FLOODPLAIN DELINEATION STUDY for SKUNK CREEK

Between the Central Arizona Project and Happy Valley Road

Two-Dimensional Hydraulic Model

BOOK 1 OF 2

Prepared for:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FCD 2000-C016

JUNE 2002

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SECTION 1: INTRODUCTION

1.1 PURPOSE OF STUDY

This Technical Data Notebook (TDN) documents the two-dimensional hydraulic analysis conducted for Skunk Creek from Happy Valley Road to the Central Arizona Project (CAP) Canal. The study reach is located in Sections 25-27 and 34-36 of Township 5 North, Range 2 East, and Sections 1 and 2 of Township 4 North, Range 2 East, G&SRB&M, Maricopa County, Arizona. See Figure 1 for a location map.

1.2 AUTHORITY FOR STUDY

This study was completed by Tetra Tech, Inc. for the Flood Control District of Maricopa County (FCDMC). The FCDMC project number is FCD-2000-C016. Mr. Richard Harris is the Project Manager for FCDMC. Mr. Pedro Calza is the Project Manager for Tetra Tech, Inc..

1.3 DESCRIPTION OF STUDY AREA

Skunk Creek is a typical alluvial desert wash which originates in the northern mountains of Maricopa County. It is a tributary of the New River and courses through unincorporated portions of Maricopa County and the cities of Phoenix, Glendale, and Peoria. The Skunk Creek watershed above Adobe Dam is approximately 90 square miles in area and drains generally from north to south. The Central Arizona Project (CAP) Canal transects the lower portion of the watershed. The natural confluence of Skunk Creek and Sonoran Wash, a tributary, occurs on a very flat floodplain area, immediately downstream of the CAP Canal. To preserve the natural drainage pattern, overchute structures were built as part of the CAP construction project to convey each wash over the canal. As a result, the CAP embankment acts like a roadway crossing, blocking the floodplain flows during large events and forcing them to contract and pass through the overchute structures. Downstream of the confluence, Skunk Creek has been almost completely channelized by various City of Phoenix (the City) and U.S. Army Corps of Engineers (the Corps) projects until it reaches Adobe Dam.

1.4 BACKGROUND

The very broad, flat floodplain in the confluence area, in combination with the structures associated with the CAP Canal, produces complex, two-dimensional flow patterns upstream and downstream of the canal during flood stage. The *Skunk Creek Watercourse Master Plan*, completed in August 2001, included a two-dimensional hydraulic analysis of the confluence, overchutes, and ponding area upstream of the CAP Canal. The analysis identified locations where flow breaks out of the Skunk Creek and Sonoran Wash channel corridors during the 100-year event and provided estimates of breakout flow magnitudes and frequency. The results of the study indicated that the 100-year floodplain would cross Interstate 17 upstream of the CAP Canal, which warranted further study of the area.

This study expands upon the previous work and includes the following analyses for both the 100-year and Standard Project Flood (SPF) events:

- A expanded two-dimensional analysis of existing conditions. The Skunk Creek study limits are from Happy Valley Road (downstream limit) to the CAP Canal. Buchanan Wash, from the CAP Canal to its confluence with Skunk Creek, is also included in the study area.

- A floodplain analysis for the area west of I-17.

- Two pre-development condition models; one without the CAP Canal and another without I-17 or the CAP Canal.

- An analysis of widening the CAP overchutes as a possible remedial alternative.

- An analysis of extending the existing levee system to contain breakout flows.

The Scope of Work for this project included an analysis of a future bridge over Skunk Creek at Happy Valley Road. The existing crossing is at-grade. The City of Phoenix is presently working on a bridge design, but the project is still in the preliminary design stage and there was no design data available at the time that the models for this project were being prepared. Therefore, the proposed bridge was not included in any of the models.

1.5 METHODOLOGY

The criteria and guidelines contained in the *Drainage Design Manual for Maricopa County, Volume II: Hydraulics* were used as a basis to conduct the hydraulic analysis. The *FLO-2D User's Manual*, revised June 2001, was used as a reference while constructing the hydraulic models. A summary of information contained in the FLO-2D input and output files is presented in Appendices A and B.

Each floodplain condition or alternative that was analyzed for this study was modeled for both the 100-year and SPF events. The model used inflow hydrographs for Skunk Creek, Sonoran Wash, and Buchanan Wash. For the 100-year event, the effective Flood Insurance Study (FIS) hydrology was provided by the Flood Control District of Maricopa County. SPF hydrographs were derived using hydrology developed by the U.S. Army Corps of Engineers for the design of Adobe Dam.

The hydraulic analysis was completed using the FLO-2D computer program (Version 2002.6.3, FLO Engineering, Inc.). No sediment transport analysis was conducted for the study. The hydraulic analysis was conducted assuming clear-water discharges.

1.6 SUMMARY OF RESULTS

- The existing conditions model shows breakouts north of the CAP Canal, over Interstate 17, in both the 100-year and SPF flood events.

- The existing conditions model showed that significant ponding occurs north of the CAP Canal on Buchanan Wash. This ponding causes significant attenuation in the model that is not accounted for in the effective FIS hydrologic model. The land in the ponding area is presently owned by the State of Arizona, according to FCDMC records.

- The pre-development models show that the flows were fairly well contained only after I-17 was built. The addition of the CAP Canal only helped to contain the flows within the system.

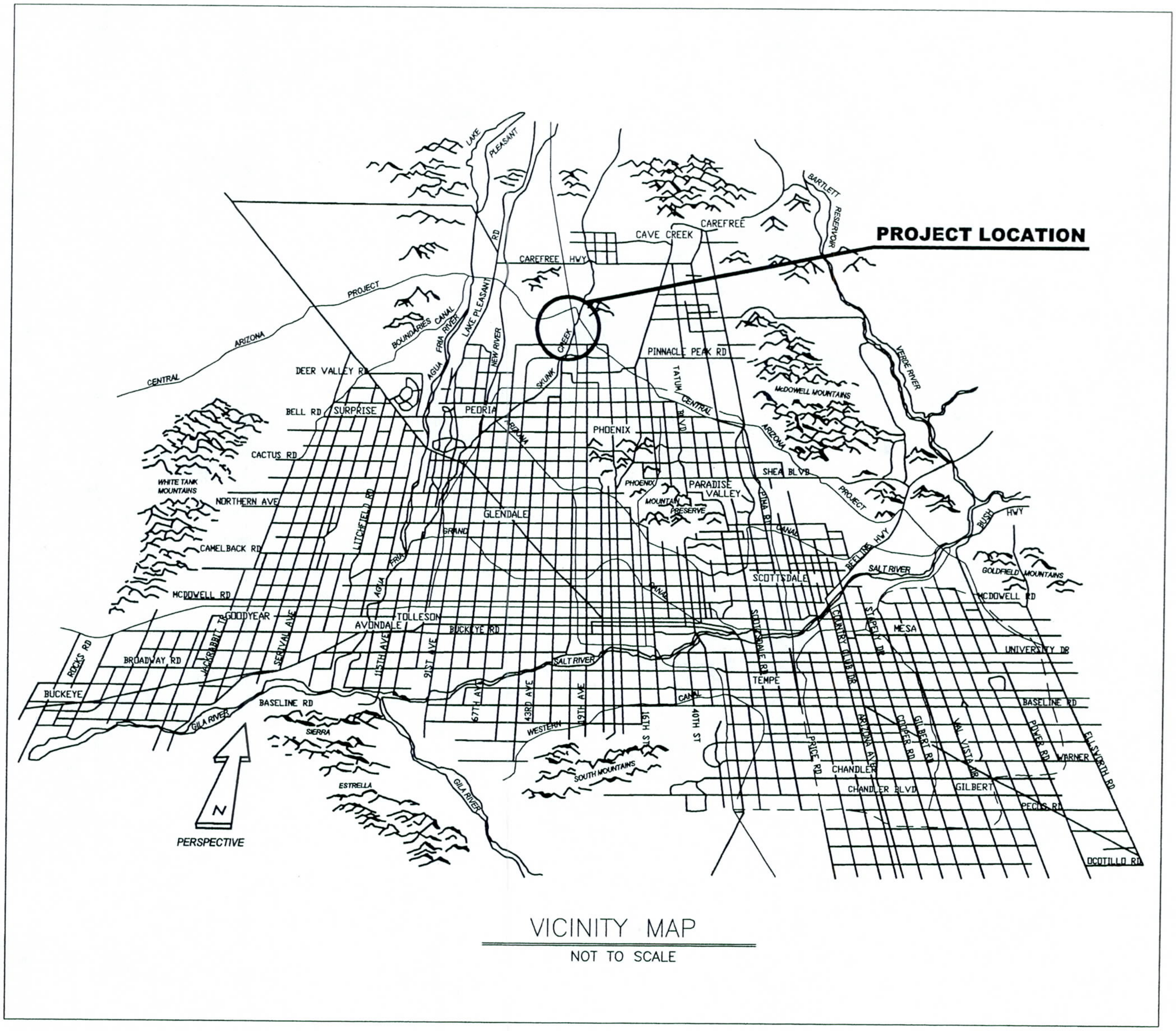
- Widening the overchutes does not help to alleviate the flooding problems within the system. Flow still breaks out over I-17 north of the CAP Canal.

- Extending the levees upstream from current locations to the CAP Canal, and north of the Canal, on both the east and west sides effectively confines the flows in the channel corridor during the 100-year event. During the SPF event, there is some backwater leaving the channel through the opening between the Corps' levees and the City of Phoenix landfill levees. The conceptual design and estimated cost of extending the levees is discussed in Section 5.2.

- The existing conditions models show that flooding during the 100-year event remains in the Adobe Dam watershed. However, during the SPF event, it is possible that flow may break out of the channel corridor and bypass Adobe Dam, flowing southward on both east and west sides of I-17. This condition is discussed further in Section 5.3.

- After the models were completed, it was found that the invert elevation of the Skunk Creek CAP Canal overchute in the FLO-2D model did not match the value in the HEC-RAS model used to develop the overchute rating curve. An analysis of the impact of the elevation difference on flooding depths was completed. It was found that revising the overchute invert elevation created minor changes in flooding depths upstream of the CAP Canal. The total increase in flooding volume between the original and revised models was compared to the total inflow volume from Skunk Creek and Sonoran Wash. The volume difference upstream of the CAP Canal between the original and revised models is 0.05% of the total inflow volume and is considered insignificant. More details of the analysis and a table showing the difference in maximum floodplain depth for each grid element upstream of the CAP Canal is included at the end of Appendix D. The HEC-RAS model, the revised FLO-2D models, and the analysis spreadsheets are included on a CD in Appendix M.

FIGURE 1-1: Location Map



SECTION 2: SURVEY AND MAPPING INFORMATION

2.1 FIELD SURVEY INFORMATION

No new survey work was performed for this study. The dimensions of the CAP Canal overchutes and embankment elevations were obtained from the *Skunk Creek Watercourse Master Plan*. The dimensions of the I-17 median outfalls into Skunk Creek were measured in the field, as discussed in Section 4.2.6. Existing Elevation Reference Marks (ERM's) and Geodetic Densification and Cadastral Survey points (GDACS) in the study area are listed below and shown on Exhibit A. The information was obtained from the Flood Control District of Maricopa County GDACS database.

TABLE 2-1: Elevation Reference Marks

State Plane Coordinates Arizona Central - NAD83					
Northing [Int. Feet]	**Easting [Int. Feet]**	**Elevation [NGVD29]**	**Type**	**Name**	**Description**
991620.6463	638472.7461	1468.8	NGS	DV0122 SKUNK	Triangulation station disk set in top of concrete monument. Stamped SKUNK 1947.
997812.5689	636904.3537	1510.27	NGS	DV0129 M343	Benchmark disk set in top of concrete monument. Stamped M 343 1959.
991670.318	644231.693	1498.964	MCDOT GDACS	1IE1	3" aluminum cap, Arizona Highway Department, set in concrete. North-bound frontage road, Highway 17, Sta. P.O.S.L. 1061+43.60, 0.3 feet +/- above natural ground, east side of frontage road.
991515.6	633855.0	1555.108	FEMA	RM519	Found stone at the SE corner of Sec 34 T5N R2E.
996468.5	629935.6	1502.168	FEMA	RM516	Found US Dept of the Interior BC along CAP Canal stamped Point #43, Station 386+00 125' Right.
996647.5	630771.9	1500.398	FEMA	RM511	Found US Dept of the Interior BC along CAP Canal stamped Point #44, Station 373+41.83 125' Right.
996816.7	631562.7	1499.817	FEMA	RM517	Found US Dept of the Interior BC along CAP Canal stamped Point #45, Station 402+67.37 125' Right.

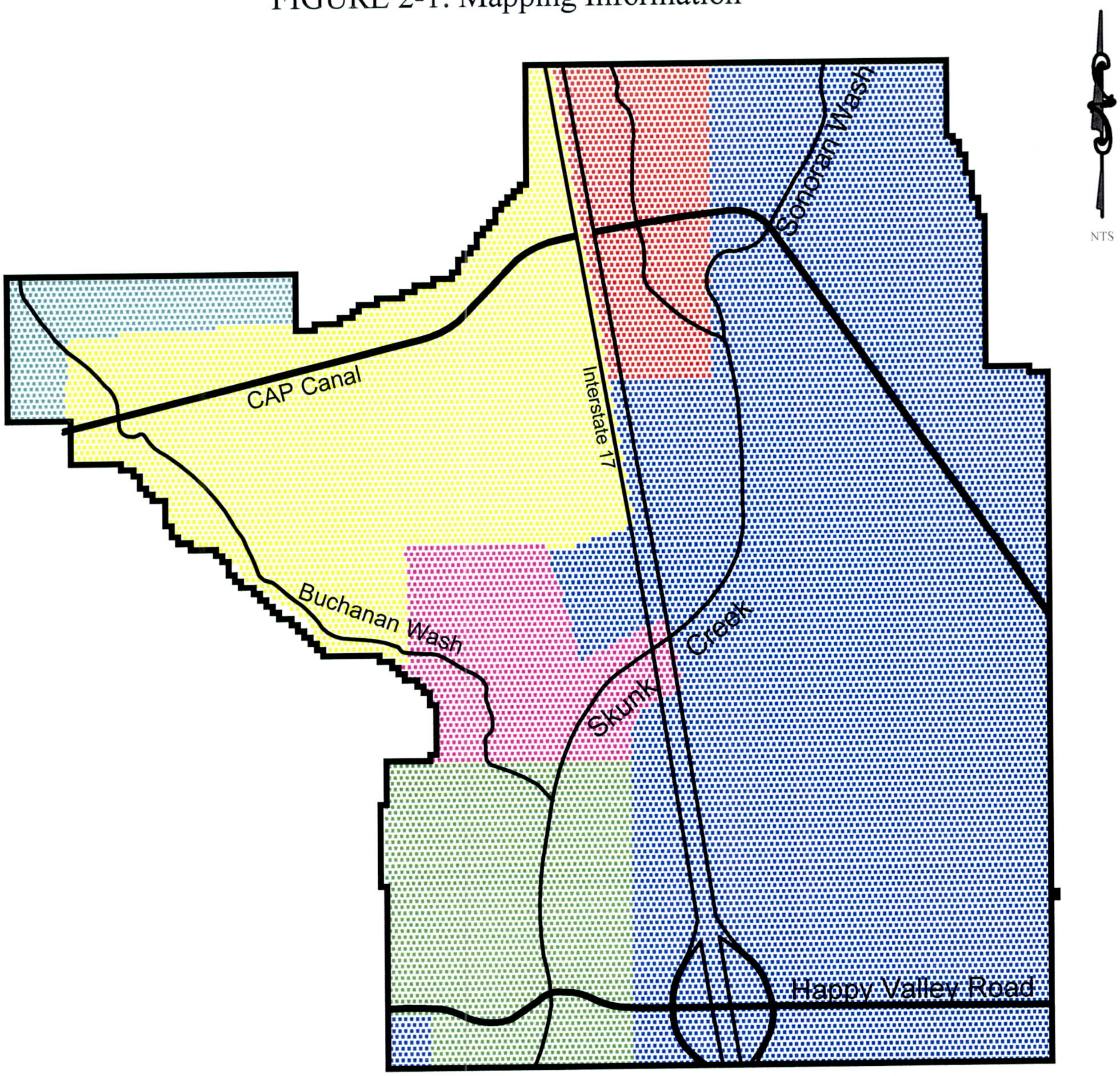
2.2 MAPPING

Mapping of the study area was compiled from multiple sources, as shown in Figure 2-1. The Flood Control District of Maricopa County provided mapping from two past studies that covered about 70% of the study area. The area between Interstate 17 and Buchanan Wash was not covered, so new mapping was produced for this area. The mapping subcontractor was Aerial Mapping Company, Job #01229, flown on September 26, 2001. Panel points were laid by Tetra Tech Inc. The new mapping was prepared at a scale of 1"=100', with two-foot contour intervals.

