AWQS. A request for closure of the site was submitted in 1996. Closure has not yet been granted.

Just Enterprises Inc.

This site is located at 3250 West Broadway Road (Point 7 on Figure 5). One monitor well registered with ADWR (Registration No. 55-586366) was drilled at this site as part of a UST investigation in 2001. No records for this site were found at ADEQ.

Patton Boggs L.L.P.

This site is located on the southeast corner of 43rd Avenue and Lower Buckeye Road (Point 8 on Figure 5). According to ADWR registration records, two monitor wells were installed at this site (Registration Nos. 55-564801 and 55-564802). No other information for this site was found.

5.0 CONCLUSIONS

The primary findings and conclusions of this project are summarized as follows:

- As the Salt River is ephemeral and the average annual rainfall in the area is less than 8 inches per year, it is not possible to collect surface water samples on a regular or routine basis to develop a comprehensive data set for analysis against all the identified surface water quality standards.

- There are numerous sources that impact the surface water quality in and around the Salt River. This impact comes primarily in the form of stormwater run-off, but also includes ungaged agricultural drains. Based on land use, analysis of available numeric data, and field observations compared against narrative surface water quality standards, it is clear the stormwater has the ability to negatively impact stormwater quality by introducing pollutants to the Salt River.

- Groundwater elevations in the study area have declined approximately 15 to 20 feet in the last 25 years; groundwater gradient remains to the west-northwest. The gradient in the eastern end of the site is influenced by heavy groundwater production, which alters the local gradient except during the winter months.

- Overall, the general stratigraphy of the alluvial units is consistent throughout the study area.

- The estimated value of transmissivity for the UAU (Units A_1, A_2, B and C) is 27,000 ft^2/day, and the hydraulic conductivity is estimated to be 200 ft/day.

- Groundwater in the eastern half of the study area has lower TDS relative to other portions of the study area. However, groundwater has been impacted by several petroleum hydrocarbon releases from USTs and may have elevated concentrations of 1,1-DCE.

- Available groundwater quality data indicate that groundwater in the southwestern part of the study area has elevated concentrations of TDS and nitrates.

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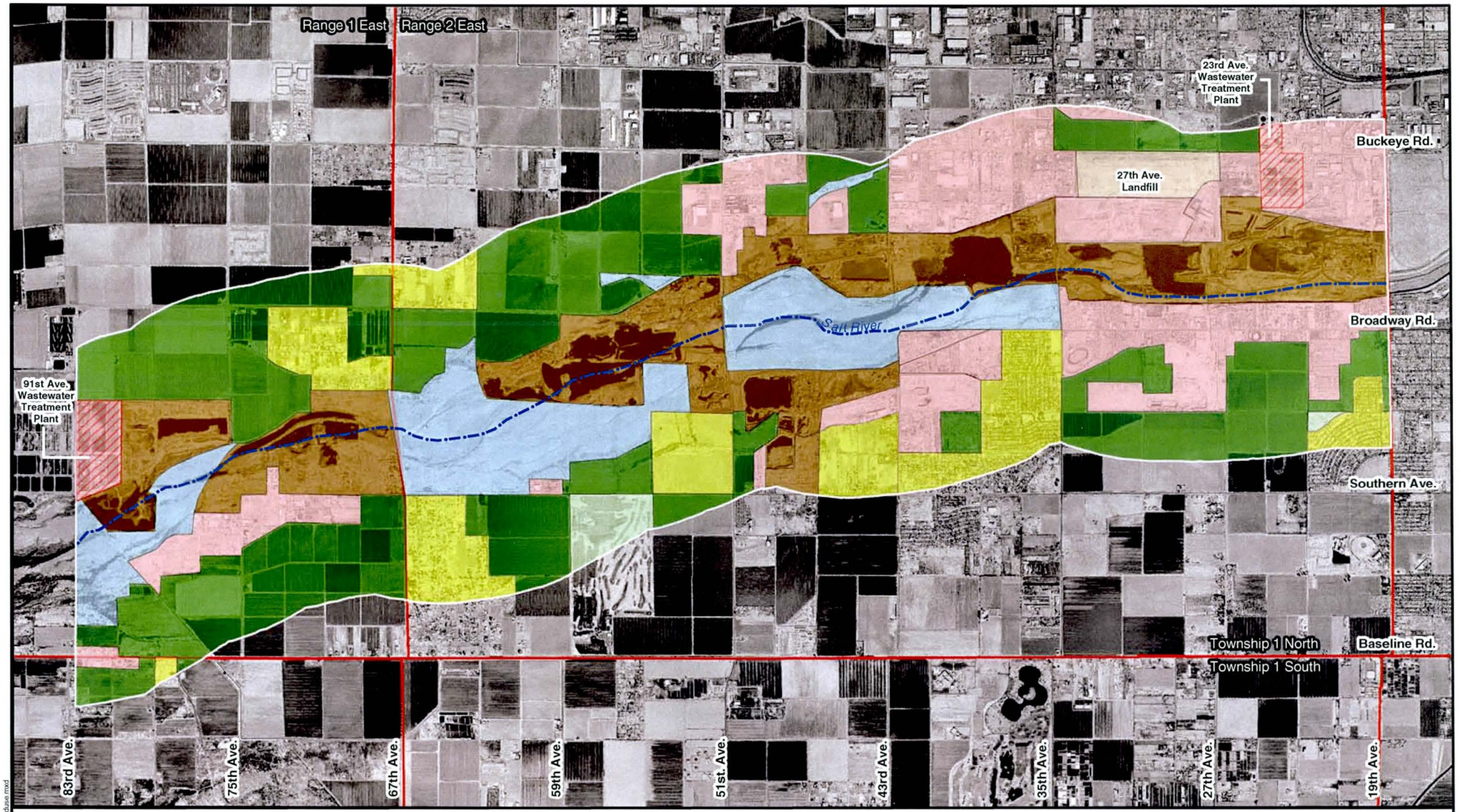
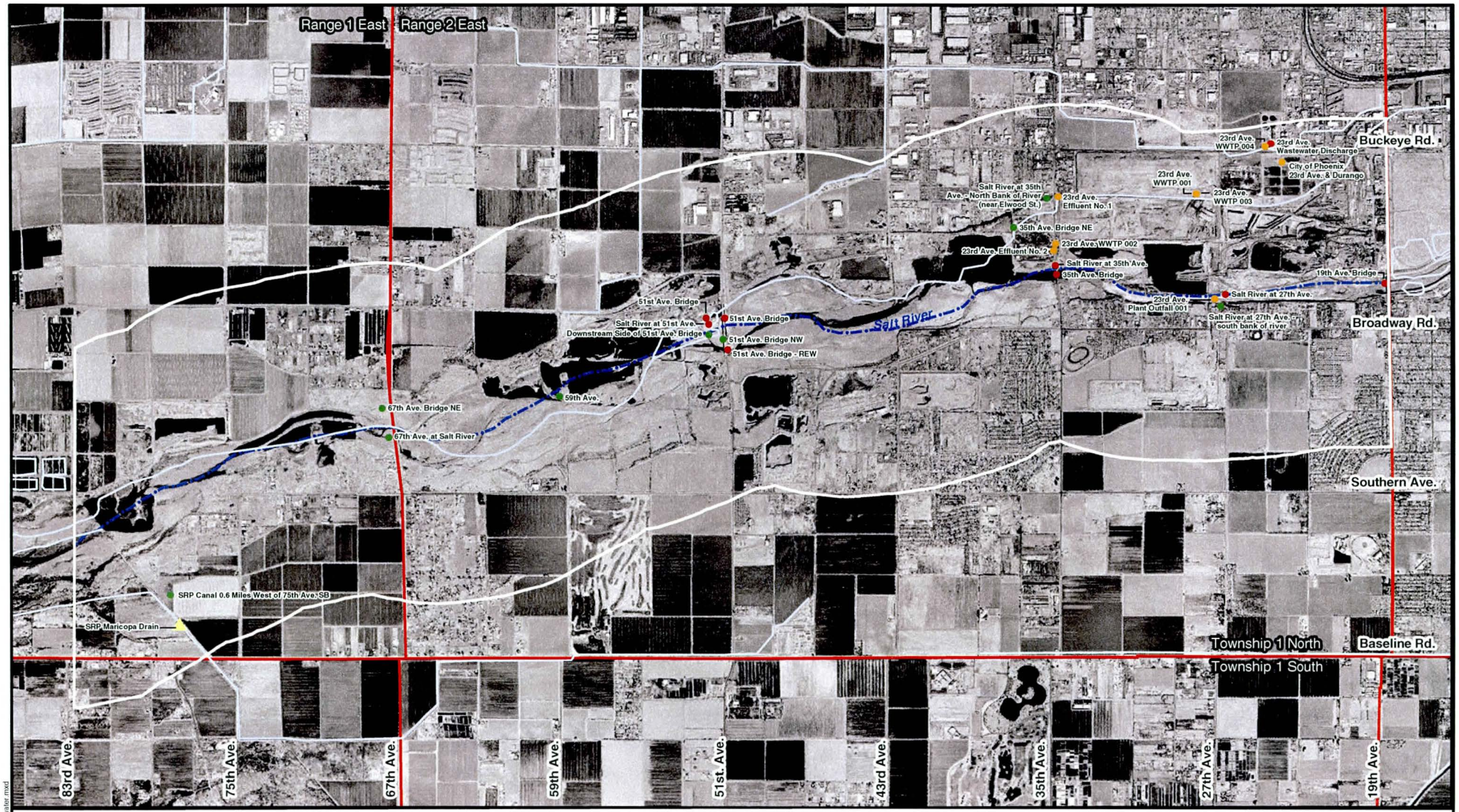
FIGURES



Existing Land Use

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

Figure 1



Legend

- SRP Drain
- Storet Location
- City of Phoenix Stormwater
- City of Phoenix Wastewater Treatment Plant
- Small Streams

0 0.25 0.5 1

Scale In Miles

Map Scale 1:35,000

Image Source:
Kenney Aerial Mapping, 2000

N

Surface Water Features and Sampling Locations

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

Figure 2

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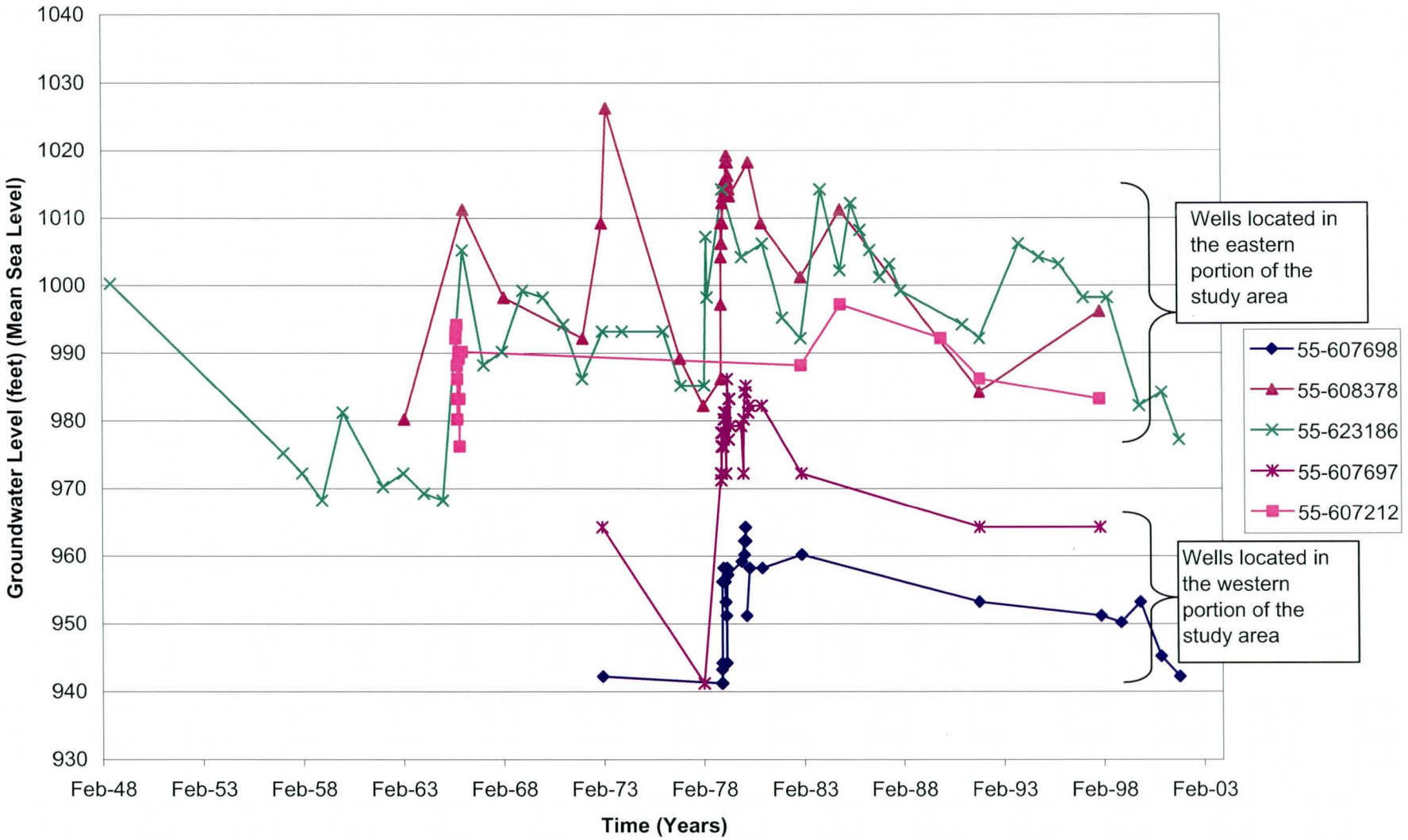
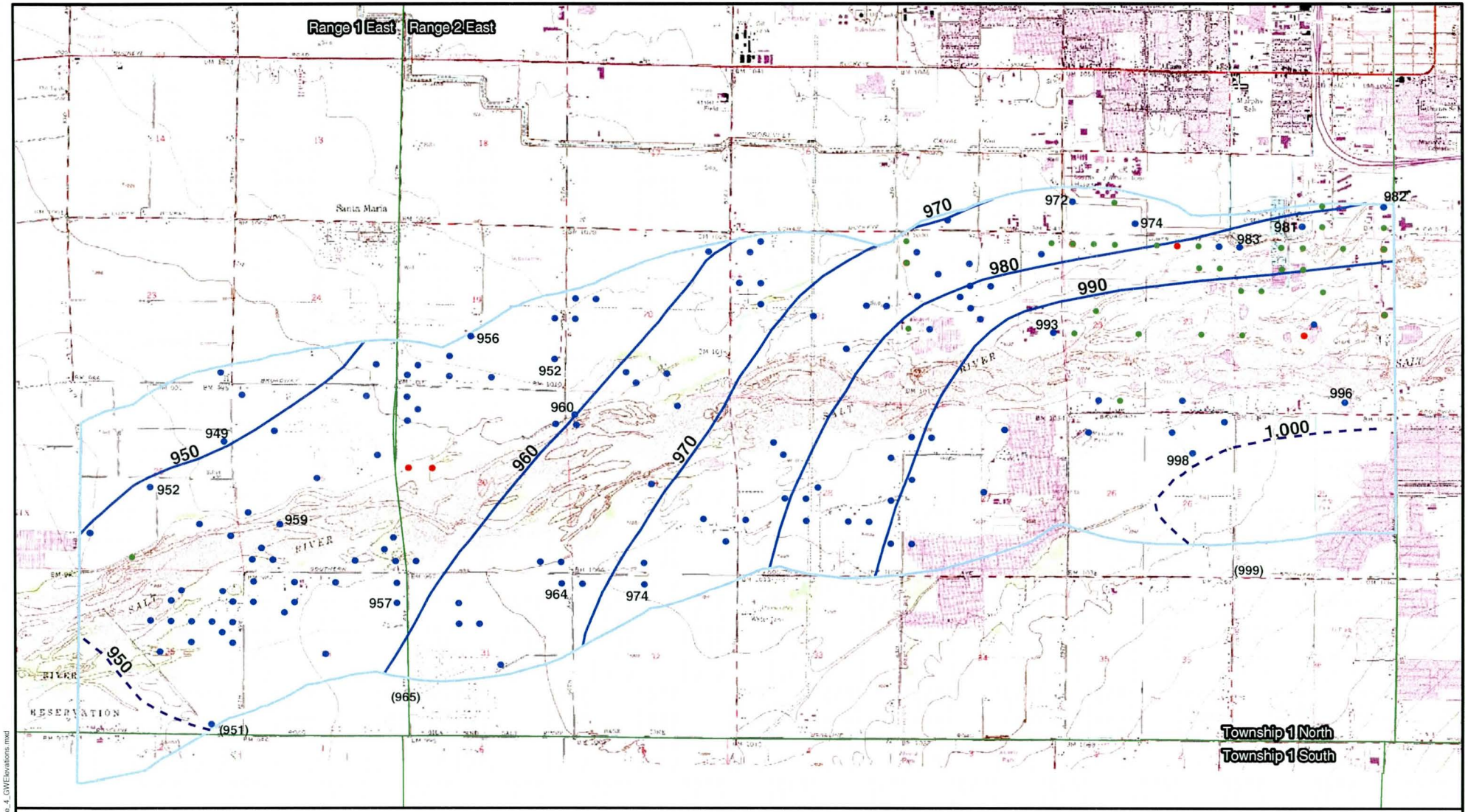
Figure 3
Selected Hydrographs in the Rio Salado Oeste Study Area





Legend

- Rio Salado Oeste Project Boundary
- Groundwater Elevation Contour (Mean Sea Level) (Feet). Contour Interval 10 Feet
- Inferred G.W. Elevation Contour
- Township and Range Lines

ADWR Well Database

- Monitor
- Observation
- Production

(952) - Groundwater Well Elevation (Feet).

Parentheses denote values from wells outside study area used for contouring.

0 0.25 0.5 1

Scale In Miles

Map Scale 1:35,000

Source:
1997 Elevations from ADWR Database 2/27/02,
USGS Topographic Quads: Phoenix and Fowler

1997 Static Groundwater Elevations

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

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Figure 4

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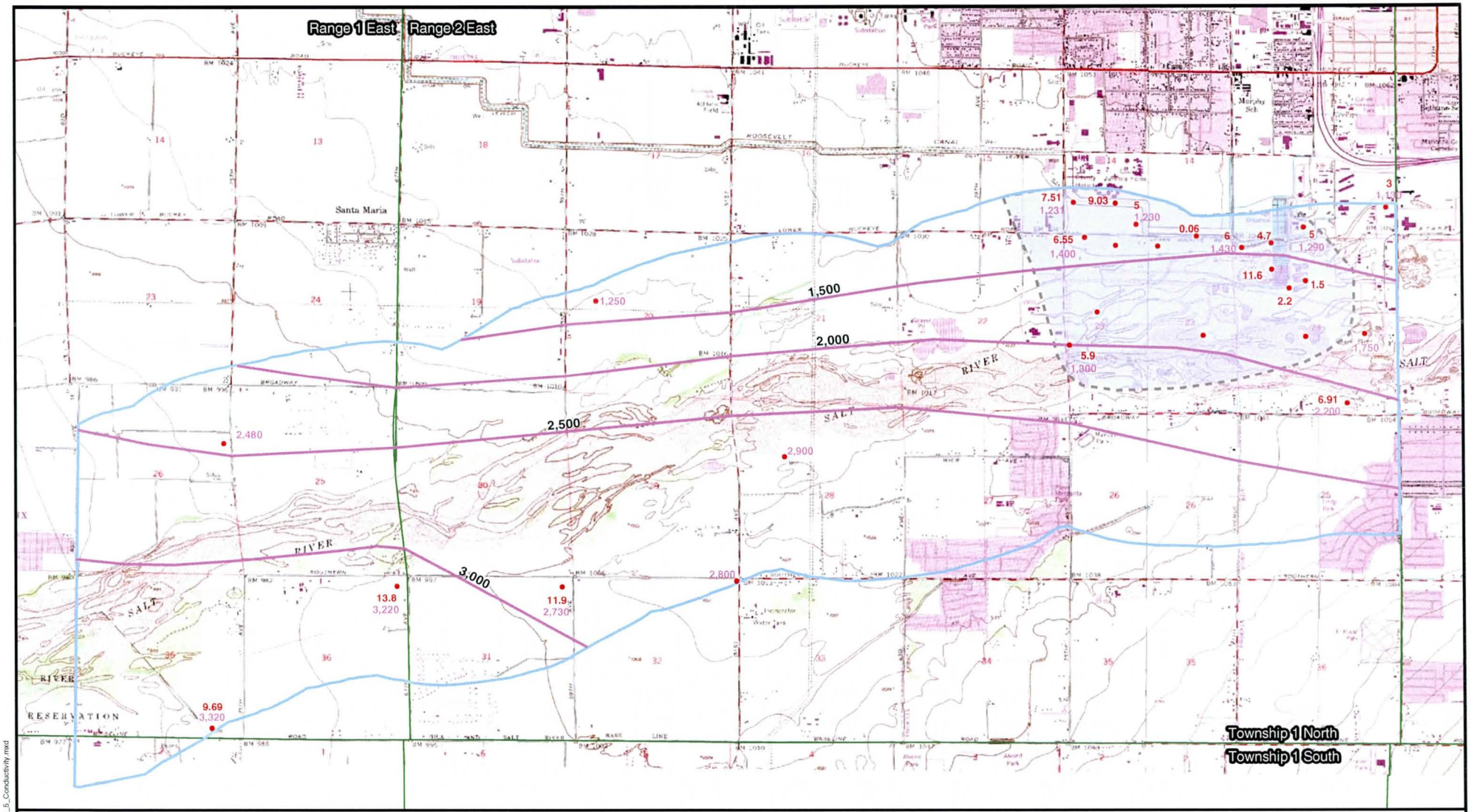

Legend

- Rio Salado Oeste Project Boundary
- Area with lower conductivity in shallow aquifer. (Wells screened in Subunit A of UAU. Values 1,000 +/- 500 umhos/cm)
- Conductivity (Wells screened in UAU and MFU) micromhos per centimeter - (umhos/cm)
- Township and Range Lines
- Wells with available groundwater quality data.
- 6.4 Nitrate concentrations in milligrams per liter (mg/L)
- 2,730 Conductivity (Wells Screened in UAU and MFU) umhos/cm

0 0.25 0.5 1

Scale In Miles

Map Scale 1:35,000

Source:
USGS Topographic Quads: Phoenix and Fowler

Conductivity and Nitrate Concentrations

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

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Figure 5

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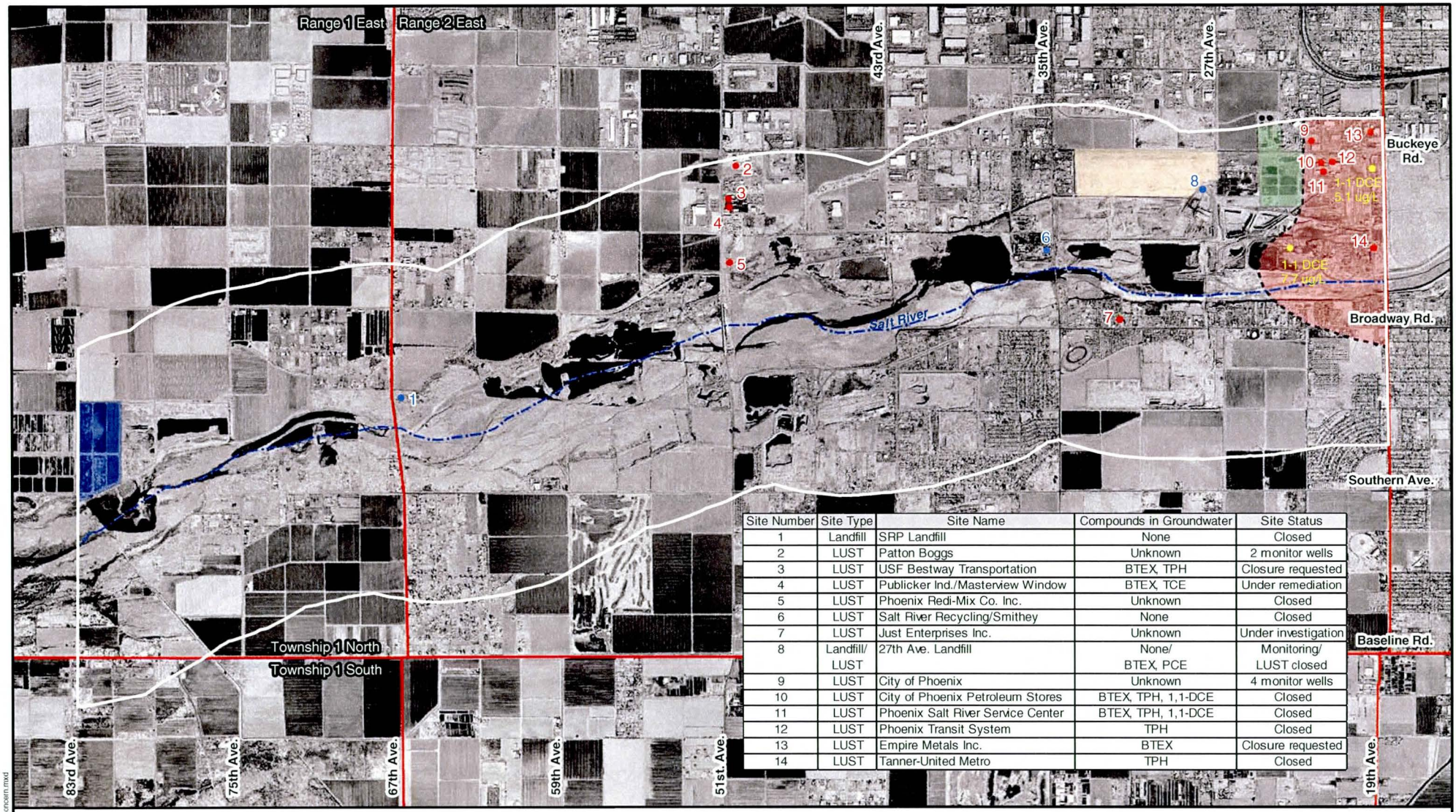

Site Number	Site Type	Site Name	Compounds in Groundwater	Site Status
1	Landfill	SRP Landfill	None	Closed
2	LUST	Patton Boggs	Unknown	2 monitor wells
3	LUST	USF Bestway Transportation	BTEX, TPH	Closure requested
4	LUST	Publicker Ind./Masterview Window	BTEX, TCE	Under remediation
5	LUST	Phoenix Redi-Mix Co. Inc.	Unknown	Closed
6	LUST	Salt River Recycling/Smithey	None	Closed
7	LUST	Just Enterprises Inc.	Unknown	Under investigation
8	Landfill/ LUST	27th Ave. Landfill	None/ BTEX, PCE	Monitoring/ LUST closed
9	LUST	City of Phoenix	Unknown	4 monitor wells
10	LUST	City of Phoenix Petroleum Stores	BTEX, TPH, 1,1-DCE	Closed
11	LUST	Phoenix Salt River Service Center	BTEX, TPH, 1,1-DCE	Closed
12	LUST	Phoenix Transit System	TPH	Closed
13	LUST	Empire Metals Inc.	BTEX	Closure requested
14	LUST	Tanner-United Metro	TPH	Closed

Legend

- 27th Ave. Landfill
- Possible extent of 1, 1- DCE plume
- 23rd Ave. Wastewater Treatment Plant
- 91st Ave. Wastewater Treatment Plant
- Wells with elevated concentrations of 1- 1 DCE
- Sites with known or probable groundwater contamination
- Groundwater investigation sites with no known impacts

0 0.25 0.5 1

Scale In Miles

Map Scale 1:35,000

Image Source:
Kenney Aerial Mapping, 2000

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Sites With Groundwater Concerns

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

Figure 6

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APPENDIX A

WELL INVENTORY REPORTS

AVAILABLE UPON REQUEST

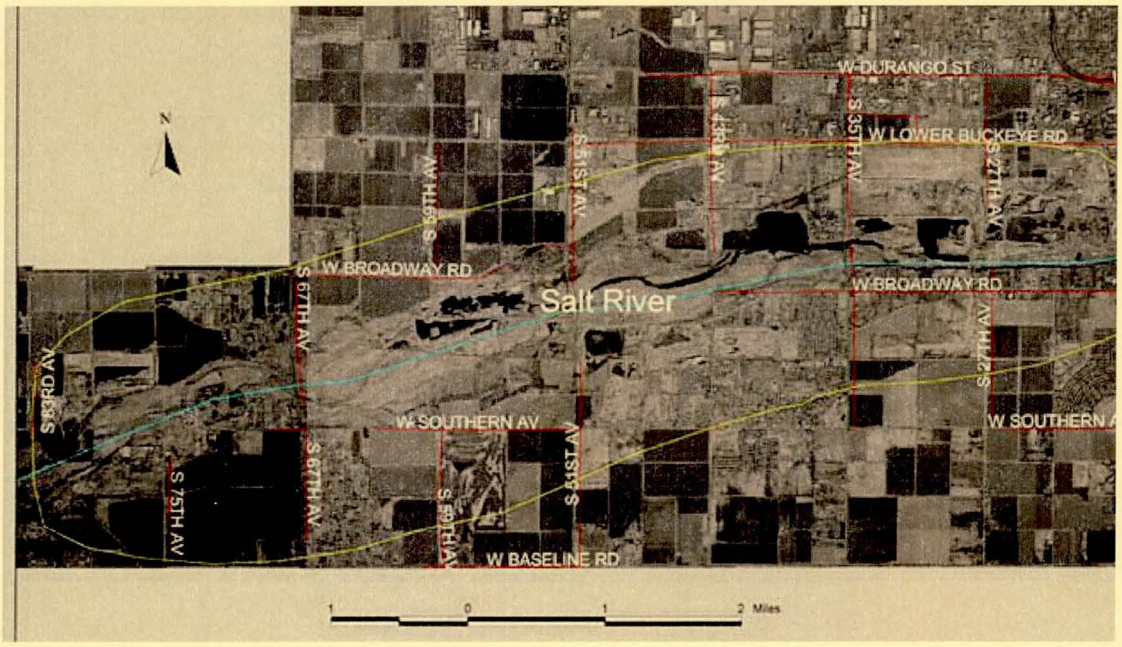
US Army Corps
of Engineers

Rio Salado Project

Oeste Area

Maricopa County, Arizona

APPENDIX E GEOTECH



By

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February 2006

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1.0 Study Purpose. The U.S. Army Corps of Engineers Los Angeles District (USACE LAD) and the City of Phoenix (COP) initiated this study to evaluate the design and construction of a riparian habitat restoration project. The Rio Salado Oeste (Salt River East) site comprises approximately 8 river miles and the Rio Salado Phoenix environmental restoration project area abuts the study area on the east. The project lies primarily within the City of Phoenix, however, portions of Maricopa County, state and federal land is also included. The proposed project construction activities will occur mostly within the river floodplain; however, the study area encompasses overbank areas north and south of the riverbed.

USACE has produced a prior planning document; the Feasibility Study Project Management Plan dated May 2001. This Geotechnical Appendix for the Feasibility F-4 Phase (without project conditions) contains input to the study by the USACE LAD Geotechnical Branch and consists of pertinent literature and website information.

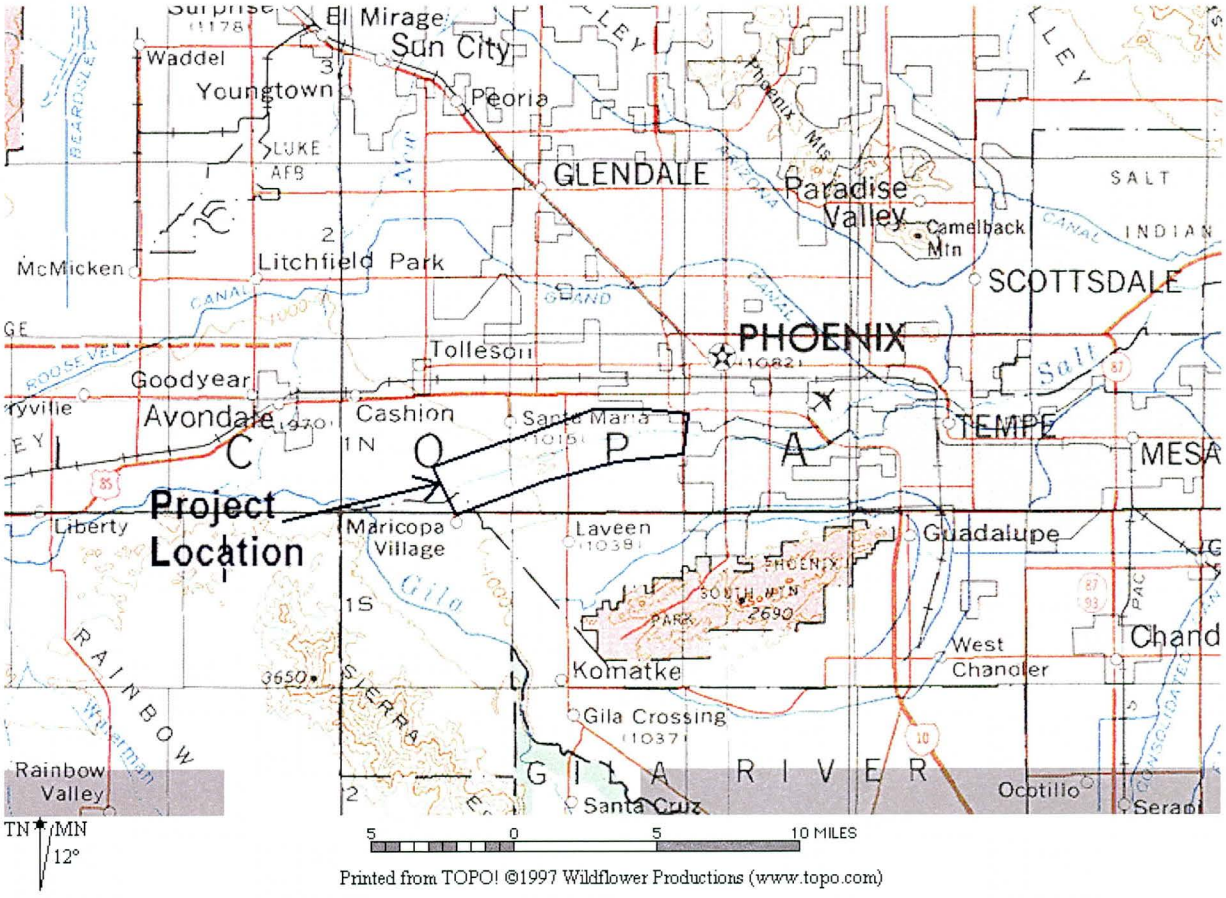

Figure 1. Location of the Rio Salado Oeste study area.

2.0 Description of Study Area. The Rio Salado Oeste study area is located southwest of Phoenix within Maricopa County, Arizona (see Figures 1 and 2). The area is approximately 8 miles long and 2 miles wide, following the centerline of the Salt River, and comprises approximately 10,000 acres. The upstream boundary of the Rio Salado Oeste Study area is 19th Avenue. From there the study area extends southwest to 83rd Avenue. The study area includes river channel and overbank areas. Topographic relief is very low to flat, ranging from about

1050 feet at the upstream (east) end of the area, gently sloping down to about 980 feet at the downstream (west) end (see Figure 2).

The Rio Salado study area is covered by the following topographic map sheets: Phoenix, Arizona 1:250,000 sheet; Phoenix, Ariz. 1:62,500 sheet; and Phoenix and Fowler, Ariz. 1:24,000 sheets.

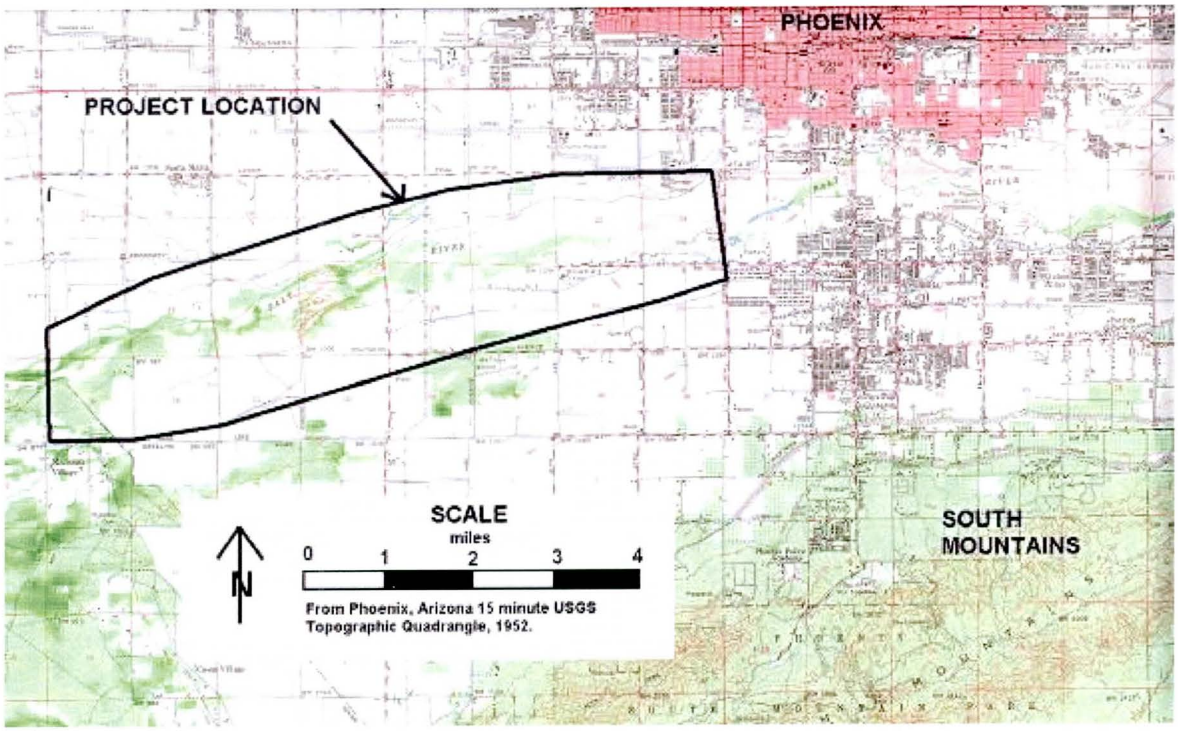

Figure 2. Site Topographic Map.

3.0 Physiography. The Rio Salado Oeste study area lies in the Salt River valley near the center of the Phoenix basin of south-central Arizona, and is geomorphically within the Gila Lowland Section of the Sonoran Desert subprovince, a small portion of the Southern Basin and Range physiographic province. This province is characterized by broad, gently sloping, interconnected alluvial basins bounded by generally northwest-southeast trending mountain ranges.

The Phoenix Basin comprises a series of topographical and structural basins bounded on the north and east by the Bradshaw-Mazatzal-Superstition Mountains, on the west by the Hassayampa River, on the southwest by the Buckeye Hills, and on the south by the Sierra Estrella and South Mountains (Salt River Mountains on some maps) (Péwé, 1978). The Phoenix Basin contains several small ranges, including the Phoenix, South, and White Tank Mountains. Several major rivers pass through the area, including the Rio Salado, Gila, Verde, and Agua Fria Rivers. The Salt River enters the basin on the east side, flowing southwestward to its junction with the south-flowing Verde River near the west edge of the Mazatzal Mountains. From this junction near Mesa, the Salt River flows westward across the broad Salt River Valley to its confluence with the Gila River. The Gila River continues westward along the northern edge of the Buckeye Hills to its confluence with the Hassayampa River where it turns south toward Gila Bend and exits the basin on its way to the Colorado River. The Agua Fria River enters the basin

from the north near the Hieroglyphic Mountains, and flows south to its confluence with the Gila River near the center of the basin, 15 miles west of Phoenix and 7 miles west of the study area.

Elevations range from over 7,000 feet for the highest peaks of the Mazatzal Mountains, 4,500 feet in the Sierra Estrella, and 2,540 feet in the South Mountains, to a low of about 800 feet on the Gila Riverbed where it exits the basin on the southwest. Interbasin ranges range in height from 3,780 feet in the White Tank Mountains to 2,440 feet in the Phoenix Mountains and to 1,750 feet in the Buckeye Hills.

4.0 Regional Geology. The study area lies near the center of the Phoenix Basin of south-central Arizona, within the Southern Basin and Range Province. Broad, gently sloping, interconnected alluvial basins bounded by generally northwest-southeast trending mountain ranges characterize this province. Geologic structure in the area is dominated by block faulting, which produces topography of sharp contrasts, in which isolated, almost parallel mountain ranges rise in stark contrast above low-lying desert plains. In many cases, the basin areas are filled with thousands of feet of sediment and debris eroded from the adjacent mountains. However, some of the basin areas are pediments-erosional surfaces cut into the edges of nearby uplands.

Valley fill has been accumulating since the onset of basin and range tectonism, and reaches up to 9,800 feet thick in the interior of the Phoenix Valley. Numerous low-lying isolated bedrock hills (inselbergs) project above the valley surfaces. These hills represent peaks of former mountain ranges that are now almost completely buried by alluvial material. Valley fill consists mostly of poorly to well-consolidated (cemented) and unconsolidated gravel, sand, silt, and clay, representing several environments and ages of deposition. The valley fills tend to be coarser near the mountain fronts, and finer in the interior of the valley. Calcium carbonate cementation is common, and considerable caliche (cemented soils) is present near the mountain fronts. In the interior of the valley, most of the valley floor is covered by coarse to fine-grained alluvium. This material has been continuously deposited by the shifting channels of streams eroding the mountains.

4.1 Faulting. Geologic structure in the study area is dominated by block faulting attributable to late Tertiary Basin and Range tectonic events. This extensional event began between 13-10 Ma in the southern Basin and Range province, and resulted in formation of most of the present structural basins in southern and central Arizona (Peartree and Scarborough, 1984). Major extension ceased in the area during the late Miocene or Pliocene.

Quaternary-age faulting in Arizona is mostly confined by a northwest-trending belt which bisects the state, separating domains of little or no neotectonic faulting in the northeast (Colorado Plateau Province) and southwest (Southern Basin and Range Province) (Menges, 1984). Historically, the Phoenix area exhibits a very low level of seismicity, and evidence of late Quaternary faulting is sparse (Peartree and Scarborough, 1984). Quaternary faults in southern and central Arizona consistently show evidence of very long recurrence intervals, on the order of 100,000+ years, and displacement rates of <0.03mm/yr (Peartree and Scarborough, 1984). The nearest mapped Quaternary faults are found to the northeast of the study area along the western flanks of the Mazatzal Mountains (Peartree and Scarborough, 1984). These faults are composed of short northeast and north-south segments, the nearest of which is the Carefree Fault 20 miles due north of Mesa and 28 miles northeast of the study area.

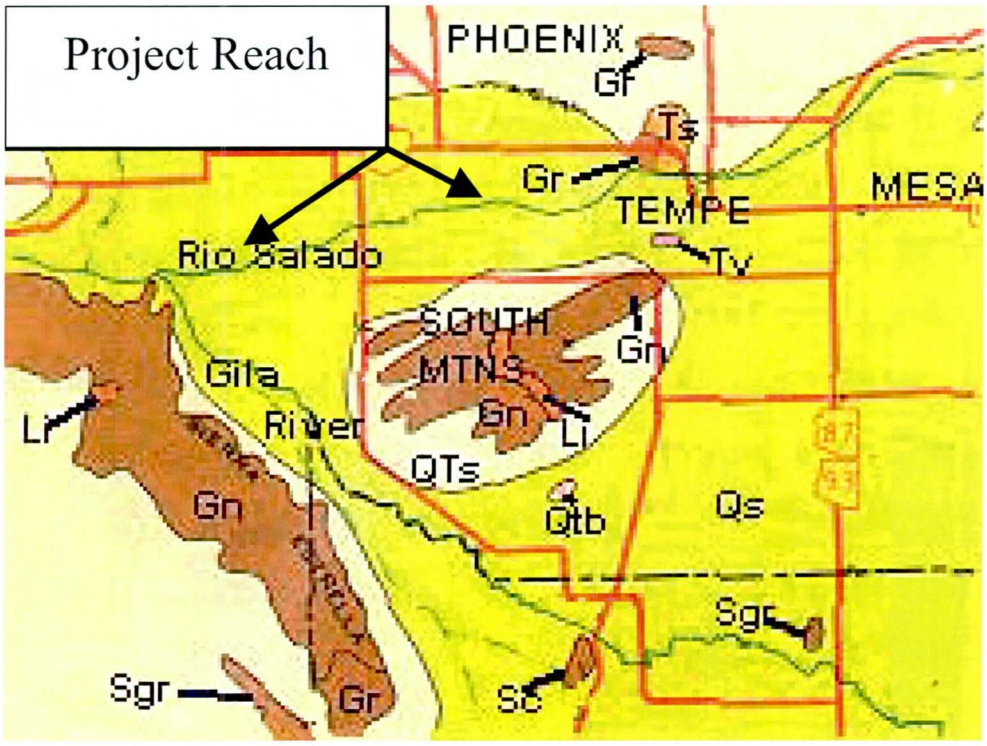

Figure 3. Geologic Map from Arizona Highway Geologic Map, Published by Arizona Geologic Society, 1967.

EXPLANATION		
Map Symbol	**Geologic Time**	**Rock Type**
Qs	Quaternary	Unconsolidated flood plain alluvium.
QTb	Quaternary	Basaltic rocks, cinder cones, dikes and necks. Includes rhyolite and andesite flows and tuffs.
QTs	Quaternary	Weakly to moderately consolidated alluvium, including Gila Group (Gila Conglomerate) in parts of central and southern Arizona. Includes terrace deposits, alluvial fans, and deposits overlying pediments of late Quaternary age. Unconformities are present in the alluvial sequence.
Ts	Middle Tertiary	Sedimentary rocks including the Hement Fanglomerate, Pantano Formation, Whitetail Conglomerate, and Locomotive Fanglomerate in southern Arizona.
Tv	Tertiary	Andesite, rhyolite, latite, dacite flows, welded tuff, and tuff.
Li	Late Cretaceous-Early Tertiary	Intrusive igneous rocks consisting mainly of granite and monzonite, usually porphyritic. Laramide Orogeny.
Gr	Precambrian	Granite.
Sgr	Precambrian	Schist and granite undivided.
Sc	Precambrian	Schist, including Yavapai, Pinal and Vishunu.
Gn	Precambrian	Gneiss.

4.2 Study Area Geology. The geology of the Rio Salado Oeste study is dominated by valley fills and alluvium associated with the Salt River channel. No bedrock outcrops in the project area, however, the South (Salt River) Mountains lie a few miles south of the project and are composed of Precambrian gneiss and late Cretaceous to early Tertiary granite and monzonite (see Figure 3). The surface materials within the Rio Salado Oeste study area are Quaternary age river sediment deposited as alluvium and, to a lesser extent, sheet wash deposited alluvium and slope deposited colluvium. This alluvium thins in the direction of local mountains.

Sand and gravel, moderately well-sorted and stratified, compose the bulk of the deposits left by the Salt River. These deposits consist of well-rounded clasts and are locally interbedded with irregular silt, sand, and clay lenses. The fine sediments are derived from overbank flows. No prominent terraces of the Salt River are present within the limits of the Rios Salado Oeste project. Colluvium is formed of loose to well-cemented silt, sand, clay and gravel. The colluvium and alluvial deposits rest upon bedrock consisting of Tertiary sedimentary and volcanic rocks, as well as the Precambrian basement complex. The depth to bedrock in the project varies from 1200 feet on the east end of the project site to 2200 feet on the west side of the project as shown on the depth to bedrock map in Figure 4 (Corkhill 1993).

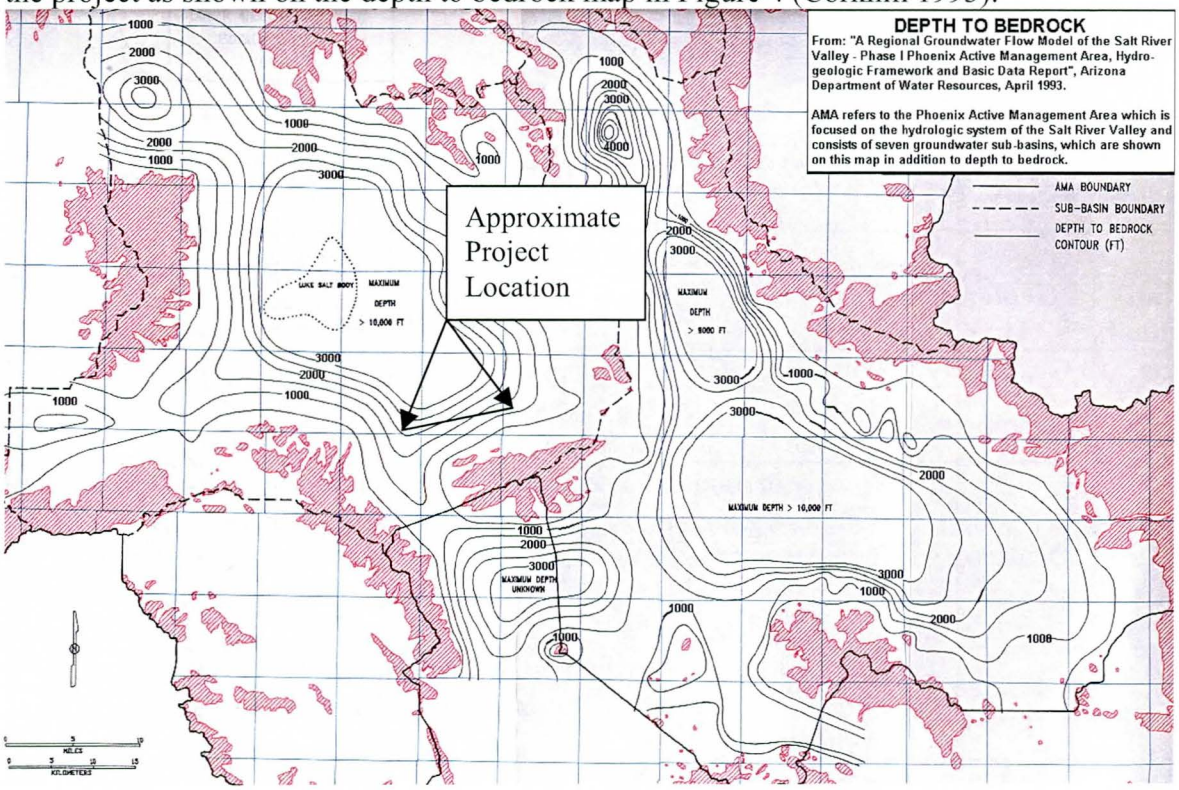

Figure 4. Depth to Bedrock

5.0 Surface and Ground Water. The Salt River in this reach is ephemeral, flowing only in response to local flooding and releases from upstream reservoirs. Downstream from the study area 3 ½ miles, below the confluence between the Gila River and Salt River, the Gila river flows perennially due in part to effluent from wastewater treatment plants.

5.1 Ground Water. In the Salt River valley groundwater occurs within three major and one minor hydrogeological units that are bounded below by impermeable Tertiary and Precambrian

basement rocks (USEPA 1991), and to the south by the Sierra Estrella Mountains which provide a physical boundary to the alluvial aquifer and to groundwater movement. The U.S. Bureau of Reclamation, the U.S. Geological Survey, and the Arizona Department of Water Resources have independently identified the following units, although the descriptions and nomenclature used by these agencies differ slightly:

- Upper Alluvial Unit (UAU),
- Middle Alluvial Unit (MAU),
- Lower Alluvial Unit (LAU), and
- The Red Unit.

The amount of storage and flow within the units varies considerably with area and depth (USEPA 1993). The four hydrogeologic units are derived from Phoenix Basin alluvial materials. The units are described as the following (their age increasing with descending order) (ADWR 1993):

The UAU comprises all alluvial materials at the ground surface, and extends to depths over 500 feet. It varies from 100 feet to 400 feet in thickness under the Salt River, and is thinnest near mountain fronts and bedrock outcrops. The UAU varies in thickness from 250 feet to 300 feet at the project site. This unit was formed during the final stages of alluvial development of the Phoenix Basin, approximately late Pleistocene to recent (Holocene) time. It consists of unconsolidated sand, gravel, cobble and boulders with local thin interlayered beds of clay and silt. The unit is a semi-perched to unconfined aquifer that is both saturated and unsaturated.

The Salt River flows over the UAU and was once the most important source of groundwater recharge for this unit. Water within the UAU is legally referred to as subflow to differentiate it from groundwater in the MAU and LAU. Historically, surface flows from streams and washes provided most water to recharge the UAU. Presently, the minor recharge sources-such as seepage from canals and irrigated land, underflow along major streams, and rainfall-have become more important. Approximately 25% of groundwater withdrawal in the Phoenix basin is from this unit. A very large portion of the groundwater is used for agriculture, while little or none is used for drinking water purposes (Wilson 1991).

The MAU underlies the UAU. At the project site the MAU contact with the LAU varies from 550 feet to 1280 feet below ground surface. The thickness of the unit at this location varies from 300 feet to 1100 feet. The MAU was formed during the middle stages of alluvial development of the Phoenix Basin, approximately late Tertiary to late Pleistocene time. Unit lithology consists of weakly cemented interlayered beds of clay, silt, sand and gravel. This unit is a semi-confined saturated aquifer comprised of more than several discontinuous semi-confining layers that consist predominantly of silt and clay (USEPA 1993). Approximately 50% of the groundwater production in the Phoenix basin is withdrawn from this unit, most of it used for agriculture. A smaller portion of the groundwater is used for drinking water purposes (Wilson 1991).

The LAU underlies the MAU and the depth to the contact between the LAU and bedrock in the project reach varies from 1750 feet to 2380 feet. The thickness of the unit in this area is from 900 feet to 1100 feet. This unit was formed during the early stages of alluvial development of the Phoenix basin, approximately late to middle Tertiary time. Unit lithology consists of weakly

to strongly cemented gravel, boulders, sand, sandy clay, silty sand and interlayered beds of clay. This unit is a semi-confined saturated aquifer comprised of more than several discontinuous semi-confining layers that consist predominantly of clay and mudstone. Approximately 25% of groundwater production in the basin is withdrawn from this unit, the largest portion being used for agriculture. A smaller portion of the groundwater is used for drinking water purposes (Wilson 1991).

The LAU contains a direct or fault contact with the Red Unit at an unknown depth. The Red Unit is included in the LAU and was formed during the earliest stages of alluvial development of the Phoenix basin, approximately late Miocene (Tertiary) time. The Red Unit lithology consists of debris flow materials comprised of reddish well-cemented breccia, conglomerate, sandstone and siltstone rock. The Red Unit is a saturated aquifer and it is not know whether it is confined or unconfined. Aquifer characteristics for the Red Unit are unknown, except that it's groundwater likely originates from within faults and fracture zones within bedrock (ADWR 1993).

Groundwater movement and connection within all three of the upper alluvial units is mostly lateral and somewhat vertical. Vertical groundwater flow occurs through a combination of leakage through all three unit geologic contacts and through water wells that extend vertically across more than one unit.

Before modern development of the Phoenix basin, groundwater flowed toward the Salt River and then westward, generally following the topography of the land surface. Near Tempe and Buckeye, bedrock constrictions bring water to the surface.

The current groundwater conditions are complex and dominated by drawdown from pumping centers and recharge from agricultural irrigation, canals and flood events (ADWR 1993). Long term regional pumping has led to a groundwater divide in the east Phoenix and Tempe area of the basin. Groundwater in the west Salt River valley flows towards two large groundwater depressions. One is north of Glendale (20 miles north of the project) and one is west of Luke Air Force Base (16 miles northwest of the project site). The 1993 ADWR report had a detailed groundwater map from 1983 data that showed groundwater in the project reach flowed toward the northwest. The Groundwater Quality and Hydrogeology Report for the Rio Salado Oeste Project (URS April 2002), which compiles 1997 groundwater data, shows a generally northward trend of groundwater flow in the eastern portion of the study reach from the upstream end of the project until 30th Avenue. Downstream from 30th Avenue groundwater flow ranges from the west to northwest.

5.2 Depth to Groundwater. According to the April 2002 URS report, the average depth to shallow groundwater in the project area ranges from 20 to 50 feet below ground surface in the channel and from 60 to 80 feet below ground surface north and south of the riverbed. Groundwater depths in the immediate study area are best determined by field observations at local gravel pit "lakes", and will be addressed in the design phase of this project.

6.0 Soils. Soils in the study area have been mapped in great detail by the Natural Resources Conservation Service (NRCS) (formerly called the U.S. Soil Conservation Service) on aerial photographs at a scale of 1:20,000 (U.S. Soil Conservation Service, 1974 and 1977). These maps provide a view of soil conditions in and near the river channels in the early 1970's. Since

that time, conditions in the channels have changed in many areas, but the floodplain and terrace soils have remained generally unchanged. The soils in the vicinity of the river channels in the study area are of the hypothermic torrifluvents association, a group of soils that are well-drained to excessively well-drained on nearly level or gently sloping surfaces. The area soils are often sandy to gravelly, may include lenses of finer particles, and are often redistributed by water flows associated with nearby active channels.

7.0 Geologic Hazards. Geologic hazards that were considered in this report are seismicity and subsidence. Hazardous and/or Toxic Wastes (HTW) are considered in the Modified Phase I Environmental Site Assessment Rio Salado Oeste Project.

7.1 Seismicity. Faults in central Arizona are generally short, discontinuous normal faults, some of which displace Quaternary formations. Most of these faults are within the Jerome-Wasatch Structural Zone, a 50-mile-wide band that extends from Utah to Mexico. In Arizona, the zone includes the Main Street Fault in the northwest corner of the state and the Verde Fault about 50 miles north of Tempe. Both of these faults are considered to be potentially active.

Near the study area to the east, a zone (¼ mile wide) of exposed, Tertiary age inactive normal faults, exists immediately north of Tempe Butte gap. The zone trends northwest to southeast, and extends northwestward for a distance of 2.7 miles. An east to west trending (1.1 miles long) Tertiary age fault lies concealed below the alluvium, in the middle of the Salt River, at Tempe Butte Gap, 9 miles east of the upstream end of the study area.

The proposed project is in an area of low seismicity as referenced in Zone 1 of the Seismic Zone Map of the Contiguous States (U.S. Army Corps of Engineers, 1983). About 30 earthquakes with maximum epicentral intensities between II and VI on the Modified Mercalli Intensity Scale (MM) have occurred within a 100-mile radius of the project area from 1870 through 1980 (I-III represent slight shaking, IV-VI represent non-damaging, widely perceptible shaking). The largest of these known earthquakes occurred southeast of Ajo in 1961, northeast of Globe in 1969, and northwest of Prescott in 1976. The 1961 event, 82 miles from the project area, had a Richter magnitude of 4.7. The 1969 event, 95 miles from the project area, had a Richter magnitude between 4.4 and 5.1. The 1976 event, 90 miles from the site, had a Richter magnitude of 5.1.

The largest known earthquake to occur in Arizona was of Richter magnitude 5.7 recorded in 1959 near Fredonia, 240 miles from the project area. The seismic historical record for the last 124 years indicates that only one major damaging earthquake (1887 Sonora, Mexico) has occurred and was located outside the 100-mile radius. This earthquake measured a Richter magnitude of 7.2, and was located more than 255 miles from Tempe, AZ, causing rockfalls (MM VI) in the project area. The most recent (1974) regional events, the "New River earthquakes", located 37 miles northeast of the project area, had recorded Richter magnitudes of 2.5 and 3.0.

Because of the relatively low and infrequent seismic activity in and near the study area, it is not expected that strong earthquake motions will have any effect this project.

7.2 Subsidence. Ground failure in the form of (pumping) subsidence and earth-fissures has occurred in areas of the Phoenix basin. Typically groundwater has declined 100 feet in land subsidence areas. The closest ground failure occurrences to the Rio Salado Oeste area is near

Luke Air Force Base, 12 miles north-northwest from the project area, where 1 to 3 feet of subsidence has been measured.

Available information suggests that subsidence in the project area has not occurred in the past and there is very little potential for subsidence to occur in the future. Therefore, subsidence is not projected to influence design or operation of the Rio Salado Oeste project.

8.0 Sources of Construction Materials. Sand and gravel borrow materials are abundant and currently being utilized in the local area, but are not expected to be needed for this construction. Two stone borrow sites have been identified as sources of construction material and may be available for potential use to a contractor. The two quarries have produced stone for previous Corps flood control projects at the Arizona Diversion Canal and Indian Bend Wash areas. Stone from both locations exhibits a good service record and has previously passed all rock quality compliance tests. The quarries are:

Sun State Rock and Materials Corp.
-located at 115th Ave. and E. Beardsley Rd, Phoenix, AZ
-passed rock 1990 quality tests
-passed 1994 visual inspection
-rock type: granite
877-566-3304

Salt River Sand & Rock Company
-located at Dobson & McKellips Roads, Phoenix, AZ
-passed 1994 rock quality tests
-passed 1994 visual inspection
-rock type: green schist
480-990-1987

A more detailed evaluation of borrow materials and site specific locations (if required for construction) will be conducted by a geotechnical engineer/geologist during the design phase of this project. At that time more will be known about quantities necessary for construction.

9.0 Previous Geotechnical Investigations. A number of geotechnical field investigations in the study area were completed by engineers of the Los Angeles District and private engineering consulting firms. One relevant study was undertaken for the early planning phases of the Rio Salado Oeste project property between 35th Avenue and 51st Avenue, which lies in the center of the Oeste site. Subsurface drilling was conducted on April 9 and 10, 2001 and consisted of four (4) Rotosonic boreholes to a depth of 30 feet. All four boreholes encountered similar sediments, fine to coarse sand and gravel, with minor amounts of clay. The materials logged are described as tan/brown medium to coarse sand and coarse gravel up to 3 inches diameter. Groundwater was not reported in any of the four borings to 30 feet. All the boreholes were sampled throughout their depths and submitted to Speedie and Associates in Phoenix for laboratory grain size analysis (Parkinson, C.L., 2001).

At each surface location similar materials were found, with the addition of abundant cobbles (at least 10 inches diameter) and less clay-size materials. The project geologist personally examined the entire reach of the project area from 35th Avenue to 51st Avenue and concluded that geologic conditions to a depth of 30 feet are likely representative of the sediments encountered in the four borings referred to above. No cemented materials were encountered in these borings or in the adjoining portions of the Salt River where the project is located; therefore caliche will not be an issue during construction.

The Los Angeles District has completed similar Salt River environmental restoration projects in the general area around Phoenix. These include Rio Salado, Tres Rios and Gila River. On the Rio Salado project immediately upstream of Oeste, the same homogenous coarse sand and gravel fluvial deposits exist. There the Los Angeles District has built four (4) RCC grade control structures and thirty-two (32) buried RCC guide dikes. Geotechnical analysis was conducted for foundation conditions in the Planning, Engineering, and Design (PED) phase for that project and will be likewise undertaken during PED on Oeste. The Salt River remains the same meandering channel downstream along the Oeste reach and clearly does not change geomorphically in this short distance. The fluvial processes (floodplain aggradation and channel meandering) remain identical.

Because of the geotechnical knowledge and experience already accumulated by the Corps of Engineers in the immediate Salt River area, the Project Delivery Team (PDT) elected to forgo additional geotechnical exploration expenditures until the PED phase of this project. Additionally, since the geotechnically designed construction features are allocated less than one-percent (1%) of the total project cost, it was purposely decided by the PDT to move forward in the feasibility phase without delay, deferring additional exploration to the PED.

10.0 Design Considerations. The roller compacted concrete mix and details of the liners will be determined during the PED phase. Foundation conditions will be analyzed by several subsurface boreholes and/or trenches to furnish potential contractors with site specific information and water levels relating to construction of the permanent project structures. Existing gravel pits upstream, downstream and within the study area exhibit excellent exposures of the Recent and Holocene stratigraphy to well below the projected project depths. These gravel pits will be revisited in the PED phase of the project.

11.0 Construction Considerations. Conventional construction equipment will be used to construct the project features. The diversion and control of water requirements are minimal due to the ephemeral nature of the Salt River. Dewatering will be required to construct the grade control structure upstream of 35th Avenue. During PED phase the nearby gravel pits will be inspected and correlated with special attention to accurate groundwater levels as they relate to design and construction parameters.

Unknown volumes of waste and trash removal will be need to be addressed in the construction phase, as the banks of the Salt River have served as an uncontrolled trash dump for many years. There is a strong possibility that some of the trash may be identified as hazardous and toxic waste (HTRW) and will require additional testing and analysis before disposition.

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US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Salt River-Phoenix, Arizona

Appendix F

Modified Phase I Environmental
Site Assessment

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
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1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) and the City of Phoenix (the City) have initiated a feasibility study of the Rio Salado Oeste Project area for the purpose of evaluating the design and completion of a riparian habitat restoration project. The project site actually lies within the Salt River between 19th Avenue on the east and 83rd Avenue on the west in Phoenix, Maricopa County, Arizona. However, the north and south study boundaries for this report will be approximately Durango Street and Southern Avenue for the eastern portion, and Broadway Road and Baseline Road for the western portion, respectively. URS was retained by the City of Phoenix to conduct a Modified Phase I Environmental Site Assessment (ESA) for the Rio Salado Oeste Project (the "site" or "subject property"). This Modified Phase I ESA was conducted in accordance with URS' proposal to the City of Phoenix, dated February 4, 2002.

1.1 PURPOSE AND SCOPE OF WORK

Because of the size of the project study area, approximately 20 square miles total, a typical Phase I ESA was not possible. Consequently, a Modified Phase I ESA was decided by the City to be most appropriate for the size of the project. The basic difference being that a site reconnaissance of every property within the project area would not be conducted, or feasible. The Modified Phase I ESA was conducted to review past and current land use practices along the site corridor to identify areas of known or suspected contamination that may environmentally impact the subject property. Due to the size of the project study area and the proposed scope of work, this report will vary slightly from the methods and procedures described in the American Society for Testing and Materials (ASTM) *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process* published September 2000 (Standard Designation E 1527-00).

ASTM Standard E 1527-00 defines a "recognized environmental condition" as the presence or likely presence of hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release into structures, ground, groundwater, or surface water on the subject property. The term includes hazardous substances or petroleum products even under conditions in compliance with laws. The term is not intended to include de minimis conditions that generally do not present a material risk of harm to public health or the environment and that generally would not be the subject of an enforcement action if brought to the attention of appropriate governmental agencies.

This Modified Phase I ESA will focus on a broader aspect than identifying a specific "recognized environmental condition". The tasks completed for this project will identify

properties or areas of potential contamination and discuss steps for identifying recognized environmental conditions associated with each property (i.e. ASTM Phase I ESA, further document review, Phase II Investigation). The conclusions presented in this report are qualified by URS' judgement as low, medium, or high, for the potential of significant environmental contamination to exist in an area (or specific property) and is based on URS' experience in Arizona.

The Modified Phase I ESA was accomplished by, and limited to, a visual reconnaissance of the site from existing right-of-ways and public areas, a drive-by survey of the site corridor (or vicinity), a review of publicly available records (including aerial photographs), and a review of pertinent documentation presently and readily available from the client and/or through URS' standard resources. The report consists of two volumes labeled *Volume I – Report* and *Volume II – Aerial Photographs*. Volume I consists of the main report which includes the narrative description of aerial photographs, review of regulatory databases, findings, conclusions, and recommendations. Volume II consists of copies of all aerial photographs reviewed for the project. The site corridor is defined as the neighboring properties and facilities along the Salt River within an approximate distance of 1-mile north and south of the river's centerline, the nature of which may adversely affect or have affected environmental conditions at the site due to the presence and/or release of hazardous substances or petroleum products to the environment. URS' scope of services for the environmental assessment included the following elements:

X Review aerial photographs and update the portion of the Oeste study area from 17th to 51st Avenue that was originally conducted by URS (formerly Dames & Moore) in August 1998.

X Review aerial photographs for the portion of the Oeste project not previously discussed; 19th to 27th Avenues and 51st to 83rd Avenues. Available aerial photographs will be examined and discussed in narrative form to identify current and previous land use as well as potential sites of environmental contamination.

X Review and interpretation of available archival topographic maps, historical land use maps of the site for information regarding historical site land use that could have involved the manufacture, generation, use, storage and/or disposal of hazardous substances.

X Review of the following state and federal agency lists of known or potential hazardous waste sites, and sites currently under investigation for potential environmental violations as prescribed by ASTM. All databases were extended out approximately 1 mile from the Salt River centerline to include the project corridor study area (or "buffer" area):

Federal NPL site list
Federal CERCLIS list
Federal RCRA CORRACTS TSD facilities list
Federal RCRA non-CORRACTS TSD facilities list
Federal RCRA generators list
Federal ERNS list
State lists of hazardous waste sites identified for investigation or remediation:
State-equivalent NPL
State-equivalent CERCLIS
State landfill and/or solid waste disposal site lists
State leaking UST lists
State registered UST lists

X Review previous environmental reports conducted within or relating to the Oeste study area, including the "Middle Gila River Watershed Management Study Phase 2 GIS Database Update and Functionality Enhancement", prepared by Greeley and Hanson, and the "Environmental Contaminants in Fish and Wildlife of the Lower Gila River, Arizona" report, prepared by the U.S. Fish and Wildlife Service.

X Performance of an onsite visual reconnaissance of the subject property and the area within a 1-mile radius of the Salt River centerline to make visual observations of existing site conditions, activities, and types of land use and businesses within the project corridor area. URS also used this reconnaissance to field verify some of the more predominant identified sites.

X Preparation of a final report describing the research performed and presenting URS' findings and professional opinion regarding properties of potential contamination and a discussion of further steps for identifying recognized environmental conditions associated with areas and/or facilities.

1.2 LIMITING CONDITIONS

It was not the intent of URS to conduct a field reconnaissance of the entire subject property corridor and 1-mile buffer area as part of our scope of work. Our visual site reconnaissance was conducted to help interpret aerial photographs and to verify some of the more environmentally predominant sites in the area. Because URS was not granted Rights-of-Entry for any of the properties, our visual reconnaissance was conducted from right-of-ways and public areas.

1.3 LIMITATIONS OF THE PHASE I ESA

The Modified Phase I Environmental Site Assessment was prepared in accordance with the Scope of Work described in URS' proposal to the City of Phoenix, dated February 4, 2002. The work conducted by URS is limited to the services agreed to in the proposal and no other services beyond those explicitly stated should be inferred or are implied.

The findings and conclusions presented in this report are professional opinions based solely upon URS' visual observations of the site, and upon URS' interpretations of the readily available historical information, and other readily available information, as referenced in the report. These conclusions are intended exclusively for the purpose stated herein, at the site indicated, and for the project indicated.

The information provided by URS is for the exclusive use of City of Phoenix and U.S. Army Corps of Engineers. The scope of services performed during this investigation may not be appropriate for other users, and any use or re-use of this document, or the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

This study was not intended to be a definitive investigation of possible contamination within the subject property corridor and buffer area. The purpose and scope of this investigation was to determine if there is reason to suspect the possibility of contamination from properties or facilities within the site vicinity. No specific site reconnaissance, exploratory borings, soil or groundwater sampling, or laboratory analyses were performed within the subject property corridor or buffer area and, therefore, the conclusions set forth herein are made without the benefit of such investigation.

This report is intended to be used in its entirety. No excerpts may be taken to be representative of the findings of this assessment.

Opinions and recommendations presented in this report apply to site conditions and features as they existed during the course of this project, and those reasonably foreseeable. They cannot necessarily apply to conditions, features, or information of which URS is unaware and has not had the opportunity to evaluate.

2.0 SITE DESCRIPTION

Information concerning the subject property presented in the following subsections is based on a review of readily available published information and a field visit of the general subject property corridor area conducted on March 5, 2002.

2.1 PHYSICAL LOCATION AND DESCRIPTION OF PROPERTY

The Rio Salado Oeste site actually lies within the Salt River between 19th Avenue on the east and 83rd Avenue on the west in Phoenix, Maricopa County, Arizona. For purposes of this study, the north and south boundaries (or "buffer" area) will be approximately Durango Street and Southern Avenue for the eastern portion, and Broadway Road and Baseline Road for the western portion, respectively. The entire subject property is located within the following township, range, and sections of the Gila and Salt River Base Meridian;

Township 1 North, Range 2 East, Sections 13-15 and 19-32.
Township 1 North, Range 1 East, Sections 23-26, 35, and 36.
Township 1 South, Range 1 East, Section 2.

2.2 ENVIRONMENTAL SETTING

Environmental characteristics including topography, geology, and hydrogeology were evaluated based on site observations, published literature, and maps.

2.2.1 Topography

According to the United States Geological Survey (USGS) Phoenix and Fowler, Arizona 7.5-minute topographic quadrangle maps (1952, photorevised 1982), the elevation of the subject property is approximately 1,100 feet above mean sea level in the east and approximately 980 feet in the west. The general direction of surface water flow along the subject property is to the west.

2.2.2 Geology

The site is located in the Salt River Valley. The Salt River Valley is a broad alluvial basin within the Basin and Range physiographic province. The basin is almost completely surrounded by mountains composed primarily of granitic, metamorphic, and volcanic rocks and minor amounts of consolidated sedimentary rocks. The valley floor is underlain by unconsolidated to semiconsolidated basin-fill sediments. In the eastern part of the Salt River Valley area, sedimentary deposits form the main water-bearing units and consist mainly of unconsolidated and weakly consolidated clay, silt, sand, and gravel. The main water-bearing unit ranges in thickness from a few tens of feet near the mountains to more than 1,200 feet in the central part of the area (Cooley, 1973).

2.2.3 Hydrology

According to B.A. Hammett and R.L. Herther's *Maps Showing Groundwater Conditions in the Phoenix Active Management Area, Maricopa, Pinal and Yavapai Counties, Arizona - 1992,* and based on information obtained for this report, the general depth to groundwater in the area of the subject property is approximately 60-70 feet below ground surface. Although certain areas of the eastern portion of the subject property do experience heavy pumping activity 8 months out of the year, the overall general direction of groundwater flow in the vicinity of the subject property appears to be to the west.

Because the subject property is located in and along the Salt River, it is expected that it would be located within the boundaries of a 100-year floodplain. Consequently, the subject property is depicted within a 100-year floodplain according to the following Flood Insurance Rate Map Nos.; 04013C2115-E, 04013C2120-E, and 04013C2140-E, all dated July 19, 2001, published by the Federal Emergency Management Agency (FEMA).

2.2.4 Soils

URS reviewed readily available reference material providing soil types for Maricopa County. According to the U.S. Department of Agriculture Soil Conservation Service, naturally occurring on-site surface soil consists primarily of Carrizo and Brios soil in the Carrizo Series (USDA, 1977). These soils are in or adjacent to channels of the Salt River. It is bisected by small stream channels and old meander cutoffs. Once every 5 to 20 years the lower lying areas are flooded. Flooding changes the soil material and occasionally the course of the main channel. Generally this mapping unit is typically a combination of Carrizo, Brios, and Vint soils. The Carrizo soil is usually in the lowest position nearest the stream channel, the Vint soil along the outer rim, the Brios soil in the intermediate position.

The engineering classifications of the soils are also found in the USDA 1977 publication. The Brios soil is classified as a sand and very gravelly sand (SP). The Carrizo soil is classified as a very gravelly coarse sand (SW-SM) to a very coarse sandy gravel (GW-GM). The Vint soil is classified as a loamy fine sand (SM).

3.0 SITE RECONNAISSANCE

URS conducted a preliminary site reconnaissance at the commencement of this project to become familiarized with the type of properties associated with the project study area. URS traversed the major (and some of the minor) streets and roads along the north and south sides of the Salt River from 19th Avenue to 83rd Avenue. The intent of this reconnaissance was not to

observe specific properties or features, but rather to gain insight into the general existing conditions and types of properties within the project study area.

3.1 GENERAL CONDITIONS

URS viewed the project study area to observe and understand basic land use within the following seven categories; Residential, Commercial/Industrial, Landfill, Sand/Gravel Operation, Agricultural, Recreational (i.e. public parks), and River Bottom/Native (see Figure 1). To remain consistent with our historical aerial photograph review of land use, the project study area was divided into four separate portions of land; 19th - 35th Avenue, 35th - 51st Avenue, 51st - 67th Avenue, and 67th - 83rd Avenue. The following is a brief summary of general land use activities based on existing data and a preliminary reconnaissance of the project area (as shown on Figure 1 at the end of this report).

19th Avenue - 35th Avenue

Sand and gravel operations line the Salt River with no remaining native river bottom. Commercial/industrial properties flourish in this area both north and south of the river. The 27th Avenue Landfill lies north of the river bottom in an area almost surrounded by commercial/industrial properties. Only a small portion of land is occupied by residential and/or agricultural land. The following percentages are estimated for land use categories within this portion of the project study area; Residential - 3%, Commercial/Industrial – 43%, Landfill - 6, Sand/Gravel Operation - 22%, Agricultural - 26%, Recreational - 0.5%, and River Bottom/Native - 0%.

35th Avenue - 51st Avenue

Major sand and gravel operations exist in and along the Salt River with almost half the river remaining native. Large areas of commercial/industrial properties exist primarily on the north side of the river, leaving more residential properties to the south of the river. Agricultural properties are fairly sparse. The following percentages are estimated for land use categories within this portion of the project study area; Residential - 16%, Commercial/Industrial - 31%, Landfill - 0%, Sand/Gravel Operation - 26%, Agricultural - 8%, Recreational - 0%, and River Bottom/Native - 19%.

51st Avenue - 67th Avenue

Sand and gravel operations remain in and along a large portion of the Salt River with almost half the river remaining native. Almost no commercial/industrial properties exist. Although there are small pockets of residential land north and south of the river, the majority of land is still used for

agricultural purposes. The following percentages are estimated for land use categories within this portion of the project study area; Residential - 17%, Commercial/Industrial - 2%, Landfill - 0%, Sand/Gravel Operation - 17%, Agricultural - 38%, Recreational - 4%, and River Bottom/Native - 22%.

67th Avenue - 83rd Avenue

Sand and gravel operations continue to exist in and along some areas of the Salt River with a small portion remaining native. Few commercial/industrial properties exist. However, some do lie along the southern bank of the river. Although there is a small pocket of residential land north of the river, the majority of land is still used for agricultural purposes. The following percentages are estimated for land use categories within this portion of the project study area; Residential – 7 percent, Commercial/Industrial – 12 percent, Landfill – 0 percent, Sand/Gravel Operation – 23 percent, Agricultural – 49 percent, Recreational – 0 percent, and River Bottom/Native – 9 percent.

4.0 HISTORICAL AERIAL PHOTOGRAPH REVIEW

URS conducted a review of available aerial photographs to discuss and describe changes in land use within the project study area. Because of the quality and extensive coverage available at Landiscor Aerial Photography, URS concentrated our review efforts there. The review of aerial photographs included the entire project study area from 19th Avenue (on the east) to 83rd Avenue (on the west) with north and south boundaries of approximately Durango Street and Southern Avenue (for the eastern portion) and Broadway Road and Baseline Road (for the western portion), respectively. Available aerial photographs examined and discussed herein consisted of 1962 to 2002 and are contained in Volume II of this report. URS has included approximately every other year starting with 1962 and continuing until 2002. Additionally, for ease of viewing the included photographs, URS has included an overlay approximately every ten years. Because of scaling difficulties encountered by the laboratory, the overlays may have to be realigned for proper boundary placement in order to view each subsequent photograph.

The aerial photograph review consisted of viewing a photograph and then comparing it to the next available photograph in chronological sequence. Notations were made regarding changes in land use similar to the seven categories previously discussed. Specific industrial activity or land use was noted when it could be confidently identified (i.e. salvage yard, landfill, etc.) although many of the commercial/industrial activities were left unidentified (i.e. industrial complex). Because of the expanse of area covered by this project, it was not feasible to identify and record every single development or change in property that occurred. Consequently, general statements

may be made for some properties or areas that may not specifically coincide with the exact year of a photograph.

URS compiled the information according to the year of the photograph and its location within the project study area. Because of the overall size of the study area, URS divided the area into four separate portions of land consisting of approximately two miles long each; 19th - 35th Avenue, 35th - 51st Avenue, 51st - 67th Avenue, and 67th - 83rd Avenue. Within each two-mile portion of land, the area was then subdivided into quarter sections as described in the City of Phoenix Quarter Section Index Map. Basically, any given Section (1-mile square) within a Township and Range location can be divided into four quarter-sections with each of these quarter-sections already assigned a specific number (i.e. the four numbers assigned to Section 26 of Township 1 North, Range 2 East are 3-9, 3-10, 4-9, and 4-10). For discussion purposes in the narrative descriptions below, the word "quarter-section" will be denoted as QS.

19th Avenue to 35th Avenue (inclusive of Township 1 North, Range 2 East, Sections 13, 14, 23-26)

3-21 (North half of QS only); The land has been utilized primarily for agricultural purposes from 1962-2002.

3-22 (North half of QS only); The land has been utilized primarily for agricultural purposes from 1962-2002.

3-23 (North half of QS only); The land has been utilized primarily for agricultural purposes from 1962-2002.

3-24 (North half of QS only); The land has been utilized primarily for residential purposes from 1962-2002.

4-21; A racetrack (currently Manzanita Speedway) has been visible in the northwest corner of the QS from 1962-2002. Additionally, a small commercial facility has also been visible on the corner of Broadway Road and 35th Avenue from 1962-2002. Auto salvage yards begin appearing in the northeast quarter of the QS in the early-1970s and greatly expand throughout the 1970s, 1980s, and 1990s while remaining visible in 2002. The southern half of the QS is utilized for agricultural purposes from 1962-2002 with sand/gravel removal/operations occurring in the southeast corner from 1998-2002.

4-22; The land is utilized primarily for agricultural purposes with auto salvage yards along the northern edge (Broadway Road) of the QS from 1962 to the early-1980s. By the mid-1980s, some of the agricultural land has gone fallow with sand and gravel removal occurring in the

southern half of the QS. By the early-1990s, the QS has become entirely occupied by sand/gravel removal, auto salvage yards (along the northern edge), and areas of fallow agricultural land.

4-23; From 1962 to 1974, the QS is utilized for agricultural purposes. In 1976, the QS remains agricultural with two small commercial-type facilities now visible along Broadway Road. Through the remainder of the 1970s and 1980s, the northern portion of the QS expands with more commercial-type facilities and salvage yards while the remainder of the QS continues as agricultural up to 2002. However, an oval-shaped depression is visible in the southeast corner of the QS from 1982 to 2002 and appears to possibly be used as a dump with only a single structure visible.

4-24; The QS is primarily utilized for agricultural and residential purposes from 1962 to 1976. In 1978, several auto salvage yards begin to appear in the northwest quarter of the QS and expand further south up until 2002. Some remaining agricultural land is still visible but has slowly turned fallow through the years.

5-21; In 1962, the QS contained light industrial storage in the western quarter section and small sand/gravel pits in the southern half of the QS. In 1964, an industrial building along 35th Avenue was noted. An auto salvage yard was identified on 35th Avenue in 1966 until it was destroyed by flooding sometime in 1968. In the early-1970s, an auto salvage yard was identified on the north side of Broadway Road with interspersed small sand/gravel pits. By 1975, the salvage yard had expanded covering the older gravel pits. Throughout the 1980s and 1990s, the salvage yards continued operation in the south half of the QS as small sand/gravel pits were noted in the northern half.

5-22; North half of QS; Sand/gravel removal/operations seem quite prevalent throughout most of the river bottom from 1962 to 1996. By 1998, a large portion of these operations were flooded by water with continued sand/gravel removal occurring immediately surrounding the flooded areas through 2002.

South half of QS; Commercial-type facilities (auto salvage yards) line the southern edge of the QS along Broadway Road from 1962 to 2002.

5-23; North portion of QS; Although some minor sand/gravel removal occurred in the river bottom in the northern portion of the QS in the 1970s (with subsequent flooding in the early-1980s), a large expanse of sand/gravel removal occurred in the QS and in the entire area in the late-1980s, before being once again flooded through the 1990s. By 2000, the northern portion of the QS was utilized primarily as roads leading to nearby sand/gravel pits.

South portion of QS; Commercial/light industrial facilities line Broadway Road from 1962 to the mid-1970s. By 1978, it became apparent that most of the properties were now auto salvage yards that have remained along the bottom one-third of the QS to 2002.

5-24; Extensive sand/gravel removal/operations occurring in the northern half of the QS from 1962 to 2002. Based on the equipment/machinery observed in the photographs, there is likely a cement batch plant on-site also.

Commercial/light industrial/storage yard-type facilities along Broadway Road are visible in 1962 and appear to increase and expand with auto salvage yards in the early-1970s. By the mid-1980s, the salvage yards dramatically increase with junk that remains visible to 2002. One of the facilities located in the southeast corner of the QS constructs a larger building by 1994 which remains visible to 2002.

6-21; North half of QS; Land is utilized primarily for agricultural purposes from 1962 to 1974. By 1976, sand/gravel removal of the north half of the QS was visible for the initial stages of the 27th Avenue Landfill. By 1982, landfill activity began while an auto salvage yard was noted in the northwest corner of the QS with additional industrial properties visible along the western edge. By the early-1990s, the landfill appeared to be capped while industrial facilities and the auto salvage yard remained active along the western edge of the QS through 2002.

South half of QS; The south half of the QS consists of a large (effluent) recharge basin from the 27th Avenue Wastewater Treatment Plant (located to the northeast). The basin appears wet and dry throughout the years from 1962 to the mid-1980s. It then appears to remain (dry) dormant through 2002.

6-22; North half of QS; Land is used in part for agricultural purposes with a portion appearing as native river bottom from 1962 to 1974. By 1976, sand/gravel removal of the north half of the QS was visible for the initial stages of the 27th Avenue Landfill. By 1982, landfill activity was visible and by the early-1990s, the landfill appeared to be capped.

South half of QS; The south half of the QS consists of a large (effluent) recharge basin from the 27th Avenue Wastewater Treatment Plant (located to the northeast). The basin appears wet and dry throughout the years from 1962 to the mid-1980s. It then appears to remain (dry) dormant through 2002. However, a large industrial facility was visible in the southeast corner of the QS from 1993 to 2002.

6-23; North half of QS; Wastewater treatment ponds associated with the (adjacent) 27th Avenue Wastewater Treatment plant are visible in the north-central and northeast corner of the QS from

1962 to 2002. The northwest corner of the QS consists of sand/gravel removal activities in the 1960s before turning into a disorganized-type property with numerous buildings and heavily stained soil visible from 1970 to 2002.

South half of QS; The south half of the QS consists basically of native river bottom with two man-made drainage channels visible in the 1960s and 1970s; one leading from the wastewater treatment pond area and one leading from an adjacent (QS 6-24) storage lot and facility first visible in the 1960s. A road is later visible in the mid-1970s transecting one of the drainage channels. Large sand/gravel pits are prevalent in the 1980s and 1990s as one of the drainage channels still appears visible in 2002.