The FCDMC mapping did not reflect channel improvements that have been constructed through the Skunk Creek Landfill by the City of Phoenix. Updated mapping of the Skunk Creek Landfill and Buchanan Wash diversion channel was obtained from the City. This mapping was used to set grid elevations for the channel and levees in the landfill reach. The topographic mapping shown in Exhibit A includes the updated mapping in the landfill area. However, the FLO-2D grid system was created using the FCDMC mapping. Only the elevations for the channel and levee grid elements were adjusted using the City of Phoenix mapping. The remainder of the grid elements in the landfill area reflect the FCDMC mapping elevations. This discrepancy is not considered to be a significant problem, because of the dynamic topographic conditions within the landfill. As the landfill cells are filled, the ground elevation keeps increasing. Ultimately, all the cells will be filled to a level high above the channel levees. For this reason, the models were run assuming that the landfill has reached ultimate capacity and all the cells are filled. The model was configured to prevent flow from entering the landfill cells.

Initial modeling runs showed that ponding of Buchanan Wash north of the CAP Canal extended beyond the detailed mapping limits. The grid was extended in this area using contours from the Hedgpeth Hills USGS quadrangle map, photorevised in 1981.

FIGURE 2-1: Mapping Information



SOURCE: FCDMC - Arizona Canal Diversion Channel ADMS, FCD 90-19
MAP DATE: October 3, 1990

SOURCE: FCDMC - Skunk Creek Wash FDS, FCD 95-16
MAP DATE: December 1, 1995

SOURCE: New mapping for this project
PREPARED BY: Aerial Mapping Company
MAP DATE: September 26, 2001

SOURCE: City of Phoenix
PREPARED BY: M & B Aerial Mapping
MAP DATE: January 7, 1998

SOURCE: City of Phoenix
PREPARED BY: M & B Aerial Mapping
MAP DATE: February 11, 2000

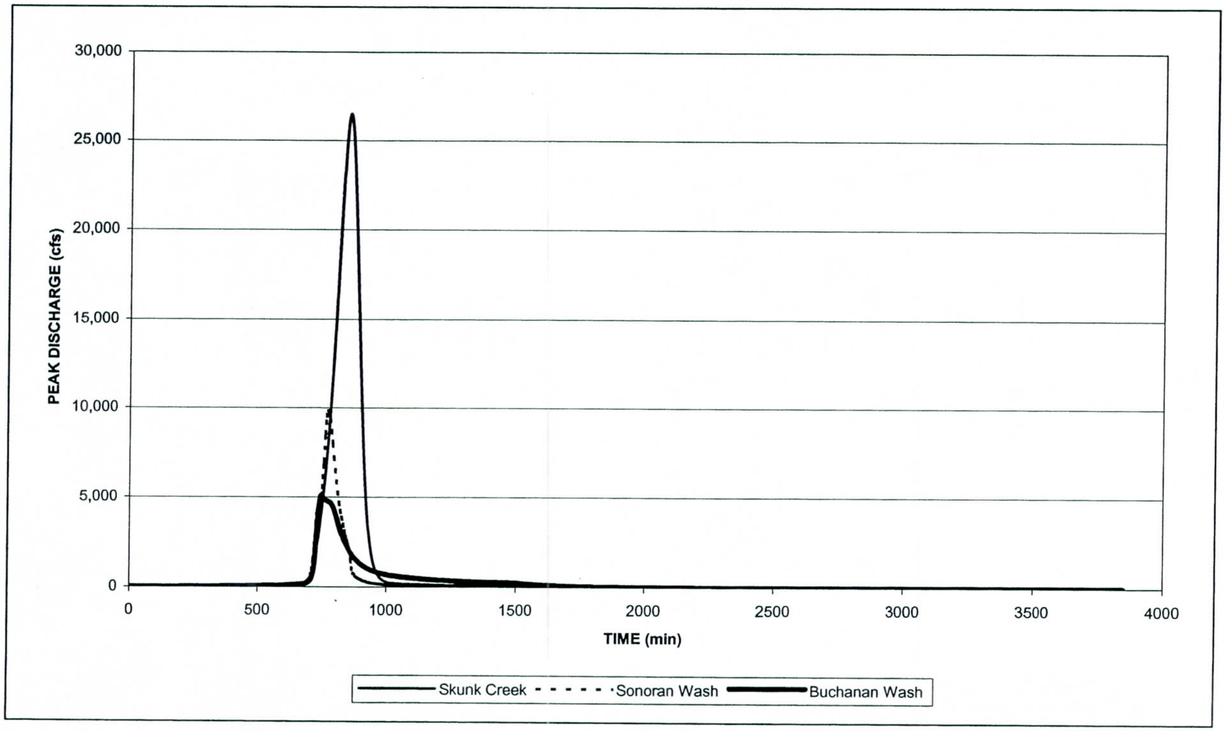
SOURCE: USGS Quadrangle Map - HEDGPETH HILLS, AZ
MAP REVISED: 1981

SECTION 3: HYDROLOGY

3.1 METHOD DESCRIPTION

Each floodplain condition or alternative that was analyzed for this study was modeled for both the 100-year and SPF events. For the 100-year event, the effective Flood Insurance Study (FIS) hydrology was provided by the Flood Control District of Maricopa County. Inflow hydrographs for Skunk Creek and Sonoran Wash were obtained from the *Skunk Creek Watercourse Master Plan* (WCMP), a study prepared by Tetra Tech Inc. These hydrographs are based on the 100-year, 24-hour rainfall event. The 100-year inflow hydrograph for Buchanan Wash was prepared using the HEC-1 model for *Hydrologic Analyses for Buchanan Wash, Maricopa County, Arizona*, prepared by AGK Engineers. The AGK study was based upon the 100-year, 6-hour rainfall event. The AGK HEC-1 model was run with a 100-year, 24-hour rainfall distribution to obtain the inflow hydrograph used for this study. The FLO-2D 100-year inflow hydrographs are presented below in Figure 3-1. The peak discharge for each hydrograph is as follows: Skunk Creek – 26,513 cfs; Sonoran Wash – 9,825 cfs; Buchanan Wash – 5,063 cfs. The hydrograph point data is included in Appendix N.

FIGURE 3-1: 100-Year Event Hydrographs

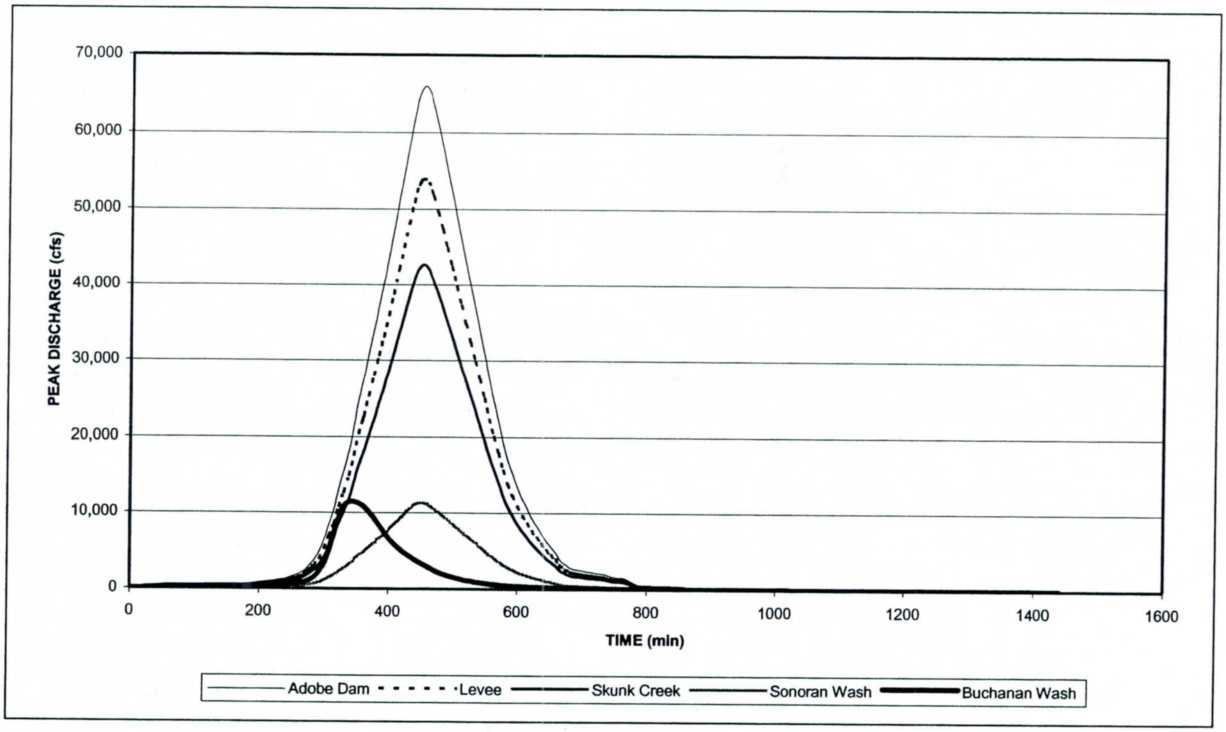


3.2 SPF HYDROGRAPH DEVELOPMENT

Inflow hydrographs for the SPF event were based on hydrology prepared by the U.S. Army Corps of Engineers during the design of Adobe Dam. The SPF hydrograph for Adobe Dam was obtained from Adobe Dam (including Skunk Creek to the Arizona Canal), Design Memorandum No. 3, General Design Memorandum – Phase II, Project Design – Part 2, dated April 1979. The SPF peak flow at Adobe Dam is 66,000 cfs. Further upstream, at the Skunk Creek levees, the peak flow is 54,000 cfs. The Adobe Dam hydrograph was scaled down to a peak of 54,000 cfs to represent the SPF hydrograph at the levees. Then, hydrographs for Skunk Creek and Sonoran Wash were derived by obtaining a peak flow ratio based upon watershed area. The levee hydrograph was divided into two additive hydrographs based upon this ratio. The resultant Skunk Creek SPF hydrograph peaks at 42,655 cfs. The Sonoran Wash SPF hydrograph peaks at 11,345 cfs.

To obtain an SPF hydrograph for Buchanan Wash, the AGK HEC-1 model was run using the rainfall hyetograph from the Adobe Dam hydrology. The timing of the resultant hydrograph was then adjusted so that the peak flow in Buchanan Wash coincided with the peak flow from Skunk Creek and Sonoran Wash. The FLO-2D SPF hydrographs are presented below in Figure 3-2. Supporting hydrologic calculations and documentation are included in Appendix N.

FIGURE 3-2: SPF Event Hydrographs



SECTION 4: HYDRAULICS

4.1 METHOD DESCRIPTION

The FLO-2D computer program (Version 2002.6.3, FLO Engineering, Inc.) was utilized to conduct the two-dimensional hydraulic analysis. The program performs flood simulations by selecting a number of components to route rainfall-runoff or flood hydrographs over complex topography. The flood routing may be accomplished as channel flow, unconfined overland flow or street flow. In addition, the flood simulation can be enhanced by applying a number of options including variable channel cross-sections, rill and gully flow, infiltration, bridge and culvert simulations, and flow obstructions. Both clear water and hyper-concentrated sediment flows can be simulated. A listing of the input files required to use FLO-2D, along with a short discussion of the parameters and settings within those files, can be found in Appendix A. It should be noted that the model will not run unless the input files are named exactly as shown in the the *FLO-2D User's Manual*. The program also requires that the input files not be "read-only".

Options are available within FLO-2D to create output files with either spatial or temporal format. Output files can be generated which have substantial detail involving all the time steps or all the grid elements. On the other hand, some output files are designated for a simple review of specific flow hydraulics. General output parameters include water surface elevation, flow depth, velocity, discharge and sediment concentration. Overland flow hydraulics may be viewed as individual grid elements or the elements can be grouped together to produce floodplain cross-sections. The available output files are described in Appendix B.

The computer used to run the simulations was equipped with dual 1.7GHz processors and 1Gb of RAM. The operating system was Windows 2000. The total run time for each model is shown in the SUMMARY.OUT output file. It should be noted that the model run times may be significantly longer than those shown in the output files if the models are run on systems with less processing power.

4.1.1 Two-Dimensional Grid

To conduct the FLO-2D flood simulation, a finite element grid system that defines contiguous grid elements in the four compass directions must be established. The grid system was constructed using a digital terrain model (DTM) created using Autodesk Land Development Desktop software. The DTM was then imported to a FLO-2D grid development program for conversion to the proper file format. The study area was modeled using 18,038 grid elements that are 100-foot square. Each grid element contains a ground point elevation at the center. The software used to create the grid system assigned the point elevation for each grid element. The assigned elevation is generally sufficient, except in critical areas where the elevation changes significantly within the grid element area, i.e., at levees or small drainage ditches. After the grid system file was created, the elevations of levees, ditches, and other significant terrain features were adjusted manually. See Exhibit A for a map showing the study area grid system and topography.