6-24; The starting point of a man-made drainage channel is located in the western portion of this QS and remains visible from 1962 to 2002. In 1962, the following additional observations were made; several yards (auto salvage, construction, industrial) are located along the eastern portion of the QS (west side of 19th Avenue), sand/gravel removal is occurring along the western half of the QS, and a storage area for trailers is noted in the center of the QS.

By 1966, the sand/gravel operations were replaced by a new facility in the northwest quarter of the QS, while the northeast quarter has expanded with a larger storage yard and more structures. However, sand/gravel operations now expand into the southeast corner of the QS.

By 1972, the entire east portion of the QS is filled with various facilities and yards, including one near the center that stretches ¼-mile from north to south. By 1978, the ¼-mile long facility yard now stretches west.

In 1982, a new (large) building is visible in the north-central portion and the entire QS is filled with numerous commercial/industrial facilities, yards, and buildings. Sand/gravel removal continues to occur along the southern edge of the QS while the remainder of the QS continues with ongoing industrial activities through 2002.

7-21 (South half of QS only); The land has been utilized primarily for agricultural purposes from 1962-2000. By 2002, three large facilities were visible in the southeast quarter of the QS with continued construction/development occurring in the south-central portion and agricultural land remaining in the southwest portion of the QS.

7-22; (South half of QS only); Land primarily utilized for agricultural purposes from 1962 to 1996, then becoming fallow between 1998 to 2000 and finally appearing graded in the 2002 photograph.

7-23; (South half of QS only); The west half of the QS is utilized for agricultural purposes from 1962 to 2002. The east half of this QS contains a large wastewater treatment plant with numerous ponds, buildings, and structures (including aboveground storage tanks) visible from 1962 to 2002. Although the lay-out and design of the ponds have changed throughout the years, the wastewater treatment plant has occupied the east half of this QS from 1962 to 2002.

7-24; (South half of QS only); Although some farm-type homes/properties existed in the northeast corner of the south half, the area appeared somewhat industrial in nature beginning in the 1960s, containing several large buildings and a portion of the wastewater treatment plant facilities along the western edge of the QS. By the late-1970s, the western portion contained more paved-type of facilities, whereas the eastern portion contained open-ground properties with dark soil staining, which remained visible into the late-1990s. By 2000, several facilities occupied the QS with large areas now covered by paved parking lots and unpaved storage yards.

35th Avenue to 51st Avenue (inclusive of Township 1 North, Range 2 East, Sections 15, 21, 22, 27, and 28)

3-17; Land is primarily utilized for agricultural purposes from 1962 to 1980. In 1982, commercial activity appears to begin along the western half of the QS. By 1994, a large portion of the agricultural land becomes fallow and by the late-1990s, is used for sand/gravel removal.

3-18; The land is a mixture of agricultural land and residential properties from 1962 to the late-1970s. Some of the properties then become commercial. By the late-1980s a mixture of agricultural land, residential and commercial properties are prevalent, especially in the northeast corner and along the southern edge of the QS. The northern tip of the QS contains a portion of an industrial facility (elongated buildings) from 1982 to 2002.

3-19; (North half of QS); The land is utilized primarily for agricultural purposes in to the late-1960s until residential homes begin development in the early-1970s. By the mid-1980s, some commercial development is visible and by the mid-1990s, the entire northwest quarter of the QS appears to be commercial. Conversely, the northeast quarter of the QS turns fallow and remains this way into 2002.

(South half of QS); From 1962-1964, this portion of the QS is fallow agricultural. By 1966, homes begin development at which by 1972, the area is completely developed with single-family homes which remain visible to 2002.

3-20; The land is primarily utilized for agricultural purposes with a residential subdivision in the northeast quarter and one (large) building in the northwest corner of the QS in the early-1960s.

By the late-1960s, the QS is filled with more homes as the agricultural land slowly changes to residential use. The large building in the northwest corner expands to a large (commercial) complex of several buildings by 1972. With the southeast corner still primarily vacant, the entire QS has remained relatively unchanged since the early-1970s.

4-17; (North half of QS); Native river bottom with intermittent sand/gravel removal from 1962-2002.

(South half of QS); Agricultural land with associated farm houses visible from 1962-1986. By 1988, sand/gravel operations are visible and slowly taking over the land to 2002.

4-18; (North half of QS); River bottom and riverbank from 1962 to 2002.

(South half of QS); Land utilized primarily for agricultural purposes with possible cattle lot located in the southeast corner of the QS from 1962 to 1980. A large scale sand/gravel operation (currently Vulcan) was visible from the early-1980s to 2002 along with an industrial (concrete mold) facility in the southeast corner of the QS.

4-19 (North half of QS); Land utilized primarily for agricultural purposes from 1962 to 1976. By the late-1970s, auto salvage yards were quite predominant and increasing with debris to 2002.

(South half of QS); Land utilized primarily for agricultural purposes with a farm house from 1962 to 1988. From 1990 to 2002, the land was then utilized for sand/gravel removal by the 27th Avenue Landfill; likely for capping of individual cells.

4-20; The eastern ¾ of the QS has been a residential subdivision from 1962 to 2002. The western ¼ of the QS has been a combination of native, agricultural, and residential, with a portion used just as an access road (1993-2002) to a nearby sand/gravel pit from 1962 to 2002.

5-17; (North half of QS); Land utilized primarily for agricultural purposes from 1962 to 1982 before being graded (but not fallow) from 1985 to 1998. In 2000 and 2002, sand/gravel removal is occurring within this portion of the QS.

(South half of QS); Native river bottom from 1962 to 2002.

5-18; (Northern portion of QS); The northern portion of the QS has been agricultural from 1962 to 1998 before being used for sand/gravel removal in 2000 and 2002.

(Middle portion of QS); Although minor sand/gravel removal may have occurred in the early-1960s, more predominant sand/gravel operations began in the late-1960s and continued to 2002 with major operations and buildings first visible in 2000.

(Southern portion of QS); Land is primarily native river bottom from 1962 to 2002 with a small portion in the north used for sand/gravel removal.

5-19; (North half of QS); Land is primarily utilized for agricultural purposes from 1962 to 1970. In 1972, the beginning of a large sand/gravel removal/operation is visible in the northwest corner of the QS which then expands to include the entire northern half of the QS by 1983.

(South half of QS); The southern half of the QS remains native river bottom (with some small sand/gravel removal in the southwest corner in the 1960s) until the late-1980s. At that time, the sand/gravel removal encompasses more of the southern half of the QS. By 1998, the sand/gravel appeared to diminish in activity and by 2000, equipment associated with the sand/gravel operation had been removed from the site. In 2002, the sand/gravel site (in the northwest corner) was paved and now consists of a storage yard for semi-trucks/trailers. Water still occupies the former sand/gravel pit in the east portion of the quarter while the southern portion remains native river bottom.

5-20; Although the QS is primarily native river bottom in the early-1960s, sand/gravel removal is evident in various places such as the northeast, southeast, and southwest corners of the QS. It appears that someone may have tried to farm a portion of land in the southwest corner of the QS in 1962 and 1964. In 1966, the northeast corner of the QS contained a property resembling a salvage yard that expanded in the 1970s with piles of mounded debris and winding roads visible. By the late-1980s, the piles of debris diminished (until 1996) as the buildings multiplied. By 1998, the debris piles once again increased as the site looks quite disorganized and "dirty" in 2002.

6-17; In the early to mid-1960s, the QS appears as agricultural and residential in use. In 1968, an industrial yard is noted in the southwest corner of the QS with miscellaneous parts and scrap. This yard immensely expands by 1974 to encompass the entire southwest corner of the QS and appears to now consist of a cluster of four to five businesses. In 1976, a roof truss manufacturer (previously identified as such) replaces one of the junkyards, and by 1983, expands to the south. In 1985, a large industrial building (and smaller one) is noted in the northwest corner of the QS. Also in 1985, the residence located in the northeast corner of the QS appears to become industrial in nature as some of the agricultural land turns fallow and the buildings and debris increase dramatically. In 1986, a smaller commercial building is visible in the extreme northwest corner of the QS and remains visible through 2002. By 1998, the large industrial property in the northwest corner of the QS increases with additional buildings, pavement, and the storage of over 100 tractor trailers.

6-18; The land is utilized primarily for agricultural purposes with a natural wash running through it and a residence located in the southeast corner of the QS from 1962 to 1998. A large industrial building is visible in the southwest quarter of the QS in 2000 and 2002 with the storage of large metal pieces or equipment to the south of the building.

6-19; The land is utilized primarily for agricultural purposes from 1962 to 1972. From 1974 to 1978, the QS remains agricultural with a stock yard visible in the southwest quarter. By the early-1980s, several facilities were constructed along the west half of the QS, along with an additional facility (sand/gravel operation) visible in the southeast corner. In 1988, a junk yard appeared along the southwest corner of the QS. Another facility became visible in 1998 in the center of the QS, which included a large parking lot. By 2000, the sand/gravel pit in the southeast corner has been shaped with uniform even slopes and by 2002, it appears as if it is being used as a landfill.

6-20; From 1962 to the early–1970s, most of the land was used for agricultural purposes (orchards or possibly a nursery). By 1972, a wastewater treatment facility was observed in the southeast corner of the QS. In 1974, a small sand/gravel operation was visible in the eastern middle section of the QS and an industrial facility (previously identified as a pipe yard) is first visible in the northwest corner. In 1978, auto salvage yards were visible in the northeast quarter and the western central quarter of the QS. By 1980, the orchard is completely replaced by industrial activities. In 1982, a large industrial yard is visible in the northern-central quarter section which later expands throughout the 1980s and early-1990s.

7-19 (South half of QS only); Land is utilized primarily for agricultural purposes from 1962 to 1976. However, a small building (first visible in the southeast quarter of the QS) begins to expand in the late-1970s with a junkyard. The buildings and junkyard remain visible through 2002. Back in 1978, a large portion of land is graded and two large buildings are constructed in the southwest corner by 1980. These two buildings remain visible in 2002.

7-20 (South half of QS only); Land is utilized primarily for agricultural purposes from 1962 to 1970. By 1972, two industrial complexes (with several buildings each) are visible. In 1974, a salvage yard is visible in the north, and by 1978, a second salvage yard is visible just south of the first one. The industrial complexes and salvage yards remain visible in 2002.

51st Avenue to 67th Avenue (inclusive of Township 1 North, Range 2 East, Sections 19, 20, 29, 30, and 31)

1-13 (North half of QS only); Land is utilized primarily for agricultural purposes from 1962 to 1974. From 1976 to 2002, the QS is residential.

1-14 (North half of QS only); Land is utilized primarily for agricultural purposes from 1962 to 1974 with one farm in the northwest corner of the QS. Residential homes begin development in the west portion of the QS in 1985 while the east portion remains agricultural to 2002.

2-13; Land is utilized primarily for agricultural purposes from 1962 to 1980. The development of residential homes begins in 1982 and continues to expand across the QS to 2002 with the agricultural land becoming almost non-existent.

2-14; Land is utilized primarily for agricultural purposes from 1962 to 2002.

2-15; Land is utilized primarily for agricultural purposes (with a farm house visible in the northwest corner of the QS) from 1962 to 1992. From 1994 to 2002, the QS contains a golf course.

2-16; Land is utilized primarily for agricultural purposes (with four farm house visible in the southeast corner of the QS) from 1962 to 1974. From 1976 to 2002, the farm houses have been removed and the QS consists entirely of agricultural land.

3-13; The QS primarily consists of native river bottom from 1962 to 2002 with small sand/gravel removal occurring in the northwest corner (throughout the years) and a large sand/gravel operation in the southwest corner (especially in the 1960s and 1970s and finally fading in the 1990s).

3-14; The QS consists of native river bottom from 1962 to 1985. From 1986 to 2002, the QS consists of native river bottom with a commercial business visible in the southeast corner of the QS.

3-15; The QS consists of agricultural land and native river bottom from 1962 to 2002.

3-16; The QS is utilized primarily for agricultural purposes (with numerous farm houses and related structures, especially in the 1960s and 1970s) from 1962 to 2002.

4-13; The QS consists of agricultural land (with a farm house along the west edge) and native river bottom from 1962 to 2002. However, a small oval-shaped track is visible from near the farm house from 1968 to 1974.

4-14; The north half of the QS is utilized for agricultural purposes from 1962 to 2002. The south half of the QS is river bottom with sand/gravel removal occurring from 1962 to 2002.

4-15; The northwest corner of the QS is utilized for agricultural purposes from 1962 to 1985 before sand/gravel operations take over. The remainder of the QS has sand/gravel operations

periodically occurring from 1962 to 2002 with major activity occurring in the late-1980s and 1990s.

4-16; The QS appears primarily as native river bottom with periodic sand/gravel removal in the southeast corner in the 1960s to early-1970s. Major sand/gravel operations in the southeast corner (and in the north) occur from 1980 to 1994. By 1996, the entire QS is utilized for sand/gravel removal/operations.

5-13; The QS is utilized for agricultural and residential purposes from 1962 to 2002.

5-14; The QS is primarily utilized for agricultural purposes with several large buildings along the eastern edge. The buildings appear to be farm related and may have been used as a cattle lot in the 1960s. From the early-1970s to 2000, the QS remains agricultural with several farm-type structures along the eastern edge. By 2002, the eastern portion of the QS is developed with a residential subdivision while the eastern portion of the QS has graded for upcoming residential development.

5-15; The QS is primarily utilized for agricultural purposes except for a residence/farm area along the northwestern edge. In the 1960s, the northwestern edge appears to be utilized as a cattle lot (likely associated with the one adjacent to the west in QS 5-14).

5-16; The northern half of the QS is utilized for agricultural purposes from 1962 to 2002. The southern half of the QS is native river bottom from 1962 to 1985 and then utilized for major sand/gravel operations from 1986 to 2002.

6-15; The QS is primarily utilized for agricultural purposes from 1962 to 2002 with one or two farm houses visible throughout the years.

6-16; The QS is primarily utilized for agricultural purposes from 1962 to 1994. From 1996 to 2002, the west half of the QS remains agricultural while the east half contains a large industrial facility in the southwest quarter and two industrial facilities (visible in 2002 only) in the northeast quarter of the QS.

67th Avenue to 83rd Avenue (inclusive of Township 1 North, Range 1 East, Sections 24, 25, 26, 35, 36 and Township 1 South, Range 1 East, Section 2)

01-9 (North half of QS only); The QS is utilized for agricultural and residential purposes from 1962 to 1968. From 1970 to 2002, the QS contains some commercial buildings along with the original agricultural land and residential homes..

01-10 (North half of QS only); The QS is utilized for agricultural and residential purposes (including a cattle feed lot) from 1962 to 2002.

1-9; The northwest quarter of the QS is native land and river bottom from 1962 to 2002. The northeast quarter of the QS is river bottom with a small piece of agricultural land from 1962 to 1976. From 1978 to 2002, the northeast quarter of the QS is primarily agricultural land with some native river bottom. However, a wastewater pond is visible in the northeast quarter from 1988 to 1994 with two ponds then visible from 1996 to 2002. the south half of the QS has been agricultural with some farmhouses and small commercial properties from 1962 to 2002.

1-10; The QS has been utilized primarily for agricultural purposes from 1962 to 2002.

1-11; The QS has been utilized primarily for agricultural purposes from 1962 to 2002.

1-12; The QS has been utilized primarily for agricultural purposes from 1962 to 1972. From 1974 to 2002, the QS has been half agricultural and half residential.

2-9; The north half of the QS is native river bottom from 1962 to 1984. From 1986 to 2002, a large sand/gravel operation (primarily removal) is visible from 1986 to 2002 in the north half. The south half of the QS is primarily native river bottom with a small agricultural farm in the southeast corner visible from 1962 to 2002. The southwest corner contains a small sand/gravel operation from 1962 to the early-1980s.

2-10; The northeast quarter of the QS is native river bottom from 1962 to 1970. By the early-1970s, industrial properties began to develop, and by 1980, the area began an increase in industrial activity to 2002. The northwest quarter of the QS has remained native river bottom from 1962 to 2002. The southeast quarter of the QS has been agricultural with farmhouses from 1962 to 2002. The southwest quarter of the QS has been native river bottom from 1962 to the late-1970s before becoming a horse farm which has remained visible to 2002.

2-11; The north half of the QS has been primarily agricultural from 1962 to 1968 with one building visible in 1966 and 1968. By the early 1970s, the northwest quarter of the QS was divided into several parcels with commercial/light industrial facilities slowly being constructed . In 1978, a salvage yard appeared in the lower portion of the northwest quarter and expanded slowly northward until 1986. In 1988, the northwest corner was again graded and now utilized to store sand and gravel. The south half of the QS has been utilized for agricultural purposes from 1962 to 2002.

2-12; The QS has been utilized for agricultural purposes from 1962 to 2002, except for the northwest corner, which has been industrial from 1970 to 2002.

3-9; The west half of the QS has been utilized for agricultural purposes from 1962 to the early-1980s. From 1985 to 2002, the west half has contained several large drying beds associated with the 91st Avenue Wastewater Treatment Plant. The east half of the QS has been primarily utilized for agricultural purposes (and some native river bottom) from 1962 to 1985. From 1986 to 2002, the east half is slowly engulfed by a large sand/gravel operation.

3-10; The north half of the QS is utilized for agricultural purposes from 1962 to 1994. From 1996 to 2002, the agricultural land is replaced by a large sand/gravel operation occurring in the area. The south half of the QS is native river bottom from 1962 to 2002 except for the southeast corner. The southeast corner contained a small facility visible at the corner of Southern and 75th Avenues in the middle of the river. The facility grows larger expanding to the west and then to the north with north-south elongated buildings (as many as 12) through 1976. The elongated buildings (or structures) appear to diminish through 1988 until only a single building remains through 1996. From 1998 to 2002, this portion of the QS remains vacant.

3-11; The north half of the QS is agricultural and native river bottom from 1962 to 2002. The south half of the QS is native river bottom from 1962 to 1968. A sand/gravel operation is then visible from 1970 to 2002.

3-12; Sand/gravel removal occurs in the QS from 1962 to 1974 with commercial/light industrial activity along the eastern edge of the QS. Larger scale sand/gravel operation/removal occurs in the 1980s and 1990s with continued commercial/light industrial properties along the eastern edge of the QS to 2002.

4-9; The QS is primarily utilized for agricultural purposes with two farm areas visible from 1962 to 2002.

4-10; The QS is primarily utilized for agricultural purposes from 1962 to 2002.

4-11; The QS is used primarily for agricultural purposes with two farms visible from 1962 to 1966. It then remains agricultural with a dairy farm in the northwest corner of the QS through 1974. From 1976 to 2002, the QS primarily remains agricultural, but is subdivided between several residential homes. The dairy farm in the northwest corner is visible through 2002.

4-12; The QS is entirely agricultural with a dairy farm visible in the northeast corner from 1962 to 1974. Beginning in 1976, the dairy farm expands and the remainder of the QS is subdivided between several residential homes visible to 2002.

5-10 (South half of QS only); This half of the QS is agricultural with one house visible from 1962 to 2000. However, from 1968 to 1986, a large tailwater sump is visible along the northern

edge of the QS. In 2002, the development of a subdivision is visible throughout the entire south half of the QS.

5-11 (South half of QS only); This half of the QS has been utilized for agricultural purposes from 1962 to 2002 with only a small area of ground disturbance located in the northeast corner from 1962 to 1982.

5-12 (South half of QS only); This half of the QS has been utilized primarily for agricultural purposes from 1962 to 1980 except for a residential home located in the northeast corner. From 1982 to 2002, the QS is agricultural except for a commercial development located in the northeast corner.

4.1 FINDINGS

Based on the above aerial photographs reviewed, URS has provided a summary of the findings to help delineate and identify areas (Quarter Sections) for further investigation. The following tables have been designed to generally describe the current overall use of each QS, the potential contaminant that may be associated with that land use, and a priority ranking for further investigation. The land use category identified for each QS is similar to that previously described; Residential, Commercial/Industrial, Landfill, Sand/Gravel Operation, Agricultural, Recreational (i.e. public parks), and River Bottom/Native.

For this summary, URS attempted to assign land use categories based on what the QS primarily consisted of in 2002. In some cases, a QS may have been assigned multiple categories if they appeared to consist of a large percentage of a certain use (i.e. a QS consisting of half agricultural land and half industrial land will be assigned both categories). Potential contaminants associated with a certain land use are general in nature but are listed based on URS' past experience conducting site assessments on various properties. This is not to say that other contaminants may or may not be associated with a certain land use, but rather that these contaminants may be the most commonly found. The priority ranking of Low, Medium, and High (and derivations of these) are based on the type of current land use and the potential contaminant that is usually found during associated activities. Although there may be many other contaminants found, the following guidelines were typically used; insecticides/pesticides for Agricultural, petroleum products for Sand/Gravel Operations, and petroleum products and solvents for Commercial/Industrial. If auto salvage yards or junkyards were specifically observed in a Commercial/Industrial setting, the contaminant of metals was also listed.

19th Avenue to 35th Avenue			
Quarter Section	**Current Overall Land Use**	**Potential Containment**	**Priority Ranking (for Further Investigation)**
3-21 (North ½ only) 3-22 (North ½ only) 3-23 (North ½ only) 7-22 (South ½ only)	Agricultural	Insecticides/Pesticides	Low- Medium
3-24 (North ½ only)	Residential	---	Low
4-24 7-21 (South ½ only) 7-23 (South ½ only) 7-24 (South ½ only)	Commercial/Industrial	Petroleum products, solvents, metals	High
4-21	Agricultural commercial/ industrial sand/gravel	Insecticides/pesticides, petroleum products, solvents, metals	High
4-23	Agricultural commercial industrial	Insecticides/pesticides petroleum products solvents, metals	High
4-22, 5-21, 5-22, 5-23, 5-24, 6-23, 6-24	Commercial/industrial and sand/gravel operations	Petroleum products, solvents, metals	High
6-21, 6-22	Commercial/industrial and landfill	Petroleum products, solvents, metals	High

35th Avenue to 51st Avenue			
Quarter Section	**Current Overall Land Use**	**Potential Containment**	**Priority Ranking (for Further Investigation)**
3-2, 4-20	Residential	---	Low
3-17, 4-17, 5-18, 5-19	Sand/gravel operations	Petroleum products	Medium-High
4-19, 6-17, 6-20 7-19 (South ½ only) 7-20 (South ½ only)	Commercial/industrial	Petroleum products, solvents, metals	High
3-18	Agricultural, residential commercial/industrial	Insecticides/pesticides petroleum products, solvents, metals	High
3-19	Residential and commercial/industrial	Petroleum products solvents	High
4-18, 5-20	Sand/gravel operations commercial/industrial	Petroleum products, solvents, metals	High
5-17	Native/river bottom sand/gravel operations	Petroleum products	Medium-High
6-18	Agricultural and commercial/industrial	Insecticides/pesticides petroleum products solvents	High
6-19	Commercial/industrial and landfill	Petroleum products, solvents	High

51st Avenue to 67th Avenue			
Quarter Section	**Current Overall Land Use**	**Potential Containment**	**Priority Ranking (for Further Investigation)**
1-14, 2-14, 2-16, 4-13, 5-13, 5-15, 6-15	Agricultural	Insecticides/pesticides	Low-Medium
1-13, 2-13, 3-16, 5-14	Residential	---	Low
2-15	Recreational	---	Low
3-13, 3-14	Native/river bottom	---	Low
4-15, 4-16	Sand/gravel operations	Petroleum products	Medium-High
3-15	Agricultural and native/ river bottom	Insecticides/pesticides	Low-Medium
4-14, 5-16	Agricultural and sand/gravel operations	Insecticides/pesticides and petroleum products	Medium-High
6-16	Agricultural and commercial/industrial	Insecticides/pesticides, petroleum products, solvents	High

67th Avenue to 83rd Avenue			
Quarter Section	**Current Overall Land Use**	**Potential Containment**	**Priority Ranking (for Further Investigation)**
01-9, 01-10, 1-9, 1-10, 1-11, 1-12, 2-10, 2-12, 4-9, 4-10, 4-11, 4-12, 5-11 (South ½ only) 5-12	Agricultural	Insecticides/pesticides	Low-Medium
2-9	Native/river bottom	---	Low
3-11	Sand/gravel operations	Petroleum products	Medium-High
5-10 (south ½ only)	Residential	---	Low
2-11	Agricultural and commercial/industrial	Insecticides/pesticides, petroleum products, solvents	High
3-9, 3-12	Sand/gravel operations and commercial/industrial	Petroleum products, solvents	High
3-10	Native/river bottom and sand/gravel operations	Petroleum products	Medium-High

5.0 REGULATORY AGENCY REVIEW

A review of applicable regulatory agency documents and lists of known or potential hazardous waste sites or landfills, and properties or facilities currently under investigation for potential environmental violations was conducted by Environmental Data Resources, Inc. (EDR). A list and brief description of the EPA and state agency databases reviewed is tabled below. A copy of the EDR report is presented in Appendix A.

Type of Database	Description of Database	Date of Database Revision
Federal Databases		
NPL	The National Priorities List (NPL) identifies uncontrolled or abandoned hazardous waste sites. To appear on the NPL, sites must have met or surpassed a predetermined hazard ranking system score, been chosen as a state's top priority site, pose a significant health or environmental threat, or be a site where the EPA has determined that remedial action is more cost-effective than removal action.	10/22/01
CERCLIS	The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database identifies hazardous waste sites that require investigation and possible remedial action to mitigate potential negative impacts on human health or the environment.	11/21/01
RCRA TSDs	The EPA's Resource Conservation and Recovery Information System (RCRIS) identifies and tracks hazardous waste from the point of generation to the point of disposal. The RCRIS Treatment, Storage, Disposal (TSD) Facilities List is a compilation by EPA of reporting facilities that generate, transport, store, treat, or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA) but are not undergoing any "corrective action".	6/21/00
CORRACTS	RCRA TSD facilities ordered to implement corrective actions. A "corrective action order" is issued pursuant to RCRA Section 3008 (h) when there has been a release of hazardous waste or constituents into the environment from a RCRA TSD facility. Corrective actions may be required beyond the facility's boundary and can be required regardless of when the release occurred, even if it predates RCRA.	11/14/01
RCRA Generators	RCRA-regulated hazardous waste generator notifiers list; both Large and Small Quantity Generators are included in this list. (LQG – Large Quantity Generator, SQG – Small Quantity Generator)	6/21/00
ERNS	EPA's Emergency Response Notification System (ERNS) list contains reported spill records of oil and hazardous substances.	8/08/00
ROD	The EPA's Record of Decision (ROD) documents mandate a permanent remedy at a NPL site containing technical and health information to aid in the cleanup.	9/30/00
Arizona State Databases		
SPL/WQARF	A Water Quality Assurance Revolving Fund (WQARF) area (referred to as a State Priority List (SPL) site by EDR) which is also referred to as a state Superfund area, is a region designated by ADEQ for further investigation regarding environmental concerns. This designation is typically based on known areas of groundwater contamination, or past or present land uses which have been known to use and discharge chemicals that can contaminate groundwater.	6/12/01

Type of Database	Description of Database	Date of Database Revision
SHWS/ACIDS	The Arizona CERCLIS Information Data System (ACIDS) List has been used by the ADEQ Superfund Programs Section (SPS) for the past decade in tracking WQARF sites and portions of sites, potential WQARF sites, referrals, and other cases of interest to the SPS. As of March 13, 2000, there were approximately 1,500 entries on the ACIDS list. While some of the cases on this list are relevant to Arizona's Superfund Program, others are not and their inclusion may be misleading. For this reason, the SPS has elected to archive the ACIDS list, and no longer distribute it. In its stead, the ACIDS List has been replaced by the Arizona Superfund Programs List (SPL). This list is more representative of the sites and potential sites within the jurisdiction of the ADEQ SPS. According to ADEQ, the listing of properties on the ACIDS list is not an indication of liability or potential liability. Many of these properties on this list have no present involvement in WQARF or federal Superfund.	1/3/00
SWLF	State inventory of solid waste disposal and landfill sites.	11/01/00
LUST	List of information pertaining to all reported leaking underground storage tanks.	11/08/01
UST	State underground storage tank sites listing. The state of Arizona requires that owners of most underground storage tanks (USTs) register their USTs with ADEQ.	11/07/01
AZ-Spills	Releases and incidents recorded by ADEQ Emergency Response Unit.	6/30/00
Drywells	State drywell registration list. Dry wells are typically constructed on commercially-developed properties to collect rainwater surface runoff, and therefore, have the potential to introduce contaminants into the subsurface.	12/01/01

EDR compiled a list of properties or facilities located within the project study area (approximately one mile north and south of the Salt River) that appeared on one or more of the above-mentioned databases. URS reviewed the information presented by EDR and additional information presented on-line by EPA and ADEQ to identify sites that may have the potential to adversely affect environmental conditions at the subject property. A summary of the listed sites, addresses, database on which the site is listed, and the site's potential to adversely affect environment conditions at the subject property is tabled below. The tables are complied in one-mile increments north of the river and south of the river and listed separately. The identification numbers listed in the tables are those assigned for reference purposes only by EDR. Additional tables compiled by regulatory databases are included in Appendix B.

The priority ranking is based on current and prior activities as provided by the above-reference material. It should be noted that all facilities with registered USTs or listed LUSTs were ranked with a Low to Medium priority due to the potential for past and/or future contamination involving the USTs and their current status (i.e. closed/open LUST case, active/removed UST, etc.). A brief summary of all sites with a Medium or High Priority Ranking follows each of the associated tables.

7th Avenue to 19th Avenue - North of the Salt River

Although this area is outside the site boundaries as described in Section 2.1, these sites lie within one mile and are hydrologically upgradient of the subject property and therefore, may have a potential environmental affect on the subject property.

ID	Site Name	Site Address	Database	Status	Priority
Z	19th Avenue Landfill	19th Ave and Lower Buckeye Road	CERCLIS	Remedy assessment phase	High
			NPL	Status: Final	
			ROD	See additional information below	
			LUST	2 closed 1993	
			UST	0 active / 3 removed	
			SWLF	Closed	
2	Blue Circle West Leasing	2625 S. 19th Ave.	RCRIS-SQG	No violations found	Low
2	Kenworth of AZ Sunward Materials	2625 S. 19th Ave.	RCRIS-SQG	No violations found	Low
			CERC-NFRAP	1988 PA – NFRAP	
			SHWS	WVB	
2	Williams Detroit Diesel	2602 S. 19th Ave.	RCRIS-SQG	No violations found	Low
2	Neils Detroit Diesel Inc.	2602 S. 19th Ave.	UST	0 active / 3 removed	Low- Med.
2	Frontier Freightways	2465 S. 19th Ave.	RCRIS-SQG	No violations found	Low
2	Cypress Environmental	2465 S. 19th Ave.	RCRIS-SQG	No violations found	Low
2	Superior Companies	2402 S. 19th Ave.	LUST	1 Closed – 1995	Low- Med.
			UST	0 active / 1 removed	
2	Arizona Beef	2401 S. 19th Ave.	LUST	1 Closed – 1990	Low- Med.
			UST	0 active / 2 removed	
2	Marlam Industries, Inc.	2465 S. 19th Ave.	RCRIS-LQG	2 Low priority violations	Low- Med.
2	Arizona Truck & Trailer	2235 S. 19th Ave.	Dry Wells	1 Dry well	Low
2	Bradley Investment Co.	2235 S. 19th Ave.	UST	0 active / 2 removed	Low- Med.
4	Greenfield Environmental (AKA Innovative Waste Utilization)	2575 S. 16th Ave.	RCRIS-LQG	49 Violations	Medium
			RCRIS-TSD	Med. CORRACTS priority	
			CORRACTS		
4	MP Environmental	2530 S. 16th Ave.	AZ Spills	1994 incident	Low- Med.
			ERNS		

ID	Site Name	Site Address	Database	Status	Priority
10	Phoenix Tallow	2602 S. 15th Ave.	LUST	3 closed – 1999	Low- Med.
			UST	0 active / 6 removed	
13	Phoenix Metal Recycling	3210 S. 19th Ave.	RCRIS-SQG	No violations found	Low
13	Asphalt Products Transport Co.	3050 S. 19th Ave.	UST	0 active / 2 removed	Low- Med.
			AZ Spills	1993 incident	
13	Lincoln Auto	3020 S. 19th Ave.	UST	0 active / 2 removed	Low
13	Waste Management of Phoenix (AKA Universal Waste Control)	3000 S. 19th Ave.	LUST	1 closed 1996 / 1 unknown	Low-Med.
			UST	2 active/3 removed	
			Dry Wells	1 Dry well	
			RCRIS-SQG	No violations found	
19	United Metro Material Plant 11	3640 S. 19th Ave.	RCRIS-SQG	1 low priority violation	Low- Med.
			AZ Spills	1995 Diesel release	
19	Tanner-United Metro	3640 S. 19th Ave.	LUST	1 closed 1999	Low- Med.
			UST	4 active / 7 removed	

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

19th Avenue Landfill

The 19th Avenue Landfill facility is located near the southeast corner of 19th Avenue and Lower Buckeye Road in Phoenix and covers approximately 213 acres within the floodplain of the Salt River. Although the site was originally used as a sand and gravel operation, it has been a landfill since the late-1950s.

During the remedial investigation, the groundwater was found to contain low concentrations of volatile organic compounds, various heavy metals, and beta radiation. Currently, only one compound (1,1-dichloroethene) is above drinking water standards. Because groundwater in the area is used for industrial purposes only and there are no direct pathways to the City of Phoenix drinking water supply, the landfill is not considered to be a threat to public health.

A consent decree (entered in June 1992) called for capping of the landfill cells, removal and treatment of methane gas, monitoring of groundwater, and a contingency plan to treat groundwater if standards are exceeded. ADEQ is the lead regulatory agency on this EPA project through WQARF. ADEQ approved the Remedial Design Plans and Project Specifications in

May 1995 and completed the required five-year monitoring of the site. According to ADEQ, the remedy is protective of human health and the environment.

Greenfield Environmental (AKA Innovative Waste Utilization)

The Greenfield Environmental facility is located near the northeast corner of 19th Avenue and Lower Buckeye Road in Phoenix. According to information obtained from the EPA, the facility handles, stores, transports, and manages many chemicals including volatile organic compounds and various heavy metals. The types of waste management conducted at the facility include incineration, energy recovery, solidification and stabilization, and wastewater treatment.

According to EDR, Greenfield Environmental has received 49 RCRA violations between 1985 and 1996. Of the 49 violations, 41 were reported as low priority and 8 high priority. All the violations appear to have been brought back into compliance by 1998. Although the Greenfield facility releases volatile organic compounds into the air, according to the EPA the facility is currently in compliance.

7th Avenue to 19th Avenue - South of the Salt River

Although this area is outside the site boundaries as described in Section XX, these sites are within one mile and hydrologically upgradient of the subject property therefore, may have a potential environmental affect on the subject property.

ID	Site Name	Site Address	Database	Status	Priority
20	Ace Asphalt of Arizona	895 W. Elwood	LUST	3 closed 1998	Low- Med.
			UST	2 active / 3 removed	
			RCRIS-SQG	No violations found	
			AZ Spills	1988 Unknown release	
23	Laidlaw Environmental Services	888 W. Illini Street	RCRIS-SQG	3 low priority violations	Low
23	Disposal Control Services, Inc.	888 W. Illini Street	SHWS	PA/SI	Low
25	Circle K #670	4422 S. 19th Ave.	LUST	1 closed 1996	Low- Med.
			UST	0 active / 3 removed	
25	Cooley Wholesale Lumber Co.	1930 W. Broadway	LUST	1 closed date unknown	Low- Med.
			UST	0 active / 2 removed	
25	Arizona Teamsters App.	1820 W. Broadway	LUST	1 closed 2000	Low- Med.
			UST	0 active / 2 removed	
25	CSW Contractors Inc.	1824 W. Broadway	UST	0 active / 2 removed	Low
25	Industrial Recycling Solutions	2610 W. Holly	RCRIS-SQG	No violations found	Low

ID	Site Name	Site Address	Database	Status	Priority
25	Solvent Recyclean Inc.	1850 W. Broadway	RCRIS-SQG	1 low priority violation	Low
25	Circle K #1968	4305 S. 19th Ave.	UST	3 active / 0 removed	Low- Med.
25	Arizona Barrel and Can Co.	4225 S. 19th Ave.	CERC-NFRAP	Site inspection completed 1992	Low
25	Western Block Company	4021 S. 19th Ave.	LUST	1 closed 1998	Low- Med.
			UST	0 active / 4 removed	
25	19th Ave. Airstrip	NEC 19th/Broadway	SHWS	PA/SI	Low
27	Road Jammers Machinery	4300 S. 17th Ave.	LUST	1 closed 1994	Low- Med.
			UST	0 active / 3 removed	
30	Briscoe Inc.	15th Ave./Broadway	AZ Spills	1985 petroleum release	Low-Med.
30	Broadway Cardlock #23	1307 W. Broadway	LUST	1 closed 1999	Low- Med.
			UST	0 active / 3 removed	
30	Progressive Roofing	1501 W. Broadway	UST	0 active / 1 removed	Low- Med.
30	Sandvick Equipment & Supply Co.	1502 W. Broadway	UST	0 active / 1 removed	Low- Med.
30	Turners Machine Shop	1521 W. Broadway	RCRIS-SQG	No violations found	Low
30	Brown Tank & Steel	4300 S. 15th Ave.	UST	0 active / 2 removed	Low- Med.
44	CJ Joregenstein Elementary	1701 W. Roeser	AZ Spills	1998 incident	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

19th Avenue to 27th Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 5-23, 5-24, 6-23, 6-24, 7-23, and 7-24.

ID	Site Name	Site Address	Database	Status	Priority
NL	23rd Avenue Landfill	23rd Ave./ Low Buck Rd	SWLF	Closed	Low-Med.
3	Old 23rd Ave. Sludge Disp. Ponds	23rd & Low Buck Rd	SHWS	WVB	Low
5	27th Avenue Landfill	27th Ave. & Lower Buckeye Road	LUST	1 closed 1998	Low-Med.
			UST	0 active / 1 removed	
			AZ Spills	1992 incident	
			Dry Wells	1 Dry well	
			SWLF	Transfer station	
			SHWS	WVB	
5	Phoenix Union High School	2800 S. 27th Ave.	AZ Spills	1991 incident	Low

ID	Site Name	Site Address	Database	Status	Priority
6	Phoenix Transit System	2225 W. Low Buck Rd	RCRIS-SQG	No violations found	Medium
			RCRIS-LQG	1 low priority violation	
			LUST	1 closed 2000	
			UST	19 active / 0 closed	
6	COP Petroleum Storage Facility	2239 W. Low Buck Rd	Dry Wells	1 dry well	Medium
			RCRIS-SQG	No violations found	
			LUST	1 closed 1998	
			UST	0 active / 7 removed	
6	Kerley Chemical Corp.	2248 W. Low Buck Rd	AZ Spills	1986 incident	Low- Med.
			UST	0 active / 1 removed	
			RCRIS-SQG	No violations found	
			SHWS	WVB	
6	Phoenix Salt River Service Center	3045 S. 22nd Ave.	LUST	6 closed 1997 – 1999	Medium
			UST	8 active / 16 removed	
9	Empire Metals Inc.	2010 W. Low Buck Rd	LUST	2 closed 1994	Low- Med.
			UST	0 active / 3 removed	
			RCRIS-SQG	1 low priority violation	
14	Operating Engineers Road	3225 S. 22nd Ave.	UST	0 active / 3 removed	Low- Med.

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
NL – Not listed
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

Phoenix Transit System/Phoenix Salt River Service Center/COP Petroleum Storage Facility

The Phoenix Transit System, Salt River Service Center, and COP Petroleum Storage Facility are all fueling and/or maintenance yards for the City of Phoenix vehicles. They are all located at approximately 22nd Avenue and Lower Buckeye Road in Phoenix. Although the facilities do not appear to have any substantial violations, they are considered medium priority rankings due to the high number of active and removed USTs at each site.

19th Avenue to 27th Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-23, 3-24, 4-23, and 4-24.

ID	Site Name	Site Address	Database	Status	Priority
32	Yank Your Part	2104 W. Broadway	RCRIS-SQG	No violations found	Low
32	AETS	2301 W. Broadway	SWF/LF	Active (accepts PCS)	Low- Med.
33	AG Products	2630 W. Broadway	RCRIS-SQG	No violations found	Low
33	Chemical Waste Management	2301 W. Broadway	AZ Spills	8 incidents from 1984-89	Med./High
33	Onyx Environmental Services	2301 W. Broadway	RCRIS-SQG	22 low priority violations	
			RCRIS-LQG		
			CORRACTS	Low CORRACTS priority	
			CERC-NFRAP	Site inspection completed 1990	
			SHWS	PA/SI	
33	M&M Auto Storage Pool Inc	2299 W. Broadway	UST	0 active / 1 removed	Low
33	Fuelco #112	2401 W. Broadway	UST	0 active / 5 removed	Low- Med.
33	Smith Pre-Cast	2410 W. Broadway	UST	2 active / 0 removed	Low
33	AG Products	2525 W. Broadway	Dry Wells	2 Dry wells	Low
33	Alan Harris Trucking	2505 W. Broadway	UST	0 active / 1 removed	Low- Med.
33	Regent Auto & Truck Parts	2528 W. Broadway	SHWS	PA/SI	Low- Med.
33	A&S Auto Wrecking	2528 W. Broadway	SHWS	PA/SI	Low- Med.
34	Motorola (Bic)	2200 W. Broadway	AZ Spills	1984 incident	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
PCS – Petroleum contaminated soil
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

Chemical Waste Management (AKA Onyx Environmental Services)

Chemical Waste Management is a hazardous waste handler and transporter located on 23rd Avenue and Broadway in Phoenix. The facility had 22 low priority RCRA violations between 1985 through 1996 and 8 spill incidents during approximately the same time frame. According to EDR, two low priority corrective actions were completed by the facility in 1990 and 1992 (one each year). EPA conducted a preliminary assessment and site inspection at the facility in 1990. No further remedial action is currently planned by the EPA.

27th Avenue to 35th Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 5-21, 5-22, 6-21, 6-22, 7-21, and 7-22.

ID	Site Name	Site Address	Database	Status	Priority
15	Maricopa By-Products Inc.	3602 W. Elwood St.	UST	0 active / 6 removed	Low-Med.
			SHWS	WVB	
15	Copperstate Express Lines	3044 S. 35th Ave.	RCRIS-SQG	No violations found	Low
15	Quality Block Company Inc.	3035 S. 35th Ave.	LUST	3 closed 1997	Low-Med.
			UST	0 active / 3 removed	
			SHWS	WVB	
15	Arizona Precast	3045 S. 35th Ave.	SHWS	WVB	Low
22	Metal Management of Arizona	3640 S. 35th Ave.	AZ Spills	1999 Auto shreds fire	Low-Med.
22	Salt River Recycling / Smithey	3640 S. 35th Ave.	LUST	1 closed 1999 / 2 2000	Low-Med.
			UST	0 active / 3 removed	
22	Smithey Recycling Company	3649 S. 35th Ave.	SHWS	WVB	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

27th Avenue to 35th Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-21, 3-22, 4-21, and 4-22.

ID	Site Name	Site Address	Database	Status	Priority
31	Vista Construction	2836 W. Broadway	UST	2 active / 0 removed	Low-Med.
31	Royden Construction Co	2844 W. Broadway	UST	0 active / 4 removed	Low-Med.
31	Enviro-Solv	2844 W. Broadway	AZ Spills	2000 incident	Low-Med.
			RCRIS-SQG	No violations found	
31	Construction Yard	2850 W. Broadway	UST	0 active / 2 removed	Low-Med.
31	Unknown	2744 W. Broadway	AZ Spills	1995 incident	Low
35	All-A-Matic Transmissions	3011 W. Broadway	AZ Spills	1993 incident	Low
35	Swift Transport	3106 W. Broadway	RCRIS-SQG	No violations found	Low
36	Bob Auto and Pickup Wrecking	3408 W. Broadway	RCRIS-SQG	No violations found	Low
36	Western States Petroleum	3331 W. Broadway	AZ Spills	1985 gasoline release	Low
36	Urban Forest Products Co.	3330 W. Broadway	AZ Spills	1995 incident	Low
36	Fuelco #113	3331 W. Broadway	LUST	1 closed 1993	Low-Med.
			UST	0 active / 3 removed	
36	Liquid Air Co.	3332 W. Broadway	AZ Spills	1985 incident	Low
36	Rotman Properties	3250 W. Broadway	LUST	1 unknown closed date	Low-Med.
			UST	0 active / 2 removed	

ID	Site Name	Site Address	Database	Status	Priority
36	Ricketts Trucking Inc	3434 W. Broadway	LUST	1 Closed date unknown	Low-Med.
			UST	0 active / 4 removed	
36	Phillips 66 Company	3449 W. Broadway	UST	0 active / 4 removed	Low-Med.
36	Manzanita Speedway	35th Ave / Broadway	SHWS	WVB	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

35th Avenue to 43rd Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 5-19, 5-20, 6-19, 6-20, 7-19, and 7-20.

ID	Site Name	Site Address	Database	Status	Priority
1	Circle K #8870	3501 W. Low Buck Rd	UST	3 active / 0 removed	Low-Med.
1	Rio Salado Auto Body	2801 S. 35th Ave.	RCRIS-SQG	No violations found	Low
			SHWS	WVB	
1	EMCO Recycling	3700 W. Lower Buckeye Road	LUST	1 closed 1999	Low-Med.
			UST	0 active / 4 removed	
			AZ Spills	2 1996 incidents	
1	Unknown	3650 W. Low Buck Rd	SHWS	WVB	Low
1	ChemCon Inc.	3702 W. Low Buck Rd	RCRIS-SQG	1 low priority violation	Low-Med.
			CORRACTS	Low CORRACTS priority	
1	Copperstate Metals Inc.	3720 W. Low Buck Rd	RCRIS-SQG	1 low priority violation	Low-Med.
			AZ Spills	2 incidents (1986/1988)	
			CERC-NFRAP	Discovery Assessment	
			SHWS	WVB	
1	Desert Transformer Inc.	3751 W. Low Buck Rd	LUST	1 closed 1999	Low-Med.
			UST	0 active / 3 removed	
1	RJ Ruff & Co.	3883 W. Low Buck Rd	LUST	1 closed 1998	Low-Med.
			UST	0 active / 3 removed	
1	Reuter Equipment Co.	3816 W. Low Buck Rd	UST	0 active / 3 removed	Low-Med.
1	Unknown	39 Ave. / Low Buck Rd	AZ Spills	1 incident (2000)	Low-Med.
1	CAVCO Industries Inc.	2602 S. 35th Ave.	UST	0 active / 2 removed	Low-Med.
			Dry wells	7 Dry Wells	
1	CAVCO Industries Inc.	2502 W. Durango	UST	0 active / 2 removed	Low-Med.
1	Castle MFG, Inc.	3702 W. Low Buck Rd	SHWS	WVB	Low

ID	Site Name	Site Address	Database	Status	Priority
1	Dagleys	2455 S. 35th Ave.	SHWS	WVB	Low
1	Angel Auto	2450 S. 35th Ave.	SHWS	WVB	Low
7	Mardian Construction Company	4044 W. Low Buck Rd	LUST	2 closed 1996	Low-Med.
			UST	0 active / 4 removed	
7	Zieman MFG	4025 W. Low Buck Rd	RCRIS-SQG	No violations found	Low-Med.
			UST	0 active / 1 removed	
8	Phoenix Redi Mix Company Inc.	3635 S. 43rd Ave.	RCRIS-SQG	No violations found	Low-Med.
			LUST	5 closed 1998-1999	
			UST	0 active / 9 removed	
8	Glenn Wienberger Landfill	3425 S. 43rd Ave.	RCRIS-SQG	No violations found	Low
			UST	1 active / 0 removed	
			SWLF	Closed	
8	A&K Partnership	3211 S. 43rd Ave.	UST	0 active / 2 removed	Low-Med.
8	Publicker Ind / Masterview Window	3065 S. 43rd Ave.	LUST	1 closed date unknown	Low-Med.
			UST	0 active / 1 removed	
8	USF Bestway Transportation	3045 S. 43rd Ave.	LUST	1 closed 1988	Low-Med.
			UST	1 active / 4 removed	
			RCRIS-SQG	No violations found	
8	Stanton Industries of Arizona	4215 W. LBR	UST	0 active / 1 removed	Low-Med.
11	C and M Enterprises	3240 S. 37th Ave.	RCRIS-SQG	No violations found	Low
17	Sunrise / Scorpio Steel Inc.	3420 S. 39th Ave.	LUST	3 closed 1997	Low-Med.
			UST	0 active / 2 removed	
17	All Valley Wrecker	3401 S. 39th Ave.	UST	0 active / 2 removed	Low-Med.
21	Reynolds Aluminum Plant Ponds	43rd Ave. / Salt River	AZ Spills	1 incident 1998	Low
			SHWS	WVB	

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

35th Avenue to 43rd Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-19, 3-20, 4-19, and 4-20.

ID	Site Name	Site Address	Database	Status	Priority
38	CalMat Yard	4830 S. 43rd Ave.	LUST	1 closed 1990	Low-Med.
			UST	0 active / 1 removed	

ID	Site Name	Site Address	Database	Status	Priority
42	Tatel Inc.	5250 S. 43rd Ave.	UST	2 active / 0 removed	Low-Med.
42	Coreslab Structures Inc.	5026 S. 43rd Ave.	LUST	1 closed 2000	Low-Med.
			UST	0 active / 3 removed	

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

43rd Avenue to 51st Avenue – North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 5-17, 5-18, 6-17, and 6-18.

ID	Site Name	Site Address	Database	Status	Priority
16	Royden Construction Company	3423 S. 31st Ave.	UST	0 active / 2 removed	Low-Med.
16	RPS Inc.	3410 S. 51st Ave.	RCRIS-SQG	No violations found	Low
16	FedEx Ground	3410 S. 51st Ave.	AZ Spills	1996 Diesel release	Low-Med.
			UST	1 active / 0 removed	
16	Arizona Truss Fabricators	3207 S. 51st Ave.	LUST	1 closed 1990	Low-Med.

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

43rd Avenue to 51st Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-17, 3-18, 4-17, and 4-18.

ID	Site Name	Site Address	Database	Status	Priority
43	Arizona Oil Recyclers Assoc.	5040 S. 51st Ave.	RCRIS-SQG	No violations found	Low
			AZ-Spills	1992 oil release	
48	A-1 Tire Company	4825 W. Southern	AZ-Spills	1990 fire	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

51st Avenue to 59Th Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 4-15, 4-16, 5-15, 5-16, 6-15 and 6-16.

X No Sites

51st Avenue to 59Th Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 2-15, 2-16, 3-15, and 3-16.

X No Sites

59Th Avenue to 67th Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 4-13, 4-14, 5-13, and 5-14.

X No Sites

59Th Avenue to 67th Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 1-13, 1-14, 2-13, and 2-14.

ID	Site Name	Site Address	Database	Status	Priority
49	USA Tire Recycling	5922 W. Southern	AZ Spills	1992 fire	Low
51	Arnold Machinery Company of AZ	6024 W. Southern	RCRIS-SQG	No violations found	Low-Med.
			UST	1 active / 0 removed	
52	Mobile Soil Processing Unit	5922 W. Southern	RCRIS-SQG	No violations found	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

67th Avenue to 75th Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-11, 3-12, 4-11, and 4-12.

ID	Site Name	Site Address	Database	Status	Priority
28	Farm	7502 W. Broadway	UST	0 active / 2 removed	Low-Med.
28	Marbella	75th Ave / Broadway	Dry wells	9 Dry wells	Low

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

67th Avenue to 75th Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 1-11, 1-12, 2-11, and 2-12.

ID	Site Name	Site Address	Database	Status	Priority
47	Iron Horse Equipment Corp	7316 W. Southern	RCRIS-SQG	No violations found	Low
53	Western Meat Company	7201 W. Southern	LUST	1 closed 1997	Low-Med.
			UST	0 active / 2 removed	

Notes:
ID – Map ID (see Figure 2)
NFRAP – No further remedial action planned
PA/SI – Preliminary Assessment/Site Investigation
WVB –Sites with this notation have been investigated as part of the West Van Buren (WVB) WQARF program

75th Avenue to 83rd Avenue - North of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 3-09, 3-10, 4-09, and 4-10.

X No Sites

75th Avenue to 83rd Avenue - South of the Salt River

City of Phoenix Quarter Section Index Map Numbers: 1-09, 1-10, 2-09, and 2-10.

X No Sites

6.0 PREVIOUS REPORT REVIEW

URS reviewed two previous assessments provided by the City of Phoenix: Middle Gila River Watershed Management Study Phase 2 (Greeley, 2001) and Environmental Contaminants in Fish and Wildlife of the Lower Gila River, Arizona (U.S. F&W, 1997). Although the study areas of neither report were inclusive of the entire subject property, the general subject matter as it pertains to conditions along rivers such as the Gila or Salt was reviewed.

The 1997 Fish and Wildlife report summarizes the investigation of work conducted along the lower Gila River and the associated agricultural canals (see Appendix C). From 1994 through 1995, six study sites were investigated along the lower Gila River watershed between 59th Avenue and Painted Rock Dam. According to that report, organochlorine pesticides (including DDT, DDE, dieldrin, and chlordane), polychlorinated biphenyls (PCBs), and metals (including primarily aluminum, copper, mercury, nickel, selenium, vanadium, and zinc) were detected in the fish and wildlife along the watershed study area. The high levels of pesticides were found to be directly related to those agriculturally applied within the area. Based on the overall agricultural use along the lower Gila River watershed, similar pesticide contamination may exist

in areas of heavy agricultural use along the Salt River. The source for metals contamination was not discussed in the report.

The Phase 2 report summarizes the comprehensive study of the Gila River watershed. The purpose of the report was to consolidate data obtained during the Phase 1 and 2 studies and to enhance the current database of this information. Included in this report is information concerning groundwater and surface water quality, stormwater issues, land use, etc. as they pertain to water resource. Although the information contained in this report was not directly used in this ESA, the data was included in URS' Groundwater Quality and Hydrogeology Report.

7.0 CONCLUSIONS AND RECOMMENDATIONS

URS conducted this Modified Phase I Environmental Site Assessment of the Rio Salado Oeste Project area for the purpose of identifying potential sites of contamination as part of the due diligence process of evaluating the design and completion of a riparian habitat restoration project. The project site lies within the Salt River between 19th Avenue and 83rd Avenue in Phoenix, Maricopa County, Arizona. This study was also conducted to help delineate and identify areas for further investigation. The findings of this study have been accomplished primarily by two tasks and are presented with separate findings above. URS' recommendations are presented below for each of the two primary tasks;

7.1 CURRENT AND HISTORICAL AERIAL PHOTOGRAPHS

The findings of our current and historical aerial photograph review have identified several areas by Quarter Section (QS) for further investigation. Each area has been identified with a Priority Ranking of Low, Medium, or High (or derivation therein). URS recommends that areas with a Medium-High or High priority ranking be further investigated by first conducting a "windshield survey", since Rights-of-Entry to many of these sites will not be able to be obtained. The windshield survey report would be conducted to observe and document the environmental conditions of a facility (or area) as much as possible to determine the potential for past or future contamination of the project area. Based on the information obtained during the windshield survey, the City of Phoenix may wish to conduct an ASTM Phase I Environmental Site Assessment on the identified site (or area).

Because a large portion of the project study area has been utilized for agricultural purposes for many years, insecticide/pesticide residuals may be present in soils. It is beyond the scope of this project to assess the specific impact of current or former insecticide/pesticide use in the project study area. Former studies (as presented in Section 6.0) show that pesticide use can have a dramatic negative impact to fish and wildlife in the surrounding area. Consequently, further

investigation should be conducted to specifically address the potential for insecticides/pesticides to impact the Rio Salado Oeste project area from past (or current) agricultural use.

7.2 REGULATORY AGENCY REVIEW

The findings of the Regulatory Review have identified specific facilities for further investigation and again assigned a Priority Ranking of Low, Medium, or High (or derivation therein). URS recommends that the facilities (or sites) listed as Medium or High be further investigated by reviewing specific regulatory files associated with each to determine the potential for past or future contamination of the project area. Based on the information obtained during the regulatory records review, the City of Phoenix may wish to conduct an ASTM Phase I Environmental Site Assessment on the identified site (or facility).

8.0 REFERENCES

American Society for Testing and Materials (ASTM), Standard E 1527-00, "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process," published September 2000.

Arizona Department of Environmental Quality (ADEQ), The Superfund Programs Section Information Packet, June 1999.

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FEMA, Flood Insurance Rate Map (FIRM), Maricopa County, Arizona and Incorporated Areas, Panel 2120 of 4350, Map Number 04013C2120-E, July 19, 2001.

FEMA, Flood Insurance Rate Map (FIRM), Maricopa County, Arizona and Incorporated Areas, Panel 2140 of 4350, Map Number 04013C2140-E, July 19, 2001.

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U.S. Department of Agriculture, Soil Conservation Service, Soil Survey of Maricopa County, Arizona, Central Part, September 1977.

U.S. Fish and Wildlife Service, Environmental Contaminants in Fish and Wildlife of the Lower Gila River, Arizona, December 1997.

U.S. Geological Survey, 7½-Minute Topographic Quadrangle Map, "Fowler, Arizona" 1952, Photorevised, 1982.

U.S. Geological Survey, 7½-Minute Topographic Quadrangle Map, "Phoenix, Arizona" 1952, Photorevised, 1982.

APPENDIX A

EDR DATABASE REPORT

AVAILABLE UPON REQUEST

APPENDIX B

SUMMARY OF SITES BY REGULATORY DATABASE

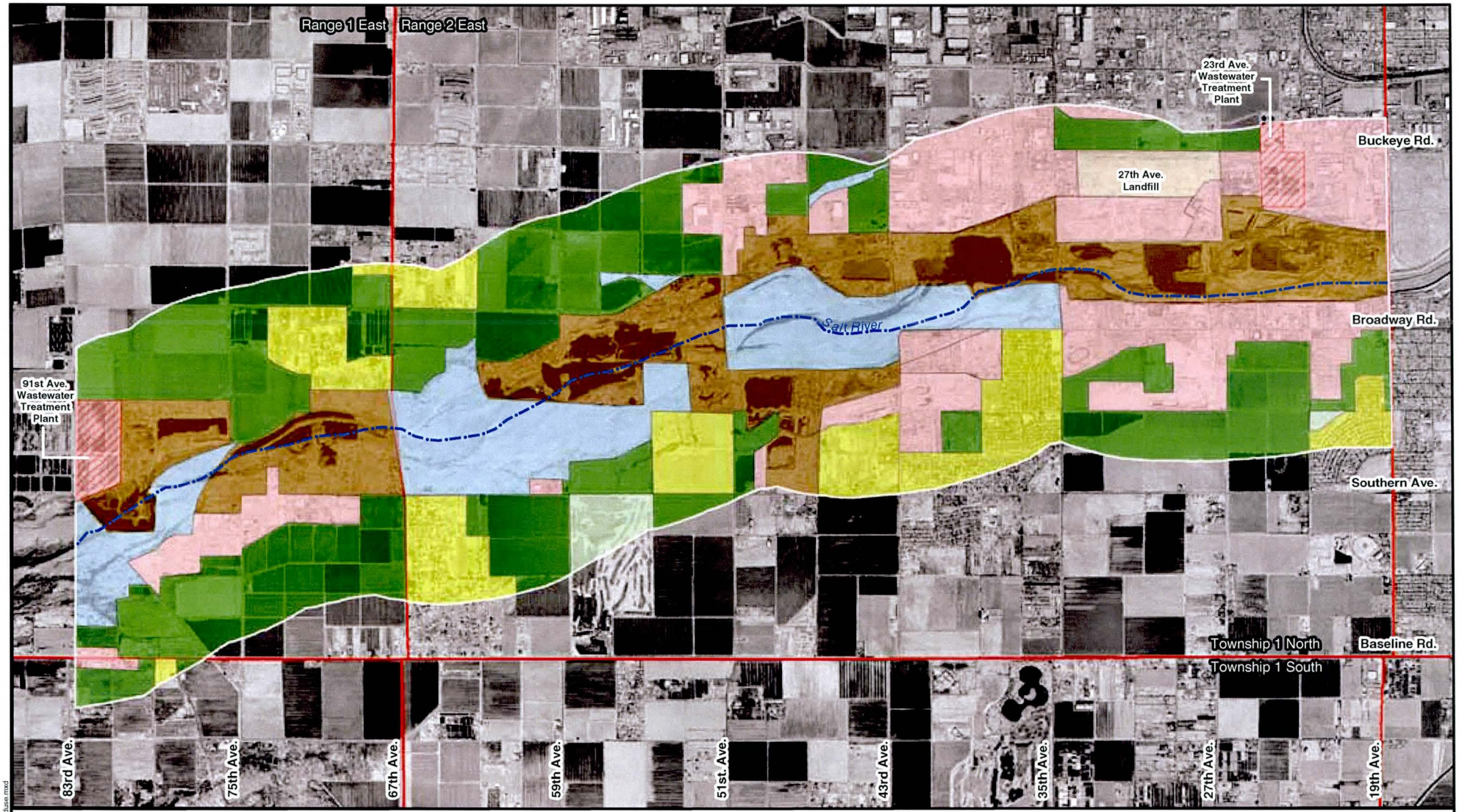
AVAILABLE UPON REQUEST

APPENDIX C

REPORT - ENVIRONMENTAL CONTAMINANTS IN FISH AND WILDLIFE OF THE LOWER GILA RIVER, ARIZONA

AVAILABLE UPON REQUEST

FIGURES



x:\city\of\phoenix\riooeste\gis\mxds\landuse.mxd

Legend

- Residential
- Commercial/Industrial
- Landfill
- Sand/Gravel Operation
- Agricultural
- Recreational
- River Bottom/Native

0 0.25 0.5 1

Scale In Miles

Map Scale 1:35,000

Image Source:
Kenney Aerial Mapping, 2000

N

Existing Land Use

Groundwater Quality and Hydrogeology Report
Rio Salado Oeste Project

Figure 1

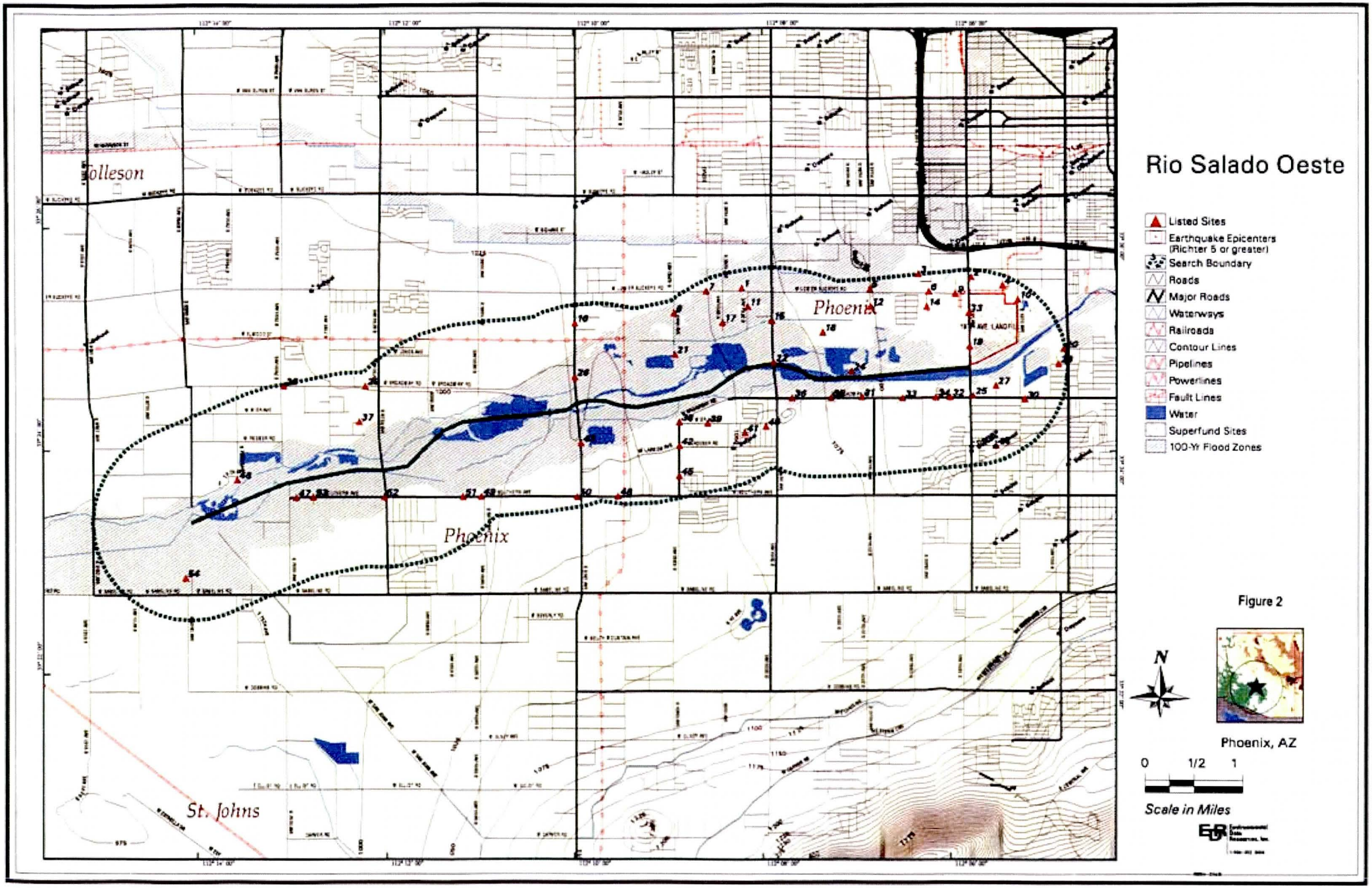

Rio Salado Oeste
Listed Sites
Earthquake Epicenters (Richter 5 or greater)
Search Boundary
Roads
Major Roads
Waterways
Railroads
Contour Lines
Pipelines
Powerlines
Fault Lines
Water
Superfund Sites
100-Yr Flood Zones
Tolleson
Phoenix
Phoenix
St. Johns
N
Phoenix, AZ
0 1/2 1
Scale in Miles

Figure 2

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE

Salt River-Phoenix, Arizona

Appendix G

Economics

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, ECONOMICS GROUP
P.O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

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PURPOSE

The following presents an economic evaluation of the benefits and costs associated with riparian habitat restoration, flood control and recreation opportunities along the Salt River (19th Avenue to 83rd Avenue) in Phoenix, Arizona.

METHODOLOGY

Methodology employed for this economic analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the *Planning Guidance Notebook – ER 1105-2-100.* Evaluation of environmental restoration alternatives has been completed in conformance with *IWR Report #95-R-1 -- Evaluation of Environmental Investments: Procedures Manual (May 1995).* Benefits and costs are computed at FY 2006 price levels utilizing the current Federal Discount rate of 5 1/8 percent. The period of analysis is 50 years. The Base Year for economic computations is 2010.

STUDY AREA

Location

The study area is located along the Salt River, in Phoenix, Arizona, between 19th Ave and 83rd Avenue. The study area is located in between the authorized Rio Salado and Tres Rios project areas. The study area includes portions of the City of Phoenix, Maricopa County, state and federal land. **Figure 1** shows the location of the Rio Salado Oeste study area. **Figure 2** provides an aerial view of the study area.

Problems & Opportunities

Environmental Resources

In pre-settlement times (prior to 1900) the Salt River was one of the few perennially-watered riparian areas of the Arizona Sonoran Desert, with highly productive cottonwood, willow, and mesquite habitats. These areas were rich in habitat diversity, supporting a wide variety of wildlife species. As the lower Salt River valley became developed, riparian habitat degraded significantly. The once perennial Salt River has now been transformed into a dry riverbed virtually devoid of habitat. Native plant species and wildlife habitat have been eliminated along the Salt River and adjacent overbank areas due to upstream water resources development, increased depths to groundwater beneath the river channel, changes in the natural flood regime, and land use changes, e.g., landfills and sand and gravel mining.

There is an opportunity to take advantage of existing open water bodies, in the river and adjacent properties, as potential restoration sites. Discharges from the 23rd Avenue Waste Water Treatment Plant, as well as underground water supply currently used for agricultural purposes, could be utilized to supplement surface water sources of water for restoration and other needs. There is also an opportunity to link other upstream and downstream projects to provide a continuous restoration and flood control corridor. These would include the authorized Rio Salado project, located immediately upstream of the project area, and the Tres Rios project, located immediately downstream of the project area.

FIGURE 1
RIO SALADO OESTE STUDY AREA
LOCATION

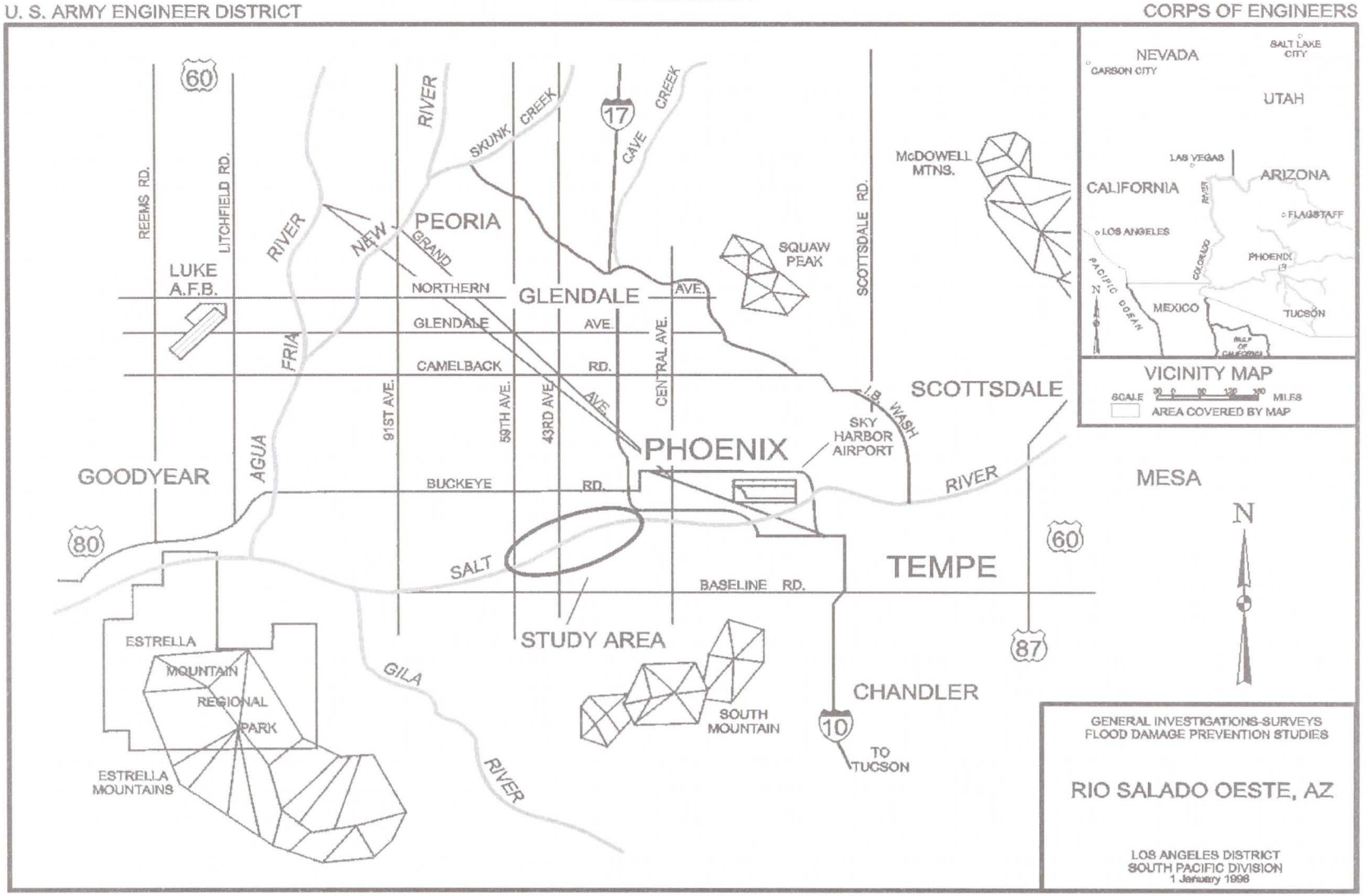
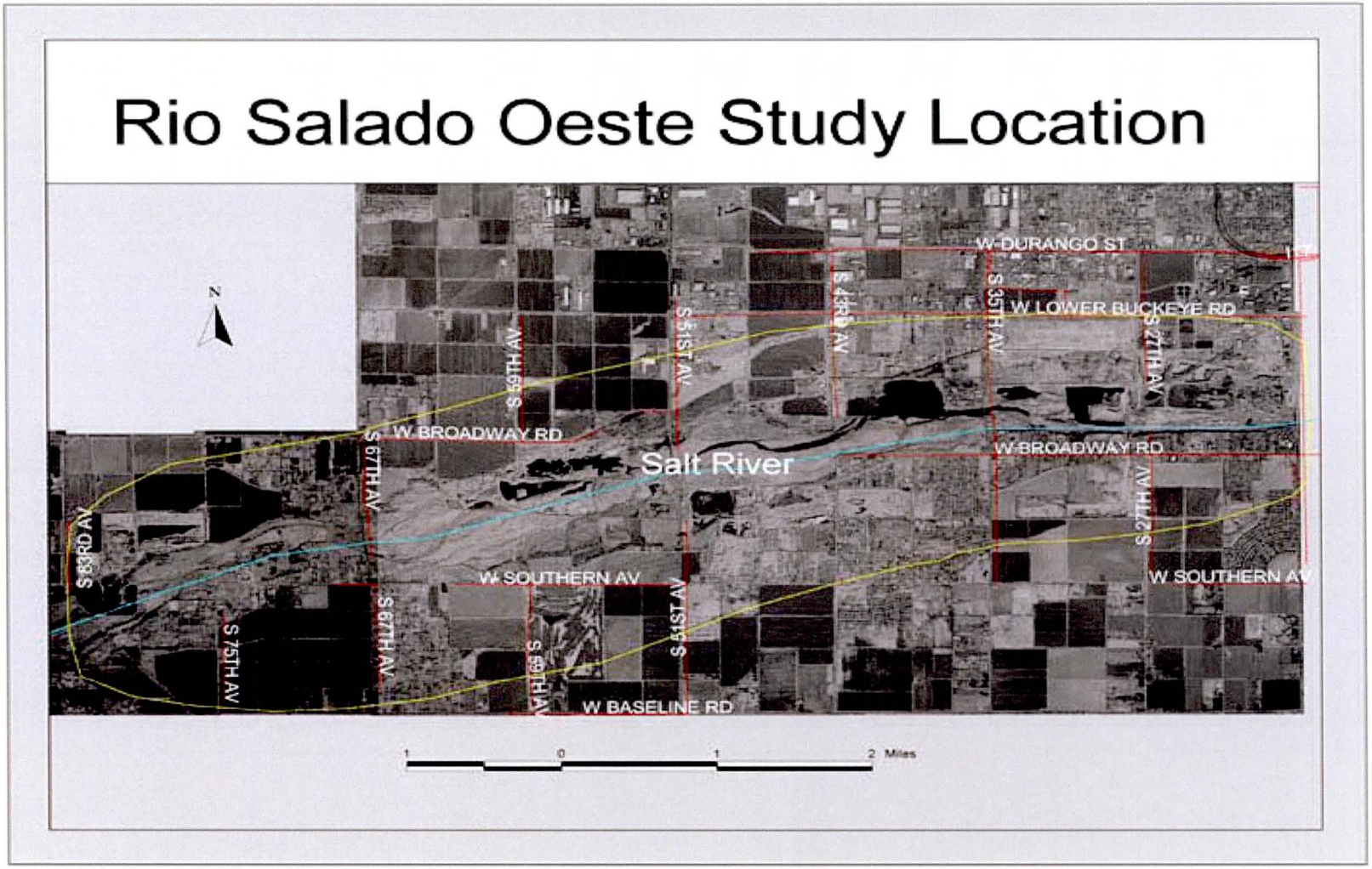


FIGURE 2
RIO SALADO OESTE STUDY AREA – AERIAL VIEW



Flooding

Flood flows along the Salt River through the Study Area that result from frequent flooding events are generally contained within the channel banks. However, during less frequent events, such as the 100-year and 500-year events, hydrologic and hydraulic analyses indicate that under existing conditions, there is a potential for significant flood damages. During these low-probability events, flood flows may overtop the channel banks and break out, primarily to the south of the River, and inundate many residential, industrial and agricultural properties. However, there are two anticipated actions that it is assumed will be taken under without-project conditions that will significantly reduce the potential for flooding in the Study Area.

The first important assumption is that improvements will be made to the 35th Avenue Bridge that crosses the Salt River. The configuration of this bridge contributes to the flooding problem in the Study Area. A hydraulic analysis has been conducted to determine the impact the proposed improvements will have on flooding in the Study Area. This analysis indicates that the flooding problem will be significantly reduced, and most structures that are currently susceptible to flooding during major events will no longer be threatened. Although flood damages with the planned bridge improvements would be limited, there still might have been opportunities to reduce potential food damages by implementing projects to increase the conveyance capacity of the Salt River through specific areas, particularly in the vicinity of 35th Avenue.

The second assumption relates to future aggregate mining operations within the Salt River. In 2003 the City of Phoenix purchased approximately 250 acres of riverbed between 35th and 51st Avenues. They have been working on a plan to lease the property for aggregate mining in a manner that allows aggregate to be removed while leaving a river cross section suitable for restoration. The likely alternative to have excess material removed from this reach and leave it in a state suitable for restoration will include an active channel varying in width from 300-600 feet and at the approximate elevation of the existing thalweg. Approximate 5 million tons of river material will be removed for this to occur. Once permitting and lease agreement is completed the City will allow aggregate to be removed as specified. The City has confirmed that this area would be leased for mining under both with and without-project conditions.

The impact of the proposed aggregate mining on flood damages is significant. An analysis of water surface profiles that incorporate the expected channel geometry after mining is completed shows that water surface elevations in the reaches where the mining will take place are significantly reduced. These same reaches also happen to be those with the highest damage potential under existing conditions.

Recreation

The City of Phoenix and Maricopa County have experienced tremendous population growth. While the number of parks has steadily increased in the greater Phoenix area, it has not kept pace with the growth in population. The current supply of recreation in the Study Area is insufficient, based upon local and national standards of required acres of recreation facilities per capita. This deficit is anticipated to increase in the future due to continued population growth in the Study Area.

There are no formal existing recreation or environmental education opportunities associated with the existing Salt River corridor in the Study Area. The 27th Avenue Solid Waste Recycling Facility (just north of the river) has an existing environmental education master plan. The facility provides tours for children and adults. The 23rd Avenue Waste Water Treatment Plant also does environmental education programming and touring for water treatment. These existing facilities provide an opportunity to link environmental education that could be developed for a restored river corridor. Upstream of the Study Area, the Rio Salado Project will include over ten miles of trails, an environmental education facility and passive recreation opportunities.

Passive recreation facilities are also planned downstream for the Tres Rios project. There are opportunities to link recreation facilities at the Study area with those that will be constructed upstream and downstream.

Population

The study area is located in central Maricopa County and extends through the city of Phoenix. As of July 2003, Maricopa County had a population of 3.39 million (the fourth highest in the nation). From 2000 to 2003, County population grew by over 317,000, representing an average annual growth rate of over 3.3 percent.

The city of Phoenix is by far the largest in the county in terms of population. Phoenix's population grew from about 1.15 million in 1995 to over 1.42 million in 2004, or by about 2.4 percent on an annual basis. About 41 percent of the County population resides within the City of Phoenix, although this ratio is declining, due to higher growth rates outside the city.

Population Projections

The following table displays population estimates and growth projections for Maricopa County and the City of Phoenix, obtained from the Maricopa County Association of Governments (MAG) and US Census websites. Strong growth for the County and City is expected through year 2050, although the rates of growth will be substantially lower than those experienced the past decade.

Table 1
Projected Population & Annual Growth Rate (AGR)
Maricopa County and the City Phoenix

Year	Maricopa County	AGR	City of Phoenix	AGR
1995	2,529,000		1,154,000	
2000	3,072,000	4.0	1,321,000	2.7
2010	3,710,000	2.0	1,544,000	1.6
2020	4,516,000	2.0	1,796,000	1.5
2050	7,265,000	1.6	2,568,000	1.2

Source: US Census and Arizona Department of Economic Security

The Arizona Department of Economic Security projects that population within the Phoenix metropolitan area will total over 7.26 million by the year 2050. Growth rates for the region are anticipated to be more than double the national average throughout the period of analysis.

The City of Phoenix is divided into 14 Urban Villages, with each addressing problems and needs related to the implementation of the General Plan. The two main villages in the study area are the Estrella Village to the north of the River and the Laveen Village to the south. Estrella Village encompasses about 41 square miles and is bounded by Interstate 10 on the north, 19th Avenue on the east, the Salt River on the south and 107th Avenue on the west. The Laveen planning area encompasses about 28 square miles and extends south of the Salt River and north of South Mountain between 27th Avenue and the Gila River Indian Community. The combined population in these two planning areas as of 2000 was approximately 53,000. The area experienced an annual growth rate of about 4.2 percent over the prior five years. MAG projections indicate that the

population for this area is expected to increase to about 86,000 by the year 2010 (or nearly five percent per year). Hence, this area is anticipated to experience high growth, outpacing the city and county as a whole.

The Study Area also includes a portion of the Rio Montaña subarea of the South Mountain Village. Rio Montaña encompasses about 10.4 square miles and extends from 27th Avenue to South Central Avenue, south of the Salt River and north of South Mountain Preserve. The Study Area therefore excludes that portion of Rio Montaña east of 19th Avenue. Rio Montaña had a population of about 26,000 as of 1995, although a significant portion of this total is upstream of the Study Area.

The Estrella Village Plan, approved by the Phoenix City Council in March 1999, projects that this planning area can accommodate a population of nearly 105,000. The current plans for Laveen (*Laveen: A Guide for Development*, prepared by the City of Phoenix South Area Planning Team) indicate that this planning area can accommodate a population of about 95,000. Hence, the planning areas extending along the Salt River through the study area have buildout population estimated at about 200,000 (excluding that portion of Rio Montaña between 27th and 19th Avenues).

Land Use

Based upon the City of Phoenix General Plan (Revised February 2001), most of the land area on the north side of the Salt River between 19th Avenue and 59th Avenue is zoned industrial, with some high-density residential between 43rd Avenue and 60th Avenue. From 60th Avenue to 83rd Avenue, the primary land use is low-density residential. South of the Salt River, there is some land between 19th Avenue and 35th Avenue zoned commercial. Otherwise the prevailing land use designation is low to medium density residential.

As noted earlier, Estrella Village and Laveen Village are the two primary planning areas that lie adjacent to the Salt River between 19th Avenue and 83rd Avenue. Estrella Village is characterized by an ample supply of undeveloped land, large parcels, natural and scenic amenities and excellent transportation access. As noted on the City of Phoenix website, the village also poses unique challenges given the isolation of its existing residential neighborhoods and the extensive industrial activities that have developed over the years. Approximately 62 percent of the Village is undeveloped, either vacant or with agricultural uses. However, there are 21 residential developments in various phases of approval and development.

The Laveen Village contains largely undeveloped and agricultural properties. Primary agricultural crops grown in the area include cotton, citrus and corn. The area has been valued by farmers, equestrians and those looking for solitude and mountain access. However, development pressures have increased in this area due to its proximity (about seven miles) to downtown. This pressure is expected to increase along with access to the future South Mountain Loop transportation corridor. There are twelve residential developments in various phases of approval and development in the Laveen Village area, which is anticipated to result in a doubling of population over the next decade.

The Rio Montaña planning area is also primarily comprised of agriculture, vacant land, and low-density residential uses. In fact, these categories, along with open space, represent over 85 percent of the space in this planning area.

Housing Unit Projections

According to the US Census and MAG, the ratio of persons per housing unit in the city and county is about 2.5. Assuming that this ratio holds in the future, Table 2 shows the number of additional housing units that would need to be built to accommodate the anticipated population increases.

Table 2
Projected Housing Unit Growth
Maricopa County and the City of Phoenix

	Maricopa County		City of Phoenix	
Period	Population Inc.	HU Inc.	Population Inc.	HU Inc.
2000-2010	638,000	255,000	223,000	89,000
2010-2020	806,000	322,000	252,000	101,000
2020-2050	2,749,000	1,100,000	772,000	309,000
Total	4,193,000	1,677,000	1,247,000	499,000

Table 2 shows that roughly 1.68 million new housing units would be needed in the county and about 499,000 in the city between 2000 and 2050 to accommodate projected future population increases.

Based upon the Proposed Land Use Map and Plan Element for Phoenix and the interactive maps supplied by the Maricopa County Association of governments obtained through the Internet, the residential land for the County and City will be developed at an average density ranging from two to five dwelling units per acre. The publication, *Valley Vision 2025* (February 2000), also posted on the MAG website, specifies an assumed density in the region of about 3.7 dwelling units per acre. Based upon this ratio, about 453,000 additional acres in the county, and about 135,000 additional residential acres in the city would need to be developed between 2000 and 2050.

MAG data indicate that, as of 1995, there were about 329,000 acres of residential property in the County. However, the General Plan shows that nearly ten times that amount is designated for future residential development. Most of that land is currently designated vacant, although it is assumed that a significant portion of existing agricultural land will be used in the future for residential development.

The current plans for Estrella and Laveen Villages project the number of dwelling units at buildout in these areas will be approximately 38,300 and 35,000, respectively. With a combined buildout population of about 200,000 and a combined number of dwelling units of about 73,000, the corresponding projected ratio of persons/household in the study area is about 2.74, which is slightly higher than the county average

Non-Household Projections

Commercial, industrial, office and public property currently represents about 39 percent of total residential development in area based upon 1995 data from MAG. Assuming that this ratio reflects future non-residential development requirements, the County, non-residential development through 2050 for the County is expected to total about 177,000 acres. The corresponding total for the city is about 53,000 acres.

According to 1995 land use data, there are 3,033,408 acres of vacant land in Maricopa County. Hence, it is not anticipated that the County will be completely built out by the end of the period of analysis. *Valley Vision 2025* states that there is enough vacant and planned land to adequately meet the demand for housing between now and 2025 without putting abnormal pressure on market prices, noting that less than ten percent of the 9,200 square miles in the region have been developed.

Summary

Rapid population growth is anticipated for the City of Phoenix as well as Maricopa County as a whole. Significant development of residential and non-residential land will be required to accommodate the projected growth. In the Study Area, existing land uses are primarily comprised of agriculture, industrial and low-density residential. It is anticipated that additional low-to-medium density residential development will take place due to the close proximity of the area to the City core. Existing vacant lots and agriculture land will likely be converted to residential uses.

Employment & Economy

The Phoenix area population growth illustrated above has been due primarily to net migration into the area. Factors contributing to this inmigration include diverse job availability, climate, quality of life, low cost of living, and a strong, diversified industrial base.

Statistics obtained from the City of Phoenix indicate that greater Phoenix accounts for 64 percent of Arizona=s workforce, with a labor force exceeding 650,000. Inmigration and high graduation levels from Arizona State University have provided local employers with a quality labor force. Primary industries in the area include aerospace and electronics manufacturing, business services, travel and tourism and information processing. Phoenix is also the state capital and home to the Maricopa County government, as well as many Federal government services. The following table provides breakdown of employment by industry in the greater Phoenix area.

Table 3
Greater Phoenix Employment by Industry

Services	33%
Trade	24%
Government	12%
Manufacturing	10%
Finance, Insur., & Real Estate	8%
Construction	7%
Transport., Comm. & Utilities	5%
Ag. & Mining	1%

Source: Arizona Dept. of Economic Security (December 2000)

From 1998 to 2003, non-farm payroll employment in Maricopa County increased by nearly 158,000. The largest increases have come in the construction, services and trade sectors. By far, the largest employer in the Phoenix area is the State of Arizona, which employs approximately 60,000. The City and County are also major public sector employers. Among private sector employers, information technology businesses have provided a large influx of employment to the area. As shown on Table 4 below, several high-tech firms, including Honeywell, Inc., Raytheon Co. and Intel Corporation, are now among the area=s five largest employers.

Table 4 Greater Phoenix Largest Private Employers	
Wal-Mart Stores, Inc.	19,189
Honeywell Inc.	13,303
Banner Health Systems	12,408
Raytheon Co.	10,100
Intel Corp.	9,575
Albertsons, Inc.	9,500
Bashas' Supermarkets	9,282
Wells Fargo & Co.	9,100
Kroger Co.	9,053
Target Corp.	8,778

Source: Arizona Republic:Tthe Republic 100 (2003)

The substantial growth in employment opportunities has helped maintain low unemployment rates in the Phoenix area in recent years. For example, unemployment rates in the Phoenix-Mesa Metropolitan Area (4.4 percent as of October 2005) have remained below the state (4.9 percent) and the national rates (5.0 percent).

To accommodate the population expansion in the area, more than 39,000 new residential building permits were issued in the greater Phoenix area in the first nine months of 2003 alone, exceeding the total for the entire year of 2002 according to the *Phoenix Business Journal* (December 1, 2003). According to information obtained from the City of Phoenix, over 30 percent of the housing stock has been constructed in the past 10 years. Most of the newer homes are constructed in master-planned communities, offering such amenities as lakes, golf courses and bike trails. New homes in the area are reasonably priced compared to other metropolitan areas. Low housing costs are a primary factor making the overall cost of living in Phoenix among the lowest of major U.S. metropolitan areas.

WITHOUT PROJECT CONDITIONS

Without Project Conditions are those conditions projected to prevail over the 50-year period of analysis in the absence of any management measures designed to address the problems and opportunities outlined earlier in this report. They serve as the basis for comparison to determine the benefits of proposed management measures. Hence, without-project conditions must first be calculated in order to ascertain the potential benefits that may result from implementing alternatives.

Environmental Resources

Due to dams and diversions, perennial flows on the Salt River have ceased. This has caused detrimental environmental impacts to natural wildlife habitat and riparian communities along the Salt River. The elimination of natural base flows reduced Salt River flows to summer or fall rainfall-related flood events. The ground water table beneath the river dropped. The soil moisture in the riverbed was virtually eliminated, and the native cottonwoods, willows and riparian ecosystem rapidly died out. Most areas of the Salt River are barren today. What little vegetation that does exist is mostly limited to salt cedar, an exotic non-native species with little habitat value.

There are a large number of open water areas along the Salt River, mostly the results of gravel mining. Adjacent to several of these there is dense vegetation including some cottonwood and willows as well as cattails and bulrush.

Hydrogeomorphic Model Description

The value of the limited amount of habitat existing in the Study Area has been assessed using a Hydrogeomorphic Modeling (HGM) process. HGM is an evaluation methodology in which the environmental impacts of projects are measured in ecological, rather than monetary terms. As a result, it is not possible to perform a direct benefit/cost analysis. Rather, the focus of HGM analysis, as well as other non-monetary evaluation techniques, is to determine the most cost-effective way to provide an array of environmental outputs. This is typically completed through an incremental cost analysis in which the marginal cost of providing additional environmental outputs is determined.

The U.S. Army Engineer Waterways Experiment Station has developed HGM for the purpose of assessing wetland functions. Wetland functions are a result of the interaction between the structural components of wetlands, such as soil, plants and animals, and the physical, chemical and biological processes that occur in wetlands. The assessment phase of the procedure is to measure the ability of a wetland to perform functions, in terms of its functional capacity. The functional capacity of a wetland is determined using a functional capacity index (FCI).

In HGM, an FCI model is a quantitative estimate of the functional capacity for a wetland. The ideal goal of an FCI model is to quantify and produce an index that reflects the functional capacity at the subject site. The results of an FCI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents the low functional capacity for the wetland, and 1.0 represents the high function capacity for the wetland. The FCI model can be defined in words or mathematical equations that clearly describe the rules and assumptions necessary to combine functional capacity indices.

Functional Capacity Units (FCU's) are a quantitative environmental value, considered to be the biological currency in the HGM methodology. FCUs are calculated by multiplying the area of available wetland (quantity) by the quality of the wetland based on functionality, which is represented by values derived from the FCIs. FCU = Area times FCI. Changes in FCUs represent potential impacts or improvements of proposed actions.

HGM Results – Without Project Conditions

FCI functions have been developed specifically for the desert southwest ecosystem along the Salt River. These functions have been applied to the existing areas of habitat throughout the Study Area to derive estimates of FCUs, both for existing and future without project conditions.

The first four functions (F1-F4) are water-related variables, such as surface and subsurface water storage and channel dynamics. The next three (F5-F7) are biochemical-related variables, such as the presence of required nutrients. Finally, the last three variables (F8-F10) are habitat-related variables, such as the quantity, type and locations of vegetation. Table 5 below summarizes the results. Note that FCUs for each function have been estimated for Target Years 0, 1, 6, 26, and 51 (Target Year 0 being existing conditions and Target Year 1 being equivalent to the first year of construction). These projected values were then converted into average annual FCUs (AAFCUs) for each function. The total combined AAFCU representative of without project conditions was derived by simply averaging the AAFCU values for each of the ten functions (i.e., no weighting was applied to the different functions, and each was therefore assigned equal importance in terms

of measuring the without project condition habitat value).

Table 5
Rio Salado Oeste Study Area
Without Project AAFCUs

	T0	T1	T6	T26	T51	AAFCUs
F1	414	414	414	414	414	414
F2	749	746	744	742	742	743
F3	452	443	436	439	439	439
F4	783	799	814	826	826	821
F5	496	485	472	465	465	468
F6	669	659	647	645	645	647
F7	589	585	580	578	578	579
F8	748	744	740	737	737	738
F9	531	523	514	508	508	511
F10	401	401	437	438	438	435
Avg	583	580	580	579	579	**580**

As shown in Table 5, AAFCUs are projected to remain fairly stable over the planning horizon. The AAFCU value of 580 will be the basis for comparison when assessing the potential benefits of proposed restoration alternatives.

Flood Damages

The Salt River Project maintains four dams on the Salt River, as well as two on the Verde River. Granite Reef Diversion Dam is located about five miles downstream of the confluence of the Salt and Verde Rivers. At this dam site, all water is taken from the Salt River and diverted into the Arizona and South Canals, which deliver drinking and irrigation water to the greater Phoenix area. During significant flood events, the Salt River Project is forced to release water over Granite Reef Dam into the normally dry Salt River.

Historical Flood Damages

The highest release from Granite Reef Dam since the construction of the Salt and Verde River dams occurred in February 1980, when 178,000 cubic feet per second was released because of heavy rains and rapid snowmelt in the watersheds. All downstream bridges through Phoenix were forced to close during that flood except the Central Avenue Bridge. Subsequently, most of the remaining bridges crossing the Salt River have been rebuilt to withstand flow rates of 200,000 cfs and greater.

High releases were also experienced in 1993 (approximately 130,000 cfs). Winter floods during the first three months of 1993 caused extensive damage to property and crops. Total flood damages throughout Arizona during this storm were estimated at over $250 million in current dollars.

Information regarding damages estimates specific to the study reach were not available. However, current hydrologic data for the Salt River through the Study Area shows that peak discharges for the 50-year, 100-year and 200-year events are approximately 135,000 cfs, 165,000 cfs and 200,000 cfs, respectively. Current hydraulic analysis indicates that there are very few structures in the 50-year floodplain, and most floodplain structures are outside the 100-year floodplain. Therefore, it is likely that damages throughout the Study Area reach were limited during these storms.

Floodplain Boundaries & Reach Definitions

As specified earlier in the report, there is potential for significant flood damages under *existing* conditions. However, the planned improvements to the 35th Avenue Bridge and the aggregate mining that will take place from 35th to 51st Avenues will virtually eliminate damages in the adjacent reaches. **Figure 3** shows the Base Year floodplain boundaries which reflect the proposed bridge improvements being in place, but *do not reflect the assumed aggregate mining*. As shown on Figure 3, the floodplain is primarily confined within the channel, with only minor flooding even for the 500-year flood event. **Figure 4** shows a comparison of the 500-year floodplains for existing and Base Year conditions with the assumed bridge improvements. As clearly shown on Figure 4, potential flood damages without the planned bridge improvements would be significantly higher. Additional floodplain delineations showing Base Year floodplain boundaries with both the bridge improvements and the mining have not been prepared. However, water surface profiles have been developed, and an analysis of these water surface profiles shows that the potential for flooding in the 35th Avenue area is greatly reduced.

The following presents a summary of the analysis of potential flood damages WITHOUT the assumed aggregate mining. It was previously assumed that the aggregate mining would only take place under the with-project conditions, and accordingly, the without-project flood damage analysis did not reflect the impact of the mining. Also, price levels for the structure inventory & damages represent FY05 price levels.

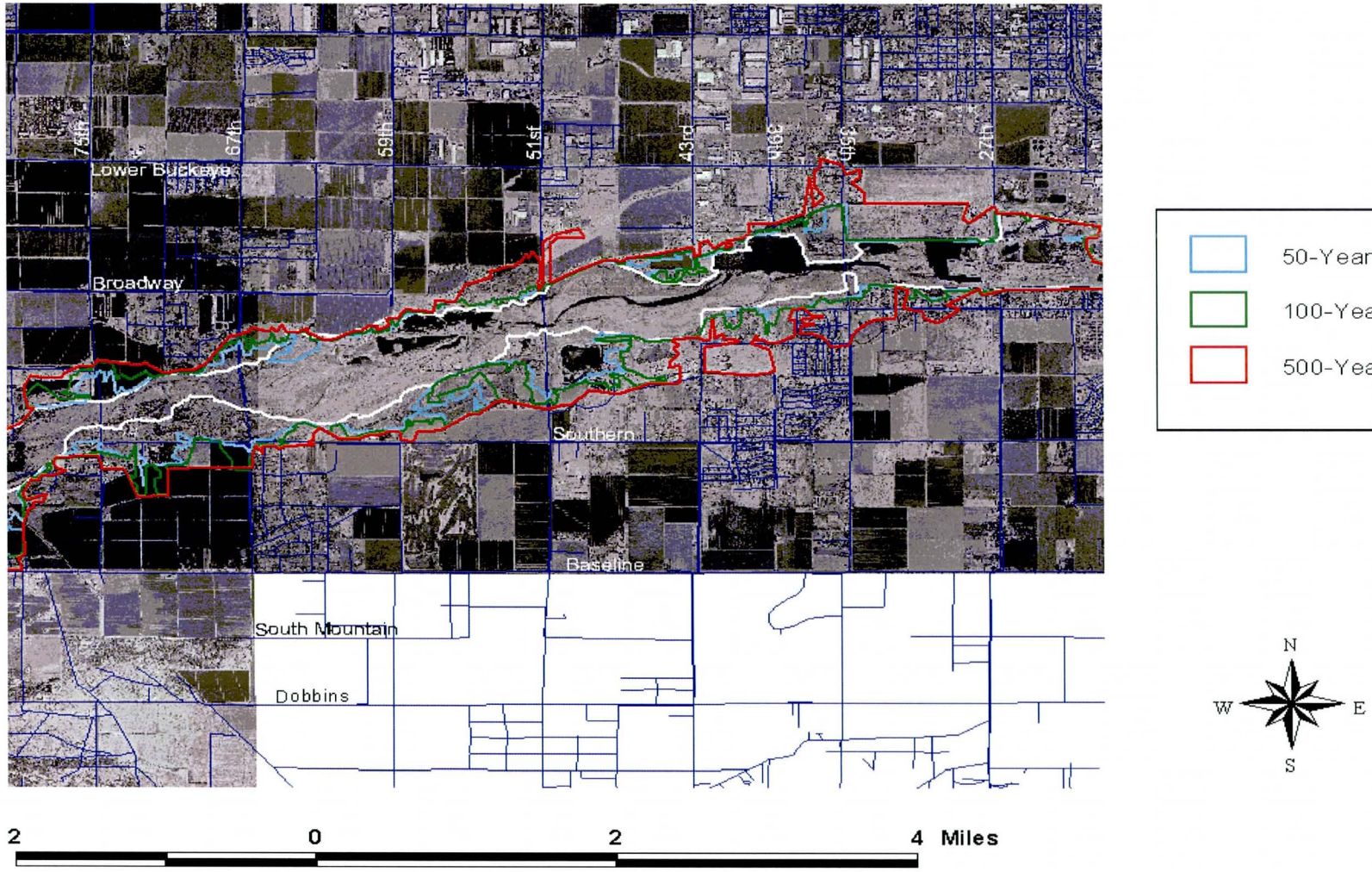
Before determining potential damages within the floodplain, an inventory of structures susceptible to damage and estimates of the value of these structures must first be developed. The floodplain has been further segmented into sub areas, or Reaches, for analysis purposes. Critical factors used to determine reach boundaries include: discharge/frequency characteristics, overflow spatial characteristics, and economic activity. **Figure 5** shows floodplain reach Boundaries. **Table 6** below provides a summary of reach characteristics, including approximate upstream and downstream boundaries. The "R" and "L" designations denote that the reach only includes the areas on the north (Right, looking downstream) or south (Left) side of the river, respectively.

Table 6
Rio Salado Oeste
Floodplain Reach Definitions

Reach Name	Upstream Limit	Downstream Limit	Notes
1L	75th Ave.	91st Ave.	Only a few structures in this reach.
2L	67th Ave.	75th Ave.	Small # of industrial and agric. properties along Southern Ave., some residential along Baseline Road
2R	67th Ave.	75th Ave.	Small # of Structs at NW corner of Roeser & 67th
3L	51st Ave.	67th Ave.	Residential development at downstream end –NW of Baseline and 67th. Removed under Base Year Conds.
4L	43rd Ave.	51st Ave.	Small Number of Structures along 51st Ave. North of Southern.
4R	43rd Ave.	51st Ave.	Includes a few structures just west of 51st Ave. adjacent to floodway.
5L	35th Ave.	43rd Ave.	Large residential dvlpmt.in this reach on south side of River. Most of development removed from floodplain under Base Yr. conditions.
5R	35th Ave.	43rd Ave.	Mostly industrial structures, concentrated south of Lower Buckeye, between 35th & 39th Aves.
6L	27th Ave.	35th Ave.	Limited industrial/commercial development, primarily along Broadway Road
6R	27th Ave.	35th Ave.	Mostly industrial structures, concentrated along east side of 35th Ave., Lower Buckeye to floodway.
7R	19th Ave.	27th Ave.	Small number of structures near 27th Ave. on north side of Salt River under Existing Conditions – Removed under Base Year conditions.

NOTE – DOES NOT REFLECT ASSUMED W/O PROJECT MINING FROM 35th to 51st Ave.

Figure 3
Rio Salado Oeste Floodplain Boundaries (Base Year)



NOTE – DOES NOT REFLECT ASSUMED W/O PROJECT MINING FROM 35th to 51st Ave

Figure 4
Rio Salado Oeste 500-Year Floodplains - Existing & Base Year

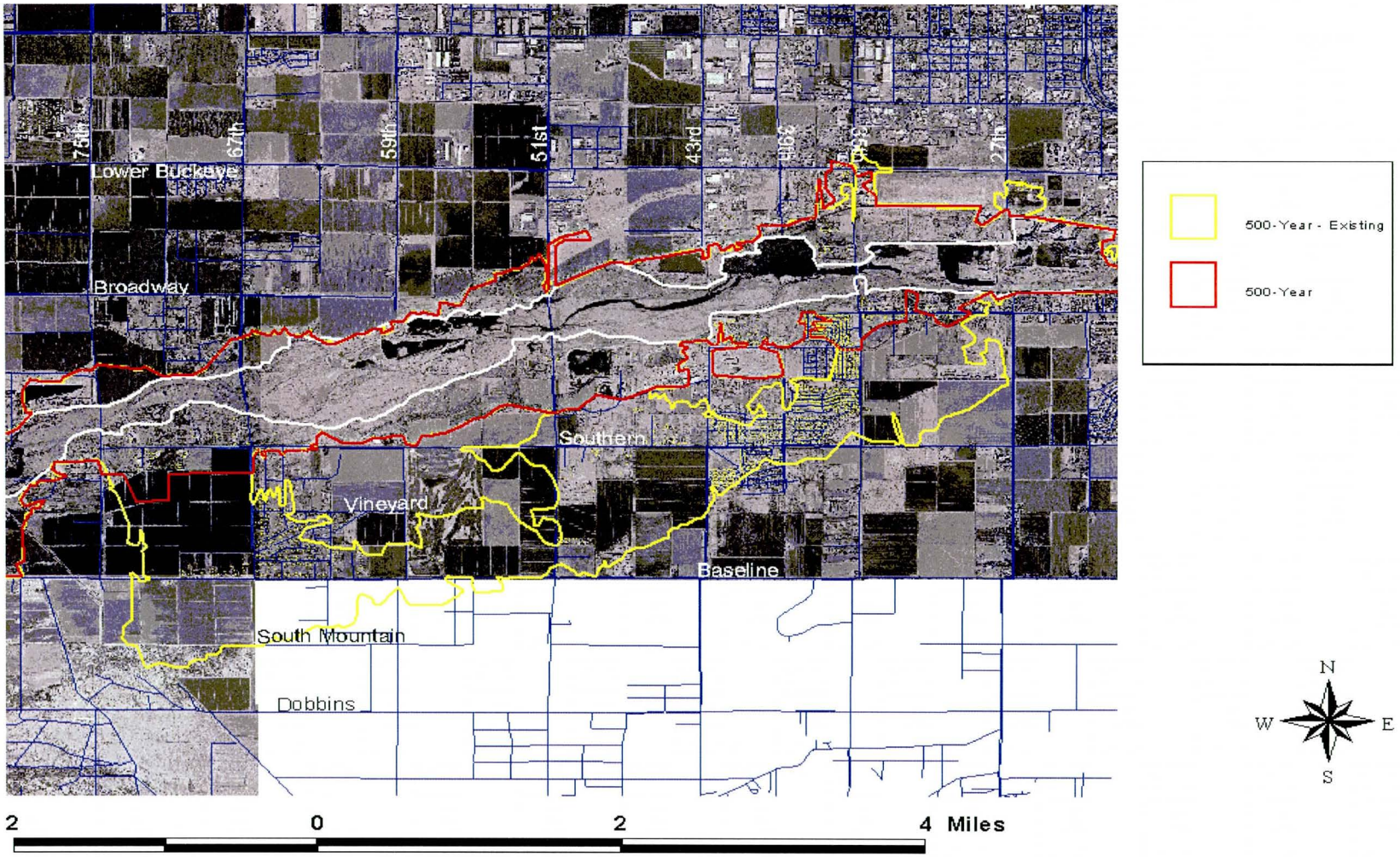
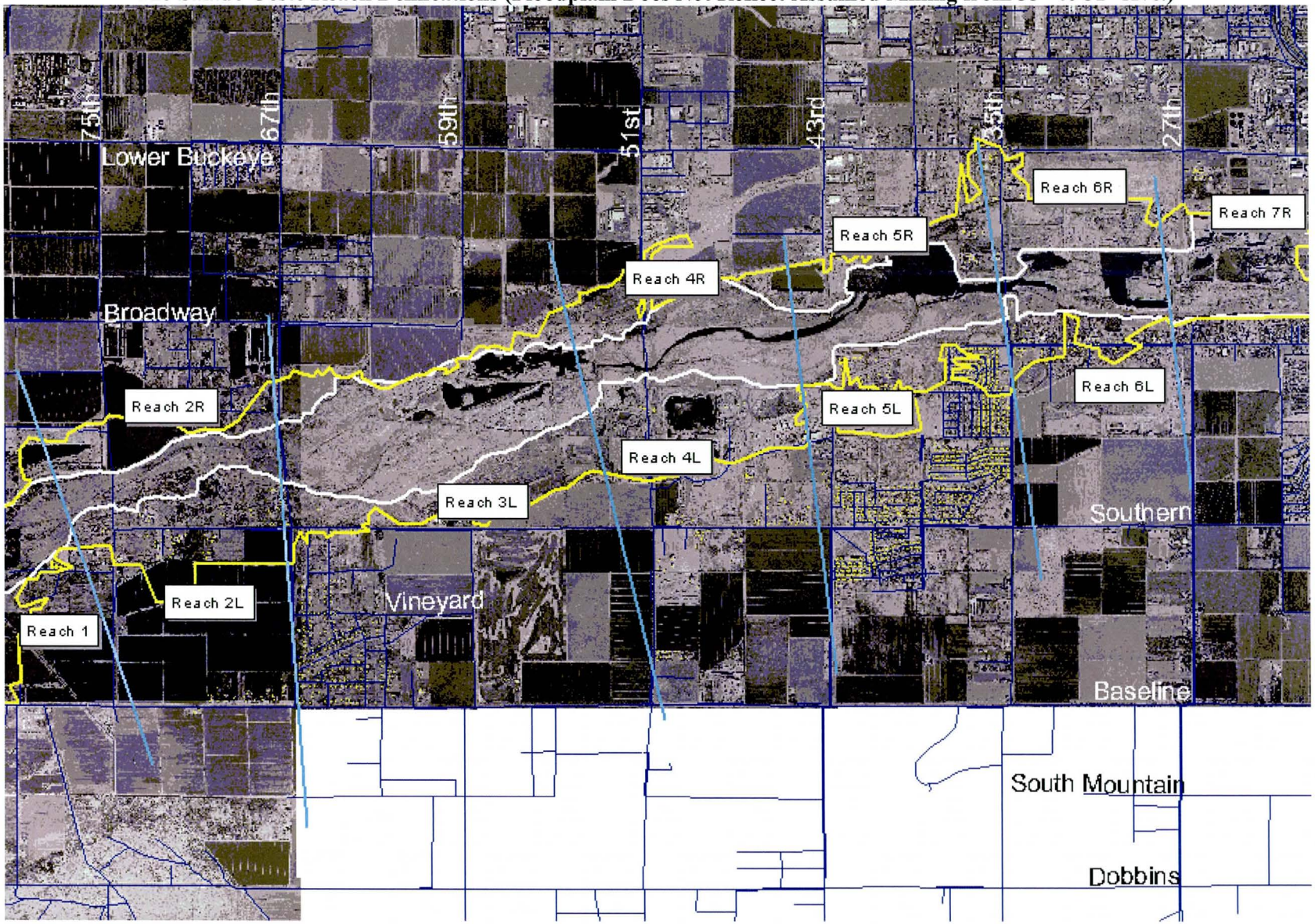


FIGURE 5

Rio Salado Oeste Reach Delineations (Floodplain Does Not Reflect Assumed Mining from 35th to 51st Ave.)



As indicated in the notes in Table 6 and as can be seen in Figure 5, Reach 5L contains the majority of floodplain structures. This area contains about 200 structures, primarily residential (including both single-family residences and mobile homes). Structures in this area are generally of fair to low-cost construction. Most single-family residential structures are of block construction. It is likely that most, if not all of these structures would be removed from the floodplain with the anticipated aggregate mining reflected in the delineation.

Number of Structures

The number of structures in the 100-year and 500-year floodplains was determined based upon an analysis of aerial photography, parcel maps, real estate assessor's data and a site survey. **Tables 7 and 8** which follow show the number of structures by reach, floodplain and structure type.

Table 7
Rio Salado Oeste 100 & 500-Year Floodplains
Number of Structures

Structure Type	100-Year	500-Year
SFR	15	207
MH	19	22
Industrial/Agric.	78	114
Office/Commercial	27	43
Public	0	0
Total	139	386

Table 7 shows that there are approximately 386 structures in the Rio Salado Oeste floodplain. Of this total, most (59 percent) are residential. Roughly 139 structures are located within the 100-year floodplain boundaries (about 36 percent of the structures in the 500-year floodplain).

Table 8
Rio Salado Oeste 500-Year Floodplain
Number of Structures by Reach

Location	Number of Structures
Reaches 2R through 7R (All North of River)	70
Reaches 1L, 2L (S. of River, West of 67th)	36
Reach 3L (S. of River, 67th to 51st)	8
Reach 4L (S. of River, 51st to 43rd)	5
Reach 5L (S. of River, 43rd to 35th)	195
Reach 6L (S. of River, East of 35th)	72
Total	386

As indicated in Table 8, more than half of floodplain structures are located in Reach 5L, and about 19 percent are located in Reach 6L. There are very few structures located within the floodplain on the north side of the Salt River. Most are industrial and storage structures located in Reaches 5R and 6R.

Value of Structures & Contents

Depreciated structure values were calculated as follows:

1) Square footage for each structure was obtained from real estate assessor's data.

2) Structure construction type and condition were noted during a field survey.
3) Appropriate Marshall & Swift Valuation Service multipliers were determined for each structure based upon its condition, classification and construction type. These multipliers were applied to square footage estimates to derive depreciated structure replacement values.
4) Values were adjusted to reflect local building costs for the Maricopa County area using Marshall & Swift locality multipliers.

Content values were estimated as a percentage of depreciated structure value for each structure. Content ratios by structure type were based upon values derived for several recent Los Angeles District Feasibility Studies. The study areas for all of these projects were located in the Southwestern U.S. Ratios were developed based upon a statistical analysis of content surveys mailed to local residents. The content ratios by structure type used for this study are as follows:

- Residential 50%
- Commercial 140%
- Industrial/Agriculture 171%
- Office 80%
- Public 33%

Tables 9 and 10 provide a summary of floodplain structure and content values, respectively, by structure category and reach.

Table 9
Rio Salado Oeste 500-Year Floodplain
Value of Structures & Contents By Structure Type
(In $Millions)

Structure Type	Struct Val	Cont Val	Total
SFR	10.5	5.3	15.8
MH	1.3	0.6	1.9
Industrial/Agric.	11.4	19.4	30.8
Office/Commercial*	5.6	5.2	10.8
Public	0	0	0
Total	28.8	30.5	59.3

** Structure & content values and damages calculated separately for office and commercial structures, but added for report purposes.*

Table 10
Rio Salado Oeste 500-Year Floodplain
Value of Structures & Contents By Reach
(In $Millions)

Location	Struct Val	Cont Val	Total
Reaches 2R through 7R (All N. of River)	11.7	15.7	27.4
Reaches 1L, 2L (S. of River, West of 67th)	2.8	3.3	6.1
Reach 3L (S. of River, 67th to 51st)	1.0	0.5	1.5
Reach 4L (S. of River, 51st to 43rd)	0.3	0.2	0.5
Reach 5L (S. of River, 43rd to 35th)	8.8	5.0	13.8
Reach 6L (S. of River, East of 35th)	4.2	5.8	10
Total	28.8	30.5	59.3

As displayed on Tables 9 and 10, the total estimated value of property in the floodplain is about $59.3 million.

Although nearly 51 percent of floodplain structures are located in Reach 5L, the value of property in this reach is only about 23 percent of the total value for the 500-year floodplain. This is attributable to the fact that almost all of the structures in Reach 5L are fair/low cost residential structures, whereas other reaches include more higher-value industrial and commercial structures. Table 9 shows that although residential structures (i.e., single family residences and mobile homes) represent about 59 percent of total floodplain structures, they only account for about 30 percent in terms of value.

Without Project Structure & Content Damages

Overview of Methodology

A risk-based analysis (RBA) procedure has been used to evaluate without project flood damages in the study area. Guidance for conducting RBA is included in Corps Engineering Regulation 1105-2-101, *Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability and Economics in Flood Damage Reduction Studies (1 March 1996).*

The guidance specifies that the derivation of expected annual flood damage must take into account the uncertainty in hydrologic, hydraulic and economic factors. Risk and uncertainty are intrinsic in water resource planning and design. They arise from measurement errors and the inherent variability of complex physical, social and economic situations. Best estimates of key variables, factors, parameters and data components are developed, but are often based on short periods of record, small sample sizes, measurements subject to error, and innate residual variability in estimating methods. RBA explicitly analytically incorporates these uncertainties by defining key variables in terms of probability distributions, rather than single-point estimates. The focus of RBA is to concentrate on the uncertainties of variables having the largest impact on study conclusions.

The following are the primary sources of uncertainty for flood damage analysis studies:

1) Discharge/Probability: For a flood or storm event with a given probability of occurrence, there is uncertainty regarding what the resulting discharge will be at a specific location along the stream or river. The reliability of discharge/probability estimates is directly linked to the historical record of stream gauge data available. In cases where records are small or incomplete, the associated uncertainty increases. To address this uncertainty, an analytical or graphical method is typically used to determine statistical distributions of discharge for a range of probabilities at locations throughout the floodplain.

   For this study, discharge/probability uncertainty has been estimated for each reach using the graphical method, based upon an equivalent record length of 105 years.

2) Stage/Discharge: For a given discharge, there is uncertainty regarding what the resulting water surface elevation will be at a given location. Factors contributing to this uncertainty include bed forms, water temperatures, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, changes in channel shape during or as a result of flood events, as well as other factors. To address this uncertainty, standard deviation estimates are developed for stages associated with a range of discharges at locations throughout the floodplain.

   For this study, the standard deviations of error for stages associated with a range of discharges were provided for each reach by Engineering Division. The error values generally increase in value from about 0.1 feet for the 5-year flood event up to about0.7 feet for 100-year to 500-year

flood events.

3) Geotechnical Features: When there are improvements such as levees along a river or stream, there is uncertainty regarding how effective they will be in containing a given flood event. Specifically, there is uncertainty regarding what combination of discharge and stage will result in levee failure. To address this uncertainty, probable failure and non-failure points (elevations) for levees are determined at various locations along the levee's length.

There are not any existing levees along the Salt River in the Rio Salado Oeste study area.

4) Structure Elevation: A structure's susceptibility to being inundated is a function of its location within the floodplain and its elevation. There are two sources of potential error in determining elevation. The first is the topographic ground elevation of the structure. This uncertainty is a function of the data source used to derive the elevation estimate. For example, there is greater potential error associated with elevation estimates derived from examining a 5-foot contour topographic map than a 2-foot aerial survey contour map. The other source of uncertainty is associated with estimates of first floor elevations above ground level (or foundation height). This variable is key, as a structure built on fill or with a large crawl space, for example, may sustain only minor or no damages, even though the surrounding ground is underwater. First floor elevation estimate errors also vary with the methods used to derive them, ranging from best-guess estimates from windshield surveys to professional surveys. Statistical uncertainty in elevation is typically determined by referencing the standard deviation estimates contained in Corp Engineering Manual 1110-2-1619 – *Risk Based Analysis for Flood Damage Reduction Studies (1 August 1996).* This publication presents standard deviation estimates for a wide range of measurement methods.

For this study, ground elevations for each structure were derived from a 2-foot interval digital elevation model in GIS format. First floor elevations above ground level were estimated during a field survey. Based upon the Engineering Manual cited above, the error associated with first floor elevation estimates is assumed to be normal, with a mean of 0 and a standard deviation of 0.6 feet.

5) Structure Values: Structure values have been determined based upon Marshall & Swift multiplication factors applied to square footage estimates. Square footage estimates were primarily obtained from real estate assessor's data and are determined to be accurate. The primary source of potential error results from misclassification of a given structure in terms of its construction quality and condition. The errors associated with structure value estimates are assumed to be normal, with a mean of 0 and standard deviations ranging from 10 to 21 percent (depending on structure type), based upon upper and lower ranges of M&S factors.

6) Inundation Depth/Percent Damage: There is considerable uncertainty regarding the percentage of damage to structures and contents given a certain level of flooding. The National Flood Insurance Program of FEMA collects damage data following flood disasters and publishes depth/damage functions. These functions are used to derive estimates of damages to non-residential structures. For residential structures, depth-damage functions and associated standard error estimates have been developed by the Institute for Water Resources based upon a statistical analysis of actual flood damages that have occurred throughout the United States. Damage percentages for both structures and contents are based upon corresponding structure values. These functions were used for this analysis.

The Corps of Engineers Hydrologic Engineering Center has developed software specifically designed for

conducting RBA, referred to as the HEC-FDA Program (Version 1.2 used for this analysis). This program applies a Monte Carlo simulation process, whereby the expected value of damages is determined explicitly through a numerical integration technique accounting for uncertainty in the basic parameters described above. Data requirements for the program include:

- Structure data, including structure I.D., category (sfr, mfr, etc.), stream location, ground and/or first floor elevation, structure value and content value. This data was developed in a Microsoft Excel spreadsheet and imported into the HEC-FDA program.
- Hydrologic and hydraulic data, including water surface profiles, frequency/discharge relationships, and stage/discharge relationships. For this study, water surface profiles were developed using the HEC-RAS program. These functions were imported into the HEC-FDA program.
- Depth/Damage functions. Functions for residential and non-residential structures were obtained from the Institute for Water Resources and FEMA's National Flood Insurance Program.
- Risk & Uncertainty Parameters, as described in detail previously, were also entered into the program.

Results – Base Year (2010)

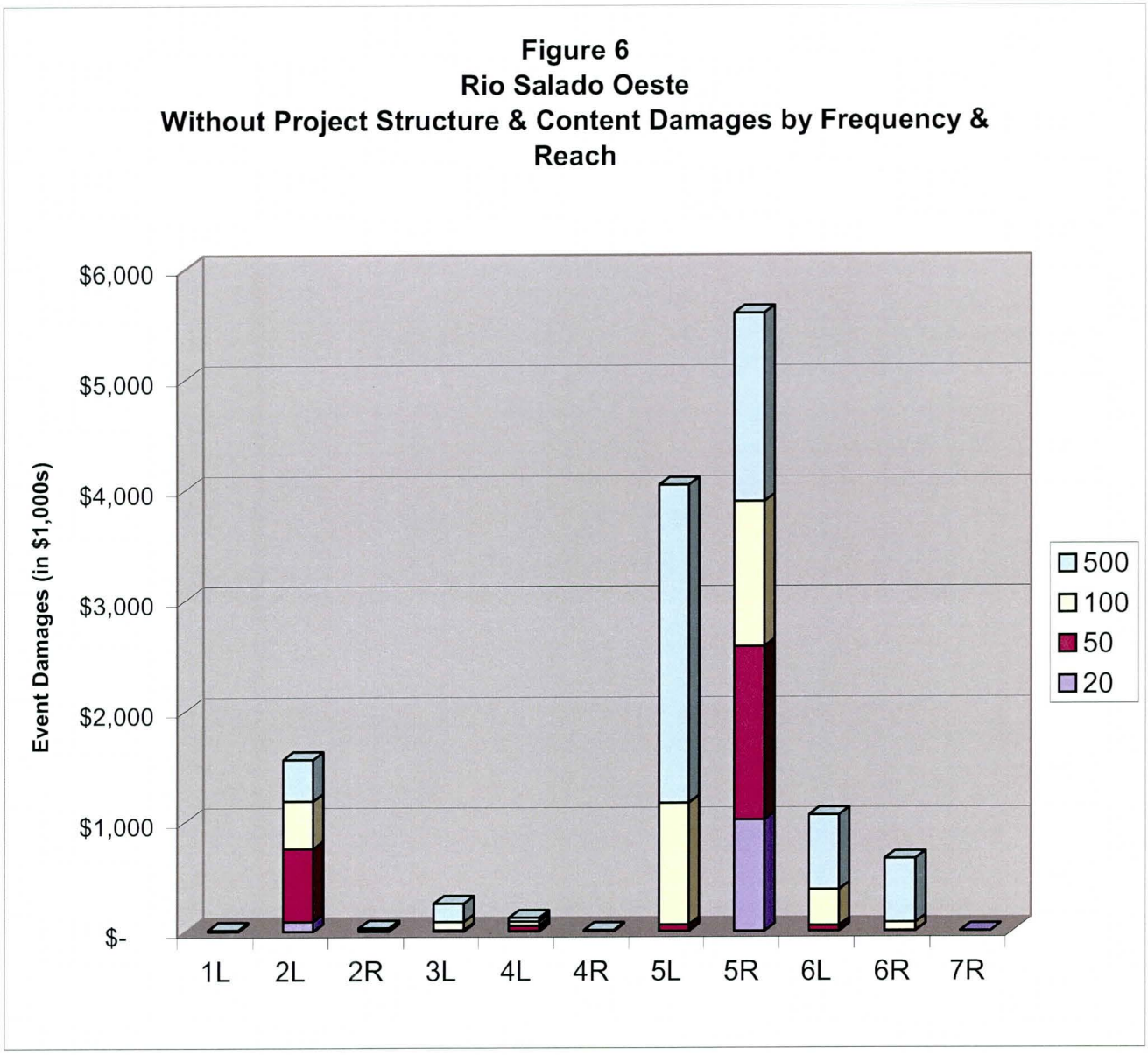
Without project damages by event for Base Year conditions, as calculated by the HEC-FDA program, are shown in **Tables 11** and on **Figure 6.** The non-damaging event is approximately the 10-year event. However, most reaches do not incur damages until less frequent events. Damages calculated for the 20-year event are approximately $1.14 million. A majority of these damages are attributable to one parcel within Reach 5R. There are approximately 11 industrial structures on this parcel (located adjacent to the floodway on the west side of 35th Avenue) owned by a metal scrap recycling business.

Damages increase significantly for the 50-year event, and approximately double subsequently for the 100-year and 500-year events. A majority of damages for these flood events are expected to occur in Reaches 5R and 2L (primarily industrial properties) and 5L (which is the reach with the large residential development discussed previously).

Table 11
Rio Salado Oeste
Without Project Damages By Reach & Event (Base Year – 2010)
(in $1,000s)

Reach	10	20	50	100	500
1L	$ -	$ -	$ -	$ 1	$ 13
2L	$ -	$ 88	$ 754	$ 1,183	$ 1,561
2R	$ -	$ -	$ -	$ 8	$ 30
3L	$ -	$ -	$ 10	$ 87	$ 254
4L	$ -	$ 4	$ 52	$ 90	$ 125
4R	$ -	$ -	$ -	$ -	$ 10
5L	$ -	$ -	$ 59	$ 1,163	$ 4,039
5R	$ 38	$ 1,050	$ 2,615	$ 3,929	$ 5,633
6L	$ -	$ -	$ 52	$ 378	$ 1,056
6R	$ -	$ -	$ 2	$ 78	$ 659
7L/7R	$ -	$ -	$ -	$ -	$ -
Total	$ 38	$ 1,142	$ 3,544	$ 6,917	$ 13,380

Figure 6
Rio Salado Oeste
Without Project Structure & Content Damages by Frequency & Reach



Expected annual damages by reach and structure type are shown on Table 12. Damages to industrial and agricultural structures and contents, primarily located in Reaches 2L and 5R, comprise most of the expected annual damages. This is attributable to the fact that these two reaches contain structures that are within close proximity of the floodway, and therefore are susceptible to more frequent flood events. It should be noted that these results reflect planned bridge improvements at 35th Avenue. Preliminary analysis indicates that expected annual damages without these improvements would be substantially higher (approximately $670,000 vs. $245,000).

Table 12 Rio Salado Oeste Without Project Expected Annual Damages – Base Year (in $1,000s)					
Reach	**SFR/MH**	**Ind/Ag**	**Office/Com**	**Public**	**Total**
1L	$ -	$ -	$ -	$ -	$ -
2L	$ 8	$ 26	$ 2	$ -	$ 35
2R	$ -	$ -	$ -	$ -	$ -
3L	$ 2	$ -	$ -	$ -	$ 2
4L	$ 2	$ -	$ -	$ -	$ 2
4R	$ -	$ -	$ -	$ -	$ -
5L	$ 31	$ 4	$ 1	$ -	$ 36
5R	$ -	$ 138	$ 17	$ -	$ 155
6L	$ 1	$ 6	$ 3	$ -	$ 10
6R	$ 1	$ 3	$ 1	$ -	$ 5
7L/7R	$ -	$ -	$ -	$ -	$ -
Total	$ 45	$ 177	$ 24	$ -	$ 245

Results – Future Conditions (2059)

Hydrologic and hydraulic analyses were conducted for future without project conditions to determine the impacts of processes such as sedimentation and channel degradation and the resulting impacts on potential flooding. Updated water surface profiles and stage/discharge uncertainty data were used to recompute expected annual damages under future conditions. Table 13 summarizes the results.

Table 13 Rio Salado Oeste Without Project Expected Annual Damages – Future Conditions (2059) (in $1,000s)					
Reach	**SFR/MH**	**Ind/Ag**	**Office/Com**	**Public**	**Total**
1L	$ -	$ -	$ -	$ -	$ -
2L	$ 4	$ 16	$ 1	$ -	$ 21
2R	$ -	$ -	$ -	$ -	$ -
3L	$ 2	$ -	$ -	$ -	$ 2
4L	$ 1	$ -	$ -	$ -	$ 1
4R	$ -	$ -	$ -	$ -	$ -
5L	$ 8	$ 4	$ 1	$ -	$ 13
5R	$ -	$ 98	$ 14	$ -	$ 112
6L	$ 1	$ 5	$ 2	$ -	$ 8
6R	$ -	$ 1	$ 1	$ -	$ 2
7L/7R	$ -	$ -	$ -	$ -	$ -
Total	$ 16	$ 124	$ 19	$ -	$ 159

Without project expected annual damages actually decrease from about $245,000 under Base Year conditions to about $159,000 under future conditions (a drop of about 35 percent). Water surface elevations are generally lower throughout the Study Area under future conditions due primarily to projected channel degradation and resulting increases in channel capacity (refer to Hydraulic appendix for details).

Equivalent annual damages were computed based upon forecast annual damages using a discount rate of 5 1/8% (see Table 14).

Table 14 Rio Salado Oeste Without Project Equivalent Annual Damages (50 Yrs, 5 1/8%) (in $1,000s)					
Reach	**SFR/MH**	**Ind/Ag**	**Office/Com**	**Public**	**Total**
1L	$ -	$ -	$ -	$ -	$ -
2L	$ 7	$ 23	$ 2	$ -	$ 32
2R	$ -	$ -	$ -	$ -	$ -
3L	$ 2	$ -	$ -	$ -	$ 2
4L	$ 2	$ -	$ -	$ -	$ 2
4R	$ -	$ -	$ -	$ -	$ -
5L	$ 24	$ 4	$ 1	$ -	$ 29
5R	$ -	$ 126	$ 16	$ -	$ 142
6L	$ 1	$ 6	$ 3	$ -	$ 10
6R	$ 1	$ 2	$ 2	$ -	$ 5
7L/7R	$ -	$ -	$ -	$ -	$ -
Total	$ 37	$ 161	$ 24	$ -	$ 222

Without Project Emergency & Cleanup Costs

Cleanup, Debris Removal & Public Infrastructure Repairs

Emergency costs are defined as those expenses resulting from a flood that would not otherwise be incurred. Emergency costs include such items as emergency protective measures, post-flood cleanup and debris removal, utility repairs, and evacuation, reoccupation and temporary housing costs for floodplain residents.

Emergency costs related to public infrastructure repairs, debris removal and post-flood cleanup have been calculated by applying an average per acre cost to the number of developed acres inundated by flood event. Based upon several recent Los Angeles District studies, per acre costs for these items may range from $1,250 to $7,500 per acre. In accordance with this range, $5,000 per acre has been assumed for this analysis.

Per acre costs are applied to floodplain acreage with existing development. Floodway and undeveloped acreage are not included. ArcView GIS software was utilized to determine acreage by flood event that would require cleanup, public repairs and debris removal. Table 15 displays without project cleanup related costs by frequency, while Table 16 displays expected annual costs by reach.

Table 15 Rio Salado Oeste Without Project Cleanup Costs (in $1,000s)		
Event	**Acres**	**Costs**
20	11	$ 55
50	70	$ 350
100	105	$ 525
500	387	$ 1,935
Expected Annual Damages		**$ 24**

Table 16

Rio Salado Oeste Without Project Expected Annual Cleanup Costs By Reach (in $1,000s)	
Reach	**Expected Annual Costs**
2L	$10
3L	$1
4L	$0
5L	$4
6L	$3
Total South of River	$18
2R	$0.5
5R	$5
6R&7R	$0.5
Total North of River	$6
Total – All Reaches	**$24**

Temporary Evacuation, Relocation and Housing Assistance Costs

FEMA provides grants to assist individuals and families to find suitable housing when they are displaced in cases of federally declared disasters. The program assures that people have a safe place to live until their homes can be repaired. This assistance is directly attributable to the disaster and being an expenditure that would not be undertaken except for the disaster falls under the emergency cost guidance of ER 1105-2-100. Therefore, the funds expended by FEMA for temporary housing assistance in the event of flooding are NED flood damages.

An Internet database search of FEMA disaster reports for flood and storm damage was performed. Data was collected and analyzed for ten recent flood disasters, including the October/November 2000 flooding in Maricopa and La Paz counties in Arizona. For these ten disasters, 18,799 housing assistance claims were approved for a total payout of $27.93 million. This represents an average amount per claim of approximately $1,500.

To estimate temporary housing costs by flood event for this study, the number of houses and mobile homes inundated by frequency was ascertained through an analysis of HEC-FDA output files, and the per housing unit claim of $1,500 was applied. Table 17 shows the results.

Table 17 Rio Salado Oeste Without Project Temporary Housing Costs (in $1,000s)		
Event	**Structures**	**Costs**
20	2	$ 3
50	6	$ 9
100	14	$ 21
200	41	$ 62
500	212	$ 318
Expected Annual Damages		**$ 1.6**

Note that the number of residential structures shown in Table 17 as sustaining inundation for the 100-year and 500-year events differs from the number of estimated floodplain structures shown in Table 7. This is because the structure counts shown in Table 7 are based strictly on floodplain delineation maps overlaid onto aerial photography of the study area. These floodplain boundaries are based upon median discharge values and do not account for the probabilistic ranges of values for either discharge or stage. The figures in Table 17 are based upon the results of the HEC-FDA model, which incorporate risk and uncertainty in such areas as frequency/discharge, stage/discharge, and structure elevation, i.e., Table 17 represents expected values resulting from the simulation model.

Table 18 shows expected annual without project temporary housing costs by reach.

Table 18
Rio Salado Oeste
Without Project Expected Annual Temporary Housing Costs
By Reach (in $1,000s)

Reach	Expected Annual Costs
2L	$0.4
3L	$0.1
4L	$0.1
5L	$0.9
6L	$0.1
Total South of River	$1.6
Total North of River	$0
Total – All Reaches	**$1.6**

Without Project Flood Damage Analysis Summary

Without project flood damages are summarized on Table 19.

Table 19
Rio Salado Oeste
Without Project Equivalent Annual Damages
(in $1,000s)

Reach	Structure & Content	Cleanup	Temp. Housing	Total
2L	$ 32	$ 10	$ 0.4	$ 42
3L	$ 2	$ 1	$ 0.1	$ 3
4L	$ 2	$ -	$ 0.1	$ 2
5L	$ 29	$ 4	$ 0.9	$ 34
6L	$ 10	$ 3	$ 0.1	$ 13
Total - S. of River	$ 75	$ 18	$ 1.6	$ 95
5R	$ 142	$ 5	$ -	$ 147
6R	$ 5	$ 0.5	$ -	$ 6
Total - N. of River	$ 147	$ 6	$ -	$ 153
Total	$ 222	$ 24	$ 2	$ 247

Notes: *Damages for Reaches Not Shown are Minimal*

As shown on Table 19, equivalent annual damages are concentrated in a few reaches. Reach 5R accounts for about 60 percent of total without project damages. This reach contains a small concentration of industrial structures along 35th Avenue, primarily south of Lower Buckeye Road. There are several parcels with multiple structures that are within the 50-year floodplain, and just outside of the 20-year floodplain. The risk and uncertainty analysis indicates that these structures may be flooded by events more frequent than the 20-year event.

On the south side of the Salt River, Reach 2L has the highest amount of expected annual damages. Damages in this reach are attributable to the close proximity of several structures to the floodway on the north side of Southern Avenue between 75th and 67th Avenues.

The highest concentration of residential damages is located in Reach 5L. Although there are nearly 200 structures in this reach, damages are limited due to the low per unit structure values and because most are outside the 100-year floodplain. Most of the structures in this reach are located just southwest of Broadway Road and 35th Avenue.

The only other reach with significant damages is Reach 6L. This reach includes industrial and commercial structures located along Broadway Road between 35th and 27th Avenues.

Impact of Assumed Aggregate Mining on Without Project Damages

A detailed analysis of without-project flood damages reflecting the assumed mining operations between 35th and 51st Avenues has not been completed. However water surface profiles have been developed for with-project alternatives which reflect the impacts of both the mining and the features of the alternatives. It has been determined that the impacts of the mining, particularly in Reach 5 area, are significant. In fact, it appears that the additional channel capacity created by this mining will greatly reduce the potential for any flooding in this area. As this was the primary damage area under previous assumptions, the removal of the flood threat for this area essentially leaves only minor residual flooding, primarily in Reach 2, under without-project conditions.

Recreation

As demonstrated earlier in this report, the Phoenix area has experienced rapid population growth. As the Phoenix MSA population has now expanded to over three million people, so has the demand for both passive and active recreation opportunities. Envisioned recreational opportunities coinciding with habitat restoration projects for the study area consist primarily of passive recreation, such as bird watching, walking, jogging, hiking, bike riding, horse-back riding, picnicking, and other passive uses of open space.

Existing Recreation Resources in Market Area

Based upon conversations with representatives from the City of Phoenix Parks, Recreation and Library Department, the Arizona Game and Fish Department and other agencies, the proposed habitat and recreation features would attract visitors throughout the Phoenix Valley region. The greater Phoenix area does not currently have any significant riparian habitat areas with supporting recreation facilities. The major existing parks in the area consist primarily of desert mountain preserves, which do not contain the types of habitat that could be supported in the study area. For purposes of this analysis, the market area will be defined as the greater Phoenix metropolitan area, which would include Maricopa and Pinal Counties, although it is likely that many visitors would be drawn from even greater distances.

The following presents the primary recreation areas in the greater Phoenix area. This does not include the area's numerous golf courses and man-made lakes.

National Trails Systems

- North Mountain Trail: Nine miles of trails located in Northwest Phoenix.
- South Mountain Trail: Fourteen miles of desert trails in the center of South Mountain Park, providing for hiking and horseback riding.
- Sun Circle Trail: Includes 110 miles of urban to open desert trails forming a loop around the Phoenix Valley for hiking and bicycling.
- Squaw Peak Trail: 1.2 miles of urban wilderness area.

State Parks

- Painted Rocks State Park: 140 acre historical park located approximately 15 miles west of Gila Bend on the Gila River.
- Lost Dutchman State Park: 300 acres of desert park on the Apache Trail located near the Maricopa/Pinal County border. Includes 35 campsites, picnic facilities, and restrooms.

BLM Lands

- Greenbelt Resource Conservation Area located south of Buckeye -- includes hunting and hiking.

State Game & Fish Department

- Black Canyon Shooting Range: 1,290 acres located 20 miles north of Phoenix.
- Base and Meridian: 173 acres of wildlife habitat located three miles south of Cashion.
- Gila River Wildlife Area: 6,896 acres of wildlife habitat extending from Avondale to the Gillespie Dam.

Major Water Bodies

- Apache Lake Marina: Located approx. 35 miles east of Phoenix in Maricopa and Gila County.

- Bartlett Lake: Maricopa County (approx. 35 miles northeast of Phoenix)..
- Canyon Lake: Maricopa County (approx. 30 miles east of Phoenix).
- Lake Pleasant: Maricopa and Yavapai County (approx. 25 miles north of Phoenix).
- Saguaro Lake: Maricopa County (approx. 25 miles east of Phoenix).

Maricopa County

- Estrella Mountain Regional Park: 19,200 acres located three miles south of Goodyear.
- Thunderbird Park/Adobe Dam
- Cave Buttes Recreation Area

Municipal Parks & Other Recreation Areas

Papago Park	South Mountain Park
Case Abbot Recreational Area	Phoenix Municipal Stadium
Phoenix Zoo	A.S.U. Sun Devil Stadium
Phoenix Mountain Preserve	Moeur Park
Tempe Beach Park	Playa Margarita
El Prado Park	Lindo Park
Rio Salado Industrial Park	Echo Canyon Recreation Area
Encanto Park	Estaban Park
Hayden Park	Green Valley Park
Nuestro Park	Nueve Park
Harmon Park	Barrios Unidos
Alkire Park	University Park
Canal Park	McKellips Lake Park
Eldorado Park	Indian School Park
Chapparal Park	Vista del Camino Park
Coffelt Park	Cesar Chavez Park

Estrella Mountain Regional Park, South Mountain Park and Papago Park are three of the largest recreation areas listed above which are nearby the study area. Estrella Mountain Regional Park is owned and managed by Maricopa County Parks and Recreation Department. The rugged and scenic Sierra Estrella Mountains are the most dominant feature of Estrella Mountain Regional Park. The terrain of these mountains is characterized by very steep slopes, numerous rock out-crops, shallow soils and sparse desert vegetation.

The County has developed a master plan for the 19,200-acre park, located approximately 20 miles southwest of downtown Phoenix. The master plan envisions the preservation of scenic desert wilderness areas while incorporating sensitive development of recreational facilities and activities. The Plan accommodates the expected annual demand of 1 million visitors while insuring that the existing Sonoran Desert environment remains in its existing condition. In fact, 90 percent of the park will remain essentially untouched. The remaining 10 percent will be sensitively utilized for educational, camping, picnicking, and sporting activities.

South Mountain Park is located about three miles south of the Salt River and extends from about 48th Street on the east to 43rd Avenue on the west -- a distance of over 10 miles. The park encompasses about 17,000 acres of desert mountain landscape and is the largest municipal park in the U.S. It is bounded on the north by Baseline Road and on the south by Chandler Boulevard, and is over three miles wide in some places. It contains an activity complex, hiking and riding trails (extending over 40 miles), an interpretive center, lookouts, ramadas, picnic areas and restrooms. According to the *Sonoran Preserve Master Plan*, annual park visitation during the 1990s exceeded 3 million.

Papago Park is located just north of the Salt River in eastern Phoenix and western Tempe. It includes about 1,400 acres bounded on the north by Oak Street, on the south by State Highway 202, on the west by 52nd Street and on the east by 68th Street. The park includes: rock formations dating back 15 million years, ramadas, picnic facilities, three fish ponds stocked with rainbow trout and channel catfish, a baseball stadium, a softball complex, volleyball courts, the Phoenix Zoo, botanical gardens, a state historical museum, two golf courses, an archery shooting range, nature trails and restrooms. Annual visitation at this park exceeds 2 million.

In addition to South Mountain Park, Phoenix Mountain Preserve is the other major mountain preserve area in greater Phoenix. Located in the northeastern section of the city, the Phoenix Mountains are a combination of regional parks and preserves. The regional parks represent the partially developed areas while the preserves represent the areas which are completely undeveloped except for trails. There are about 1,800 acres of regional parks embedded within the preserves, including the North Mountain, Squaw Peak, and Shaw Butte recreation areas. These parks include an extensive trails system, picnic areas and restrooms. North Mountain recreation area also features basketball and volleyball facilities and a playground. The combined visitation at North Mountain and Squaw Peak Recreation Areas has totaled approximately 1.5 million in recent years.

Existing Recreation Resources in Study Area

Recreation along the study area is highly dependent upon the availability of surface water and riparian habitat, both of which are dependent upon the supply and availability of ground water. The Salt River through the City of Phoenix has, until the recently constructed Rio Salado and Tres Rios projects and the upstream Tempe Town Lake, consisted of dry river bottom. As a result, virtually no recreation activities took place.

The only improved recreation area adjacent to the Salt River was Rio Salado Park, which is located at 12th Street and Elwood. The park encompasses about 14 acres and contains picnic facilities and racquetball and basketball courts. Most of the users are employees who work at industrial businesses located in the area. According to the City of Phoenix Parks Department, fewer than 200 people visit the park on a weekly basis (or less than 10,400 annually). There are currently no plans for expansion of the park, and visitation is not expected to increase in the absence of a Corps project.

The following shows the names and annual visitation for other community parks in the Phoenix area.

Park	Visitation	Features
Hayden Park	121,000	14 acres, with picnicking, softball, basketball, playground, restrooms
Estaban Park	58,000	62 acres, with picnicking, softball, soccer, volleyball, tennis, playground, restrooms
El Prado	61,000	40 acres, with swimming pool, softball, picnicking, playground, restrooms
Cesar Chavez	310,000	353 acres, with 25 acre lake with fishing/ sailing/canoeing, picnicking, restrooms
Encanto	1,200,000	63 acres, with fishing lagoon, 18-hole golf course, clubhouse, swimming pool, racquetball, tennis, basketball, softball, children's play area
Echo Canyon	350,000	387 acres, with hiking trails, mountain biking, horseback riding

The Rio Salado Project stretches from an upstream limit of Interstate 10 to a downstream limit of 19th Avenue (which is the upstream limit for this study) and is comprised of environmental restoration and passive recreation components along the Salt River. Approximately five miles (and 580 acres) of the Salt River has been restored to create riparian and wetland habitat. Passive recreation facilities, including over ten miles of trails and interpretive signage are also included. Construction commenced on the project in 2000 and was just recently completed. Recreation project features include parking lots, information kiosks, a visitor center, overlooks, shade structures, bridges, trails, an equestrian staging area, signage and landscaping. Recreation activities provided by the plan include: walking, hiking, biking, horseback riding, roller blading, picnicking, and bird watching. Scenic overlooks will be included for the enjoyment of the restored desert riparian habitat. Information kiosks and the visitor center will provide education on the resource, including restoration of the habitat, the hydro cycle, a historical perspective of the Salt River, and flora and fauna within the project area. As documented in the Rio Salado Feasibility Study, annual visitation is anticipated to exceed 500,000.

In addition to the Rio Salado Project, the Tres Rios project just downstream of the Study area will also provide recreation opportunities. The Tres Rios Project is located immediately downstream of the Study Area, beginning at the 91st Avenue Wastewater Treatment Plant. Components of this plan include new levee alignments for flood control, the establishment of wetland, marsh and riparian habitat and passive recreation/environmental education facilities.

Immediately upstream of the Rio Salado Project is Tempe Town Lake. The lake was constructed within the existing Salt River flood control channel (about 850 feet in width), extending from the Salt River's confluence with Indian Bend Wash to approximately two miles downstream. The river's flood control conveyance capacity is retained through the use of a system of rubber dams which can be deflated during significant floods.
The lake contains about 220 surface acres and 20,000 feet of shoreline supporting paddle boating, canoeing, sailing and fishing. Tempe is hoping to establish the state's largest urban fishing program. Over 1,000 acres of adjacent land has been dedicated for recreational development and open space. Activities will include picnicking, hiking, bicycling, horseback riding, softball/baseball, volleyball, golfing, water slides and play areas. Other possible recreational uses include soccer and major sports events, such as marathons.

Recreation Demand

Many factors contribute to make the proposed riparian habitat area extremely attractive in terms of recreation potential. They include:

1) Environment: Demand for recreation opportunities must be considered in the context of the surrounding environment. Although there are many recreation areas in greater Phoenix, the only recreation facilities located within wetland/riparian habitat areas are those provided adjacent to the study area by the Rio Salado and Tres Rios projects. Most of the existing parks are small community parks. The larger regional parks are located in desert mountain terrain (e.g., South Mountain) and not in wetland and riparian habitat areas. This is expected to result in significant recreation demand at the study area if such habitat is established. As discussed previously, riparian habitat would also attract wildlife to the area. According to the 1991 *National Survey of Fishing, Hunting and Wildlife-Associated Recreation (Arizona)*, published by the U.S. Fish and Wildlife Service, over 1.1 million Arizona residents 16 years and older (or 40 percent of the population) participated in non-consumptive activities where the enjoyment of wildlife was the primary purpose of the activity. Such activities include observing and photographing wildlife. Nearly 3.3 million trips were taken by Arizona residents to participate in non-consumptive activities one mile or greater from their residence.

2) Location: In a study conducted for the 1994 Arizona Statewide Comprehensive Outdoor Recreation Plan (SCORP), over 1,200 respondents were asked what the primary barriers were to outdoor recreation participation. After lack of time, the number two and three barriers cited were: 2) recreation areas are too far away; and 3) don't know where to go. The 1991 Fish and Wildlife Survey indicated that Arizona residents travel an average distance of nearly 30 miles to participate in non-consumptive recreation activities. The closest major water bodies to the city of Phoenix are located approximately 25 miles away. These barriers would not be associated with recreation at the study area. According to the publication, *Arizona Trails 2000*, prepared by the Arizona State Parks Board (October 1999), the number one reason given by recreation trail users for preferring a particular area is its proximity to home.

The study area is located in the middle of the Phoenix metropolitan area, which has a population exceeding three million. Portions of the study area are located within minutes of downtown Phoenix, and are thus easily and quickly accessible to the public. In addition, a major freeway (Interstate 10) and several major bridges cross the Salt River. This provides the area with tremendous exposure, and would likely attract many who would otherwise not frequent such a park.

Family and lifestyle changes also contribute to high demand for more local recreation facilities. As described in the *Town Lake Capacity and Needs Study: Rio Salado Project* (BRW Moffatt & Nichol Engineers, 1996), "More single-parent families, more families where both spouses work full-time, moderate growth in income and less time for leisure time activities all contribute to heavy pressure on local park and recreation facilities. People are looking for park and recreation facilities which are close, offer a variety of water-based and land-based activities and are in an attractive setting."

3) Attitudes: Arizonans place high importance on the state's outdoor recreation resources. In the 1994 SCORP survey, 94 percent of respondents stated that parks and recreation areas are important to their everyday lifestyles. There is also strong support for protecting natural and cultural resources and for environmental education. Arizonans care deeply about the state's air, water and riparian areas. Seventy-five percent (75%) favor preserving rivers and stream-side habitats, even if it means limiting some uses of privately owned lands. A separate study conducted by the Arizona Game & Fish Heritage Fund (*Attitudes Toward Urban Wildlife Management, Volume 1, May 1995*) supports these statistics. A statewide survey was conducted of 1,200 residents. In the Heritage Fund survey, 89 percent of respondents stated that the continued presence of wildlife in their town is important to them. The importance placed on protecting water-based habitat and recreation areas can be attributed to the limited amount of surface water available. Arizona has approximately 113,642 square miles of land surface, but only about 360 square miles are water-covered.

4) Activities: Proposed recreational activities for the study area include trails for hiking, biking, jogging, and horseback riding, birdwatching, and picnicking. In addition, interpretive centers and lookout points could be established along the banks of the river at key scenic vantage points. In a ranking of overall demand for outdoor activities in the recent SCORP, visiting outstanding scenic areas was ranked first, picnicking ranked fourth, and walking ranked fifth. Other envisioned recreation features for the study area were ranked as follows: day trail hiking (10); bicycling (14); horseback riding (18); mountain biking in a natural setting (26); nature study/birdwatching (27); and jogging/running (36). Among those activities identified as having the greatest latent or unmet demand, picnicking, visiting outstanding scenic areas, walking, trail hiking, horseback riding and bicycling all ranked in the top fifteen. In terms of public funding priorities, visiting outstanding scenic areas, picnicking, trail hiking, and walking all ranked in the top ten.

According *Arizona Trails 2000*, over half of Arizona residents consider themselves non-motorized

recreation trail users. Surveys indicated that trail users spent an average of 22 days using trails during the prior year. Over 70 percent of respondents indicated that they supported using state funds to develop trails. Survey results are supported by the fact that Arizona State parks have experienced a 16 percent increase in visitation over the past five years.

There is also a shift in the types of recreation demanded by Americans in general. The National Survey on Recreation and the Environment conducts periodic surveys on public recreation use and demand. From 1983 to 1995, the percentage of Americans involved in such activities as fishing and hunting actually declined. On the other hand, the activities that have seen the most dramatic increases in demand have been hiking (+94%), birdwatching (+155%) and backpacking (+73%).

5) Population Growth: As demonstrated earlier in this report, the greater Phoenix area has experienced tremendous growth. For example, Maricopa County's population has grown from 2.12 million to over three million between 1990 and 2000 (or nearly 45 percent), and is expected to reach over 4.5 million by the year 2020. With this projected growth, there will be increasing demand for outdoor recreation opportunities. As quoted in the 1994 SCORP report (p. 68),

*This large and rapidly growing population in our two metropolitan counties has several implications for outdoor recreation. Most obvious, local providers are hard-pressed to keep up with demand for facilities and services. As development continues to expand, providing and protecting open space becomes an important issue. Increasingly, city dwellers mention a major barrier to participation that recreation providers must address: outdoor recreation areas are too far away."*6) Education: The establishment of riparian habitat would attract diverse wildlife to the study area. Elementary and high schools would frequent the area for class field trips, and colleges could utilize the area for environmental-related research.

According to the article, "Assessing Recreation Demand", posted on the U.S. Department of Transportation Statistics' Internet site, the use of population based standards represents one of the most widely used methods for assessing community demand and need for open space and recreation. This is attributed to the fact that they are easily understood and administratively convenient. Such standards are considered most useful as a means for generating alternatives for consideration and as a means for supporting participation data. The City of Phoenix Parks Recreation and Library Department's *Long Range Plan (Draft, September 2001)* (LRP) describes national standards that have been established for various types of recreation. These standards indicate desired and ideal service levels on a per capita basis. The National Recreation and Parks Association (NRPA) established a range of standards, but also recommended that each community develop individual standards to the most appropriate range, quantity and quality of recreation facilities within their fiscal restrictions.

The standard established by the City is 4.5 acres of developed park space per 1,000 residents, although historical NRPA standards are higher. According to the LRP, the 4.5-acre standard (rather than a higher level) was selected because the area has Desert Parks, Sonoran Desert Preserves and Mountain Preserves, which also provide recreation activities. Even though the preserves do not provide a wide range of recreation opportunities like neighborhood, community and district parks, they do provide additional open space and some amenities (such as multi-use trails) on portions of the land.

There are currently about 132 parks covering about 4,086 acres within the City. As noted earlier, the population in Phoenix is about 1.4 million. Hence, the existing service level is about 2.9 acres per thousand residents. This figure is well below the desired standard of 4.5, and the supply deficit will become worse with the anticipated rapid population growth in the future. For example, by 2020, the population in the City is expected to reach 1.8 million. With no additional parks, the ratio of parks per thousand residents would

worsen to 2.3. Based upon an expected population of 2.6 million by 2050, the corresponding ratio would be about 1.6. As noted in the LRP, over 2,800 acres of additional parks would be required over the next decade to both meet the desired standards and keep up with the population influx.

The LRP specifically discusses the Study area by noting that the new growth areas of Estrella and Laveen continue to present a problem as they are developing and growing faster than previously projected. For example, in the Central Phoenix planning area, which includes Estrella Village, the existing service level is only about 2.4 acres per thousand residents.

Trails would likely be an important component of any recommended plan for the Study area. According to the LRP, nearly 100 miles of new trails would be needed in the City by the year 2010 to meet the established standard of one mile per 8,000 residents. The LRP specifically notes the desire to implement new trails to link with those of the Rio Salado project.

As the above analysis indicates, the Phoenix area lacks sufficient recreation resources. As noted in the City of Phoenix *Sonoran Preserve Master Plan*, although the amount of dedicated open space has continually increased within the City and County, the acreage per capita has decreased. Unless a significant number of recreation facilities are built, the projected population growth will make the existing deficit become worse.

Recreation Opportunities

While water is a highly attractive feature for recreationists, park trails and facilities have presently been planned away from the Gila River. Once the County completes its Sun Circle Trail System through this reach of the Gila and Salt Rivers, recreation use patterns are expected to expand throughout the study area. The Sun Circle Trail, a component of the National Recreation Trail system, comprises a 110-mile loop encompassing the Phoenix metro area. The trail offers a unique opportunity for hiking, horseback riding and bicycling throughout the urban area. Approximately 70 percent of the Sun Circle trail system is in place. The County has an agreement with the Maricopa County Flood District to establish the Sun Circle Trail within the flood control district corridor from Skunk Creek to the Gila River - Salt River confluence. The Rio Salado Oeste Project is an excellent opportunity to designate a segment of the Sun Circle Trail. This will benefit Tres Rios, Rio Salado, and Rio Salado Oeste with a major non-motorized travelway connecting the three river restoration projects to the other valley areas.

The Rio Salado Oeste project provides a unique opportunity to enhance resource-based recreation and environmental education. The restoration of the dry Salt River channel will bring a riparian open space feature to the rapidly expanding Laveen and Estrella Planning Areas. Rio Salado Oeste will provide a habitat and recreational connection to the desert riparian habitat corridor created by the Rio Salado and Tres Rios Projects. By connecting the seven-mile gap between the two projects, Rio Salado Oeste will enhance the unique recreation and education opportunities for residents and out-of-town visitors. Drawing on a population base of over three million in the Valley, it is estimated that visitation to the Rio Salado Oeste project will be significant. Primary use times for this unique resource would coincide with the "visitor season" between October and May when temperatures are moderate.

The goal of the environmental education and recreation component is to provide opportunities for visitors of all ages, abilities, and backgrounds to enjoy this unique resource while developing an awareness, knowledge and understanding of desert riparian habitat and its relationship to the surrounding environment. Additionally, it presents an opportunity to acknowledge and understand the influence of Salt Rivers on the environment and cultures throughout the Valley's history. Visitors to potential recreation facilities along the Study Area reach could participate in a variety of pursuits from enjoying scenic views, picnicking with the family, learning

about the habitat, or exploring the resource on foot, by bicycle or horseback. Recognizing the diverse local society, the Rio Salado Oeste project would employ design components ranging from areas adapted for special needs to multi-lingual signage.

WITH PROJECT CONDITIONS

Environmental Resources

The following provides an analysis of alternatives developed to provide ecosystem restoration benefits. Note that Alternative 1 represents the No Action Plan, or Without Project Condition, which has already been described earlier in this report.

Description of Alternatives

Below is a summary description of the restoration alternatives. Please refer to the Main Report and Environmental Impact Statement for a more detailed description of these alternatives.

Alternative 2

Storm water and Channel: This alternative includes the modification of existing storm-water outfall areas to improve retention and water spreading as well as increasing the existing habitat currently supported by these outfalls. It also includes modification and/or restructuring of the primary conveyance channel to a more natural state. This could include grading and terracing the river corridor from 19th avenue to 83rd avenue. No additional water source is included in this alternative.

Alternative 3

Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive: This alternative includes the features described in alternative 2 and ads a supplemental water supply in the form of effluent. At locations identified as suitable throughout the project area cottonwood/willow and mesquite cover types will be restored. This alternative would also address the management, control and removal of invasive species within the study area. Two types of irrigation (drip and flood) will be evaluated for each.

Alternative 4

Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent: This alternative adds restoration of emergent wetlands at the existing lake in the channel immediately downstream of 19th Avenue.

Alternative 5

Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent, Lake: Added to this alternative is lake restoration at the existing gravel pits at 29th and 37th Avenues.

Alternative 5A

Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent, Lake: Instead of restoration of both gravel pit lakes to permanent water for fishing this alternative includes regrading to incorporate the pits to the floodplain and restoration of wetland and riparian habitat.

Alternative 5B

Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent, Lake: This alternative is similar to 5 and 5A. However it includes the restoration of one gravel pit to a lake and the other to a wetland/riparian area.

Benefits of Alternatives

Based upon the individual features proposed for each alternative, the number of acres and functional capacity indices were projected in order to derive with-project estimates of average annual functional capacity units (AAFCUs). The same methodology as was employed for assessing without project conditions was also employed to assess the habitat output of each alternative. Benefits are defined as the increase in AAFCUs for each alternative relative to without project conditions. Table 20 shows the results.

TABLE 20
RIO SALADO OESTE STUDY AREA
WITH PROJECT AVERAGE ANNUAL FUNCTIONAL CAPACITY UNITS (FCUs)

	Without Project	Alt 2	Alt 3	Alt 4	Alt 5	Alt 5A	Alt 5B
T0	583	583	583	583	583	583	583
T1	580	619	689	691	766	791	778
T6	580	627	716	717	796	822	809
T26	579	635	751	755	828	857	842
T51	579	633	771	775	851	879	865
Avg (T0-T51)	580	631	742	745	820	847	833
Increase (T0-T51)		**51**	**162**	**165**	**240**	**267**	**253**

As shown on Table 20, the proposed alternatives result in increased AAFCUs (relative to without project conditions) ranging from 51 for Alternative 2 to 267 for Alternative 5A.

Cost Estimates

Table 21 which follows displays the derivation of average annual costs by alternative. Total first costs range from $39.9 million for Alternative 2 to $189.8 million for Alternative 5.

TABLE 21
RIO SALADO OESTE STUDY AREA
WITH PROJECT AVERAGE ANNUAL COSTS BY ALTERNATIVE (in $1,000s)

	Alt 2	Alt 3	Alt 4	Alt 5	Alt 5A	Alt 5B
Construction	$ 12,102	$ 41,500	$ 41,623	$ 94,676	$ 69,683	$ 82,180
Contingency (25%)	$ 3,025	$ 10,375	$ 10,406	$ 23,669	$ 17,421	$ 20,545
PED/EDC (11%)	$ 1,331	$ 4,565	$ 4,579	$ 10,414	$ 7,665	$ 9,040
S&A (6.5%)	$ 787	$ 2,697	$ 2,705	$ 6,154	$ 4,529	$ 5,342
Real Estate	$ 21,994	$ 36,313	$ 36,313	$ 49,485	$ 49,485	$ 49,485
Subtotal	$ 39,238	$ 95,449	$ 95,625	$ 184,398	$ 148,784	$ 166,591
Monitoring & Adapt. Mgmt.	$ 690	$ 2,365	$ 2,373	$ 5,397	$ 3,972	$ 4,684
Total First Cost	**$ 39,928**	**$ 97,815**	**$ 97,998**	**$ 189,795**	**$ 152,756**	**$ 171,275**
IDC	$ 2,011	$ 8,724	$ 8,741	$ 19,385	$ 15,641	$ 17,513
Gross Investment	$ 41,939	$ 106,539	$ 106,739	$ 209,180	$ 168,397	$ 188,788
Annualized Investment Cost	$ 2,342	$ 5,949	$ 5,960	$ 11,680	$ 9,403	$ 10,542
Associated Cost (Water Delivery System)	$ -	$ 34	$ 34	$ 34	$ 34	$ 34
Associated Cost (Water Supply)	$ -	$ 312	$ 331	$ 654	$ 817	$ 811
O&M	$ 101	$ 1,698	$ 1,698	$ 2,224	$ 2,080	$ 2,137
Total Annual Cost	**$ 2,443**	**$ 7,993**	**$ 8,022**	**$ 14,592**	**$ 12,334**	**$ 13,524**

Note – O&M Costs include annualized equivalent values of projected replanting costs, invasive species control, channel, wetland and lake regrading and excavation costs, and water supply and irrigation system related costs.

Cost Effectiveness & Incremental Cost Analysis

Average Cost per Average Annual Function Capacity Unit

Table 22 summarizes average annual output and cost by alternative, as well as average annual cost per AAFCU.

TABLE 22
RIO SALADO OESTE STUDY AREA
AVERAGE ANNUAL COSTS PER AVERAGE ANNUAL FCU BY ALTERNATIVE
(in $1,000s)

Alternative	AAFCU	AA COST	AAC/AAFCU
Alt 2	51	$ 2,443	$ 47.73
Alt 3	162	$ 7,993	$ 49.23
Alt 4	165	$ 8,022	$ 48.55
Alt 5	240	$ 14,592	$ 60.71
Alt 5A	267	$ 12,334	$ 46.15
Alt 5B	253	$ 13,524	$ 53.50

Cost Effectiveness Analysis

Alternatives are considered cost effective if there are not any other alternatives which provide greater output for the same cost or provide the same output for a lesser cost. This step eliminates alternatives that are inefficient from further consideration. Table 23 shows the cost effective plans.

TABLE 23
RIO SALADO OESTE STUDY AREA
COST EFFECTIVENESS ANALYSIS
(in $1,000s)

	AAFCU	AA COST	AAC/AAFCU
Alt 2	51	$ 2,443	47.73
Alt 3	162	$ 7,993	49.23
Alt 4	165	$ 8,022	48.55
Alt 5A	**267**	**$ 12,334**	**46.15**

As shown above, there are only four cost effective plans. Alternatives 5 and 5B are not cost effective because they have a higher cost than Alternative 5A, but provide less environmental benefits.

Incremental Cost Analysis

Incremental Cost Analysis goes beyond cost effectiveness analysis to identify "best buy" plans. Best Buy plans are those that have the lowest incremental average annual cost per incremental increase in output. For the alternatives formulated for this study, Alternative 5A has the greatest output and the lowest average annual cost per average annual functional capacity unit. Therefore, it is the only Best Buy plan. Figure 7 shows the average annual costs for each alternative, and Figure 8 shows the average annual costs per habitat unit for the cost effective alternatives.

Figure 7
Rio Salado Oeste
Cost Effectiveness/Incremental Coast Analysis

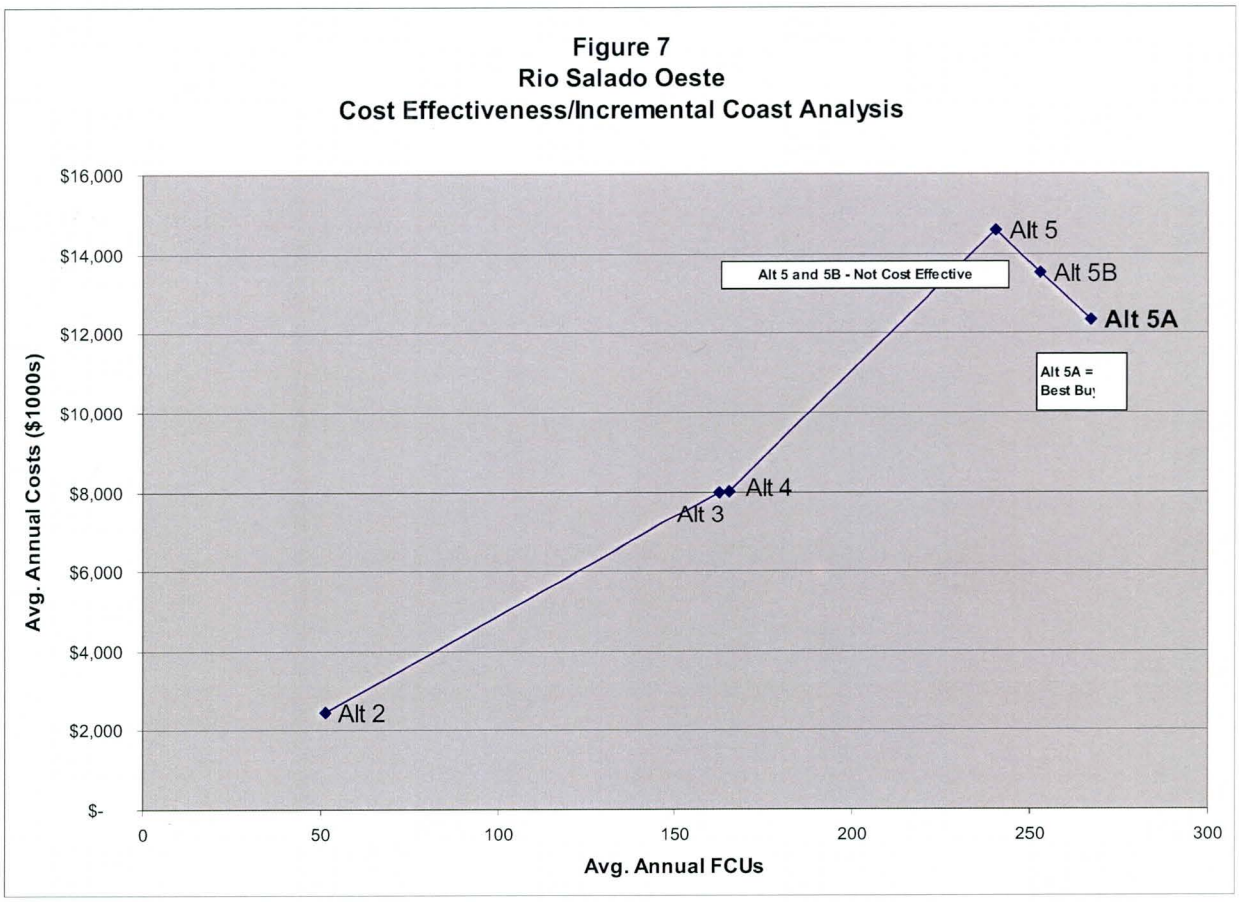
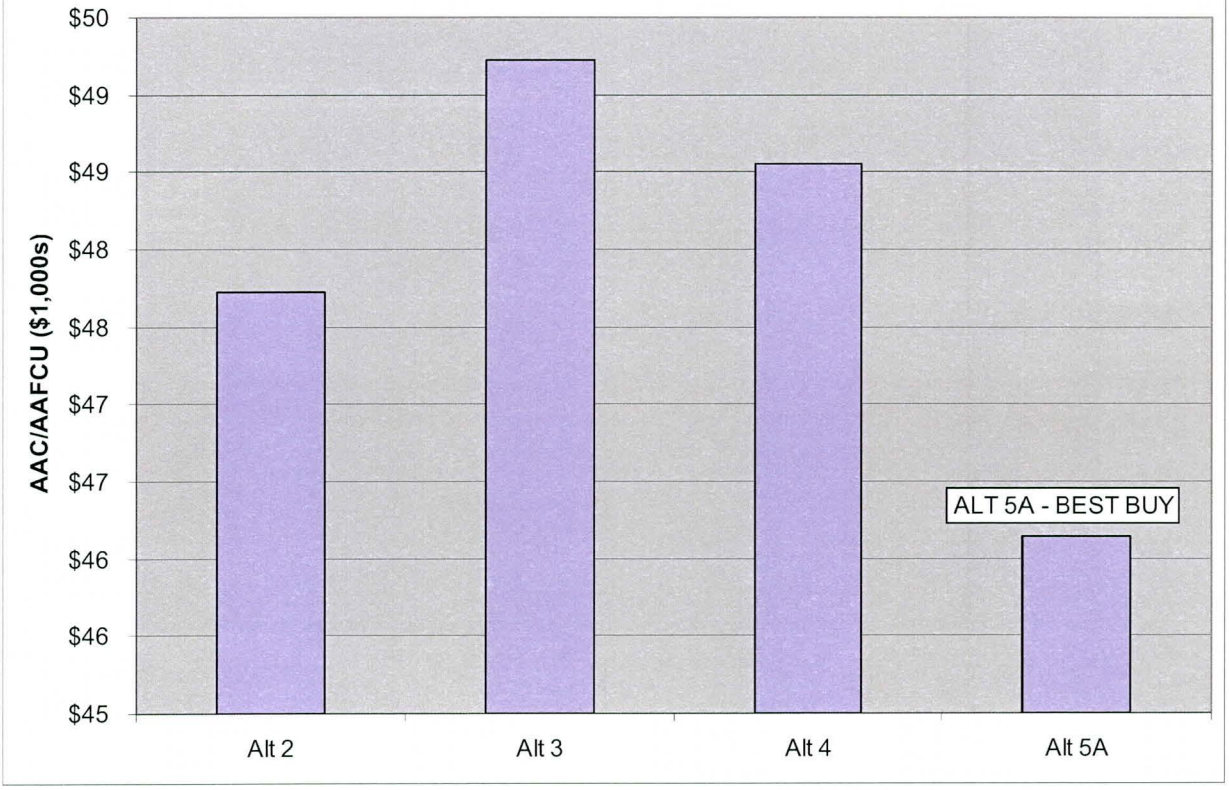


Figure 8
Rio Salado Oeste
AAC/AAFCU for Cost Effective Plans



Recommended Ecosystem Restoration Plan

Based upon the CE/ICA analysis, Alternative 5A has been identified as the NER Plan. Because this plan is also the locally preferred alternative, Alternative 5A is the Recommended Plan.

MCACES Cost Estimate

Table 24 shows the MCACES cost estimate for the Recommended Plan. The First Cost and Average Annual cost are somewhat less than the costs shown for Alternative 5A in Table 21. This is primarily attributable to a lower contingency that was applied due to the higher level of detail associated with the MCACES estimate.

Table 24
Rio Salado Oeste-Recommended Plan

Estimate MCACES Cost Estimate ($1,000s FY 06 PL 5 1/8%)	
Construction	$64,633
Contingency (20%)	$12,927
Subtotal	$77,560
PED/EDC (11%)	$8,532
Subtotal	$86,091
S&A (6.5%)	$5,596
Total Construction Cost	$91,687
Real Estate (including 25% contingency)	$55,900
Subtotal	$147,587
Monitoring and Adaptive Management	$3,667
Total First Cost	$151,254
IDC	$15,515
Gross Investment	$166,769
Annualized Investment Cost	$9,312
Associated Cost (water supply)	$817
O&M	$2,080
Total Annual Cost	**$12,209**

Flood Damage Analysis

An assessment has been completed of residual flood damages in the Study Area under the Recommended Plan. One important factor in the with-project flood damage assessment is a key assumption relating to actions to be taken by the Local Sponsor. In 2003 the City of Phoenix purchased approximately 250 acres of riverbed between 35th and 51st Avenues. They have been working on a plan to lease the property for aggregate mining in a manner that allows aggregate to be removed while leaving a river cross section suitable for restoration. The likely alternative to have excess material removed from this reach and leave it in a state suitable for restoration will include an active channel varying in width from 300-600 feet and at the approximate elevation of the existing thalweg. Adjacent to that channel will be 500 foot wide terraces. Approximate 5 million tons of river material will be removed for this to occur. Once permitting and lease agreement is completed the City will allow aggregate to be removed as specified.

As described in the Without-Project section of this report, the impact of the proposed aggregate mining on flood damages is significant. An analysis of the water surface profiles shows that water surface elevations with the proposed project are generally lower throughout the Study Area, resulting in the reduced potential for flood damages. However, because of the proposed mining in the 35th Avenue area, the water surface elevations in the reaches adjacent (Reaches 4-6) are especially reduced. These same reaches also happen to be those with the highest without-project damage potential. Since the water surface profiles incorporate both the gravel mining and restoration features, it is not possible to ascertain the reduction in flood damages attributable to each.

The following table shows the reduction in equivalent annual structure and content damages resulting from

the Recommended Plan AND assumed aggregate mining.