Each grid was assigned a base Manning's roughness coefficient that ranged from 0.018 to 0.060. Guidance for selection of Manning's coefficients was obtained from *Drainage Design Manual for Maricopa County, Volume II: Hydraulics* and *Computed Roughness Coefficients for Skunk Creek above Interstate 17, Maricopa County, Arizona* (O'Day and Phillips, 2000). Table 4-1 shows the various Manning's coefficients that were used.

TABLE 4-1: Manning's Roughness Coefficients

Terrain Type	Manning's Roughness Coefficient
CAP Canal	0.018
Roadway	0.020
Bare graded earth	0.025
Levees	0.025
Developed areas	0.045
Sparse desert scrub	0.035
Dense desert scrub	0.060
Skunk Creek channel	0.035
Sonoran Wash channel	0.040
Buchanan Wash channel	0.050

Ultimately, the selection of roughness coefficients is less significant than it is when using one-dimensional hydraulic modeling programs like HEC-RAS. In order to maintain a subcritical flow regime, FLO-2D adjusts the roughness coefficients as needed during the modeling run. The range of adjustment done by the program for each grid element, or node, is documented in the ROUGH.OUT output file.

4.1.2 Input and Output Hydrographs

The data file used to input the inflow hydrographs and describe the outflow conditions is FPINOUT.DAT (reference Appendix A). A discretized flood hydrograph from the upstream basin is input to the floodplain to begin the flood simulation. More than one grid element can have an inflow hydrograph. As shown on Exhibit A, the inflow hydrographs for Skunk Creek and Sonoran Wash were input at grid elements 6856 and 10747, respectively. The Buchanan Wash hydrograph was input at grid element 35.

Two FPINOUT.DAT files were created, one for the 100-year event and another for the SPF event. Each floodplain condition or alternative that was analyzed for this study was modeled for both the 100-year and SPF events.

For boundary outflow elements, the outflow discharge is set equal to the sum of the inflow to that grid element. This outflow discharge is removed from the system and added to the outflow volume to check conservation of mass. Outflow elements were set only at the downstream edges of the grid system. There were no internal floodplain outflow elements.

4.1.3 Routing Computations

FLO-2D provides the option of using either the diffusive wave or the full dynamic wave equation for flood routing. The diffusive wave method is only stable for shallow overland flow. Initially, the CAP Canal was not modeled using the FLO-2D channel option; it was simply treated as a topographic feature of the floodplain. This initial model was run using diffusive wave routing. When the model was modified to represent the CAP Canal using the channel option, it was necessary to use the full dynamic wave routing method. All final models were run using full dynamic wave routing.

4.2 EXISTING CONDITIONS ANALYSIS

4.2.1 Overchute Rating Curves

Skunk Creek and Sonoran Wash are conveyed over the CAP Canal in rectangular concrete overchute structures. The CAP Canal embankment acts like a roadway crossing, blocking the floodplain flows during large events and forcing them to contract and pass through the overchute structures. To model the hydraulics of the overchutes, they were treated like culverts. A rating curve was developed for each overchute. The rating curves were established by applying the HEC-RAS computer program to the existing overchute conditions and assuming critical depth at the overchute inlet. The model was run at different flow rates to establish the depth and flow area relationship. The rating curve information was inserted in the CULVERT.DAT input file (refer to Appendix A for more information on the necessary input parameters).

The Sonoran Wash overchute is 155 feet wide with 7.5-foot high sidewalls. Because of its orientation with the grid system, it could be modeled as one culvert using one grid element for the inlet and one for the outlet. The Skunk Creek Overchute is 244 feet wide with 8.5-foot high sidewalls. However, because of its orientation with the grid system, it was modeled as three culverts using three grid elements each for the inlet and outlet, and assuming an even flow distribution through the three culverts.

Tables 4-2 and 4-3 list the rating curves used for the two overchute structures. Note that the three grid elements (each representing one culvert) used to model the Skunk Creek overchute have identical rating tables.

The model output indicated that the water surface elevations downstream of the overchute structures were less than the critical depth elevations in the overchutes for the 100-year discharge. The water surface elevations upstream of the overchute structures were greater than critical depth. This verified that the flow passes through critical depth in the structure and confirmed the assumption of inlet control used in the model.

TABLE 4-2: Rating Table for Skunk Creek CAP Canal Overchute

Headwater Depth (feet)	Culvert Discharge (cfs)	Culvert Flow Area (sq. ft.)
(Grid Elements 6706, 6845, and 6984)		
0	0	0
0.6	83.3	47.2
0.8	166.7	68.4
1.2	333.3	99.9
1.8	666.7	146.8
2.3	1,000	185.3
2.7	1,333.3	218.6
3.1	1,666.7	249.5
3.4	2,000	276.9
3.7	2,333.3	304
4.1	2,666.7	329.6
4.4	3,000	353.8
4.6	3,333.3	376.6
5.3	4,1667	431.3
5.9	5,000	481.6
6.5	5,833.3	529.1
7.1	6,666.7	574.6
7.6	7,500	617.5
8.1	8,333.3	659.2
8.6	9.166.7	700.3
9.1	10,000	738.3

TABLE 4-3: Rating Table for Sonoran Wash CAP Canal Overchute

Headwater Depth (feet)	Culvert Discharge (cfs)	Culvert Flow Area (sq. ft.)
(Grid Element 9902)		
0	0	0
0.76	250	118
1.1	500	170
1.6	1,000	248
2.36	2,000	366
2.98	3,000	462
3.53	4,000	547
4.03	5,000	625
4.49	6,000	696
4.92	7,000	763
5.34	8,000	828
5.74	9,000	890
6.11	10,000	948
6.84	12,000	1,061
7.52	14,000	1,166
8.16	16,000	1,265
8.77	18,000	1,359
9.36	20,000	1,451
9.94	22,000	1,541
10.5	24,000	1,628
11.06	26,000	1,711

4.2.2 Buchanan Wash Culvert Rating Curve

Buchanan Wash passes under the CAP Canal in three 66-inch diameter concrete pipe culverts. The culvert rating curve for this crossing was derived using HY-8, the Federal Highways Administration culvert analysis software program, version 4.0. The electronic files are included on CD #1 in Appendix M. Table 4-4 shows the Buchanan Wash culvert rating table.

TABLE 4-4: Rating Table for Buchanan Wash Culverts

Headwater Depth (feet)	Culvert Discharge (cfs)	Culvert Flow Area (sq. ft.)
	(Grid Element 34)	
0	0	0
13.96	1,151	71.3
22.43	2,293	501.3
22.77	3,442	841.3
23.04	4,567	1111.3
23.14	5,042	1211.3
23.49	6,878	1561.3
23.69	8,038	1761.3
23.87	9,194	1941.3
24.05	10,346	2121.3
24.22	11,498	2291.3
24.25	11,506	2321.3

4.2.3 CAP Canal

FLO-2D simulates channel flow as one-dimensional flow. The average flow hydraulics of velocity and depth define the discharge between grid elements through a channel reach. The CAP Canal was modeled as a channel using the FLO-2D input file CHANNEL.DAT. The channel dimensions were approximated from the topographic mapping and aerial photography. The FLO-2D channel bottom elevation was set at the existing CAP water surface, leaving only the existing channel freeboard available to convey floodwaters that break into the Canal. These channel dimensions resulted in a channel top width that slightly exceeded the 100 foot grid length, which caused problems because the model will adjust adjacent grid elevations as required to accommodate the input channel dimensions. To prevent this, the channel depth and side slopes were slightly modified to retain the same flow area but limit the top width to 100 feet. It was then possible to model the CAP Canal as a single row of grid elements.

The CAP Canal embankments block floodplain flows during large events and force them to contract and pass through the overchute structures. The embankments were modeled by manually adjusting grid elevations to match the topographic mapping contours. Both channel banks were modeled in this manner.

4.2.4 Skunk Creek Channelization

Downstream of its confluence with Sonoran Wash, Skunk Creek has been almost completely channelized by various City of Phoenix and U.S. Army Corps of Engineers projects until it reaches Adobe Dam. The Corps constructed earthen levees both upstream and downstream of the I-17 crossing to contain Skunk Creek and direct flow into the culvert. The Corps levees end approximately 2,000 feet downstream of I-17. Buchanan Wash enters Skunk Creek at this point. The channel then bisects the City of Phoenix Skunk Creek Landfill until it reaches the downstream study limit at Happy Valley Road. The City has constructed levees on both banks to keep floodwaters out of the landfill.

Two methods were used to model the channel. In most areas, the Skunk Creek levees and channel bottom were modeled by manually adjusting grid elevations to match the topographic mapping contours. The two-dimensional overland flow hydraulic computations were used.

A short section of channel that includes the Interstate 17 crossing was defined as a channel in the CHANNEL.DAT input file and modeled using one-dimensional flow computations. This situation is described in more detail in Section 4.2.5, Interstate 17 Crossing.

4.2.5 Interstate 17 Crossing

Interstate 17 passes over Skunk Creek on a concrete slab bridge with seven piers and vertical abutments, which effectively create a large eight-barrel box culvert in the channel. Concrete channel transition sections are located both upstream and downstream of the crossing. These interim sections transition channel flow to and from the wide trapezoidal channels created by the Corps' levees. The I-17 crossing was designed to create a supercritical flow regime through the culverts. A hydraulic jump occurs downstream of the culverts where the flow returns to subcritical.

Initially, this crossing was modeled as a culvert, with a defined rating curve. However, the channel reaches its narrowest point at the I-17 crossing and the inability to accurately model channel dimensions using a 100-foot square grid system resulted in unreasonably high water surface elevations upstream and downstream of the channel. In addition, the limiting Froude value of 0.90 for overland flow did not allow the model to reflect the supercritical flow immediately upstream of I-17.

For these reasons, this section of Skunk Creek was modeled as a channel, using the CHANNEL.DAT input file. This channel segment begins just upstream of I-17, where the levees end and the concrete transition section begins. The channel segment ends at the downstream outlet of the Corps' levee system, where the newer City of Phoenix levee improvements begin. The channel and culvert dimensions were obtained from I-17 as-builts and the Corps' plans for the Skunk Creek channel and levees. Copies of these documents are included in Appendix O. Since there is no way to represent bridge piers in the channel, they were accounted for by subtracting their width from the total channel width and increasing the Manning's n-value to 0.030 through the culvert section.

The ARF.DAT file was used in conjunction with CHANNEL.DAT to model this channel segment. Since the channel was defined using diagonally adjacent grid elements and FLO-2D allows flow to move in eight possible directions, the model was allowing flow to enter the floodplain grid elements that were interspersed diagonally within the channel elements. To prevent this, these grid elements were totally blocked from receiving flow using the ARF.DAT file.

4.2.6 Interstate 17 Drainage Ditches

Through the study area, Interstate 17 is a divided four-lane highway with a frontage road on each side. The freeway and the frontage roads are both elevated a minimum of two to three feet above the adjacent natural ground. There are unlined open drainage ditches in the freeway median and between the freeway and the frontage roads. The ditch between the east frontage road and northbound I-17 is approximately 30 feet wide and ranges in depth from approximately 2 feet to 4 feet at the point where it outfalls into the Skunk Creek culvert at the I-17 crossing. The depressed median is approximately 60 feet wide and ranges in depth from approximately 3 feet to 5 feet at the outfall into Skunk Creek.

The grid elevations were manually adjusted to represent these terrain features. An exact representation of the ground surface was not possible, due to the limitations imposed by the 100-foot square grid size. Since the overall effect of the ditches was to impede flooding of the freeway, a "ditch" was simulated on the east side of the freeway/frontage road. The roadway grids were adjusted to reflect a uniform elevation and slope, since the DTM had assigned widely varying elevations to each grid element, depending upon whether the program was reading the ditch or roadway elevation. The single column of grid elements immediately east of the roadway were then lowered from one to two feet and given a continuous slope.

This approach posed an interesting modeling challenge at the Skunk Creek/I-17 crossing, which was modeled as a channel. It was not possible to run the freeway drainage ditch into the upstream side of the crossing, because the required elevation was below the headwater surface and allowed Skunk Creek to overflow into the ditch. Therefore, the ditch outfall was represented by a weir rating curve, which was entered into the CULVERT.DAT input file. The outfall flow is released back into the floodplain grid system in the Skunk Creek channel, immediately downstream of the I-17 channel segment.

In order to simulate the existing conditions of the drainage ditch outfalls, the dimensions of the ditch openings in the side of the Skunk Creek culvert were measured in the field. This data was then used to obtain a weir rating curve for each outfall, using the Ohio Department of Natural Resources Uneven Weir computer program, Fortran version 1.0. The electronic files are included on CD #1 in Appendix M. The outfalls were then combined and modeled in FLO-2D as a single culvert with its inflow at the end of the drainage ditch and its outflow in the Skunk Creek channel. Table 4-5 shows the combined weir rating curve.

TABLE 4-5: Weir Rating Table for Interstate 17 Drainage Ditches

Headwater Depth (feet)	Culvert Discharge (cfs)	Culvert Flow Area (sq. ft.)
(Grid Element 4951)		
0	0	0
0.5	48.54	11.66
1.0	120.03	26.36
1.5	217.55	52.85
2.0	345.51	64.83
2.5	507.77	88.62
3.0	698.01	111.42
3.5	926.29	137.26
4.0	1196.71	173.63
4.5	1526.94	214.26
5.0	1887.44	260.34
5.5	2296.05	312.13
6.0	2764.92	369.81
6.5	3334.75	431.13
7.0	3981.12	493.8
7.5	4689.63	557.15
8.0	5424.78	620.5
8.5	6201.82	683.85
9.0	7021.81	747.2
9.5	7886.08	810.55
10.0	8787.75	873.9

4.2.7 Skunk Creek Landfill

As discussed in Section 2.2, the original project mapping provided by FCDMC did not reflect channel improvements that have been constructed through the Skunk Creek Landfill by the City of Phoenix. Updated mapping of the Skunk Creek Landfill and Buchanan Wash diversion channel was obtained from the City. This mapping was used to set grid elevations for the channel and levees in the landfill reach. However, only the elevations within the channel and the adjacent levee grid elements were adjusted using the City of Phoenix mapping. The FLO-2D grid system was created using the FCDMC mapping. Therefore, the remainder of the grid elements in the landfill area reflect the FCDMC mapping elevations. At the time that the project mapping was produced, some of the cells were excavated and unfilled, and the levees that now protect the landfill were not complete. This resulted in large quantities of water being retained in the unfilled landfill cells. In order to better assess the possibility that floodwater may break out of the Skunk Creek corridor and be diverted away from Adobe Dam, the models were run assuming that the landfill has reached ultimate capacity and all the cells are filled. The model was configured to prevent flow from entering the landfill cells by utilizing the ARF.DAT input file.

4.2.8 Results

Figures 4-1 and 4-2 were generated by the MAXPLOT function of the FLO-2D program. They show the maximum depths of flooding during the 100-year and SPF event model runs, respectively. These results are presented on a larger scale in Exhibits B and C, which show the entire study area at 1" = 500' scale. The same exhibits have been prepared at 1"=200' scale and are included in EPS format on the CD in Appendix M. The 200 scale exhibits require five sheets each to cover the entire study area.