Table 25
Rio Salado Oeste
With Project Flood Damage Analysis
Recommended Plan – Alt 5A (in $1,000s)

Reach	W/O Project*	With Project	Reduction
1L	$ -		$ -
2L	$ 32	$ 22	$ 10
2R	$ -	$ -	$ -
3L	$ 2	$ 1	$ 1
4L	$ 2	$ 1	$ 1
4R	$ -	$ -	$ -
5L	$ 29	$ -	$ 29
5R	$ 143	$ -	$ 143
6L	$ 10	$ -	$ 10
6R	$ 4	$ -	$ 4
7L/7R	$ -	$ -	$ -
Total	$ 222	$ 24	$ 198

* Without Project does not reflect impact of aggregate mining.
Note – Includes Structure & Content Damages Only.

As shown above, the potential for flood damages is essentially eliminated under the with-project condition assumptions for reaches five and six, and are substantially reduced for the other reaches. A significant portion of the reduced damages is attributable to the assumed future aggregate mining operations, which is really a without-project assumption that is not reflected in the without-project damage estimate. Hence, most of the damages reduced, or benefits, can not be attributed to the features of the Recommended Plan. However, the Recommended Plan does generally result in reduced water surface elevations throughout the study area, as can be shown in Table 25 for Reach 2 (which is not impacted by the planned mining). Therefore, it can be stated that the Recommended Plan provides incidental flood damage reduction benefits, but the amount of these benefits is uncertain.

Before environmental restoration alternatives were finalized and the assumptions relating to proposed aggregate mining were developed, potential single-purpose alternatives were formulated to reduce flood damages, primarily in Reaches 5 and 6. Alternatives analyzed included channel improvements, levees, floodwalls and relocation. The only economically viable alternative identified was constructing floodwalls to protect parcels owned by a single property owner. Because of Corps policies relating to single beneficiaries, it is unlikely that a Federally cost-sharable alternative could be identified. However, due to the subsequent analysis documented above showing that flooding related problems will essentially be eliminated in these reaches, there is no need for additional flood damage reduction measures anyway.

Recreation

Overview of Methodology

National Economic Development benefits arising from recreation opportunities created by a project are measured in terms of aggregate willingness to pay. Corps Principles and Guidelines describe three techniques which have been developed to estimate recreation demand and value. They include: 1) the Travel Cost Method; 2) the Contingent Value Method; and 3) the Unit Day Method. The Unit Day method was the method chosen for this analysis.

The Unit Day method does not attempt to account for the impact of price on visitation to a recreation site. Instead, an assigned user day value is applied to the total number of estimated visitors. User day values are simulated market values judgmentally derived from a range of values agreed to by Federal water resource agencies. It is intended to represent the users' average willingness to pay for a day of recreation activity at the site. When a properly formulated unit day value is applied to estimated use, an approximation of the area under the site demand curve is obtained, which is used in estimating recreation benefits.

A national schedule is available showing a range of values for both specialized and general recreation opportunities. A point rating system can be used to select a specific value from the published schedule of value ranges. Once alternatives have been formulated and recreation and environmental components identified and described, then unit day values can be selected with the input of Corps and local government agencies. These values are then applied to projected visitation.

There are several techniques available for projecting visitation. These include regional and site-specific use estimating models, the similar project method, and the capacity method. Since it has been established that there is substantial unmet demand for recreation in the market area, the method which will be utilized to estimate visitation is the capacity method. The capacity method involves the estimation of annual recreation use based on instantaneous resource or facility capacities and expected daily, weekly and seasonal use patterns. As specified in *National Economic Development Procedures Manual - Recreation* (IWR Report 86-R-4, p. 13-14), ABecause the capacity method does not involve the estimation of site-specific demand, its use is valid only when it has been otherwise determined that sufficient need exists in the market area of the proposed project to accommodate the project=s calculated capacity...The capacity method has its greatest potential for use in urban settings when it is immediately obvious that sufficient need exists for the opportunities that the proposed project could provide.≅

Unit day values will be calculated by assigning points to each activity (based upon Federal guidelines) and then converting total points to dollar recreation values (per Economics Guidance Memorandum 06-03 conversion table). Point values are derived by ranking the potential recreation resource according to five different criteria:

TABLE 26
Unit Day Point Values

Criteria	Key Variables	Range of Point Values
Recreation Experience	Number & type of activities	0-30
Availability of Opportunity	# of similar opportunities nearby	0-18
Carrying Capacity	Adequacy of facilities for activities	0-14
Accessibility	Ease of access to and within site	0-18
Environmental	Esthetic quality of site	0-20
Total		0-100

Based upon the total number of points assigned, UDV=s (FY 2006) can range from $3.19 to $9.57 per recreation day.

Proposed Recreation Alternatives

The City of Phoenix has developed a Recreation Plan. A copy of the analysis conducted by the City is included in the Recreation Appendix of the Feasibility Report. Please refer to this document for a detailed description of the proposed recreation plan. The plan=s goal is to provide opportunities for visitors of all ages from varied backgrounds to enjoy the environmental resource created by the restoration project while developing an awareness, knowledge and understanding of desert riparian habitats and its interrelatedness to the environment as a whole.

Major project features include parking lots, information kiosks, overlooks, shade structures, bridges, multi-use trails, restrooms, signage and landscaping. Recreation activities provided by the plan include: walking, hiking, biking, horseback riding, roller blading, picnicking and birding. Scenic overlooks will be included for the enjoyment of the restored desert riparian habitat. Information kiosks will provide education on the resource, including restoration of the habitat, the hydro cycle, a historical perspective of the Salt River, and flora and fauna within the project area.

Benefit Analysis

Visitation Projections

Visitation at the resource will be limited based upon the available parking in the area. Phoenix=s design includes several parking lots with a total of 500 spaces. Visitation data maintained by the City for other recreation sites indicates an average number of visitors per vehicle of 2.75. In addition, it is estimated that ten percent of visitors arrive to the site by an alternative mode of transportation, e.g., bicycle, foot traffic and public transportation.

Annual visitation has been estimated for both winter (October - May) and summer (June - September) seasons. In addition, visitation has also been broken down by prime time (weekends and holidays) and non-prime time (weekdays). The following summarizes the results.

Table 27
Rio Salado Oeste
Recreation Plan
Baseline Visitation Estimate

	Days	Turnover/Day	Visits*
Winter (Oct-May)	243		
Prime Time	78	1.50	160,875
Non-Prime Time	165	0.50	113,438
Winter Total			274,313
Summer (Jun-Sep)	122		
Prime Time	36	1.00	49,500
Non-Prime Time	86	0.25	29,563
Summer Total			79,063
Grand Total (By Vehicle)			353,375
Add - Arrive by Alternative Mode (10%)			35,338
Total Visitation			388,713
Less Transfers (10%)			38,871
Baseline Visitation for Benefit Analysis (Rounded)			350,000

* Note - Based Upon Parking Capacity of 500 Spaces & Avg. of 2.75 Persons/Vehicle

Transfers are expected to be minimal due to the unique recreation opportunities and setting offered at the restoration site. The City expects the primary transfers to be in the categories of education field trips, bird watchers, passive nature watchers, canal joggers and recreational cyclists. Annual transfers were estimated at ten percent of total visitation. Excluding transfers, annual visitation is estimated at 350,000.

The above visitation projections were also compared to standards established by the National Recreation & Parks Association (NRPA), regarding trail usage and capacity. NRPA standards for trail capacity and use range from 40 to 90 users per day per trail mile (or between 14,600 to 32,850 users per year per trail mile). The proposed recreation plan includes approximately 24 miles of multipurpose trails. With baseline visitation projected at 350,000, this equates with a value of about 14,600 users per year per trail mile, which supports that the proposed facilities should be able to accommodate the projected visitation. Further, the proposed facilities should also be able to support likely increases in visitation over time, as the general population growth in the Study Area will inevitably increase demand and use of the facilities.

Unit Day Point Value Estimates

A panel of Phoenix Parks, Recreation and Library department personnel including Park Managers, Recreation Supervisors, Recreation Coordinators, and Landscape Architects reviewed the recreation plan in light of its location within the planned environmental restoration study area and derived the following point values for the Unit Day Value analysis:

Criteria	Range of Point Values	Assigned Value
Recreation Experience	0-30	29
Availability of Opportunity	0-18	12
Carrying Capacity	0-14	14
Accessibility	0-18	18
Environmental	0-20	17
Total	0-100	90

Recreation experience was rated very high, although most recreation activities could be described as general recreation. This is because of the context within which the recreation takes place. There are very few recreation sites in the market area located in a riparian and wetland environmental setting. This enhances the value of these activities. In addition, non-general recreation and education opportunities are provided, such as interpretive areas and scenic overlooks, birding, etc. The project will be designed to maximize recreational values in the other categories to the extent possible. Please refer to the City=s recreation analysis for additional details.

EGM 06-03 provides ranges for point value to dollar value conversion. The dollar value corresponding with a point value of 90 is $9.17. This point value was applied to projected annual visitation to derive the annual value of the recreation resource. The resulting annual recreation value totals $3,209,500.

US Army Corps of Engineers
Los Angeles District

Rio Salado Oeste
Maricopa County, Arizona

Real Estate Appendix

Feasibility Report

Appendix H
Real Estate Plan

March 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

NARRATIVE SUMMARY

1. Project Location:

Rio Salado Oeste translates into Salt River- West. The Area is located within Maricopa County, Arizona and consists of an 8-mile reach of the Salt River. This project lies immediately between the Rio Salado and the Tres Rios environmental restoration projects, both authorized and currently under construction and sponsored by the City of Phoenix. The Rio Salado study area extends from 19th avenue, the lower end of the Rio Salado project, to 83rd Avenue, the point of commencement for the Tres Rios Project. The entire area where environmental restoration features will be implemented is within the 100 year floodplain. Restoration of this reach of the Salt River will provide connectivity and a corridor of environmental restoration on the Salt River through the city. The project is also aimed at providing some measure of flood damage protection and a holistic approach to the hydraulic and riparian processes and functions of the Salt River.

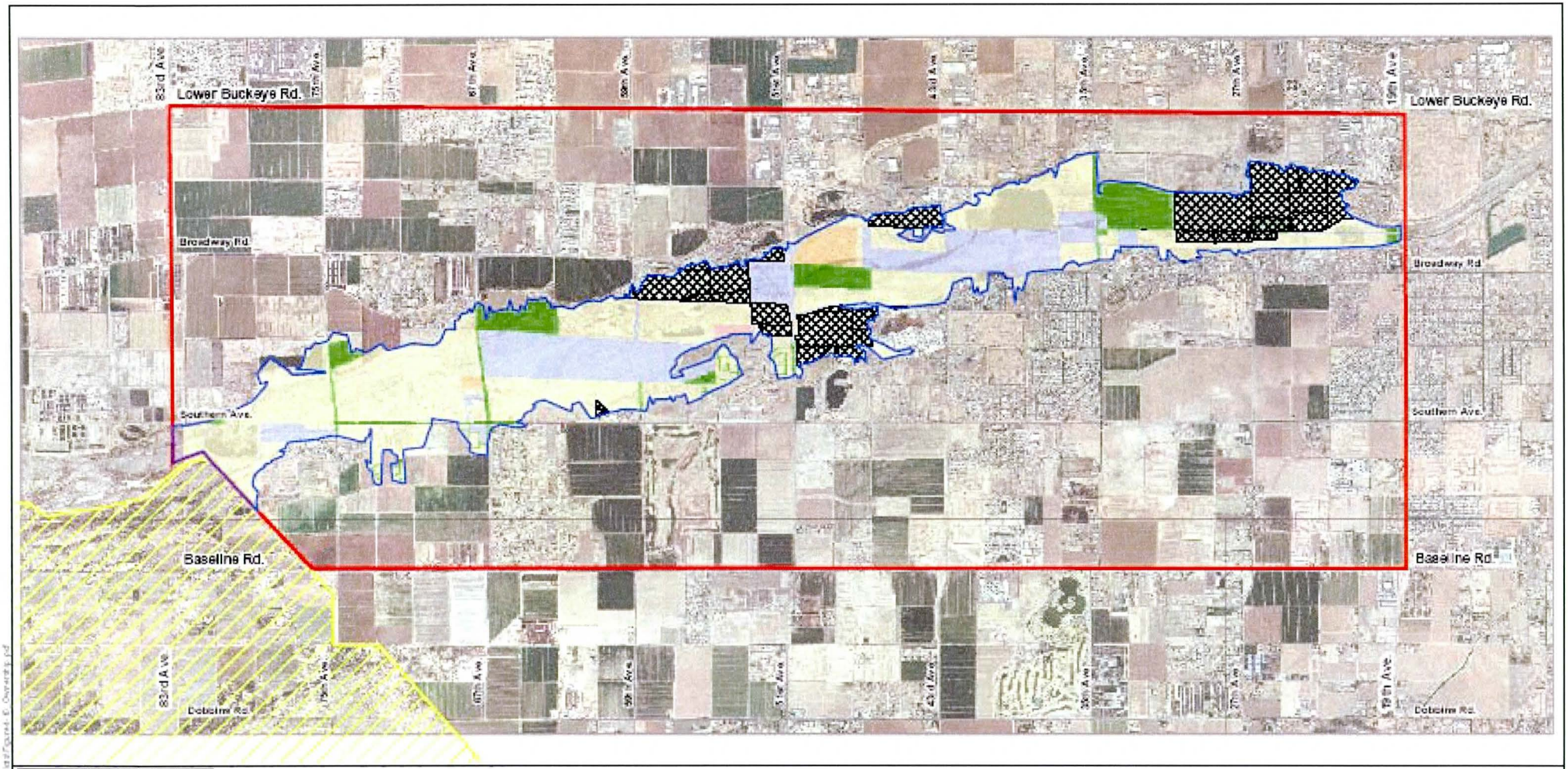
2. Estimated Values:

A gross appraisal has been completed for the project. The total LERRD estimates which includes amounts for contingencies and incidental expenses is $55,900,000.

3. Special Note on Estates (ER 405-1-12, paragraph c).

The Real Estate Plan and Feasibility Report recommends that the estate to implement this project is fee simple. At the Alternative Formulation Briefing held October 14, 2005 a consensus and agreement was reached to preserve the option and flexibility in the future , to explore the acquisition of a permanent and assignable easement during subsequent development (PED) and prior to the signing of a PCA and project construction phases. Any use of an easement estate would be submitted to HQ for required approval in accordance with ER-405-1-12, Chapter 12 Paragraph 12-9 c. One element or prerequisite made know by HQ is that any easement estate must be a permanent and assignable easement in which a reviewing attorney for the District can attests will "run with the land" under Arizona State law.

Should the Non-Federal Sponsor and complete Project Delivery Team later recommend that an easement estate may be beneficial, even in limited applications, a complete proposal and attorneys' opinion supporting the use of an easement estate designed for this project will be submitted to HQ in accordance with the cited regulation and approval process.



Property Ownership and Use Within Project Study Area

Legend

- Project Study Area
- Project Implementation Area
- Private
- Federal Government
- State of Arizona
- Maricopa County
- City of Phoenix
- Existing Sand and Gravel Operation
- Gila River Indian Community

0 5,000 10,000

Feet

April 2005

Rio Salado Oeste

US Army Corps of Engineers

Appendix H: Draft Real Estate Plan
Rio Salado Oeste
Phoenix, Arizona
Feasibility Study

Abstract of Project Data:

Project Name: Rio Salado Oeste , Phoenix, Arizona

Location: City of Phoenix , Arizona

Project Purpose: Environmental Restoration

Acreage: Lands Required for Environmental Restoration (Alt. 5A) 1500 Total Acres;

Project Sponsor: City of Phoenix.

1. Purpose of this Report:

The purpose of this Real Estate Plan (REP) is to support the Feasibility Study decision document in the process of preparing a complete Feasibility Report, and a Chief's Report to Congress and ultimately an approved new project start in subsequent WRDA authorization.

2. Environmental Restoration Purposes and Related Project Features.

The Rio Salado Oeste, (Salt River -West) Study is being performed to investigate water resources related issues and ecosystem restoration opportunities on this reach of the Salt River.

The Salt River has experienced large-scale channel and environmental degradation over the last century. The construction of upstream dam and reservoirs for irrigation and reclamation coupled with the impacts of urbanization have resulted in the loss of critical riparian habitat and overall ecosystem degradation on the Salt River basin. Prior to development and urbanization in the Phoenix area, the Salt River flowed as a major perennial river, fed by the snowmelt and watersheds of the lands upon the Mogollan Rim and northeastern Arizona. In the early 1900's the construction of irrigation dams on the Salt River diverted water for agricultural and urban uses. Urbanization and development along the Salt River corridor further changed the natural river system. The habitat became severely degraded and disrupted due to these sudden changes. In conjunction, the basin experienced reduced flows, both in terms of surface flows surviving into the Phoenix reach and in the depth and availability of groundwater needed to support a riparian community. Today only isolated fragments of a once healthy riparian system, once capable of sustaining the Hohokam and Pima cultures, remain.

All of the acreage to be acquired for this project will be allocated to the project purpose of environmental restoration and credited accordingly for cost sharing purposes. There are no separable recreation lands and no separate recreation component. Any

recreational use described in the report falls under the heading of incidental recreation use.

The project footprint has been determined through the application of sound real estate principles including blocking out along regular and definable boundaries; minimizing severance; and maintaining usable and economic remainders. The project footprint is the minimal area needed to accommodate the construction, operation, maintenance, repair and replacement of the proposed project and will be the area potentially credited toward the project.

Restoration features of the selected alternative include grading and terracing the river channel to form a more natural channel state from 19th Avenue to 83rd Avenue. The project will also include water detention and retention measures to contain water and hold it in the river system to sustain riparian vegetation and communities. Along the project area there will be various associations and plantings of cottonwood/willow communities as well as mesquite bosques and wetland and riparian cover types. Irrigation systems will be developed. The selected alternative also includes the control of invasive species such as Salt Cedar.

Major Land Owners/Classes

The following present the major land uses and categorizes of ownership of the 1500 acres to be acquired within the project footprint of the project.

Landowner/Class	**Type of Land**	**Acreage**
City of Phoenix	Riverbed/Open Space	410
Maricopa County	Bridge rights of way/floodplain	110
State of Arizona	River bed/Open Space	65
Sand and Gravel	Materials Extraction	690
BLM- (City has Existing Lease)	River bottom	160
Private	Various	65
Total		1500

*acres have been rounded and are approximate

3. Description of Lands owned by Non-Federal Sponsor – City of Phoenix.

The City owns approximately 400 acres. In addition the City has an indefinite Lease on BLM lands on another 160 acres. The City manages operates and maintains the land under the lease, including all expenses for operation and maintenance responsibilities. It is recommended that the city perfect it lease to obtain a Recreation and Public Purposes Patent, thus acquiring the land in fee simple title. This parcel includes 160 acres of project land situated within the river corridor and floodplain. The acquisition of

this BLM land through a Recreation and Public Purposes Patent is perfectly feasible and achievable by the City of Phoenix. The City of Tempe obtained such a Patent for its Town Lake Project on the Salt River. The United States Patent coveys full "fee simple title" to the land.

The comprehensive plan would contemplate that privately held lands within the river corridor be acquired to support a public use and managed for their natural amenities and open space attributes that are important to the quality of life.

The land within the study area includes a number of privately owned parcels. Other parcels are owned by the State of Arizona and Maricopa County. The City of Phoenix is also acquiring some of this private land as opportunities arise in an ongoing effort at regenerating this urban corridor for public use. The City is acquiring this land independently of the proposed Rio Salado Oeste Project and Feasibility Study. By letter dated June 22, 2005, the City was provided with a written notice concerning the acquisition of lands in advance of project authorization.

Based upon the City of Phoenix General Plan (dated February 2001) most of the land adjacent to the project that is usable and developable and situated on the north side of the river corridor between 19th avenue and 59th Avenue is zoned industrial with some residential use predominately between 43rd avenue and 60th avenue. Westward of 60th avenue to 83rd avenue, the land outside of the 100-year floodplain and beyond the floodplain is zoned residential. The majority of the land on the south side of the Salt River is characterized by residential zoning. *The BLM (Federal Government) owns one parcel near 67th Avenue.*

Within the 100-year floodplain, where the environmental restoration features will be located, the land ownership includes private owners, sand and gravel operators, the State of Arizona, Maricopa County and the City of Phoenix. Because the land is within the river corridor and within the floodplain, there is a high degree of public agency ownership of the river basin and corridor.

4. Non- Standard Estates:

There are no non-standard estates being recommended with this Feasibility Report. It is recommended that the City obtain fee simple title, via a Patent on the BLM lands and on the State Lands.

5. Existing Federal Project:

There is no existing Federal or local cooperation project within this study area.

6. Federal Lands, Interests or Reservations:

There is one parcel of BLM land in the vicinity 67th t Avenue containing 125 acres of land This parcel is situated within the confines of the river and within the floodplain influence. The City has an indefinite Lease for Recreation and Public Purposes. It is recommended that the City acquire a recreation and Public Purposes Patent, thus acquiring fee ownership of this parcel and perfecting their ownership.

If the City does not obtain its Recreation and Public Purposes Patent from BLM, the City of Phoenix may require the assistance of the Corps of Engineers in acquiring this parcel. These determinations will be made subsequently in the PED phase and prior to PCA signing and project construction. If the sponsors lack authority or cannot acquire Federal owned land for procedural or other reasons, it is recommended that the sponsor enlist the assistance of the Corps in acquiring the land on its behalf. All acquisition expenses, including payments for appraised value or just compensation would be a Non-Federal Sponsor costs. Acquisition on behalf on the Non-Federal sponsor, if necessary, would be a by a separate reimbursable agreement.

7. Navigation Servitude:

The Salt River is not navigable; therefore navigation servitude is not being invoked for this project.

8. Project Maps:

The Project Real Estate Map is provided with this Real Estate Appendix as Figure -1. Additional maps are included in the Main Report and may be located in the Table of Contents and List of Figures

9. Construction or Project Induced Flooding:

Appropriate measures will be taken for the care and diversion of water, if any, during construction. There will be no construction induced or project induced flooding on lands. The appropriate hydraulic and hydrologic studies and assessments have been performed to avoid any induced flooding as a result of the project or its features.

10. Baseline Cost Estimate:

A gross appraisal of the Lands, Easements, Rights-of-ways, Relocations and Disposal Areas (LERRDS) has been obtained. Including administrative incidentals and estimated contingencies, the project LERRD estimate is $55,900,000. This figure is reflected in the project cost summaries submitted with the main report.

11. Crediting for LERRD's:

Crediting will follow standard procedures as set out in a model Project Cooperation Agreement (PCA). No Credit will be afforded to any lands or interests previously acquired and credited for any applicable Corps of Engineers Project.

Credit will only be applied to the acreage within the "project footprint", namely the lands or corridor required for the Recommended Plan of improvements to be included in the Federal/Local Sponsor environmental restoration plan. Lands outside of the project requirements and lands that may be acquired for the sponsor's own purposes would not be creditable LERRD's.

Corps policy prescribes that credit will <u>not</u> be afforded for lands purchased with Federal funds or grants where the granting of such credit is not permissible. This might apply, for example, to lands acquired with funding from Department of the Interior agencies such as Fish and Wildlife Lands purchased with Federal funds.

12. Mineral Activity:

Sand and gravel extraction activities are present within the study area. If at the time of valuation and acquisition of specific parcels, these activates are still present on lands to be acquired for the project, the appropriate valuation and highest and best use determinations will be applied as to any sand and gravel operations. It is contemplated that sand and gravel extraction will be diminishing and allowed to "play out" prior to the time that project implementation actually proceeds. Since this project is in the planning stages (contingent on future WRDA authorization), project construction may be several years in the future. At the time of this writing it is thought that a WRDA Authorization for the Rio Salado Oeste Project may occur in 2008 perhaps later, and that actual physical construction is not anticipated until 2010.

As has been the practice on the Tres Rios and Rio Salado projects, the in place value of any merchantable sand and gravel and "common variety materials" will be incorporated into the valuation of river bottom lands where such materials exist and where it has been found appropriate by the appraiser as to include in the lands' valuation. This has been fully considered when developing a gross appraisal and "LERRD" estimate.

There is no timber activity in this xeric /riparian environment of the desert southwest.

13. Sponsor's Capability Assessment.

The non-federal sponsor is a duly organized municipal organization in the State of Arizona and is vested with sufficient power to acquire and hold title, and to condemn lands as needed for public purposes. The sponsor has previously participated in other Corps of Engineers' Local Cooperation Projects such as the Rio Salado and Tres Rios projects. Both of these are similar large scale environmental restoration efforts. The City of Phoenix has demonstrated its capabilities in acquiring real estate and performing the related obligations of a Non-Federal Sponsor. A capability assessment has been completed and shows the City of Phoenix is highly capable of undertaking this project and fulfilling the responsibilities of a Non-federal Sponsor.

14. Other Matters, Other Property Interests, Use of Zoning:

The sponsor is not using any zoning ordinances in lieu of acquisitions within the project take areas.

15. LERRD Acquisition Schedule.

The sponsor has already to begun to acquire some lands, based on a possible WRDA authorization. It is thought that project construction might not commence until Fiscal 2010. The City already owns approximately 25% of the lands in the overall project area. The City thus would have at least 30 months and possibly more to acquire the LERRDS before the first construction contract was let. Based on the City of Phoenix record with the Tres Rios project this is well within its capabilities. It is anticipated that the project will be constructed in phases as available construction funding is appropriated. *For example*, the project may be divided into separate reaches or phases, e.g.

19th to 35th Avenues	2 miles
35th to 51ist Avenues	2 miles
51st to 67th Avenues	2 miles
67th to 83rd Avenues	2 miles

There are approximately 20 -25 parcels in each of these reaches. By proceeding to develop the total project in separate phases and construction contracts, the City of Phoenix should have no difficulty in acquiring the LERRDS for each of these phases. A more detailed land acquisition schedule would be developed following WRDA authorization, and during the PED phase, and during the time to negotiate and approve the PCA for implementation. The exact project phasing would be developed in concert with the Sponsor and based on funding capabilities. The dictates of Federal funding would be more influential on the project schedule than the capability to acquire right-of-way (LERRDS) in a phased implementation approach. Project phasing would be developed after WRDA approval during PED and development of a PCA in close coordination with the Non Federal Sponsor by the Project Delivery Team, and is anticipated to closely follow the dictates and availability of Federal Funding for construction.

16. Facility Relocations:

To date the necessity for any facility relocations in the project area, is not anticipated. Further engineering and design work will refine requirements for facility relocations during subsequent phases of the study and Pre-Construction Engineering and Design (PED), if a project is approved for implementation.

Note: The following policy statement and disclaimer concerning any potential facility relocations prevails over any other statement, description or presentation in this report:

> *Any conclusion or categorization contained in this report that an item is a utility or facility relocation to be performed by the Non Federal Sponsor as part of its LERRD responsibilities is preliminary only. The Government will make a final determination of the relocations necessary for the construction, operation and maintenance of the project after further analysis. An Attorney's Opinion of Compensability will be generated for each facility/utility relocation that is required for the project which will be performed by, and credited to, the Non-Federal Sponsor under the definitions and terms of the PCA.*

Because the project is aimed at maximizing environmental restoration outputs in the river channel, it is contemplated that the physical relocation of utilities and pre-existing facilities will be avoided in formulation and design. This will enable the project to concentrate its funding and resources on environmental outputs rather than utility infrastructure. Physical relocation of existing utilities, particularly underground utilities, will be avoided as the outputs are realized by the resulting riparian habitat on the surface. A guiding principle of this project is that the surface habitat can be restored without disturbing or removing underground utilities.

17. Relocation Assistance (URA Relocations):

The City of Phoenix will accomplish all property acquisitions in accordance with Public Law 91-646, as amended, and the Uniform Regulations as promulgated by the U.S. Department of Transportation. The property within the project footprint is largely unimproved. It does not appear that any displacements of businesses or residences will be required due to the design and configuration of the project.

18. Attitude of Landowners:

There is no focused or organized landowner opposition to the project. The sponsor will be conducting landowner and public information meetings to promote understanding of the project and how the landowners will be affected. The City has acquired lands upstream and downstream of the study reach for other Corps projects (Tres Rios and Rio Salado). The City has only had to condemn in isolated cases. The City has handled these projects successfully without causing any widespread landowner antipathy toward its land acquisition efforts.

19. Hazardous Waste Assessments Known or Suspected Contaminants:

The sponsor fully understands its responsibilities for assessing the properties for any potential or presence of hazardous waste materials as defined and regulated under CERCLA. There are no known "Superfund" sites or sites presently under CERCLA remediation or response orders identified in the project area. There are no known presences of any substances in the project area that are regulated under CERCLA or other environmental statutes or regulations. Assessments and site investigations for the presence of such substances have not been conducted to date. The LERRD estimate is predicated on the assumption that all lands and properties are clean and require no remediation. The model PCA conditions contain specific terms and conditions governing the sponsor's responsibility for environmental cleanup for CERCLA regulated substances. Hazardous Waste Assessments are covered as a project cost under the model PCA.

20. Recreation:

There is no identified separable land (i.e., land acquired exclusively for recreation purposes for this project). All lands are allocated for the project purpose of environmental restoration. There are incidental recreation features included in the selected plan such as access points and interpretive and educational materials. These features do not require additional or separable project land.

21. Statement of Risks.

The sponsor has been notified in writing (June 22, 2005) about the attendant risks of acquiring land in the project area prior to Congressional authorization of a cost shared project. The City of Phoenix has participated with the Corps on two other large scale environmental restoration projects and is very much aware of the timelines and approval processes required to obtain a WRDA authorization.

22. Report Content:

This report follows the requirements of ER-405-1-12, Chapter 12 and was prepared using the information on the project formulation that has been provided. Comments received during internal Corps review have been incorporated. This report recommends that the Non-Federal Sponsor acquire fee simple estate through obtaining fee patents from the State of Arizona and the Bureau of Land Management.

February 2006

Recreation Costs & Benefit/Cost Analysis

Table 28, which follows, details the cost estimates for the proposed recreation plan.

Table 28
Rio Salado Oeste
Recreation Plan
Expected Annual Costs

First Cost		
Site Preparation	$	1,125,000
Parking Lots (500 Spaces)	$	750,000
Entry Roads	$	750,000
Sidewalks & Ramps	$	255,000
Multi-Use Trails	$	425,730
Bridges & Culverts	$	90,000
Minor Access Points	$	54,000
Access Control	$	946,250
Security Lighting	$	472,000
Signage	$	191,000
Picnic/Trail Shelters	$	1,390,000
Restroom Facilities	$	1,250,000
Utilities	$	920,000
Park Furniture	$	176,500
Interpretive Guidance Media	$	136,700
Subtotal - Construction	$	8,932,180
Contingency (20%)	$	1,786,436
PED/EDC (11%)	$	982,540
S&A (7%)	$	625,253
Total First Cost	**$**	**12,326,000**
Interest During Construction	$	632,000
Gross Investment	**$**	**12,958,000**
Annualized Investment Cost	$	723,500
OMRR&R	$	2,055,000
Total Annual Cost	**$**	**2,778,500**

Average annual benefits have been estimated at $3,209,500, and average annual costs are estimated at about $2,778,500. Therefore, the proposed recreation plan is economically justified, with net benefits of $431,000 and a benefit/cost ratio of 1.16.

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Salt River-Phoenix, Arizona

Appendix I
Functional Assessment

January 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

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Introduction

The Rio Salado Oeste Ecosystem Restoration Feasibility Study is being conducted as a joint effort between the U.S. Army Corps of Engineers (USACE), Los Angeles District and the Non Federal Sponsor, the City of Phoenix (COP). The purpose of the study is to evaluate problems and opportunities related to ecosystem restoration, flood damage reduction and recreation. This analysis is meant to quantify ecosystem benefits and assist in the decision making process within the feasibility study.

This report contains the analysis, results, and documentation of the Rio Salado Oeste HGM assessment. An intensive Hydrogeomorphic Wetland Assessment (HGM) was undertaken to quantify benefits generated by proposed wetland ecosystem restoration alternatives for the Rio Salado Oeste, Phoenix, Arizona, Ecosystem Restoration Feasibility Study (Oeste). The Rio Salado Oeste study area lies within and along the Salt River between 19th and 83rd Avenues in Phoenix, Maricopa County, Arizona. The 3,148-acre study area is approximately eight river miles in length. The study area lies upstream of the Tres Rios Feasibility Study area, and downstream of the authorized Rio Salado project area. The non-federal sponsor for the feasibility phase of the study is the City of Phoenix.

The District requested the assistance of the U. S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC) to develop and evaluate a hydrogeomorphic wetland assessment (HGM)-based functional assessment methodology for use in Arizona restoration studies. Early in the evaluation process, an interagency Ecosystem Assessment Team (E-Team) was convened for the purpose of completing the field assessments. The E-team consisted of representatives from Planning Section C, the Los Angeles District technical sections, the U.S. Fish and Wildlife Service (USFWS), the Arizona Game and Fish Department (AZGFD), several environmental consulting firms, academia, and local and county governments. Each project team also included individuals responsible for project design and management. Together these individuals brought together the necessary technical expertise to support planning efforts requiring disciplines related to botany, soils, hydrology, hydraulics, geomorphology, and wildlife ecology.

Between 2002 and 2003, the E-Team completed intensive baseline habitat sampling activities at ten sites within the Gila River watershed. These sites consisted of the five feasibility study areas (including Rio Salado Oeste), and five "reference standard sites" for the calibration of the Functional Capacity Index (FCI) models. Based on the land uses present, the areas assessed were categorized into one of 19 cover types, or partial wetland assessment areas (PWAAs). Twenty-eight separate variables were measured for each PWAA in an attempt to develop a description of the baseline (2002) conditions at these sites. Ten FCI models were developed and used in the assessment to capture the functional capacity of the riparian habitats. These models focused on maintenance of characteristic channel dynamics, dynamic surface water storage and energy dissipation, long term surface water storage, dynamic subsurface water storage, nutrient cycling, removal and/or detention of imported elements, detention of particulates, maintenance of characteristic plant communities, maintain spatial structure of habitat, and the maintenance of corridors for interspersion and connectivity.

The specific, HGM-based functional assessment method resulting from these efforts is now known as the Arizona Riverine Assessment Tool (Functional Assessment Tool). The functional

assessment was designed to evaluate the future changes in quantity (acres) and quality (functional capacity) of riverine, wetland and terrestrial riparian strand ecosystems. The model is described in its entirety in the following report, which is incorporated by reference.

Burks-Copes, K. A. and A. C. Webb. 2003. Tres Rios del Norte (Pima County, Arizona) Ecosystem Restoration Functional Assessment Using HGM: Analyses, Results and Documentation. Draft Report. U. S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. 112 pp. + appendices.

Methods

The functional assessment tool utilized in this project is based upon a Habitat Evaluation Procedures-like approach to assessing the functional capacity of a wetland using standard wetland assessment protocols typically deployed in the regulatory arena (Smith et al. 1995). Referred to as the Hydrogeomorphic Approach or HGM, an assessment model is developed and serves as a simple representation of functions performed by a wetland ecosystem (Ainslie et al. 1999). The functional models developed in HGM define the relationships between one or more characteristics/processes of the wetland ecosystem (or surrounding landscape) and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function as it compares to the level of performance in reference standard wetlands.

HGM is an accounting system that can be used to estimate the functional value of the study area wetland habitat(s) relative to the functional value of reference wetland habitat(s). In the HGM process, the currency denoting functional value is defined as Functional Capacity Units (FCU's). A functional capacity unit considers two factors: 1) the quality of the wetland habitat and 2) the quantity of the wetland habitat providing the functional value(s).

The quality of the habitat is measured as the Functional Capacity Index (FCI). The FCI is derived from limiting environmental factors (variables) associated with the various functions attributable to wetland ecosystems. It is a function made up of arithmetic, geometric, or multiplicative combinations of the scores for each cover type. Due to time and economic constraints, and the need to estimate future conditions, several limiting environmental factors are obtained through the use of literature searches, aerial photographic analysis, historical and contemporary mapping and GIS products.

A basic assumption of the HGM approach is that the highest, sustainable functional capacity is achieved in wetland ecosystems and landscapes that have not been subject to long-term disturbance (Smith et al. 1995). It is further assumed that under these conditions the structural components and physical, chemical, and biological processes within the wetland and surrounding landscape reach a dynamic equilibrium necessary to achieve the highest, sustainable functional capacity.

A FCI score varies between 0.0 and 1.0 because the value is determined as the ratio of the study area conditions to those measured or estimated at a reference wetland standard. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes. Conversely, an index of 1.0 indicates that a wetland performs a function at the highest sustainable functional capacity, the level

equivalent to a wetland under reference standard conditions in a reference domain. An HGM model developed for a given subclass of wetlands is essentially an assimilation of several FCI models to evaluate overall site functionality. All FCI models are described using a single FCI formula. Some examples of HGM FCI models include floodwater detention, internal nutrient cycling, organic carbon export, removal and sequestration of elements and compounds, maintenance of characteristic plant communities, and wildlife habitat maintenance.

The quantity is merely the number of acres of a cover type or partial wetland assessment area (PWAA) receiving the FCI score. When the FCI is multiplied by the number of acres present, the results is the relative value (FCU) of the wetland habitat being considered. More precisely, the resulting FCU value provides a means of assessing the gains or losses in functional value for a single target year of interest. In order to assess the functional value of restored wetland habitats relative to reference wetlands over time, gains and losses are averaged over the life of the project. This resulting meter is termed the AAFCU or average annual functional capacity units.

In summary, HGM combines both the wetland functionality (FCIs) developed with measured or estimated variables and areal extent of a site to generate a measure of change referred to as Functional Capacity Units (FCUs). Once the FCI and PWAA quantities have been determined, the FCU values can be mathematically derived with the following equation: FCU = FCI x Area (measured in acres). When the HGM process is employed, one FCU is equivalent to one optimally functioning wetland acre. HGM can be used to evaluate future conditions and the long-term effects of proposed alternatives by generating FCUs for wetland functions over several target years (TYs). In such cases, future wetland conditions are estimated for both Without Project and With Project conditions. Projected long-term effects of the project are reported in terms of Average Annual Functional Capacity Units (AAFCUs) values. Based on the AAFCU results, alternative designs can be formulated and trade-off analyses can be simulated to optimize ecosystem restoration efforts.

Applying Functional Assessment to the Rio Salado Oeste Study

Ten steps were completed in the assessment of Rio Salado Oeste's proposed ecosystem restoration designs using this functional assessment method. Briefly, they included:

1. Building a multi-disciplinary evaluation team (E-Team).
2. Defining the project.
3. Mapping the site's PWAAs.
4. The Arizona Riverine Functional Assessment Tool
5. Conducting field sampling.
6. Performing data management and statistical analyses.
7. Calculating baseline conditions.
8. Setting goals and objectives, and defining project life and Target Years (TYs).
9. Generating without-project conditions and calculating outputs.
10. Generating with-project conditions and calculating outputs.

Step 1: Ecosystem Evaluation Team (E-team)

In using functional assessment, an interagency, interdisciplinary team is formed to lead both the model selection/development phase of the project, and to establish the baseline and future

conditions of the site(s). In this study scientists from the U. S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC) facilitated the model development and initial ecosystem evaluation efforts. The evaluation team also included members from the Los Angeles District, U.S. Fish and Wildlife Service (USFWS), the Arizona Game and Fish Department (AZGFD), several environmental consulting firms, and local and county agency personnel.

The multidisciplinary ecosystem evaluation team (E-Team) was convened early in June of 2002 to conduct without project assessments and again in 2004 to evaluate with project conditions. Members of the E-Team participating in the Rio Salado Oeste Feasibility Study are listed in Table 1. Note that due to the length of the study and staffing changes not all of those listed below participated in each portion of the evaluation.

Table 1 ***E-Team Members Participating in the Rio Salado Oeste Study***

NAME	ORGANIZATION/COMPANY	DISCIPLINE
Mr. Scott Estergard	USACE, Los Angeles District	Study Mgr/Biologist
Mr. Mike Fink	USACE, Los Angeles District	Biologist
Ms. Antisa Webb	ERDC-EL	Facilitator
Ms. Kelly Burks-Copes	ERDC-EL	Facilitator
Ms. Amy Lee	ERDC-EL	Ecologist
Ms. Karen Dada	City of Phoenix	Study Manager
Mr. Walt Kinsler	City of Phoenix	Landscape Architect
Mr. Mike Martinez	U.S. Fish and Wildlife Service	Biologist
Ms. Kathy Reichert	City of Phoenix	Parks and Recreation
Ms. Michele Waltz	Jones & Stokes	Project Manager
Mr. Bill Werner	Arizona Game & Fish	Ecologist
Ms. Karen Williams	City of Phoenix	Project Manager
Mr. Timothy Kennedy	USACE, Los Angeles District	Environmental Coordinator
Mr. Glenn Mashburn	USACE, Los Angeles District	Hydraulic Engineer
Mr. Michael Hrzic	USACE, Los Angeles District	Hydrologist/Hydraulic Engineer
Ms. Lois Goodman	USACE, Los Angeles District	Biologist

Step 2: Defining the Rio Salado Oeste Project

Geographic Location. The study area is located in the lower Sonoran Desert in the Salt River Watershed. The study area includes portions of the City of Phoenix, Maricopa County, and state and federal land. The study reach extends from the upstream limit of 19th Avenue down to the

lower limit of 83rd Avenue – a distance of approximately eight miles. The downstream boundary of the study reach lies approximately 2.5 miles upstream of the confluence of the Salt and Gila Rivers. Figure 1 shows the location of the Rio Salado Oeste study area.

Hydrology and Geomorphology. Metropolitan Phoenix is geomorphically located within the Gila Lowland Section of the Sonoran Desert Subprovince, a part of the Southern Basin and Range Physiographic Province. This province is characterized by broad, gently sloping, connected alluvial valleys (basins) bounded by moderately high, rugged, northwest- to southeast-trending mountains (ranges).

The Rio Salado Oeste study area lies within the lower Salt River valley near the center of the Gila River basin. The Salt River drains 14,500 square miles of mountainous terrain in central and eastern Arizona. By far, the largest tributary of the Salt River is the Verde River, which joins the Salt River approximately 30 miles upstream of 19th Avenue. The Salt River is the largest tributary to the Gila River. Annual average rainfall in the lower Salt River Valley is approximately 8 inches, while rainfall at the highest elevations of the watershed ranges up to 14 inches annually.

Within the study area, the Salt River flows through a major valley with a relatively flat floor of deep alluvium. Soils in the vicinity of the channel are well drained to excessively well drained on nearly level or gently sloping surfaces. They are often sandy to gravelly, but may include lenses of finer particles. These soils are often redistributed by water flows associated with nearby active channels.

Prior to the onset of European settlement, the Salt River was one of the few perennially watered riparian areas of the Sonoran Desert, supporting Native Americans, wildlife, and highly productive cottonwood, willow, and mesquite habitats. Flows in the river had a distinct seasonal pattern, with highest flows occurring in December and January and lowest flows in October. The river was a significant source of ground water recharge in some areas and a recipient of ground water discharge in other areas.

Beginning in the early 1900's, the historical conditions of the Salt River were altered by construction of dams on the Salt and Verde Rivers upstream of the study area. Due to dam construction, flow diversions and subsequent ground water withdrawal, perennial flows on the Salt River ceased. This caused detrimental environmental impacts to natural wildlife habitat and riparian communities along the Salt River. The elimination of natural base flows reduced Salt River flows to summer or fall rainfall-related flood events. The ground water table beneath the river dropped, soil moisture in the riverbed was virtually eliminated, and the native cottonwoods, willows and riparian ecosystem rapidly died out. The river has been further impacted by construction of bridges and levees, and ongoing sand and gravel mining operations. Most areas of the Salt River are barren today. What little vegetation does exist is mostly limited to salt cedar, an exotic non-native species with little habitat value.

Soil moisture within close proximity to the surface (in the bed and banks of the channel) remains high in areas adjacent to wastewater treatment plant effluent discharges. However, this water is

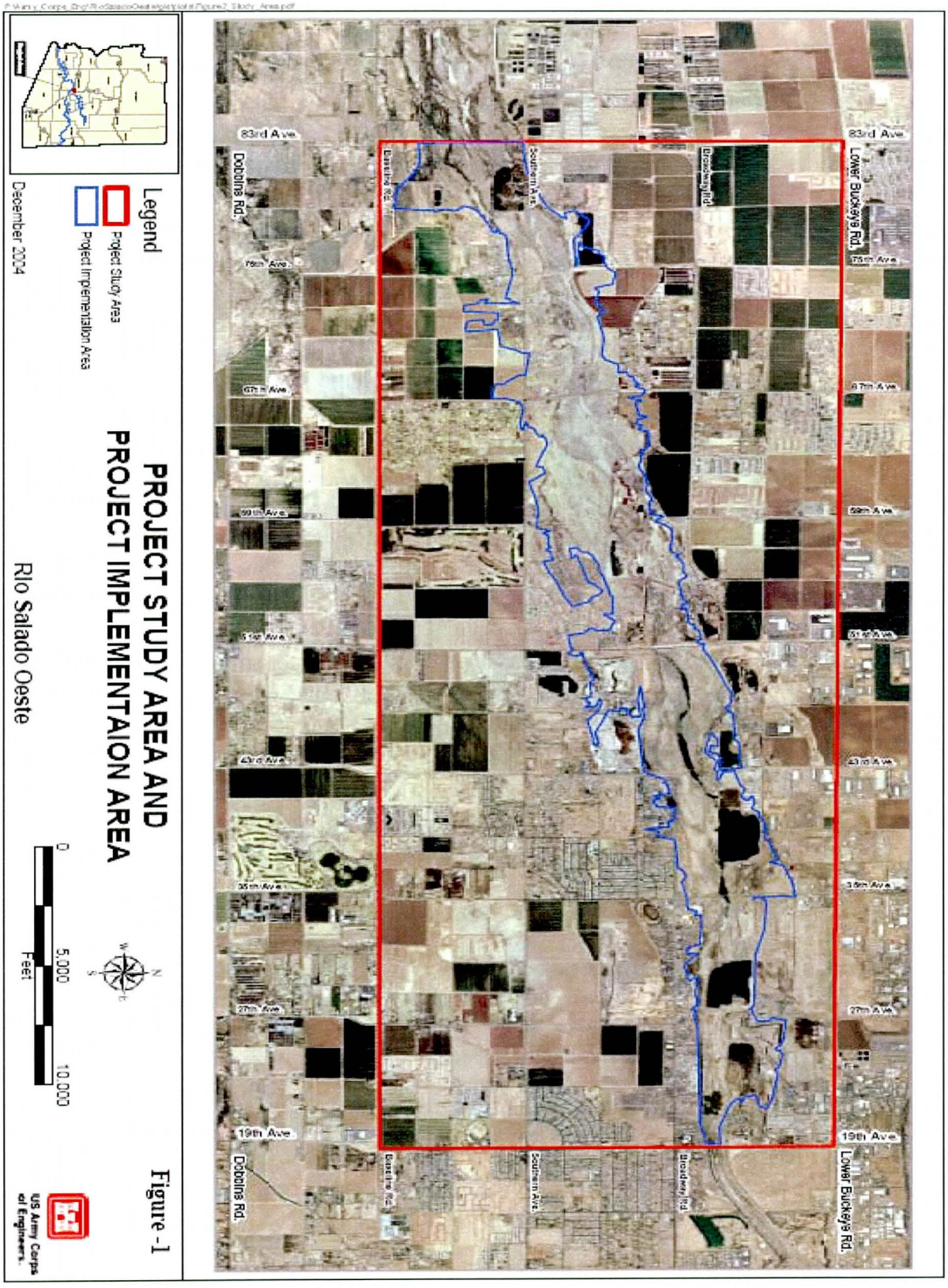

Figure 1Project Study Area

not available throughout the study area, nor is it available to support historical extent of riparian vegetation once associated with these reaches. Indeed, changes in water availability and extent have permanently impacted surface/groundwater interactions and sedimentation dynamics important in the sustenance and regeneration of riparian vegetation. While a significant portion of this effluent flow infiltrates into the bed of the channel, groundwater levels in the Rio Salado Oeste study area currently range from approximately 30 to 100 feet below the land surface.

As a direct results of the disconnection between surface and groundwater over the last century, the Salt River has changed from a braided and meandering streambed with a broad floodplain to a channel morphology shaped by sand and gravel mining, as well as uncharacteristic flood discharges that have scoured and incised the river.

Land Use Practices. Agriculture, urbanization and resource extraction have adversely affected the diversity and extent of the Salt River ecosystem. Historically, the perennial water source encouraged human settlement and agricultural practices that date back thousands of years. The Salt River also served as an important transportation route for Native Americans, missionaries, Spanish explorers, colonizers, miners, cattlemen, and settlers.

The water supply and hydropower benefits that the dams provided led to the economic development of the Phoenix metropolitan area. Phoenix grew from a settlement that supplied food and animal feed to the Army outposts and mines in the area to its current population of 3.2 million people. Agricultural land was rapidly being converted to urban uses to support this growth. Beginning in the late 1970s and early 1980s, sand and gravel mining operations were introduced. The demand for these construction and landscape materials is increasing along with the human population. Sand and gravel mining continues to this date along the Salt River within the study area. Today, the study area consists of a mixture of urban residential, commercial, industrial, agricultural, and open space land uses.

A rapid but declining rate of population growth is anticipated for the City of Phoenix and Maricopa County as a whole. Significant development of residential and non-residential land will be required to accommodate the projected growth. In the study area, existing land uses are primarily comprised of agriculture, industrial and low-density residential. It is anticipated that additional low-to-medium density residential development will take place due to the close proximity of the area to the city core. Existing vacant and agricultural land will likely be converted to residential uses.

Riparian Habitat. Like many rivers in the southwest, the Salt River once had a highly mobile channel that periodically changed location across a wide floodplain. Within this floodplain, the high water table supported extensive riparian forests of cottonwood, willow and mesquite. Subsurface flows and groundwater discharge supported biologically productive cienegas (seep marshlands). With the establishment and growth of the Phoenix metropolitan area, the Salt River has experienced severe and accelerated degradation and loss of riparian habitat. Upstream dams and increasing withdrawal of surface and groundwater flow (primarily attributed to a growing human population and agriculture) has changed the Salt River from a river with a highly available surface and subsurface flow to a primarily dry channel that flows only in response to storm runoff. The lower Salt River within the study area has perennial flow only in association with wastewater discharges from the 23rd Avenue Wastewater treatment plant. As a result of the

aforementioned hydrological alterations, stands of native riparian habitat are rare along the lower Salt River, particularly in the study area.

As land within the lower Salt River watershed has been converted to other uses, most of the biological resources and native habitat in the study area have been lost. Degradation of the river bottom, channel banks and adjacent overbank areas due to changing land uses has significantly impacted the once biologically rich and diverse habitat associated with the river. Biologically rich mesquite bosque habitats have largely disappeared. Sand and gravel extraction has removed large volumes of sediment, leaving open pits with very little resource value that function as sediment traps.

Project Evolution, Purpose, Ecosystem Approach. The study area is currently experiencing negative impacts due to the rapid shift of land uses within the watershed. Urban development has increased impervious cover, resulting in increased peaks and volumes of runoff entering tributaries and the Salt River itself. This has led to erosion of channel beds and banks and increased destruction of the vegetative resources. Conversion of open space has resulted in the loss of overbank storage during flood events. Where water once overflowed the banks of the river during floods, flood protection measures (meant to protect former floodplains) have caused increased volumes of flow to be held within the channel, necessitating bank protection and channelization. This in turn has led to accelerated loss of resources within the channel and in overbank areas. Urban development has also brought increased population pressure to the study area. The increased human presence has resulted in soil compaction, increased damage to the environment due to vehicle usage, and the introduction of large amounts of litter and debris. Demographic projections indicate a continued high rate of development in the study area over the 50-year planning horizon. This trend suggests that development of the floodplain and subsequent channelization and loss of associated resources would be the likely outcome in the absence of measures taken to restore and set aside both the land and its associated habitats. If restoration efforts are delayed, the land needed for effective projects may no longer be available.

Step 3: Mapping Partial Wetland Assessment Areas

To effectively evaluate the existing conditions, the study area was divided into manageable sections and quantified in terms of acres. This process, referred to as partial wetland assessment area (PWAA) mapping or "cover typing", required differentiation between vegetative covers (e.g., mesquite wetlands, shrub lands, open water, and river bottom streams, etc.), hydrology and soils characteristics, and clearly delineate these distinctions on a map. The final classification system, based primarily upon dominant vegetation cover, captured "natural" settings and common land-use practices in a specific and orderly fashion that accommodated the plan formulation process.

Cover types (PWAA) utilized in the model are listed and described in Table 2 below. Quantities of each, existing in the study area, are detailed later in this report.

Table 2 ***Cover Types Identified for the Arizona Riverine Functional Assessment Tool***

NO.	CODE	DESCRIPTION
1	AGCROP	Farms and Croplands - Dairy, Cotton, and Alfalfa
2	CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel
3	DESERT	Desert Areas – Bare Earth, Cacti, Rabbitbush, Acacia, Ironwood, Palo Verde
4	DITCHES	Existing Ditches
5	DRY RIVER BOTTOM	Existing Dry River Bottom Areas in the Active Channel - Largely Unvegetated
6	MESQUITE	Existing Mesquite Woodlands – on the Terraces and in the Active Channel, can and often does contain Palo Verde, Ironwood and Acacia within these woodlands.
7	NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel
8	NEWDRYRVRBOTTOM	Newly Developed Dry River Bottom Areas in the Active Channel - Largely Unvegetated
9	NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel, can and often does contain Palo Verde, Ironwood and Acacia within these woodlands.
10	NEWOPENWAT	Newly Developed Open Water Areas in the Active Channel
11	NEWSCRUB	Newly Planted Scrub – Shrub-lands in the Active Channel
12	NEWWETRVRBOTTOM	Newly Developed Wetted River Bottom Areas in the Active Channel – Primarily Emergent Vegetation
13	OPENWATER	Existing Open Water Areas in the Active Channel - Inactive Sand and Gravel Operations
14	PARKS	Parks and Recreation Areas
15	SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel
16	SCRUBSHRUB	Existing Scrub - Shrublands in the Active Channel – Rabbitbush, Quailbush, , and Saltbush
17	SOILCEMENT	Existing Soil Cement Areas on the Slopes of the Active Channel
18	URBAN	Existing Residential, Industrial and Transportation Avenues
19	WETRVRBOTTOM	Existing Wetted River Bottom Areas in the Active Channel - Primarily Emergent Vegetation

Step 4: The Arizona Riverine Functional Assessment Tool

The final version of the model contains 10 discrete functions. It is important to note that the functions described here were selected on the basis of their representation of ongoing critical ecosystem processes within the wetland subclass. These functions, and the reasons supporting their inclusion in the characterization of arid riverine wetlands for the region, can be found in Table 3 below.

Table 3 ***Functions in the Arizona Riverine Functional Assessment Tool***

CODE	NAME	DESCRIPTION
CHANNELDYN	Function 1: Maintenance of Characteristic Channel Dynamics	Physical processes and structural attributes that maintain characteristic channel dynamics. These include flow characteristics, bedload, in-channel coarse woody debris, and potential coarse woody debris inputs, channel dimensions, and other physical features (e.g. bank vegetation, slope).
WATSTORENR	Function 2: Dynamic Surface Water Storage/Energy Dissipation	Dynamic water storage and dissipation of energy at bankfull and greater discharges. These are a function of channel width, depth, bedload, bank roughness (coarse woody debris, vegetation, etc.), presence and number of in-channel coarse woody debris jams, and connectivity to off-channel pits, ponds, and secondary channels.
WATSTORLNG	Function 3: Long Term Surface Water Storage	The capability of a wetland to temporarily store (retain) surface water for long durations; associated with standing water not moving over the surface. Water sources may be overbank flow, overland flow, and/or channelized flow from uplands, or direct precipitation.
WATSTORSUB	Function 4: Dynamic Subsurface Water Storage	Availability of water storage beneath the wetland surface. Storage capacity becomes available due to periodic drawdown of water table.
NUTRIENT	Function 5: Nutrient Cycling	Abiotic and biotic processes that convert elements from one form to another; primarily recycling processes.
ELEMENTS	Function 6: Detention of Imported Elements and Compounds	The detention of imported nutrients, contaminants, and other elements or compounds.
DETPARTICL	Function 7: Detention of Particles	Deposition and detention of inorganic and organic particulates (>0.45 um) from the water column, primarily through physical processes.
PLANTS	Function 8: Maintain Characteristic Plant Communities	Species composition and physical characteristics of living plant biomass. The emphasis is on the dynamics and structure of the plant community as revealed by the species of TVVs, shrubs, seedlings, saplings, and herbs and by the physical characteristics of the vegetation.
HABSTRUCT	Function 9: Maintain Spatial Structure of Habitat	The capacity of a wetland to support animal populations and guilds by providing heterogeneous habitats.
INTERSPERS	Function 10: Maintain Interspersion and Connectivity	The capacity of the wetland to permit aquatic organisms to enter and leave the wetland via permanent of ephemeral surface channels, overbank flow, or unconfined hyporheic gravel aquifers. The capacity of the wetland to permit access of terrestrial or aerial organisms to contiguous areas of food and cover.

The first four functions (Channel Dynamics, Surface Water Storage, Long Term Surface Water Storage and Subsurface Water Storage) comprise the hydrologic components of the functional assessment model. The next three functions (Nutrient Cycling, Elements and Compound Importation, and Particulate Detention) are the biogeochemical components of the functional assessment model. The last three functions (Plants, Habitat and Insterspersion/Connectivity) together complete the biological components of the functional assessment model.

Variables Associated with the Arizona Riverine Functional Assessment Model. Within each function of the model, a series of variables have been defined, and are used to relate the value of the wetland to the reference standard condition. Of the 25 variables developed, 14 could be measured in the field using simple sampling protocols. The remaining 11 variables were obtained through searches of historical records and Geographic Information System (GIS) database exercises. Refer to Step 5: Field Sampling for the Rio Salado Oeste study below to review the overall field sampling process and data gathering methods used for the study in greater detail.

Table 4 ***Variable names and descriptions used in the HGM assessment***

Variable Code	Variable Description	Variable Code	Variable Description
AGSA	Algal Growth Surface Area as an indicator of past inundation.	LITTER	Abundance of leaf litter and other detrital matter in the FPA.
BUFFCOV	Percent of native vegetation cover in the buffer.	PORE	Soil pore spaces available for storing subsurface water. Performance is related to soil texture and permeability.
BUFFLENGTH	Percent of area with sufficient buffer.	Q	Alterations of hydroregime that affect the assessment area.
BUFFWIDTH	Width of Buffer (m).	SED	Extent of sediment delivery to the water/wetland from culturally accelerated sources.
CONTIG	Contiguous vegetation cover between waters/wetlands and uplands (%).	SHRUB	Abundance as measured through vegetation volume of shrubs (multiple stems, woody species).
CWD	Abundance of dead and down woody debris ≥ 2.5" in diameter (coarse) .	SPECRICH	Species richness.
DEC'AY	The presence of coarse woody debris in various stages of decomposition.	SUBIN	Subsurface flow into the water/wetland via interflow and return flow.
DEPSATSED	Depth of saturated sediments (m).	SURFIN	Surface inflow to the wetland via sheetflow.

FPA	Floodprone area as defined by the projection of a horizontal plane at a level twice the bankfull thalweg depth.	TOPO	Macro (large scale) and microtopographic (small scale) relief. Macrotopography generally refers to large-scale features such as secondary channels and in-channel ponds. Microtopography generally refers to small-scale features such as pit-and-mound and hummock-and-hollow patterns.
FREQ	Frequency of inundation.	TREE	Abundance as measured through vegetation volume of trees.
FWD	Abundance of dead and down woody debris < 2.5" in diameter (fine).	TRIB	Presence of connected tributaries.
HERB	Abundance as measured through vegetation volume of herbaceous species.	VEGSTRATA	Number of vegetation layers present.
INVASIVES	Abundance of invasive species.	WIS	Wetland indicator score.
LANDUSE	Type of adjacent landuse.		

FCI Model Formulas in the Arizona Riverine HGM Model. Once the E-Team participants had addressed the critical components (e.g., variables) that capture the essence of wetland functionality for the model, they set out to combine these variables in a mathematical model. Each variable was weighted in terms of "importance" in characterizing the function, and standard mathematical logic was used to generate the formulas. Below, the functions are provided with their associated variable combinations.

Hydrology Functions

Function 1: Maintenance of Characteristic Channel Dynamics

$(V_Q + V_{FPA} + V_{SED})/3$

Function 2: Dynamic Surface Water Storage/Energy Dissipation

$(V_{FREQ}*(V_{FPA}+((V_{TOPO}+V_{TVV}+V_{CWD})/3)/2))^{1/2}$

Function 3: Long Term Surface Water Storage

$(((V_{TOPO}*V_{FREQ})^{1/2})*(((1 - V_{PORE})+V_{SUBIN})/2))^{1/2}$

Function 4: Dynamic Subsurface Water Storage

$(V_{DEPSATSED})$

Biogeochemistry Functions

Function 5: Nutrient Cycling

$((V_{TVV}+(3* V_{AGSA})/4)+((V_{DECAY}*((V_{LITTER}+ V_{FWD}+ V_{CWD})/3))^{1/2}))/2$

Function 6: Detention of Imported Elements and Compounds

$(((V_{FREQ}+V_{SURFIN}+V_{SUBIN})/3)+((V_{AGSA}+V_{LITTER}+(1-V_{PORE}))/3)+V_{TVV})/3$

Function 7: Detention of Particles

$((2*V_{FPA})+V_{TOPO}+((V_{CWD}+V_{FWD}+ V_{SED}+V_{TVV})/4))/4$

Habitat Functions

Function 8: Maintain Characteristic Plant Communities
Cottonwood-Willow and Mesquite Communities:

$(((((V_{SPECRICH}+V_{WIS}+V_{INVASIVES})/3)*((V_{CANHERB} + V_{CANSHRUB} + V_{CANTREE})/3))^{1/2})* V_{LANDBUFF})^{1/2}$

Scrub - Shrublands Communities:

$(((((V_{SPECRICH}+V_{WIS}+V_{INVASIVES})/3)*((V_{CANHERB} + V_{CANSHRUB})/2))^{1/2}) * V_{LANDBUFF})^{1/2}$

River Bottom Communities:

$(((((V_{SPECRICH} +V_{WIS}+V_{INVASIVES})/3)*(V_{CANHERB}))^{1/2}) * V_{LANDBUFF})^{1/2}$

Function 9: Maintain Spatial Structure of Habitat

$(((V_{VEGSTRATA} +((V_{CWD}+V_{FWD}+V_{LITTER})/3))/2) * V_{LANDBUFF})^{1/2}$

Function 10: Maintain Interspersion and Connectivity

$(((V_{FREQ}+ V_{TOPO}+ V_{CONTIG}+ V_{TRIB})/4) * V_{LANDBUFF})^{1/2}$

It is important to note that the E-Teams for the five feasibility studies adapted the original formulas provided by the workshop participants as planning constraints and data availability issues were encountered. It should also be noted that the E-Teams chose to tailor the formula for Function 8 to address functional capacity variations among cover types. Thus, the maintenance of characteristic plant communities in Scrub-Shrublands, Wet River Bottom Areas, and Dry River Bottom Areas did not include measures of tree canopy cover (or shrub canopy cover in the latter two cover types).

Reference Standards for the Arizona Riverine Functional Assessment Model. By definition, reference standard sites represent the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass (riverine overbank in this case). Because these wetland ecosystems exhibited a wide range of conditions as a result of natural processes and anthropogenic disturbance, and few undisturbed wetland ecosystems or landscapes were known to exist post-impoundment, the HGM approach established reference standards based on reference wetlands. Reference wetlands were actual wetland sites that represented the range of variability exhibited by regional wetlands as a result

of natural processes and anthropogenic disturbance. When the E-Team established reference standards for the five feasibility studies, the geographic area from which these reference wetlands were selected became the model's reference domain. For details regarding the Arizona Riverine Functional Assessment model reference domain and selection of reference wetlands, refer to Chapter 3 of Webb, Burks-Copes and Henderson 2003.

Step 5: Field Sampling for the Rio Salado Oeste Study

Basic site characterization and data collection are the first steps in inventorying an ecosystem restoration site (Fischenich 1999). Characterization for the subject study included gathering data on water quality, geochemistry, hydrology, fluvial geomorphology, substrate conditions, flora, and fauna, and to the greatest extent possible, identifications of underlying stressors in the region. In particular, land-use activities, physical habitat alterations, and invasive species were identified. In addition to the physical and chemical characteristics of the study area, land ownership and regulatory jurisdictions played an important role in determining opportunities for restoration. Much of this information was geographically-based and stored in a GIS database. As part of the basic site characterization, historical data on landscape-scale habitat conditions, land-use characteristics and ownership patterns was collected as well. Site- and landscape-level data were collected in the spring and fall of 2001. Historical data was obtained and reviewed during the winter of 2001. These datasets, in turn, were used to characterize the baseline conditions of the study area and the reference standard sites.

Several members of the E-Team participated in the field sampling efforts initiated in the early spring months of 2001. The 3-5 member field crews, facilitated by the ERDC, included members from 5 separate federal, state, and local agencies, as well as volunteers from the local community, and experts from nearby universities. For details regarding field sampling protocols, refer to Chapter 4 of Webb, Burks-Copes and Henderson 2003. The original field data is available in the Los Angeles District.

Step 6: Data Management and Statistical Analysis

Some limitations on the data collected during the functional assessment should be acknowledged. When data management problems arose, ERDC consulted with the E-Team prior to data handling, and solutions were devised with their knowledge and consent. This additional effort reduced the uncertainty in the findings, and allowed the E-Team to better delineate the wet and dry river bottom areas. Detailed notes and minutes were taken during these meetings to provide documentation for the assessment.

Step 7: Calculate Baseline Conditions

Once the baseline inventory was completed, the variable means/modes and the PWAA acreages were calculated, and the baseline conditions in terms of Functional Capacity Units (FCUs) were generated by multiplication. Strictly speaking, the means/mode values for each variable were applied to the Variable Subindex graphs (VSIs) as dictated by the model documentation (Webb, Burks-Copes, and Henderson, 2003). A new VSI graph was developed for each variable based on the reference standard and reference site findings. The means for each variable at the Rio Salado Oeste site were then "scored" on the VSI graphs – providing a comparison of the baseline conditions to that of reference. The basic mathematical premise is fairly straightforward and

easy to complete. For example, if the average percent of ground cover in the cottonwood-willow stands on-site was found to be 50 percent, the value "50" was entered into the "X-axis" on the Variable Subindex curve below, and the resultant VSI score (Y-axis) was recorded (VSI = 1.0) (Figure 2).

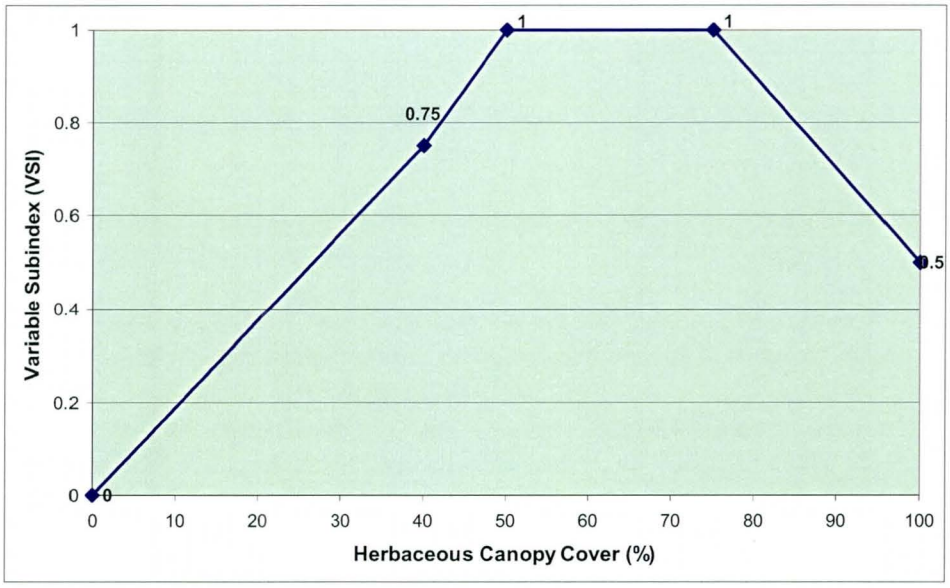

Figure 2 Example Variable Subindex (VSI) curve

The process was repeated for every variable in each PWAA for each of the 10 functional models. The individual VSI scores were entered into the FCI formula by PWAA, and individual cover type FCIs were generated. Each answer, referred to as the PWAA FCI, was then weighted by the relative area (RA)[1] of the PWAA, and combined with the answers from the remaining associated cover types in an additive fashion. The model's formula was considered to be the sum of the PWAA FCIs, arithmetically written as follows:

$$FCI_{\text{Subclass Model}} = \sum \left(\text{PWAA FCI} \times \text{RA}\right)_X$$

where:

PWAA FCI = Results of the PWAA FCI calculation,
X = Number of PWAAs associated with the model, and
RA = Relative area of each PWAA.

The final step was to multiply the FCI result against the habitat acres (i.e., cover type acres associated with the model). The final results, referred to as FCUs, quantified the quality and quantity of the wetland conditions at the site for baseline. The details of this study's findings for baseline conditions are fully documented in Chapter 3 of this report.

[1] Relative Area: The relative area is a mathematical process used to "weight" the various applicable PWAAs on the basis of quantity. To derive the relative area of a model's PWAA for the study, the following equation was utilized: Relative Area = PWAA Area/Total Area where: PWAA Area = only those acres assigned to the PWAA of interest and Total Area = the sum of the acres utilized in the model

Step 8: Project Objectives, Project Life, and Target Years

In an attempt to generate quantifiable objectives for the study, the District set out specific ecosystem goals, and developed a series of performance measures to assess the success of the ecosystem restoration designs.

Project Objectives. The primary purpose of the Rio Salado Oeste feasibility study is ecosystem restoration. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for the formulation of alternatives. These planning objectives reflect the problems and opportunities and represent desired positive changes in the without-project conditions. Planning objectives evaluated in this feasibility study are as follows:

- Restore native riparian, wetland, and floodplain habitats and manage undesirable plant, fish and wildlife species.
- Reduce flood damages to infrastructure and structures.
- Improve passive recreation and environmental education opportunities within the study area.

Selection of a Project Life and Target Years (TYs). Given these goals and objectives, the District designated a "Project Life" or Period of Analysis of 50 years for the study, and asked the E-Team to develop a series of TYs within this 50-year setting to guide the projections of both Without-Project and With-Project activities. Five TYs were defined by the E-Team:

1. TY = "0" refers to the baseline or existing condition.
2. TY = "1" refers to the first year of groundbreaking activities.
3. TY = "6" was chosen to capture 5 full years of vegetative growth under the proposed With-Project Conditions.
4. TY = "26" was selected to capture 25 full years of vegetative growth under the With-Project Conditions.
5. TY = "51" was chosen to capture 50 full years of vegetative growth under With-Project Conditions.

Step 9: Without-Project Conditions

To develop plans for a community or region, it becomes necessary to predict both the short-term and long-term future conditions of the environment. Forecasting, the process of developing these predictions, is undertaken to identify patterns in natural systems and human behavior, and to discover relationships among variables and systems, so that the timing, nature, and magnitude of change in future conditions can be estimated. Though many forecasting methods can be used in a standard assessment application such as functional assessment, a judgment-based method, supported by the scientific and professional expertise of the evaluation team, is often relied upon to forecast the effectiveness of ecosystem restoration alternatives, rate project performance, and determine many other important aspects of both Without- and With-Project conditions.

The Without-Project condition is universally regarded as a vital and important element of the evaluation. The future without-project condition is the same as the "no action" alternative, and describes what is expected to happen in the absence of federal or non-federal action. Under this alternative, the Corps of Engineers would take no action to provide ecosystem restoration within

the study area, nor to develop plans with potential incidental benefits associated with flood damage reduction, recreation, and water quality and supply. The no action alternative assumes the future will bring change, despite a lack of Corps participation. No single element is more critical to the planning process than the prediction of the most likely future conditions anticipated for the study area if no action is taken as a result of the study.

Most federal agencies use annualization as a means to display benefits and costs, and ecosystem restoration analyses should provide data that can be directly compared to the traditional benefit: cost analyses typically portrayed in standard evaluations of this nature. Federal projects are evaluated over a period of time that is referred to as the "period of analysis" and is defined as that period of time between a project becoming operational and the end of the analysis period as dictated by the construction effort or lead agency. However, in many cases, gains or losses in wildlife habitat may occur before the project becomes operational and these changes should be considered in the assessment. Examples of such changes include construction impacts, implementation and compensation plans, and/or other land-use impacts. Ecosystem restoration analyses incorporate these changes into their evaluations by using a "period of analysis" that includes pre-construction impacts. Functional Capacity Units (FCUs) are annualized by summing FCUs across all years in the period of analysis and dividing the total (cumulative FCU) by the number of years in the period of analysis. In this manner, pre-start changes can be considered in the analysis. The results of this calculation are referred to as Average Annual Functional Capacity Units (AAFCUs).

The assumptions that went into the projection of future conditions for the Rio Salado Oeste study area under the "No Action Alternative" are reported later in this report. Results, in terms of AAFCUs as well as expectations of change in terms of FCIs and acres for the study are fully documented therein.

Step 10: With-Project Scenarios

The E-team evaluated restoration alternatives and made assumptions pertaining to the outcomes and effects on each variable and function. From those assumptions and projections of future conditions the FCI and AAFCU's for each alternative were calculated and compared. Those results are reported later in this report.

Baseline Conditions

Baseline Acres

The study area comprises 3,148 acres (100 year floodplain) and is covered predominantly in scrub shrub (1,566 acres; 49.7%), sand and gravel operations (671 acres; 21.3%) and adjacent urban areas (327 acres; 10.4%). Although degraded, cottonwood willow and wetland areas do occur (142 acres), but comprise a minor portion of the study area. The majority of existing cover types have been degraded because of a lack of water or due to other anthropogenic activities. A complete listing of baseline cover types and their respective acreages is presented in Table 5.

Table 5 ***Baseline Acres and Cover Types for Rio Salado Oeste***

CODE	DESCRIPTION	BASELINE ACRES (TY 0)
AGCROP	Farms and Croplands in the Uplands – Dairy, Cotton, and Alfalfa	133
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112
DESERT	Desert or bare earth, Palo Verde, Ironwood, cacti	0
DITCHES	Ditches in the Uplands	3
DRY RIVER BOTTOM	Existing Dry River Bottom Areas in the Active Channel - Largely Unvegetated	66
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240
PARKS	Parks and Recreation Areas	0
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671
SCRUBSHRUB	Existing Scrub - Shrublands in the Active Channel - Rabbitbush, Quailbush, and Saltbush	1,566
SOIL CEMENT	Existing Soil Cement Areas on the Slopes of the Active Channel	0
WETRVRBOTTOM	Existing Wetted River Bottom Areas in the Active Channel - Primarily Emergent Vegetation	30
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327
TOTAL		3,148

Baseline Variable Values for Each Cover Type

Baseline field data was collected in the summer of 2002 to determine existing conditions for the site. Data for each variable per cover type (PWAA) was recorded, and the means/modes were calculated to generate baseline Functional Capacity Index (FCIs) per function in the functional assessment model. For detailed information regarding the field data collected by the Biological Team, please refer to Webb, A. C., K. A. Burks-Copes, and J. E. Henderson, 2003.

Baseline Functional Assessment Results

The results of the Rio Salado Oeste baseline functional assessment are summarized below. Functional capacity indices (FCIs) capture the quality of the acreage within the study area. Interpretations of these findings are generalized in Table 6. The FCI scores are multiplied by their respective PWAA acreages to determine the number of functional capacity units (i.e., FCUs). Both FCIs and FCUs are reported for each function included in the Functional Assessment Tool.

Table 6 ***Interpretation of FCI Scores Resulting From HGM Assessments***

FCI SCORE	INTERPRETATION
0.0	Non-functional – the wetland or PWAA does not perform to a measurable level and will not recover through natural processes
Above 0.0 to 0.19	Extremely low or very poor functional capacity - the wetland or PWAA's functional capacity can be measured, but it cannot be recovered through natural processes
0.2 to 0.29	Low or poorly functioning
0.3 to 0.39	Fair to moderately low functional capacity
0.4 to 0.49	Moderate functional capacity
0.5 to 0.59	Moderately high functional capacity
0.6 to 0.79	High or good functional capacity
0.8 to 0.99	Very high or excellent functional capacity
1.0	Optimum functional capacity - the wetland or PWAA performs function at highest the same level as reference standard settings

Table 7 below includes calculated values from the baseline conditions as well as a description of the problems and potential restoration options to recover that function. In most instances, the baseline FCI scores indicate either low/poor or fair to moderately low functional capacity. At baseline, 1,774 acres are associated with the model (e.g., this is the combination of existing cottonwood-willow forests, wet and dry river bottom areas, and scrub-shrublands). Given a maximum FCI of 1.0, and 1,774 acres of associated PWAAs within the study area at baseline, the highest possible FCU score is 1,774 units per function. The site is therefore operating at approximately one third of its potential functional capacity (i.e., average functional outputs ÷ possible outputs).

Table 7. Description of Existing Conditions in Terms of Ecological Processes, and Ecosystem Restoration Goals

Function Name	FCI	AAFCUs	Specific Problems	Description of Ecosystem Restoration Options and Goals
Function 1: Maintenance of Characteristic Channel Dynamics	0.23	41.4	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent. 2. Upstream dams, flow constrictions at bridges and sand/gravel mining have affected the historic topographic relief; deposition is occurring upstream of 35th Avenue while erosion is occurring downstream of 35th Avenue. 3. Sediment inputs have been artificially accelerated by adjacent land use practices.	To recover this function, flow patterns must be returned to simulate historic conditions, in-channel coarse woody debris inputs must be increased, and channel dimensions must be re-engineered.
Function 2: Dynamic Surface Water Storage/Energy Dissipation	0.42	74.9	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent. 2. Upstream dams, flow constrictions at bridges and sand/gravel mining have affected the historic topographic relief; deposition is occurring upstream of 35th Avenue while erosion is occurring downstream of 35th Avenue. 3. The removal of water and channelization has degraded the vegetative communities, which in turn has reduced the amount of coarse woody debris in the system.	To restore this function, channel widths and depths must be modified, roughness through the introduction of coarse woody debris and vegetation must be increased, and a connection between remnant wetlands, ponds, and secondary channels must be restored.
Function 3: Long Term Surface Water Storage	0.25	45.2	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent. 2. Upstream dams, flow constrictions at bridges and sand/gravel mining have affected the historic topographic relief; deposition is occurring upstream of 35th Avenue while erosion is occurring downstream of 35th Avenue. 3. The removal of water and channelization has degraded the vegetative communities, which in turn has reduced the amount of coarse woody debris in the system. 4. Lack of a restrictive layer to slow infiltration.	To recover this function, wetland areas that pond water over the short term must be created. Vegetation and restrictive layers are key to this recovery.
Function 4: Dynamic Subsurface Water Storage	0.44	78.3	The depth to groundwater is excessive in this setting.	To restore this function, additional water sources must be introduced and/or existing water sources must be committed to the system and, and an emphasis must be placed on improving infiltration rates in the system with the creation of a more extensive network of wetlands.

Function Name	FCI	AAFCUs	Specific Problems	Description of Ecosystem Restoration Options and Goals
Function 6: Detention of Imported Elements and Compounds	0.38	66.9	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent. 2. The system lacks a restrictive soil layer. 3. The study area lacks organic sources.	To restore this function, perennial effluent flows must be better utilized to establish large quantities of vegetative stands.
Function 7: Detention of Particles	0.33	58.9	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent. 2. The system lacks a restrictive soil layer. 3. The study area lacks organic sources.	To recover this function, perennial effluents flows must be better utilized to establish large quantities of vegetative stands.
Function 8: Maintain Characteristic Plant Communities	0.42	74.8	The existing vegetated areas within the project boundaries show promise in terms of characteristic plant maintenance functionality. However, the communities are subject to restricted water availability in the near future that would result in reduced support for vegetative layer diversity and numbers.	To protect this function's high score, invasive plant species must be removed, water supply must be increased to remnant stands, and the aerial extent of native plant communities must be expanded.
Function 9: Maintain Spatial Structure of Habitat	0.30	53.1	The existing vegetated areas within the project boundaries show promise in terms of habitat structure. However, the communities are subject to high levels of invasive species and restricted water availability in the near future.	To protect and improve this function's output, water supply should be augmented for the remnant stands, and new species should be introduced to increase structural diversity.
Function 10: Maintain Interspersion and Connectivity	0.23	40.1	1. Diversion of surface water and groundwater to support increased range/agricultural demands has led to the disappearance of the perennial flow, except for reaches receiving effluent, which in turn has led to the reduction in contiguous communities linking river bottom areas to the uplands.	To restore this function, a connection between existing strands of riparian vegetation and newly planted wetlands should be created (e.g., create and improve aquatic and terrestrial corridors).
Avergage/Total	0.33	583		

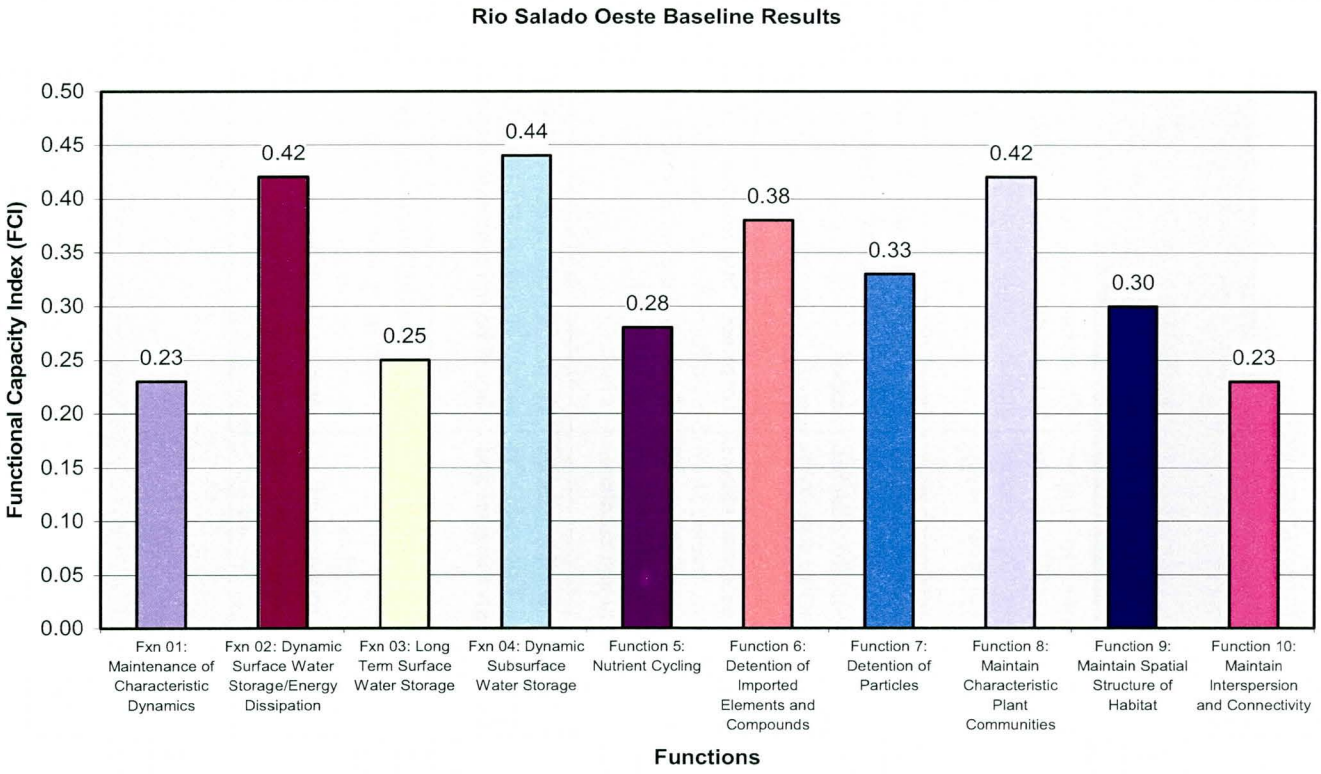

Figure 3 ***FCI for the Rio Salado Oeste Study Area***

Figure 3 above displays graphically the baseline FCI values for each of the 10 functions. The highest functional score is found in Function 4, Dynamic Subsurface Water Storage (FCI = 0.44). The lowest functional scores are Functions 1, Maintenance of Characteristic Channel Dynamics and Function 10, Maintain Interspersion and Connectivity (FCI = 0.23 for both). The mean FCI across all ten functions is 0.33.

Without-Project Conditions

It was the general consensus of the E-Team that the future Without-Project conditions of the study area were certain to reflect a loss of agricultural land and most of the remaining cottonwood-willow forest, and a concurrent increase in urban areas, desert (bare earth), and scrubshrub. These changes were forecast based on existing trends, and the anticipated pressures of increasing population growth, coupled with further reductions in available water sources. The E-Team addressed these issues, and developed trends to capture both the losses of acreage and

functionality to generate "No Action" scenario for the study. Numerous assumptions were used to support the projected values - these are presented below.

Acreage Losses in Future Without-Project Condition

Forecasting suggests that the already degraded ecosystem would continue to urbanize over the next 50 years. Agricultural lands within the study area are thought to be especially vulnerable to residential conversion over the next 50 years. In an effort to capture these significant land use changes with the Rio Salado Oeste study area, the E-Team developed a table projecting acreages per cover type on a Target Year basis (Table 8).

The FCI and AAFCU would appear to remain essentially the same in the Without-Project as a result of conversion from one cover type to cover types that are less valuable and provide fewer benefits. In general the higher value habitat, cottonwood-willow, open water and wet river bottom is being converted to desert, dry river bottom and scrub shrub.

The key assumptions made by the E team in estimating future conditions are as follow.