FLO-2D presents a summary of results for each individual grid element in the BASE.OUT output file. The BASE.OUT file provides a listing of the maximum velocity and flow depth and the times of occurrence, as well as a summary of the inflow, storage volumes, and outflow from the grid system. Hardcopies of the existing conditions BASE.OUT files are provided in Appendix D.

4.3 PRE-DEVELOPMENT OF CAP CANAL ANALYSIS

4.3.1 Key Input Parameters

To model the Skunk Creek floodplain conditions prior to the construction of the CAP Canal, the channel, embankments, and overchute structures were removed from the existing conditions FLO-2D input files. The elevations of the grid elements that represent the embankments and channel were adjusted to create a smooth transition between the upstream and downstream sides of the Canal. The Skunk Creek levees and I-17 were not altered from existing conditions.

4.3.2 Results

Figures 4-3 and 4-4 were generated by the MAXPLOT function of the FLO-2D program. They show the maximum depths of flooding during the 100-year and SPF event model runs, respectively. These results are presented on a larger scale in Exhibits D and E, which show the entire study area at 1" = 500' scale. The same exhibits have been prepared at 1"=200' scale and are included in EPS format on the CD in Appendix M. The 200 scale exhibits require five sheets each to cover the entire study area.

FLO-2D presents a summary of results for each individual grid element in the BASE.OUT output file. The BASE.OUT file provides a listing of the maximum velocity and flow depth and the times of occurrence, as well as a summary of the inflow, storage volumes, and outflow from the grid system. Hardcopies of the BASE.OUT files for the pre-development of CAP Canal are provided in Appendix F.

4.4 PRE-DEVELOPMENT OF I-17 AND CAP CANAL ANALYSIS

4.4.1 Key Input Parameters

To model the Skunk Creek floodplain conditions prior to the construction of both I-17 and the CAP Canal, all elements associated with these features were removed from the existing conditions FLO-2D input files. Features associated with the CAP Canal were removed as described in Section 4.3.1. Then the elevations of the grid elements representing I-17 and the roadside drainage ditch were adjusted to approximately match the natural ground on both sides of the freeway. The Corps channelization and levee system was also removed by lowering the grid elevations to approximate adjacent ground elevations. The Skunk Creek Landfill levees and Buchanan Wash were not altered from existing conditions.

4.4.2 Results

Figures 4-5 and 4-6 were generated by the MAXPLOT function of the FLO-2D program. They show the maximum depths of flooding during the 100-year and SPF event model runs, respectively. These results are presented on a larger scale in Exhibits F and G, which show the entire study area at 1" = 500' scale. The same exhibits have been prepared at 1"=200' scale and are included in EPS format on the CD in Appendix M. The 200 scale exhibits require five sheets each to cover the entire study area.

4.5.2 Results

The results of the second model, in which one large overchute is simulated, are presented in this report. Figures 4-7 and 4-8 were generated by the MAXPLOT function of the FLO-2D program. They show the maximum depths of flooding during the 100-year and SPF event model runs, respectively. These results are presented on a larger scale in Exhibits H and I, which show the entire study area at 1" = 500' scale. The same exhibits have been prepared at 1"=200' scale and are included in EPS format on the CD in Appendix M. The 200 scale exhibits require five sheets each to cover the entire study area.

FLO-2D presents a summary of results for each individual grid element in the BASE.OUT output file. The BASE.OUT file provides a listing of the maximum velocity and flow depth and the times of occurrence, as well as a summary of the inflow, storage volumes, and outflow from the grid system. Hardcopies of the BASE.OUT files for the widened overchute alternative are provided in Appendix J.

4.6 EXTENDED LEVEES ALTERNATIVE

4.6.1 Key Input Parameters

The second remedial alternative that was explored in order to prevent flooding of I-17 was to extend the Corps levee system upstream to the CAP Canal. The extended levees contain both Skunk Creek and Sonoran Wash. Upstream of the Canal, levees were also placed on the east side of I-17 and on the east side of Sonoran Wash to contain breakout flows in both directions. The levee grid elements were totally blocked from receiving any flow using the ARF.DAT input file. An estimate of their required construction height was obtained from the resulting channel water surface elevation. The remainder of the model was not altered from existing conditions.

4.6.2 Results

Figures 4-9 and 4-10 were generated by the MAXPLOT function of the FLO-2D program. They show the maximum depths of flooding during the 100-year and SPF event model runs, respectively. These results are presented on a larger scale in Exhibits J and K, which show the entire study area at 1" = 500' scale. The same exhibits have been prepared at 1"=200' scale and are included in EPS format on the CD in Appendix M. The 200 scale exhibits require five sheets each to cover the entire study area.

FLO-2D presents a summary of results for each individual grid element in the BASE.OUT output file. The BASE.OUT file provides a listing of the maximum velocity and flow depth and the times of occurrence, as well as a summary of the inflow, storage volumes, and outflow from the grid system. Hardcopies of the BASE.OUT files for the extended levees alternative are provided in Appendix L. A conceptual design and construction cost estimate are provided in Section 5.2.

FIGURE 4-1: Existing Conditions, 100-year Maximum Flow Depths

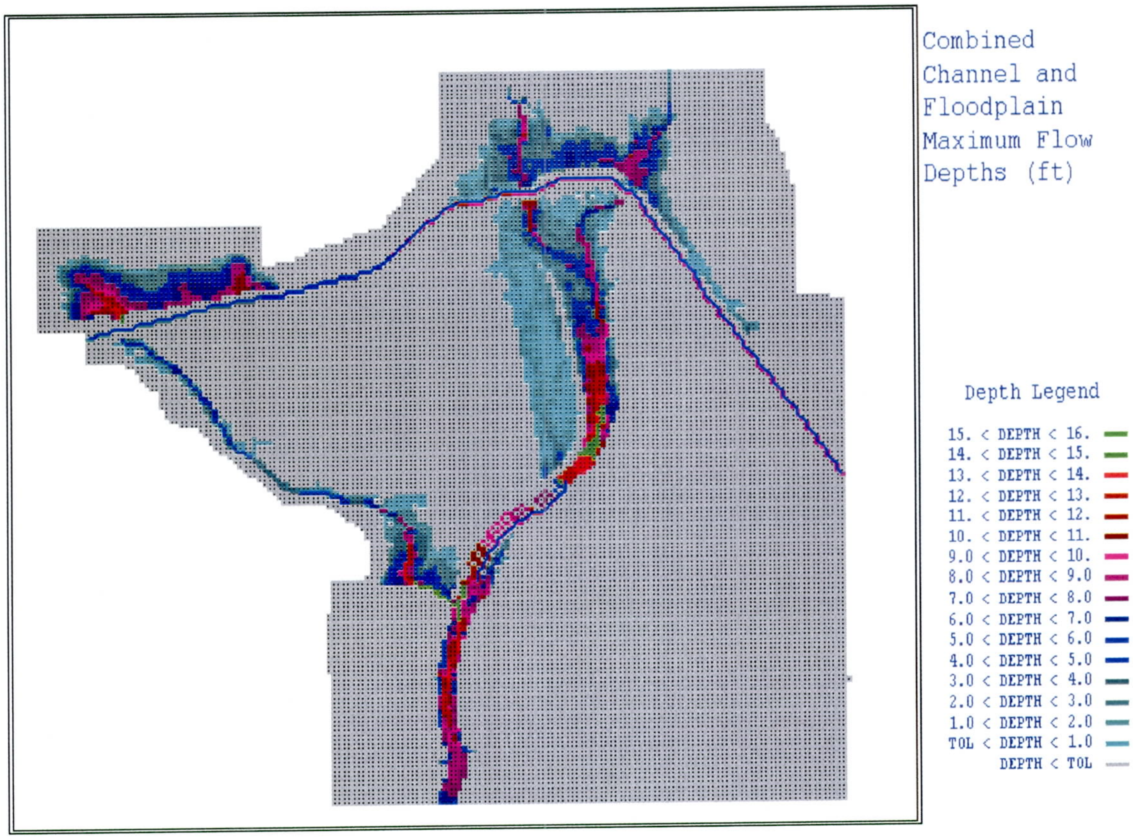


FIGURE 4-2: Existing Conditions, SPF Maximum Flow Depths

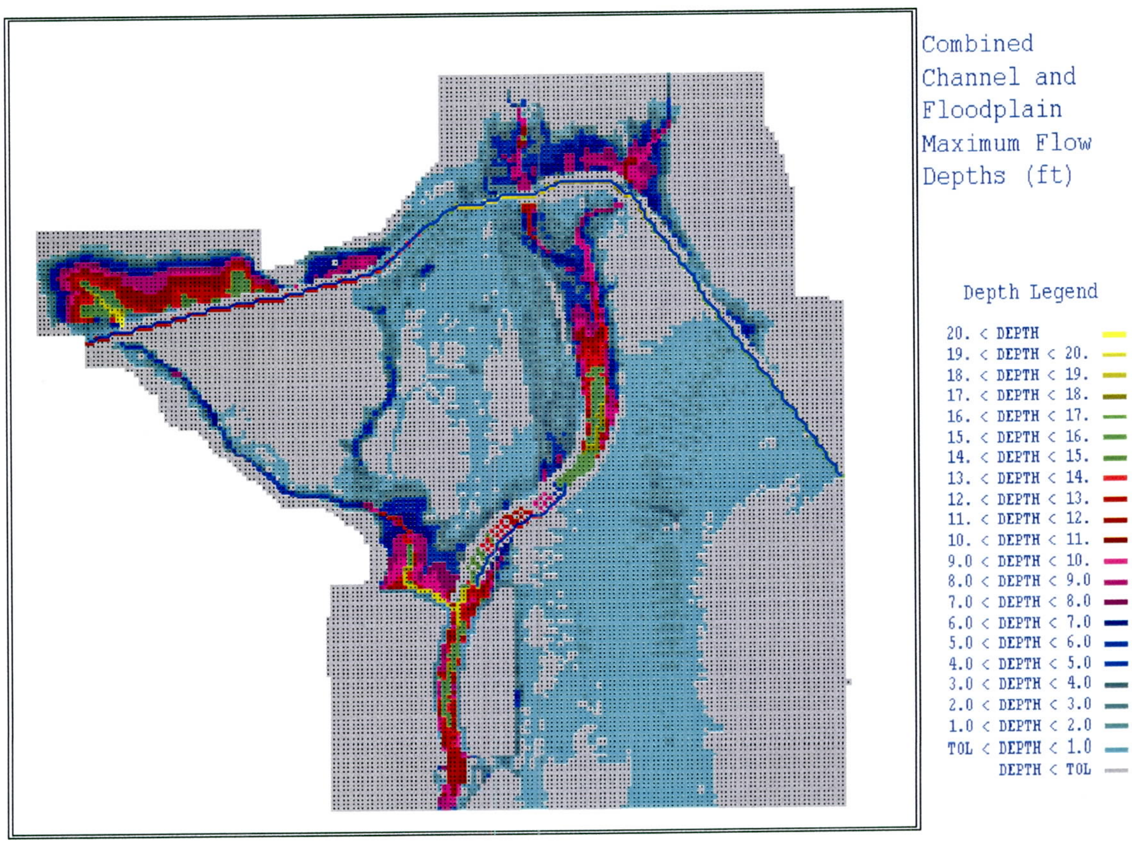


FIGURE 4-3: Pre-Development of CAP Canal, 100-year Maximum Flow Depths

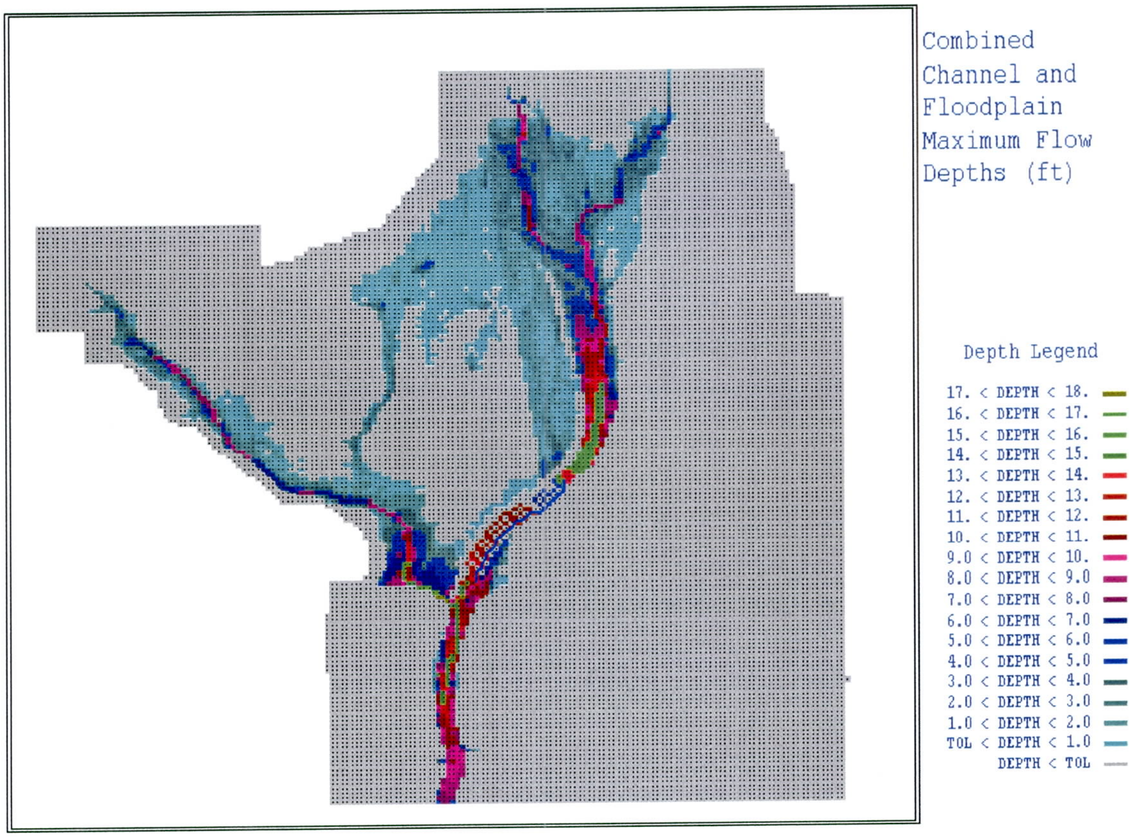


FIGURE 4-4: Pre-Development of CAP Canal, SPF Maximum Flow Depths

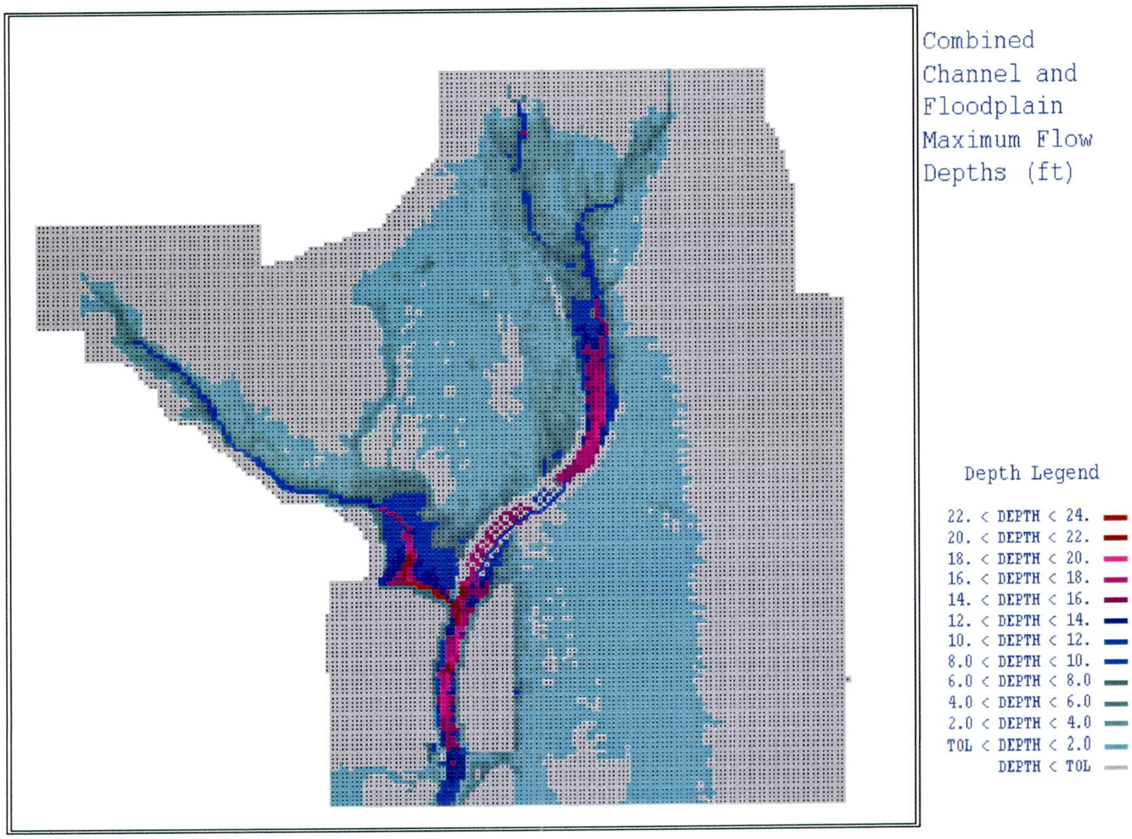


FIGURE 4-5: Pre-Development of I-17 & CAP Canal, 100-year Maximum Flow Depths

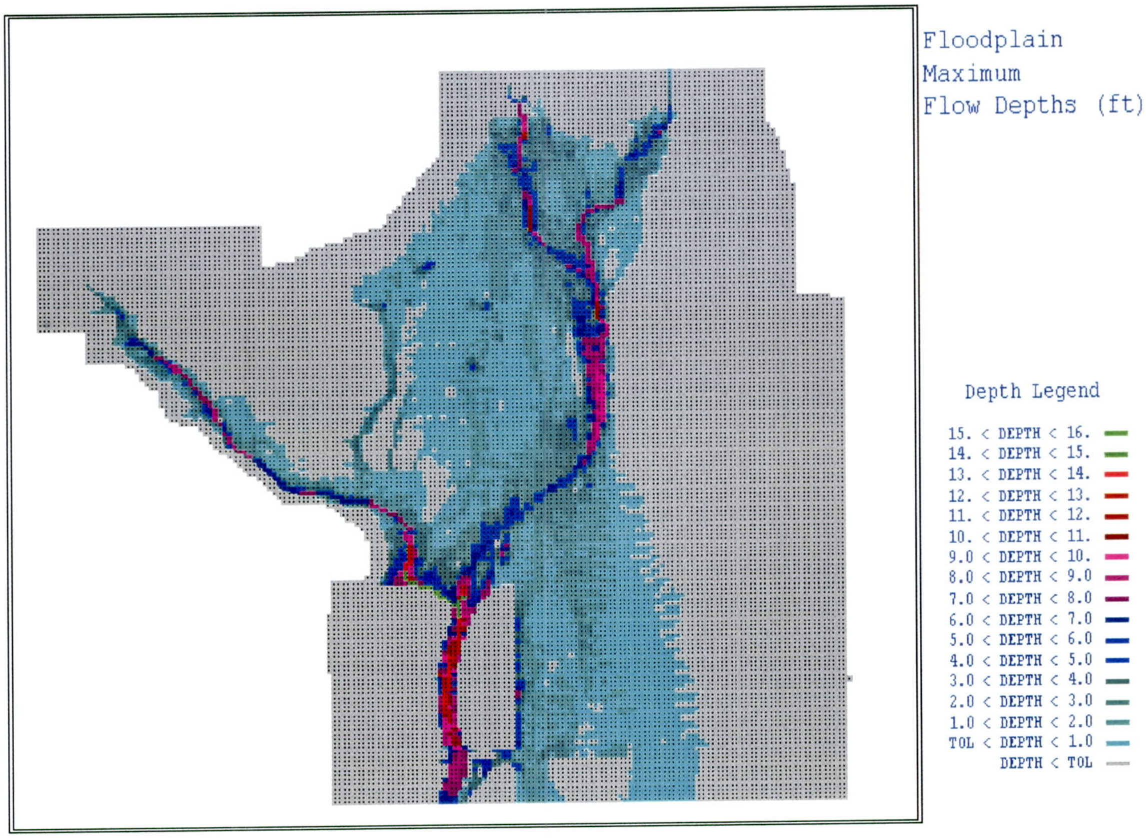


FIGURE 4-6: Pre-Development of I-17 & CAP Canal, SPF Maximum Flow Depths

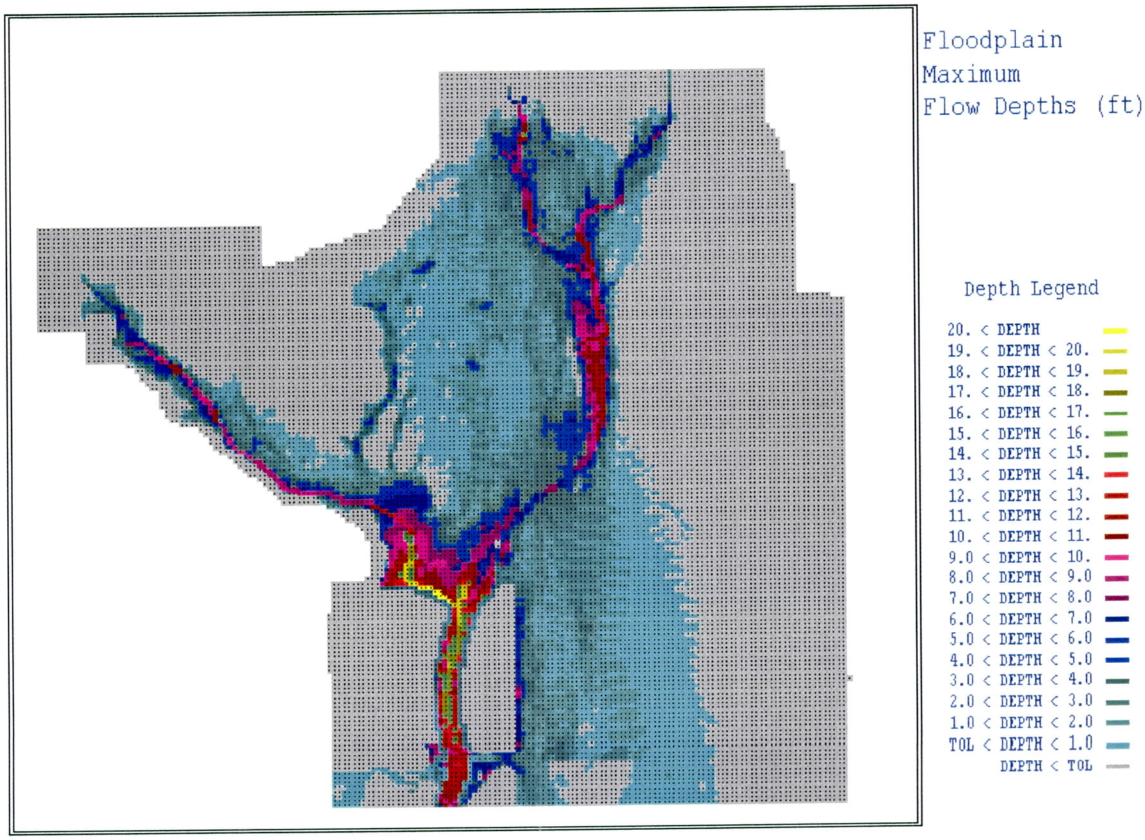


FIGURE 4-7: Widened Overchutes Alternative, 100-year Maximum Flow Depths

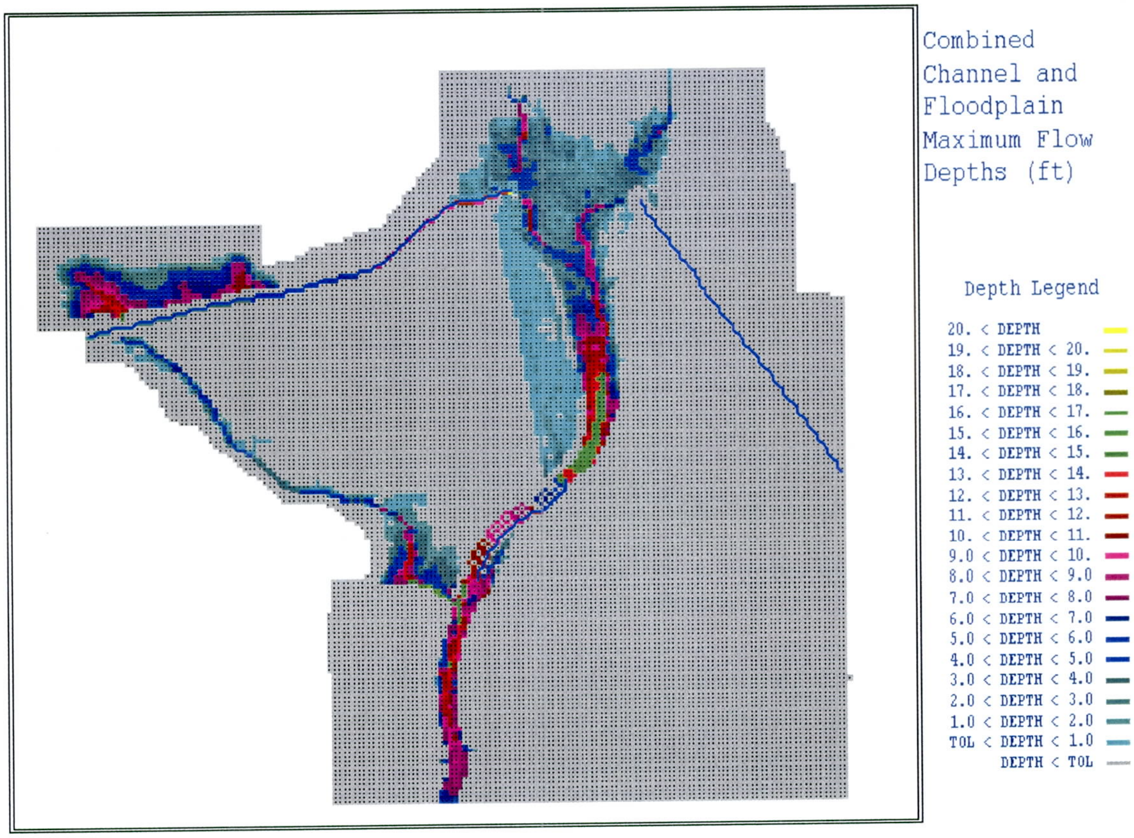


FIGURE 4-8: Widened Overchutes Alternative, SPF Maximum Flow Depths

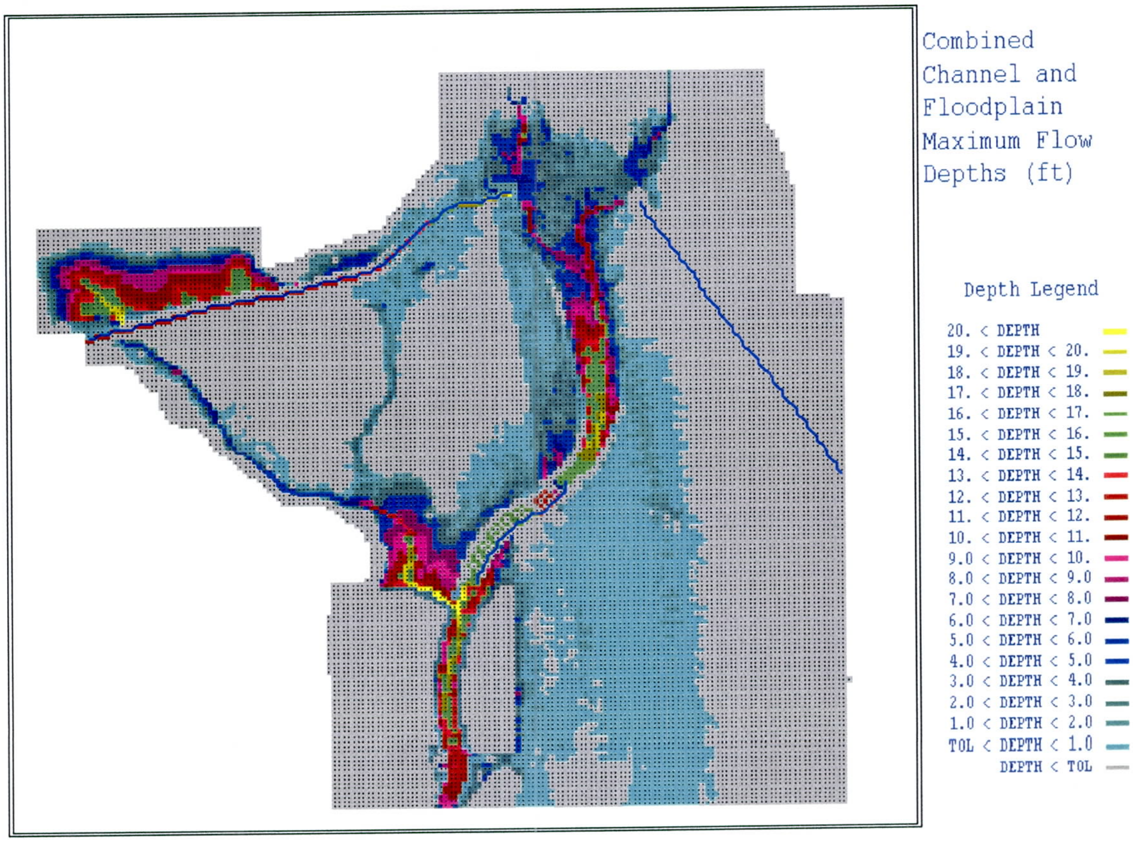


FIGURE 4-9: Extended Levees Alternative, 100-year Maximum Flow Depths

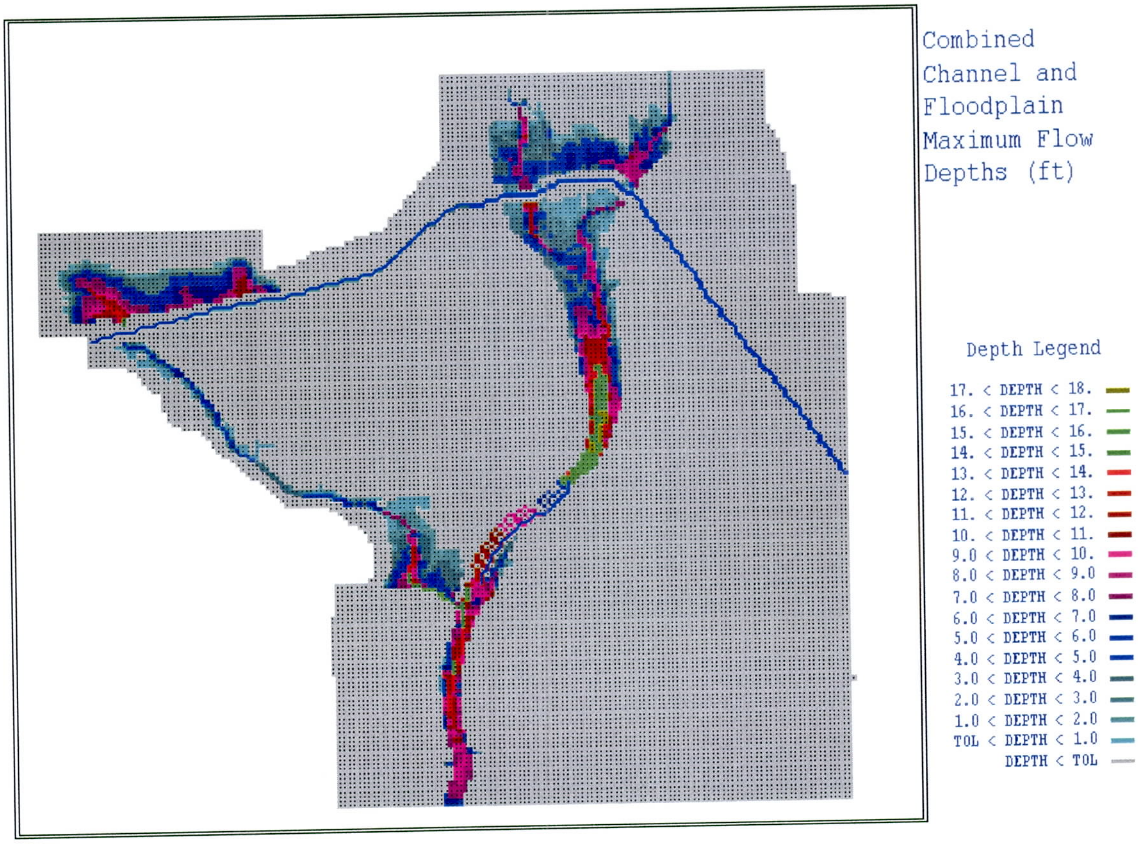
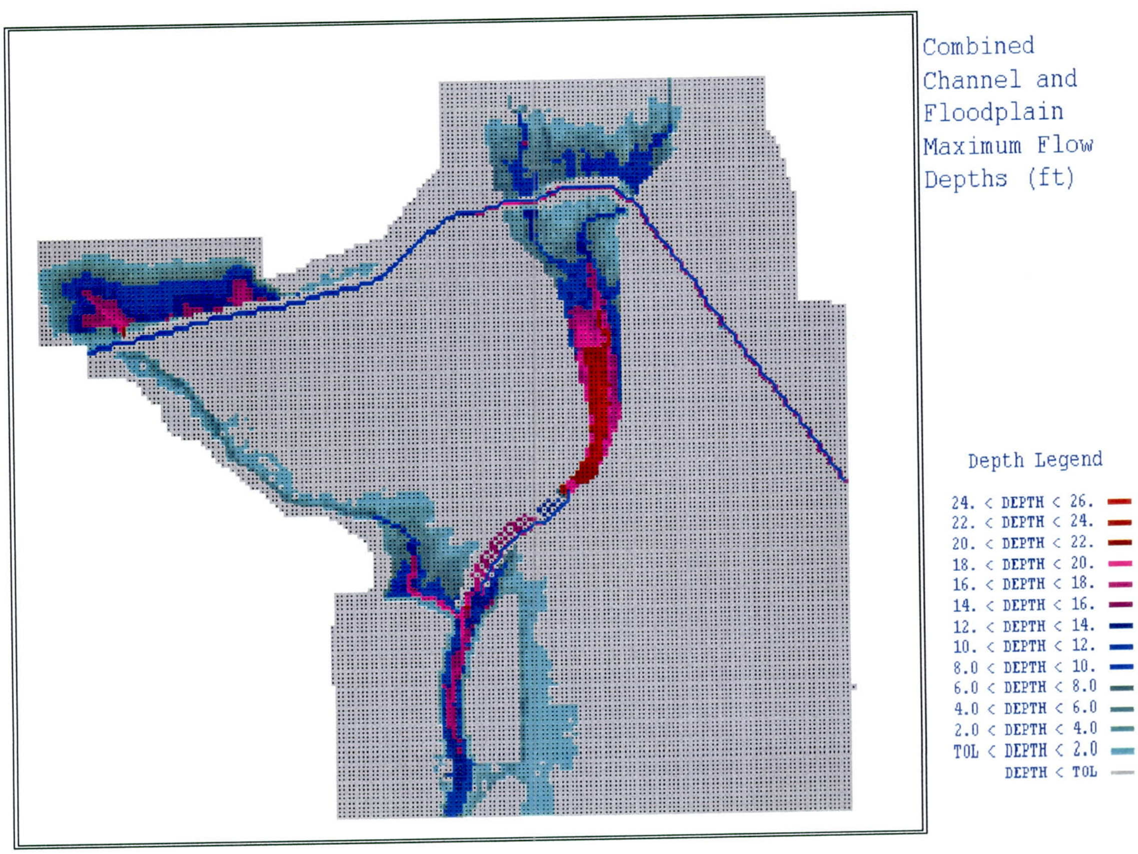


FIGURE 4-10: Extended Levees Alternative, SPF Maximum Flow Depths



SECTION 5: CONCLUSIONS & RECOMMENDATIONS

5.1 GENERAL

The FLO-2D models were effective in defining the two-dimensional flow patterns, hydraulics, and water-surface elevations for existing conditions within the study area. The models identified locations where flow breaks out of the Skunk Creek and Sonoran Wash channel corridors and provided estimates of the break-out flow depth. The existing condition model shows flooding over I-17 north of the CAP Canal. However, the flow is shallow and is contained over a relatively small area. During the SPF, there is extensive shallow flooding over large areas of the study area.

Significant ponding occurs north of the CAP Canal on Buchanan Wash. This has little negative consequence, because there is no development in the area at this time that would be flooded. The land in the ponding area is presently owned by the State of Arizona, according to FCDMC records. However, this ponding causes significant attenuation that is not accounted for in the effective FIS hydrologic model, which is documented in *Hydrologic Analyses for Buchanan Wash*, prepared by AGK Engineers in November 1987.

The pre-development models show that the construction of I-17 and the CAP Canal actually helped contain the flow breakout and reduce the size of the floodplain. The flows were fairly well contained only after I-17 was built. Prior to development, overbank flooding was widespread and shallow, as is typical in flat alluvial floodplains in Maricopa County.

The modeling shows that widening the overchutes does not help to alleviate the flooding problems upstream of the CAP Canal. Even if the Canal was completely tiled over from Skunk Creek to Sonoran Wash, floodwater still breaks out over Interstate 17.

Extending the existing Skunk Creek levees upstream to the CAP Canal and north of the Canal on both the east and west sides was effective in confining the flooding to the channel corridors. However, if total containment of the SPF event is desired, the opening in the eastern levee downstream of I-17 will need to be addressed. Further discussion of this item is included in Section 5.3. The conceptual design and estimated cost of extending the levees is discussed in Section 5.2.