- All remaining agricultural land (133 acres) will be developed within five years.
- Remaining cottonwood willow forest will decrease from 112 acres to 25 acres over 50 years due to reduced water supply, increased urbanization and expansion of non-native salt cedar.
- Emergent wetlands will decrease slightly from 30 to 25 acres but will remain in areas of surface discharge and storm water outfalls. O&M activities at these outfall locations will disturb and result in periodic reductions in quantity and quality of the existing emergent wetland areas.
- The amount of dry river bottom is expected to increase from 66 acres to 71 acres as the wetlands are lost.
- The amount of open water will decrease from 240 to 80 acres as other uses for effluent and dewatering are established. Existing areas of open water will likely be converted to bare earth or support undesirable low value and/or non-native and invasive species, eventually converting to scrub shrub and desert wash cover. The amount of scrub shrub will increase from 1,566 to 1,653 acres.
- It is not possible to project acreage changes in sand and gravel operations but it is assumed that some operations will go out of operation while others start operating. In general these activities would migrate down stream, to the west end of the study area following the urban development.
- The reduction in water supply and decrease in surface flows will result in the reduction and/or elimination of one of the key mechanisms that drive many biochemical and biogeochemical processes that are associated with movement and cycling of nutrients.
- No establishment of new: cottonwood willow forest, wet river bottom, emergent wetlands, open water or mesquite woodlands or bouquets is expected.
- There will be a decrease in the connectivity and spatial structure of the remnant high value cottonwood willow strands and a disconnect between the authorized Rio Salado Restoration and Tres Rios Demonstration projects.
- The biological diversity within the study area is expected to decrease with the reduction in high
- valley cottonwood willow forest for cover, breeding, nesting, foraging and fledging activities. The reduction of open water and emergent wetland areas reduces and/or eliminates a key habitat or life history/cycle component for many native wildlife species and neo-tropical migratory songbirds and over-wintering waterfowl and wadding birds.
- The disturbance from unregulated recreation, off-highway vehicle traffic and "wildcat" dumping is expected to continue and potentially increase in some areas, further degrading the riparian system

and remaining higher value remnant habitat it currently supports.

Table 8 ***Cover Types And Projected Acres Without Project***

DESCRIPTION	TY 0	TY 01	TY06	TY26	TY51
Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00
Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00
Existing ditches in the Uplands	3.00	3.00	3.00	3.00	3.00
Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00
Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00
Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00
Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00
Newly Developed Dry River Bottom Areas in the Active Chanel – Largely Unvegetated	0.00	0.00	0.00	0.00	0.00
Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00
Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00
Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00
Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00
Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00
Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00
Desert or bare earth	0.00	0.00	72.00	122.00	160.00
Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00
TOTAL ACRES:	3148.00	3148.00	3148.00	3148.00	3148.00

Functional Losses in the Future Without-Project Condition

The Rio Salado Oeste study area has already been highly degraded and future channel characteristics along the Salt River channel are expected to remain similar to current conditions, though the location of active sand and gravel mining activities would change.

Changes in land use practices adjacent to the project area led the E-Team to predict considerable changes in contiguous habitat (CONTIG), which in turn will lead to severe deterioration of the remnant vegetative communities. Fragmentation will leave pockets of wetlands that are subject to higher pressures from invasive species colonization (INVASIVES, WIS and SPECRICH). The overall structure of the forested communities is expected to decline or be eliminated entirely (VEGSTRATA, CANTREE, CANSHRUB and TVV) as water sources vanish and remaining cottonwood-willow forest is replaced by salt cedar.

As can be seen in Figure 4 below, the AAFCU's decrease from 583 to 579 over the planning horizon. This seemingly minor change in AAFCU can be explained in two ways. The average FCI score across the 10 functions was 0.33, which indicates a fair to moderately low functioning wetland ecosystem at best. From one aspect the already low functioning ecosystem cannot decline much more. Another factor is that the existing habitat is so degraded that conversion of cottonwood-willow and wetland cover types to other cover types has little effect on the overall AAFCU's.

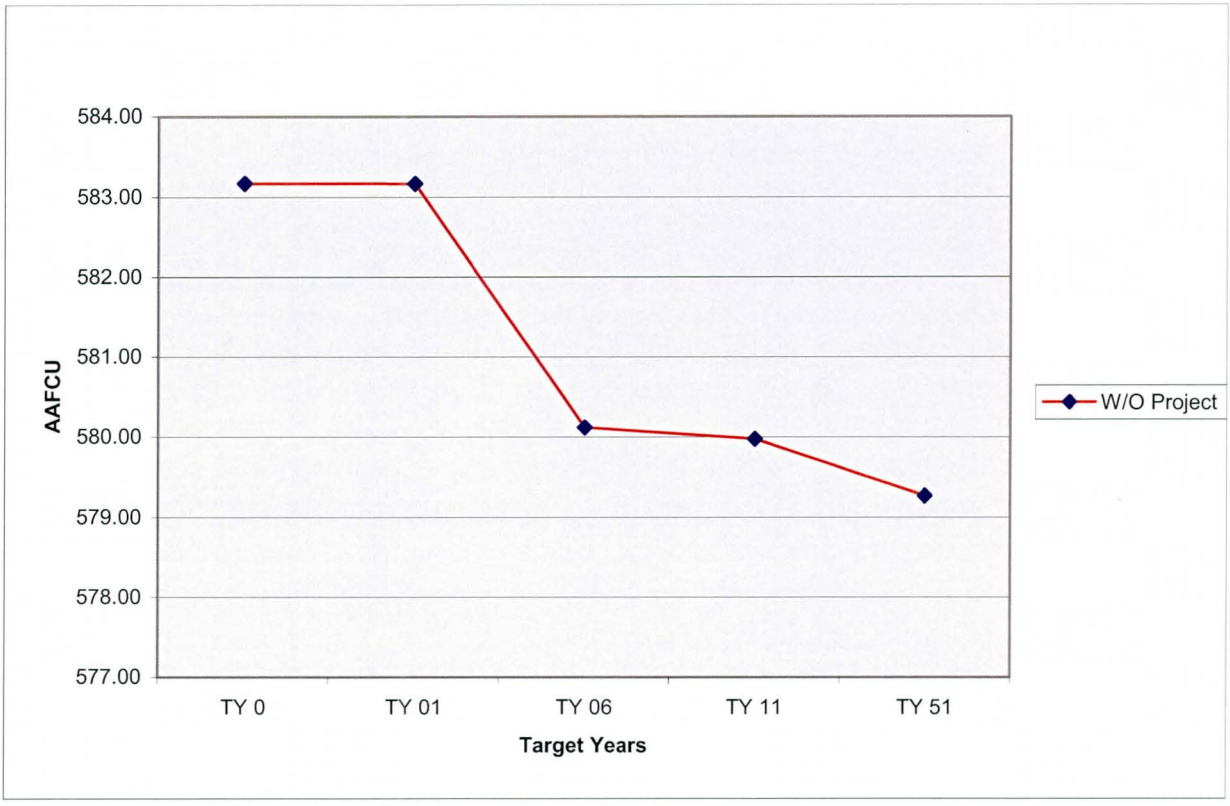

Figure 4 Future Without Project

With Project Conditions

Restoration Alternatives

Formulation of ecosystem restoration alternatives is described in detail within the feasibility report. Including No Action the team evaluated 7 alternatives with the functional assessment.

The final set of project alternatives and associated acreages of habitat are shown in Table 9 below. Measures common to the restoration alternatives include:

Channel Restoration: This measure provides a connection through the study reach and connects upstream and downstream projects. It will be accomplished by grading and terracing to restore an active channel through the entire reach.

Storm Water Outfalls: Existing outfalls would be modified to discharge to a concrete/stone channel through the river terrace and the water directed toward the low flow channel. Within that channel there would be a low weir to capture the low flows and allow floodwaters to pass. Although the wetland would in some cases be ephemeral, it would provide habitat value.

Cottonwood/Willow: This measure includes restoration of riparian cottonwood/willow stands adjacent to water sources and low terraces throughout the study area. Cottonwood-willow will be dominated by Fremont's cottonwood (Populus fremontii) and Gooding's willow (Salix gooddingii).

Mesquite: This habitat would be restored over a potentially large portion of the project area. Mesquite bosques would be dominated by velvet mesquite (Prosopis velutina), with scattered honey mesquite (Prosopis glandulosa), and some under story shrubs, such as desert thorn (Lycium spp.) palo verde (Cercidium floridum) and brittlebush (Encelia farinose), and forbes.

Wetland: Wetlands can consist of open water, submerged vegetation or mud flats, all requiring a high water table level at or near the surface. Due to the porous soils found in this project area, the site must be lined to maintain surface water. Excavation and layering of a silt/clay soil substrate approximately 12-inches thick is assumed to be sufficient to reduce permeability. Emergent wetlands contain primarily cattails (Typha domingensis), tule (Scirpus acutus), and sedges (Carex spp.).

Lakes: There are existing features created from aggregate mining operations at 27th and 37th Avenues that would require modification to implement lake restoration. These modifications are recommended to restore the floodplain landscape and improve the functionality of these features.

Invasive Control: Invasive species such as salt cedar (Tamarix spp.) and Arundo (Arundo donax) will require removal and management with project implementation. This will likely require physical removal and ongoing maintenance through the project life.

Water Supply: In addition to the storm water runoff that would be harvested with the storm water outfall measure, additional water supply will be required. Effluent from the 23rd Avenue Wastewater Treatment Plant is available for the restoration project.

Table 9 ***Final Array of Restoration Alternatives Evaluated***

Alternative	Cover Type	Acres
1. No Action No Federal Action to be conducted and no habitat restored. This is the future without project condition.		
2. Storm water and Channel This alternative includes the modification of existing storm-water outfall areas to improve retention and water spreading as well as increasing the existing habitat currently supported by these outfalls. It also includes modification and/or restructuring of the primary conveyance channel to a more natural state by grading and terracing the river corridor from 19th avenue to 83rd avenue. No additional water source is included in this alternative other than temporary irrigation to establish vegetation.	Channel	170
	In Channel Wetlands*	17
	Cottonwood/Willow	66
	Mesquite	43
	Wetlands	28
	Open Water	0
	Scrub Shrub	773
4. Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent This alternative includes the features described in Alternative 2 and adds supplemental water supply in the form of effluent. It also includes restoration of emergent wetlands at the existing lake in the channel immediately downstream of 19th Avenue. At locations identified as suitable throughout the project area cottonwood/willow and mesquite cover types will be restored. This alternative would also address the management, control and removal of invasive species within the study area.	Channel	170
	In Channel Wetlands*	34
	Cottonwood/Willow	348
	Mesquite	409
	Wetlands	33
	Open Water	0
	Scrub Shrub	423
5. Storm water, Channel, Water Supply, Cottonwood, Mesquite, Invasive, Emergent, Lake This alternative includes the features described in Alternative 4 and adds lake restoration at the existing gravel pits at 29th and 37th Avenues.	Channel	170
	In Channel Wetlands*	34
	Cottonwood/Willow	375
	Mesquite	417
	Wetlands	76
	Open Water	40
	Scrub Shrub	450
5A. Wetland/riparian restoration in lieu of permanent open water and lakes In lieu of lake restoration this alternative includes regrading the existing gravel pits to restore them to the floodplain and restoring emergent wetland and riparian areas.	Channel	170
	In Channel Wetlands*	34
	Cottonwood/Willow	375
	Mesquite	417
	Wetlands	156
	Open Water	0
	Scrub Shrub	410
5B. Hybrid of 5 and 5A This alternative includes restoration of one gravel pit to a wetland/riparian complex and the other to include the lake.	Channel	170
	In Channel Wetlands*	34
	Cottonwood/Willow	375
	Mesquite	417
	Wetlands	136
	Open Water	20
	Scrub Shrub	410

* Note that in channel wetland acreage is included in acres of channel restored

Environmental Benefits

Riparian ecosystems in the Southwest are invaluable. Although they represent less than 1% of the region's area (Knopf, F. L. 1989), a large proportion (75-80%) (Gillis 1991) of vertebrate wildlife species depends on riparian areas for food, water, cover, and migration routes. Riparian zones also improve water quality because they filter sediments and nutrients. Accumulated sediments in riparian zones store large amounts of water, which helps sustain stream flow during drier times.

Projection of Benefits

In April 2004, the E-Team consisting of members from USFWS, Arizona Game and Fish, City of Phoenix and Corps of Engineers met to review project alternatives and project benefits resulting from them. This included review of the future without project conditions and also resulted in the addition of two alternatives for analysis. Alternatives 5A and 5B were developed and benefits evaluated in this meeting. This included projections related to the acres of habitat to be restored and effects on each variable over the period of analysis. Those detailed results are not included in this report but are available upon request.

Acres Restored

In the future without project condition existing cottonwood/willow cover type was projected to decrease from 112 acres to 25 acres and existing wetland was projected to decrease from 30 to 25 acres as well. It is assumed that quality of that habitat would be low with high concentrations of invasive species such as salt cedar. Although there are scattered mesquite trees within the study area, none are dense enough to consider a mesquite cover type.

Alternative 2 relies mainly on restoration at storm water outfalls and restoration of the river channel itself without large amounts of restoration elsewhere. Alternatives 3 through 5A all maintain and improve the highly degraded 112 acres of cottonwood/willow and include restoration of mesquite and wetland habitats. Alternative 5A includes restoration of 375 acres of cottonwood/willow, 417 acres of mesquite and 190 acres of wetlands, including restoration of two large gravel pits within the floodplain. Also included in this alternative are 410 acres of scrub shrub and 170 acres river channel.

Results

Functional Capacity Index

Functional Capacity Index (FCI) describes the quality of the functional capacity of the habitat. Of the 10 functions evaluated in the without project conditions, all had low to moderate functional capacity. Implementation of project alternatives caused an increase in each FCI, with the average increasing by approximately 30% and into the ranges considered moderate to moderate-high functional capacity. The most improved functions included Function 1 (Maintenance of Characteristic Channel Dynamics), Function 7 (Detention of Particles), and Function 10 (Maintain Interspersion and Connectivity). Those functions showing the least improvement included Function 4 (Dynamic Subsurface Water Storage), Function 5 (Nutrient Cycling), and Function 6 (Detention of Imported Elements and Compounds). Table 10 below displays the FCI for the baseline condition as well as for each alternative.

Table 10 With Project Functional Capacity Indices (FCI)

Function Name	Existing	Alt 2	Alt 4	Alt 5	Alt 5A	Alt 5B
Fxn 01: Maintenance of Characteristic Dynamics	0.23	0.27	0.4	0.39	0.4	0.39
Fxn 02: Dynamic Surface Water Storage/Energy Dissipation	0.42	0.45	0.57	0.57	0.57	0.57
Fxn 03: Long Term Surface Water Storage	0.25	0.27	0.34	0.33	0.34	0.34
Fxn 04: Dynamic Subsurface Water Storage	0.44	0.50	0.51	0.51	0.52	0.52
Function 5: Nutrient Cycling	0.28	0.28	0.33	0.33	0.34	0.33
Function 6: Detention of Imported Elements and Compounds	0.38	0.39	0.45	0.45	0.46	0.45
Function 7: Detention of Particles	0.33	0.36	0.48	0.47	0.48	0.48
Function 8: Maintain Characteristic Plant Communities	0.42	0.43	0.51	0.51	0.51	0.51
Function 9: Maintain Spatial Structure of Habitat	0.30	0.32	0.42	0.41	0.42	0.41
Function 10: Maintain Interspersion and Connectivity	0.23	0.29	0.33	0.34	0.34	0.34

Average Annual Functional Capacity Units (AAFCU)

Based upon the functional assessment completed for this study the number of acres and functional capacity indices were projected in order to derive with-project estimates of average annual functional capacity units (AAFCU). The same methodology as was employed for assessing without project conditions was also employed to assess the habitat output of each alternative. Benefits are defined as the increase in AAFCU's for each alternative relative to without project conditions. As a reminder, the Functional Capacity Unit (FCU) represents the factor of habitat quality multiplied by quantity or FCI from above multiplied by acreage of habitat restored. Table 11 shows the results.

Table 11 With Project Average Annual Functional Capacity Units (AAFCUs)

Target Year	Without Project	Alt 2	Alt 4	Alt 5	Alt 5A	Alt 5B
T0	583	583	583	583	583	583
T1	580	619	691	766	791	778
T6	580	627	717	796	822	809
T26	579	635	755	828	857	842
T51	579	633	775	851	879	865
Average (T0-T51)	580	631	745	820	847	833

The proposed alternatives result in increased AAFCU's (relative to without project conditions) ranging from 51 for Alternative 2 to 267 for Alternative 5A. As can be seen in the table, the without project conditions change only slightly over 50 years and are not expected to change without some action. Each column numbered with different alternatives displays the number of FCU's that are expected in that year with the associated features of that alternative. Figure 5 below displays the various alternatives and changing outputs over the period of analysis.

Conclusion

The benefits above in Table 11 were utilized in performing Cost-effectiveness (CE) and incremental cost analyses (ICA. CE/ICA compares the costs and benefits of individual plans and identifies the least-costly solution for each level of output. Results of that evaluation are included in the main Feasibility Report and Economic Appendix.

Alternative 5A which produces 847 AAFCUs was determined to be the tentatively recommended alternative based upon both the amount of benefits produced and cost to accomplish those benefits.

Glossary

Alternative

In HGM analyses, this is the "With Project" condition commonly used in restoration studies. An Alternative can be composed of numerous activities, measures, and/or options. Some examples of Alternatives include:

Alternative 1: Plant food plots, increase wetland acreage by 10 percent, install 10 goose nest boxes, and build a fence around the entire site.

Alternative 2: Build a dam, inundate 10 acres of riparian corridor, build 50 miles of supporting levee, and remove all wetlands in the levee zone.

Alternative 3: Reduce the grazing activities on the site by 50 percent, replant grasslands (10 acres), install a passive irrigation system, build 10 escape cover stands, use 5 miles of willow fascines along the stream bank for stabilization purposes.

Average Annual Functional Capacity Units (AAFCUs)

A quantitative result of annualizing Functional Capacity Unit (FCU) gains or losses across all years in the period of analysis.
AAFCUs = Cumulative FCUs ÷ Number of years in the life of the project, where:
Cumulative FCUs = Sum (T2 -T1)[((A1 F1 +A2 F2) / 3) + ((A2 F1 +A1 F2) / 6)]
and where:

T1 = First Target Year time interval

T2 = Second Target Year time interval

A1 = Area of available wetland assessment area at beginning of T1

A2 = Area of available wetland assessment area at end of T2

F1 = FCI at beginning of T1

F2 = FCI at end of T2

Baseline Condition

In the habitat assessment and planning analyses, baseline is the point in time before proposed changes, and is synonymous with Target Year (TY = 0).

Cover Type

A homogenous zone of similar vegetative species, geographic similarities, and physical conditions that make the area unique. In general, cover types are defined on the basis of species recognition and dependence.

Ecosystem

An ecosystem is a biotic community, together with its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole, unified through life processes. Ecosystems are hierarchical, and can be viewed as nested sets of open systems in which physical, chemical, and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multi states, more localized watersheds or a smaller complex of aquatic habitat.

Existing Condition

Also referred to as the Baseline Condition, the Existing Condition is the point in time before proposed changes, and is designated as Target Year TY = 0 in the analysis.

Field Data

In HGM, this information is collected on various parameters (i.e., variables) in the field, and from aerial photos, following defined, well-documented methodology. An example is the measurement of percent herbaceous cover, over 10 quadrats, within a riparian forest cover type. The values recorded are each considered "field data." Means of variables are applied to derive functional capacity indices.

Functional Capacity Index Model (FCI)

In the HGM, an FCI Model is a quantitative estimate of functional capacity for a wetland. The ideal goal of an FCI model is to quantify and produce an index that reflects functional capacity at the site. The results of an FCI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland. An FCI model can be defined in words, or mathematical equations, that clearly describe the rules and assumptions necessary to combine functional capacity indices in a meaningful manner for the wetland. For example:

FCI = (VSI V1 * VSI V2) / 4, where:

VSI V1 is the Variable Subindex (VSI) for

variable 1;

VSI V2 is the VSI for variable 2

Functional Capacity Units (FCUs)

A quantitative environmental assessment value considered the biological currency in HGM. Functional Capacity Units are calculated by multiplying the area of available wetland (quantity) by the quality of the wetland based on functionality. Quality is determined by measuring limiting factors describing wetland function, and is represented by values derived from Functional Capacity Indices (FCIs). FCU = AREA X FCI. Changes in FCUs represent potential impacts or improvements of proposed actions.

Non-Combinable Situations

These situations occur when mutually exclusive alternatives exist in the project. Often this condition arises when environmental, economic and/or management factors contradict combinable outcomes. For example, the alternative "construction of a new highway through the Florida Everglades" will conflict with the alternative "preservation and enhancement of the existing wetlands, precluding any development." If the only alternatives are to provide protection to the wetlands, or build the highway, these two alternatives are deemed "non-combinable" on the basis of environmental incompatibility. This information is included in the cost analysis evaluations.

Partial Wetland Assessment Area (PWAA)

A homogenous zone of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, PWAAs are defined on the basis of species recognition and dependence, soils types and topography.

Relative Area

In HGM, the relative area is a mathematical process used to "weight" the various applicable cover types on the basis of quantity. To derive the relative area of a model's cover type, the following equation can be utilized:

Relative Area = Cover Type Area / Total Area where:

Cover Type Area = only those acres assigned to the cover type (or PWAA) of interest Total Area = the sum of the acres utilized in the model.

Scale (1) In some geographical methodologies, the scale is the defined size of the image in terms of miles per inch, feet per inch, or pixels per acres; (2) scale can also refer to variations of the alternative in some cost analysis software packages.

Target Year (TY)

A unit of time measurement used in Habitat Evaluation Procedures, that allows for projection of significant changes

(in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1, and a TY = X2. TY1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TYX2 designates the ending target year. A new target year must be assigned for each year the project manager intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses.

Variable

A measurable parameter that can be quantitatively described, with some degree of repeatability, using standard field sampling and mapping techniques. Often, the variable is a limiting factor for a species (or community), used in the development of SI curves and measured in the field (or from aerial photos) by personnel, to fulfill the requirements of field data collection in a HGM application. Some examples of variables include height of grass, percent canopy cover, distance to water, number of snags in 0.4 hectare, or average annual water temperature.

Variable Subindex (VSI)

In HGM, a VSI is a mathematical equation that reflects a wetland function's sensitivity to a change in a limiting factor (i.e., variable) within the PWAA. In HGM, VSIs are depicted using scatter plots and bar charts (i.e., functional capacity curves). The VSI value (Y-axis) ranges on a scale from 0.0 to 1.0, where a VSI = 0.0 represents a variable that is extremely limiting and a VSI = 1.0 represents a variable in abundance (not limiting) for the wetland.

With Project Condition

Also referred to as alternative conditions, this is the condition of the site after an alternative or alternatives are implemented.

Without Project Condition

Sometimes referred to as the Baseline condition, or the Existing condition, this is the expected condition of the site without implementation of an alternative; referred to as the "No Action" condition in planning studies. The habitat conditions at TY 0 always refer to the pre-existing conditions.

Literature Cited

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Summary Tables

AAFCU Summary tables including Acreages and AAFCU Calculations follow.

Rio Salado Oeste Baseline and Without Project

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93
1	6	0.23	0.23	1774	1774	2069.67
6	26	0.23	0.23	1774	1774	8278.67
26	51	0.23	0.23	1774	1774	10348.33
				Without Project AAFCUs:		413.93

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64
1	6	0.42	0.42	1774	1774	3737.63
6	26	0.42	0.42	1774	1774	14902.49
26	51	0.42	0.42	1774	1774	18573.62
				Without Project AAFCUs:		744.36

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12
1	6	0.25	0.25	1774	1774	2239.04
6	26	0.25	0.25	1774	1774	8798.88
26	51	0.25	0.25	1774	1774	10943.39
				Without Project AAFCUs:		439.87

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00
1	6	0.44	0.45	1774	1774	3955.00
6	26	0.45	0.46	1774	1774	16130.00
26	51	0.46	0.47	1774	1774	20506.25
				Without Project AAFCUs:		811.26

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52
1	6	0.28	0.27	1774	1774	2451.88
6	26	0.27	0.27	1774	1774	9576.43
26	51	0.27	0.26	1774	1774	11718.48
				Without Project AAFCUs:		475.34

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88
1	6	0.38	0.37	1774	1774	3320.82
6	26	0.37	0.36	1774	1774	13065.78
26	51	0.36	0.36	1774	1774	16152.25
				Without Project AAFCUs:		651.13

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51
1	6	0.33	0.33	1774	1774	2933.78
6	26	0.33	0.33	1774	1774	11653.36
26	51	0.33	0.33	1774	1774	14478.48
				Without Project AAFCUs:		581.45

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35
1	6	0.42	0.42	1774	1774	3730.78
6	26	0.42	0.42	1774	1774	14839.73
26	51	0.42	0.42	1774	1774	18456.48
				Without Project AAFCUs:		740.69

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41
1	6	0.30	0.30	1774	1774	2636.99
6	26	0.30	0.29	1774	1774	10376.28
26	51	0.29	0.29	1774	1774	12783.89
				Without Project AAFCUs:		516.25

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30
1	6	0.23	0.23	1774	1774	2006.50
6	26	0.23	0.25	1774	1774	8387.75
26	51	0.25	0.25	1774	1774	10943.82
				Without Project AAFCUs:		426.26

Project: Rio Salado Oeste
Alternative: 2

Code	Description	Without Project					With Project				
		Target Year					Target Year				
		0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	80.00	50.00	25.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	45.00	45.00	45.00	45.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	63.00	63.00	63.00	63.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	48.00	48.00	48.00	48.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	240.00	168.00	118.00	80.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	38.00	5.00	5.00	5.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	1438.00	1508.00	1538.00	1563.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	72.00	122.00	160.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM

OPENWATER
Assume less water discharged to the channel and filling the lakes. Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 10% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 2

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93		0	1	0.23	0.26	1774	1774	433.68
1	6	0.23	0.23	1774	1774	2069.67		1	6	0.26	0.25	1774	1774	2256.42
6	26	0.23	0.23	1774	1774	8278.67		6	26	0.25	0.28	1774	1774	9389.33
26	51	0.23	0.23	1774	1774	10348.33		26	51	0.28	0.27	1774	1774	12135.21
Without Project AAFCUs:						413.93		With Project AAFCUs:						474.80
								Net AAFCUs:						60.86

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64		0	1	0.42	0.46	1774	1774	784.51
1	6	0.42	0.42	1774	1774	3737.63		1	6	0.46	0.46	1774	1774	4094.70
6	26	0.42	0.42	1774	1774	14902.49		6	26	0.46	0.46	1774	1774	16271.33
26	51	0.42	0.42	1774	1774	18573.62		26	51	0.46	0.45	1774	1774	20152.34
Without Project AAFCUs:						744.36		With Project AAFCUs:						809.86
								Net AAFCUs:						65.50

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12		0	1	0.25	0.28	1774	1774	476.28
1	6	0.25	0.25	1774	1774	2239.04		1	6	0.28	0.28	1774	1774	2488.02
6	26	0.25	0.25	1774	1774	8798.88		6	26	0.28	0.28	1774	1774	9841.62
26	51	0.25	0.25	1774	1774	10943.39		26	51	0.28	0.27	1774	1774	12179.54
Without Project AAFCUs:						439.87		With Project AAFCUs:						489.91
								Net AAFCUs:						50.04

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00		0	1	0.44	0.49	1774	1774	829.25
1	6	0.44	0.45	1774	1774	3955.00		1	6	0.49	0.50	1774	1774	4425.00
6	26	0.45	0.46	1774	1774	16130.00		6	26	0.50	0.50	1774	1774	17890.00
26	51	0.46	0.47	1774	1774	20506.25		26	51	0.50	0.50	1774	1774	22362.50
Without Project AAFCUs:						811.26		With Project AAFCUs:						892.29
								Net AAFCUs:						81.03

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52		0	1	0.28	0.26	1774	1774	477.63
1	6	0.28	0.27	1774	1774	2451.88		1	6	0.26	0.27	1774	1774	2338.67
6	26	0.27	0.27	1774	1774	9576.43		6	26	0.27	0.27	1774	1774	9560.34
26	51	0.27	0.26	1774	1774	11718.48		26	51	0.27	0.28	1774	1774	12151.83
Without Project AAFCUs:						475.34		With Project AAFCUs:						480.95
								Net AAFCUs:						5.61

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88		0	1	0.38	0.38	1774	1774	672.49
1	6	0.38	0.37	1774	1774	3320.82		1	6	0.38	0.38	1774	1774	3395.14
6	26	0.37	0.36	1774	1774	13065.78		6	26	0.38	0.39	1774	1774	13719.86
26	51	0.36	0.36	1774	1774	16152.25		26	51	0.39	0.39	1774	1774	17238.39
Without Project AAFCUs:						651.13		With Project AAFCUs:						686.78
								Net AAFCUs:						35.65

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51		0	1	0.33	0.37	1774	1774	620.85
1	6	0.33	0.33	1774	1774	2933.78		1	6	0.37	0.37	1774	1774	3261.77
6	26	0.33	0.33	1774	1774	11653.36		6	26	0.37	0.37	1774	1774	13026.35
26	51	0.33	0.33	1774	1774	14478.48		26	51	0.37	0.36	1774	1774	16187.00
Without Project AAFCUs:						581.45		With Project AAFCUs:						648.94
								Net AAFCUs:						67.49

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35		0	1	0.42	0.43	1774	1774	759.25
1	6	0.42	0.42	1774	1774	3730.78		1	6	0.43	0.44	1774	1774	3867.49
6	26	0.42	0.42	1774	1774	14839.73		6	26	0.44	0.44	1774	1774	15489.64
26	51	0.42	0.42	1774	1774	18456.48		26	51	0.44	0.43	1774	1774	19273.68
Without Project AAFCUs:						740.69		With Project AAFCUs:						772.35
								Net AAFCUs:						31.66

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41		0	1	0.30	0.31	1774	1774	538.71
1	6	0.30	0.30	1774	1774	2636.99		1	6	0.31	0.31	1774	1774	2753.50
6	26	0.30	0.29	1774	1774	10376.28		6	26	0.31	0.31	1774	1774	11135.79
26	51	0.29	0.29	1774	1774	12783.89		26	51	0.31	0.32	1774	1774	13970.81
Without Project AAFCUs:						516.25		With Project AAFCUs:						556.84
								Net AAFCUs:						40.59

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30		0	1	0.23	0.25	1774	1774	419.15
1	6	0.23	0.23	1774	1774	2006.50		1	6	0.25	0.26	1774	1774	2266.95
6	26	0.23	0.25	1774	1774	8387.75		6	26	0.26	0.29	1774	1774	9869.40
26	51	0.25	0.25	1774	1774	10943.82		26	51	0.29	0.29	1774	1774	12901.29
Without Project AAFCUs:						426.26		With Project AAFCUs:						499.15
								Net AAFCUs:						72.89

Project: Rio Salado Oeste
Alternative: 3

Code	Description	Without Project					With Project				
		Target Year					Target Year				
		0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	112.00	112.00	112.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	62.00	62.00	62.00	62.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	228.00	228.00	228.00	228.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	409.00	409.00	409.00	409.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	240.00	168.00	118.00	80.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	0.00	0.00	0.00	0.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	933.00	933.00	950.00	950.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	77.00	110.00	148.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM

OPENWATER
Assume less water discharged to the channel and filling the lakes. Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 20% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 3

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93	0	1	0.23	0.30	1774	1774	470.58
1	6	0.23	0.23	1774	1774	2069.67	1	6	0.30	0.30	1774	1769	2633.25
6	26	0.23	0.23	1774	1774	8278.67	6	26	0.30	0.40	1769	1786	12312.63
26	51	0.23	0.23	1774	1774	10348.33	26	51	0.40	0.40	1786	1786	17643.75
Without Project AAFCUs:						413.93	With Project AAFCUs:						648.24
							Net AAFCUs:						234.31

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64	0	1	0.42	0.58	1774	1774	890.10
1	6	0.42	0.42	1774	1774	3737.63	1	6	0.58	0.59	1774	1769	5202.25
6	26	0.42	0.42	1774	1774	14902.49	6	26	0.59	0.56	1769	1786	20532.78
26	51	0.42	0.42	1774	1774	18573.62	26	51	0.56	0.57	1786	1786	25184.37
Without Project AAFCUs:						744.36	With Project AAFCUs:						1015.87
							Net AAFCUs:						271.51

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12	0	1	0.25	0.35	1774	1774	535.66
1	6	0.25	0.25	1774	1774	2239.04	1	6	0.35	0.35	1774	1769	3092.85
6	26	0.25	0.25	1774	1774	8798.88	6	26	0.35	0.34	1769	1786	12190.36
26	51	0.25	0.25	1774	1774	10943.39	26	51	0.34	0.34	1786	1786	15025.80
Without Project AAFCUs:						439.87	With Project AAFCUs:						604.80
							Net AAFCUs:						164.93

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00	0	1	0.44	0.51	1774	1774	843.00
1	6	0.44	0.45	1774	1774	3955.00	1	6	0.51	0.51	1774	1769	4515.01
6	26	0.45	0.46	1774	1774	16130.00	6	26	0.51	0.51	1769	1786	18145.01
26	51	0.46	0.47	1774	1774	20506.25	26	51	0.51	0.51	1786	1786	22787.50
Without Project AAFCUs:						811.26	With Project AAFCUs:						907.66
							Net AAFCUs:						96.40

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52	0	1	0.28	0.22	1774	1774	442.39
1	6	0.28	0.27	1774	1774	2451.88	1	6	0.22	0.26	1774	1769	2131.67
6	26	0.27	0.27	1774	1774	9576.43	6	26	0.26	0.28	1769	1786	9690.39
26	51	0.27	0.26	1774	1774	11718.48	26	51	0.28	0.33	1786	1786	13599.35
Without Project AAFCUs:						475.34	With Project AAFCUs:						507.13
							Net AAFCUs:						31.79

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88		0	1	0.38	0.39	1774	1774	677.68
1	6	0.38	0.37	1774	1774	3320.82		1	6	0.39	0.41	1774	1769	3529.07
6	26	0.37	0.36	1774	1774	13065.78		6	26	0.41	0.43	1769	1786	14953.24
26	51	0.36	0.36	1774	1774	16152.25		26	51	0.43	0.45	1786	1786	19743.59
Without Project AAFCUs:						651.13		With Project AAFCUs:						762.82
								Net AAFCUs:						111.68

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51		0	1	0.33	0.44	1774	1774	683.91
1	6	0.33	0.33	1774	1774	2933.78		1	6	0.44	0.45	1774	1769	3936.83
6	26	0.33	0.33	1774	1774	11653.36		6	26	0.45	0.47	1769	1786	16324.77
26	51	0.33	0.33	1774	1774	14478.48		26	51	0.47	0.48	1786	1786	21094.81
Without Project AAFCUs:						581.45		With Project AAFCUs:						824.32
								Net AAFCUs:						242.87

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35		0	1	0.42	0.46	1774	1774	781.96
1	6	0.42	0.42	1774	1774	3730.78		1	6	0.46	0.49	1774	1769	4223.09
6	26	0.42	0.42	1774	1774	14839.73		6	26	0.49	0.50	1769	1786	17715.52
26	51	0.42	0.42	1774	1774	18456.48		26	51	0.50	0.51	1786	1786	22618.52
Without Project AAFCUs:						740.69		With Project AAFCUs:						889.00
								Net AAFCUs:						148.31

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41		0	1	0.30	0.35	1774	1774	573.68
1	6	0.30	0.30	1774	1774	2636.99		1	6	0.35	0.37	1774	1769	3159.37
6	26	0.30	0.29	1774	1774	10376.28		6	26	0.37	0.39	1769	1786	13395.51
26	51	0.29	0.29	1774	1774	12783.89		26	51	0.39	0.42	1786	1786	17931.25
Without Project AAFCUs:						516.25		With Project AAFCUs:						687.45
								Net AAFCUs:						171.20

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30		0	1	0.23	0.30	1774	1774	464.00
1	6	0.23	0.23	1774	1774	2006.50		1	6	0.30	0.32	1774	1769	2710.26
6	26	0.23	0.25	1774	1774	8387.75		6	26	0.32	0.33	1769	1786	11441.05
26	51	0.25	0.25	1774	1774	10943.82		26	51	0.33	0.33	1786	1786	14670.08
Without Project AAFCUs:						426.26		With Project AAFCUs:						574.22
								Net AAFCUs:						147.96

Project: Rio Salado Oeste
Alternative: 4

Code	Description	Without Project					With Project				
		Target Year					Target Year				
		0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	112.00	112.00	112.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	67.00	67.00	67.00	67.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	228.00	228.00	228.00	228.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	409.00	409.00	409.00	409.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	240.00	168.00	118.00	80.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	0.00	0.00	0.00	0.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	928.00	928.00	950.00	950.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	77.00	105.00	143.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM
Assume less water discharged to the channel and filling the lakes.

OPENWATER
Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 20% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 4

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93		0	1	0.23	0.30	1774	1774	471.13
1	6	0.23	0.23	1774	1774	2069.67		1	6	0.30	0.30	1774	1769	2638.67
6	26	0.23	0.23	1774	1774	8278.67		6	26	0.30	0.40	1769	1791	12355.15
26	51	0.23	0.23	1774	1774	10348.33		26	51	0.40	0.40	1791	1791	17727.08
Without Project AAFCUs:						413.93		With Project AAFCUs:						650.82
								Net AAFCUs:						236.89

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64		0	1	0.42	0.58	1774	1774	891.56
1	6	0.42	0.42	1774	1774	3737.63		1	6	0.58	0.59	1774	1769	5216.80
6	26	0.42	0.42	1774	1774	14902.49		6	26	0.59	0.56	1769	1791	20612.42
26	51	0.42	0.42	1774	1774	18573.62		26	51	0.56	0.57	1791	1791	25309.36
Without Project AAFCUs:						744.36		With Project AAFCUs:						1020.20
								Net AAFCUs:						275.84

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12		0	1	0.25	0.35	1774	1774	536.28
1	6	0.25	0.25	1774	1774	2239.04		1	6	0.35	0.35	1774	1769	3099.01
6	26	0.25	0.25	1774	1774	8798.88		6	26	0.35	0.34	1769	1791	12228.01
26	51	0.25	0.25	1774	1774	10943.39		26	51	0.34	0.34	1791	1791	15088.50
Without Project AAFCUs:						439.87		With Project AAFCUs:						606.90
								Net AAFCUs:						167.03

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00		0	1	0.44	0.51	1774	1774	844.25
1	6	0.44	0.45	1774	1774	3955.00		1	6	0.51	0.51	1774	1769	4527.51
6	26	0.45	0.46	1774	1774	16130.00		6	26	0.51	0.51	1769	1791	18220.01
26	51	0.46	0.47	1774	1774	20506.25		26	51	0.51	0.51	1791	1791	22912.50
Without Project AAFCUs:						811.26		With Project AAFCUs:						911.85
								Net AAFCUs:						100.59

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52		0	1	0.28	0.22	1774	1774	443.33
1	6	0.28	0.27	1774	1774	2451.88		1	6	0.22	0.26	1774	1769	2142.28
6	26	0.27	0.27	1774	1774	9576.43		6	26	0.26	0.28	1769	1791	9753.30
26	51	0.27	0.26	1774	1774	11718.48		26	51	0.28	0.33	1791	1791	13699.92
Without Project AAFCUs:						475.34		With Project AAFCUs:						510.57
								Net AAFCUs:						35.23

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88	0	1	0.38	0.39	1774	1774	678.10
1	6	0.38	0.37	1774	1774	3320.82	1	6	0.39	0.41	1774	1769	3533.29
6	26	0.37	0.36	1774	1774	13065.78	6	26	0.41	0.43	1769	1791	14994.95
26	51	0.36	0.36	1774	1774	16152.25	26	51	0.43	0.45	1791	1791	19827.94
Without Project AAFCUs:						651.13	With Project AAFCUs:						765.38
							Net AAFCUs:						114.25

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51	0	1	0.33	0.44	1774	1774	684.87
1	6	0.33	0.33	1774	1774	2933.78	1	6	0.44	0.45	1774	1769	3946.51
6	26	0.33	0.33	1774	1774	11653.36	6	26	0.45	0.47	1769	1791	16382.92
26	51	0.33	0.33	1774	1774	14478.48	26	51	0.47	0.48	1791	1791	21192.66
Without Project AAFCUs:						581.45	With Project AAFCUs:						827.59
							Net AAFCUs:						246.13

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35	0	1	0.42	0.46	1774	1774	782.54
1	6	0.42	0.42	1774	1774	3730.78	1	6	0.46	0.49	1774	1769	4228.81
6	26	0.42	0.42	1774	1774	14839.73	6	26	0.49	0.50	1769	1791	17758.32
26	51	0.42	0.42	1774	1774	18456.48	26	51	0.50	0.51	1791	1791	22697.97
Without Project AAFCUs:						740.69	With Project AAFCUs:						891.52
							Net AAFCUs:						150.83

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41	0	1	0.30	0.35	1774	1774	573.98
1	6	0.30	0.30	1774	1774	2636.99	1	6	0.35	0.37	1774	1769	3163.12
6	26	0.30	0.29	1774	1774	10376.28	6	26	0.37	0.39	1769	1791	13430.50
26	51	0.29	0.29	1774	1774	12783.89	26	51	0.39	0.42	1791	1791	17997.94
Without Project AAFCUs:						516.25	With Project AAFCUs:						689.52
							Net AAFCUs:						173.27

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30	0	1	0.23	0.30	1774	1774	464.48
1	6	0.23	0.23	1774	1774	2006.50	1	6	0.30	0.32	1774	1769	2714.98
6	26	0.23	0.25	1774	1774	8387.75	6	26	0.32	0.33	1769	1791	11472.62
26	51	0.25	0.25	1774	1774	10943.82	26	51	0.33	0.33	1791	1791	14726.58
Without Project AAFCUs:						426.26	With Project AAFCUs:						576.05
							Net AAFCUs:						149.79

Project: Rio Salado Oeste
Alternative: 5

Code	Description	Without Project					With Project				
		Target Year					Target Year				
		0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	112.00	112.00	112.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	75.00	75.00	75.00	75.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	263.00	263.00	263.00	263.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	417.00	417.00	417.00	417.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	40.00	40.00	40.00	40.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	0.00	0.00	0.00	0.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	1077.00	1082.00	1082.00	1082.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	0.00	0.00	0.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM

OPENWATER
Assume less water discharged to the channel and filling the lakes. Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 20% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 5

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93	0	1	0.23	0.30	1774	1974	496.13
1	6	0.23	0.23	1774	1774	2069.67	1	6	0.30	0.30	1974	1974	2912.25
6	26	0.23	0.23	1774	1774	8278.67	6	26	0.30	0.39	1974	1974	13527.50
26	51	0.23	0.23	1774	1774	10348.33	26	51	0.39	0.39	1974	1974	19257.50
Without Project AAFCUs:						413.93	With Project AAFCUs:						709.67
							Net AAFCUs:						295.74

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64	0	1	0.42	0.58	1774	1974	939.55
1	6	0.42	0.42	1774	1774	3737.63	1	6	0.58	0.59	1974	1974	5758.34
6	26	0.42	0.42	1774	1774	14902.49	6	26	0.59	0.56	1974	1974	22716.70
26	51	0.42	0.42	1774	1774	18573.62	26	51	0.56	0.57	1974	1974	27825.15
Without Project AAFCUs:						744.36	With Project AAFCUs:						1122.35
							Net AAFCUs:						377.99

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12	0	1	0.25	0.35	1774	1974	564.49
1	6	0.25	0.25	1774	1774	2239.04	1	6	0.35	0.35	1974	1974	3414.67
6	26	0.25	0.25	1774	1774	8798.88	6	26	0.35	0.33	1974	1974	13442.22
26	51	0.25	0.25	1774	1774	10943.39	26	51	0.33	0.33	1974	1974	16532.18
Without Project AAFCUs:						439.87	With Project AAFCUs:						665.76
							Net AAFCUs:						225.89

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00	0	1	0.44	0.51	1774	1974	893.92
1	6	0.44	0.45	1774	1774	3955.00	1	6	0.51	0.51	1974	1974	5053.75
6	26	0.45	0.46	1774	1774	16130.00	6	26	0.51	0.51	1974	1974	20240.00
26	51	0.46	0.47	1774	1774	20506.25	26	51	0.51	0.51	1974	1974	25300.00
Without Project AAFCUs:						811.26	With Project AAFCUs:						1009.56
							Net AAFCUs:						198.30

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52	0	1	0.28	0.22	1774	1974	470.25
1	6	0.28	0.27	1774	1774	2451.88	1	6	0.22	0.27	1974	1974	2411.76
6	26	0.27	0.27	1774	1774	9576.43	6	26	0.27	0.29	1974	1974	10876.63
26	51	0.27	0.26	1774	1774	11718.48	26	51	0.29	0.33	1974	1974	15130.90
Without Project AAFCUs:						475.34	With Project AAFCUs:						566.46
							Net AAFCUs:						91.12

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88	0	1	0.38	0.39	1774	1974	717.48
1	6	0.38	0.37	1774	1774	3320.82	1	6	0.39	0.41	1974	1974	3941.78
6	26	0.37	0.36	1774	1774	13065.78	6	26	0.41	0.43	1974	1974	16623.30
26	51	0.36	0.36	1774	1774	16152.25	26	51	0.43	0.45	1974	1974	21806.85
Without Project AAFCUs:						651.13	With Project AAFCUs:						844.89
							Net AAFCUs:						193.76

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51	0	1	0.33	0.44	1774	1974	721.27
1	6	0.33	0.33	1774	1774	2933.78	1	6	0.44	0.45	1974	1974	4353.26
6	26	0.33	0.33	1774	1774	11653.36	6	26	0.45	0.47	1974	1974	17993.46
26	51	0.33	0.33	1774	1774	14478.48	26	51	0.47	0.47	1974	1974	23149.03
Without Project AAFCUs:						581.45	With Project AAFCUs:						906.22
							Net AAFCUs:						324.76

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35	0	1	0.42	0.46	1774	1974	826.33
1	6	0.42	0.42	1774	1774	3730.78	1	6	0.46	0.49	1974	1974	4690.63
6	26	0.42	0.42	1774	1774	14839.73	6	26	0.49	0.50	1974	1974	19564.58
26	51	0.42	0.42	1774	1774	18456.48	26	51	0.50	0.51	1974	1974	24856.04
Without Project AAFCUs:						740.69	With Project AAFCUs:						979.17
							Net AAFCUs:						238.48

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41	0	1	0.30	0.35	1774	1974	605.00
1	6	0.30	0.30	1774	1774	2636.99	1	6	0.35	0.36	1974	1974	3500.42
6	26	0.30	0.29	1774	1774	10376.28	6	26	0.36	0.39	1974	1974	14793.09
26	51	0.29	0.29	1774	1774	12783.89	26	51	0.39	0.41	1974	1974	19692.45
Without Project AAFCUs:						516.25	With Project AAFCUs:						756.69
							Net AAFCUs:						240.44

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30	0	1	0.23	0.29	1774	1974	489.23
1	6	0.23	0.23	1774	1774	2006.50	1	6	0.29	0.31	1974	1974	2998.27
6	26	0.23	0.25	1774	1774	8387.75	6	26	0.31	0.33	1974	1974	12654.31
26	51	0.25	0.25	1774	1774	10943.82	26	51	0.33	0.34	1974	1974	16376.89
Without Project AAFCUs:						426.26	With Project AAFCUs:						637.62
							Net AAFCUs:						211.36

Project: Rio Salado Oeste
Alternative: 5A

		Without Project					With Project				
		Target Year					Target Year				
Code	Description	0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	112.00	112.00	112.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienegas and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	115.00	115.00	115.00	115.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	263.00	263.00	263.00	263.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	417.00	417.00	417.00	417.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	0.00	0.00	0.00	0.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	0.00	0.00	0.00	0.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	1077.00	1082.00	1082.00	1082.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	0.00	0.00	0.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM

OPENWATER
Assume less water discharged to the channel and filling the lakes. Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 20% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 5A

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30	401.30	0	1	0.23	0.30	1774	2014	504.60
1	6	0.23	0.23	1774	1774	2006.50	401.30	1	6	0.30	0.30	2014	2014	3002.25
6	26	0.23	0.25	1774	1774	8387.75	437.48	6	26	0.30	0.40	2014	2014	13974.17
26	51	0.25	0.25	1774	1774	10943.82	438.03	26	51	0.40	0.40	2014	2014	19924.17
Without Project AAFCUs:						426.26		With Project AAFCUs:						733.43
								Net AAFCUs:						307.17

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64	748.64	0	1	0.42	0.59	1774	2014	958.18
1	6	0.42	0.42	1774	1774	3737.63	746.41	1	6	0.59	0.60	2014	2014	5958.34
6	26	0.42	0.42	1774	1774	14902.49	743.84	6	26	0.60	0.57	2014	2014	23516.70
26	51	0.42	0.42	1774	1774	18573.62	742.05	26	51	0.57	0.57	2014	2014	28825.14
Without Project AAFCUs:						744.36		With Project AAFCUs:						1161.93
								Net AAFCUs:						417.57

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12	452.12	0	1	0.25	0.35	1774	2014	573.79
1	6	0.25	0.25	1774	1774	2239.04	443.50	1	6	0.35	0.35	2014	2014	3514.99
6	26	0.25	0.25	1774	1774	8798.88	436.39	6	26	0.35	0.34	2014	2014	13843.47
26	51	0.25	0.25	1774	1774	10943.39	439.08	26	51	0.34	0.34	2014	2014	17033.74
Without Project AAFCUs:						439.87		With Project AAFCUs:						685.61
								Net AAFCUs:						245.74

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00	783.00	0	1	0.44	0.52	1774	2014	913.06
1	6	0.44	0.45	1774	1774	3955.00	799.00	1	6	0.52	0.52	2014	2014	5253.75
6	26	0.45	0.46	1774	1774	16130.00	814.00	6	26	0.52	0.52	2014	2014	21040.00
26	51	0.46	0.47	1774	1774	20506.25	826.50	26	51	0.52	0.52	2014	2014	26300.00
Without Project AAFCUs:						811.26		With Project AAFCUs:						1049.15
								Net AAFCUs:						237.89

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52	495.52	0	1	0.28	0.23	1774	2014	482.64
1	6	0.28	0.27	1774	1774	2451.88	485.23	1	6	0.23	0.27	2014	2014	2545.00
6	26	0.27	0.27	1774	1774	9576.43	472.41	6	26	0.27	0.30	2014	2014	11479.52
26	51	0.27	0.26	1774	1774	11718.48	465.06	26	51	0.30	0.34	2014	2014	15935.40
Without Project AAFCUs:						475.34		With Project AAFCUs:						596.91
								Net AAFCUs:						121.57

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88	668.88	0	1	0.38	0.39	1774	2014	727.94
1	6	0.38	0.37	1774	1774	3320.82	659.45	1	6	0.39	0.41	2014	2014	4048.62
6	26	0.37	0.36	1774	1774	13065.78	647.13	6	26	0.41	0.44	2014	2014	17106.08
26	51	0.36	0.36	1774	1774	16152.25	645.05	26	51	0.44	0.46	2014	2014	22481.67
Without Project AAFCUs:						651.13		With Project AAFCUs:						869.89
								Net AAFCUs:						218.76

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51	588.51	0	1	0.33	0.44	1774	2014	734.57
1	6	0.33	0.33	1774	1774	2933.78	585.00	1	6	0.44	0.45	2014	2014	4495.96
6	26	0.33	0.33	1774	1774	11653.36	580.33	6	26	0.45	0.47	2014	2014	18591.43
26	51	0.33	0.33	1774	1774	14478.48	577.94	26	51	0.47	0.48	2014	2014	23931.84
Without Project AAFCUs:						581.45		With Project AAFCUs:						936.35
								Net AAFCUs:						354.90

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35	748.35	0	1	0.42	0.46	1774	2014	838.86
1	6	0.42	0.42	1774	1774	3730.78	743.96	1	6	0.46	0.49	2014	2014	4818.88
6	26	0.42	0.42	1774	1774	14839.73	740.01	6	26	0.49	0.50	2014	2014	20073.12
26	51	0.42	0.42	1774	1774	18456.48	736.51	26	51	0.50	0.51	2014	2014	25491.71
Without Project AAFCUs:						740.69		With Project AAFCUs:						1004.36
								Net AAFCUs:						263.67

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41	531.41	0	1	0.30	0.35	1774	2014	612.73
1	6	0.30	0.30	1774	1774	2636.99	523.39	1	6	0.35	0.37	2014	2014	3587.41
6	26	0.30	0.29	1774	1774	10376.28	514.24	6	26	0.37	0.39	2014	2014	15189.66
26	51	0.29	0.29	1774	1774	12783.89	508.47	26	51	0.39	0.42	2014	2014	20225.97
Without Project AAFCUs:						516.25		With Project AAFCUs:						776.78
								Net AAFCUs:						260.53

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30	401.30	0	1	0.23	0.30	1774	2014	497.07
1	6	0.23	0.23	1774	1774	2006.50	401.30	1	6	0.30	0.32	2014	2014	3083.45
6	26	0.23	0.25	1774	1774	8387.75	437.48	6	26	0.32	0.33	2014	2014	13007.95
26	51	0.25	0.25	1774	1774	10943.82	438.03	26	51	0.33	0.34	2014	2014	16844.54
Without Project AAFCUs:						426.26		With Project AAFCUs:						655.55
								Net AAFCUs:						229.29

Project: Rio Salado Oeste
Alternative: 5B

Code	Description	Without Project					With Project				
		Target Year					Target Year				
		0	1	6	26	51	0	1	6	26	51
AGCROP	Farms and Croplands in the Uplands - Dairy, Cotton, and Alfalfa	133.00	133.00	0.00	0.00	0.00	133.00	133.00	0.00	0.00	0.00
CWWFOREST	Existing Cottonwood-Willow Forests in the Active Channel	112.00	112.00	80.00	50.00	25.00	112.00	112.00	112.00	112.00	112.00
DITCHES	Ditches in the Uplands	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
WETRVRBOTTOM	Existing Emergent Wetlands in the Uplands - Cattails, Cienega and Grasses	30.00	30.00	25.00	25.00	25.00	30.00	30.00	25.00	25.00	25.00
MESQUITE	Existing Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWWETRVRBOTTOM	Newly constructed river channel, includes emergent wetlands within the channel	0.00	0.00	0.00	0.00	0.00	0.00	95.00	95.00	95.00	95.00
NEWCWWFOR	Newly Planted Cottonwood-Willow Forests in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	263.00	263.00	263.00	263.00
NEWDRYRVRBOTTOM	Newly Planted Emergent Wetlands in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEWMESQUIT	Newly Planted Mesquite Woodlands - on the Terraces and in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	417.00	417.00	417.00	417.00
NEWOPENWAT	Newly Developed Open Water in the Active Channel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPENWATER	Existing Open Water in the Active Channel - Inactive Sand and Gravel Operations	240.00	240.00	168.00	118.00	80.00	240.00	20.00	20.00	20.00	20.00
DRY RIVER BOTTOM	Existing River Bottom in the Active Channel - Largely Unvegetated	66.00	66.00	71.00	71.00	71.00	66.00	0.00	0.00	0.00	0.00
SCRUBSHRUB	Existing Scrub-Shrublands in the Active Channel - Rabbitbush, Quailbush, Ironwood, and Saltbush	1566.00	1566.00	1598.00	1628.00	1653.00	1566.00	1077.00	1082.00	1082.00	1082.00
SANDGRAVEL	Existing Sand and Gravel Operations/Extractions in the Active Channel	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00	671.00
DESERT	Desert or bare earth	0.00	0.00	72.00	122.00	160.00	0.00	0.00	0.00	0.00	0.00
URBAN	Existing Residential, Industrial and Transportation Avenues in the Uplands	327.00	327.00	460.00	460.00	460.00	327.00	327.00	460.00	460.00	460.00
	TOTALS:	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00	3148.00

NEWWETRVRBOTTOM
28 acres of stormwater wetlands

WETRVRBOTTOM
Assume reduction in discharge at 43rd Ave, and less wet river bottom in that vicinity. 5 acres convert to DRYRVRBOTTOM

OPENWATER
Assume less water discharged to the channel and filling the lakes. Dry lake beds classified as Desert or bare earth.

CWWFOREST
Converts to scrub shrub as water decreases

Channel Restoration is approximately 170 acres. Assume 20% will be emergent wetland from Rio Salado inflows, dry weather flows, and excess stormwater runoff.

Arizona Rivers Ecosystem Restoration Studies

Rio Salado Oeste Alternative 5B

AAFCU Calculation Summary

Fxn 01: Maintenance of Characteristic Dynamics

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	413.93	0	1	0.23	0.30	1774	1994	500.37
1	6	0.23	0.23	1774	1774	2069.67	1	6	0.30	0.30	1994	1994	2957.25
6	26	0.23	0.23	1774	1774	8278.67	6	26	0.30	0.39	1994	1994	13750.83
26	51	0.23	0.23	1774	1774	10348.33	26	51	0.39	0.39	1994	1994	19590.83
Without Project AAFCUs:						413.93	With Project AAFCUs:						721.55
							Net AAFCUs:						307.62

AAFCU Calculation Summary

Fxn 02: Dynamic Surface Water Storage/Energy Dissipation

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.64	0	1	0.42	0.58	1774	1994	948.88
1	6	0.42	0.42	1774	1774	3737.63	1	6	0.58	0.59	1994	1994	5858.34
6	26	0.42	0.42	1774	1774	14902.49	6	26	0.59	0.57	1994	1994	23116.70
26	51	0.42	0.42	1774	1774	18573.62	26	51	0.57	0.57	1994	1994	28325.15
Without Project AAFCUs:						744.36	With Project AAFCUs:						1142.14
							Net AAFCUs:						397.78

AAFCU Calculation Summary

Fxn 03: Long Term Surface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.25	0.25	1774	1774	452.12	0	1	0.25	0.35	1774	1994	569.14
1	6	0.25	0.25	1774	1774	2239.04	1	6	0.35	0.35	1994	1994	3464.83
6	26	0.25	0.25	1774	1774	8798.88	6	26	0.35	0.34	1994	1994	13642.84
26	51	0.25	0.25	1774	1774	10943.39	26	51	0.34	0.34	1994	1994	16782.96
Without Project AAFCUs:						439.87	With Project AAFCUs:						675.68
							Net AAFCUs:						235.81

AAFCU Calculation Summary

Fxn 04: Dynamic Subsurface Water Storage

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.44	0.44	1774	1774	783.00	0	1	0.44	0.52	1774	1994	903.50
1	6	0.44	0.45	1774	1774	3955.00	1	6	0.52	0.52	1994	1994	5153.75
6	26	0.45	0.46	1774	1774	16130.00	6	26	0.52	0.52	1994	1994	20640.00
26	51	0.46	0.47	1774	1774	20506.25	26	51	0.52	0.52	1994	1994	25800.00
Without Project AAFCUs:						811.26	With Project AAFCUs:						1029.36
							Net AAFCUs:						218.10

AAFCU Calculation Summary

Function 5: Nutrient Cycling

Without Project							With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs	TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.28	0.28	1774	1774	495.52	0	1	0.28	0.23	1774	1994	476.46
1	6	0.28	0.27	1774	1774	2451.88	1	6	0.23	0.27	1994	1994	2478.38
6	26	0.27	0.27	1774	1774	9576.43	6	26	0.27	0.29	1994	1994	11178.08
26	51	0.27	0.26	1774	1774	11718.48	26	51	0.29	0.33	1994	1994	15533.15
Without Project AAFCUs:						475.34	With Project AAFCUs:						581.69
							Net AAFCUs:						106.35

AAFCU Calculation Summary

Function 6: Detention of Imported Elements and Compounds

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.38	0.38	1774	1774	668.88		0	1	0.38	0.39	1774	1994	722.71
1	6	0.38	0.37	1774	1774	3320.82		1	6	0.39	0.41	1994	1994	3995.20
6	26	0.37	0.36	1774	1774	13065.78		6	26	0.41	0.43	1994	1994	16864.69
26	51	0.36	0.36	1774	1774	16152.25		26	51	0.43	0.45	1994	1994	22144.26
Without Project AAFCUs:						651.13		With Project AAFCUs:						857.39
								Net AAFCUs:						206.26

AAFCU Calculation Summary

Function 7: Detention of Particles

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.33	0.33	1774	1774	588.51		0	1	0.33	0.44	1774	1994	727.92
1	6	0.33	0.33	1774	1774	2933.78		1	6	0.44	0.45	1994	1994	4424.61
6	26	0.33	0.33	1774	1774	11653.36		6	26	0.45	0.47	1994	1994	18292.45
26	51	0.33	0.33	1774	1774	14478.48		26	51	0.47	0.48	1994	1994	23540.43
Without Project AAFCUs:						581.45		With Project AAFCUs:						921.28
								Net AAFCUs:						339.83

AAFCU Calculation Summary

Function 8: Maintain Characteristic Plant Communities

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.42	0.42	1774	1774	748.35		0	1	0.42	0.46	1774	1994	832.60
1	6	0.42	0.42	1774	1774	3730.78		1	6	0.46	0.49	1994	1994	4754.76
6	26	0.42	0.42	1774	1774	14839.73		6	26	0.49	0.50	1994	1994	19818.85
26	51	0.42	0.42	1774	1774	18456.48		26	51	0.50	0.51	1994	1994	25173.87
Without Project AAFCUs:						740.69		With Project AAFCUs:						991.77
								Net AAFCUs:						251.07

AAFCU Calculation Summary

Function 9: Maintain Spatial Structure of Habitat

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.30	0.30	1774	1774	531.41		0	1	0.30	0.35	1774	1994	608.87
1	6	0.30	0.30	1774	1774	2636.99		1	6	0.35	0.37	1994	1994	3543.91
6	26	0.30	0.29	1774	1774	10376.28		6	26	0.37	0.39	1994	1994	14991.37
26	51	0.29	0.29	1774	1774	12783.89		26	51	0.39	0.41	1994	1994	19959.21
Without Project AAFCUs:						516.25		With Project AAFCUs:						766.73
								Net AAFCUs:						250.49

AAFCU Calculation Summary

Function 10: Maintain Interspersion and Connectivity

Without Project								With Project						
TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs		TY 1	TY 2	FCI 1	FCI 2	Area 1	Area 2	Cumulative FCUs
0	1	0.23	0.23	1774	1774	401.30		0	1	0.23	0.30	1774	1994	493.15
1	6	0.23	0.23	1774	1774	2006.50		1	6	0.30	0.31	1994	1994	3040.86
6	26	0.23	0.25	1774	1774	8387.75		6	26	0.31	0.33	1994	1994	12831.13
26	51	0.25	0.25	1774	1774	10943.82		26	51	0.33	0.34	1994	1994	16610.71
Without Project AAFCUs:						426.26		With Project AAFCUs:						646.59
								Net AAFCUs:						220.32

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
F4 MILESTONE
Salt River-Phoenix, Arizona

Appendix J
Design

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532711
LOS ANGELES, CALIFORNIA 90053-2325

Appendix J
Design and Cost Estimate

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1.0 OBJECTIVE

The primary objective the Rio Salado Oeste project is to establish the feasibility of environmental restoration, flood damage reduction, and recreation along the Salt River in Phoenix, Arizona. The purpose of this appendix is to present feasibility study results of the civil design effort. Design data and calculations were developed sufficient to determine the technical and economic feasibility of each alternative and in the event the project is authorized, to provide a base design leading to the development of the construction plans and specifications.

2.0 STUDY AREA

The Rio Salado Oeste Salt River Restoration project is located along the Salt River, southwest of Phoenix, Arizona, within Maricopa County, between 19th and 83rd Avenues. The Salt River (Rio Salado in Spanish) is a major tributary to the Gila River in Arizona. The river originates in eastern Arizona and flows westward to its confluence with the Gila River west of downtown Phoenix. The study area is located between the authorized Rio Salado project area and the Tres Rios Feasibility Study area. The Oeste study area is approximately seven miles in length, averages 2 miles in width, and encompasses approximately 10,000 acres. However, the project area is a smaller extent including the 100-year floodplain, which is near an average of ¾ mile width and nearly 3200 acres.

3.0 DESIGN CRITERIA

3.1 Structural Requirements

The structural materials required for storm drain piping and outlet structures, involves reinforced concrete pipe (RCP), gravel, riprap, reinforce concrete, and grouted stone.

The structural material required for the drop structure at 35th Avenue involves roller compacted concrete (RCC) and compacted back fill. These are rigid materials that have been successfully used before on previous projects under these types of hydraulic conditions.

The structural requirements for the bank stabilization and concrete spillway include static and dynamic stability.

3.2 Hydrology and Hydraulic Requirements

Hydrology and hydraulic design criteria are discussed in their respective appendices. The Hydrology Appendix provides the design discharges for the existing drainage structure that discharge into the study reaches.

Evaluations of the hydraulic considerations of the low flow channel and drainage areas are discussed in the Hydraulic Appendix.

3.3 Geotechnical Requirements

River rock is readily available throughout the study are and has been used for construction of numerous features in the Rio Salado project upstream. It is assumed that the same materials will be suitable for construction on the Rio Salado Oeste project. Should additional materials be necessary, two stone borrow sites have been identified as sources of construction material and are available for use, in the event an engineering design is proposed for the project. Two quarries have provided stone for previous Corps flood control projects.

3.4 Environmental Considerations

The project area includes approximately 8 miles of river channel and encompasses 3147 acres within the 100-year floodplain. Scattered remnants of natural vegetation remain, those cover types include cotton-willow forest, mesquite, scrub-shrub lands, and emergent wetlands. Of those cover types scrub-shrub lands are the most dominant in the study area covering approximately 1500 acres. The scarcest is cottonwood-willow forest extant within merely 112 acres of which salt cedar dominates.

3.5 Contaminants

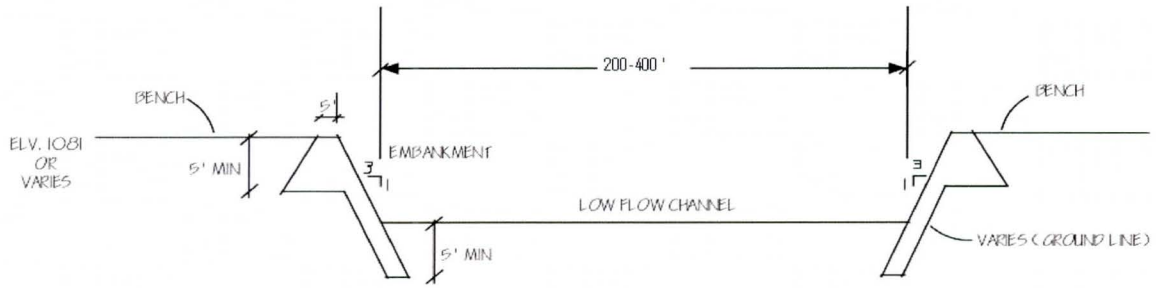
Sites identified with possible HTRW concerns are for the most part outside the 100 year floodplain and location where project features would be located. Project features are for the most part located within the 100 year floodplain and avoid the known HTRW sites. In accordance with Engineer Regulation 1165-2-132 the Corps will not participate in clean up of materials regulated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or by the Resource Conservation and Recovery Act (RCRA). Project cost estimates have included a percentage estimate for potential removal of inert debris not falling under CERCLA or RCRA should they be unearthed during construction. A remediation and management plan will need to be developed during design for unknown HTRW and other deleterious material should they be encountered during construction.

4.0 DESIGN FEATURES

4.1 Channel Restoration

Reshaping the Salt River riverbed is required through the entire project reach to restore a natural river channel. Channel restoration will be accomplished through grading and terracing of an area within the 10-year discharge area of inundation and following historic channel conditions. This includes a low flow channel design for the 5-year return period discharge (20,200 cfs) and is also assumed that the final channel may meander slightly and be braided as it was historically. This includes a total cutting and fill volume of approximately 660,000 cubic yards. It has been assumed that materials from reshaping will be disposed of onsite throughout the project area to form terraces and fill depressions and abandoned sand and gravel pits.

Liner materials will be investigated for use in wetlands and surface irrigation canals. An impermeable layer was added to surface irrigation canals in the Rio Salado project to reduce infiltratoin and increase efficiency. For estimating purposes in the feasibility study it was assumed that a 12 inch silt-clay soil substrate would be added to the stormwater wetlands to reduce permeability. Similar materials will be utilized to line surface irrigation canals in the water distribution system. Since the project area has extensive modification and existing aggregate mining operations throughout it is assumed that the soil-clay substrate is available onsite or near the project area. This may include fine materials discarded from aggregate operations and currently stockpiled at various locations.



TYPICAL LOW FLOW CHANNEL CROSS-SECTION

SCALE: 1" = 500' HORIZ.; 1" = 10' VERT.

4.2 Wetland

Wetlands are restored throughout the project area with a total area of approximately 190 acres. Typical cross section of restored new wetland is shown in project plates.

4.3 Control Invasive Vegetation

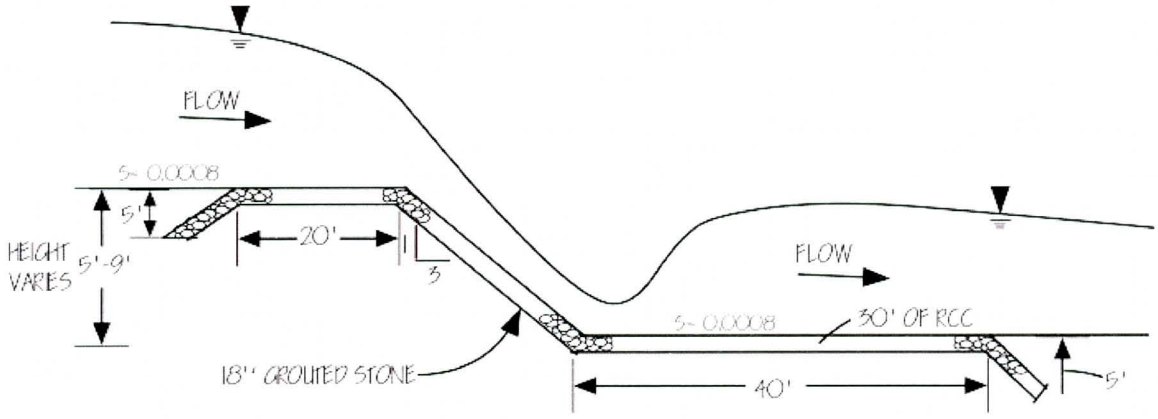
Control invasive vegetation is required in the vicinity of 37th Avenue where there is an existing stand of Salt Cedar and 43rd Avenue where there is a stand of Arundo with a total area of approximately 120 acres. The locations will be defined in the next phase of the study.

4.4 Planting

Planting includes approximately 375 acres of Cottonwood/ Willow and 417 acres of Mesquite. The locations of the plantings are shown on the project plates. Although detail design will be developed in the next project phase it was assumed that planting will include a combination of pole and containerized plants, as well as hydro seeding.

4.5 Drop Structure

A drop structure will be constructed down stream of the 35th Avenue Bridge. This structure is design to protect the bridge abutments and footings from damage during a flood event. That drop structure follows the same design as those constructed for the Rio Salado Project upstream and is shown below.

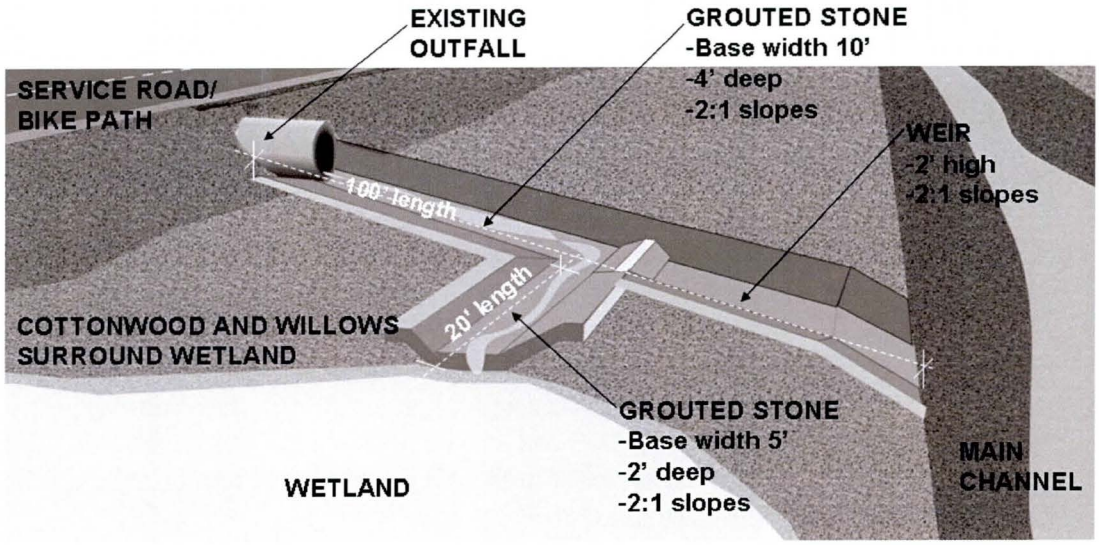


DROP STRUCTURE DETAIL

not to scale

4.6 Grouted Rock Outfall

At eight locations within the project site, grouted rock outfalls will extend from the banks into the channel from existing pipe outfalls. The grouted rock will extend approximately 100 feet from the existing pipe outfall and vary from 2-4 feet in height. The required grout is approximately thirty percent of the needed rock. Each outfall will require 221 cubic yards of rock and 67 cubic yards of grout. An estimated 1 ft. of fill will be required under the grout layer. The eight outfall sites will require a total of 1768 cubic yards of rock and 536 cubic yards of grout. The following diagram represents the typical grouted rock outfall location although each channel will be designed specifically for the discharge of the pipe during design phase.



4.7 Water Supply and Distribution System

Description of the water supply and distribution system is attached at the end of this report. It provides detailed discussion of the proposed system provided by the project sponsor, City of Phoenix.

5.0 CONSTRUCTABILITY

5.1 Construction Materials

The construction materials required for the design features described above include soil and gravel for structural fill, soil and soil cement,

cement, water, concrete, clay, PVC pipe, pumps and specified plants. All of these materials are available locally. Plants can be purchased locally or can be grown locally from native seed sources in advance of up to two years to develop healthy rootstock.

5.2 Access Roads

Recreational trails on both sides of the channel, and throughout will be used as access roads for operation and maintenance purposes. Specific alignment of access roads will be determined in the PED phase, but is anticipated to include underpasses at the major road crossings such as 19th, 35th, 51st, and 67th Avenues.

6.0 UTILITY RELOCATION

No utility relocation has been identified in the study. Any possible utility relocation will be defined in the PED phase. Local sponsor will be responsible for constructing the utility relocation.

7.0 CONSTRUCTION TIME OF RECOMMENDED PLAN

Construction time of the recommended plan is being estimated to be approximately 4 years.

8.0 OPERATION AND MAINTENANCE REQUIREMENTS

8.1 Structures: Operational inspections for structural cracking and functional capability are made periodically, with at least one official annual inspection, and as needed during the flood season. Inspections should include unwanted wild plants that if allowed to grow may exacerbate a structural crack. These plants are controlled by cutting or spray.

8.2 Plants: Replacement for plants will be required due to occasional flooding events and other natural causes. Up to 25% of vegetation may require replacement following a flood event at some time during the project life. (Extent of plant replacement will be strongly determined by size of event. Only in the case of catastrophic damage should the City consider an alternative to natural succession).

8.3 Invasive Species Control: Annual removal of exotic species was assumed to be necessary. This would include removal of non native species that threaten to overtake an area and become a monoculture. This wouldn't necessarily include removal of 100% of non natives through the project area.

8.4 Storm water wetlands: Regrading and excavation was assumed to be needed once every 10 years. It was assumed that 50% of the construction quantity would need to be regraded in this period.

8.5 Irrigation System: Maintenance of the irrigation infrastructure including replacement of infrastructure will occur annually. Costs were estimated on a per acre basis for those acres planted to vegetation.

8.6 Lakes/Wetlands: The restored wetlands at existing lakes (gravel pits) will require regrading and excavation once every 20 years of up to 1 foot of material over the 40 acres of wetlands.

8.7 Channel: The active channel will require regrading up to once every 20 years for up to 50% of the estimated construction quantity or 330,000 cy.

9.0 VALUE ENGINEERING

9.1 In accordance with CESPD-CM-P Memorandum Value Engineering Studies During Planning (September 30, 2003) a Value Engineering Study was conducted for the Rio Salado Oeste Feasibility Study. That VE study is dated December 2, 2004. Pertinent VE proposals were considered in plan formulation and all remaining proposals will be revisited during the design phase of the project.

PROPOSED ALTERNATIVES' DESIGN FEATURES

DESIGN FEATURES	ALTERNATIVES				
	2	4	5	5A	5B
1. Channel Restoration	X	X	X	X	X
2. Stormwater Outfall	X	X	X	X	X
3. Wetland Ponds	X	X	X	X	X
4. Clearing and Grubbing	X	X	X	X	X
5. Planting (including temporary irrigation)	X	X	X	X	X
6. Grade Control Structure	X	X	X	X	X
7. Debris Removal	X	X	X	X	X
8. Inspections and Surveys	X	X	X	X	X
9. Invasive Species Control	X	X	X	X	X
10. Wetlands	X	X	X	X	X
11. Channel	X	X	X	X	X
12. Water Supply		X	X	X	X
13. Additional Irrigation		X	X	X	X
14. Effluent Water		X	X	X	X
15. Emmergent Wetlands		X	X	X	X
16. Lake Restoration			X		
17. Restoration of Two Gravel Pit Lakes and Wetland/ Riparian				X	
18. Restoration of one Gravel Pit Lake and one Wetland/Riparian					X
19. Pump Station		X	X	X	X
20. Electronic Flow Regulated Valves		X	X	X	X
21. Reservoir		X	X	X	X
22. Ground Water Pond/Reservoir on Overbank		X	X	X	X
23. Waterline Pipes		X	X	X	X
24. Waterline Pipes Loops		X	X	X	X
25. Bridge Crossing		X	X	X	X
26. Terrace and LFC Canal Delivery Conveyance Channels		X	X	X	X
27. Overbank Canal Delivery Conveyance Channels		X	X	X	X
28. Waterfall to Move Water from Overbank to Terrace		X	X	X	X
29. Internal Drainage Conveyance Channels		X	X	X	X
30. Waste & Tire Removal		X	X	X	X
31. Supply Well		X	X	X	X
32. Monitoring Wells		X	X	X	X

10.0 WATER SUPPLY AND DISTRIBUTION SYSTEM (CITY OF PHOENIX)

Introduction:

Before the turn of the 20th century the Salt River was one of the few perennially watered riparian areas of the Sonoran desert with highly productive cottonwood, willow, and mesquite forest. These habitats were once rich in ecological diversity and supported a wide variety of wildlife species. Today, the River is in a state of environmental degradation from water projects constructed upstream. The River's hydrology has effectively been eliminated, taking with it the highly valued native riparian ecosystem. With virtually no flows in the river, except during storms and periodic upstream dam releases, a reliable water supply and distribution system is needed to support the Rio Salado Oeste Project (Oeste). The primary objective is to restore a portion of the Salt River riparian ecosystem.

At the time of this report, the United States Army Corps of Engineers (Corps of Engineers) and the City of Phoenix are developing the Rio Salado Environmental Restoration Project (Rio Salado) between 19th Avenue and 28th Street. The Tres Rios project which runs from 83rd Avenue to about 117th Avenue is soon to begin construction. Oeste, between 19th and 83ed Avenues, will employ many of the same environmental restoration principals that were developed for the Rio Salado and Tres Rios projects. The Rio Salado project employs ground water to sustain a variety of project habitat features, while Tres Rios, will be supported by reclaimed water from the City's 91st Avenue Water Reclamation Plant.

Water Supply Alternatives:

Three water source alternatives were evaluated for Oeste. The first was to maximize ground water pumping from the Rio Salado project wells and deliver by either pipe or open channels to Oeste. Rio Salado drilled five wells into the shallow aquifer and is currently evaluating wellhead treatment for at least two wells to remove volatile organic compounds (VOC). The upper aquifer lies close to the surface and is about 300-400 feet thick. This ground water is under utilized and according to the City's Water Services Department, is not suitable for urban water supplies. It contains varying concentrations of pollutants resulting from agricultural, urban, and adjacent landfill impacts making it available for environmental restoration purposes.

The Rio Salado wells can yield, if pumped 24 hours a day, 7 days a week, approximately 12.5 mgd. This could provide the Oeste Project with approximately 5.7 mgd to 8 mgd if piped or 4.5 mgd to 6.5 mgd if conveyed in open channels.

There are concerns however with using the Rio Salado supply wells. The main River channel or a low flow channel (LFC) could be used for conveyance reducing construction cost, but a substantial pump would be required in the River to move the water into Oeste's distribution system. Plus, if the water were to be conveyed through open channels, it is estimated that evaporation and percolation losses would be 20%-30% of the piped amount.

These losses could be reduced if the water was piped, but could double the conveyance cost of getting water from Rio Salado to Oeste compared to using an open channel delivery system. Trenching though the overbanks in the Rio Salado involves a high degree of waste removal, over excavation for structural stability, and more expensive construction methods to reduce impacts to existing landfills such as, double containment pipes to capture water that could result from a line break.

The cone of depression that could result and the impact to one of the contaminated groundwater plumes that exist within close proximity of the area is of critical concern. This would affect water quality and quantity for the current Rio Salado project and the future Oeste project. If this happened it could affect the Rio Salado wellhead treatment technology, possibly requiring a modification to respond to the introduction of new constituents. Legally there would be risks associated with drawing a contaminated groundwater plume into the area where it could affect the water quality of area wells.

The cone of depression concerns, conveyance costs, increases in Rio Salado pump maintenance costs (a 33% reduction in the pump's useful life expectancy due to the longer run times would increase replacement costs). Add to these the costs associated with the Rio Salado treatment operations, increase in hazardous material removal from the treatment facilities, and the potential water table drawdown concluded this alternative was too costly for further consideration.

The second alternative looked at duplicating what was done for the Rio Salado project and installing new supply wells for Oeste. The most critical issue with this alternative is the relationship Oeste's water supply would have with the City's conservation requirements.

The average daily demand for the Rio Salado is approximately 4.35 million gallons per day (mgd) with a peak demand of approximately 6.5 mgd.

State mandated conservation requirements, limits water use on a per capita basis and limits the total amount of groundwater available for the City's future use. Groundwater and most surface water use is calculated every year to evaluate compliance with the City's "gallons per capita per day" (GPCD) water use limitation. In 2003, the target water use rate for the City was 215 GPCD. This conservation requirement becomes progressively more restrictive in future years. The expected target GPCD will decrease from an estimated 209 GPCD in 2005, to 202 GPCD in 2010.

The City must also comply with groundwater use limitations that are part of the 100-year Assured Water Supply (AWS) Designation. The AWS designation quantifies a limited groundwater supply that is intended to serve as a "backup" water supply to offset reductions in surface water availability during times of drought. This backup groundwater supply equates to less than 10 percent of total water use annually.

The key concerns with pumped water are as follows:

- Any recovered effluent credits could potentially reduce the volume of water available for the Rio Salado project over the long-term. Availability of these credits is tied to the amount of effluent that the Roosevelt Irrigation District (RID), an agricultural area in southwest Phoenix, is willing to take each year based on an agricultural demand. RID has not yet demonstrated an ability to use enough effluent consistently to generate credits for both the Rio Salado and Oeste projects over a long period. It is estimated that Oeste's needs could result in a tripling of the demand for these credits.

- If groundwater is pumped (either in the form of incidental recharge credits or the allowance credit, this water will be charged against the GPCD conservation requirement as discussed above. The Oeste demand alone would increase the City of Phoenix's per-capita rate by 6 GPCD, which could create a compliance concern with the state limit.

- Recovered Central Arizona Project (CAP) credits were deemed impractical for Rio Salado, and the same applies to Oeste. This water, like groundwater, would be subject to the GPCD conservation requirements. In addition, the cost to the project in acquiring and storing this water would be substantial. Phoenix is relying on CAP supplies to meet future potable system demands that would be used more efficiently in other areas of the City.

To protect effluent and groundwater credits, and to avoid conservation compliance issues, the use of pumped groundwater for Oeste should be considered only for: 1) maintaining a certain water quality for selected project features; and 2) maintaining system redundancy (in the event of loss of direct effluent during an unplanned outage).

For the third alternative the City of Phoenix Water Services Department evaluated their 91st Avenue and 23rd Avenue Water Reclamation Plants for a sustainable water source. The City determined that 8 million gallons per day (mgd) could be directed to the Oeste project from the 23rd Avenue Water Reclamation Plant if certain conditions could be met. The 91st Avenue plant was determined to be too costly to deliver water up gradient to the far east reaches of Oeste. Supplemental water could come from a variety of underground sources including: 1) effluent credits "recovered" (pumped) from within the area of hydrologic impact of the RID Groundwater Savings Facility; 2) incidental recharge credits associated with increased recharge from project implementation; 3) groundwater (based on the City's Assured Water Supply allowance); and 4) recovered credits for Central Arizona Project water (stored by the City). The use of pumped water (rather than direct effluent) has several limitations. One of these relates to the City's ability to comply with state mandated water conservation requirements. Storm water is also considered and may prove sufficient to support ephemeral wetlands or riparian habitat in portions of the project, but because it is not a reliable water source it is only identified as a supplement to the effluent.

The Selected Alternative:

The water supply and distribution system is critical to the success and sustainability of the Oeste Environmental Restoration Project. A sufficient quantity and adequate quality of water must be available to maintain the viability of the various habitat types that are being considered for Oeste. The primary water supply for the Oeste project is effluent obtained directly from the 23rd Avenue Water Reclamation Plant. Supplemental water could come from a variety of underground sources including: 1) effluent credits "recovered" (pumped) from within the area of hydrologic impact of the RID Groundwater Savings Facility; 2) incidental recharge credits associated with increased recharge from project implementation; 3) groundwater (based on the City's Assured Water Supply allowance); and 4) recovered credits for Central Arizona Project water (stored by the City).

Treated effluent from the City's 23rd Avenue Water Reclamation Plant and one ground water well have been identified as the primary water sources for Oeste. The use of pumped water (rather than direct effluent) has several limitations. One of these relates to the City's ability to comply with state mandated water conservation requirements as discussed above. Secondary influxes of dry weather flows and storm water flows from the network of storm drains that empty into the River, residual Rio Salado flows, and discharges east of 35th Avenue on the north bank from the 23rd Avenue Water Reclamation Plant and at 43rd Avenue on the north bank are also included.

The sustainable water supply and distribution system consists of the following features:

- (1) 20 MGD Pump Station
- (1) Supply well
- (2) Monitoring Wells
- (6) Electronic Flow Regulated Valves
- (5) Reservoirs
- (5) Pump stations
- Open channel canals
- Irrigation system
- Pressurized distribution piping

Design Assumptions:

The following design assumptions were made for the water supply and distribution system:
Project Water will be a combination of:

- 8 mgd (or 8,976 acre-feet per year) of reclaimed water from the 23rd Avenue Water Reclamation Plant.
- 1.85 mgd (or 2,075 acre-feet per year) from a ground water supply well. The well will be used for maintaining system redundancy in case of a direct lose of effluent during an unplanned outage and to provide water for the reservoir/urban fishing pond.

- 3.35 mgd (or 3,762 acre-feet per year) residual from Rio Salado when all wells are pumping to design capacity.
- 2 mgd (or 2,252 acre-feet per year) which is 50% of the storm water collection capacity.
- 7.1 mgd (or 7,966 acre-feet per year) as an average discharge from the 23rd Avenue Water Reclamation Plant to the River just east of 35th Ave. (This quantity is subject to diurnal variations. Historically, in fall and winter, has recorded peak flows over 50 mgd and on some days during the summer months as low as 0 mgd).
- The maximum velocity for all pressure and gravity pipelines will be 5 feet per second (fps); limiting the velocity in small pipes (<24 inches in diameter) to 5 fps is a commonly accepted engineering practice so as to reduce head loss and surge potential.
- The head requirements for the pump stations will be determined using the Hazen-Williams equation with a friction factor of 130. It is a commonly accepted engineering practice to accept this friction factor as a good average factor for the lifetime of most pipeline materials.
- Manning's equation will be used to calculate the capacity of all of the gravity pipelines using a friction factor of n=0.013. It is a commonly accepted engineering practice to accept this friction factor as a good average factor for the lifetime of most pipeline materials.
- Hydraulic Institute Standards will be met for the pump station configurations.

Water Supply for Each Reach:

The water distribution system will be a series of traditional and nontraditional irrigation methods. It is envisioned that water will be pumped from reservoirs along the banks into canals located on the banks or into a pressurized irrigation system. The canal water will move via gravity from along the over banks down spillways, waterfalls, channels, or piped to open ponds and wetlands along the terrace, then down to the perennial stream and ponds of the main river channel.

The wetlands, open ponds, and streams will be lined with either fine-grained soils or synthetic materials to reduce percolation and enhance horizontal migration of water to create a saturated soil profile. This wetted margin is needed to sustain riparian vegetation. Careful attention is needed to optimize plant densities to mitigate overcrowding, encroachment from exotics, and improved vector control. Design considerations will be made to control mosquito larva infestation by fluctuating water levels, increasing water movement, developing and managing appropriate planting densities and providing adequate access points for chemical applications.

The water distribution system should be designed to provide an uninterrupted supply of water to the open water features (reservoirs, ponds, wetlands, and canals) as well as meet the irrigation demands of the various habitat types throughout Oeste. To meet these goals, the water distribution system will have a built in redundant connection by discharge piping and isolation valves so that if any of the reservoirs are taken out of service, water can still be delivered to the various habitats. Based on this approach, a reservoir may provide a supply of water to any of the features and the pressurized irrigation system. The advantages of this system are as follows:

- Facilitates adding additional reservoirs if needed in the future.
- Facilitates delivery of water to all features if a reservoir is out of commission.

Generally, water will be delivered from the 23rd Avenue Water Reclamation Plant by a 20 mgd pump station conveyed through a pipe directly to Oeste's reservoirs. Electronically controlled flow regulated valves will adjust the flow of water from the plant to match the demand by the irrigation or the canal system.

Pump Station Requirements and Demand:

The pump station requirements are based on the available effluent that exists from the 23rd Avenue Water Reclamation Plant. A pipeline and reservoir network will be designed to provide a supply of water for the overall Project. The pump station will be equipped to vary the output of the reclaimed water to match the demand requirements. However, there will be a limit to the maximum supply that can be delivered based on plant output and City's prior water delivery commitments.

Supply Well Equipping:

The following assumptions are made for equipping the supply well:

- The well pump will be vertical turbine pump for cost efficiencies. Their life cycle cost are lowest based on installation, ease of operation and long-term maintenance. Similar pumps were installed in the Rio Salado providing familiarity for maintenance staff and an inventory of replacement parts.
- The supply well, associated appurtenant equipment and the electrical equipment will be located in a secured structure. The structure will have an open air roofing system that will protect the components from ultraviolet rays and vandalism. Individual climate control units will maintain the required operating temperatures of the electrical equipment.
- The well will include a flow meter and low-flow sampling port to monitor the quantity and quality of groundwater that is extracted because monitoring will be part of the City's Arizona Pollution Discharge Elimination System (AZPDES)

Supply Well Location:

The supply well location will depend upon available hydrology, real estate, utilities, access for installation, and maintenance of the well. Water quality and locating the well within the zone of influence must also be considered.

Hydrogeology:

The Rio Salado Project lies within the Salt River Valley (SRV) sub-basin of the Phoenix Active Management Area. The Project area is underlain by alluvium primarily consisting of unconsolidated to semi-consolidated clays, silts, sands, and gravels. The alluvium is subdivided into three major units: the upper alluvial unit (UAU), the middle alluvial unit (MAU), and the lower alluvial unit (LAU). These units vary in thickness across the SRV, with a general thickening toward the center of the SRV, northwest of the Project area. Depth to groundwater varies seasonally due to the effects of production and irrigation wells.

The UAU typically consists of unconsolidated coarser grained material providing unconfined groundwater conditions. Based on boring logs from wells within the Rio Salado study area between 19th Avenue and 28th Street, the UAU consists primarily of coarse sands, gravels, and boulders with interblended clay and silt. The MAU is characterized by generally finer grained sediments and a lack of gravel. The MAU is a semi confined aquifer. The contact between these two units ranges between 175 and 250 feet below ground surface within the Project area.

Groundwater Availability:

Groundwater from the UAU will be the primary source of water for Oeste's urban fishing pond and to maintain water quantity during unplanned water reclamation plant shut downs or diurnal fluctuations. The reliability of the quantity and quality of this water is critical to its success.

Currently, it is estimated the well will supply approximately 1.85 mgd. A series of pump test conducted by the Corps for the Rio Salado project indicate the UAU is showing a decrease in groundwater elevation and there is data indicating that over the past 25 years groundwater elevations within Rio Salado and Oeste areas have decreased approximately 15 to 20 feet. One well, for example, not far from the Rio Salado and Oeste projects has dropped about 4.5 feet per year between 1993 and 2000.

Groundwater Quality:

To a large extent, ground water sampling has shown in the Rio Salado project that the UAU is likely to be contaminated with many industrial compounds negatively impacting the aquifer. Groundwater quality in the eastern half of Oeste has been impacted by hydrocarbon releases and elevated concentrations of 1,1-DCE. The southwestern area of Oeste, indicate elevated concentrations of total dissolved solids and nitrates as concerns. A DCE plume from an unknown source is positioned along the south side of the River near the Del Rio Landfill, 8th Street to 14th Streets, and crosses over to the north side of the River near the 19th Avenue Landfill.

The UAU is highly impacted by contamination with fewer impacts on the MAU and the LAU. The main chemicals of concern (COC) are tetrachloroethene (PCE), trichloroethylene (TCE), 1,1-dichloroethene (DCE), and chromium. Other chemicals of less concern include nitrate and BTEX. Several sites near the Rio Salado Project area have been impacted by at least one of the COCs.

The Corps installed monitoring wells for the Rio Salado project in 1999 and 2001 to characterize the groundwater contamination near the production wells sites. Several of these have exceeded the state and federal water quality standards for volatile organic compound (VOC). Concentrations of DCE in some exceeded the Arizona Department of Environmental Quality (ADEQ) Fish Consumption (FC) standard. PCE has repeatedly been detected at concentrations exceeding the maximum concentration level (MCL) in monitoring wells located just north of Lower Buckeye Road and west of 7th Avenue. Chromium concentrations have also been reported to frequently exceed the MCL's.

Preliminary information on Oeste and the more extensive groundwater sampling program done for Rio Salado anticipate that some form of wellhead treatment may be required for

Oeste. An evaluation of the wellhead treatment cost must be weighted against acquiring real estate outside the immediate project boundaries, but within the cone of depression for a well installation, and the cost of a conveyance system to deliver the water to the project.

Access/Right-of-Way/Utility Constraints:

The well must be accessible to heavy equipment for well maintenance, rehabilitation, and replacement. The wellhead treatment compound, if needed must be accessible to heavy equipment to install, maintain, and supply the treatment units. The preferred well location would be within the Project area adjacent to a major arterial street down river of the ground water reservoir to capture water in the River. Electrical power is required at the well and all pump station locations but should not drastically affect the location.

Recommended Well Location:

It is probable that water from the proposed supply well will not meet the AZPDES water quality criteria used for permitting and may match the water quality seen in the Rio Salado project. With the UAU identified as the primary source of supply water for pond and make up water, some factors will impact the time it will take for the well to be affected. These factors include:

- Available real estate
- Access to install and maintain the well
- Water production of the well/flow rate
- Length of time the well will operate daily/annually
- Existing groundwater treatment and impacts on contamination
- Hydrologic properties of the upper alluvial unit
- Changes in water levels induced by Rio Salado water entering the Project and the pumping of the well

The driving forces in locating the well will be access, real estate availability, installation parameters, piping distance, and the potential for wellhead treatment system.

Until additional ground water test data is available, at this time the supply well location is uncertain, but near 35th Avenue is initially desired. Additional wells may be required beyond the one proposed due to limitations in the capacity of the well yield, operation criteria, and water quality constraints.

Water Quality Considerations:

The discharge of groundwater and effluent to the Oeste Project will be regulated by two sets of standards from the Arizona Administrative Code; Title 18, Chapter 11, Article 1 – Water Quality Standards for Surface Waters; and Title 18, chapter 11, Article 4 – Aquifer Water Quality Standards. The designated uses for this reach of the Salt River include aquatic and wildlife warm water, partial body contact, and fish consumption. The surface water quality standards that are applicable for these designated uses must be met at the point of discharge to the Salt River.

Water quality should be taken into account with regard to impacts on the plant life, water supply and distribution infrastructure. As an example, water with high total dissolved solids (TDS) may be deleterious to certain vegetative species as well as increase

maintenance and operations costs to the pipelines, pump stations, and other water delivery components.

Distribution System:

Reclaimed water and ground water will be held in reservoirs. The water will flow, by gravity, to an adjacent pump station. The pump stations will then pump water to the water supply systems along the overbank and terrace areas. Piping installed along the overbank area will distribute water across the Project site. At specific locations, surface or subsurface water turnout structures will deliver water to the terrace area. The pump station locations will be based on water demand zones and habitat needs, available real estate, piping distances, public and maintenance access. The preliminary locations are:

- North side 35th Avenue (ground water pond/reservoir)
- North side 51st Avenue
- North side 75th Avenue
- South side 35th Avenue
- South side 51st Avenue

There will be two sets of criteria for the pump stations: 1) pressure and flow requirements for a permanent drip irrigation system on the overbanks and a temporary system on the terrace, and 2) pressure and flow requirements for the supplemental water delivery system. During the startup period a large daily volume of water will be required to meet the plant establishment demand of the various habitat zones. Higher volumes and pressures will be required to water larger zones once plant maturity has occurred. The design elements that are part of the pressurized system include:

- Pipeline from the reservoir to the pump stations
- Pump stations
- Pressure distribution pipelines
- Turnout structures at the terrace area (surface and subsurface)
- Localized distribution system

Design Assumptions

The following design assumptions are made for the pressure distribution system:

- Pump intake design will be in accordance with the Hydraulic Institute standards, an accepted engineering standard for pump stations.
- Pumps will be vertical turbine type pumps because of ease of maintenance, and a preference by the City.
- A standby pump will be provided for each pump type; this is a commonly accepted engineering practice that allows for minimal down time during required maintenance. Use of a stand by pump is more cost effective than frequent switching between pumps because the latter requires additional instrumentation and control.
- Pump motors will be high-efficiency, 480-volt, three-phase and will be constant speed to reduce power costs and maintenance requirements.

- No backup power will be provided since power loss for a relatively short period of time (<24 hours) should not significantly impact the Project.

Water Distribution System:

Distribution piping will be installed in the overbank area for the entire reach of the Project. The piping will be designed to withstand a constant system pressure. Turnout structures, at strategic locations, will convey the water from the overbank to the terrace by surface or subsurface means. Automated Control Valves should be installed at turnouts to allow a supply of water to be delivered to individual areas from a remote location.

To maintain a level of system redundancy, pipes will be attached to the bridge structures at 35th Avenue, and 51st Avenue. This will interconnect reservoirs and pump stations on opposite sides of the river.

Several types of material for the distribution system piping will be considered. The potential piping materials are:

- Ductile iron pipe (DIP)
- High-density polyethylene (HDPE)
- Polyvinyl chloride pipe (PVC)

Pump Station Capacity:

The pump stations will be designed to meet the water demand requirements for the specific habitat zones they will be responsible for. The system should operate off of system pressure. A desired pressure in the system should be targeted. Once a system pressure drops below an acceptable value, the pumps should turn on to pressurize the system and turn off at a predetermined maximum pressure. The pump stations should be sized to meet the different pressure requirements of the temporary/establishment irrigation system and the longer-term supplemental water system. As a result of the different pressure requirements for these two systems, there should be two dedicated pumps, one for the temporary irrigation system and one for the supplemental water and permanent irrigation systems.

The pump stations are planned to be pre-engineered stations similar to stations that are in the Rio Salado project. Water will be conveyed from the reservoirs through a gravity pipeline to a wet well. The pumps will be installed above the wet well and will use adjustable-frequency-drive units. These stations will have local controls and will be housed outside. These stations will be located in similar enclosures as were used in the Rio Salado Project, with minor aesthetic changes to integrate the Oeste project design vernacular.

Pump Station Aesthetics:

The pump stations should be adjacent to the public staging areas and associated reservoirs. The functional nature of the enclosure requires close access to a stable road surface for routine maintenance with some screening of the equipment to improve aesthetics, reduce equipment noise, ultra violet ray damage and vandalism.

The aesthetic objectives for pump stations are as follows:

- Minimize straight lines and regular forms to increase shadow opportunities (thereby decreasing apparent mass) and to preventing a structured silhouette against the skyline. The overall aesthetic approach to these structures will be based on preserving the pretense of an existing natural environment separate from the built environment.
- Maximize landscape screening where practicable.
- Coordinate sitting issues to minimize adjacency to pedestrian elements and interpretive areas while also assuring the system can operate at peak efficiency.
- Investigate the use of recycled materials and/or green building technologies such as; reused river ruins, recycled steel, and tires.
- Maximize built shading opportunities and dark colors to better blend the structure with the natural environment.
- Maintain a rustic aesthetic consistent with the project objectives by using exposed weathered metal, and raw masonry elements, and/or natural stone.

Open Channel Distribution System:

Delivering water from the reservoirs along the overbank to the terrace and wetlands is proposed to be predominately with open canals. The canals will deliver water from the reservoirs using gravity flow whenever possible. Canals will be located where possible on the overbank and terrace levels to provide water to the wetlands and surface-irrigated vegetation in select habitats such as the cottonwood-willow and emergent zones adjacent to the wetlands. The canals and waterfalls can increase habitat value by adding movement to the water thus increasing the dissolved oxygen levels, cooling the water, and altering the adjacent microclimates by increasing humidity.

Design Assumptions:

The following criteria and assumptions will be used to design the canal system:

- As a safety measure, a minimum horizontal separation of 5-feet should be maintained between the maintenance road and all canals plus a maximum gradient of 20:1 should be provided at the edge or near the canal. Canals will be designed to meander where feasible for natural purposes. Other features, such as small waterfall-like drops, crossings, pools, etc., will be provided where reasonable as determined in the detail design phases. The canal cross section design should also maintain a minimum flow depth of approximately 6 inches, a velocity ranging between 2 fps and 6 fps, with the ability of providing occasional high-velocity zones to imitate the audio, visual, and functional effects of a natural stream. To replicate a natural stream bed and achieve the desired cross section, construction materials from the River that includes river rock, cobbles, and/or concrete river ruins should be employed.
- In the overbank areas, canals should be lined with an impermeable liner to prevent seepage. Maintaining the required water supply is crucial to the success of the Oeste Project and saturation of the soils behind the riverbanks could jeopardize bank stability in places. The canals should be located approximately 6 to 8 feet from the top of the riverbank slope. In areas that are identified to be more susceptible to

erosion from flood flows, the canals and other overbank facilities will be located as far away as possible from the top of the bank. Canals located between the maintenance road and the top of slope of the riverbank on the overbank level can also function as a barrier for safety purposes between pedestrians and the bank's slope.

- On the terrace level, all canals will be lined with a low permeable liner to prevent seepage, except reaches where a "leaky" canal is specifically desired for subsurface irrigation purposes. This may occur adjacent or near some wetlands to help saturate the soils in aquatic or emergent zone habitats. To improve protection of the canals, separation between the canals and flood conveyance features such as a low flow channel will be maintained. In most locations, the canals will be located on the outside edge of the terrace. Where canals are located adjacent to wetlands they should be located between the wetlands and the riverbank. This arrangement can help augment the gravity water flow delivery system to the wetlands.

Open Canal System:

Canals will typically be located along the overbank and terrace levels between 19th Avenue and 83rd Avenue. Further geotechnical investigations and project boundaries may provide information limiting the actual extent of the open canal system.

The canals located on the southern terraces and overbanks will be fed from two reservoirs located at 35th and 51st Avenues and the river. In general, west of 51st Avenue the existing grades in the overbank parallel the riverbed grades, sloping downward in a westerly direction. Preliminary investigation indicates that gravity flow is possible west of 51st Avenue. Where gravity flow is not possible a pump station could be installed to deliver water where needed.

The canals located on the northern terraces and overbanks will be fed by three reservoirs, located at 35th Avenue, 51st Avenue and 75th Avenue and the river. Gravity delivery of water from these reservoirs is possible west of 51st Avenue for the entire northern reach. As along the south reaches, in locations where gravity becomes an exception, a small pump station could be assigned to deliver the water.

From the standpoint of delivery, operation, and maintenance it is desirable to have consistent flow conditions throughout the open canal system. However, a uniform canal appearance is not generally acceptable for an environmental restoration project because it detracts from the natural stream effect. Desirable velocities will need to consider the require slopes and actual slope of the terrain. Velocities of 2 fps are permissible but flow velocities in excess of 3 fps are more desirable. Higher velocities are a deterrent to sediment buildup and to plant and algae growth. Fast moving, noisy, tumbling water also increases dissolved oxygen levels, cools the water and provides for better vector control. Oeste should optimize opportunities for high velocity small waterfalls to improve ecosystem restoration value, vector control, aesthetics, and maintenance. This may require the installation of some small pump stations. The location, quantity, practicality, and feasibility of these pumps, if they are necessary, will be determined during the design phase.

On the terrace level, the canals should complement the layout of the wetlands. The proposal for the wetland design will be to operate them in series such that the upstream

wetland pond overflows into the next lower elevated pond and so on. The concept for the canal is for them to feed the wetlands. To improved operations the canals may also be used as a bypass water source for each terrace wetland in case a given pond needs to be taken offline for maintenance or repairs. Drops and grade breaks in the vertical alignment should be incorporated to minimize grading and optimize the habitat value the canals offer.

It is unlikely the canals will flow continuously within the terrace and overbank levels from one end of the site to the other. Naturally undulating grades, waste pockets, and other constraints may limit the extent the canals can be located. The goal is to align the canals to follow the natural grades as much as possible and to limit the earthwork efforts. Typically, the terrace-level canals flow from east to west but anticipate there will be exceptions. The design grades for the gravity canals and pipeline system will not be determined until the project is in detailed design.

Canal Hydraulics

The canals will be designed to carry the peak demand for the proposed wetlands ponds for select habitats zones. At this conceptual phase, the minimum demand for a given reach is between 0.20 cubic feet per second (cfs) and the maximum demand of about 5.05 cfs. This results in canal top widths for a trapezoidal section ranging from 5 feet to 12 feet. The design velocity and flow-depth will be sized to prevent erosion from velocities over 6.0 fps, and prevent water quality and maintenance problems associated with velocities under 2.0 fps.

In areas where sufficient nuisance water exists, storm water nuisance flows will be captured in the canal system as an additional water source. Diversion weirs designed at the outfalls will help direct the water to these locations. Water delivered to the wetlands can be achieved through a system of diversion weirs.

To reduce percolation and potential structural problems to the overbank slopes it is proposed that all of the overbank canals and some of the terrace-level canals be lined with a low permeable lining system. Lining system alternatives will be selected to provide aesthetic enhancement and promote a natural system. Various alternatives should be investigated that will allow for river rock and sand (or other natural covering) to be placed over the liner to provide a solution that meets both the hydraulic, environmental, and aesthetic design criteria.

Overbank Canal:

The water supply and distribution system on the overbank areas will be composed of channels that vary in width and depth and make their way along the overbank areas. The canals may periodically cross underneath the maintenance road and trail system to allow the streams to be viewed, heard, studied, and experienced. This system is envisioned as a stream channel lined with river rock materials punctuated periodically by a large salvaged rock outcropping, boulder, and/or salvaged concrete river ruins set to mimic a natural boulder outcropping. The system may incorporate a variety of alternative uses for recycled concrete river ruins to create check dams, drop structures, and augment grade changes.

Overbank to Terrace Canal:

The water supply and distribution system transition from overbank to terrace level will capture the sound and visual effects of splashing water. These transitions will be strategically located to provide the necessary quantity of water to the terrace area delivery system and ultimately to the wetlands.

Both native stone and concrete river ruins that are discovered during the excavation of the wetland ponds and other construction activities should be incorporated to create the desired effects, reduce waste removal fees, and exhibit to visitors how recycled materials can be used effectively in the physical environment. These spillways are not envisioned to encroach into the river channel and should be designed to complement the natural grade and hydraulic flows against the embankment.

Terrace Canal:

The water supply and distribution system on the terrace areas will be composed of a wide variety of diverse delivery systems. The backbone of the delivery system will be very similar to that of the overbank area: meandering stream channels that vary in width and depth and snake their way along the terrace areas. The channel design on the terrace, like that of the overbank, is meant to reflect a naturally occurring babbling brook, creek or streambed.

This main system should be designed with river rock materials punctuated periodically by a large salvaged rock or concrete river ruin outcroppings, boulder, and/or salvaged concrete slabs set to appear as a naturally occurring boulder outcropping. It is envisioned that this system would use these same materials to create check dams, drop structures, spillways, and grade changes along the channel.

In addition to the main channel, the terrace delivery system will also consist of "rill irrigation". These rills would occur off the main channel and deliver water in a network of small cut, possibly braided channels that would feed the terrace areas. The main purpose of the rills is to help saturate soils beyond the reaches of the wetland pond areas. If manually controlled and operated, these features could produce a controlled flood through selected vegetation to assist in natural recruitment that depends on periodic flooding to reproduce.

Water Delivery:

Design Assumptions

The prevalent assumptions and approaches for Oeste's water delivery irrigation systems are:

1. Water for the Project's wetland features will be supplied from a ground water well reclaimed effluent from the 23rd Avenue Water Reclamation Plant, Rio Salado residual, storm outfall structures, and other discharges delivered by a surface (canal) and subsurface (pipe) delivery systems. This watering system can be used to irrigate specific habitat vegetation whenever the site and soil conditions are appropriate, both on the overbank as well as in the terrace areas.

2. Delivering water to the varies habitat zones may be accomplished through a variety of methods including flooding, rill ditches, constructed perched aquifers, and two different drip irrigation system concepts. The two drip systems include a long-lasting "hard pipe" drip irrigation system to irrigate the overbanks, and a temporary plant establishment irrigation system for irrigated species on the terrace and slope areas, composed primarily of PVC piping.

3. Both proposed drip irrigation systems will consist of a combination of methods and devices including pressure-compensating emitters, micro sprays, and pressure-compensating bubblers. The exact combination and use of these devices in each of the habitats will be determined during the systems' detailed design phase. The drip irrigation systems will be designed to meet City of Phoenix Parks and Recreation standards.

4. The main infrastructure (reservoirs, pump stations, transmission pipelines, etc.) will be sized to provide a sustainable water supply. The system will be configured to provide an appropriate level of redundancy to ensure water delivery in the event of equipment or well failures. The sustainable water supply is defined as the amount of water necessary to keep the vegetation living during the month of July

Specific recommendations for the methods and approach that will be followed during design will include the combination of the following techniques.

Overbank Areas

5. The overbank areas will be irrigated mostly with a combination of pressure-compensating emitters, bubblers, and micro sprays using the hard pipe (PVC pipe) irrigation concepts designed to City of Phoenix Parks and Recreation standards. A few focus areas on the overbanks could also be irrigated using the surface (canal, or rill) water supply system.

Terrace Areas:

The terrace area may use a combination of irrigation approaches:

- Temporary drip system for establishment of vegetation
- Subsurface liners to create an artificially perched aquifer
- Canal or Rill (ditch or flood)
- Water harvesting polymer or polymer type products

Temporary Drip System:
The intent is to build from the "backbone"; water source infrastructure, mainline, and control system of the overbank irrigation system, but to use small-diameter flexible polyethylene lateral pipe and drip emitters. It is intended to be in operation for about an 18 to 24-month establishment/growth period of the containerized plant materials. This approach is anticipated to be used on specific terrace areas to start plantings that need a reliable water source during establishment or they would likely parish. This was done on the Rio Salado to align with the Corp's policy guidance of minimizing and eventually eliminating the amount of irrigation on the terrace and the local sponsor's concern of high mortality during the first few years of establishment.

Perched Aquifer:
The perched aquifer system relies on the creation of a low permeable layer below the ground that will retain water at a certain level. The perched aquifer is created within the proposed wetland and extends beyond the edges of the wetland ponds. This aquifer is perched through the use of engineered liner systems consisting of geotextile fabrics, clay, and local soils or a combination of these materials to produce impervious and semi-impervious layers that lie below the surface creating the perched aquifer effect. This water system is highly desirable in maintaining the cottonwood-willow habitats associated with wetlands. The relatively shallow depth of the naturally occurring aquifer within the river channel also presents itself as a long-term potential water source for Oeste. As a design goal, the irrigation system will be selected on the ability to facilitate and encourage deep rooting by appropriate plant materials such that the existing and naturally occurring aquifer will sustain the desired project habitats. The water for these perched aquifers could be generated through the wetland water delivery system, and potentially augmented with dry-weather flows and storm water runoff in select locations and under appropriate conditions. These areas should comprise a mosaic of indigenous riparian vegetative types producing a cottonwood-willow gallery forest and open water wetland marsh habitats.

These perched aquifer areas will also serve as an incubator for seed germination by the cottonwood and willow over story through the man-made and controlled flooding that these areas should be designed to receive. This system should not be considered within 50 feet of an excavated channel if bank stability is an issue. These systems, as with the rill system, are in harms way and could experience catastrophic damage by flood events. A cost analysis should be conducted after further engineering data can be collected and evaluated to determine the practicality and life cycle cost..

Rill/Flooding:
Rill/flooding delivery consists of ditches that have been formed, or bladed, into the natural soil to channel water towards vegetation planted along the banks and within their wet zones. These natural ditches, or rills, may or may not be lined to contain and direct the flow of water. However, the system is envisioned as one that allows leakage and percolation of the water source to aid in feeding the surrounding plant materials and to create wet zones. The use of rills within the terrace areas and at existing storm water outfalls will be one of the water supply methods for these planting zones. It is envisioned that the method of diverting water into these rills will be controlled and regulated by check dams and diversion structures that force storm water or canal water into the rills to create the leaky canal system that make up the rill irrigation system. The rill technique should be designed to supply some water to those areas that lie outside of the lined wetland pond areas and to optimize the water coming out of the storm water outfalls. These systems may be severely impacted by significant flood events, but their low initial development cost, routing, and ease of recreating them allows for quick restoration or even to rerouted as Oeste's vegetation and habitats develop and matures.

Polymers:

A possible solution for areas that fall beyond the reaches of an irrigation system or possibly in lieu of a temporary establishment system is amend the planting mix with a

polymer or polymer type product. Polymers are tiny molecules strung in long repeating chains. These tiny pellets or sponges absorb water many times there their size then release it slowly to the plant material by means of soil capillary action and pressures. In the landscape industry these are typically synthetic, but there are also natural polymer type products that could be researched.

Driwater is a natural product that is placed around individual plants during the planting operation, in either a PVC tube that can be monitored and reloaded, or in a biodegradable quart carton. The unit and the plant are wetted to activate the product. it then releases absorbed water and the Driwater product biodegrades. Driwater was used fairly successfully along the Las Vegas Wash project without the need for a temporary irrigation system, but for a large planted area it has been reported to be expensive and highly labor intensive to maintain.

The Corp and City are currently evaluating several alternatives to irrigation on a demonstration project initiated in May 2004 between 18th and 20th Streets on the south bank of the Rio Salado project. Four different plant backfill material receipts were used on 350 1-gallon containerized trees. The alternatives included polymers, Driwater, fine grained soil with a polymer additive from a local sand and gravel operator, and native backfill. Over the next several years the Corps will monitor each tree and their selected backfill material to determine if a temporary irrigation system is needed through the plant establishment period.

Slope Areas:

Slope areas leading down to the terrace should be seeded with grasses and forbs to increase habitat values, assist in erosion control, and improved aesthetics. One alternative which is being implemented on Rio Salado and needs to be reviewed once activated is to supply water to a limited area of these seeded slopes using lower-pressure, shorter-radius rotor sprinklers on short risers located at the top of the over bank. The use of this method, as in the Rio Salado, should be very focused and selective. It is envisioned to be concentrated in areas composed of inert debris and other waste sites where removal of the material would be cost prohibitive or unwise and the area should be mitigated to visually mask undesirable views and potential erosion zones. This technique should be evaluated for it's relation to Oeste's overall restoration goals, project terrain, visibility, and the habitat zones.

Supervisory Control and Data Acquisition (SCADA):

Overview:

It is intended that the Rio Salado SCADA system will integrate with Oeste's water delivery system. The Rio Salado SCADA computer located in the Rio Salado Maintenance Facility monitors and provides supervisory control for remote sites, including the production well, reservoirs, irrigation pump stations, and canal transfer pump stations. Communication between each remote site and the SCADA computer may match the Rio Salado project using a spread-spectrum radio link, which does not require licensing, or possibly a telephone connection.

Design Assumptions:

It will need to be determined if radio or telephone is the most feasible communication link between the Supervisory Control and Data Acquisition (SCADA) computer, the central irrigation controller located at the Rio Salado Maintenance Facility, and the various remote sites in Oeste. This is verified by a radio survey and cost comparison for the telephone connection. The radio survey consists of two major tasks: (1) modeling each radio link to determine if it has adequate radio strength; and (2) verifying the model by field-measuring radio signal strength for each link. The telephone connection will be based on the City's ability to procure telephone communications into some of the more remote areas of Oeste and what these capital cost would be.

Dry Weather Flows:

The majority of the storm drain outfalls in Oeste have storm water discharge only after a rainfall event. However, regular discharges of a significant quantities, have been observed in dry weather conditions at the northeast side of 35th Avenue where the 23rd Avenue Water Reclamation Plant discharges and at 43rd Avenue where agricultural tail water discharges.

Reuse of a portion of the storm water flow poses some design challenges. These challenges include designing flow-splitting structures (splitter boxes), variable-flow-rate canals, and variable-flow-rate wetlands ponds. Splitter boxes are structures that allow small nuisance flows to be diverted from the storm water channel into the water supply canals while allowing larger damaging flows, such as storm runoff, to flow directly to the River without overloading the canals and endangering the integrity of the canals or wetlands. The design challenge is to optimize these available flows, when and where possible. The maximum peak startup canal flow is estimated to be only 5.0 cfs (3.2 mgd) and the maximum sustaining canal flow is only 3.0 cfs (1.9 mgd). Dry weather flows for some of the outfalls may exceed the total water demand for portions of Oeste.

Storm water Quality:

The majority of pollutants in storm water are contained in the first flush after runoff begins. First flush describes the washing action that storm water has on the watershed. Pollutants that are deposited on impervious surfaces during dry periods are transported by the initial runoff, creating a high-pollutant load at the early stages of runoff. After the first flush, the pollutant load decreases significantly for many of the pollutants, even if the flow rate increases. Capturing the first flush can treat the majority of pollutants i.e. petroleum compounds, metals, sediment, litter and trash. It should be noted that some pollutants behave differently than others and as such the first flush concept is applicable in varying degrees.

The concept of first flush is a highly variable, often misunderstood concept. The metropolitan Phoenix area does not have accepted guidelines that establish a recommended level of pollutants that should be removed during rainfall events. A commonly accepted threshold is to treat runoff from the 90th percentile storm to represent the first flush. A study was completed in 1997 for the Flood Control District of Maricopa County (FCDMC), in which 50 years of rainfall data was listed for the Phoenix

metropolitan area. The data reveals that 90 percent of all storms recorded during the period from 1945 to 1995 were less than or equal to 0.37 inches in depth.

Trash Removal:

Storm water generated from the upstream watershed will contain floating and suspended debris. Capturing a majority of this debris as it enters Oeste is desired for aesthetics, public health, maintenance, operations and hydraulic functions of the wetlands, and canals.

In the Rio Salado project some storm water outfalls were outfitted with trash removal structures. These structures were constructed from concrete River ruins salvaged from the site and have hidden screens and openings that let water pass through. The structures have a basin on the upstream side of the openings that collect floating and suspended debris. These features also provide a visually pleasing water feature during dry weather non-storm flows. Monitoring the Rio Salado trash removal structures over several years will provide historical data on the merits of their success and application for Oeste.

To concentrate the floating and suspended debris, the trash removal structures can also be used as a splitter-box type feature. A finite amount of water can be diverted through the trash removal structure, using a bypass weir system and spillway. These weirs divert a predetermined amount of the flows generated from the storm water outfalls through the trash removal system, but still allow large storm flows to pass through to the primary River channel. The amount of flow diverted is determined during the detailed design phase and will vary from outfall to outfall depending on its size and design discharge. Although the discharge volume has not yet been quantified, it is desired to be equivalent to the first flush or greater.

Operation and Maintenance:

Water Supply and Distribution System Operations/Maintenance

Operations and maintenance considerations for the water supply and distribution system are:

- Periodic maintenance will be required on the well submersible pumps. Periodically the pumps will need to be pulled from the wells and inspected. It is anticipated that this level of inspection would mirror Rio Salado and likely occur once every two years.
- If wellhead treatment is required, the required maintenance for this facility will increase significantly. It is anticipated the regime would be similar to the Rio Salado well head treatment facilities maintenance requirements and would include maintaining equipment, replacing filters, and daily facility monitoring.
- It is anticipated that required maintenance for the reservoirs themselves should be minimal. Additional upkeep and maintenance of the plant material will be ongoing and as monitoring and adaptive management principals are adapted could involve a variety of maintenance responsibilities. As the Rio Salado reservoir shells are monitored and the cost and functional operations of the liner material is further

evaluated, additional components like a leak detection monitoring system may be warranted for Oeste.

- The pump stations will require routine preventative maintenance including all the electrical and mechanical equipment. Maintenance should include exercising valves, lubricating pumps, and monitoring electrical devices for adequate power draws.

Canal Overbank: The use of the river rock in association with the channel will create pockets for dirt and debris to accumulate and may require periodic flushing/cleanings to minimize debris and potential odors.

The manually operated rill irrigation system will require periodic maintenance to ensure that it is operating effectively. The rill irrigation system is a dynamic system and has the propensity to meander in response to the flow of water pushed through the system. Because these systems would not typically be lined with a geotextile or liner material, when the river floods the terrace areas, the rills may need to be reestablished.

- Collection and removal of trapped debris from the basin floor and the debris screen.
- Inspection of debris screen for signs of corrosion, damage from high flows, or detachment from trash rack structure.
- Inspection of trash rack structure for indications of staining, damage from high flows, vandalism, or movement of concrete block/rock that might indicate a reduction in the stability of the structure.
- The trash rack aesthetic operations and maintenance issues will be in replacement of the screen and mesh once the metal screen has surpassed its submerged life cycle.
- The spillway should be monitored to ensure that undercutting by the channel is not eroding the stability of the structure.
- The headwall treatment should be monitored to ensure that undercutting by the flows that are coming out of the associated storm drains is not eroding the stability of the headwall treatment or the structure.
- The concrete spillway should be monitored to ensure stability of the structure(s).
- Rodent control and repair of rodent damage
- Vandalism control and repair of vandalism damage
- Water supply scheduling in accordance with local and real-time Et rates
- Filtration system and lateral flushing procedures
- Fertilizer injection if provided
- Chemical (chlorine) injection for emitter maintenance
- Emitter operational check procedures
- Sprinkler performance evaluation and sprinkler operation check procedures

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Maricopa County, Arizona
Feasibility Study

Appendix K

Cost Estimates

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
LOS ANGELES, CALIFORNIA 90053-2325

The purpose of this Basis of Cost Estimate is to document the sources of data and assumptions used in developing the study cost estimates for the alternatives formulated in the Rio Salado Oeste Feasibility Study.

Where possible, unit cost information was established from actual cost data provided by manufacturers. Additional data and lessons learned were derived from the Rio Salado project currently under construction.

A. CONSTRUCTION COSTS

1. Excess Excavated Material: It is assumed that all excess material will be utilized on site throughout the project area for reshaping of the floodplain.

2. Contingency: A 20% contingency was included, in accordance with Corps of Engineers regulations for feasibility study construction cost estimates.

3. Planning, Engineering & Design (PED) and Engineering During Construction (EDC): The PED and EDC were 10% and 1%, respectively.

4. Supervision & Administration (S&A): A 7% S&A cost was taken on the construction cost. This percentage is required by the Corps of Engineers regulations.

B. OPERATION AND MAINTENANCE COSTS

The restoration is designed with the intent to restore ecosystem functions and be a self-sustaining natural riparian ecosystem. However, as in any manmade, controlled system, maintenance will be required.

1. Invasive Control: $60/acre as provided by invasive control companies. This applies for both Salt Cedar and Arundo.

2. Restored Channel:

   i. Grading – Assume once every 20 years a volume equal to ½ of the initial construction quantity or 330,000 c.y.

   ii. Estimated at $4/c.y.

3. Storm water Wetlands: Regrading and excavation will be required once every 10 years. Assume 50% of construction quantity or approximately 75,000 c.y.

4. Irrigation System Maintenance: Assume $1000 per acre repair and replacement of irrigation infrastructure.

5. Associated Cost, Water Supply: Assumed cost similar to that of Central Arizona Project water $106/acre-ft as recommended by City of Phoenix Water Services Department.

7. Replanting and replacement cost: Assumed 25% of planting/irrigation will require replacement after a flood event.

8. Lakes: Assume that excavation and regrading would be required once every 20 years, 40 acres at 10 ft depth. Approximately 645,000 cy at $7/cy.

C. RECREATION COSTS

Estimates for the recreation features are based upon known costs for the Rio Salado project currently under construction.

Oeste Feas. Study Cost Estimate
Phoenix, Az.
Feasibility Study Cost Estimate

Designed By: Los Angeles District, USACE.
Estimated By: Cost/Structural Engr'g Section

Prepared By: Phillip Eng
Cost/Structural Engr'g Section

Preparation Date: 02/15/06
Effective Date of Pricing: 02/15/06
Est Construction Time: 1440 Days

Sales Tax: 8.10%

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The project site of this feasibility study is located between the authorized Rio Salado project area (located upstream) and the Tres Rios Feasibility Study area (immediately downstream). The Oeste ("West" in Spanish) study area is approximately 8 river miles in length. The study area encompasses approximately 8 square miles.

The study area is located between S. 27th Ave. and S. 83rd Ave. along the Salt River. It includes portions of the City of Phoenix, Maricopa County, as well as state and federal land.

The purpose of the study is to develop alternatives and recommend an implementable solution to the identified water resources problems including native riparian ecosystem restoration, flood damage reduction, storm water retention, water conservation and supply, and the recreational needs of the Rio Salado Oeste study area.

Construction Duration:
1 year channel restoration simultaneously with water supply and distribution
1 year stormwater restoration
2 years lake restoration
18 months habitat restoration with lake restoration
Total = 4 years of construction = 1440 days

Arizona Business Transaction Privilege Tax for Construction:
State = 5.6%
Maricopa County = 0.7%
City of Phoenix = 1.6%

Total = 8.1% [Source: Arizona Dept. of Revenue, www.azdor.gov, www.revenue.state.az.us, (800) 634-6494, (602) 255-2060]

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01	LERRD's	1.00	EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06	Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809
TOTAL	Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land			43,900,000	10,975,000	0	0	54,875,000	
01.002 ROW for Water Supply & Distribu-			800,000	200,000	0	0	1,000,000	
TOTAL LERRD's	1.00	EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06 Wetland Restoration								
06. 03 Wetland Restoration	1.00	EA	64,633,227	12,926,645	8,531,586	5,595,945	91,687,403	91687403
06. 14 Recreation	1.00	EA	8,964,180	1,792,836	1,183,272	776,119	12,716,406	12716406
TOTAL Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land			43,900,000	10,975,000	0	0	54,875,000	
01.002 ROW for Water Supply & Distribu-			800,000	200,000	0	0	1,000,000	
TOTAL LERRD's	1.00	EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06 Wetland Restoration								
06. 03 Wetland Restoration								
06. 03. 00 Mob/Demob	1.00	EA	763,910	152,782	100,836	66,139	1,083,667	1083667
06. 03. 01 Clearing and Grubbing	36.00	ACR	156,725	31,345	20,688	13,569	222,328	6175.77
06. 03. 02 Invasive Removal	120.00	ACR	1,139,164	227,833	150,370	98,629	1,615,995	13466.63
06. 03. 03 Debris Removal	1.00	EA	743,807	148,761	98,183	64,399	1,055,150	1055150
06. 03. 09 Channel Restoration Excavation	660000.00	CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
06. 03. 10 Grade Control Structure (1 ea)	2400.00	CY	253,384	50,677	33,447	21,938	359,446	149.77
06. 03. 11 Maintainence Structures			6,003,058	1,200,612	792,404	519,745	8,515,819	
06. 03. 12 Water Supply & Distribution			23,595,219	4,719,044	3,114,569	2,042,874	33,471,706	
06. 03. 73 Stormwater Outfall	8.00	EA	328,958	65,792	43,422	28,481	466,653	58331.61
06. 03. 74 Wetland Ponds	28.00	ACR	1,097,642	219,528	144,889	95,034	1,557,093	55610.45
06. 03. 75 Emergent Wetlands	13.00	ACR	207,719	41,544	27,419	17,984	294,665	22666.57
06. 03. 76 Cottonwood/willow (1 gal)	378.00	ACR	5,114,055	1,022,811	675,055	442,775	7,254,696	19192.32
06. 03. 77 Mesquite Bosque (1 gal)	244.00	ACR	4,089,877	817,975	539,864	354,102	5,801,818	23777.94
06. 03. 78 Mesquite Xeric	168.00	ACR	2,218,877	443,775	292,892	192,110	3,147,654	18736.04
06. 03. 79 Lake Restoration	2.00	EA	16,138,702	3,227,740	2,130,309	1,397,289	22,894,040	11447020
TOTAL Wetland Restoration	1.00	EA	64,633,227	12,926,645	8,531,586	5,595,945	91,687,403	91687403
06. 14 Recreation								
06. 14.001 Access Point, Maint. Fac.	1.00	EA	1,691,280	338,256	223,249	146,431	2,399,216	2399216
06. 14.002 Access Points	1.00	EA	7,272,900	1,454,580	960,023	629,688	10,317,190	10317190
TOTAL Recreation	1.00	EA	8,964,180	1,792,836	1,183,272	776,119	12,716,406	12716406
TOTAL Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land			43,900,000	10,975,000	0	0	54,875,000	
01.002 ROW for Water Supply & Distribu-			800,000	200,000	0	0	1,000,000	
TOTAL LERRD's	1.00	EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06 Wetland Restoration								
06. 03 Wetland Restoration								
06. 03. 00 Mob/Demob								
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	67,010	13,402	8,845	5,802	95,059	1901.17
06. 03. 00.002 Setup and Dismantling	50.00	EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	26,804	5,361	3,538	2,321	38,023	3802.34
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	134,019	26,804	17,691	11,603	190,117	47529.27
06. 03. 00.005 Move & transport around job site	50.00	EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.006 Miscellaneous	1.00	EA	268,039	53,608	35,381	23,207	380,234	380234.13
TOTAL Mob/Demob	1.00	EA	763,910	152,782	100,836	66,139	1,083,667	1083667
06. 03. 01 Clearing and Grubbing	36.00	ACR	156,725	31,345	20,688	13,569	222,328	6175.77
06. 03. 02 Invasive Removal								
06. 03. 02.001 Arundo Removal	10.00	ACR	402,058	80,412	53,072	34,810	570,351	57035.12
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	737,106	147,421	97,298	63,819	1,045,644	9505.85
TOTAL Invasive Removal	120.00	ACR	1,139,164	227,833	150,370	98,629	1,615,995	13466.63
06. 03. 03 Debris Removal	1.00	EA	743,807	148,761	98,183	64,399	1,055,150	1055150
06. 03. 09 Channel Restoration Excavation								
06. 03. 09.001 Excavation	660000.00	CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
TOTAL Channel Restoration Excavation	660000.00	CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
06. 03. 10 Grade Control Structure (1 ea)								
06. 03. 10.001 RCC	2400.00	CY	112,576	22,515	14,860	9,747	159,698	66.54
06. 03. 10.002 Portland Cement	285.00	TON	42,015	8,403	5,546	3,638	59,602	209.13
06. 03. 10.003 Pozzolan (Fly Ash)	109.00	TON	6,574	1,315	868	569	9,325	85.55
06. 03. 10.004 Gabion Weirs and Water "V" Ditch	1.00	EA	92,219	18,444	12,173	7,984	130,821	130820.66
TOTAL Grade Control Structure (1 ea)	2400.00	CY	253,384	50,677	33,447	21,938	359,446	149.77

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 11	Maintainence Structures								
06. 03. 11.001	Maintenance Facility			2,666,984	533,397	352,042	230,907	3,783,330	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	940,949	188,190	124,205	81,467	1,334,812	266962.38
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	828,038	165,608	109,301	71,692	1,174,638	117463.83
06. 03. 11.004	Maintenance Road Underpass @19th			1,336,574	267,315	176,428	115,721	1,896,037	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	134,019	26,804	17,691	11,603	190,117	38023.41
06. 03. 11.006	Project Signage	6.00	EA	96,494	19,299	12,737	8,354	136,884	22814.05
	TOTAL Maintainence Structures			6,003,058	1,200,612	792,404	519,745	8,515,819	
06. 03. 12	Water Supply & Distribution								
06. 03. 12.001	20 mgd pump station,			3,203,061	640,612	422,804	277,321	4,543,798	
06. 03. 12.002	Electronic Flow Regulated Valve			53,608	10,722	7,076	4,641	76,047	
06. 03. 12.003	Electronic Flow Regulated Valves			268,039	53,608	35,381	23,207	380,234	
06. 03. 12.004	Pump Station (incl. mechanical,			2,680,386	536,077	353,811	232,068	3,802,341	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,501,016	300,203	198,134	129,958	2,129,311	
06. 03. 12.006	Ground Water Pond/Reservoir on			375,254	75,051	49,534	32,489	532,328	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	2,122,865	424,573	280,218	183,798	3,011,454	228.14
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	3,551,511	710,302	468,799	307,490	5,038,102	190.12
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	3,570,273	714,055	471,276	309,114	5,064,719	136.88
06. 03. 12.010	Bridge crossing of 16" Waterline			643,293	128,659	84,915	55,696	912,562	
06. 03. 12.011	Bridge crossing of 10" Waterline			428,862	85,772	56,610	37,131	608,375	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	402,058	80,412	53,072	34,810	570,351	114.07
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	938,135	187,627	123,834	81,224	1,330,819	53.23
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	750,508	150,102	99,067	64,979	1,064,656	30.42
06. 03. 12.015	Waterfal to Move Water from			402,058	80,412	53,072	34,810	570,351	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	480,057	96,011	63,368	41,563	680,999	22699.98
06. 03. 12.017	Waste and Tire Removal (incl.			1,594,829	318,966	210,517	138,080	2,262,393	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	533,397	106,679	70,408	46,181	756,666	756665.91
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	96,011	19,202	12,674	8,313	136,200	68099.93
	TOTAL Water Supply & Distribution			23,595,219	4,719,044	3,114,569	2,042,874	33,471,706	
06. 03. 73	Stormwater Outfall								
06. 03. 73.001	Grading/Excavation	3312.00	CY	20,219	4,044	2,669	1,751	28,683	8.66
06. 03. 73.002	Concrete	416.00	CY	93,990	18,798	12,407	8,138	133,332	320.51
06. 03. 73.003	Cobble	22400.00	SF	210,142	42,028	27,739	18,194	298,104	13.31
06. 03. 73.004	Weir, concrete	16.00	CY	3,615	723	477	313	5,128	320.51
06. 03. 73.005	V-Ditch Excavation	148.00	CY	992	198	131	86	1,407	9.51
	TOTAL Stormwater Outfall	8.00	EA	328,958	65,792	43,422	28,481	466,653	58331.61
06. 03. 74	Wetland Ponds								
06. 03. 74.001	Grading/Excavation	149890.00	CY	828,169	165,634	109,318	71,703	1,174,824	7.84

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 74.002 Liner, 12" fines, 3:1 slope,	45128.00	CY	194,422	38,884	25,664	16,833	275,803	6.11
06. 03. 74.003 Hydroseeding	28.00	ACR	75,051	15,010	9,907	6,498	106,466	3802.34
TOTAL Wetland Ponds	28.00	ACR	1,097,642	219,528	144,889	95,034	1,557,093	55610.45
06. 03. 75 Emergent Wetlands								
06. 03. 75.001 Grading/Excavation	20952.00	CY	117,452	23,490	15,504	10,169	166,616	7.95
06. 03. 75.002 Liner, 12" fines, 3:1 slope,	20952.00	CY	90,266	18,053	11,915	7,815	128,050	6.11
TOTAL Emergent Wetlands	13.00	ACR	207,719	41,544	27,419	17,984	294,665	22666.57
06. 03. 76 Cottonwood/willow (1 gal)								
06. 03. 76.001 Planting	378.00	ACR	605,378	121,076	79,910	52,414	858,778	2271.90
06. 03. 76.002 Irrigation	378.00	ACR	4,458,017	891,603	588,458	385,975	6,324,054	16730.30
06. 03. 76.003 Maintenance of Plants & Irrigat-	378.00	ACR	50,659	10,132	6,687	4,386	71,864	190.12
TOTAL Cottonwood/willow (1 gal)	378.00	ACR	5,114,055	1,022,811	675,055	442,775	7,254,696	19192.32
06. 03. 77 Mesquite Bosque (1 gal)								
06. 03. 77.001 Planting	244.00	ACR	1,171,339	234,268	154,617	101,415	1,661,638	6809.99
06. 03. 77.002 Irrigation	244.00	ACR	2,877,662	575,532	379,851	249,148	4,082,194	16730.30
06. 03. 77.003 Maintenance of Plants and Irrig-	244.00	ACR	40,876	8,175	5,396	3,539	57,986	237.65
TOTAL Mesquite Bosque (1 gal)	244.00	ACR	4,089,877	817,975	539,864	354,102	5,801,818	23777.94
06. 03. 78 Mesquite Xeric								
06. 03. 78.001 Planting	168.00	ACR	215,021	43,004	28,383	18,616	305,024	1815.62
06. 03. 78.002 Irrigation	168.00	ACR	1,981,341	396,268	261,537	171,545	2,810,691	16730.30
06. 03. 78.003 Maintenance of Plants and Irrig-	168.00	ACR	22,515	4,503	2,972	1,949	31,940	190.12
TOTAL Mesquite Xeric	168.00	ACR	2,218,877	443,775	292,892	192,110	3,147,654	18736.04
06. 03. 79 Lake Restoration								
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	15,752,667	3,150,533	2,079,352	1,363,866	22,346,418	7.45
06. 03. 79.002 Emergent Wetlands (2 lakes)	40.00	ACR	386,035	77,207	50,957	33,423	547,622	13690.55
TOTAL Lake Restoration	2.00	EA	16,138,702	3,227,740	2,130,309	1,397,289	22,894,040	11447020
TOTAL Wetland Restoration	1.00	EA	64,633,227	12,926,645	8,531,586	5,595,945	91,687,403	91687403

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 14	Recreation								
06. 14.001	Access Point, Maint. Fac.								
06. 14.001.001	Site Preparation	1.00	EA	200,000	40,000	26,400	17,316	283,716	283716.00
06. 14.001.002	Access and Circulation	1.00	EA	573,330	114,666	75,680	49,639	813,314	813314.47
06. 14.001.003	Protection Access Control	1.00	EA	157,750	31,550	20,823	13,658	223,781	223781.00
06. 14.001.004	Signage	1.00	EA	40,000	8,000	5,280	3,463	56,743	56743.20
06. 14.001.005	Shelters	1.00	EA	495,000	99,000	65,340	42,857	702,197	702197.10
06. 14.001.006	Utilities	1.00	EA	180,000	36,000	23,760	15,584	255,344	255344.40
06. 14.001.007	Park Furniture	1.00	EA	21,000	4,200	2,772	1,818	29,790	29790.18
06. 14.001.008	Interpretive Guidance Media	1.00	EA	24,200	4,840	3,194	2,095	34,330	34329.64
TOTAL	Access Point, Maint. Fac.	1.00	EA	1,691,280	338,256	223,249	146,431	2,399,216	2399216
06. 14.002	Access Points								
06. 14.002.001	Site Preparation	1.00	EA	927,000	185,400	122,364	80,260	1,315,024	1315024
06. 14.002.002	Access and Circulation	1.00	EA	1,766,400	353,280	233,165	152,935	2,505,780	2505780
06. 14.002.003	Protection access Control	1.00	EA	1,260,500	252,100	166,386	109,134	1,788,120	1788120
06. 14.002.004	Signage	1.00	EA	166,000	33,200	21,912	14,372	235,484	235484.28
06. 14.002.005	Shelters	1.00	EA	2,145,000	429,000	283,140	185,714	3,042,854	3042854
06. 14.002.006	Utilities	1.00	EA	740,000	148,000	97,680	64,069	1,049,749	1049749
06. 14.002.007	Park Furniture	1.00	EA	155,500	31,100	20,526	13,463	220,589	220589.19
06. 14.002.008	Interpretive Guidance Media	1.00	EA	112,500	22,500	14,850	9,740	159,590	159590.25
TOTAL	Access Points	1.00	EA	7,272,900	1,454,580	960,023	629,688	10,317,190	10317190
TOTAL	Recreation	1.00	EA	8,964,180	1,792,836	1,183,272	776,119	12,716,406	12716406
TOTAL	Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809
TOTAL	Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land			43,900,000	10,975,000	0	0	54,875,000	
01.002 ROW for Water Supply & Distribu-			800,000	200,000	0	0	1,000,000	
TOTAL LERRD's	1.00	EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06 Wetland Restoration								
06. 03 Wetland Restoration								
06. 03. 00 Mob/Demob								
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	67,010	13,402	8,845	5,802	95,059	1901.17
06. 03. 00.002 Setup and Dismantling	50.00	EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	26,804	5,361	3,538	2,321	38,023	3802.34
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	134,019	26,804	17,691	11,603	190,117	47529.27
06. 03. 00.005 Move & transport around job site	50.00	EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.006 Miscellaneous	1.00	EA	268,039	53,608	35,381	23,207	380,234	380234.13
TOTAL Mob/Demob	1.00	EA	763,910	152,782	100,836	66,139	1,083,667	1083667
06. 03. 01 Clearing and Grubbing	36.00	ACR	156,725	31,345	20,688	13,569	222,328	6175.77
06. 03. 02 Invasive Removal								
06. 03. 02.001 Arundo Removal	10.00	ACR	402,058	80,412	53,072	34,810	570,351	57035.12
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	737,106	147,421	97,298	63,819	1,045,644	9505.85
TOTAL Invasive Removal	120.00	ACR	1,139,164	227,833	150,370	98,629	1,615,995	13466.63
06. 03. 03 Debris Removal	1.00	EA	743,807	148,761	98,183	64,399	1,055,150	1055150
06. 03. 09 Channel Restoration Excavation								
06. 03. 09.001 Excavation								
06. 03. 09.001.001 Excavation	660000.00	CY	1,416,747	283,349	187,011	122,662	2,009,769	3.05
06. 03. 09.001.002 Backfill	660000.00	CY	515,387	103,077	68,031	44,622	731,118	1.11
06. 03. 09.001.003 Hauling	660000.00	CY	849,995	169,999	112,199	73,593	1,205,786	1.83
TOTAL Excavation	660000.00	CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
TOTAL Channel Restoration Excavation	660000.00	CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
06. 03. 10 Grade Control Structure (1 ea)								
06. 03. 10.001 RCC	2400.00	CY	112,576	22,515	14,860	9,747	159,698	66.54

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	42,015	8,403	5,546	3,638	59,602	209.13
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	6,574	1,315	868	569	9,325	85.55
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	92,219	18,444	12,173	7,984	130,821	130820.66
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	253,384	50,677	33,447	21,938	359,446	149.77
06. 03. 11	Maintainence Structures								
06. 03. 11.001	Maintenance Facility			2,666,984	533,397	352,042	230,907	3,783,330	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	940,949	188,190	124,205	81,467	1,334,812	266962.38
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	828,038	165,608	109,301	71,692	1,174,638	117463.83
06. 03. 11.004	Maintenance Road Underpass @19th			1,336,574	267,315	176,428	115,721	1,896,037	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	134,019	26,804	17,691	11,603	190,117	38023.41
06. 03. 11.006	Project Signage	6.00	EA	96,494	19,299	12,737	8,354	136,884	22814.05
	TOTAL Maintainence Structures			6,003,058	1,200,612	792,404	519,745	8,515,819	
06. 03. 12	Water Supply & Distribution								
06. 03. 12.001	20 mgd pump station,			3,203,061	640,612	422,804	277,321	4,543,798	
06. 03. 12.002	Electronic Flow Regulated Valve			53,608	10,722	7,076	4,641	76,047	
06. 03. 12.003	Electronic Flow Regulated Valves			268,039	53,608	35,381	23,207	380,234	
06. 03. 12.004	Pump Station (incl. mechanical,			2,680,386	536,077	353,811	232,068	3,802,341	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,501,016	300,203	198,134	129,958	2,129,311	
06. 03. 12.006	Ground Water Pond/Reservoir on			375,254	75,051	49,534	32,489	532,328	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	2,122,865	424,573	280,218	183,798	3,011,454	228.14
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	3,551,511	710,302	468,799	307,490	5,038,102	190.12
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	3,570,273	714,055	471,276	309,114	5,064,719	136.88
06. 03. 12.010	Bridge crossing of 16" Waterline			643,293	128,659	84,915	55,696	912,562	
06. 03. 12.011	Bridge crossing of 10" Waterline			428,862	85,772	56,610	37,131	608,375	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	402,058	80,412	53,072	34,810	570,351	114.07
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	938,135	187,627	123,834	81,224	1,330,819	53.23
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	750,508	150,102	99,067	64,979	1,064,656	30.42
06. 03. 12.015	Waterfal to Move Water from			402,058	80,412	53,072	34,810	570,351	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	480,057	96,011	63,368	41,563	680,999	22699.98
06. 03. 12.017	Waste and Tire Removal (incl.			1,594,829	318,966	210,517	138,080	2,262,393	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	533,397	106,679	70,408	46,181	756,666	756665.91
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	96,011	19,202	12,674	8,313	136,200	68099.93
	TOTAL Water Supply & Distribution			23,595,219	4,719,044	3,114,569	2,042,874	33,471,706	
06. 03. 73	Stormwater Outfall								
06. 03. 73.001	Grading/Excavation	3312.00	CY	20,219	4,044	2,669	1,751	28,683	8.66
06. 03. 73.002	Concrete	416.00	CY	93,990	18,798	12,407	8,138	133,332	320.51
06. 03. 73.003	Cobble	22400.00	SF	210,142	42,028	27,739	18,194	298,104	13.31
06. 03. 73.004	Weir, concrete	16.00	CY	3,615	723	477	313	5,128	320.51

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 73.005 V-Ditch Excavation	148.00	CY	992	198	131	86	1,407	9.51
TOTAL Stormwater Outfall	8.00	EA	328,958	65,792	43,422	28,481	466,653	58331.61
06. 03. 74 Wetland Ponds								
06. 03. 74.001 Grading/Excavation	149890.00	CY	828,169	165,634	109,318	71,703	1,174,824	7.84
06. 03. 74.002 Liner, 12" fines, 3:1 slope,	45128.00	CY	194,422	38,884	25,664	16,833	275,803	6.11
06. 03. 74.003 Hydroseeding	28.00	ACR	75,051	15,010	9,907	6,498	106,466	3802.34
TOTAL Wetland Ponds	28.00	ACR	1,097,642	219,528	144,889	95,034	1,557,093	55610.45
06. 03. 75 Emergent Wetlands								
06. 03. 75.001 Grading/Excavation	20952.00	CY	117,452	23,490	15,504	10,169	166,616	7.95
06. 03. 75.002 Liner, 12" fines, 3:1 slope,	20952.00	CY	90,266	18,053	11,915	7,815	128,050	6.11
TOTAL Emergent Wetlands	13.00	ACR	207,719	41,544	27,419	17,984	294,665	22666.57
06. 03. 76 Cottonwood/willow (1 gal)								
06. 03. 76.001 Planting	378.00	ACR	605,378	121,076	79,910	52,414	858,778	2271.90
06. 03. 76.002 Irrigation	378.00	ACR	4,458,017	891,603	588,458	385,975	6,324,054	16730.30
06. 03. 76.003 Maintenance of Plants & Irrigat-	378.00	ACR	50,659	10,132	6,687	4,386	71,864	190.12
TOTAL Cottonwood/willow (1 gal)	378.00	ACR	5,114,055	1,022,811	675,055	442,775	7,254,696	19192.32
06. 03. 77 Mesquite Bosque (1 gal)								
06. 03. 77.001 Planting	244.00	ACR	1,171,339	234,268	154,617	101,415	1,661,638	6809.99
06. 03. 77.002 Irrigation	244.00	ACR	2,877,662	575,532	379,851	249,148	4,082,194	16730.30
06. 03. 77.003 Maintenance of Plants and Irrig-	244.00	ACR	40,876	8,175	5,396	3,539	57,986	237.65
TOTAL Mesquite Bosque (1 gal)	244.00	ACR	4,089,877	817,975	539,864	354,102	5,801,818	23777.94
06. 03. 78 Mesquite Xeric								
06. 03. 78.001 Planting	168.00	ACR	215,021	43,004	28,383	18,616	305,024	1815.62
06. 03. 78.002 Irrigation	168.00	ACR	1,981,341	396,268	261,537	171,545	2,810,691	16730.30
06. 03. 78.003 Maintenance of Plants and Irrig-	168.00	ACR	22,515	4,503	2,972	1,949	31,940	190.12
TOTAL Mesquite Xeric	168.00	ACR	2,218,877	443,775	292,892	192,110	3,147,654	18736.04
06. 03. 79 Lake Restoration								

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	15,752,667	3,150,533	2,079,352	1,363,866	22,346,418	7.45
TOTAL Lake Restoration (2 lakes)	3000000	CY	15,752,667	3,150,533	2,079,352	1,363,866	22,346,418	7.45
06. 03. 79.002 Emergent Wetlands (2 lakes)								
06. 03. 79.002.001 Emergent Wetlands	64469.00	CY	277,748	55,550	36,663	24,047	394,007	6.11
06. 03. 79.002.002 Hydroseeding	40.00	ACR	107,215	21,443	14,152	9,283	152,094	3802.34
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	1,072	214	142	93	1,521	38.02
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	386,035	77,207	50,957	33,423	547,622	13690.55
TOTAL Lake Restoration	2.00	EA	16,138,702	3,227,740	2,130,309	1,397,289	22,894,040	11447020
TOTAL Wetland Restoration	1.00	EA	64,633,227	12,926,645	8,531,586	5,595,945	91,687,403	91687403
06. 14 Recreation								
06. 14.001 Access Point, Maint. Fac.								
06. 14.001.001 Site Preparation	1.00	EA	200,000	40,000	26,400	17,316	283,716	283716.00
06. 14.001.002 Access and Circulation	1.00	EA	573,330	114,666	75,680	49,639	813,314	813314.47
06. 14.001.003 Protection Access Control	1.00	EA	157,750	31,550	20,823	13,658	223,781	223781.00
06. 14.001.004 Signage	1.00	EA	40,000	8,000	5,280	3,463	56,743	56743.20
06. 14.001.005 Shelters	1.00	EA	495,000	99,000	65,340	42,857	702,197	702197.10
06. 14.001.006 Utilities	1.00	EA	180,000	36,000	23,760	15,584	255,344	255344.40
06. 14.001.007 Park Furniture	1.00	EA	21,000	4,200	2,772	1,818	29,790	29790.18
06. 14.001.008 Interpretive Guidance Media	1.00	EA	24,200	4,840	3,194	2,095	34,330	34329.64
TOTAL Access Point, Maint. Fac.	1.00	EA	1,691,280	338,256	223,249	146,431	2,399,216	2399216
06. 14.002 Access Points								
06. 14.002.001 Site Preparation	1.00	EA	927,000	185,400	122,364	80,260	1,315,024	1315024
06. 14.002.002 Access and Circulation	1.00	EA	1,766,400	353,280	233,165	152,935	2,505,780	2505780
06. 14.002.003 Protection access Control	1.00	EA	1,260,500	252,100	166,386	109,134	1,788,120	1788120
06. 14.002.004 Signage	1.00	EA	166,000	33,200	21,912	14,372	235,484	235484.28
06. 14.002.005 Shelters	1.00	EA	2,145,000	429,000	283,140	185,714	3,042,854	3042854
06. 14.002.006 Utilities	1.00	EA	740,000	148,000	97,680	64,069	1,049,749	1049749
06. 14.002.007 Park Furniture	1.00	EA	155,500	31,100	20,526	13,463	220,589	220589.19
06. 14.002.008 Interpretive Guidance Media	1.00	EA	112,500	22,500	14,850	9,740	159,590	159590.25
TOTAL Access Points	1.00	EA	7,272,900	1,454,580	960,023	629,688	10,317,190	10317190
TOTAL Recreation	1.00	EA	8,964,180	1,792,836	1,183,272	776,119	12,716,406	12716406
TOTAL Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
01 LERRD's							
01.001 Flood Plain Project Land		43,900,000	10,975,000	0	0	54,875,000	
01.002 ROW for Water Supply & Distribu-		800,000	200,000	0	0	1,000,000	
TOTAL LERRD's	1.00 EA	44,700,000	11,175,000	0	0	55,875,000	55875000
06 Wetland Restoration							
06. 03 Wetland Restoration							
06. 03. 00 Mob/Demob							
06. 03. 00.001 Equipment (major and heavy)	50.00 EA	67,010	13,402	8,845	5,802	95,059	1901.17
06. 03. 00.002 Setup and Dismantling	50.00 EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.003 Replacement of worn-out quipment	10.00 EA	26,804	5,361	3,538	2,321	38,023	3802.34
06. 03. 00.004 Setup & Dismantling of cranes	4.00 EA	134,019	26,804	17,691	11,603	190,117	47529.27
06. 03. 00.005 Move & transport around job site	50.00 EA	134,019	26,804	17,691	11,603	190,117	3802.34
06. 03. 00.006 Miscellaneous	1.00 EA	268,039	53,608	35,381	23,207	380,234	380234.13
TOTAL Mob/Demob	1.00 EA	763,910	152,782	100,836	66,139	1,083,667	1083667
06. 03. 01 Clearing and Grubbing	36.00 ACR	156,725	31,345	20,688	13,569	222,328	6175.77
06. 03. 02 Invasive Removal							
06. 03. 02.001 Arundo Removal	10.00 ACR	402,058	80,412	53,072	34,810	570,351	57035.12
06. 03. 02.002 Salt Cedar Removal	110.00 ACR	737,106	147,421	97,298	63,819	1,045,644	9505.85
TOTAL Invasive Removal	120.00 ACR	1,139,164	227,833	150,370	98,629	1,615,995	13466.63
06. 03. 03 Debris Removal	1.00 EA	743,807	148,761	98,183	64,399	1,055,150	1055150
06. 03. 09 Channel Restoration Excavation							
06. 03. 09.001 Excavation							
06. 03. 09.001.001 Excavation	660000.00 CY	1,416,747	283,349	187,011	122,662	2,009,769	3.05
06. 03. 09.001.002 Backfill	660000.00 CY	515,387	103,077	68,031	44,622	731,118	1.11
06. 03. 09.001.003 Hauling	660000.00 CY	849,995	169,999	112,199	73,593	1,205,786	1.83
TOTAL Excavation	660000.00 CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
TOTAL Channel Restoration Excavation	660000.00 CY	2,782,130	556,426	367,241	240,877	3,946,674	5.98
06. 03. 10 Grade Control Structure (1 ea)							
06. 03. 10.001 RCC	2400.00 CY	112,576	22,515	14,860	9,747	159,698	66.54

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	42,015	8,403	5,546	3,638	59,602	209.13
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	6,574	1,315	868	569	9,325	85.55
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	92,219	18,444	12,173	7,984	130,821	130820.66
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	253,384	50,677	33,447	21,938	359,446	149.77
06. 03. 11	Maintainence Structures								
06. 03. 11.001	Maintenance Facility			2,666,984	533,397	352,042	230,907	3,783,330	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	940,949	188,190	124,205	81,467	1,334,812	266962.38
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	828,038	165,608	109,301	71,692	1,174,638	117463.83
06. 03. 11.004	Maintenance Road Underpass @19th			1,336,574	267,315	176,428	115,721	1,896,037	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	134,019	26,804	17,691	11,603	190,117	38023.41
06. 03. 11.006	Project Signage	6.00	EA	96,494	19,299	12,737	8,354	136,884	22814.05
	TOTAL Maintainence Structures			6,003,058	1,200,612	792,404	519,745	8,515,819	
06. 03. 12	Water Supply & Distribution								
06. 03. 12.001	20 mgd pump station,			3,203,061	640,612	422,804	277,321	4,543,798	
06. 03. 12.002	Electronic Flow Regulated Valve			53,608	10,722	7,076	4,641	76,047	
06. 03. 12.003	Electronic Flow Regulated Valves			268,039	53,608	35,381	23,207	380,234	
06. 03. 12.004	Pump Station (incl. mechanical,			2,680,386	536,077	353,811	232,068	3,802,341	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,501,016	300,203	198,134	129,958	2,129,311	
06. 03. 12.006	Ground Water Pond/Reservoir on			375,254	75,051	49,534	32,489	532,328	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	2,122,865	424,573	280,218	183,798	3,011,454	228.14
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	3,551,511	710,302	468,799	307,490	5,038,102	190.12
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	3,570,273	714,055	471,276	309,114	5,064,719	136.88
06. 03. 12.010	Bridge crossing of 16" Waterline			643,293	128,659	84,915	55,696	912,562	
06. 03. 12.011	Bridge crossing of 10" Waterline			428,862	85,772	56,610	37,131	608,375	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	402,058	80,412	53,072	34,810	570,351	114.07
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	938,135	187,627	123,834	81,224	1,330,819	53.23
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	750,508	150,102	99,067	64,979	1,064,656	30.42
06. 03. 12.015	Waterfal to Move Water from			402,058	80,412	53,072	34,810	570,351	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	480,057	96,011	63,368	41,563	680,999	22699.98
06. 03. 12.017	Waste and Tire Removal (incl.			1,594,829	318,966	210,517	138,080	2,262,393	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	533,397	106,679	70,408	46,181	756,666	756665.91
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	96,011	19,202	12,674	8,313	136,200	68099.93
	TOTAL Water Supply & Distribution			23,595,219	4,719,044	3,114,569	2,042,874	33,471,706	
06. 03. 73	Stormwater Outfall								
06. 03. 73.001	Grading/Excavation	3312.00	CY	20,219	4,044	2,669	1,751	28,683	8.66
06. 03. 73.002	Concrete	416.00	CY	93,990	18,798	12,407	8,138	133,332	320.51
06. 03. 73.003	Cobble	22400.00	SF	210,142	42,028	27,739	18,194	298,104	13.31
06. 03. 73.004	Weir, concrete	16.00	CY	3,615	723	477	313	5,128	320.51

		QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 73.005	V-Ditch Excavation	148.00	CY	992	198	131	86	1,407	9.51
	TOTAL Stormwater Outfall	8.00	EA	328,958	65,792	43,422	28,481	466,653	58331.61
06. 03. 74	Wetland Ponds								
06. 03. 74.001	Grading/Excavation	149890.00	CY	828,169	165,634	109,318	71,703	1,174,824	7.84
06. 03. 74.002	Liner, 12" fines, 3:1 slope,	45128.00	CY	194,422	38,884	25,664	16,833	275,803	6.11
06. 03. 74.003	Hydroseeding	28.00	ACR	75,051	15,010	9,907	6,498	106,466	3802.34
	TOTAL Wetland Ponds	28.00	ACR	1,097,642	219,528	144,889	95,034	1,557,093	55610.45
06. 03. 75	Emergent Wetlands								
06. 03. 75.001	Grading/Excavation	20952.00	CY	117,452	23,490	15,504	10,169	166,616	7.95
06. 03. 75.002	Liner, 12" fines, 3:1 slope,	20952.00	CY	90,266	18,053	11,915	7,815	128,050	6.11
	TOTAL Emergent Wetlands	13.00	ACR	207,719	41,544	27,419	17,984	294,665	22666.57
06. 03. 76	Cottonwood/willow (1 gal)								
06. 03. 76.001	Planting	378.00	ACR	605,378	121,076	79,910	52,414	858,778	2271.90
06. 03. 76.002	Irrigation	378.00	ACR	4,458,017	891,603	588,458	385,975	6,324,054	16730.30
06. 03. 76.003	Maintenance of Plants & Irrigat-	378.00	ACR	50,659	10,132	6,687	4,386	71,864	190.12
	TOTAL Cottonwood/willow (1 gal)	378.00	ACR	5,114,055	1,022,811	675,055	442,775	7,254,696	19192.32
06. 03. 77	Mesquite Bosque (1 gal)								
06. 03. 77.001	Planting	244.00	ACR	1,171,339	234,268	154,617	101,415	1,661,638	6809.99
06. 03. 77.002	Irrigation	244.00	ACR	2,877,662	575,532	379,851	249,148	4,082,194	16730.30
06. 03. 77.003	Maintenance of Plants and Irrig-	244.00	ACR	40,876	8,175	5,396	3,539	57,986	237.65
	TOTAL Mesquite Bosque (1 gal)	244.00	ACR	4,089,877	817,975	539,864	354,102	5,801,818	23777.94
06. 03. 78	Mesquite Xeric								
06. 03. 78.001	Planting	168.00	ACR	215,021	43,004	28,383	18,616	305,024	1815.62
06. 03. 78.002	Irrigation	168.00	ACR	1,981,341	396,268	261,537	171,545	2,810,691	16730.30
06. 03. 78.003	Maintenance of Plants and Irrig-	168.00	ACR	22,515	4,503	2,972	1,949	31,940	190.12
	TOTAL Mesquite Xeric	168.00	ACR	2,218,877	443,775	292,892	192,110	3,147,654	18736.04
06. 03. 79	Lake Restoration								

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	15,752,667	3,150,533	2,079,352	1,363,866	22,346,418	7.45
TOTAL Lake Restoration (2 lakes)	3000000	CY	15,752,667	3,150,533	2,079,352	1,363,866	22,346,418	7.45
06. 03. 79.002 Emergent Wetlands (2 lakes)								
06. 03. 79.002.001 Emergent Wetlands								
06. 03. 79.002.001. 1 Liner, 12" fines, 3:1 slope,	64469.00	CY	277,748	55,550	36,663	24,047	394,007	6.11
TOTAL Emergent Wetlands	64469.00	CY	277,748	55,550	36,663	24,047	394,007	6.11
06. 03. 79.002.002 Hydroseeding	40.00	ACR	107,215	21,443	14,152	9,283	152,094	3802.34
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	1,072	214	142	93	1,521	38.02
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	386,035	77,207	50,957	33,423	547,622	13690.55
TOTAL Lake Restoration	2.00	EA	16,138,702	3,227,740	2,130,309	1,397,289	22,894,040	11447020
TOTAL Wetland Restoration	1.00	EA	64,633,227	12,926,645	8,531,586	5,595,945	91,687,403	91687403
06. 14 Recreation								
06. 14.001 Access Point, Maint. Fac.								
06. 14.001.001 Site Preparation	1.00	EA	200,000	40,000	26,400	17,316	283,716	283716.00
06. 14.001.002 Access and Circulation	1.00	EA	573,330	114,666	75,680	49,639	813,314	813314.47
06. 14.001.003 Protection Access Control	1.00	EA	157,750	31,550	20,823	13,658	223,781	223781.00
06. 14.001.004 Signage	1.00	EA	40,000	8,000	5,280	3,463	56,743	56743.20
06. 14.001.005 Shelters	1.00	EA	495,000	99,000	65,340	42,857	702,197	702197.10
06. 14.001.006 Utilities	1.00	EA	180,000	36,000	23,760	15,584	255,344	255344.40
06. 14.001.007 Park Furniture	1.00	EA	21,000	4,200	2,772	1,818	29,790	29790.18
06. 14.001.008 Interpretive Guidance Media	1.00	EA	24,200	4,840	3,194	2,095	34,330	34329.64
TOTAL Access Point, Maint. Fac.	1.00	EA	1,691,280	338,256	223,249	146,431	2,399,216	2399216
06. 14.002 Access Points								
06. 14.002.001 Site Preparation	1.00	EA	927,000	185,400	122,364	80,260	1,315,024	1315024
06. 14.002.002 Access and Circulation	1.00	EA	1,766,400	353,280	233,165	152,935	2,505,780	2505780
06. 14.002.003 Protection access Control	1.00	EA	1,260,500	252,100	166,386	109,134	1,788,120	1788120
06. 14.002.004 Signage	1.00	EA	166,000	33,200	21,912	14,372	235,484	235484.28
06. 14.002.005 Shelters	1.00	EA	2,145,000	429,000	283,140	185,714	3,042,854	3042854
06. 14.002.006 Utilities	1.00	EA	740,000	148,000	97,680	64,069	1,049,749	1049749
06. 14.002.007 Park Furniture	1.00	EA	155,500	31,100	20,526	13,463	220,589	220589.19
06. 14.002.008 Interpretive Guidance Media	1.00	EA	112,500	22,500	14,850	9,740	159,590	159590.25

	QUANTITY	UOM	CONTRACT	CONTINGN	PE&D+edc	S&A	TOTAL COST	UNIT COST
TOTAL Access Points	1.00	EA	7,272,900	1,454,580	960,023	629,688	10,317,190	10317190
TOTAL Recreation	1.00	EA	8,964,180	1,792,836	1,183,272	776,119	12,716,406	12716406
TOTAL Wetland Restoration	1.00	EA	73,597,407	14,719,481	9,714,858	6,372,063	104,403,809	104403809
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	118,297,407	25,894,481	9,714,858	6,372,063	160,278,809	160278809

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's	1.00	EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration	1.00	EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			43,900,000	0	0	0	0	43,900,000	
01.002 ROW for Water Supply & Distribu-			800,000	0	0	0	0	800,000	
TOTAL LERRD's	1.00	EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration	1.00	EA	48,226,814	4,822,681	4,243,960	6,875,215	464,557	64,633,227	64633227
06. 14 Recreation	1.00	EA	8,964,180	0	0	0	0	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land		43,900,000	0	0	0	0	43,900,000	
01.002 ROW for Water Supply & Distribu-		800,000	0	0	0	0	800,000	
TOTAL LERRD's	1.00 EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration								
06. 03 Wetland Restoration								
06. 03. 00 Mob/Demob	1.00 EA	570,000	57,000	50,160	81,259	5,491	763,910	763909.87
06. 03. 01 Clearing and Grubbing	36.00 ACR	116,942	11,694	10,291	16,671	1,126	156,725	4353.48
06. 03. 02 Invasive Removal	120.00 ACR	850,000	85,000	74,800	121,176	8,188	1,139,164	9493.03
06. 03. 03 Debris Removal	1.00 EA	555,000	55,500	48,840	79,121	5,346	743,807	743806.98
06. 03. 09 Channel Restoration Excavation	660000.00 CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
06. 03. 10 Grade Control Structure (1 ea)	2400.00 CY	189,066	18,907	16,638	26,953	1,821	253,384	105.58
06. 03. 11 Maintainence Structures		4,479,250	447,925	394,174	638,562	43,148	6,003,058	
06. 03. 12 Water Supply & Distribution		17,605,840	1,760,584	1,549,314	2,509,889	169,593	23,595,219	
06. 03. 73 Stormwater Outfall	8.00 EA	245,456	24,546	21,600	34,992	2,364	328,958	41119.72
06. 03. 74 Wetland Ponds	28.00 ACR	819,018	81,902	72,074	116,759	7,889	1,097,642	39201.49
06. 03. 75 Emergent Wetlands	13.00 ACR	154,992	15,499	13,639	22,096	1,493	207,719	15978.35
06. 03. 76 Cottonwood/willow (1 gal)	378.00 ACR	3,815,910	381,591	335,800	543,996	36,758	5,114,055	13529.25
06. 03. 77 Mesquite Bosque (1 gal)	244.00 ACR	3,051,708	305,171	268,550	435,051	29,396	4,089,877	16761.79
06. 03. 78 Mesquite Xeric	168.00 ACR	1,655,640	165,564	145,696	236,028	15,948	2,218,877	13207.60
06. 03. 79 Lake Restoration	2.00 EA	12,042,076	1,204,208	1,059,703	1,716,718	115,998	16,138,702	8069351
TOTAL Wetland Restoration	1.00 EA	48,226,814	4,822,681	4,243,960	6,875,215	464,557	64,633,227	64633227
06. 14 Recreation								
06. 14.001 Access Point, Maint. Fac.	1.00 EA	1,691,280	0	0	0	0	1,691,280	1691280
06. 14.002 Access Points	1.00 EA	7,272,900	0	0	0	0	7,272,900	7272900
TOTAL Recreation	1.00 EA	8,964,180	0	0	0	0	8,964,180	8964180
TOTAL Wetland Restoration	1.00 EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407
TOTAL Oeste Feas. Study Cost Estimate	1.00 EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY							25,894,481	
SUBTOTAL							144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)							9,714,858	
SUBTOTAL							153,906,746	
CONTN MANAGEMENT (Acct. 31)							6,372,063	

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's								
01.001 Flood Plain Project Land		43,900,000	0	0	0	0	43,900,000	
01.002 ROW for Water Supply & Distribu-		800,000	0	0	0	0	800,000	
TOTAL LERRD's	1.00 EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration								
06. 03 Wetland Restoration								
06. 03. 00 Mob/Demob								
06. 03. 00.001 Equipment (major and heavy)	50.00 EA	50,000	5,000	4,400	7,128	482	67,010	1340.19
06. 03. 00.002 Setup and Dismantling	50.00 EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.003 Replacement of worn-out quipment	10.00 EA	20,000	2,000	1,760	2,851	193	26,804	2680.39
06. 03. 00.004 Setup & Dismantling of cranes	4.00 EA	100,000	10,000	8,800	14,256	963	134,019	33504.82
06. 03. 00.005 Move & transport around job site	50.00 EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.006 Miscellaneous	1.00 EA	200,000	20,000	17,600	28,512	1,927	268,039	268038.55
TOTAL Mob/Demob	1.00 EA	570,000	57,000	50,160	81,259	5,491	763,910	763909.87
06. 03. 01 Clearing and Grubbing	36.00 ACR	116,942	11,694	10,291	16,671	1,126	156,725	4353.48
06. 03. 02 Invasive Removal								
06. 03. 02.001 Arundo Removal	10.00 ACR	300,000	30,000	26,400	42,768	2,890	402,058	40205.78
06. 03. 02.002 Salt Cedar Removal	110.00 ACR	550,000	55,000	48,400	78,408	5,298	737,106	6700.96
TOTAL Invasive Removal	120.00 ACR	850,000	85,000	74,800	121,176	8,188	1,139,164	9493.03
06. 03. 03 Debris Removal	1.00 EA	555,000	55,500	48,840	79,121	5,346	743,807	743806.98
06. 03. 09 Channel Restoration Excavation								
06. 03. 09.001 Excavation	660000.00 CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
TOTAL Channel Restoration Excavation	660000.00 CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
06. 03. 10 Grade Control Structure (1 ea)								
06. 03. 10.001 RCC	2400.00 CY	84,000	8,400	7,392	11,975	809	112,576	46.91
06. 03. 10.002 Portland Cement	285.00 TON	31,350	3,135	2,759	4,469	302	42,015	147.42
06. 03. 10.003 Pozzolan (Fly Ash)	109.00 TON	4,905	491	432	699	47	6,574	60.31
06. 03. 10.004 Gabion Weirs and Water "V" Ditch	1.00 EA	68,811	6,881	6,055	9,810	663	92,219	92219.44
TOTAL Grade Control Structure (1 ea)	2400.00 CY	189,066	18,907	16,638	26,953	1,821	253,384	105.58

		QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			1,990,000	199,000	175,120	283,694	19,169	2,666,984	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	702,100	70,210	61,785	100,091	6,763	940,949	188189.87
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	617,850	61,785	54,371	88,081	5,952	828,038	82803.81
06. 03. 11.004	Maintenance Road Underpass @19th			997,300	99,730	87,762	142,175	9,607	1,336,574	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	100,000	10,000	8,800	14,256	963	134,019	26803.86
06. 03. 11.006	Project Signage	6.00	EA	72,000	7,200	6,336	10,264	694	96,494	16082.31
	TOTAL Maintainence Structures			4,479,250	447,925	394,174	638,562	43,148	6,003,058	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			2,390,000	239,000	210,320	340,718	23,022	3,203,061	
06. 03. 12.002	Electronic Flow Regulated Valve			40,000	4,000	3,520	5,702	385	53,608	
06. 03. 12.003	Electronic Flow Regulated Valves			200,000	20,000	17,600	28,512	1,927	268,039	
06. 03. 12.004	Pump Station (incl. mechanical,			2,000,000	200,000	176,000	285,120	19,266	2,680,386	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,120,000	112,000	98,560	159,667	10,789	1,501,016	
06. 03. 12.006	Ground Water Pond/Reservoir on			280,000	28,000	24,640	39,917	2,697	375,254	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	1,584,000	158,400	139,392	225,815	15,258	2,122,865	160.82
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	2,650,000	265,000	233,200	377,784	25,527	3,551,511	134.02
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	2,664,000	266,400	234,432	379,780	25,662	3,570,273	96.49
06. 03. 12.010	Bridge crossing of 16" Waterline			480,000	48,000	42,240	68,429	4,624	643,293	
06. 03. 12.011	Bridge crossing of 10" Waterline			320,000	32,000	28,160	45,619	3,082	428,862	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	300,000	30,000	26,400	42,768	2,890	402,058	80.41
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	700,000	70,000	61,600	99,792	6,743	938,135	37.53
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	560,000	56,000	49,280	79,834	5,394	750,508	21.44
06. 03. 12.015	Waterfal to Move Water from			300,000	30,000	26,400	42,768	2,890	402,058	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	358,200	35,820	31,522	51,065	3,450	480,057	16001.90
06. 03. 12.017	Waste and Tire Removal (incl.			1,190,000	119,000	104,720	169,646	11,463	1,594,829	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	398,000	39,800	35,024	56,739	3,834	533,397	533396.72
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	71,640	7,164	6,304	10,213	690	96,011	48005.70
	TOTAL Water Supply & Distribution			17,605,840	1,760,584	1,549,314	2,509,889	169,593	23,595,219	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	15,087	1,509	1,328	2,151	145	20,219	6.10
06. 03. 73.002	Concrete	416.00	CY	70,131	7,013	6,172	9,998	676	93,990	225.94
06. 03. 73.003	Cobble	22400.00	SF	156,800	15,680	13,798	22,353	1,510	210,142	9.38
06. 03. 73.004	Weir, concrete	16.00	CY	2,697	270	237	385	26	3,615	225.94
06. 03. 73.005	V-Ditch Excavation	148.00	CY	740	74	65	105	7	992	6.70
	TOTAL Stormwater Outfall	8.00	EA	245,456	24,546	21,600	34,992	2,364	328,958	41119.72
06. 03. 74	Wetland Ponds									
06. 03. 74.001	Grading/Excavation	149890.00	CY	617,948	61,795	54,379	88,095	5,953	828,169	5.53