The existing conditions models show that flooding during the 100-year event remains in the Adobe Dam watershed (see Figure 4-1). However, during the SPF event, it is possible that flow may break out of the channel corridor and bypass Adobe Dam, flowing southward on both east and west sides of I-17 (see Figure 4-2). This condition is discussed further in Section 5.3.

5.2 EXTENDED LEVEE DESIGN AND COST ESTIMATE

Figure 5-1 shows the conceptual design of the levee extensions. Figure 5-2 shows the typical levee cross-section that was used to estimate construction costs. This cross-section is the same one used for the Corps' levees upstream of I-17. The cost estimate shown in Table 5-1 is based upon levees constructed with cement soil alluvium (CSA) containing 9% cement. It is assumed that all aggregate can be found onsite. No additional bank protection is included. The base cost of $62.50 per cubic yard was provided by Laurence Spanulescu, of FCDMC.

An assumed toe-down depth of 15 feet below existing ground was used to calculate the volume and costs for levee scour protection. Initially, the costs were calculated assuming that the cut-off walls would be constructed with the same CSA mix used for the levees. However, Table 5-1 shows that the cost of the CSA cut-off walls exceeded the cost for the levees. For this reason, a second cost estimate is provided in Table 5-2 assuming that the same CSA levees are constructed using concrete for the cut-off walls. This allows for a reduction in the volume of the cut-off wall, as shown in Figure 5-2. The total estimated cost of the extended levees with concrete cut-off walls is $3,659,000, as compared to $5,906,000 using CSA cut-off walls, a reduction of 38%.

TABLE 5-1: Levee Construction Cost Estimate – Cement Soil Alluvium Toe-down

Location	Height [ft]			Length [ft]	Avg. End Area [sf]		Volume [cy]		Construction Cost[1]		
	High	Low	Avg.		Levee	Toe-Down	Levee	Toe-Down	Levee	Toe-Down	Total
East bank from existing levee to CAP Canal	6	2	3.3	4,600	78	135	13,289	23,000	$830,600	$1,437,500	$2,268,100
East bank from CAP Canal to end	12	3	6.6	1,200	251	135	11,156	6,100	$697,300	$375,000	$1,072,300
West bank from existing levee to CAP Canal	6	1	3.1	3,000	85	135	9,444	15,000	$590,300	$937,500	$1,527,800
West bank from CAP Canal to end	7	1	3.8	2,000	89	135	6,593	10,000	$412,100	$625,000	$1,037,100
TOTAL									$2,530,300	$3,375,000	$5,906,000

[1] Construction cost = $62.50 per cubic yard, per FCDMC.

TABLE 5-2: Levee Construction Cost Estimate – Concrete Toe-down

Location	Construction Cost[1]		
	Levee	Toe-Down	Total
East bank from existing levee to CAP Canal	$830,600	$480,700	$1,311,300
East bank from CAP Canal to end	$697,300	$125,400	$822,700
West bank from existing levee to CAP Canal	$590,300	$313,500	$903,800
West bank from CAP Canal to end	$412,100	$209,000	$621,100
TOTAL	$2,530,300	$1,128,600	$3,659,000

[1] Construction cost = $62.50 per cubic yard for Cement Soil Alluvium (levee), per FCDMC.
$94 per cubic yard for concrete (toe-down), per CalTrans Construction Cost Index.