	QUANTITY UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 74.002 Liner, 12" fines, 3:1 slope,	45128.00 CY	145,070	14,507	12,766	20,681	1,397	194,422	4.31
06. 03. 74.003 Hydroseeding	28.00 ACR	56,000	5,600	4,928	7,983	539	75,051	2680.39
TOTAL Wetland Ponds	28.00 ACR	819,018	81,902	72,074	116,759	7,889	1,097,642	39201.49
06. 03. 75 Emergent Wetlands								
06. 03. 75.001 Grading/Excavation	20952.00 CY	87,638	8,764	7,712	12,494	844	117,452	5.61
06. 03. 75.002 Liner, 12" fines, 3:1 slope,	20952.00 CY	67,353	6,735	5,927	9,602	649	90,266	4.31
TOTAL Emergent Wetlands	13.00 ACR	154,992	15,499	13,639	22,096	1,493	207,719	15978.35
06. 03. 76 Cottonwood/willow (1 gal)								
06. 03. 76.001 Planting	378.00 ACR	451,710	45,171	39,750	64,396	4,351	605,378	1601.53
06. 03. 76.002 Irrigation	378.00 ACR	3,326,400	332,640	292,723	474,212	32,042	4,458,017	11793.70
06. 03. 76.003 Maintenance of Plants & Irrigat-	378.00 ACR	37,800	3,780	3,326	5,389	364	50,659	134.02
TOTAL Cottonwood/willow (1 gal)	378.00 ACR	3,815,910	381,591	335,800	543,996	36,758	5,114,055	13529.25
06. 03. 77 Mesquite Bosque (1 gal)								
06. 03. 77.001 Planting	244.00 ACR	874,008	87,401	76,913	124,599	8,419	1,171,339	4800.57
06. 03. 77.002 Irrigation	244.00 ACR	2,147,200	214,720	188,954	306,105	20,683	2,877,662	11793.70
06. 03. 77.003 Maintenance of Plants and Irrig-	244.00 ACR	30,500	3,050	2,684	4,348	294	40,876	167.52
TOTAL Mesquite Bosque (1 gal)	244.00 ACR	3,051,708	305,171	268,550	435,051	29,396	4,089,877	16761.79
06. 03. 78 Mesquite Xeric								
06. 03. 78.001 Planting	168.00 ACR	160,440	16,044	14,119	22,872	1,545	215,021	1279.88
06. 03. 78.002 Irrigation	168.00 ACR	1,478,400	147,840	130,099	210,761	14,241	1,981,341	11793.70
06. 03. 78.003 Maintenance of Plants and Irrig-	168.00 ACR	16,800	1,680	1,478	2,395	162	22,515	134.02
TOTAL Mesquite Xeric	168.00 ACR	1,655,640	165,564	145,696	236,028	15,948	2,218,877	13207.60
06. 03. 79 Lake Restoration								
06. 03. 79.001 Lake Restoration (2 lakes)	3000000 CY	11,754,031	1,175,403	1,034,355	1,675,655	113,224	15,752,667	5.25
06. 03. 79.002 Emergent Wetlands (2 lakes)	40.00 ACR	288,045	28,804	25,348	41,064	2,775	386,035	9650.88
TOTAL Lake Restoration	2.00 EA	12,042,076	1,204,208	1,059,703	1,716,718	115,998	16,138,702	8069351
TOTAL Wetland Restoration	1.00 EA	48,226,814	4,822,681	4,243,960	6,875,215	464,557	64,633,227	64633227

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.									
06. 14.001.001 Site Preparation	1.00	EA	200,000	0	0	0	0	200,000	200000.00
06. 14.001.002 Access and Circulation	1.00	EA	573,330	0	0	0	0	573,330	573330.00
06. 14.001.003 Protection Access Control	1.00	EA	157,750	0	0	0	0	157,750	157750.00
06. 14.001.004 Signage	1.00	EA	40,000	0	0	0	0	40,000	40000.00
06. 14.001.005 Shelters	1.00	EA	495,000	0	0	0	0	495,000	495000.00
06. 14.001.006 Utilities	1.00	EA	180,000	0	0	0	0	180,000	180000.00
06. 14.001.007 Park Furniture	1.00	EA	21,000	0	0	0	0	21,000	21000.00
06. 14.001.008 Interpretive Guidance Media	1.00	EA	24,200	0	0	0	0	24,200	24200.00
TOTAL Access Point, Maint. Fac.	1.00	EA	1,691,280	0	0	0	0	1,691,280	1691280
06. 14.002 Access Points									
06. 14.002.001 Site Preparation	1.00	EA	927,000	0	0	0	0	927,000	927000.00
06. 14.002.002 Access and Circulation	1.00	EA	1,766,400	0	0	0	0	1,766,400	1766400
06. 14.002.003 Protection access Control	1.00	EA	1,260,500	0	0	0	0	1,260,500	1260500
06. 14.002.004 Signage	1.00	EA	166,000	0	0	0	0	166,000	166000.00
06. 14.002.005 Shelters	1.00	EA	2,145,000	0	0	0	0	2,145,000	2145000
06. 14.002.006 Utilities	1.00	EA	740,000	0	0	0	0	740,000	740000.00
06. 14.002.007 Park Furniture	1.00	EA	155,500	0	0	0	0	155,500	155500.00
06. 14.002.008 Interpretive Guidance Media	1.00	EA	112,500	0	0	0	0	112,500	112500.00
TOTAL Access Points	1.00	EA	7,272,900	0	0	0	0	7,272,900	7272900
TOTAL Recreation	1.00	EA	8,964,180	0	0	0	0	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			43,900,000	0	0	0	0	43,900,000	
01.002 ROW for Water Supply & Distribu-			800,000	0	0	0	0	800,000	
TOTAL LERRD's	1.00	EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob									
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	50,000	5,000	4,400	7,128	482	67,010	1340.19
06. 03. 00.002 Setup and Dismantling	50.00	EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	20,000	2,000	1,760	2,851	193	26,804	2680.39
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	100,000	10,000	8,800	14,256	963	134,019	33504.82
06. 03. 00.005 Move & transport around job site	50.00	EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.006 Miscellaneous	1.00	EA	200,000	20,000	17,600	28,512	1,927	268,039	268038.55
TOTAL Mob/Demob	1.00	EA	570,000	57,000	50,160	81,259	5,491	763,910	763909.87
06. 03. 01 Clearing and Grubbing	36.00	ACR	116,942	11,694	10,291	16,671	1,126	156,725	4353.48
06. 03. 02 Invasive Removal									
06. 03. 02.001 Arundo Removal	10.00	ACR	300,000	30,000	26,400	42,768	2,890	402,058	40205.78
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	550,000	55,000	48,400	78,408	5,298	737,106	6700.96
TOTAL Invasive Removal	120.00	ACR	850,000	85,000	74,800	121,176	8,188	1,139,164	9493.03
06. 03. 03 Debris Removal	1.00	EA	555,000	55,500	48,840	79,121	5,346	743,807	743806.98
06. 03. 09 Channel Restoration Excavation									
06. 03. 09.001 Excavation									
06. 03. 09.001.001 Excavation	660000.00	CY	1,057,122	105,712	93,027	150,703	10,183	1,416,747	2.15
06. 03. 09.001.002 Backfill	660000.00	CY	384,562	38,456	33,841	54,823	3,704	515,387	0.78
06. 03. 09.001.003 Hauling	660000.00	CY	634,234	63,423	55,813	90,416	6,109	849,995	1.29
TOTAL Excavation	660000.00	CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
TOTAL Channel Restoration Excavation	660000.00	CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
06. 03. 10 Grade Control Structure (1 ea)									
06. 03. 10.001 RCC	2400.00	CY	84,000	8,400	7,392	11,975	809	112,576	46.91

		QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	31,350	3,135	2,759	4,469	302	42,015	147.42
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	4,905	491	432	699	47	6,574	60.31
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	68,811	6,881	6,055	9,810	663	92,219	92219.44
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	189,066	18,907	16,638	26,953	1,821	253,384	105.58
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			1,990,000	199,000	175,120	283,694	19,169	2,666,984	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	702,100	70,210	61,785	100,091	6,763	940,949	188189.87
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	617,850	61,785	54,371	88,081	5,952	828,038	82803.81
06. 03. 11.004	Maintenance Road Underpass @19th			997,300	99,730	87,762	142,175	9,607	1,336,574	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	100,000	10,000	8,800	14,256	963	134,019	26803.86
06. 03. 11.006	Project Signage	6.00	EA	72,000	7,200	6,336	10,264	694	96,494	16082.31
	TOTAL Maintainence Structures			4,479,250	447,925	394,174	638,562	43,148	6,003,058	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			2,390,000	239,000	210,320	340,718	23,022	3,203,061	
06. 03. 12.002	Electronic Flow Regulated Valve			40,000	4,000	3,520	5,702	385	53,608	
06. 03. 12.003	Electronic Flow Regulated Valves			200,000	20,000	17,600	28,512	1,927	268,039	
06. 03. 12.004	Pump Station (incl. mechanical,			2,000,000	200,000	176,000	285,120	19,266	2,680,386	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,120,000	112,000	98,560	159,667	10,789	1,501,016	
06. 03. 12.006	Ground Water Pond/Reservoir on			280,000	28,000	24,640	39,917	2,697	375,254	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	1,584,000	158,400	139,392	225,815	15,258	2,122,865	160.82
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	2,650,000	265,000	233,200	377,784	25,527	3,551,511	134.02
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	2,664,000	266,400	234,432	379,780	25,662	3,570,273	96.49
06. 03. 12.010	Bridge crossing of 16" Waterline			480,000	48,000	42,240	68,429	4,624	643,293	
06. 03. 12.011	Bridge crossing of 10" Waterline			320,000	32,000	28,160	45,619	3,082	428,862	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	300,000	30,000	26,400	42,768	2,890	402,058	80.41
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	700,000	70,000	61,600	99,792	6,743	938,135	37.53
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	560,000	56,000	49,280	79,834	5,394	750,508	21.44
06. 03. 12.015	Waterfal to Move Water from			300,000	30,000	26,400	42,768	2,890	402,058	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	358,200	35,820	31,522	51,065	3,450	480,057	16001.90
06. 03. 12.017	Waste and Tire Removal (incl.			1,190,000	119,000	104,720	169,646	11,463	1,594,829	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	398,000	39,800	35,024	56,739	3,834	533,397	533396.72
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	71,640	7,164	6,304	10,213	690	96,011	48005.70
	TOTAL Water Supply & Distribution			17,605,840	1,760,584	1,549,314	2,509,889	169,593	23,595,219	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	15,087	1,509	1,328	2,151	145	20,219	6.10
06. 03. 73.002	Concrete	416.00	CY	70,131	7,013	6,172	9,998	676	93,990	225.94
06. 03. 73.003	Cobble	22400.00	SF	156,800	15,680	13,798	22,353	1,510	210,142	9.38
06. 03. 73.004	Weir, concrete	16.00	CY	2,697	270	237	385	26	3,615	225.94

	QUANTITY UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 73.005 V-Ditch Excavation	148.00 CY	740	74	65	105	7	992	6.70
TOTAL Stormwater Outfall	8.00 EA	245,456	24,546	21,600	34,992	2,364	328,958	41119.72
06. 03. 74 Wetland Ponds								
06. 03. 74.001 Grading/Excavation	149890.00 CY	617,948	61,795	54,379	88,095	5,953	828,169	5.53
06. 03. 74.002 Liner, 12" fines, 3:1 slope,	45128.00 CY	145,070	14,507	12,766	20,681	1,397	194,422	4.31
06. 03. 74.003 Hydroseeding	28.00 ACR	56,000	5,600	4,928	7,983	539	75,051	2680.39
TOTAL Wetland Ponds	28.00 ACR	819,018	81,902	72,074	116,759	7,889	1,097,642	39201.49
06. 03. 75 Emergent Wetlands								
06. 03. 75.001 Grading/Excavation	20952.00 CY	87,638	8,764	7,712	12,494	844	117,452	5.61
06. 03. 75.002 Liner, 12" fines, 3:1 slope,	20952.00 CY	67,353	6,735	5,927	9,602	649	90,266	4.31
TOTAL Emergent Wetlands	13.00 ACR	154,992	15,499	13,639	22,096	1,493	207,719	15978.35
06. 03. 76 Cottonwood/willow (1 gal)								
06. 03. 76.001 Planting	378.00 ACR	451,710	45,171	39,750	64,396	4,351	605,378	1601.53
06. 03. 76.002 Irrigation	378.00 ACR	3,326,400	332,640	292,723	474,212	32,042	4,458,017	11793.70
06. 03. 76.003 Maintenance of Plants & Irrigat-	378.00 ACR	37,800	3,780	3,326	5,389	364	50,659	134.02
TOTAL Cottonwood/willow (1 gal)	378.00 ACR	3,815,910	381,591	335,800	543,996	36,758	5,114,055	13529.25
06. 03. 77 Mesquite Bosque (1 gal)								
06. 03. 77.001 Planting	244.00 ACR	874,008	87,401	76,913	124,599	8,419	1,171,339	4800.57
06. 03. 77.002 Irrigation	244.00 ACR	2,147,200	214,720	188,954	306,105	20,683	2,877,662	11793.70
06. 03. 77.003 Maintenance of Plants and Irrig-	244.00 ACR	30,500	3,050	2,684	4,348	294	40,876	167.52
TOTAL Mesquite Bosque (1 gal)	244.00 ACR	3,051,708	305,171	268,550	435,051	29,396	4,089,877	16761.79
06. 03. 78 Mesquite Xeric								
06. 03. 78.001 Planting	168.00 ACR	160,440	16,044	14,119	22,872	1,545	215,021	1279.88
06. 03. 78.002 Irrigation	168.00 ACR	1,478,400	147,840	130,099	210,761	14,241	1,981,341	11793.70
06. 03. 78.003 Maintenance of Plants and Irrig-	168.00 ACR	16,800	1,680	1,478	2,395	162	22,515	134.02
TOTAL Mesquite Xeric	168.00 ACR	1,655,640	165,564	145,696	236,028	15,948	2,218,877	13207.60
06. 03. 79 Lake Restoration								

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	11,754,031	1,175,403	1,034,355	1,675,655	113,224	15,752,667	5.25
TOTAL Lake Restoration (2 lakes)	3000000	CY	11,754,031	1,175,403	1,034,355	1,675,655	113,224	15,752,667	5.25
06. 03. 79.002 Emergent Wetlands (2 lakes)									
06. 03. 79.002.001 Emergent Wetlands	64469.00	CY	207,245	20,724	18,238	29,545	1,996	277,748	4.31
06. 03. 79.002.002 Hydroseeding	40.00	ACR	80,000	8,000	7,040	11,405	771	107,215	2680.39
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	800	80	70	114	8	1,072	26.80
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	288,045	28,804	25,348	41,064	2,775	386,035	9650.88
TOTAL Lake Restoration	2.00	EA	12,042,076	1,204,208	1,059,703	1,716,718	115,998	16,138,702	8069351
TOTAL Wetland Restoration	1.00	EA	48,226,814	4,822,681	4,243,960	6,875,215	464,557	64,633,227	64633227
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.									
06. 14.001.001 Site Preparation	1.00	EA	200,000	0	0	0	0	200,000	200000.00
06. 14.001.002 Access and Circulation	1.00	EA	573,330	0	0	0	0	573,330	573330.00
06. 14.001.003 Protection Access Control	1.00	EA	157,750	0	0	0	0	157,750	157750.00
06. 14.001.004 Signage	1.00	EA	40,000	0	0	0	0	40,000	40000.00
06. 14.001.005 Shelters	1.00	EA	495,000	0	0	0	0	495,000	495000.00
06. 14.001.006 Utilities	1.00	EA	180,000	0	0	0	0	180,000	180000.00
06. 14.001.007 Park Furniture	1.00	EA	21,000	0	0	0	0	21,000	21000.00
06. 14.001.008 Interpretive Guidance Media	1.00	EA	24,200	0	0	0	0	24,200	24200.00
TOTAL Access Point, Maint. Fac.	1.00	EA	1,691,280	0	0	0	0	1,691,280	1691280
06. 14.002 Access Points									
06. 14.002.001 Site Preparation	1.00	EA	927,000	0	0	0	0	927,000	927000.00
06. 14.002.002 Access and Circulation	1.00	EA	1,766,400	0	0	0	0	1,766,400	1766400
06. 14.002.003 Protection access Control	1.00	EA	1,260,500	0	0	0	0	1,260,500	1260500
06. 14.002.004 Signage	1.00	EA	166,000	0	0	0	0	166,000	166000.00
06. 14.002.005 Shelters	1.00	EA	2,145,000	0	0	0	0	2,145,000	2145000
06. 14.002.006 Utilities	1.00	EA	740,000	0	0	0	0	740,000	740000.00
06. 14.002.007 Park Furniture	1.00	EA	155,500	0	0	0	0	155,500	155500.00
06. 14.002.008 Interpretive Guidance Media	1.00	EA	112,500	0	0	0	0	112,500	112500.00
TOTAL Access Points	1.00	EA	7,272,900	0	0	0	0	7,272,900	7272900
TOTAL Recreation	1.00	EA	8,964,180	0	0	0	0	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			43,900,000	0	0	0	0	43,900,000	
01.002 ROW for Water Supply & Distribu-			800,000	0	0	0	0	800,000	
TOTAL LERRD's	1.00	EA	44,700,000	0	0	0	0	44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob									
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	50,000	5,000	4,400	7,128	482	67,010	1340.19
06. 03. 00.002 Setup and Dismantling	50.00	EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	20,000	2,000	1,760	2,851	193	26,804	2680.39
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	100,000	10,000	8,800	14,256	963	134,019	33504.82
06. 03. 00.005 Move & transport around job site	50.00	EA	100,000	10,000	8,800	14,256	963	134,019	2680.39
06. 03. 00.006 Miscellaneous	1.00	EA	200,000	20,000	17,600	28,512	1,927	268,039	268038.55
TOTAL Mob/Demob	1.00	EA	570,000	57,000	50,160	81,259	5,491	763,910	763909.87
06. 03. 01 Clearing and Grubbing	36.00	ACR	116,942	11,694	10,291	16,671	1,126	156,725	4353.48
06. 03. 02 Invasive Removal									
06. 03. 02.001 Arundo Removal	10.00	ACR	300,000	30,000	26,400	42,768	2,890	402,058	40205.78
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	550,000	55,000	48,400	78,408	5,298	737,106	6700.96
TOTAL Invasive Removal	120.00	ACR	850,000	85,000	74,800	121,176	8,188	1,139,164	9493.03
06. 03. 03 Debris Removal	1.00	EA	555,000	55,500	48,840	79,121	5,346	743,807	743806.98
06. 03. 09 Channel Restoration Excavation									
06. 03. 09.001 Excavation									
06. 03. 09.001.001 Excavation	660000.00	CY	1,057,122	105,712	93,027	150,703	10,183	1,416,747	2.15
06. 03. 09.001.002 Backfill	660000.00	CY	384,562	38,456	33,841	54,823	3,704	515,387	0.78
06. 03. 09.001.003 Hauling	660000.00	CY	634,234	63,423	55,813	90,416	6,109	849,995	1.29
TOTAL Excavation	660000.00	CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
TOTAL Channel Restoration Excavation	660000.00	CY	2,075,918	207,592	182,681	295,943	19,997	2,782,130	4.22
06. 03. 10 Grade Control Structure (1 ea)									
06. 03. 10.001 RCC	2400.00	CY	84,000	8,400	7,392	11,975	809	112,576	46.91

		QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	31,350	3,135	2,759	4,469	302	42,015	147.42
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	4,905	491	432	699	47	6,574	60.31
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	68,811	6,881	6,055	9,810	663	92,219	92219.44
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	189,066	18,907	16,638	26,953	1,821	253,384	105.58
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			1,990,000	199,000	175,120	283,694	19,169	2,666,984	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	702,100	70,210	61,785	100,091	6,763	940,949	188189.87
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	617,850	61,785	54,371	88,081	5,952	828,038	82803.81
06. 03. 11.004	Maintenance Road Underpass @19th			997,300	99,730	87,762	142,175	9,607	1,336,574	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	100,000	10,000	8,800	14,256	963	134,019	26803.86
06. 03. 11.006	Project Signage	6.00	EA	72,000	7,200	6,336	10,264	694	96,494	16082.31
	TOTAL Maintainence Structures			4,479,250	447,925	394,174	638,562	43,148	6,003,058	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			2,390,000	239,000	210,320	340,718	23,022	3,203,061	
06. 03. 12.002	Electronic Flow Regulated Valve			40,000	4,000	3,520	5,702	385	53,608	
06. 03. 12.003	Electronic Flow Regulated Valves			200,000	20,000	17,600	28,512	1,927	268,039	
06. 03. 12.004	Pump Station (incl. mechanical,			2,000,000	200,000	176,000	285,120	19,266	2,680,386	
06. 03. 12.005	Reservoir (incl. excavation, sub			1,120,000	112,000	98,560	159,667	10,789	1,501,016	
06. 03. 12.006	Ground Water Pond/Reservoir on			280,000	28,000	24,640	39,917	2,697	375,254	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	1,584,000	158,400	139,392	225,815	15,258	2,122,865	160.82
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	2,650,000	265,000	233,200	377,784	25,527	3,551,511	134.02
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	2,664,000	266,400	234,432	379,780	25,662	3,570,273	96.49
06. 03. 12.010	Bridge crossing of 16" Waterline			480,000	48,000	42,240	68,429	4,624	643,293	
06. 03. 12.011	Bridge crossing of 10" Waterline			320,000	32,000	28,160	45,619	3,082	428,862	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	300,000	30,000	26,400	42,768	2,890	402,058	80.41
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	700,000	70,000	61,600	99,792	6,743	938,135	37.53
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	560,000	56,000	49,280	79,834	5,394	750,508	21.44
06. 03. 12.015	Waterfal to Move Water from			300,000	30,000	26,400	42,768	2,890	402,058	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	358,200	35,820	31,522	51,065	3,450	480,057	16001.90
06. 03. 12.017	Waste and Tire Removal (incl.			1,190,000	119,000	104,720	169,646	11,463	1,594,829	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	398,000	39,800	35,024	56,739	3,834	533,397	533396.72
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	71,640	7,164	6,304	10,213	690	96,011	48005.70
	TOTAL Water Supply & Distribution			17,605,840	1,760,584	1,549,314	2,509,889	169,593	23,595,219	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	15,087	1,509	1,328	2,151	145	20,219	6.10
06. 03. 73.002	Concrete	416.00	CY	70,131	7,013	6,172	9,998	676	93,990	225.94
06. 03. 73.003	Cobble	22400.00	SF	156,800	15,680	13,798	22,353	1,510	210,142	9.38
06. 03. 73.004	Weir, concrete	16.00	CY	2,697	270	237	385	26	3,615	225.94

		QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 73.005	V-Ditch Excavation	148.00	CY	740	74	65	105	7	992	6.70
	TOTAL Stormwater Outfall	8.00	EA	245,456	24,546	21,600	34,992	2,364	328,958	41119.72
06. 03. 74	Wetland Ponds									
06. 03. 74.001	Grading/Excavation	149890.00	CY	617,948	61,795	54,379	88,095	5,953	828,169	5.53
06. 03. 74.002	Liner, 12" fines, 3:1 slope,	45128.00	CY	145,070	14,507	12,766	20,681	1,397	194,422	4.31
06. 03. 74.003	Hydroseeding	28.00	ACR	56,000	5,600	4,928	7,983	539	75,051	2680.39
	TOTAL Wetland Ponds	28.00	ACR	819,018	81,902	72,074	116,759	7,889	1,097,642	39201.49
06. 03. 75	Emergent Wetlands									
06. 03. 75.001	Grading/Excavation	20952.00	CY	87,638	8,764	7,712	12,494	844	117,452	5.61
06. 03. 75.002	Liner, 12" fines, 3:1 slope,	20952.00	CY	67,353	6,735	5,927	9,602	649	90,266	4.31
	TOTAL Emergent Wetlands	13.00	ACR	154,992	15,499	13,639	22,096	1,493	207,719	15978.35
06. 03. 76	Cottonwood/willow (1 gal)									
06. 03. 76.001	Planting	378.00	ACR	451,710	45,171	39,750	64,396	4,351	605,378	1601.53
06. 03. 76.002	Irrigation	378.00	ACR	3,326,400	332,640	292,723	474,212	32,042	4,458,017	11793.70
06. 03. 76.003	Maintenance of Plants & Irrigat-	378.00	ACR	37,800	3,780	3,326	5,389	364	50,659	134.02
	TOTAL Cottonwood/willow (1 gal)	378.00	ACR	3,815,910	381,591	335,800	543,996	36,758	5,114,055	13529.25
06. 03. 77	Mesquite Bosque (1 gal)									
06. 03. 77.001	Planting	244.00	ACR	874,008	87,401	76,913	124,599	8,419	1,171,339	4800.57
06. 03. 77.002	Irrigation	244.00	ACR	2,147,200	214,720	188,954	306,105	20,683	2,877,662	11793.70
06. 03. 77.003	Maintenance of Plants and Irrig-	244.00	ACR	30,500	3,050	2,684	4,348	294	40,876	167.52
	TOTAL Mesquite Bosque (1 gal)	244.00	ACR	3,051,708	305,171	268,550	435,051	29,396	4,089,877	16761.79
06. 03. 78	Mesquite Xeric									
06. 03. 78.001	Planting	168.00	ACR	160,440	16,044	14,119	22,872	1,545	215,021	1279.88
06. 03. 78.002	Irrigation	168.00	ACR	1,478,400	147,840	130,099	210,761	14,241	1,981,341	11793.70
06. 03. 78.003	Maintenance of Plants and Irrig-	168.00	ACR	16,800	1,680	1,478	2,395	162	22,515	134.02
	TOTAL Mesquite Xeric	168.00	ACR	1,655,640	165,564	145,696	236,028	15,948	2,218,877	13207.60
06. 03. 79	Lake Restoration									

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	11,754,031	1,175,403	1,034,355	1,675,655	113,224	15,752,667	5.25
TOTAL Lake Restoration (2 lakes)	3000000	CY	11,754,031	1,175,403	1,034,355	1,675,655	113,224	15,752,667	5.25
06. 03. 79.002 Emergent Wetlands (2 lakes)									
06. 03. 79.002.001 Emergent Wetlands									
06. 03. 79.002.001. 1 Liner, 12" fines, 3:1 slope,	64469.00	CY	207,245	20,724	18,238	29,545	1,996	277,748	4.31
TOTAL Emergent Wetlands	64469.00	CY	207,245	20,724	18,238	29,545	1,996	277,748	4.31
06. 03. 79.002.002 Hydroseeding	40.00	ACR	80,000	8,000	7,040	11,405	771	107,215	2680.39
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	800	80	70	114	8	1,072	26.80
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	288,045	28,804	25,348	41,064	2,775	386,035	9650.88
TOTAL Lake Restoration	2.00	EA	12,042,076	1,204,208	1,059,703	1,716,718	115,998	16,138,702	8069351
TOTAL Wetland Restoration	1.00	EA	48,226,814	4,822,681	4,243,960	6,875,215	464,557	64,633,227	64633227
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.									
06. 14.001.001 Site Preparation	1.00	EA	200,000	0	0	0	0	200,000	200000.00
06. 14.001.002 Access and Circulation	1.00	EA	573,330	0	0	0	0	573,330	573330.00
06. 14.001.003 Protection Access Control	1.00	EA	157,750	0	0	0	0	157,750	157750.00
06. 14.001.004 Signage	1.00	EA	40,000	0	0	0	0	40,000	40000.00
06. 14.001.005 Shelters	1.00	EA	495,000	0	0	0	0	495,000	495000.00
06. 14.001.006 Utilities	1.00	EA	180,000	0	0	0	0	180,000	180000.00
06. 14.001.007 Park Furniture	1.00	EA	21,000	0	0	0	0	21,000	21000.00
06. 14.001.008 Interpretive Guidance Media	1.00	EA	24,200	0	0	0	0	24,200	24200.00
TOTAL Access Point, Maint. Fac.	1.00	EA	1,691,280	0	0	0	0	1,691,280	1691280
06. 14.002 Access Points									
06. 14.002.001 Site Preparation	1.00	EA	927,000	0	0	0	0	927,000	927000.00
06. 14.002.002 Access and Circulation	1.00	EA	1,766,400	0	0	0	0	1,766,400	1766400
06. 14.002.003 Protection access Control	1.00	EA	1,260,500	0	0	0	0	1,260,500	1260500
06. 14.002.004 Signage	1.00	EA	166,000	0	0	0	0	166,000	166000.00
06. 14.002.005 Shelters	1.00	EA	2,145,000	0	0	0	0	2,145,000	2145000
06. 14.002.006 Utilities	1.00	EA	740,000	0	0	0	0	740,000	740000.00
06. 14.002.007 Park Furniture	1.00	EA	155,500	0	0	0	0	155,500	155500.00
06. 14.002.008 Interpretive Guidance Media	1.00	EA	112,500	0	0	0	0	112,500	112500.00

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Access Points	1.00	EA	7,272,900	0	0	0	0	7,272,900	7272900
TOTAL Recreation	1.00	EA	8,964,180	0	0	0	0	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	57,190,994	4,822,681	4,243,960	6,875,215	464,557	73,597,407	73597407
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	101,890,994	4,822,681	4,243,960	6,875,215	464,557	118,297,407	118297407
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
OVERHEAD (10.0%)								4,822,681	
SUBTOTAL								106,713,676	
HOME OFC (8.0%)								4,243,960	
SUBTOTAL								110,957,635	
PROFIT (12.0%)								6,875,215	
SUBTOTAL								117,832,850	
BOND (0.72%)								464,557	
TOTAL INCL INDIRECTS								118,297,407	
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			0	0	0	043900000		43,900,000	
01.002 ROW for Water Supply & Distribu-			0	0	0	0	800,000	800,000	
TOTAL LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86533002203		48,226,814	48226814
06. 14 Recreation	1.00	EA	0	0	0	0	8964180	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
OVERHEAD (10.0%)								4,822,681	
SUBTOTAL								106,713,676	
HOME OFC (8.0%)								4,243,960	
SUBTOTAL								110,957,635	
PROFIT (12.0%)								6,875,215	
SUBTOTAL								117,832,850	
BOND (0.72%)								464,557	
TOTAL INCL INDIRECTS								118,297,407	
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			0	0	0	043900000		43,900,000	
01.002 ROW for Water Supply & Distribu-			0	0	0	0	800,000	800,000	
TOTAL LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob	1.00	EA	0	0	0	0	570,000	570,000	570000.00
06. 03. 01 Clearing and Grubbing	36.00	ACR	2,667	62,032	49,910	0	5,000	116,942	3248.40
06. 03. 02 Invasive Removal	120.00	ACR	0	0	0	0	850,000	850,000	7083.33
06. 03. 03 Debris Removal	1.00	EA	0	0	0	0	555,000	555,000	555000.00
06. 03. 09 Channel Restoration Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
06. 03. 10 Grade Control Structure (1 ea)	2400.00	CY	944	24,144	6,135	38,532	120,255	189,066	78.78
06. 03. 11 Maintainence Structures			0	0	0	0	4479250	4,479,250	
06. 03. 12 Water Supply & Distribution			0	0	0	017605840		17,605,840	
06. 03. 73 Stormwater Outfall	8.00	EA	597	15,630	11,382	61,643	156,800	245,456	30681.95
06. 03. 74 Wetland Ponds	28.00	ACR	13,402	368,063	384,223	10,732	56,000	819,018	29250.63
06. 03. 75 Emergent Wetlands	13.00	ACR	2,476	67,646	82,363	4,983	0	154,992	11922.43
06. 03. 76 Cottonwood/willow (1 gal)	378.00	ACR	0	0	0	0	3815910	3,815,910	10095.00
06. 03. 77 Mesquite Bosque (1 gal)	244.00	ACR	0	0	0	0	3051708	3,051,708	12507.00
06. 03. 78 Mesquite Xeric	168.00	ACR	0	0	0	0	1655640	1,655,640	9855.00
06. 03. 79 Lake Restoration	2.00	EA	146,679	4151813	7238488	570,975	80,800	12,042,076	6021038
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86533002203		48,226,814	48226814
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.	1.00	EA	0	0	0	0	1691280	1,691,280	1691280
06. 14.002 Access Points	1.00	EA	0	0	0	0	7272900	7,272,900	7272900
TOTAL Recreation	1.00	EA	0	0	0	0	8964180	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
OVERHEAD (10.0%)								4,822,681	
SUBTOTAL								106,713,676	
HOME OFC (8.0%)								4,243,960	
SUBTOTAL								110,957,635	
PROFIT (12.0%)								6,875,215	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
SUBTOTAL								117,832,850	
BOND (0.72%)								464,557	
TOTAL INCL INDIRECTS								118,297,407	
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			0	0	0	043900000		43,900,000	
01.002 ROW for Water Supply & Distribu-			0	0	0	0	800,000	800,000	
TOTAL LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob									
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	0	0	0	0	50,000	50,000	1000.00
06. 03. 00.002 Setup and Dismantling	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	0	0	0	0	20,000	20,000	2000.00
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	0	0	0	0	100,000	100,000	25000.00
06. 03. 00.005 Move & transport around job site	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.006 Miscellaneous	1.00	EA	0	0	0	0	200,000	200,000	200000.00
TOTAL Mob/Demob	1.00	EA	0	0	0	0	570,000	570,000	570000.00
06. 03. 01 Clearing and Grubbing	36.00	ACR	2,667	62,032	49,910	0	5,000	116,942	3248.40
06. 03. 02 Invasive Removal									
06. 03. 02.001 Arundo Removal	10.00	ACR	0	0	0	0	300,000	300,000	30000.00
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	0	0	0	0	550,000	550,000	5000.00
TOTAL Invasive Removal	120.00	ACR	0	0	0	0	850,000	850,000	7083.33
06. 03. 03 Debris Removal	1.00	EA	0	0	0	0	555,000	555,000	555000.00
06. 03. 09 Channel Restoration Excavation									
06. 03. 09.001 Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
TOTAL Channel Restoration Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
06. 03. 10 Grade Control Structure (1 ea)									
06. 03. 10.001 RCC	2400.00	CY	0	0	0	0	84,000	84,000	35.00
06. 03. 10.002 Portland Cement	285.00	TON	0	0	0	0	31,350	31,350	110.00
06. 03. 10.003 Pozzolan (Fly Ash)	109.00	TON	0	0	0	0	4,905	4,905	45.00
06. 03. 10.004 Gabion Weirs and Water "V" Ditch	1.00	EA	944	24,144	6,135	38,532	0	68,811	68810.58
TOTAL Grade Control Structure (1 ea)	2400.00	CY	944	24,144	6,135	38,532	120,255	189,066	78.78

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			0	0	0	0	1990000	1,990,000	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	0	0	0	0	702,100	702,100	140420.00
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	0	0	0	0	617,850	617,850	61785.00
06. 03. 11.004	Maintenance Road Underpass @19th			0	0	0	0	997,300	997,300	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	0	0	0	0	100,000	100,000	20000.00
06. 03. 11.006	Project Signage	6.00	EA	0	0	0	0	72,000	72,000	12000.00
	TOTAL Maintainence Structures			0	0	0	0	4479250	4,479,250	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			0	0	0	0	2390000	2,390,000	
06. 03. 12.002	Electronic Flow Regulated Valve			0	0	0	0	40,000	40,000	
06. 03. 12.003	Electronic Flow Regulated Valves			0	0	0	0	200,000	200,000	
06. 03. 12.004	Pump Station (incl. mechanical,			0	0	0	0	2000000	2,000,000	
06. 03. 12.005	Reservoir (incl. excavation, sub			0	0	0	0	1120000	1,120,000	
06. 03. 12.006	Ground Water Pond/Reservoir on			0	0	0	0	280,000	280,000	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	0	0	0	0	1584000	1,584,000	120.00
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	0	0	0	0	2650000	2,650,000	100.00
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	0	0	0	0	2664000	2,664,000	72.00
06. 03. 12.010	Bridge crossing of 16" Waterline			0	0	0	0	480,000	480,000	
06. 03. 12.011	Bridge crossing of 10" Waterline			0	0	0	0	320,000	320,000	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	0	0	0	0	300,000	300,000	60.00
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	0	0	0	0	700,000	700,000	28.00
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	0	0	0	0	560,000	560,000	16.00
06. 03. 12.015	Waterfal to Move Water from			0	0	0	0	300,000	300,000	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	0	0	0	0	358,200	358,200	11940.00
06. 03. 12.017	Waste and Tire Removal (incl.			0	0	0	0	1190000	1,190,000	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	0	0	0	0	398,000	398,000	398000.00
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	0	0	0	0	71,640	71,640	35820.00
	TOTAL Water Supply & Distribution			0	0	0	017605840		17,605,840	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	290	7,938	7,149	0	0	15,087	4.56
06. 03. 73.002	Concrete	416.00	CY	296	6,980	3,792	59,360	0	70,131	168.59
06. 03. 73.003	Cobble	22400.00	SF	0	0	0	0	156,800	156,800	7.00
06. 03. 73.004	Weir, concrete	16.00	CY	11	268	146	2,283	0	2,697	168.59
06. 03. 73.005	V-Ditch Excavation	148.00	CY	0	444	296	0	0	740	5.00
	TOTAL Stormwater Outfall	8.00	EA	597	15,630	11,382	61,643	156,800	245,456	30681.95
06. 03. 74	Wetland Ponds									
06. 03. 74.001	Grading/Excavation	149890.00	CY	11,635	320,472	297,476	0	0	617,948	4.12

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 74.002	Liner, 12" fines, 3:1 slope,	45128.00	CY	1,767	47,591	86,747	10,732	0	145,070	3.21
06. 03. 74.003	Hydroseeding	28.00	ACR	0	0	0	0	56,000	56,000	2000.00
TOTAL	Wetland Ponds	28.00	ACR	13,402	368,063	384,223	10,732	56,000	819,018	29250.63
06. 03. 75	Emergent Wetlands									
06. 03. 75.001	Grading/Excavation	20952.00	CY	1,655	45,550	42,088	0	0	87,638	4.18
06. 03. 75.002	Liner, 12" fines, 3:1 slope,	20952.00	CY	820	22,095	40,275	4,983	0	67,353	3.21
TOTAL	Emergent Wetlands	13.00	ACR	2,476	67,646	82,363	4,983	0	154,992	11922.43
06. 03. 76	Cottonwood/willow (1 gal)									
06. 03. 76.001	Planting	378.00	ACR	0	0	0	0	451,710	451,710	1195.00
06. 03. 76.002	Irrigation	378.00	ACR	0	0	0	0	3326400	3,326,400	8800.00
06. 03. 76.003	Maintenance of Plants & Irrigat-	378.00	ACR	0	0	0	0	37,800	37,800	100.00
TOTAL	Cottonwood/willow (1 gal)	378.00	ACR	0	0	0	0	3815910	3,815,910	10095.00
06. 03. 77	Mesquite Bosque (1 gal)									
06. 03. 77.001	Planting	244.00	ACR	0	0	0	0	874,008	874,008	3582.00
06. 03. 77.002	Irrigation	244.00	ACR	0	0	0	0	2147200	2,147,200	8800.00
06. 03. 77.003	Maintenance of Plants and Irrig-	244.00	ACR	0	0	0	0	30,500	30,500	125.00
TOTAL	Mesquite Bosque (1 gal)	244.00	ACR	0	0	0	0	3051708	3,051,708	12507.00
06. 03. 78	Mesquite Xeric									
06. 03. 78.001	Planting	168.00	ACR	0	0	0	0	160,440	160,440	955.00
06. 03. 78.002	Irrigation	168.00	ACR	0	0	0	0	1478400	1,478,400	8800.00
06. 03. 78.003	Maintenance of Plants and Irrig-	168.00	ACR	0	0	0	0	16,800	16,800	100.00
TOTAL	Mesquite Xeric	168.00	ACR	0	0	0	0	1655640	1,655,640	9855.00
06. 03. 79	Lake Restoration									
06. 03. 79.001	Lake Restoration (2 lakes)	3000000	CY	144,155	4083826	7114562	555,643	0	11,754,031	3.92
06. 03. 79.002	Emergent Wetlands (2 lakes)	40.00	ACR	2,525	67,987	123,926	15,332	80,800	288,045	7201.12
TOTAL	Lake Restoration	2.00	EA	146,679	4151813	7238488	570,975	80,800	12,042,076	6021038
TOTAL	Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86533002203		48,226,814	48226814

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 14	Recreation									
06. 14.001	Access Point, Maint. Fac.									
06. 14.001.001	Site Preparation	1.00	EA	0	0	0	0	200,000	200,000	200000.00
06. 14.001.002	Access and Circulation	1.00	EA	0	0	0	0	573,330	573,330	573330.00
06. 14.001.003	Protection Access Control	1.00	EA	0	0	0	0	157,750	157,750	157750.00
06. 14.001.004	Signage	1.00	EA	0	0	0	0	40,000	40,000	40000.00
06. 14.001.005	Shelters	1.00	EA	0	0	0	0	495,000	495,000	495000.00
06. 14.001.006	Utilities	1.00	EA	0	0	0	0	180,000	180,000	180000.00
06. 14.001.007	Park Furniture	1.00	EA	0	0	0	0	21,000	21,000	21000.00
06. 14.001.008	Interpretive Guidance Media	1.00	EA	0	0	0	0	24,200	24,200	24200.00
	TOTAL Access Point, Maint. Fac.	1.00	EA	0	0	0	0	1691280	1,691,280	1691280
06. 14.002	Access Points									
06. 14.002.001	Site Preparation	1.00	EA	0	0	0	0	927,000	927,000	927000.00
06. 14.002.002	Access and Circulation	1.00	EA	0	0	0	0	1766400	1,766,400	1766400
06. 14.002.003	Protection access Control	1.00	EA	0	0	0	0	1260500	1,260,500	1260500
06. 14.002.004	Signage	1.00	EA	0	0	0	0	166,000	166,000	166000.00
06. 14.002.005	Shelters	1.00	EA	0	0	0	0	2145000	2,145,000	2145000
06. 14.002.006	Utilities	1.00	EA	0	0	0	0	740,000	740,000	740000.00
06. 14.002.007	Park Furniture	1.00	EA	0	0	0	0	155,500	155,500	155500.00
06. 14.002.008	Interpretive Guidance Media	1.00	EA	0	0	0	0	112,500	112,500	112500.00
	TOTAL Access Points	1.00	EA	0	0	0	0	7272900	7,272,900	7272900
	TOTAL Recreation	1.00	EA	0	0	0	0	8964180	8,964,180	8964180
	TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994
	TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
	OVERHEAD (10.0%)								4,822,681	
	SUBTOTAL								106,713,676	
	HOME OFC (8.0%)								4,243,960	
	SUBTOTAL								110,957,635	
	PROFIT (12.0%)								6,875,215	
	SUBTOTAL								117,832,850	
	BOND (0.72%)								464,557	
	TOTAL INCL INDIRECTS								118,297,407	
	CONTINGENCY								25,894,481	
	SUBTOTAL								144,191,888	
	PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			0	0	0	043900000		43,900,000	
01.002 ROW for Water Supply & Distribu-			0	0	0	0	800,000	800,000	
TOTAL LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob									
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	0	0	0	0	50,000	50,000	1000.00
06. 03. 00.002 Setup and Dismantling	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	0	0	0	0	20,000	20,000	2000.00
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	0	0	0	0	100,000	100,000	25000.00
06. 03. 00.005 Move & transport around job site	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.006 Miscellaneous	1.00	EA	0	0	0	0	200,000	200,000	200000.00
TOTAL Mob/Demob	1.00	EA	0	0	0	0	570,000	570,000	570000.00
06. 03. 01 Clearing and Grubbing	36.00	ACR	2,667	62,032	49,910	0	5,000	116,942	3248.40
06. 03. 02 Invasive Removal									
06. 03. 02.001 Arundo Removal	10.00	ACR	0	0	0	0	300,000	300,000	30000.00
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	0	0	0	0	550,000	550,000	5000.00
TOTAL Invasive Removal	120.00	ACR	0	0	0	0	850,000	850,000	7083.33
06. 03. 03 Debris Removal	1.00	EA	0	0	0	0	555,000	555,000	555000.00
06. 03. 09 Channel Restoration Excavation									
06. 03. 09.001 Excavation									
06. 03. 09.001.001 Excavation	660000.00	CY	21,978	619,674	437,448	0	0	1,057,122	1.60
06. 03. 09.001.002 Backfill	660000.00	CY	7,260	204,514	180,048	0	0	384,562	0.58
06. 03. 09.001.003 Hauling	660000.00	CY	7,550	191,809	442,424	0	0	634,234	0.96
TOTAL Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
TOTAL Channel Restoration Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
06. 03. 10 Grade Control Structure (1 ea)									
06. 03. 10.001 RCC	2400.00	CY	0	0	0	0	84,000	84,000	35.00

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	0	0	0	0	31,350	31,350	110.00
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	0	0	0	0	4,905	4,905	45.00
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	944	24,144	6,135	38,532	0	68,811	68810.58
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	944	24,144	6,135	38,532	120,255	189,066	78.78
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			0	0	0	0	1990000	1,990,000	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	0	0	0	0	702,100	702,100	140420.00
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	0	0	0	0	617,850	617,850	61785.00
06. 03. 11.004	Maintenance Road Underpass @19th			0	0	0	0	997,300	997,300	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	0	0	0	0	100,000	100,000	20000.00
06. 03. 11.006	Project Signage	6.00	EA	0	0	0	0	72,000	72,000	12000.00
	TOTAL Maintainence Structures			0	0	0	0	4479250	4,479,250	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			0	0	0	0	2390000	2,390,000	
06. 03. 12.002	Electronic Flow Regulated Valve			0	0	0	0	40,000	40,000	
06. 03. 12.003	Electronic Flow Regulated Valves			0	0	0	0	200,000	200,000	
06. 03. 12.004	Pump Station (incl. mechanical,			0	0	0	0	2000000	2,000,000	
06. 03. 12.005	Reservoir (incl. excavation, sub			0	0	0	0	1120000	1,120,000	
06. 03. 12.006	Ground Water Pond/Reservoir on			0	0	0	0	280,000	280,000	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	0	0	0	0	1584000	1,584,000	120.00
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	0	0	0	0	2650000	2,650,000	100.00
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	0	0	0	0	2664000	2,664,000	72.00
06. 03. 12.010	Bridge crossing of 16" Waterline			0	0	0	0	480,000	480,000	
06. 03. 12.011	Bridge crossing of 10" Waterline			0	0	0	0	320,000	320,000	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	0	0	0	0	300,000	300,000	60.00
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	0	0	0	0	700,000	700,000	28.00
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	0	0	0	0	560,000	560,000	16.00
06. 03. 12.015	Waterfal to Move Water from			0	0	0	0	300,000	300,000	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	0	0	0	0	358,200	358,200	11940.00
06. 03. 12.017	Waste and Tire Removal (incl.			0	0	0	0	1190000	1,190,000	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	0	0	0	0	398,000	398,000	398000.00
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	0	0	0	0	71,640	71,640	35820.00
	TOTAL Water Supply & Distribution			0	0	0		017605840	17,605,840	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	290	7,938	7,149	0	0	15,087	4.56
06. 03. 73.002	Concrete	416.00	CY	296	6,980	3,792	59,360	0	70,131	168.59
06. 03. 73.003	Cobble	22400.00	SF	0	0	0	0	156,800	156,800	7.00
06. 03. 73.004	Weir, concrete	16.00	CY	11	268	146	2,283	0	2,697	168.59

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 73.005 V-Ditch Excavation	148.00	CY	0	444	296	0	0	740	5.00
TOTAL Stormwater Outfall	8.00	EA	597	15,630	11,382	61,643	156,800	245,456	30681.95
06. 03. 74 Wetland Ponds									
06. 03. 74.001 Grading/Excavation	149890.00	CY	11,635	320,472	297,476	0	0	617,948	4.12
06. 03. 74.002 Liner, 12" fines, 3:1 slope,	45128.00	CY	1,767	47,591	86,747	10,732	0	145,070	3.21
06. 03. 74.003 Hydroseeding	28.00	ACR	0	0	0	0	56,000	56,000	2000.00
TOTAL Wetland Ponds	28.00	ACR	13,402	368,063	384,223	10,732	56,000	819,018	29250.63
06. 03. 75 Emergent Wetlands									
06. 03. 75.001 Grading/Excavation	20952.00	CY	1,655	45,550	42,088	0	0	87,638	4.18
06. 03. 75.002 Liner, 12" fines, 3:1 slope,	20952.00	CY	820	22,095	40,275	4,983	0	67,353	3.21
TOTAL Emergent Wetlands	13.00	ACR	2,476	67,646	82,363	4,983	0	154,992	11922.43
06. 03. 76 Cottonwood/willow (1 gal)									
06. 03. 76.001 Planting	378.00	ACR	0	0	0	0	451,710	451,710	1195.00
06. 03. 76.002 Irrigation	378.00	ACR	0	0	0	0	3326400	3,326,400	8800.00
06. 03. 76.003 Maintenance of Plants & Irrigat-	378.00	ACR	0	0	0	0	37,800	37,800	100.00
TOTAL Cottonwood/willow (1 gal)	378.00	ACR	0	0	0	0	3815910	3,815,910	10095.00
06. 03. 77 Mesquite Bosque (1 gal)									
06. 03. 77.001 Planting	244.00	ACR	0	0	0	0	874,008	874,008	3582.00
06. 03. 77.002 Irrigation	244.00	ACR	0	0	0	0	2147200	2,147,200	8800.00
06. 03. 77.003 Maintenance of Plants and Irrig-	244.00	ACR	0	0	0	0	30,500	30,500	125.00
TOTAL Mesquite Bosque (1 gal)	244.00	ACR	0	0	0	0	3051708	3,051,708	12507.00
06. 03. 78 Mesquite Xeric									
06. 03. 78.001 Planting	168.00	ACR	0	0	0	0	160,440	160,440	955.00
06. 03. 78.002 Irrigation	168.00	ACR	0	0	0	0	1478400	1,478,400	8800.00
06. 03. 78.003 Maintenance of Plants and Irrig-	168.00	ACR	0	0	0	0	16,800	16,800	100.00
TOTAL Mesquite Xeric	168.00	ACR	0	0	0	0	1655640	1,655,640	9855.00
06. 03. 79 Lake Restoration									

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	144,155	4083826	7114562	555,643	0	11,754,031	3.92
TOTAL Lake Restoration (2 lakes)	3000000	CY	144,155	4083826	7114562	555,643	0	11,754,031	3.92
06. 03. 79.002 Emergent Wetlands (2 lakes)									
06. 03. 79.002.001 Emergent Wetlands	64469.00	CY	2,525	67,987	123,926	15,332	0	207,245	3.21
06. 03. 79.002.002 Hydroseeding	40.00	ACR	0	0	0	0	80,000	80,000	2000.00
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	0	0	0	0	800	800	20.00
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	2,525	67,987	123,926	15,332	80,800	288,045	7201.12
TOTAL Lake Restoration	2.00	EA	146,679	4151813	7238488	570,975	80,800	12,042,076	6021038
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86533002203		48,226,814	48226814
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.									
06. 14.001.001 Site Preparation	1.00	EA	0	0	0	0	200,000	200,000	200000.00
06. 14.001.002 Access and Circulation	1.00	EA	0	0	0	0	573,330	573,330	573330.00
06. 14.001.003 Protection Access Control	1.00	EA	0	0	0	0	157,750	157,750	157750.00
06. 14.001.004 Signage	1.00	EA	0	0	0	0	40,000	40,000	40000.00
06. 14.001.005 Shelters	1.00	EA	0	0	0	0	495,000	495,000	495000.00
06. 14.001.006 Utilities	1.00	EA	0	0	0	0	180,000	180,000	180000.00
06. 14.001.007 Park Furniture	1.00	EA	0	0	0	0	21,000	21,000	21000.00
06. 14.001.008 Interpretive Guidance Media	1.00	EA	0	0	0	0	24,200	24,200	24200.00
TOTAL Access Point, Maint. Fac.	1.00	EA	0	0	0	0	1691280	1,691,280	1691280
06. 14.002 Access Points									
06. 14.002.001 Site Preparation	1.00	EA	0	0	0	0	927,000	927,000	927000.00
06. 14.002.002 Access and Circulation	1.00	EA	0	0	0	0	1766400	1,766,400	1766400
06. 14.002.003 Protection access Control	1.00	EA	0	0	0	0	1260500	1,260,500	1260500
06. 14.002.004 Signage	1.00	EA	0	0	0	0	166,000	166,000	166000.00
06. 14.002.005 Shelters	1.00	EA	0	0	0	0	2145000	2,145,000	2145000
06. 14.002.006 Utilities	1.00	EA	0	0	0	0	740,000	740,000	740000.00
06. 14.002.007 Park Furniture	1.00	EA	0	0	0	0	155,500	155,500	155500.00
06. 14.002.008 Interpretive Guidance Media	1.00	EA	0	0	0	0	112,500	112,500	112500.00
TOTAL Access Points	1.00	EA	0	0	0	0	7272900	7,272,900	7272900
TOTAL Recreation	1.00	EA	0	0	0	0	8964180	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
OVERHEAD (10.0%)								4,822,681	
SUBTOTAL								106,713,676	
HOME OFC (8.0%)								4,243,960	
SUBTOTAL								110,957,635	
PROFIT (12.0%)								6,875,215	
SUBTOTAL								117,832,850	
BOND (0.72%)								464,557	
TOTAL INCL INDIRECTS								118,297,407	
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 LERRD's									
01.001 Flood Plain Project Land			0	0	0	043900000		43,900,000	
01.002 ROW for Water Supply & Distribu-			0	0	0	0	800,000	800,000	
TOTAL LERRD's	1.00	EA	0	0	0	044700000		44,700,000	44700000
06 Wetland Restoration									
06. 03 Wetland Restoration									
06. 03. 00 Mob/Demob									
06. 03. 00.001 Equipment (major and heavy)	50.00	EA	0	0	0	0	50,000	50,000	1000.00
06. 03. 00.002 Setup and Dismantling	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.003 Replacement of worn-out quipment	10.00	EA	0	0	0	0	20,000	20,000	2000.00
06. 03. 00.004 Setup & Dismantling of cranes	4.00	EA	0	0	0	0	100,000	100,000	25000.00
06. 03. 00.005 Move & transport around job site	50.00	EA	0	0	0	0	100,000	100,000	2000.00
06. 03. 00.006 Miscellaneous	1.00	EA	0	0	0	0	200,000	200,000	200000.00
TOTAL Mob/Demob	1.00	EA	0	0	0	0	570,000	570,000	570000.00
06. 03. 01 Clearing and Grubbing	36.00	ACR	2,667	62,032	49,910	0	5,000	116,942	3248.40
06. 03. 02 Invasive Removal									
06. 03. 02.001 Arundo Removal	10.00	ACR	0	0	0	0	300,000	300,000	30000.00
06. 03. 02.002 Salt Cedar Removal	110.00	ACR	0	0	0	0	550,000	550,000	5000.00
TOTAL Invasive Removal	120.00	ACR	0	0	0	0	850,000	850,000	7083.33
06. 03. 03 Debris Removal	1.00	EA	0	0	0	0	555,000	555,000	555000.00
06. 03. 09 Channel Restoration Excavation									
06. 03. 09.001 Excavation									
06. 03. 09.001.001 Excavation	660000.00	CY	21,978	619,674	437,448	0	0	1,057,122	1.60
06. 03. 09.001.002 Backfill	660000.00	CY	7,260	204,514	180,048	0	0	384,562	0.58
06. 03. 09.001.003 Hauling	660000.00	CY	7,550	191,809	442,424	0	0	634,234	0.96
TOTAL Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
TOTAL Channel Restoration Excavation	660000.00	CY	36,788	1015997	1059920	0	0	2,075,918	3.15
06. 03. 10 Grade Control Structure (1 ea)									
06. 03. 10.001 RCC	2400.00	CY	0	0	0	0	84,000	84,000	35.00

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 10.002	Portland Cement	285.00	TON	0	0	0	0	31,350	31,350	110.00
06. 03. 10.003	Pozzolan (Fly Ash)	109.00	TON	0	0	0	0	4,905	4,905	45.00
06. 03. 10.004	Gabion Weirs and Water "V" Ditch	1.00	EA	944	24,144	6,135	38,532	0	68,811	68810.58
	TOTAL Grade Control Structure (1 ea)	2400.00	CY	944	24,144	6,135	38,532	120,255	189,066	78.78
06. 03. 11	Maintainence Structures									
06. 03. 11.001	Maintenance Facility			0	0	0	0	1990000	1,990,000	
06. 03. 11.002	Maintenance Roads (hard surface)	5.00	MI	0	0	0	0	702,100	702,100	140420.00
06. 03. 11.003	Maintenance Roads & Trails (soft	10.00	MI	0	0	0	0	617,850	617,850	61785.00
06. 03. 11.004	Maintenance Road Underpass @19th			0	0	0	0	997,300	997,300	
06. 03. 11.005	Bridges & Culverts (med) @Storm	5.00	EA	0	0	0	0	100,000	100,000	20000.00
06. 03. 11.006	Project Signage	6.00	EA	0	0	0	0	72,000	72,000	12000.00
	TOTAL Maintainence Structures			0	0	0	0	4479250	4,479,250	
06. 03. 12	Water Supply & Distribution									
06. 03. 12.001	20 mgd pump station,			0	0	0	0	2390000	2,390,000	
06. 03. 12.002	Electronic Flow Regulated Valve			0	0	0	0	40,000	40,000	
06. 03. 12.003	Electronic Flow Regulated Valves			0	0	0	0	200,000	200,000	
06. 03. 12.004	Pump Station (incl. mechanical,			0	0	0	0	2000000	2,000,000	
06. 03. 12.005	Reservoir (incl. excavation, sub			0	0	0	0	1120000	1,120,000	
06. 03. 12.006	Ground Water Pond/Reservoir on			0	0	0	0	280,000	280,000	
06. 03. 12.007	20" Waterline Pipe (incl. trench	13200.00	LF	0	0	0	0	1584000	1,584,000	120.00
06. 03. 12.008	16" Waterline Pipe (incl. trench	26500.00	LF	0	0	0	0	2650000	2,650,000	100.00
06. 03. 12.009	10" Waterline Pipe Loop (incl.	37000.00	LF	0	0	0	0	2664000	2,664,000	72.00
06. 03. 12.010	Bridge crossing of 16" Waterline			0	0	0	0	480,000	480,000	
06. 03. 12.011	Bridge crossing of 10" Waterline			0	0	0	0	320,000	320,000	
06. 03. 12.012	8" Waterline Pipe to existing	5000.00	LF	0	0	0	0	300,000	300,000	60.00
06. 03. 12.013	Overbank Canal Delivery Convey-	25000.00	LF	0	0	0	0	700,000	700,000	28.00
06. 03. 12.014	Terrace and LFC Canal Delivery	35000.00	LF	0	0	0	0	560,000	560,000	16.00
06. 03. 12.015	Waterfal to Move Water from			0	0	0	0	300,000	300,000	
06. 03. 12.016	Internal Drainage Conveyance	30.00	EA	0	0	0	0	358,200	358,200	11940.00
06. 03. 12.017	Waste and Tire Removal (incl.			0	0	0	0	1190000	1,190,000	
06. 03. 12.018	Supply Well (incl. pump, mechan-	1.00	EA	0	0	0	0	398,000	398,000	398000.00
06. 03. 12.019	Monitoring Well (incl. pump,	2.00	EA	0	0	0	0	71,640	71,640	35820.00
	TOTAL Water Supply & Distribution			0	0	0		017605840	17,605,840	
06. 03. 73	Stormwater Outfall									
06. 03. 73.001	Grading/Excavation	3312.00	CY	290	7,938	7,149	0	0	15,087	4.56
06. 03. 73.002	Concrete	416.00	CY	296	6,980	3,792	59,360	0	70,131	168.59
06. 03. 73.003	Cobble	22400.00	SF	0	0	0	0	156,800	156,800	7.00
06. 03. 73.004	Weir, concrete	16.00	CY	11	268	146	2,283	0	2,697	168.59

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 73.005	V-Ditch Excavation	148.00	CY	0	444	296	0	0	740	5.00
	TOTAL Stormwater Outfall	8.00	EA	597	15,630	11,382	61,643	156,800	245,456	30681.95
06. 03. 74	Wetland Ponds									
06. 03. 74.001	Grading/Excavation	149890.00	CY	11,635	320,472	297,476	0	0	617,948	4.12
06. 03. 74.002	Liner, 12" fines, 3:1 slope,	45128.00	CY	1,767	47,591	86,747	10,732	0	145,070	3.21
06. 03. 74.003	Hydroseeding	28.00	ACR	0	0	0	0	56,000	56,000	2000.00
	TOTAL Wetland Ponds	28.00	ACR	13,402	368,063	384,223	10,732	56,000	819,018	29250.63
06. 03. 75	Emergent Wetlands									
06. 03. 75.001	Grading/Excavation	20952.00	CY	1,655	45,550	42,088	0	0	87,638	4.18
06. 03. 75.002	Liner, 12" fines, 3:1 slope,	20952.00	CY	820	22,095	40,275	4,983	0	67,353	3.21
	TOTAL Emergent Wetlands	13.00	ACR	2,476	67,646	82,363	4,983	0	154,992	11922.43
06. 03. 76	Cottonwood/willow (1 gal)									
06. 03. 76.001	Planting	378.00	ACR	0	0	0	0	451,710	451,710	1195.00
06. 03. 76.002	Irrigation	378.00	ACR	0	0	0	0	3326400	3,326,400	8800.00
06. 03. 76.003	Maintenance of Plants & Irrigat-	378.00	ACR	0	0	0	0	37,800	37,800	100.00
	TOTAL Cottonwood/willow (1 gal)	378.00	ACR	0	0	0	0	3815910	3,815,910	10095.00
06. 03. 77	Mesquite Bosque (1 gal)									
06. 03. 77.001	Planting	244.00	ACR	0	0	0	0	874,008	874,008	3582.00
06. 03. 77.002	Irrigation	244.00	ACR	0	0	0	0	2147200	2,147,200	8800.00
06. 03. 77.003	Maintenance of Plants and Irrig-	244.00	ACR	0	0	0	0	30,500	30,500	125.00
	TOTAL Mesquite Bosque (1 gal)	244.00	ACR	0	0	0	0	3051708	3,051,708	12507.00
06. 03. 78	Mesquite Xeric									
06. 03. 78.001	Planting	168.00	ACR	0	0	0	0	160,440	160,440	955.00
06. 03. 78.002	Irrigation	168.00	ACR	0	0	0	0	1478400	1,478,400	8800.00
06. 03. 78.003	Maintenance of Plants and Irrig-	168.00	ACR	0	0	0	0	16,800	16,800	100.00
	TOTAL Mesquite Xeric	168.00	ACR	0	0	0	0	1655640	1,655,640	9855.00
06. 03. 79	Lake Restoration									

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
06. 03. 79.001 Lake Restoration (2 lakes)	3000000	CY	144,155	4083826	7114562	555,643	0	11,754,031	3.92
TOTAL Lake Restoration (2 lakes)	3000000	CY	144,155	4083826	7114562	555,643	0	11,754,031	3.92
06. 03. 79.002 Emergent Wetlands (2 lakes)									
06. 03. 79.002.001 Emergent Wetlands									
06. 03. 79.002.001. 1 Liner, 12" fines, 3:1 slope,	64469.00	CY	2,525	67,987	123,926	15,332	0	207,245	3.21
TOTAL Emergent Wetlands	64469.00	CY	2,525	67,987	123,926	15,332	0	207,245	3.21
06. 03. 79.002.002 Hydroseeding	40.00	ACR	0	0	0	0	80,000	80,000	2000.00
06. 03. 79.002.003 Plant Maintenance (1 year)	40.00	ACR	0	0	0	0	800	800	20.00
TOTAL Emergent Wetlands (2 lakes)	40.00	ACR	2,525	67,987	123,926	15,332	80,800	288,045	7201.12
TOTAL Lake Restoration	2.00	EA	146,679	4151813	7238488	570,975	80,800	12,042,076	6021038
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86533002203		48,226,814	48226814
06. 14 Recreation									
06. 14.001 Access Point, Maint. Fac.									
06. 14.001.001 Site Preparation	1.00	EA	0	0	0	0	200,000	200,000	200000.00
06. 14.001.002 Access and Circulation	1.00	EA	0	0	0	0	573,330	573,330	573330.00
06. 14.001.003 Protection Access Control	1.00	EA	0	0	0	0	157,750	157,750	157750.00
06. 14.001.004 Signage	1.00	EA	0	0	0	0	40,000	40,000	40000.00
06. 14.001.005 Shelters	1.00	EA	0	0	0	0	495,000	495,000	495000.00
06. 14.001.006 Utilities	1.00	EA	0	0	0	0	180,000	180,000	180000.00
06. 14.001.007 Park Furniture	1.00	EA	0	0	0	0	21,000	21,000	21000.00
06. 14.001.008 Interpretive Guidance Media	1.00	EA	0	0	0	0	24,200	24,200	24200.00
TOTAL Access Point, Maint. Fac.	1.00	EA	0	0	0	0	1691280	1,691,280	1691280
06. 14.002 Access Points									
06. 14.002.001 Site Preparation	1.00	EA	0	0	0	0	927,000	927,000	927000.00
06. 14.002.002 Access and Circulation	1.00	EA	0	0	0	0	1766400	1,766,400	1766400
06. 14.002.003 Protection access Control	1.00	EA	0	0	0	0	1260500	1,260,500	1260500
06. 14.002.004 Signage	1.00	EA	0	0	0	0	166,000	166,000	166000.00
06. 14.002.005 Shelters	1.00	EA	0	0	0	0	2145000	2,145,000	2145000
06. 14.002.006 Utilities	1.00	EA	0	0	0	0	740,000	740,000	740000.00
06. 14.002.007 Park Furniture	1.00	EA	0	0	0	0	155,500	155,500	155500.00
06. 14.002.008 Interpretive Guidance Media	1.00	EA	0	0	0	0	112,500	112,500	112500.00

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
TOTAL Access Points	1.00	EA	0	0	0	0	7272900	7,272,900	7272900
TOTAL Recreation	1.00	EA	0	0	0	0	8964180	8,964,180	8964180
TOTAL Wetland Restoration	1.00	EA	203,553	5705326	8832421	686,86541966383		57,190,994	57190994
TOTAL Oeste Feas. Study Cost Estimate	1.00	EA	203,553	5705326	8832421	686,86586666383		101,890,994	101890994
OVERHEAD (10.0%)								4,822,681	
SUBTOTAL								106,713,676	
HOME OFC (8.0%)								4,243,960	
SUBTOTAL								110,957,635	
PROFIT (12.0%)								6,875,215	
SUBTOTAL								117,832,850	
BOND (0.72%)								464,557	
TOTAL INCL INDIRECTS								118,297,407	
CONTINGENCY								25,894,481	
SUBTOTAL								144,191,888	
PL'NG, EGR'NG, DESIGN + EDC (Ac. 30)								9,714,858	
SUBTOTAL								153,906,746	
CONTN MANAGEMENT (Acct. 31)								6,372,063	
TOTAL INCL OWNER COSTS								160,278,809	

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Maricopa County, Arizona
Feasibility Study

Appendix L

Recreation and Environmental Education

March 2006

City of Phoenix
Parks and Recreation Department

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1

INTRODUCTION

The United States Army Corps of Engineers and the city of Phoenix, have entered into a contract for a Feasibility Study of an environmental restoration project known as Rio Salado Oeste, Arizona, on the Salt River between 19th and 83rd Avenues. The river is virtually dry and has suffered an almost total loss of native habitat as a result of early 20th century reclamation projects. This desert riparian habitat is a critical and diminishing resource throughout Arizona.

The Rio Salado Oeste study area is approximately three miles west of downtown Phoenix. The upstream boundary is located at 19th Avenue. The study area extends west approximately seven miles.

2

RECREATION FEATURES

"A planning objective of the Rio Salado Oeste Feasibility Study is to ***"increase environmental education and passive recreation opportunities incidental to the restoration effort."*** To that end, the goal of the Recreation and Environmental Education Component is to ***provide opportunities for visitors of all ages and backgrounds to enjoy this unique resource while developing an awareness, knowledge, and understanding of desert riparian habitat and its relationship to the surrounding environment. Additionally, it presents an opportunity to acknowledge and understand the influence the of the Salt River had on the environment and cultures throughout history."***

Existing Recreation Opportunities

To the west of the study area lies Estrella Mountain Regional Park. The park is owned and managed by Maricopa County Parks and Recreation Department. The rugged and scenic Sierra Estrella mountains are the most dominant feature of Estrella Mountain Regional Park. The terrain of these mountains is characterized by very steep slopes, numerous rock out-crops, shallow soils and sparse desert vegetation.

The County has developed a master plan for the 19,200 acre park, located approximately 20 miles southwest of downtown Phoenix. The master plan envisions the preservation of scenic desert wilderness areas while incorporating sensitive development of recreational facilities and activities. The Plan accommodates the expected annual demand of 1 million visitors while insuring that the existing Sonoran Desert environment remains in its existing condition. In fact, 90 percent of the park will remain essentially untouched. The remaining 10 percent will be sensitively utilized for educational, camping, picnicking, and sporting activities.

While water is a highly attractive feature for recreationists, park trails and facilities have presently been planned away from the Gila River. Once the County completes its Sun Circle Trail System through this reach of the Gila and Salt Rivers, recreation use patterns are expected to expand throughout the study area. The Sun Circle Trail, a component of the National Recreation Trail system, comprises a 110 mile loop encompassing the Phoenix metro area. The trail offers a unique opportunity for hiking, horseback riding and bicycling throughout the urban

area. Approximately 70 percent of the Sun Circle trail system is in place. The County has an agreement with the Maricopa County Flood District to establish the Sun Circle Trail within the flood control district corridor from Skunk Creek to the Gila River - Salt River confluence. The Rio Salado Oeste Project is an excellent opportunity to designate a segment of the Sun Circle Trail. This will benefit Rio Salado Oeste, Rio Salado, and Rio Salado Oeste with a major non-motorized travelway connecting the three river restoration projects to the other valley areas.

Future Opportunities

The Rio Salado Oeste project provides a unique opportunity to enhance resource-based recreation and environmental education. The restoration of the dry Salt river channel will bring a riparian open space feature to the rapidly expanding Laveen and Estrella Planning Areas. Rio Salado Oeste will provide a habitat and recreational connection to the desert riparian habitat corridor created by the Rio Salado and Tres Rios Projects. By connecting the seven-mile gap between the two projects, Rio Salado Oeste will enhance the unique recreation and education opportunities for residents and out-of-town visitors. Drawing on a population base of over two million in the Valley, it is estimated that visitation to the Rio Salado Oeste project will exceed 350,000 annually. Primary use times for this unique resource would coincide with the "visitor season" between October and May when temperatures are moderate.

The goal of the environmental education and recreation component is to provide opportunities for visitors of all ages, abilities, and backgrounds to enjoy this unique resource while developing an awareness, knowledge and understanding of desert riparian habitat and its relationship to the surrounding environment. Additionally, it presents an opportunity to acknowledge and understand the influence of Salt Rivers on the environment and cultures throughout the Valley's history. Visitors to this day-use area can participate in a variety of pursuits from enjoying scenic views, picnicking with the family, learning about the habitat, or exploring the resource on foot, by bicycle or horseback. Recognizing our diverse society, the Rio Salado Oeste project will have design components ranging from areas adapted for special needs to multi-lingual signage.

For planning purposes the features have been divided into three primary areas: ***The Bank, The Terrace***, and ***The Channel***. Each of these areas provides a different venue for recreational opportunities which coincide with learning opportunities allowing participants to *learn, see* and *experience* the resource first-hand.

The Bank provides recreational experiences including hiking, biking, and horseback riding to scenic overlooks, and leisure walking. Constructed features, which will interpret cultural, biological, will accommodate abundant educational opportunities and ecological themes related to the restored desert riparian habitat.

The Terrace is the area where the habitat has a permanent water source to create a self-sustaining ecosystem. This area will provide more limited and controlled recreational and educational experiences, such as bird watching and guided nature walks.

The Channel represents an area seeming to be relatively unaltered by humans, and will undergo physical changes in response to seasonal river flows and flooding. People will enter this zone on its terms, and it will contain few manmade features, allowing one to observe the natural forces of land and water that define and shape desert rivers and associated habitat.

The Bank Experience

Rio Salado Oeste will provide a variety of recreation opportunities for users. Those visiting the project will be able to arrive by private vehicle or alternate mode of transportation, including horse, public transit or bicycle. Users would enter at one of four drive-in access points at 35th Ave., 51st Ave. North and South, and 75th Ave. Visitors may also enter at one of the five walk-in access points at 19th Ave., 23rd Ave., 43rd Ave., 75th Ave., or 83rd Ave. Minor access points are also occurring in nine locations which remain to be determined. These points coincide with existing river crossings or roads. Amenities at each access point will vary, but may include: parking; restroom facilities; water fountains; shade structures; site furniture; and appropriate lighting. Each access point will serve as a trailhead and will provide appropriate signage, orientation kiosk, or visitor center to give visitors an overview of the activities and experiences available and orient users to the sensitivity of the area and appropriate uses and expectations. All improved facilities will be designed to provide accessibility to all members of the community.

Opportunities available at ***The Bank*** will include:

Trails:

Multi-use non-motorized trails will allow visitors to explore ***The Bank*** on foot, horseback, or bicycle. The hard surface trail will accommodate a variety of cycling activities allowing travel along the entire project. Natural surface trails will traverse the bank leading foot traffic, equestrians and mountain bicyclists to scenic overlooks or loops throughout the area. Additionally, a barrier free trail will be provided for users with limited mobility. Interpretive trails will allow for self-guided tours of the area.

The Sun Circle Trail will be established through the bank area. Extending through other areas of the Valley, the Sun Circle Trail will serve as a non-motorized transportation corridor providing access to Rio Salado Oeste from central and south Phoenix and the East Valley along the ***Rio Vista Trail*** and from the West Valley along the West Valley Recreation Corridor.

Scenic Overlooks:

Accessible locations along the roadways and trails will allow for family picnicking, informal play and scenic vistas of the surrounding landscape. More secluded areas will accommodate informal seating and meditation areas.

Education Opportunities:

An opportunity exists for a major Interpretive Center to furnish visitors programmatic information regarding the restoration of the habitat, the water cycle, a historical perspective of the rivers, and the flora and fauna within the project area. Additionally, there will be exhibits, signage, and multimedia displays.

Outdoor Gathering Area:

Gathering areas will be provided for groups to attend lectures by special interest speakers.

Staging Areas:

Areas will be designed for groups and classes to gather and prepare for a learning experience at the Rio Salado Oeste Project.

The Terrace Experience

The Terrace is the true sensitive habitat of the Rio Salado Oeste Project, and will provide visitors unique opportunities to view, enjoy and experience a restored desert riparian habitat. This area will allow one to explore wetland habitats and surrounding cottonwood/willow forests. Areas within *The Terrace* will be designated as sanctuary or conservation areas, with restricted public use, allowing for the protection of biologically sensitive animals and plant life. Natural surface trails will lead visitors to *The Terrace* from *The Bank*, and perhaps allow for occasional crossings of *The Channel*, expanding opportunities to explore more river habitat. Visitors to the area will leave with a heightened awareness of the fragile relationship between water availability and habitat in the desert.

Opportunities available at ***The Terrace*** will include:

Trails:

Trails will provide a transition from *The Bank* to the more sensitive *Terrace Habitat* and will be available for staff-guided hikes, research activities and wildlife watching. A barrier-free interpretive trail will be provided featuring multi-lingual signage regarding the project.

Scenic Overlooks:

Locations along *The Terrace* will allow scenic vistas of the restored river bed and surrounding landscape.

Habitat Views:

Special areas will provide wildlife blinds allowing visitors an opportunity to observe wildlife in its restored natural habitat without disturbing the seclusion needed by most. Interpretive signage will be provided.

Demonstration Walks:

Pathways along *The Terrace* will provide visitors insight into the inner workings of a habitat restoration project and its role in water conservation. Special "wetlands" walks or trails to areas featuring aquatic habitat will be provided as appropriate to the season and species.

Research Areas:

These unique study areas will allow opportunities for educational institutions to conduct long- and/or short-term research into the unique workings of the Rio Salado Oeste project including water conservation, riparian areas, and habitat restoration.

Bird Watching:

These unique areas will allow opportunities for novice and experienced bird watchers to view and learn about the variety of waterfowl, birds of prey, migratory and song birds that will find sanctuary within the Rio Salado Oeste habitat.

Urban Fishing:

When water quality and habitat features allow, ponds providing habitat for fish may allow anglers opportunities to fish.

Outdoor Classrooms:

Areas will be designed for groups and classes of up to 50 to assemble for programmatic learning experiences.

The Channel Experience

The Channel will provide equestrian opportunities. *The Channel* will be accessible by the trail system from *The Bank* at select locations along *The Terrace*. At each transition point to *The Terrace*, appropriate signage will inform visitors of the new habitat they are entering, and any user restrictions and expectations. *The Channel* will provide opportunities for environmental education and developing an understanding of how the habitat has been restored. Some areas of *The Channel* may be designated as "sensitive" habitat, and will be protected from public impacts.

3

VISITATION ESTIMATES

Annual Visitation

The Rio Salado Oeste Recreation and Environmental Education Component is planned to provide high quality experiences in an outdoor setting unique to the Phoenix metropolitan area. The unparalleled desert river restoration project provides an outstanding prospect for physical and programmatic activities, yet also places a great responsibility upon the sponsoring agencies to design and manage these activities for sustainability of the restoration. From the outset of the project it will be realized that the overriding concern will be to create conditions favorable to the return of the natural systems formerly associated with the river, and that human use will be secondary. However, it is also of great value to the project that the public have the opportunity within this constraint to experience, enjoy, and learn from the river.

How to best achieve this balance is worthy of much additional study and is beyond the scope of this initial effort; however, some basic assumptions must be made in order to determine preliminary cost estimates and to serve as the basis for design. These assumptions are: (1) Cost shared recreation features are developed to be consistent with Corps policy and environmental education, although a project benefit, is not included in the Federal project cost (2) the City of Phoenix will assume operational control of the recreational and environmental education functions.

Due to the location of the project and the intimacy of the expected recreation and education experience, it is projected that most visitors will arrive by private vehicle. However, in order to mitigate potential environmental impacts from increased traffic, facilities will be developed that promote alternative transportation and energy efficiency. Initial capacity of the parking facilities will be designed for not more than 500 vehicles in order to limit the potential impact of human activities upon the restoration project.

Based on historical data maintained by the City of Phoenix for resource-based recreational sites, it is estimated that 2.75 visitors arrive in each private vehicle. Additionally, an estimated one visitor per four vehicles arrives at a site by an alternate mode of transportation including bicycle, foot traffic and public transportation. It would be a legitimate goal of the Recreation/Education component to increase the ratio of visitors arriving by alternate means such as busses.

In the Valley of the Sun, visitation to outdoor recreational sites coincides with temperature. Visitation occurs in two seasons: WINTER (October through May); and SUMMER (June through September.) The WINTER months in the Valley have maximum average temperatures of 87 degrees. Visitors from around the world come to Phoenix during this time, and numerous "winter residents" arrive. SUMMER months bring hot sunny days and occasional afternoon thunderstorms. Temperatures average 102 degrees, making the early mornings and evenings the best time for outdoor activities.

Anticipated visitation at Rio Salado Oeste is based on use projections during PRIME TIME and NON-PRIME TIME throughout the year. PRIME TIME includes weekends and holidays. NON-PRIME TIME is weekdays. A typical visit to Rio Salado Oeste is expected to span three hours, although many visits will be longer, and some much shorter. Turnover refers to the number of times a parking space will be filled daily.

Below is a breakdown of anticipated visitation during WINTER and SUMMER.

WINTER 79% of annual use

PRIME TIME	78 days	1.5 turnovers	160,875 visitors
NON-PRIME TIME	165 days	0.5 turnover	113,438 visitors
		Winter	**274,313**

SUMMER 21% of annual use

PRIME TIME	36 days	1.00 turnovers	49,500 visitors
NON-PRIME TIME	86 days	0 .25 turnover	29,263 visitors
		Summer	**79,063**

TOTAL ANNUAL VISITATION **353,375**

Future Visitation Growth

The Rio Salado Oeste project is located in an area of Phoenix that is under tremendous population growth pressure. The area from 27th Avenue to the west, city limits south of Interstate 10, and north of the Salt River (the Estrella Village Planning Area) is expected to have a population of approximately 100,000 when fully developed in about 15 years. The Laveen Village Planning Area (between the river and South Mountain from 27th Avenue to the Gila River Indian Community) adjoins the project area to the south and east of 83rd Avenue and will be home to approximately 95,000 new residents. Obviously, the existing rural, open character of the landscape in these parts of the City will change greatly with the addition of almost 200,000 people. This new population will be living within approximately 7 miles of the project. Efforts are underway to plan a network of trails and pathways to connect future parks within the area and to provide linkages to the Salt River throughout its Phoenix reach.

As the population grows, and the Rio Salado Oeste project matures, visitation to the resource is anticipated to increase. It is anticipated that WINTER PRIME TIME visitation will be at facility capacity with additional growth from those visiting the resource through alternative means such as improved trail linkages. Growth in the next 50 years could increase during the winter to a total of 274,313 visitors.

The greatest increase over time will be during the four summer months. The City of Phoenix has documented changes in user patterns during the summer months with other resource-based

facilities. As trees mature providing more shade and facilities are at capacity during SUMMER PRIME TIME, visitors will seek alternative times to enjoy Rio Salado Oeste. It is anticipated that visitation during the summer in the next 50 years will increase to a total of 79,063 visitors.

Overall visitation increase for the resource over 50 years is projected to be approximately 353,375.

Rio Salado Oeste			
Recreation Plan			
Baseline Visitation Estimate			
	Days	Turnover/Day	Visits*
Winter (Oct-May)	243		
Prime Time	78	1.50	160,875
Non-Prime Time	165	0.50	113,438
Winter Total			**274,313**
Summer (Jun-Sep)	122		
Prime Time	36	1.00	49,500
Non-Prime Time	86	0.25	29,563
Summer Total			**79,063**
Grand Total (By Vehicle)			**353,376**
Add – Arrive by Alternative Mode (10%)			35,338
Total Visitation			**388,714**
Less Transfers (10%)			38,871
Baseline Visitation for Benefit analysis (Rounded)			**349,843**
* Note – Based Upon Parking Capacity for 500 spaces			
Average of 2.75 Persons/Vehicle			

Potential Visitor Impact

While these numbers are relatively large and may be seen as potentially threatening to the success of the restoration project, it should be born in mind that the project will be constructed in proximity to over 2,500,000 people. Within the life of the project the population of metropolitan Phoenix is projected to increase to approximately 4,700,000.

The City of Phoenix has vast experience with large numbers of visitors to its resource-based recreation sites. The Summit Trail at Squaw Peak currently has about 500,000 hikers a year; the Echo Canyon Trail on Camelback Mountain carries approximately 300,000 hikers each year, and South Mountain Park, the largest municipal park in the nation, has approximately 3,000,000 visitors each year, most of whom use some portion of the natural areas.

Rio Salado Oeste must be artfully designed and carefully managed. The discussion in earlier chapters regarding the functions of the recreation and environmental education improvements stressed the intent to segregate the visitor experiences from the core restoration of the river channel where critical habitat is likely to occur. By providing visitor-related improvements at locations appropriate to the specific habitat, environmental education and recreation functions can serve as an integral part of the project. Indeed, the education and recreation components of the project are much more likely to enhance the restoration by building an informed and supportive base of popular opinion than they are likely to degrade the project by overcrowding facilities and disrupting natural functions.

Nonetheless, visitors must be carefully managed to prevent adverse effects to the project and other adjacent property owners. The presumption is that the visitor management program will include Phoenix Park Ranger coverage for the project area in addition to the design features already discussed.

4

Point Value Assessment

One of the Specific Planning Objectives stated in the Rio Salado Oeste Feasibility Study is to "improve passive recreational and environmental education opportunities". The vision for these opportunities is described in detail in Chapter One, *Description of Recreation Features.* This vision for these opportunities is in compliance with the Corps' policies on recreation development at ecosystem restoration projects defined by ER 1165-2-501 and EP1165-2-502.

There is an inherent difficulty in determining the values of environmental education and recreation when they are considered separate experiences. The dichotomy of the two is not as easily determined as it might seem. As an example, a recent survey by Arizona State Parks lists *visiting historic/archeological sites, retracing historic/prehistoric routes, and wildlife viewing/ bird watching* as three of the six most important activities for users of non-motorized trails. *Day hiking, walking*, and *backpacking* are the other three. It would be a logical deduction that the environmental education experience and the resource-based recreation experience are virtually inseparable. Indeed, the currently popular "ecotourism" trend is built upon the premise that first-hand learning experiences are rewarding not only as an educational experience but also as healthy, stimulating recreation. The education experience **is** recreation, in other words.

Nonetheless, an attempt to logically separate the facilities supportive of the individual experiences is presented in this chapter.

Point Value Estimates for Recreation

(A) RECREATION EXPERIENCE

Total possible points: 30 scored points: 29

Numerous high quality value activities to include: habitat restoration; riparian resource areas; water conservation areas; flora and fauna sanctuary and conservation areas; study areas; urban fishing opportunities; outdoor classroom; birding; interpretive opportunities and scenic overlooks.

Some general activities to include: hiking; horseback riding; cycling; fishing and picnicking.

(B) AVAILABILITY OF OPPORTUNITY

Total possible points: 18 scored points: 12

The Rio Salado and Tres Rios Projects will be connected by Rio Salado Oeste and will present similar types of activities. Rio Salado Oeste will provide a vital wildlife corridor connecting the two other projects and offering continuous riparian habitat, and spreading out impacts of visitor use. No other similar activities exist within one hour travel time. The nearest *water-based* recreation sites with a natural riparian habitat are located well over an hour and a half away, which are the Salt River Recreation Area and Verde River Recreation Area in the Tonto National Forest, northeast of the valley.

(C) CARRYING CAPACITY
Total possible points: 14 scored points: 14

Ultimate facilities to achieve intent of selected alternative. Areas within Rio Salado Oeste will be designed and managed to provide for recreational experiences while preserving the resource.

(D) ACCESSIBILITY
Total possible points: 18 scored points: 18

Good access, high standard road to site; good access within site. Rio Salado Oeste is located within a major metropolitan area with access to the interstate highway system, ultimately integrated with public transportation routes, traffic thoroughfares, and a planned system of neighborhood and regional trail linkages.