FIGURE 5-1: Conceptual Levee Design

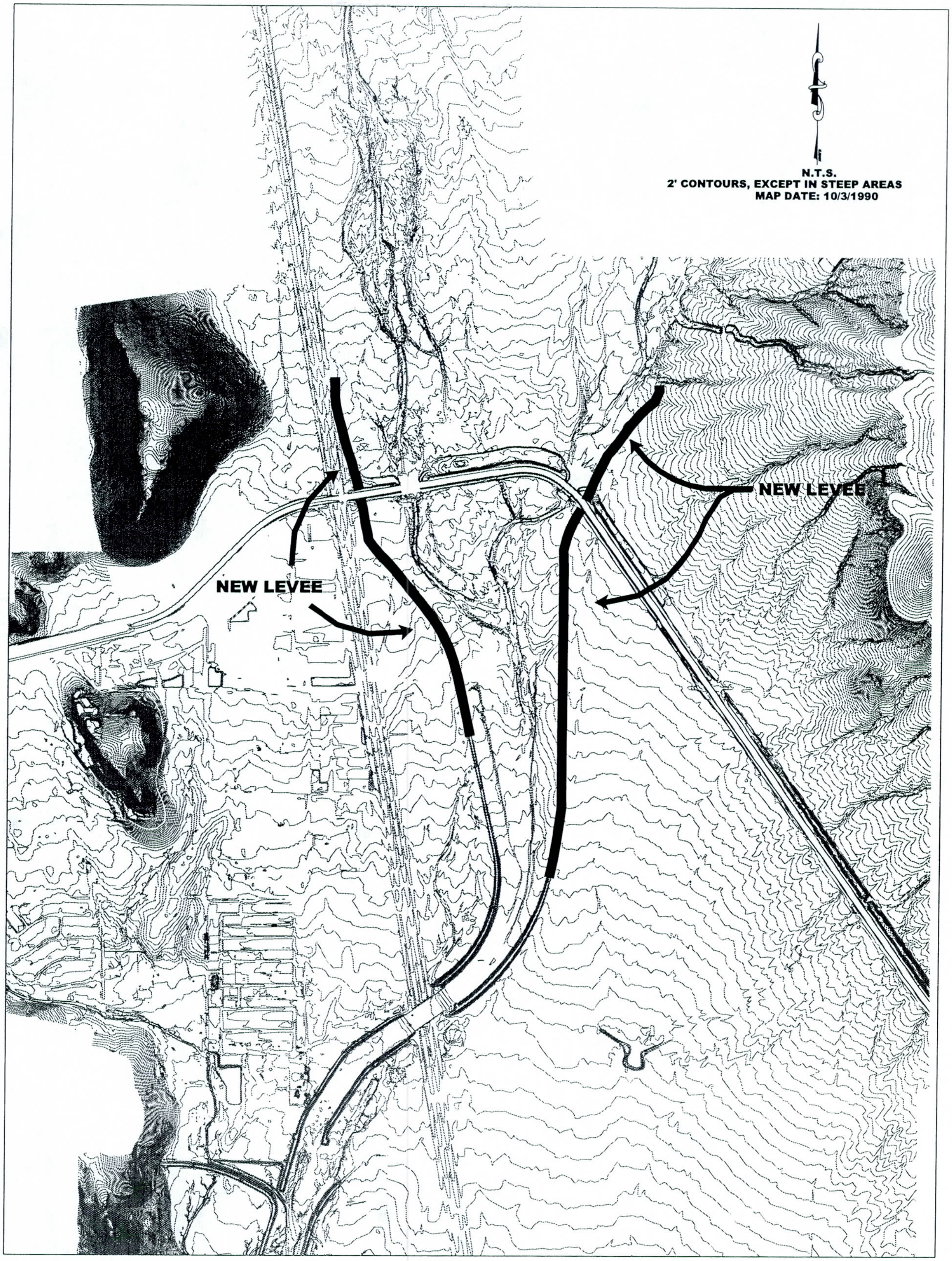
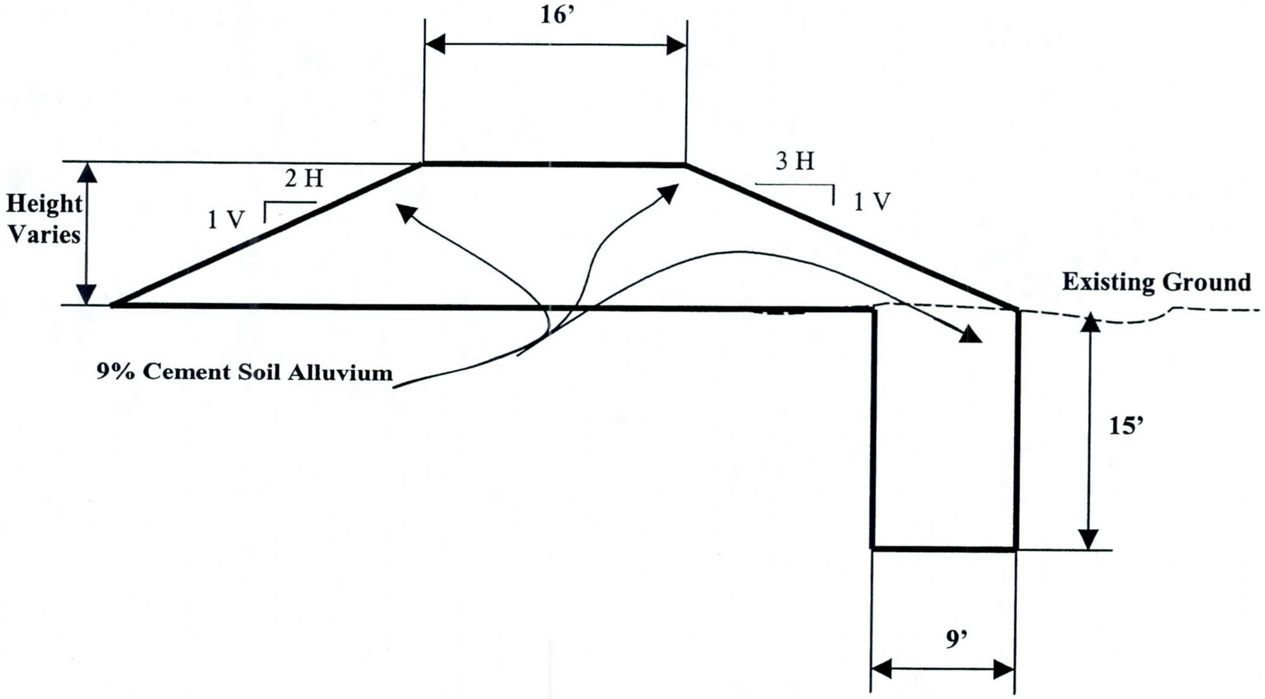
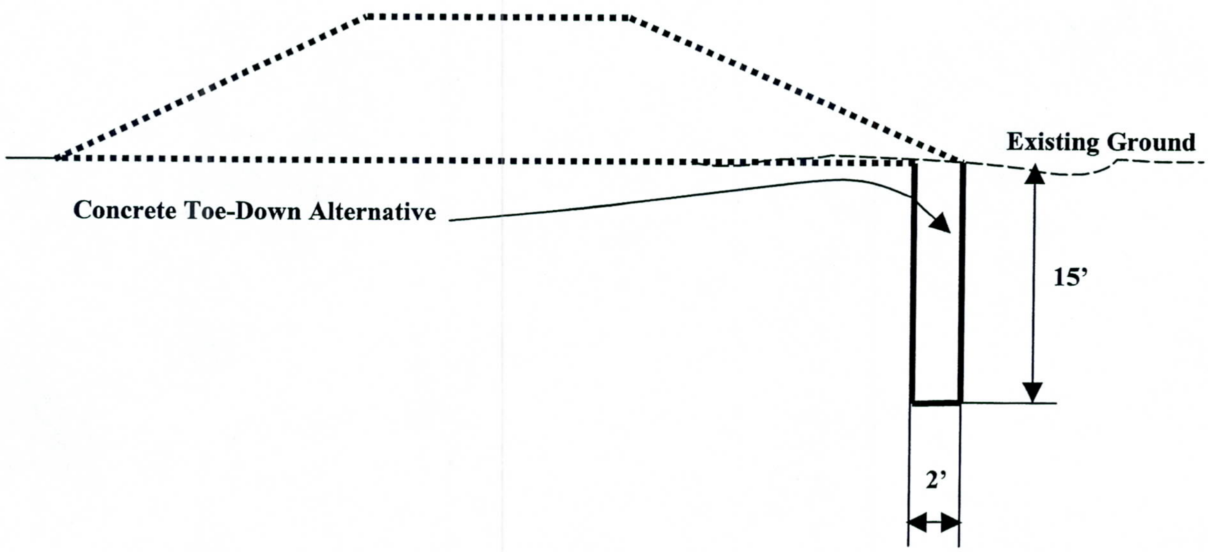


FIGURE 5-2: Typical Levee Cross-section





5.3 FLOW BYPASSING ADOBE DAM

The existing conditions SPF model shows floodwater breaking over the CAP Canal in two locations. One section is immediately west of Interstate 17. Breakout flow from this section moves southward, through the development between I-17 and Buchanan Wash. It ultimately joins Buchanan Wash just upstream of the confluence with Skunk Creek.

Another section of breakout over the CAP Canal is located east of the Sonoran Wash overchute. Flow that crosses the CAP in this area continues in a southerly direction on the east side of I-17, flowing over Happy Valley Road and continuing south to the study area boundary. In some places, it appears that shallow flooding crosses I-17. However, most of the floodwater remains on the east side of the freeway and almost certainly bypasses Adobe Dam, unless there are drainage facilities somewhere along I-17, south of the study area, that route it back to the west side of the freeway.

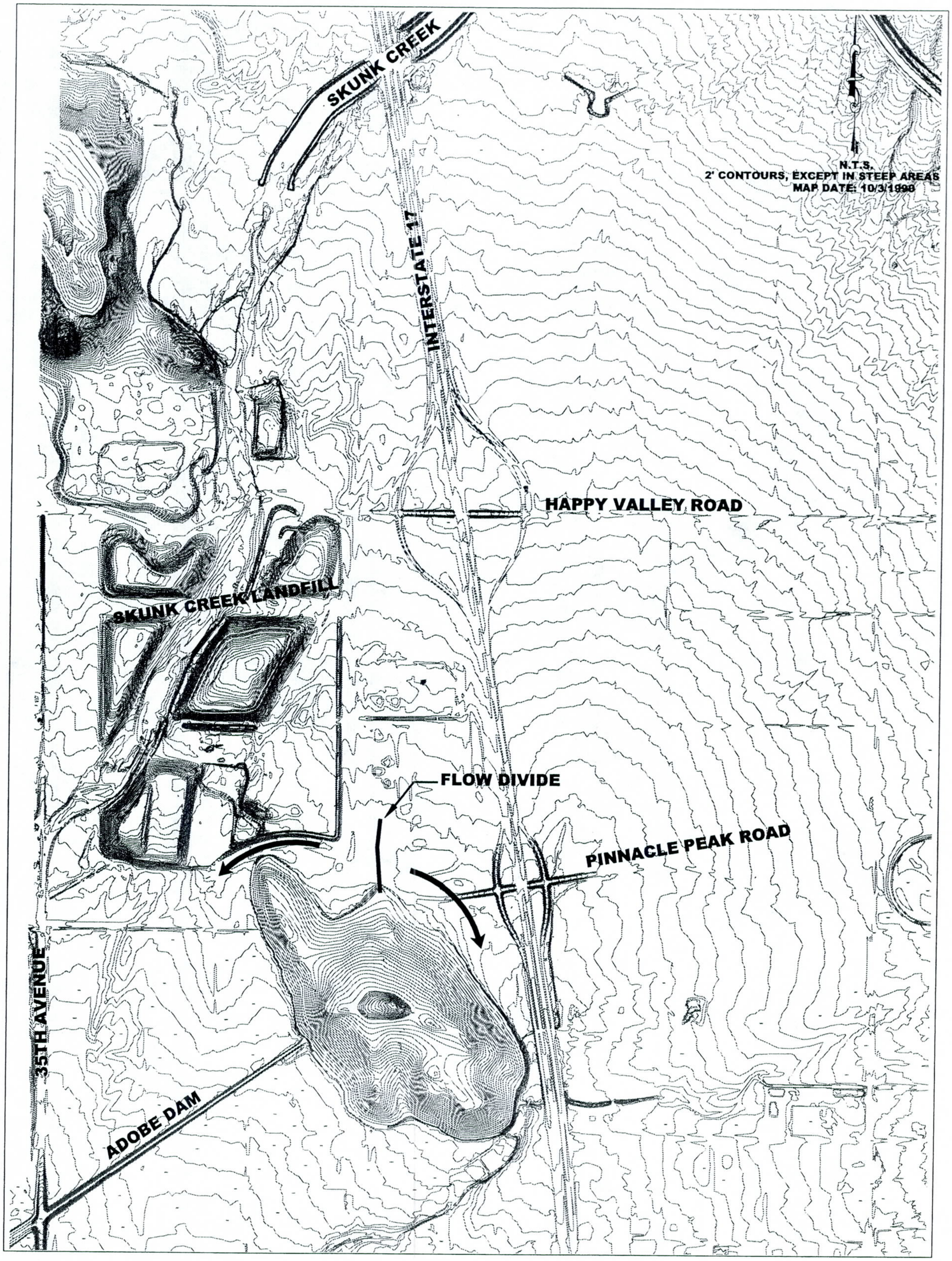
Flooding on the west side of I-17, between the freeway and Skunk Creek Landfill, originates mostly from the break between the Corps' levee and the City of Phoenix landfill levee. The SPF generates enough backwater in the channel to push flow through the levee break and around the northern tip of the landfill. From that point, the water flows along the eastern border of the landfill to Happy Valley Road, where the flow most likely stays on the east side of the landfill and heads south to Pinnacle Peak Road.

Figure 5-3 shows mapping provided by FCDMC that extends south of the study area to Pinnacle Peak Road and includes Adobe Dam, east of 35th Avenue. This mapping clearly shows that there is a flow divide on the east side of the Skunk Creek Landfill immediately north of Pinnacle Peak Road. Any water that flows around the east side of the butte at Pinnacle Peak Road will bypass Adobe Dam. However, there has been significant construction along Pinnacle Peak Road since the mapping was prepared in 1990. Updated mapping and further study of the conditions east of the landfill at Happy Valley Road and Pinnacle Peak Road are necessary before any conclusive flood delineation can be prepared.

Figure 4-10 shows that the extended levees alternative is very effective in containing the breakout flow north of the CAP Canal. There is no longer flow breaking over the Canal east of Sonoran Wash, which, in turn, greatly reduces the volume of SPF flow that may bypass

Adobe Dam. However, unless the opening in the levee downstream of I-17 is filled in, the possibility remains that some flow will bypass Adobe Dam on the east side of the landfill.

FIGURE 5-3: Path of Flow Bypassing Adobe Dam



REFERENCES

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U.S. Army Corps of Engineers, 1982, *Gila River Basin: New River and Phoenix City Streams, Arizona, Hydrology, Part 2*, Design Memorandum No. 2.

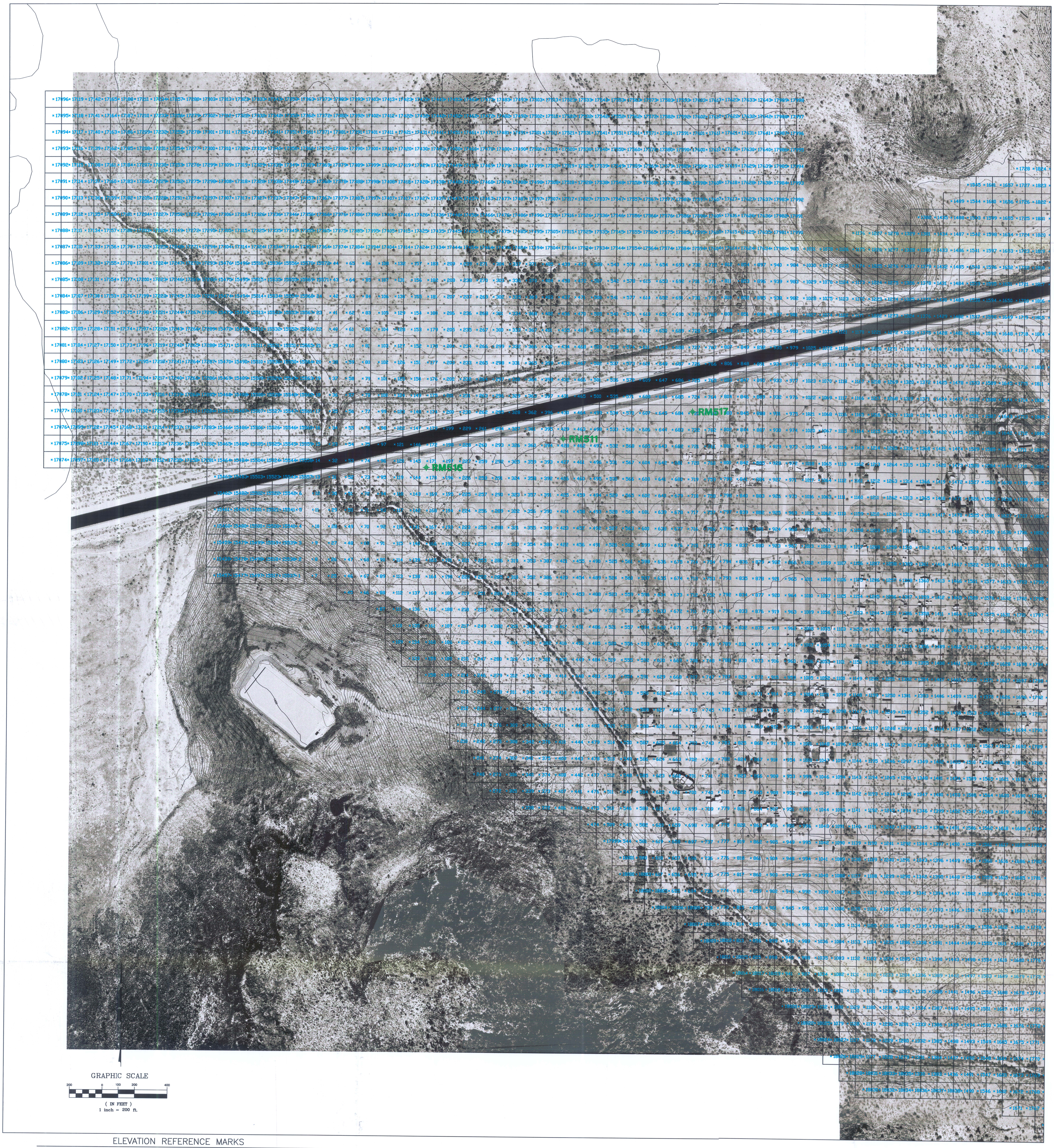
U.S. Army Corps of Engineers, 1981, *Skunk Creek Channel and Levees*, Construction Plans.