(E) ENVIRONMENTAL
Total possible points: 20 scored points: 17

High esthetic quality to include: geology; hydrology of project; topography; water resources; vegetation; and wildlife. Efforts are currently being made by local and federal governments to mitigate any existing negative factors of illegal dumping.

TOTAL POSSIBLE POINTS: 100 TOTAL SCORED POINTS: 90

5

ENVIRONMENTAL EDUCATION PROGRAM

Objectives

The purpose of the Environmental Education Program will be to provide visitors with educational information to understand and enhance the Rio Salado Oeste experience. The program will include educational information presented in a creative and exciting way. The objectives are defined in terms of what the visitor will learn while at Rio Salado Oeste.

The program is structured so visitors will learn the following:

The site is a constructed habitat restoration project that has multiple uses.
Rio Salado Oeste can benefit people
Complex ecological interactions occur among the organisms in a habitat restoration project including microorganisms, aquatic insects, plants, birds and other wildlife.
Wildlife can best be seen when visitors blend in quietly with nature.
To more fully experience the restored environment, the visitor should rely not only on sight but also on hearing, touch and smell.
People play the major role in Phoenix's urban water cycle.
A desert riparian area is a unique and limited resource to be appreciated and respected.

These learning objectives will be realized through the construction of physical features such as an environmental education center with major interpretive displays and exhibits, interpretive trails, and various view points located around the Rio Salado Oeste project and the development of interpretive signs, displays, and supplemental materials.

Partnerships

School districts, organizations, and individuals within the community as well as other governmental agencies will wish to become more involved with the Rio Salado Oeste Interpretive Education Program. They may fund or manage certain public use features and / or provide volunteer services. Individual volunteers and student programs may be organized to help with planting and replanting within the Rio Salado Oeste Project. School districts and local organizations that become partners could set up or rotate interpretive displays within the facility. A cascade effect will also be put into place. The vision is to incorporate students and programs from the universities, community colleges, high schools, elementary schools, and pre-schools, each educational level providing mentoring to the next.

School Curriculum

Support materials for school curriculum would be developed for pre- and post- visit activities as well as for onsite visits. These could include a packet of teaching materials to provide some hands on experience prior to a class visit. The packet could contain wildlife specimens, maps, diagrams, field guides for plant and animal identification, water-quality testing kits, and perhaps dip nets for viewing and identifying species during the visit. The curriculum would also be presented in an outdoor classroom setting at the site.

Guided Nature Walks

A monthly schedule of guided nature walks could become a part of the interpretive education program. These walks could be developed and led by volunteers. Environmental and wildlife organizations such as the Phoenix Audubon Society, Sonoran Arthropod Studies Institute, and the Arizona Native Plant Society as well as agencies such as the Arizona Game and Fish Department could periodically sponsor events which would be open to the general public.

Preliminary Cost Estimates

Rio Salado Oeste will serve as a recreational amenity for the public to enjoy on a 7-day a week basis, 365 days a year. Daily operation and maintenance will be consistent with the approved standards set by the City of Phoenix Parks and Recreation Department. The following are cost estimates for the recreational components of Rio Salado Oeste. These costs were developed based the current recreational operation and maintenance costs for Rio Salado. The projected operation and maintenance costs for Rio Salado Oeste are estimated at $1.945 million. This breaks down to a cost of approximately $586 per acre for the 3,315 acre site.

Rio Salado Oeste Recreation

Operation and Maintenance Costs:

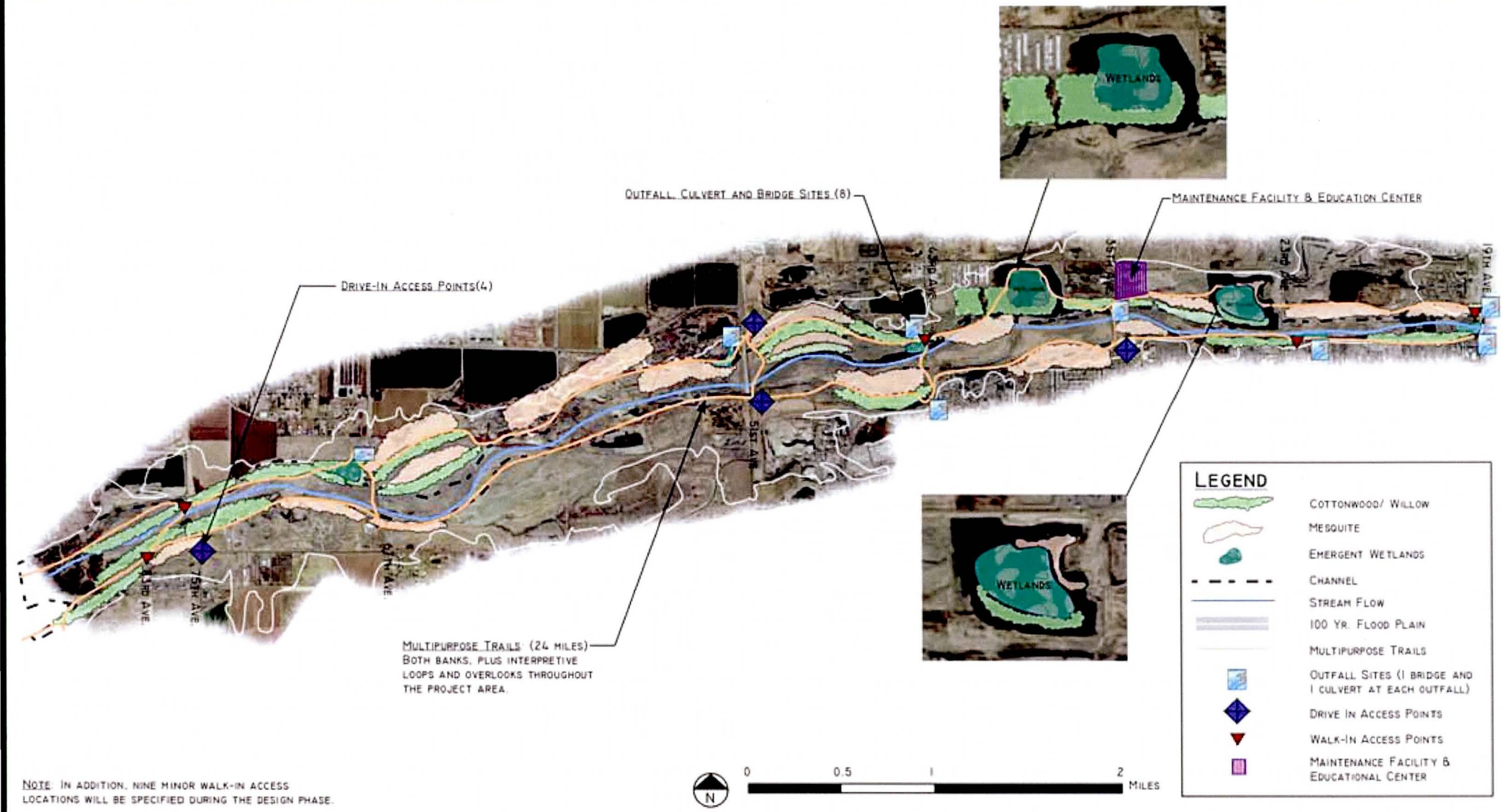
Personnel Daily operation including trail maintenance and repair, irrigation system operation and maintenance, tree and shrub maintenance, sign maintenance, site and visitor security, environmental education programming, restroom cleaning.	**$1,595,061**
Commodities Equipment and supplies for daily operation	**250,000**
Contractual Water, sewer, fleet maintenance, electrical and mechanical	**100,000**
Annual Maintenance Cost	**1,945,061**
Equipment Vehicles, furniture, fixtures and radios	**1,960,000**
FIRST YEAR & ANNUAL O & M COST	**$3,905,061**

Rio Salado Oeste Reach, Recreation Plan

Component	Quantity	Unit Cost	Rec. Cost
Access Point, Maintenance Facility and Edu. Center (35th Ave.)	**1**		
Site Preparation			
Site Prep to include: clearing, grubbing, and grading	1	Lump Sum	$50,000.00
Vegetative Restoration	1	Lump Sum	$150,000.00
Access and Circulation			
Entry Road w/Turnaround to include: curb, gutter, driveway, & road	1	Lump Sum	$150,000.00
Parking Lot	250	$1500/space	$375,000.00
Sidewalks and Ramps	2,500 sf.	$6.00 each	$15,000.00
Multi-Use Trails	555 sy	$6.00/sy	$3,330.00
Bridges and Culverts (small)	4	$7,500 each	$15,000.00
Protection Access Control			
Access Control Gates (vehicular)	2	$7,500 each	$15,000.00
Access Control Gates (pedestrian)	2	$3,500 each	$7,000.00
Handrails	500 l.f.	$50.00 each	$25,000.00
Guardrails	100 l.f.	$50.00 each	$5,000.00
Fencing	500 l.f.	$30.00 each	$15,000.00
Walls	150 l.f.	$125.00 each	$18,750.00
Security lights	18	$4,000 each	$72,000.00
Signage			
Entrance Identification Signage	2	$15,000 each	$15,000.00
Traffic Control (vehicular)	5	$500 each	$2,500.00
Traffic Control (pedestrian)	5	$500 each	$2,500.00
Instructional/Directional	10	$500 each	$5,000.00
Shelters			
Picnic (large)	1	$60,000 each	$60,000.00
Picnic (small)	2	$25,000 each	$50,000.00
Restroom Facility/Comfort Station	1	$250,000 each	$250,000.00
Shelter w/Bulletin Boards	1	$25,000 each	$25,000.00
Trail Shelter w/Railing (large)	1	$40,000 each	$40,000.00
Trail Shelter w/Railing (medium)	1	$30,000 each	$30,000.00
Trail Shelter w/Railing (small)	2	$20,000 each	$40,000.00
Utilities			
Municipal Water Supply and Wastewater Disposal	1	Lump Sum	$100,000.00
Storm Drainage	1	Lump Sum	$20,000.00
Drinking Fountain w/Chiller	2	$5,000 each	$10,000.00
Electical	1	Lump Sum	$50,000.00
Park Furniture			
Benches:	2	$1,500 each	$3,000.00
Off-the-Shelf	5	$800 each	$4,000.00
Recycled/Custom	8	$500 each	$4,000.00
Picnic Tables	5	$1000 each	$5,000.00
Trash Receptacles	10	$500 each	$5,000.00
Interpretive Guidance Media			

Display Boards	16	$600 each	$9,600.00
Interpretive Markers	16	$600 each	$9,600.00
Bulletin Boards	2	$2,500 each	$5,000.00
(*) Environmental Education Center/ Visitor Center	1	Lump Sum	$4,500,000.00
Access Points- 4 drive in (35th, 51st N&S, 75th) and 5 walk in (19th, 23rd, 43rd, 75th, 83rd) Minor Access points in 9 locations.			
Site Preparation			
Site Prep to include: clearing, grubbing, and grading	9	Lump Sum	$250,000.00
Vegetative Restoration (Drive in Access)	4	Lump Sum	$600,000.00
Vegetative Restoration (Walk in Access)	5	Lump Sum	$75,000.00
Access and Circulation			
Entry Road w/Turnaround to include: curb, gutter, driveway, & road	4	Lump Sum	$600,000.00
Parking lot	250	$1500/space	$375,000.00
Sidewalks and Ramps	40,000 sf.	$6.00 each	$240,000.00
Multi-Use Trails (24mi * 5280 * 5ft)	70,400 sy	$6.00 / sy	$422,400.00
Bridges and Culverts (small) @ Canals, and Localized Drainage Areas	10	$7,500 each	$75,000.00
Minor Access points (2 benches, gate, sign)	9	$6000/each	$54,000.00
Protection Access Control			
Access Control Gates (vehicular)	8	$7,500 each	$60,000.00
Access Control Gates (pedestrian)	18	$3,500 each	$63,000.00
Handrails	5,000 l.f.	$50.00 each	$250,000.00
Guardrails	3,000 l.f.	$50.00 each	$150,000.00
Fencing	50,00 l.f.	$30.00 each	$150,000.00
Walls	1,500 l.f.	$125.00 each	$187,500.00
Security lights	100	$4,000 each	$400,000.00
Signage			
Entrance identification signage	8	$15,000 each	$120,000.00
Traffic Control (vehicular)	20	$500 each	$10,000.00
Traffic Control (pedestrian)	27	$500 each	$13,500.00
Instructional/Directional	45	$500 each	$22,500.00
Shelters			
Picnic (large)	4	$60,000 each	$240,000.00
Picnic (small)	5	$25,000 each	$125,000.00
Restroom Facility/Comfort Station	4	$250,000 each	$1,000,000.00
Shelter w/Bulletin Boards	4	$25,000 each	$100,000.00
Trail Shelter w/Railing (large)	9	$40,000 each	$360,000.00
Trail Shelter w/Railing (medium)	4	$30,000 each	$120,000.00
Trail Shelter w/Railing (small)	10	$20,000 each	$200,000.00
Utilities			
Municipal Water Supply and Wastewater Disposal	4	Lump Sum	$400,000.00
Storm Drainage	4	Lump Sum	$80,000.00
Drinking Fountain w/Chiller	12	$5,000 each	$60,000.00
Electical	4	Lump Sum	$200,000.00
Park Furniture			

Benches:	14	$1,500 each	$21,000.00
Off-the-Shelf	40	$800 each	$32,000.00
Recycled/Custom	50	$500 each	$25,000.00
Picnic Tables	40	$1000 each	$40,000.00
Trash Receptacles	75	$500 each	$37,500.00
Interpretive Guidance Media			
Display Boards	50	$600 each	$30,000.00
Interpretive Markers	100	$600 each	$60,000.00
Bulletin Boards	9	$2,500 each	$22,500.00
NOTE:* (*) = *Betterment (Environmental Education Center)			
TOTAL COST (No Environmental Education Center)		**Subtotal**	**$8,932,180.00**
	Contingency	20%	$1,786,436.00
	PED	10%	$893,218.00
	EDC	1%	$89,321.80
	S&A	7%	$625,252.60
		Total	**$12,326,408.40**



NOTE: IN ADDITION, NINE MINOR WALK-IN ACCESS LOCATIONS WILL BE SPECIFIED DURING THE DESIGN PHASE.

RIO SALADO OESTE ECOSYSTEM RESTORATION CONCEPTUAL PLAN
RECREATION PLAN

U.S. ARMY CORPS OF ENGINEERS PARTNERING WITH THE CITY OF PHOENIX, ARIZONA

NOTES:

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Maricopa County, Arizona
Feasibility Study

Appendix M

Wetland Restoration

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532771
LOS ANGELES, CALIFORNIA 90053-2325

RIO SALADO OESTE
Wetland Restoration Report

WASS Gerke and Associates

August 2003

INTRODUCTION

The Rio Salado Oeste project site is located along the Salt River in western Phoenix, Arizona. The study area extends from 19th Avenue to 83rd Avenue within the 100-year floodplain. Land use in the river and along the banks is characterized by residential housing, sand and gravel extraction, automotive recycling, debris disposal at permitted and non-permitted landfill areas, and agricultural fields. Water sources to the project area mainly consist of effluent from the nearby 23rd Avenue WWTP, stormwater drainage, pumped groundwater from dewatering wells, and agricultural tailwater. This report describes 14 outfalls that deliver these flows on a periodic or semi-continuous basis to the Rio Salado Oeste reach of the Salt River. The goal is to assess the opportunities each outfall provides with respect to restoring, preserving, and/or creating sustainable habitat features and to provide concept level ideas for implementation. Further, the potential to realize planned or incidental water quality benefits at each outfall is also assessed at the conceptual level.

BACKGROUND

Historically, the Salt River was a perennial stream. Flow originated in the White Mountains in eastern Arizona with the highest flows typically coinciding with the runoff generated by spring snow melt in the contributing watershed. During the early 1900's

dams were constructed to store and divert river flows into canals for agricultural use, urban development, and flood control as Phoenix grew into one of the largest metropolitan areas in the Southwestern United States. The upstream series of dams have effectively reduced base flows on the river, such that the riparian vegetation historically associated with the Salt River has been destroyed.

Phoenix was developed into an urban city, built from sand and gravel mined from the dry river. In the early days, exhausted gravel pits were used as landfills for municipal and construction debris. The twentieth century left the Salt River in the Phoenix area void of high value riparian vegetation, scarred with pits, and scattered with toxic and non-toxic trash and debris.

With the exception of dam releases, river flows from the mountains were replaced with concrete pipes discharging urban stormwater, agricultural tailwater, and treated municipal and industrial wastewater into the Salt River in and around Phoenix. By the 1980's the quality of water in the river could be characterized by high levels of heavy-metals and pesticides. Improved treatment for municipal and industrial wastewater, the increased use of environmentally friendly pesticides, and stormwater management practices enacted within the watershed have dramatically improved the quality of such discharges. Currently, these discharges support vegetative communities that range from xeric to riparian in nature and provide moderate habitat values at areas proximal to the outfalls. The aerial extent and vegetative character at these sites are dependent upon the temporal occurrence and amount of flow, and the character and quality of the surrounding soils.

The availability of land and water in the Oeste project area allows many opportunities to enhance, restore, or create riparian habitats associated with these outfalls in the Salt River. These efforts will also likely result in water quality improvements to several of the discharges because of the physical, biological, and chemical reactions that take place within the wetland environment. At a minimum, one can likely expect a decrease in oxygen-demanding substances, attenuation and bioconversion of organic compounds including some pesticides, and attenuation/removal of select heavy metals via metal-sulfide complexation which can render them biologically unavailable.

INVESTIGATIONS

Field investigations conducted during May and June 2003 of the study area consisted of visual inspection of surface waters and vegetative communities associated with 14 outfalls that discharge to the Rio Salado Oeste reach of the Salt River. These outfalls provide stormwater, agricultural, and wastewater runoff to the river and were located (GPS coordinates) and characterized based on the following elements:

- presence and character of vegetation: hydro-riparian, meso-riparian, xero-riparian;
- visual assessment of soils in the immediate area of the outfall: clay/silt, sand, gravel/cobbles;
- presence and aerial extent surface water at each outfall.

RESTORATION OPPORTUNITIES

Based on the results of the findings, recommendations can be made whether existing vegetative communities might be restored, created, or preserved. Restoration is recommended at outfalls where vegetative communities are characterized by a mixture of native and non-native species. Restoration and creation is recommended at locations where water appears to be available, soils are capable of retaining sufficient moisture, e.g. the presence of silts and/or clays, and little to no native vegetation is present. Preservation is recommended at outfalls with predominately native vegetation (or at least non-invasive exotics) with limited soil and/or water conditions to support native vegetation.

In general, active restoration activities will likely include the following:

- Addition of soils or amendment of existing site soils;
- Selective removal of exotics, primarily salt cedar (*T. ramosissima*) and giant reed (*Arundo donax*);
- Clearing, grubbing, grading, and excavation to removal of material, increase open water areas, increase emergent marsh areas, and to route water for irrigation;
- Construction of energy dissipation, flow metering, and flow routing structures.

The following sections will now provide photographs and narratives regarding the findings and specific restoration recommendations for each outfall site.

FINDINGS AND RECOMMENDATIONS

The 14 outfalls investigated within the Rio Salado Oeste study area are provided in **Figure 1** which depicts the name and location given to each outfall. Field investigations were performed to document the type of outfall structure, vegetation, and soil, and to comment on its restoration potential. Field data sheets for each location are included in **Appendix A**.

Vegetation at each location was divided into three categories: hydro-riparian, meso-riparian, and xero-riparian. Hydro-riparian communities were delineated based on the presence of perennial water, distance from water source, and several indicator species. Meso-riparian communities were based on the presence of shallow (or perched) groundwater, intermittent flow, or indicator species. Xero-riparian areas contained many of the same species as the uplands, but the plants occurred at a higher density and were typically larger.

SR 07

Outfall SR 07 is a 54-inch concrete culvert with a trash screen situated on the north side of the Salt River channel immediately upstream from the 19th Avenue Bridge at N33° 24' 68.0", W112° 05' 98.5". Annually, the amount of flow expected at this site due to precipitation is approximately 79 acre-ft per year (AF/Yr). At the time of the site visit, a small amount of flowing water from the outfall supported a stand of cattails (*Typha sp.*) immediately below the concrete apron of the outfall. Meso-riparian species included Shoestring acacia (*Acacia stenophylla.*), Desert broom (*Baccharis sarothroides*), and

Chilean mesquite (*Prosopis sp*). The xero-riparian species surrounding the area were unidentified annual grasses, Russian thistle (*Salsola iberica*), and eucalyptus. Soils at this site were primarily sand with some silt.

SR 07: North bank west of 19th Avenue

Outfall SR 07 has a relatively robust meso-riparian community. The site appears to have ideal water supply and soil conditions for the creation of a mesquite bosque. Additional opportunities include removal of trash and debris, and planting of native mesquite (*P. juliflora* var. *velutina*), Paloverde (*Cercidium sp.*), and appropriate ground cover species.

Aerial extent of vegetation at SR 07

SR 31

Outfall SR 31 is a 60-inch concrete culvert with a trash screen, located on the south side of the Salt River channel near 19th Avenue at N33° 24'59.6" W112° 06'00.5". The annual stormwater runoff flow estimate for this outfall is approximately 231 AF/Yr. Below the outfall was a small pool (5 to 10 feet) of open water approximately 2-3 feet deep. Meso-riparian species surrounding the pool included velvet mesquite (*Prosopis juliflora* var. *velutina*), salt cedar (*Tamarix ramosissima*), palm (*Washingtonia sp.*), exotic emergent likely wild taro (*Colocasia esculenta*) and Paloverde (*Cercidium sp.*). Salt bush (*Atriplex sp.*), salt cedar (*T. ramosissima*), and Paloverde (*Cercidium sp.*) were also categorized as meso-riparian species at this site. Soil types included clay/silt and some sand.

SR 31: South bank west of 19th Avenue

Outfall SR 31 has standing water and lush vegetation. The site has potential, due to the water supply and low permeability soils, for the development of a wetland and riparian corridor. Restoration could be achieved with exotics removal, mainly palm and an unidentified emergent plant (likely wild taro), and replacement with native bulrush and sedges. Minor excavation at this outfall could also be used to create a wetland pond and riparian corridor which would allow additional planting areas for willow and cottonwood trees, as well as mid- and under-story riparian vegetation.

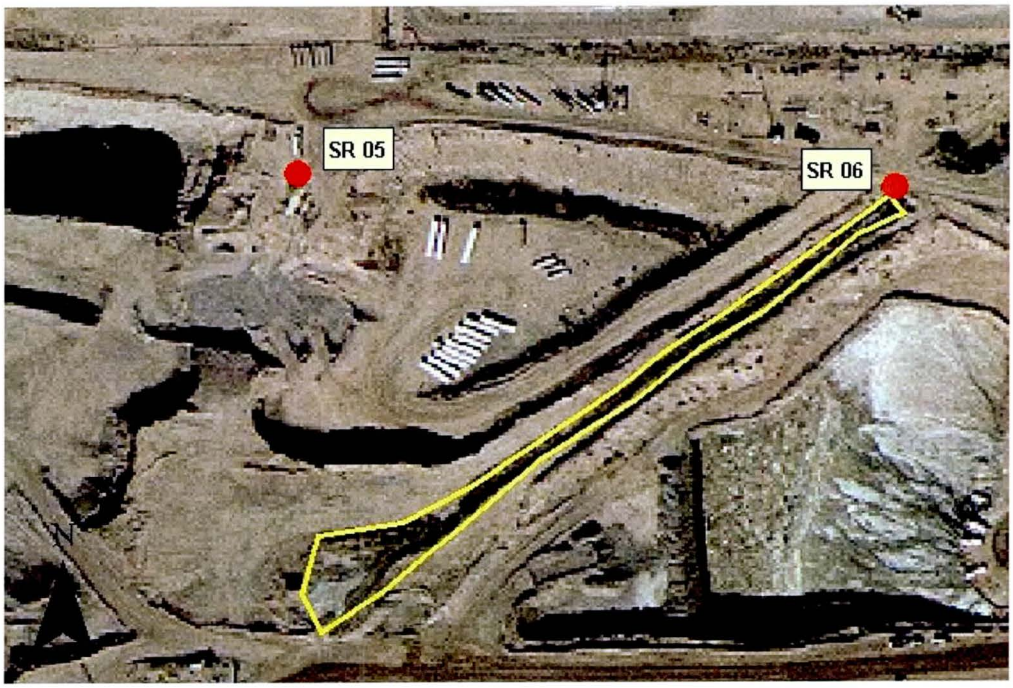
Aerial extent of vegetation at SR 31

SR 06

Outfall SR 06 is a 78-inch concrete culvert with an open channel both upstream and downstream near 22nd Avenue on the north side of the Salt River channel at N33° 25'01.3" W112° 06'59.1". Estimated runoff to this outfall is approximately 561 AF/Yr, but none of the flow reaches the Salt River channel, instead it is routed into a large sand and gravel pit and allowed to infiltrate or otherwise evaporate. An area of approximately 50 ft^2 of standing water between 0-2 feet deep was located below the outfall. Hydro-riparian species included flat-sedge (*Cyperus sp.*), Fremont cottonwood (*Populus fremontii*) Gooding's willow (*Salix gooddingii*), and eucalyptus. Desert broom (*Baccharis sp.*) dominated the meso-riparian community at this site. The xero-riparian species included unidentified annual grasses, Paloverde (*Cercidium sp.*), and salt bush (*Atriplex sp.*). Soils at the site included clay/silt, sand, gravel, and cobble.

SR 06: North bank at 25th Avenue

SR 06 is located within the property of Rinker Materials sand and gravel mine between the 19th Avenue and 27th Avenue on the northern side of the Salt River. This outfall currently receives dry-weather flows and stormwater runoff via vegetated open-channels. SR 06 discharges to sand and gravel pits where the water either infiltrates or evaporates. At this time, the restoration recommendation is to maintain and protect the open channel conveyances leading to the outfall. If land use and ownership changes in the future, the area may provide habitat features that could be used for trail alignments for access to the project.



Aerial extent of vegetation at SR 06

SR 05

Outfall SR 05 included a pair of concrete pipes emptying into a single, large concrete spill pad on the north side of the Salt River channel near 25th Avenue at N33° 25'01.7" W112° 06'78.5". Almost 125 AF/Yr of stormwater runoff was estimated to discharge from this outfall. At the time of the visit, standing water encompassed an area of approximately 20 ft^2 below the spill pad. From the spill pad water discharges to an isolated gravel pit where it infiltrates and or evaporates. Only xero-riparian species such as salt bush (*Atriplex sp.*), unidentified annual grasses, and Paloverde (*Cercidium sp.*) were documented at this site. The dominant soil type was gravel/cobble.

SR 05: North banks at 23rd Avenue

SR 05 is also located within the property of Rinker Materials sand and gravel mine on the north side of the Salt River. The outfall receives dry-weather flows and stormwater runoff. SR 05 also discharges to sand and gravel pits where the water infiltrates or evaporates. Currently, the restoration recommendation is to maintain and protect the open channel conveyances leading to the outfall. Little to no vegetative community exists at this outfall; therefore, an aerial photo is not available for this site.

SR 04

Outfall SR 04 included four 84-inch concrete pipes on the north side of the Salt River channel near 27th Avenue at N33° 24'86.5" W112° 06'98.8". Although this outfall is estimated to discharge 341 AF/Yr, no standing water was visible at the outfall, but open

water was present upstream in an open channel. Meso and xero-riparian vegetation was observed at this site and consisted of species such as Paloverde (*Cercidium sp.*), desert broom (*Baccharis sp.*), Gooding's willow (*Salix gooddingii*), and unidentified annual grasses were found upstream in the invert and side slopes of the open approach channel. The dominant soil types at this site were clay/silt and gravel.

SR 04: North bank near 27th Avenue

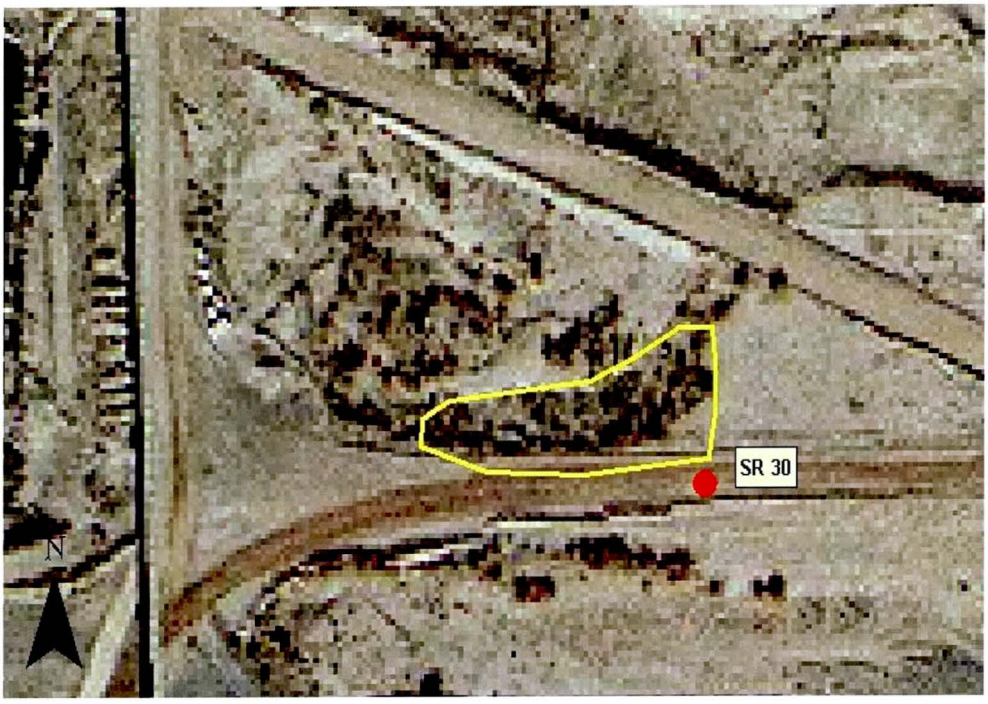
SR 04 is also located within the property of Rinker Materials sand and gravel mine on the north side of the Salt River near 27th Avenue. The outfall receives dry-weather flows and stormwater runoff. SR 04 also discharges to sand and gravel pits where the water infiltrates or evaporates. The restoration recommendation is also to maintain and protect the open channel conveyances. Little to no vegetative community exists at this outfall location; therefore, an aerial photo is not available for this site.

SR 30

Outfall SR 30 is a USGS gauge site (flow and quality) and consists of a large, 108-inch concrete culvert with a trash screen located on the south side of the Salt River channel near 27th Avenue at N33° 24'59.5" W112° 06'98.0". Up to 196 AF/Yr of stormwater flow is estimated to be discharged at this outfall. Minimal standing water (a pool of less than 5 feet across, and less than 6-inches deep) was visible at the site. Saltcedar (*T. ramosissima*) dominated the hydro-riparian vegetation at 27th Avenue. Desert broom (*Baccharis sp.*) and Paloverde (*Cercidium sp.*) were also present and comprise the meso to xero-riparian community at this site. The main soil types were sand and gravel/cobble. A review of the water quality data collected by the USGS for this site indicates a high potential to experience elevated heavy-metal and suspended solids concentrations in flows from this outfall (USGS 1995).

SR 30: South bank east of 27th Avenue

Historically, this outfall has produced significant heavy-metal concentrations and sediment loads. As such, this site could be outfitted with a treatment wetland system designed to manage sediments and the associated heavy-metals. Energy dissipation will likely need to be provided at the upstream end of the treatment wetland, as well as, access to an area that would be designed for periodic sediment removal. Given the potential for high energy flows at this site, the energy dissipation would also serve to route excessive flows to the main channel. Because this outfall flows only in response to storm events, it is recommended that project infrastructure be designed to supply an additional water source to maintain the treatment wetland and riparian area



Aerial extent of vegetation at SR 30

SR 58

Outfall SR 58 is a 60-inch concrete culvert with rock gabions located on the north side of the Salt River channel northeast of 35th Avenue at N33° 24'74.6" W112° 07'99.1". This outfall appears to flow in response to discharges of filtered effluent from the City of Phoenix 23rd Avenue Waste Water Treatment Plant (WWTP). Both standing and flowing water were apparent at this location at the time of the site visit. The size of the pool immediately below the outfall fluctuates over the course of the year as evidence by dried alga along the perimeter of the water body. At the time of the site visit, the pool was approximately 100 ft^2, four feet deep, and fed into a large water body in the Salt River channel. Lush vegetation surrounded the outfall including cattail (*Typha sp.*), velvet mesquite (*P. juliflora* var. *velutina*), salt cedar (*T. ramosissima*) and Paperflower (*Psilostrophe sp.*). Brittle-bush (*Encelia sp.*) dominated the meso-riparian community at this site. Soil types included clay/silt and gravel/cobble.

SR 58: North banks east of 35th Avenue

Outfall SR 58 discharges a large, and currently un-quantified, amount of effluent year-round. The effluent has created a large lake that extends a quarter to one-half mile downstream. The banks of the lake offer enhancement potential by replacing the non-native invasive grasses with bulrush, cattail, and native sedges. Because the area of inundation varies on a temporal basis, perimeter vegetation selection should include facultative as well as obligate wetland species. Consideration should also be given to augmenting the outfall area with cottonwood and willow tree species as long as appropriate soil conditions are present or created.

Aerial extent of vegetation at SR 58

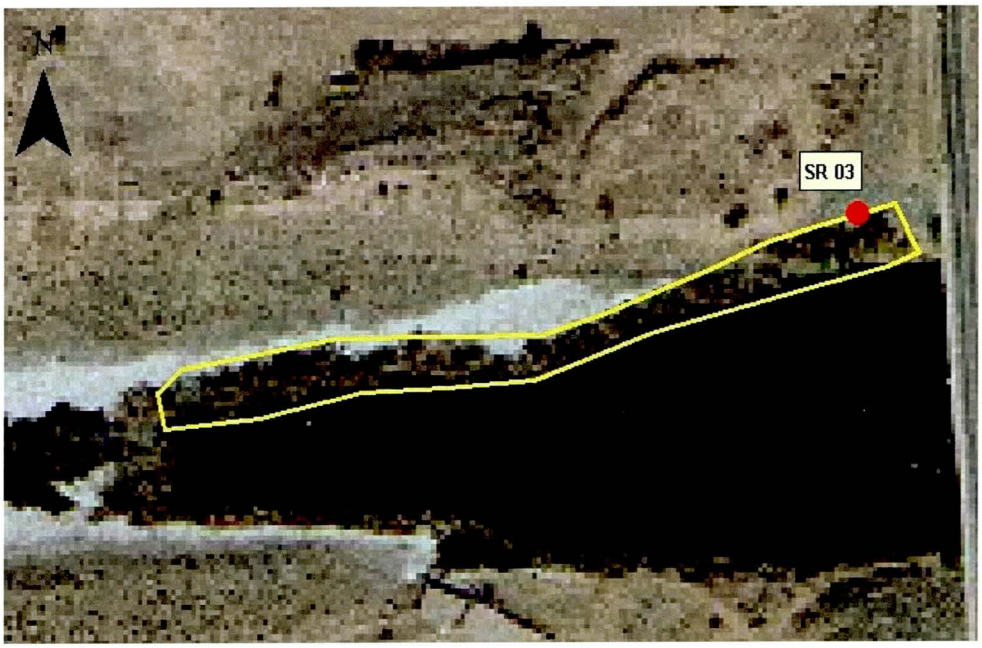
SR 03

Outfall SR 03 is a 75-inch concrete culvert located on the north side of the Salt River channel, northwest of the 35th Avenue Bridge at N33° 24'71.9" W112° 08'07.3". Approximately 224 AF/Yr of stormwater runoff is estimated to be discharged from this

outfall. At the time of the site visit a small pool existed below this outfall structure, and routed into the same in-channel large water body as SR 58. Hydro-riparian species were present at this site including Freemont cottonwood (*P. fremontii*) and Gooding's willow (*S. gooddingii*). Palm (*Washingtonia sp.*) and Paloverde (*Cercidium sp.*) were also present. The dominant soil type was gravel/cobble.

SR 03: North banks west of 35th Avenue

Outfall SR 03, north bank west of 35th Avenue, appears to have sufficient water to support hydro-riparian trees including native willows which could be established along the wetted perimeter. The site could also be restored by the removal of trash, non-native palm trees, and the establishment of a small pocket-forest of cottonwood trees. In both cases native mid- and under-story vegetation should be augmented as well.



Aerial extent of vegetation at SR 03

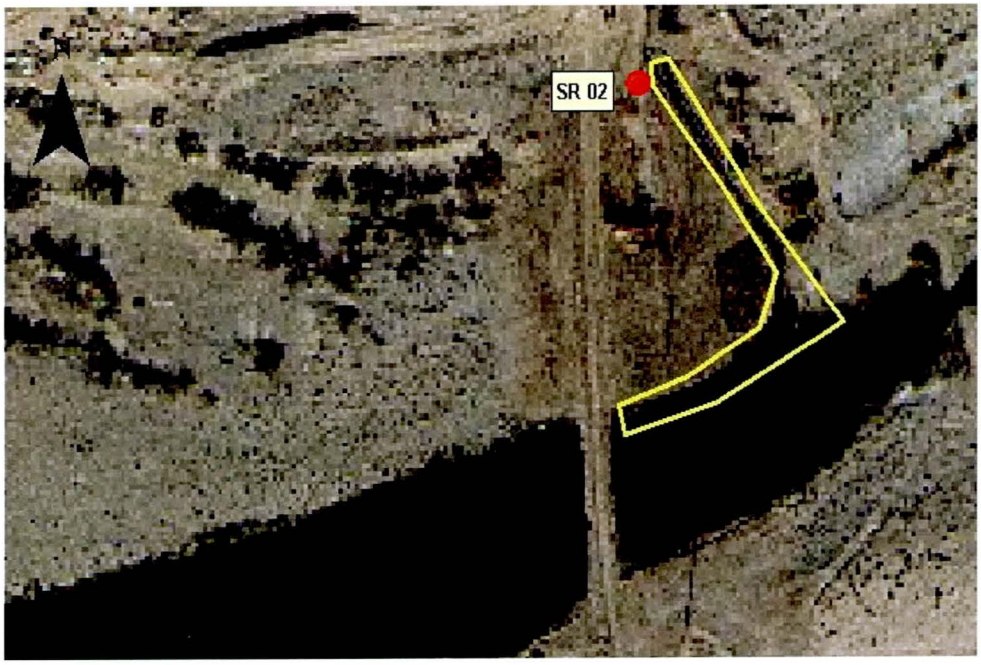
SR 02

Outfall SR 02 is a 90-inch concrete culvert flowing into an unlined canal on the north side of the Salt River channel, near the 43rd Avenue alignment at N33° 24'57.7" W112° 09'08.0". This outfall receives an undocumented amount of irrigation tailwater from Peterson's farm (effluent reuse from the 23rd Avenue WWTP). It is also estimated that up to 274 AF/Yr of stormwater runoff can be discharged from this outfall. At the time of the site visit, both standing and flowing water were visible and flow is routed into a common, large pool of water in the river channel. This pool becomes channelized at the downstream end and continues downstream with intermittent open-water and marsh areas extending all the way to the 51st Avenue Bridge at times of the year. Several hydro-riparian species surround this important water-body, including cattail (*Typha sp.*), salt cedar (*T. ramosissima*), castor bean (*Ricinus sp.*), and sunflower (*Heloanthus sp.*). The meso-riparian species at the site include Paloverde (*Cercidium sp.*), Salt bush (*Atriplex*

sp.), Brittle-bush (*Encelia sp.*), and Russian thistle (*Salsola sp.*). The soil types at this site include sand and gravel/cobble.

SR 02: North bank at 43rd Avenue

Outfall SR 02 is an unlined canal entering from Peterson farms. The water supply at this location supports a corridor of riparian plants, and lake that extends from one-quarter to nearly one mile. Restoration opportunities include planting willows and cottonwoods along the banks of the riparian corridor. In addition, non-native grasses could be selectively replaced with bulrush, cattail, and native sedges. The potential exists at this outfall to divert a portion of the flow downstream several meters from the toe of the north bank to an area that appears to have at one time supported a willow forest. Restoration in that area includes supplying water and plantings. The majority of existing dead snags in that area should be left in place.



Aerial extent of vegetation at SR 02

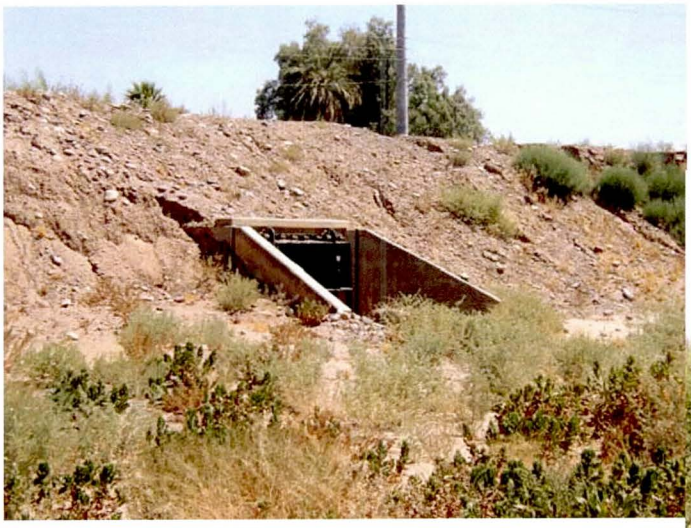
SR 48a

Outfall SR 48a is a 48-inch concrete storm drain with a flood gate on the south side of the Salt River channel near 43rd Avenue, approximately 50 feet west of 48b. No water was visible at this outfall and an estimate of annual discharge is not currently available. Several large hydro-riparian trees currently exist including cottonwood (*P. fremontii*), willow (*S. gooddingii*), Paloverde (*Cercidium sp.*), and mesquite (*Prosopis sp.*). Annual grasses surrounded the site. The dominant soil type was clay/silt with some small gravel.

SR 48a: South bank at 43rd Avenue

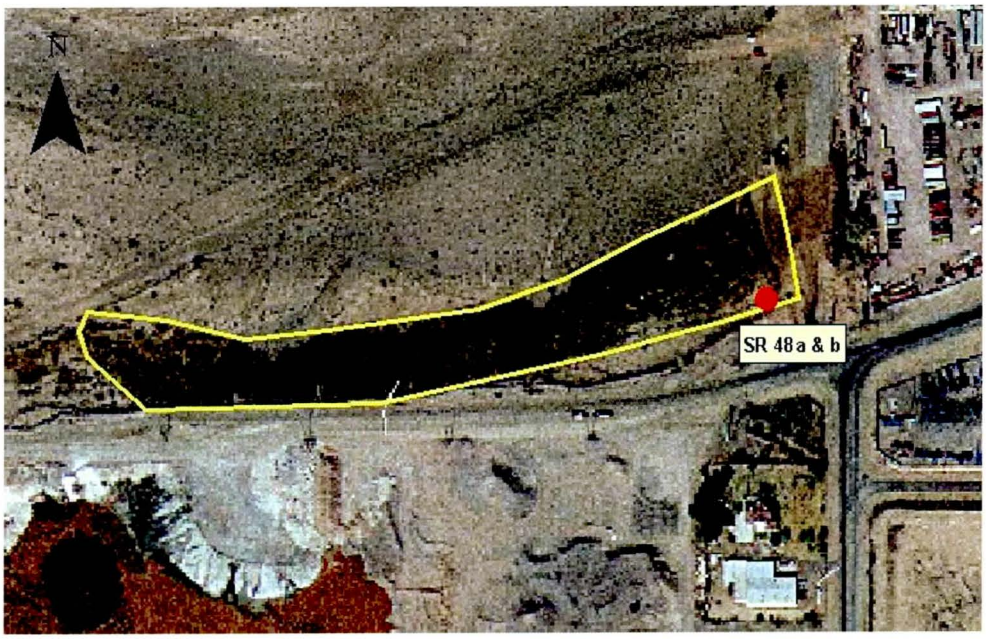
SR 48b

Outfall SR 48b is a large concrete culvert with a flood gate on the south side of the Salt River channel near 43rd Avenue at N33° 24'23.1" W112° 09'08.6". At this time, no information is available with respect to anticipated annual flow volumes from this outfall. At the time of the site visit, no standing water was visible immediately adjacent to the outfall, but standing water was found about 25 feet away in a small channel. Salt cedar (*T. ramosissima*), salt bush (*Atriplex sp.*), Giant Reed (*Arundo donax*), mesquite (*Prosopis sp.*) and Sunflower (*Helianthus sp.*) were the dominant hydro-riparian species at this site. The meso-riparian community consisted mainly of desert broom (*Baccharis sp.*) and unidentified grasses. Clay/silt and sand were the main soils at this outfall.



SR 48b: South banks west of 43rd Avenue

Outfalls SR 48a and 48b appear to deliver sporadic flows to an area of the river bottom that possesses low permeability soils. These soils appear to retain moisture between flow events. The existing community at these outfalls should be restored to reduce the Arundo population and increase native hydro- and meso-riparian species. Reeds (bulrush, spike-rush, horsetail rush, and sedges) could be planted in the shallow standing water and mesquite bosque established to surround the immediate area.



Aerial extent of vegetation at SR 48a & b

SR 47

Outfall SR 47 is a 48-inch culvert on the north side of the Salt River channel just west of 51st Avenue, 50 feet north of SR 01, at N33° 24'52.6" W112° 10'17.4". At this time, no flow estimate is available for this outfall and no standing water was visible at this site during the visit. No hydro-riparian species were evident, but annual grasses and brittle-bush (*Encelia sp.*) were found nearby. The dominant soils were sand and gravel.

SR 47: North banks west of 51st Street

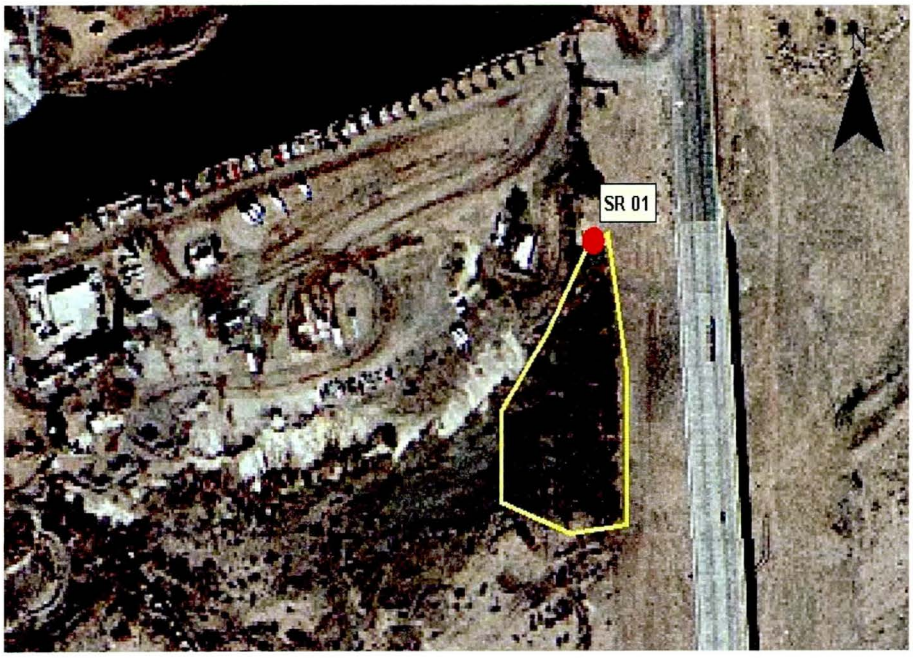
Outfall SR 47 appears to be dry the majority of the year, passing short duration high energy flow events periodically. Trash removal is recommended, at this site. Due to the lack of available water supply and high scour potential during flow events, no restoration is recommended for this site. Creation could be considered pending a thorough investigation of the need for energy dissipation and the provision of a supplemental water source and appropriate soils.

SR 01

Outfall SR 01 is a 96-inch culvert without a trash screen on the north side of the Salt River channel near 51st Avenue at N33° 24'525" W112° 10'174". The stormwater runoff discharged from this outfall on an annual basis is approximately 274 AF/Yr. A small pond of standing water approximately 3-4 feet deep was present directly below the outfall. Hydro-riparian vegetation existed within 5-10 feet of the standing water that included: cattail (*Typha sp.*), willow (*S. gooddingii*), Paloverde (*Cercidium sp.*), mesquite (*Prosopis sp.*) and Sunflower (*Helianthus sp.*). Meso-riparian species at this site included unidentified annual grasses, desert broom (*Baccharis sp.*), and Paperflower (*Psilostrophe sp.)*. Silt and gravel/cobble were the dominant soil types at this site. As was the case with the majority of the outfalls visited, trash and debris occupy significant portions of the sites and any restoration activities should include removal of such materials.

SR 01: North bank west of 51st Avenue

Outfall SR 01 has a variety of native willow and cattails surrounding the open water. Protection/preservation is suggested for the immediate region. Nearby salt cedar could be replaced with bulrush and spike rush (e.g. *Schoenoplectus martine, Eleocharis sp.*) in moist soils and mesquite in drier regions. An under-story/groundcover dominated by *Anemopsis californicus* (Yerba Manza) could likely be established under the canopy species. If desired and pending a site specific water budget, flow may be available or could be supplied via project infrastructure that could be routed from this location to support downstream features such as a cottonwood forest or mesquite bosque.



Aerial extent of vegetation at SR 01

SR 49 & SRP 67th Avenue Drain

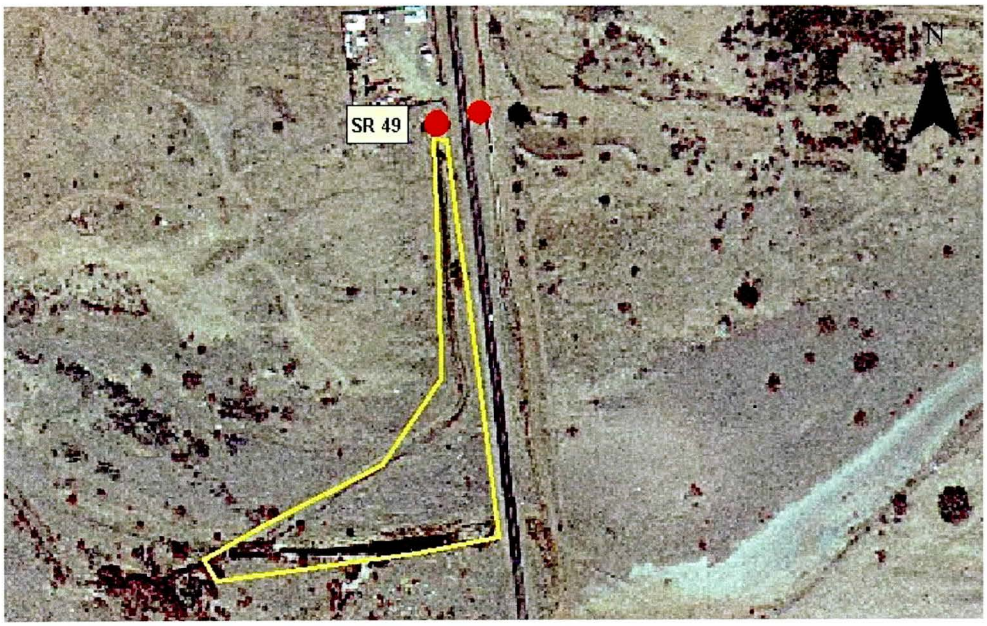
Outfall SR 49 & the SRP 67th Avenue drain consists of two open, concrete-lined channels leading from 96-inch concrete culverts on the north side of the Salt River channel near 67th Avenue at N33° 24'01.0" W112° 12'24.9". Both channels transport a combination of

agricultural and urban runoff to the Salt River channel over the course of any given year. It is estimated that the stormwater runoff discharged from these outfalls is approximately 558 AF/Yr. In addition, 1,044 AF/Yr of irrigation water is discharged from the SRP 67th Avenue Drain. No water was visible in the channel on the west side of 67th Avenue (SR 49), but flowing water was apparent in the eastern channel (SRP drain). Both channels empty into a standing pool of water on the west side of 67th Avenue. Hydro and meso-riparian species currently present included: Paloverde (*Cercidium sp.*), desert broom (*Baccharis sp.*), Canyon Ragweed (*Ambrosia ambrosioides*), salt cedar (*T. ramosissima*), and mesquite (*Prosopis sp.*). The dominant soil type is clay/silt.

SR 49:
North bank west of 67th Avenue

SRP 67th Avenue Drain:
North bank east of 67th Avenue

Outfalls SR 49 and the SRP 67th Avenue drain discharge into open channels that enter the Salt River from the north bank. The SRP 67th Avenue drain flows regularly with agricultural return flows, while SR 49 typically flows in response to runoff generating storm events. During the site visit the water appeared muddy in color, and as such, sediment removal would likely improve water quality. This is especially so since pesticides and other organic contaminants are often bond to the sediment in agricultural tail water. Restoration through the creation of a treatment wetland area is recommended to reduce sediment loads. Such a system would likely entail the creation of a forebay structure to dissipate energy, route flows, and provide initial settling. Water would then flow to a densely vegetated emergent marsh area designed for sediment removal. Treated water would be discharged into the existing open channel system and ultimately the existing riparian area located approximately ¼-mile downstream of 67th Avenue. Restoration of the existing riparian area would entail exotic plant removal, debris removal, and establishment of additional native vegetation.



Aerial extent of vegetation at SR 49

RECOMMENDATIONS

Table 1 lists the recommendation for each site.

Table 1: Site specific recommendations

Site ID	*Location*	*Create*	*Enhance*	*Protect*	*Comments*
SR 07	19th Avenue NW		X		Trash removal and increase natives; enhance mesquite bosque and Paloverde complex
SR 31	19th Avenue SW	X	X		Wetland and riparian corridor
SR 06	22nd Avenue N			X	Protect Upstream Conveyance Channel Vegetation
SR 05	25th Avenue N			X	Protect Upstream Conveyance Channel Vegetation
SR 30	27th Avenue SE	X	X	X	Trash removal, limited potential for increasing habitat, Create Treatment Wetlands for Water Quality Improvements
SR 04	27th Avenue N			X	Protect Upstream Conveyance Channel Vegetation
SR 58	35th Avenue NE		X		Augment wetland plant species with bulrush and cattails
SR 03	35th Avenue NW		X	X	Replacement of palm with willow and cottonwood
SR 02	43rd Avenue N	X	X	X	Add cottonwood and willow trees in the channel banks and bulrush and cattails in the shallow muds. Create diversion channel to historic forest area adjacent to N. bank.
SR 40	43rd Avenue S		X		Remove exotics (Arundo and salt cedar)

Table 1 cont'd

Site ID	*Location*	*Create*	*Enhance*	*Protect*	*Comments*
SR 01	51st Avenue NW		X	X	Trash removal, bar screening, bulrush, cattails, cottonwood, willow.
SR 47	51st Avenue (50 ft North of SR 01)		X	X	Trash removal only
SR 49	67th Avenue	X	X		Trash removal and the development of a settling pond to remove fine sediments from agriculture.

WATER SUPPLY VERSUS AERIAL EXTENT OF EXISTING HABITAT

The annual amount of water discharged from each outfall as estimated from regional regression equations for precipitation and gauge data for dry-weather flows was compared to the aerial extent of existing habitat (vegetative cover) in an attempt to develop a predictive relationship for subsequent restoration efforts to be focused at outfalls throughout the Oeste Reach of the Rio Salado. If one includes the combined data set for both precipitation and dry-weather flows, no real trend appears ($R^2 = 0.53$). Given that the annual precipitation is only on the order of 9 inches per year, the result indicates that a substantial amount of dry-weather flows enter this reach of the river and that dry-weather discharges such as those from the 23rd Avenue WWTP or from Peterson Farms (SR 02) likely support more vegetation than from runoff generating storm events. When the data set is reduced to include only those outfalls that receive storm water flows (Table 2), the relationship improves dramatically ($R^2 = 0.95$) as seen in Figure 2.

Table 2. Area versus existing habitat acreage at outfalls with runoff estimates.

Outfall Name	Existing Habitat (Acres)	Annual Runoff Amount (Acre-Ft)
SR 01	1.6	274
SR 03	0.9	224
SR 07	0.1	79
SR 30	0.6	196
SR 31	1.3	231
SR 49	3.5	558

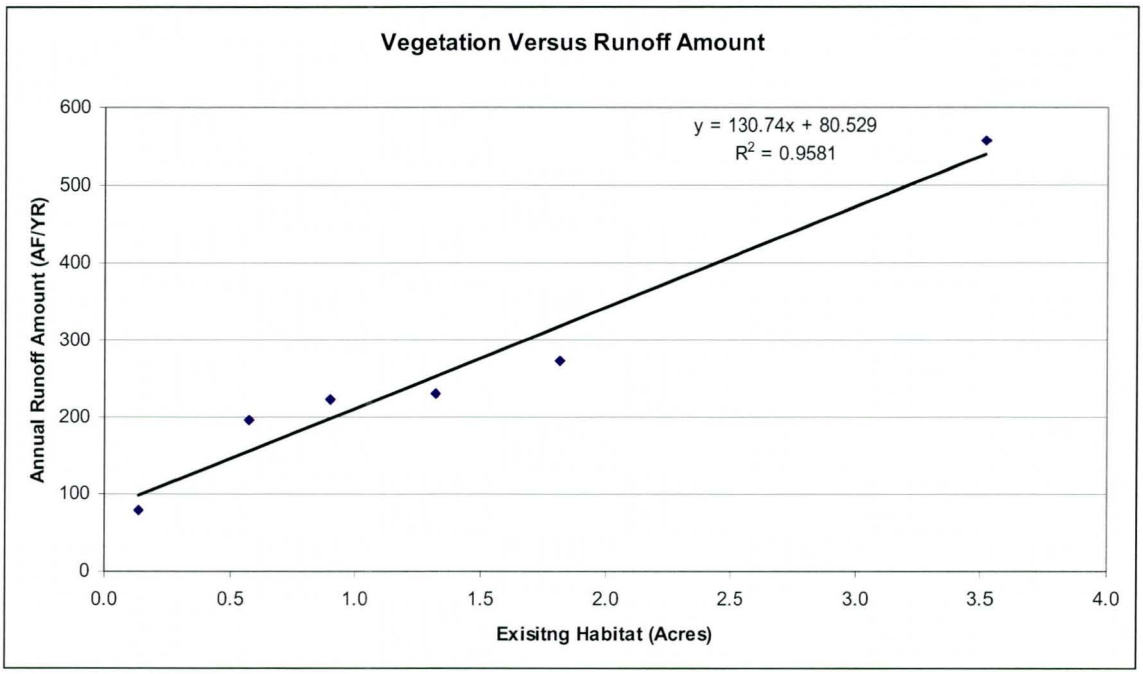


Figure 2. Plot of the existing habitat acres versus the annual runoff estimated for selected outfalls into the Oeste reach of the Rio Salado. Outfalls receiving process water from Sand and Gravel Operations were not included.

Although the relationship developed can likely be used to guide restoration activities associated with the outfalls, the data reveal how important dry weather discharges have been and continue to be to the development and sustenance of riparian habitat associated with outfalls. As such, it is recommended that restoration designs consider a means of supplying supplemental project water to sustain existing habitat should the dry weather

discharges be eliminated through future conservation measures or changes in the land use enacted in the contributing watershed.

OPERATIONS & MAINTENANCE ROADWAY ACCESS TO OUTFALL AREA(S)

High quality riparian habitat is located downstream of several outfalls in the Oeste reach of the Rio Salado. Such existing habitat, if preserved and augmented, could form the basis for full-scale restoration efforts. Because these features are located along the bank of the project, conflicts can occur between the operations and maintenance (O&M) roadway alignment and the discharge from the outfall(s). The conflict arises when high energy discharges from the outfall scour/erode the O&M roadway features placed downstream of the outfall, or roadways are impassable due to flow depth or velocity.

This section focuses upon ways of minimizing such conflicts through alignment, design, and operational methods. Careful thought in the conceptual stages of the Rio Oeste should be used to route the alignment of the O&M roadway through the project. Questions to be answered and or considered include: does the sponsor really need all-weather access to both sides of each outfall; does the alignment necessarily need to be downstream of the outfall discharge point or can the alignment route on the bank side of the outfall; does O&M access have to be contiguous along both sides of the channel?

If it is determined that all-weather access is required immediately adjacent to or downstream of the outfalls then there are several options to be considered in the conceptual phase that if adopted at that time can result in cost-effective solutions that maintain the character and extent of the existing habitat. Such considerations include

bridging the outfall, re-routing a portion of the high energy flows, and provision of energy dissipation structures. Such solutions can be independent or considered together to derive the desired result during design. In all cases, the overall goal is to provide adequate access to the outfall while preserving, and in some instances, restoring riparian habitat.

Finally, some consideration should be given to the use of "wet" crossings at outfalls that have minimal potential to discharge high energy flows to the project. Such a crossing (albeit was likely not an engineered crossing) is currently established at the SR 02 outfall (North bank, at 43rd Avenue). Such crossings are characterized by hard rock bottoms with 0 to 16 inches of flow depth. Although not a pedestrian crossing, such features can be used in areas of the project where visitation is restricted to O&M or project personnel.

In summary, there are several outfalls that discharge to the Rio Salado Oeste project that currently support riparian habitat. As the project develops, there will be times when access to these structures will be required for operation and maintenance activities, and at selected areas, by public visitors. Paramount is the ability of these structures to pass large flows while not destroying access point(s) or the existing riparian habitat. Special attention during the conceptual design phase of this project to these areas must be given by the design team so that economical and functional access will be provided. If consideration is left until the final design phases, costs alone may sway the team and result in loss of existing habitat.

CONCLUSIONS

Appropriate soil characteristics, water supply and quality are essential elements of riverine based ecosystem restoration. Paramount to guiding the development of restoration recommendations is the premise not to degrade desirable habitat areas that are currently associated with a given existing outfall. Prior to implementing any of the recommendations contained within this report, site specific water budgets should be refined to ensure that enhancement is realistic given the amount of water delivered at an outfall. Such information can also be used to assess the need for augmenting dry-weather and stormwater discharges with project infrastructure and water supply. This is especially important for outfalls like SR 02 (N. Bank at 43rd Avenue) where there may be an opportunity to divert a portion of the existing flows to an area that appears to have historically supported a riparian area. Further, the need for importing soil to a site or amending existing soils must also be defined on a site-specific basis and supported by appropriate agronomic testing and water holding analyses prior to implementing restoration enhancement or creation efforts. At least one potential borrow site has been tentatively identified (pending quality and engineering analyses) at the Rinker Materials facility located in the NW quadrant of 19th Avenue and the Salt River. Lastly, the water quality discharged from outfalls that serve agricultural (SRP 67th Ave. Drain) and industrial land use's (SR 30) should be determined so natural treatment system(s) can be designed and constructed if desired.

Literature Cited

Kearny, T.H., R.H. Peebles, and Collaborators, 1997. *Arizona Flora.* University of California Press, Los Angeles, CA.

USGS, 1995. Statistical Summary of Select Physical, Chemical, and Microbial Characteristics, and Estimates of Constituent Loads in Urban Stormwater, Maricopa County. Thomas Lopes *et al.*

Figure 1 Outfall Location Map
Appendix A Field Data Sheets

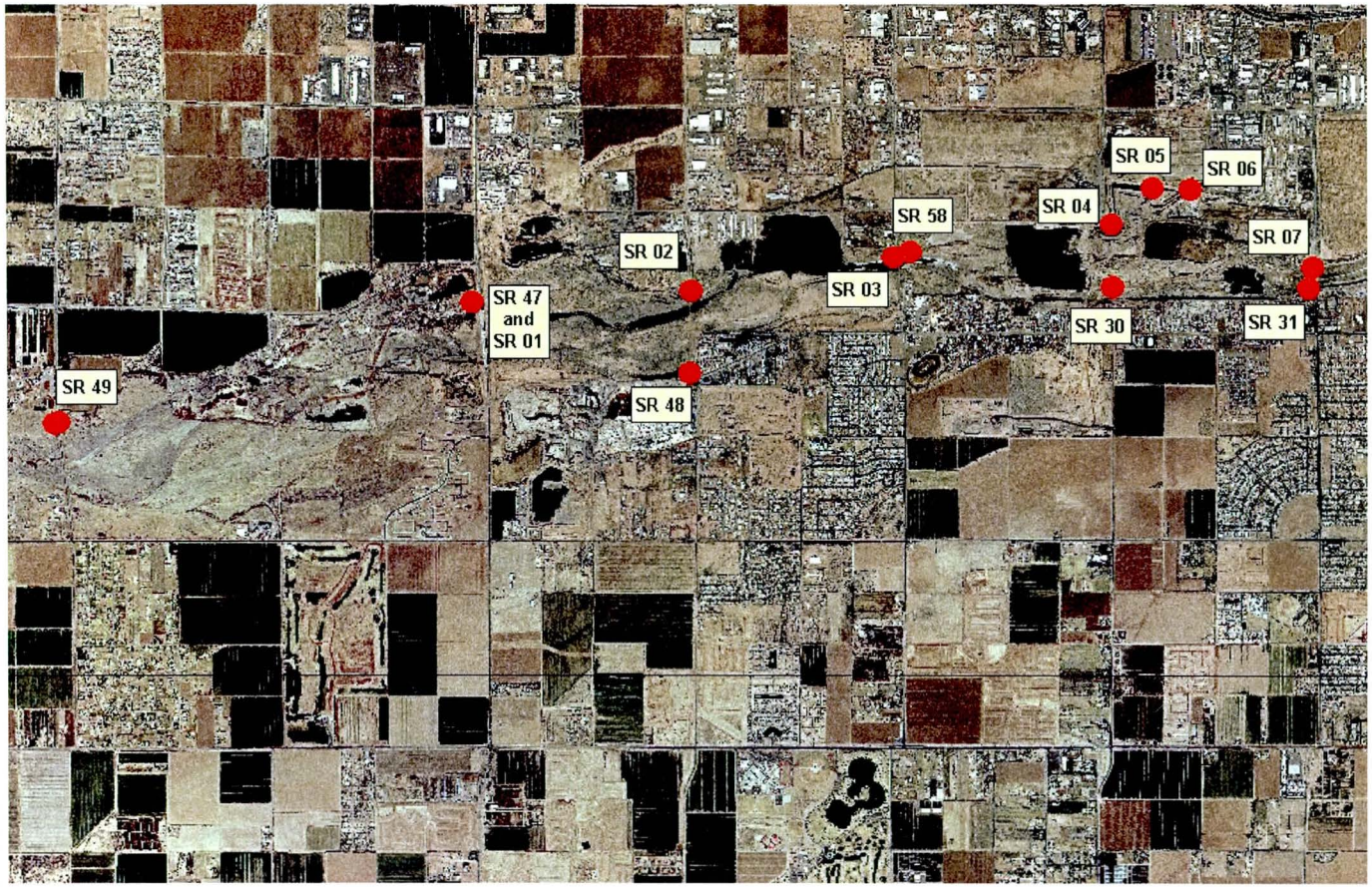


Figure 1. Rio Salado Oeste Outfall Location Map

APPENDIX A – Field Data Sheets

Stormwater Outfall field notes from 6-23-2003
Rio Salado Oeste

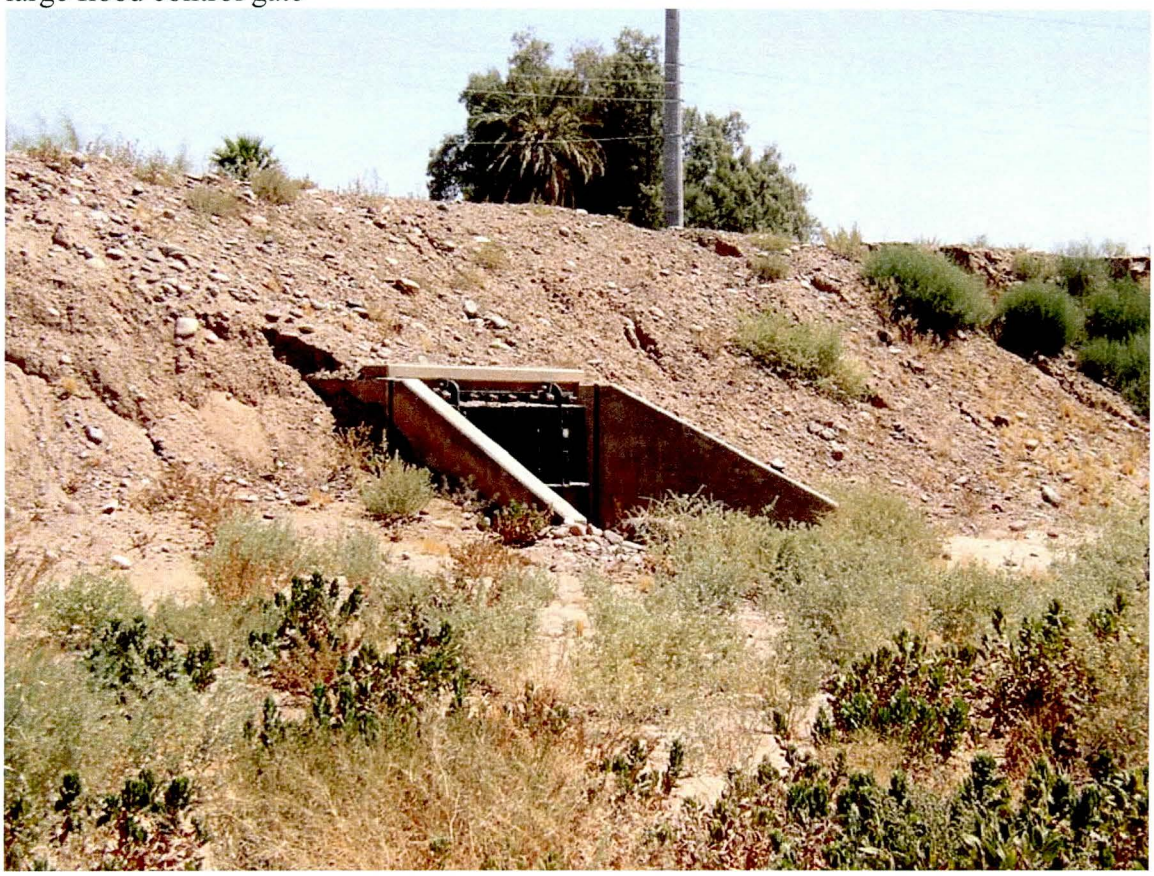
SR 47 51st Avenue and Salt River—North side 50 feet north of SR 01

SR 47 Vegetation (good) — cattails, reeds, etc.

SR47 Western pond turtle

45th Avenue and Salt River
Erosion from South bank in Vulcan operation

SR 48 45th Avenue and Salt River—South Side
actually 43rd Avenue and Salt River
large flood control gate



SR 48 45th Avenue and Salt River—South Side
actually 43rd Avenue and Salt River
standing water and lots of vegetation—some Arundo, reeds,

SR 30
27th Avenue and Salt River—South Side
large concrete pipe with trash screen

Sand and Gravel drain north side west of conveyer

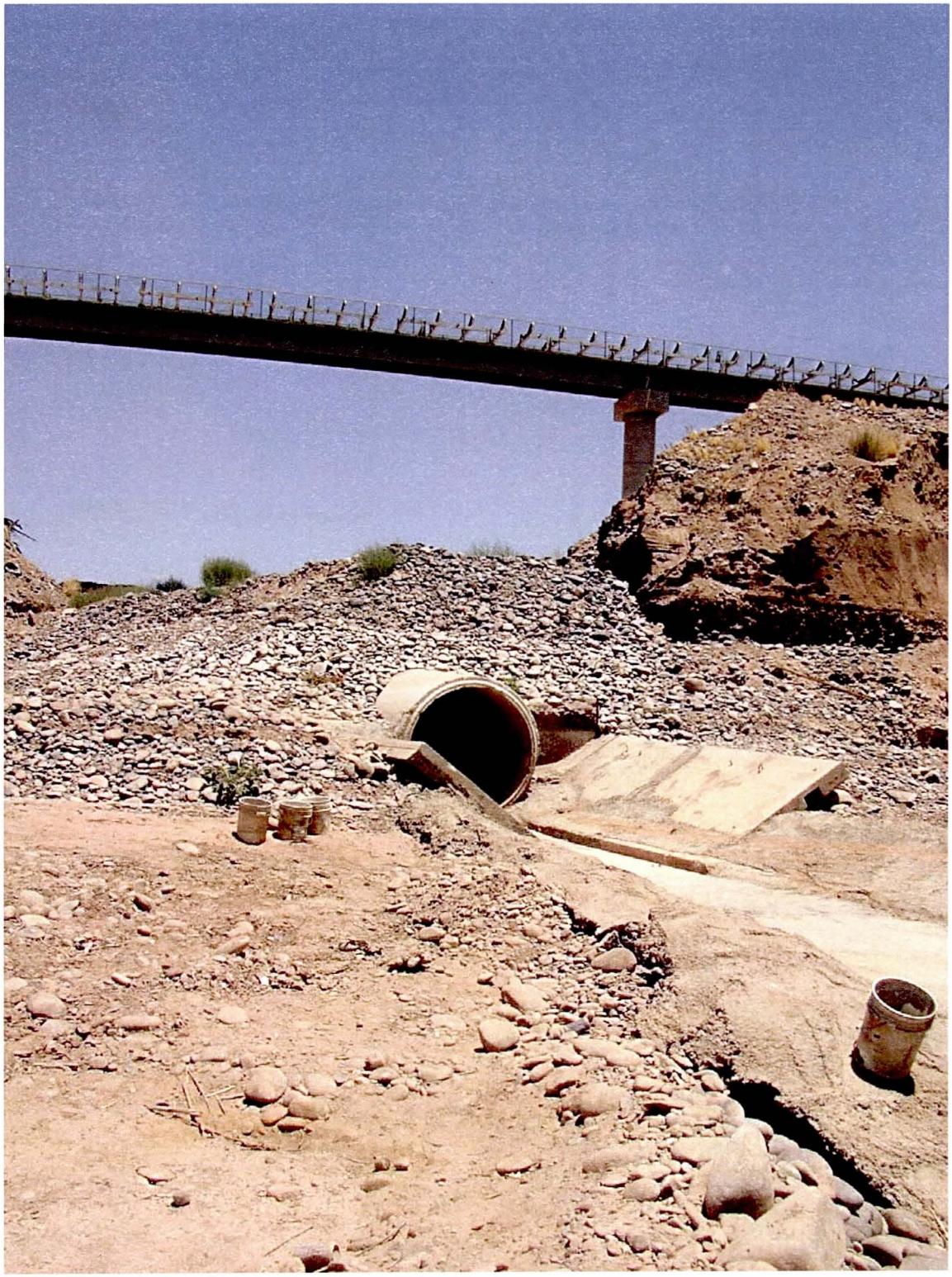
SR 48 45th Avenue and Salt River—South Side
actually 43rd Avenue and Salt River

SR 03 35th Avenue and Salt River—North Side
USGS gauging station, large concrete culvert

SR 03 35th Avenue and Salt River—North Side
Flowing water and pond
Good vegetation including cottonwood, palo verde, willow, and cattails

SR 04 27th Avenue and Salt River—North Side
flowing water north of River channel, directly adjacent to gravel mining operation
Photo 12 is of large deep gravel lake with very little vegetation downstream from SR 04

Sand and gravel culvert, south west of conveyer



SR 05 25th Avenue and Salt River—North Side
couldn't find where the outfall started, but we think we found where both SR 05 and 06 empty into large gravel pit with deep water
Think that Photo #8 is a large open water wetland cause from the outfall.
Right in the center of the gravel pit operation

SR 06
22nd Avenue and Salt River—North Side
same as SR 05, we think we may have found where water empties, but couldn't determine exactly where the water originated.

SR 07 19th Avenue and Salt River—North Side
large round concrete culvert with trash screen
small communities of plants (reeds, cattail, etc)
a little flowing water

US Army Corps of Engineers
Los Angeles District

RIO SALADO OESTE
Maricopa County, Arizona
Feasibility Study

Appendix N

MONITORING
AND
ADAPTIVE MANAGEMENT

February 2006

U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT
PLANNING DIVISION, WATER RESOURCES BRANCH
P.O. BOX 532771
LOS ANGELES, CALIFORNIA 90053-2325

Appendix N
MONITORING AND ADAPTIVE MANAGEMENT

TABLE OF CONTENTS

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Table 1 Acres Of Habitat Restored With The Tentatively Recommended Plan 4

INTRODUCTION

The Salt River, although highly modified and controlled, remains a natural river system where changes may occur. While planning for this project has accounted for the possible factors affecting the study area it is inevitable that uncertainty will remain with the outcome of the recommended plan. Implementation of a monitoring and adaptive management plan will not alleviate all uncertainty but will provide flexibility to account for changing environmental conditions and new information as well as measure project success.

The Monitoring and Adaptive Management Plan is an essential element in the overall implementation of the proposed plan. It provides a mechanism to evaluate the effectiveness of the restoration measures implemented in this project and to implement adaptive changes, if required, to realize project objectives.

As described in ER 1105-2-100 Planning Guidance Notebook Page 3-25, monitoring and adaptive management:

"*Monitoring may be necessary to determine if the predicted outputs are being achieved and to provide feed back for future projects. The cost of monitoring included in the total project cost and cost shared with the non-Federal sponsor shall not exceed one percent of the total first cost of ecosystem restoration features. For complex specifically authorized projects that have high levels of risk and uncertainty of obtaining the proposed outputs, adaptive management may be recommended. The cost of the adaptive management action, if needed, will be limited to 3 percent of the total project cost excluding monitoring costs.*"

It is assumed that Monitoring and Adaptive Management Plan for the tentative recommended plan will be 4% of total construction or $3.9 Million over 5 years. The plan includes cost shared monitoring and adaptive management actions during the first five years after initial project implementation. After the first five years, monitoring and/or adaptive management becomes the responsibility of the local sponsor (City of Phoenix). However, the local sponsor can use this plan to help guide monitoring efforts and refine the project features such that project goals and objectives are achieved.

It is recommended that the plan be reevaluated and updated during PED taking into account lessons learned from the Rio Salado and Tres Rios projects in the immediate vicinity as well as other projects such as Va Shly'ay Akimel further upstream on the Salt River. Since this project, if implemented, will complete the restoration of the Salt River from approximately I-10 to the confluence of the Agua Fria that entire 21 mile reach should be considered and monitored as one system. A monitoring and adaptive management plan may be applied to the entire area as a whole.

GOALS AND OBJECTIVES

The primary study objective was to restore native riparian, wetland, and floodplain habitats and manage undesirable plant, fish and wildlife species. In order to carry out

that objective several different measures are required including, provide water supply and distribution, restore an active channel, and implement revegetation.

To accomplish that objective the goal is to restore the necessary native vegetation within the study area. The following table includes the projected acreages of habitat assumed to be restored with the tentatively recommended plan.

Table 1 Acres Of Habitat Restored With The Tentatively Recommended Plan

Habitat	Acres
Channel	170
In Channel Wetlands	34
Cottonwood/Willow	375
Mesquite	417
Wetlands	156
Scrub Shrub	410

SUCCESS CRITERA EVALUATION

Criteria for successfully achieving the goal of native riparian habitat restoration are recommended as: 1. the restored vegetation listed above have an 80% survival rate, 2. project features are resilient to floodplain changes, and 3. increased wildlife use of the project area, and 4. public recreation use increases and does not conflict with restoration project.

RECOMMENDED METHODS

While there are potential scientific lessons to be learned from restoration projects this plan is not intended to be a rigorous scientific investigation. It is designed as guidance that will provide a means for cost effective, reliable, and effective monitoring of success of the ecosystem restoration project. The purpose of this monitoring is to ensure that the project is functioning as it was intended and to identify areas where improvement to the function can be made as necessary.

Variables to be Sampled

Aerial Mapping

Prior to and immediately following construction digital orthophotography of the project area should be obtained and vegetation mapped. This will provide an overall baseline map of the project area and verify modifications performed during construction. At a minimum the cover types identified in the recommended plan should be quantified.

Vegetation Success

Species composition and densities from implementation will be known. Monitoring of vegetation should be completed annually to determine survival and percent cover. Assessing survival will be accomplished through observations at each plot of restored habitat and can be accomplished in conjunction with percent cover measurements. The sampling recommended below follows sampling performed in measuring existing habitat conditions and described in Appendix I, Functional Assessment.

Sampling

A 100m long transect will be established generally parallel to the river channel. Along the transect establish a series of 10m x 10m quadrats, creating a belt transect. Within the quadrat species composition and survival should be noted by randomly locating a 1m X 1m square. The following data should be recorded based on the methods stated below:

Percent herbaceous cover	Record the number of decimeter hits within each meter interval. A hit is defined as any vegetation within a 10cm radius of the rod, per vertical decimeter. Estimate volume above 10m as either three or seven hits per interval. These estimations can be based on comparison with lower intervals where hits can be directly measured.
Percent shrub cover	Record the number of decimeter hits within each meter interval. A hit is defined as any vegetation within a 10cm radius of the rod, per vertical decimeter. Estimate volume above 10m as either three or seven hits per interval. These estimations can be based on comparisons with lower intervals where hits can be directly measured.
Percent tree canopy	Record the number of decimeter hits within each meter interval. A hit is defined as any vegetation within a 10cm radius of the rod, per vertical decimeter. Estimate volume above 10m as either three or seven hits per interval. These estimations can be based on comparisons with lower intervals where hits can be directly measured.

Avian surveys

The construction of the Audubon center at Central Avenue provides an opportunity to involve the public in project monitoring. Recommend that annual bird counts be coordinate with Audubon to include seasonal point count surveys throughout the restored river reaches. This should include at least one season's counts prior to construction and annually after construction.

Water Supply and Distribution

Successful restoration in this arid environment depends on water above anything else. Monitoring of the irrigation system for its ability to effectively distribute water to the restored vegetation will be necessary and perhaps an area where adaptive measures may be taken. It is also assumed at this time that lessons from other projects may be applied prior to construction.

Irrigation
Success of irrigation practices to provide sufficient water to restored habitat will be evaluated through observation and measurement of distribution and vegetative survival. Modifications to methods or quantities may be necessary to ensure survival or it may be possible to reduce water demand.

Storm water
Monitoring of storm water quantity and quality should be conducted annually. Quantities of average runoff from rainfall were calculated in the feasibility study and are included in the report. Dry weather flows however were not quantified or estimated and if sufficient may contribute to irrigation on a site specific basis. Water quality was not assumed to be a concern in the study and it is assumed that wetland vegetation will sufficiently improve poor water quality. Monitoring will either confirm or identify if corrective action is necessary.

Active Channel function

The proposed restoration includes grading and excavation to reestablish an active river channel. That channel will be an average of 5ft depth and vary in width from 200-400 feet. It is assumed that the channel will migrate slightly within this range and will change as flows occur. No stabilization was found to be necessary in project modeling other than at the proposed grade control structure downstream of the 35th Avenue Bridge. If a flow event occurs the channel should be evaluated for its performance and ability to maintain stability and function. It is assumed that where water is available vegetation will regenerate much like on Rio Salado upsteam. Seasonal flows within the channel should be measured annually and vegetation documented.

Photo points

Photo points should be established through the project area for documentation of project changes. These points should be accessible during flood events and in areas that will not be obscured as vegetation grows. Photographs should be taken prior to construction, seasonally during construction, and seasonally each year following construction. This will provide visual documentation to changes within the project area and confirm other measurements taken above.

Additional Monitoring

Insects: Mosquito monitoring should be done annually during the Operations and Maintenance period to address concerns regarding disease vector control. Monitoring should include establishing a baseline prior to construction of the project features. Such a baseline would consider routine sampling of both adult and juvenile forms of mosquitoes during the months of April through October at a minimum. Such information provides insight into the existing mosquito population dynamics and may be used to guide monitoring and management activities during and after construction.

DOCUMENTATION

Proper documentation of the monitoring efforts serves two primary purposes. First, the documentation should provide a clear picture of the project results so current conditions can be easily identified and the appropriate adaptive management measures can be applied, if necessary. Second, documentation should be easily assessable so that future projects can reference the procedures used and learn from the planning or adaptive management measures taken.

The Corps, in cooperation with the City of Phoenix, will write an annual report at the end of each of the first five years post construction. This report should include a written description of current conditions as well as the results of any surveys conducted, geo-references and maps for the area covered in the report, topographic survey results identifying all significant features (planting sites, on-going mining operations, etc.) and a well documented photographic record including photos from before, during and after construction. The exact photo point locations should be fixed using GPS coordinates so that an exact photograph can be repeated for all submissions.

After the first five years, any continuing monitoring and adaptive management will be at the discretion of the local sponsors. The City will be responsible for preparing the monitoring reports and for funding and implementing any modifications necessary to ensure the success of the project.

ADAPTIVE MANAGEMENT

The detailed Monitoring and Adaptive Management plan to be completed during PED will take into account lessons learned from both Rio Salado and Tres Rios projects and will identify adaptive management criteria and measures required for implementation of the Oeste project.

It is recommended that a Technical Committee be established to provide advice pertaining to adaptive management measures if features do not achieve the identified goal and objectives. That committee will include representatives from the Corps of Engineers, City of Phoenix and the Flood Control District of Maricopa County. It is also recommended that representatives of resource agencies (US Fish and Wildlife Service, Arizona Game and Fish) local academic institutions (Arizona State or University of Arizona) and non government organizations such as Audubon be represented on the technical committee.

Flexibility is essential to adaptive management success. This should be in the form of design contingency plans and flexible funding availability. During PED, contingency plans should be developed for situations that, while not predicted to occur, may occur given varying environmental, social, or structural conditions. These may include

accounting for a variety of site-specific soil conditions, changes in land use immediately outside of the project area, or flooding.

The allotted funding for monitoring is up to 1% of the total project cost. These funds are cost shared 65% to 35% between the Corps and the local sponsor, respectively. Adaptive Management funds are authorized up to 3% of the total project costs, again, cost shared between the Corps and local sponsors. Should the local sponsors choose to, they may begin contributing to an escrow account early in the project construction phase to maximize the funding, which helps ensure maximum flexibility. If the entire 3% of the project cost authorized for Adaptive Management needs is not utilized in the first five years after construction, the local contribution may be put into an escrow account to be used for future adaptive management needs.

CONCLUSION

The Monitoring and Adaptive Management Plan is an essential element in the overall implementation of the proposed plan. It provides a mechanism to evaluate the effectiveness of the restoration measures implemented in this project and to implement adaptive changes, if required, to realize project objectives. While planning for this project has accounted for the possible factors affecting the study area it is inevitable that uncertainty will remain with the outcome of the recommended plan. Implementation of a monitoring and adaptive management plan will not alleviate all uncertainty but will provide flexibility to account for changing environmental conditions and new information as well as measure project success.

The plan described above is a recommended plan for Rio Salado Oeste that will be built upon and modified to take into account lessons learned from the Rio Salado and Tres Rios projects as they are constructed and operated.