U.S. Army Corps of Engineers, March 1965, *Standard Project Flood Determination*, Engineer Manual 1110-2-1411.

U.S. Geological Survey, photorevised 1981, Hedgepeth Hills Quadrangle Map- Maricopa County, Arizona, 7.5 Minute Series (topographic)

Exhibit A

Study Area Work Maps
(5 sheets)



GRAPHIC SCALE

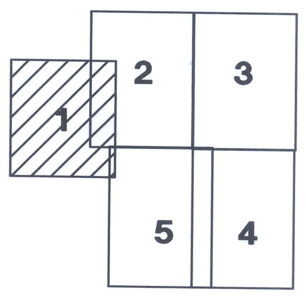
200 0 100 200 400

(IN FEET)
1 inch = 200 ft.

ELEVATION REFERENCE MARKS

NOTE: ALL ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929.
LOCATIONS (NORTHING & EASTING) ARE BASED ON ARIZONA CENTRAL STATE PLANE COORDINATES, NAD83.

I.D. NUMBER	ELEVATION (INT. FT.)	DESCRIPTION/LOCATION
RM511	1500.40	FOUND U.S. DEPARTMENT OF INTERIOR BRASS CAP ALONG C.A.P. CANAL. STAMPED POINT #44, STATION 373+41.83, 125' RIGHT. N: 996,647.5 E: 630,771.9
RM516	1502.17	FOUND U.S. DEPARTMENT OF INTERIOR BRASS CAP ALONG C.A.P. CANAL. STAMPED POINT #43, STATION 386+00, 125' RIGHT. N: 996,468.5 E: 629,935.6
RM517	1499.82	FOUND U.S. DEPARTMENT OF INTERIOR BRASS CAP ALONG C.A.P. CANAL. STAMPED POINT #45, STATION 402+67.37, 125' RIGHT. N: 996,816.7 E: 631,562.7



INDEX MAP

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INFRASTRUCTURE SOUTHWEST GROUP
4801 East Washington Street, Suite 260, Phoenix, AZ 85034
(602) 682-3300 FAX (602) 244-1164

DES:	DWN:	SCALE:	DRAWING FILE:	SHEET NO.	TOTAL SHEETS
LML	CBC	HORIZ: 1"=200'	P:\4501\GRID-PROPERTIES.DWG	1	5
JOB NO: PFCMC4501	DATE: 4/22/02				

EXHIBIT A
SKUNK CREEK TWO-DIMENSIONAL MODEL
WORK MAP

ELEVATION REFERENCE MARKS

NOTE: ALL ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929.
LOCATIONS (NORTHING & EASTING) ARE BASED ON ARIZONA CENTRAL STATE PLANE COORDINATES, NAD83.

I.D. NUMBER	ELEVATION (INT. FT.)	DESCRIPTION/LOCATION
M343	1510.27	BENCHMARK DISK SET IN TOP OF CONCRETE MONUMENT. STAMPED M 343 1959. N: 997,812.57 E: 636,904.35

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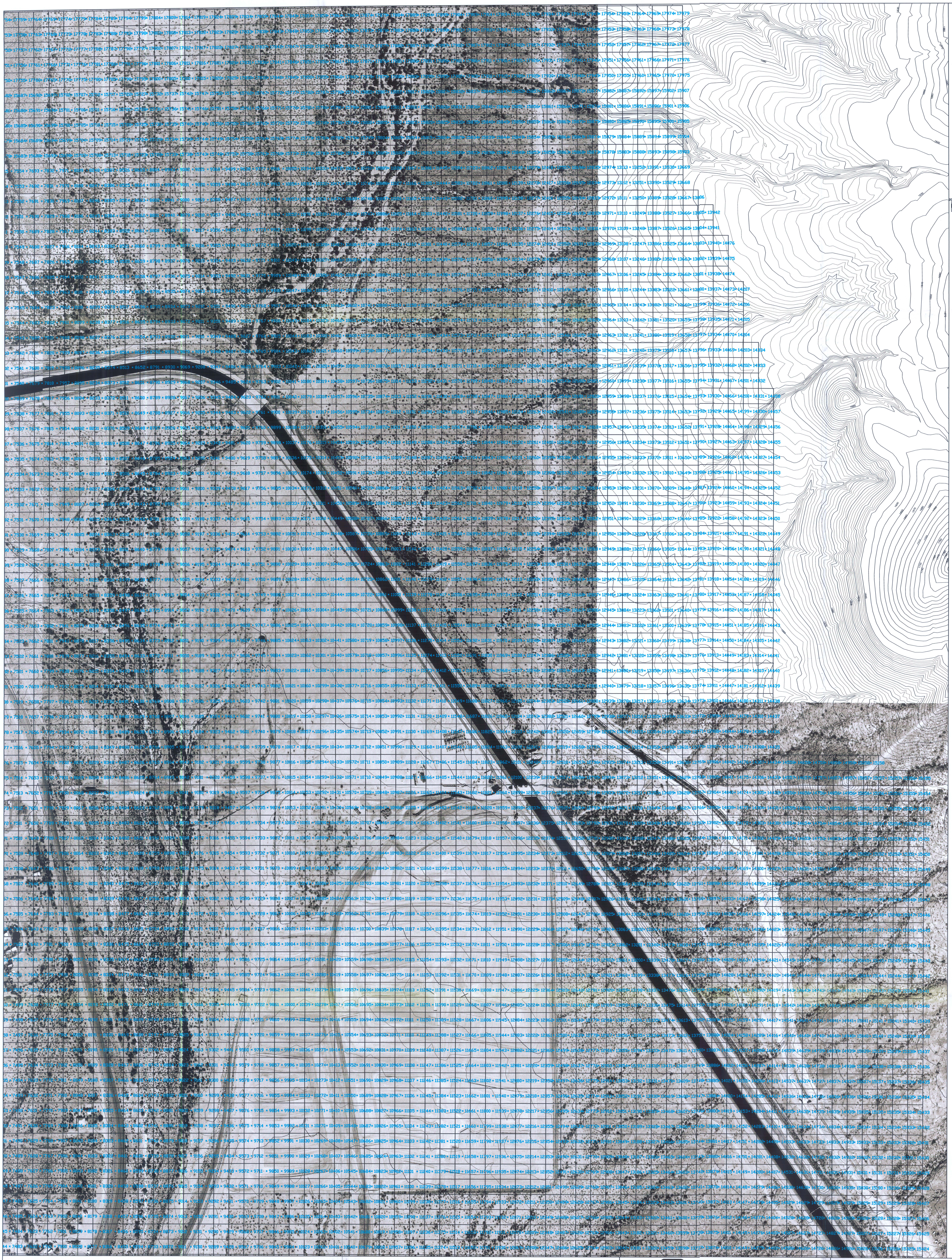
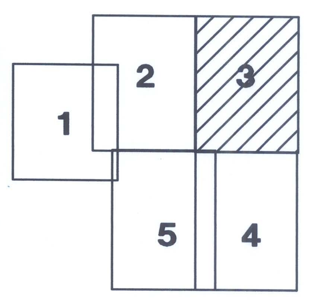
DES: LML	DWN: CBC	SCALE:	DRAWING FILE:	SHEET NO.	TOTAL SHEETS
JOB NO: PFCMC4501	DATE: 4/22/02	HORIZ: 1"= 200'	P:\4501\GRID-PROPERTIES.DWG	2	5

EXHIBIT A
SKUNK CREEK TWO-DIMENSIONAL MODEL WORK MAP





INDEX MAP

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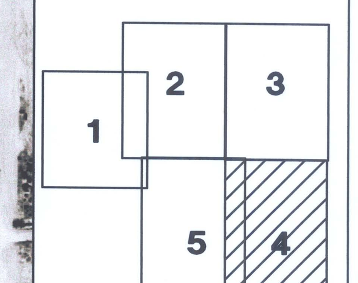
DES: LML	DWN: CBC	SCALE: HORIZ: 1"= 200'	DRAWING FILE: P:\4501\GRID-PROPERTIES.DWG	SHEET NO. 3	TOTAL SHEETS 5
JOB NO: PFCMC4501	DATE: 4/22/02				

EXHIBIT A
SKUNK CREEK TWO-DIMENSIONAL MODEL
WORK MAP

GRAPHIC SCALE

(IN FEET)
1 inch = 200 ft.



INDEX MAP

ELEVATION REFERENCE MARKS

NOTE: ALL ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929.

LOCATIONS (NORTHING & EASTING) ARE BASED ON ARIZONA CENTRAL STATE PLANE COORDINATES, NAD83.

I.D. NUMBER	ELEVATION (INT. FT.)	DESCRIPTION/LOCATION
SKUNK	1468.80	TRIANGULATION STATION DISK SET IN TOP OF CONCRETE MONUMENT. STAMPED SKUNK 1947. N: 991,620.65 E: 638,472.75
1IE1	1498.96	3" ALUMINUM CAP, AZ. HIGHWAY DEPT., SET IN CONCRETE. NB FRONTAGE ROAD, HWY. 17, STATION P.O.S.L. 1061+43.60, 0.3' +/- ABOVE NATURAL GROUND, EAST SIDE OF FRONTAGE ROAD. N: 991,670.32 E: 644,231.69

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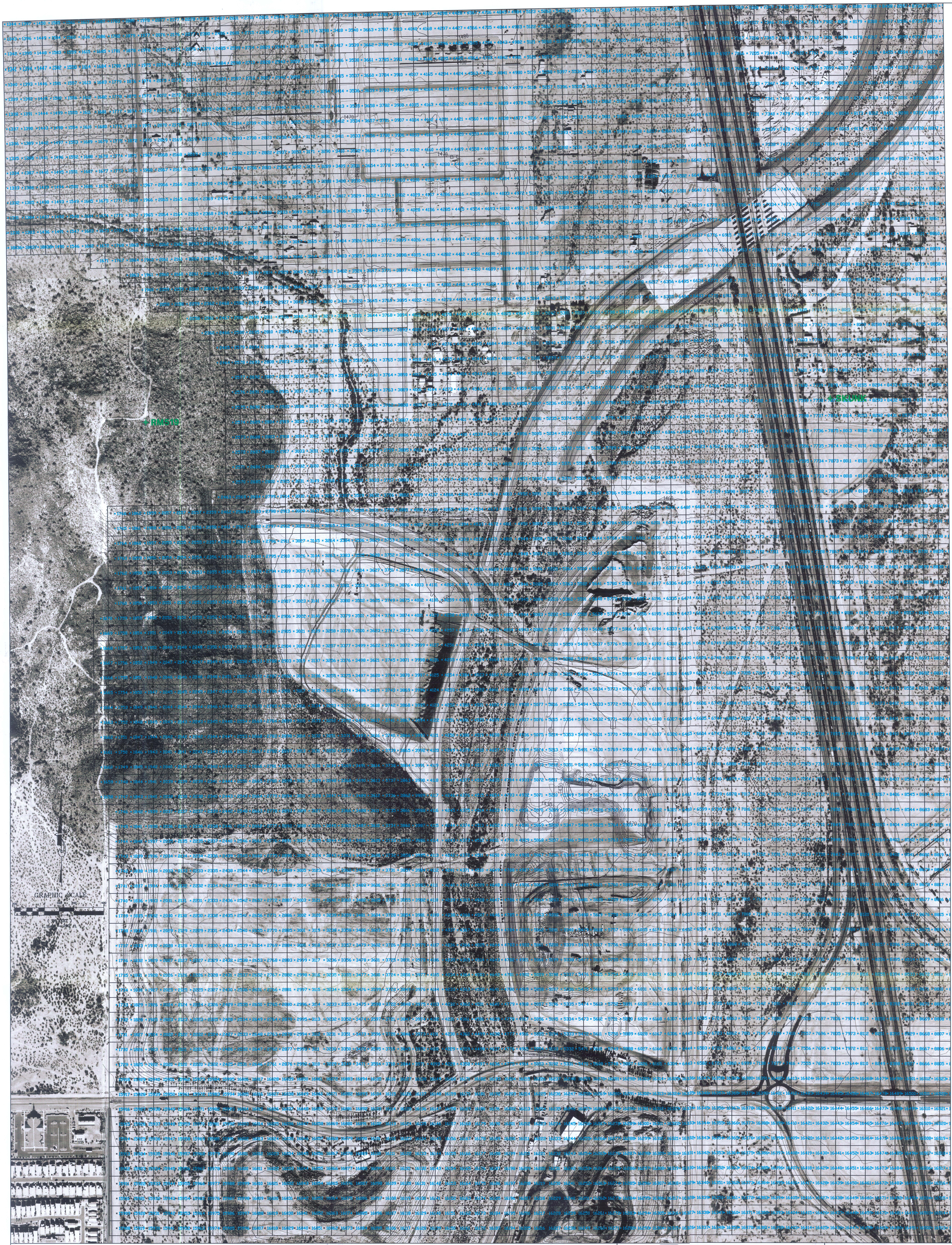
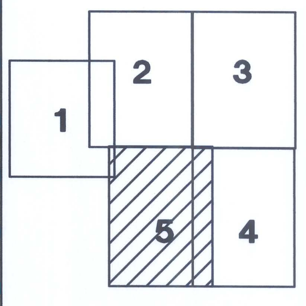
DES: LML	DWN: CBC	SCALE: HORIZ: 1"=200'	DRAWING FILE: P:\4501\GRID-PROPERTIES.DWG	SHEET NO. 4	TOTAL SHEETS 5
JOB NO: PFCMC4501	DATE: 4/22/02				

EXHIBIT A
SKUNK CREEK TWO-DIMENSIONAL MODEL WORK MAP





ELEVATION REFERENCE MARKS

NOTE: ALL ELEVATIONS ARE BASED ON NATIONAL GEODETIC VERTICAL DATUM OF 1929.

LOCATIONS (NORTHING & EASTING) ARE BASED ON ARIZONA CENTRAL STATE PLANE COORDINATES, NAD83.

I.D. NUMBER	ELEVATION (INT. FT.)	DESCRIPTION/LOCATION
SKUNK	1468.80	TRIANGULATION STATION DISK SET IN TOP OF CONCRETE MONUMENT. STAMPED SKUNK 1947. N: 991,620.65 E: 638,472.75
RM519	1555.12	FOUND STONE AT THE SE CORNER OF SEC. 34, T5N, R2E. N: 991,515.6 E: 633,855.0

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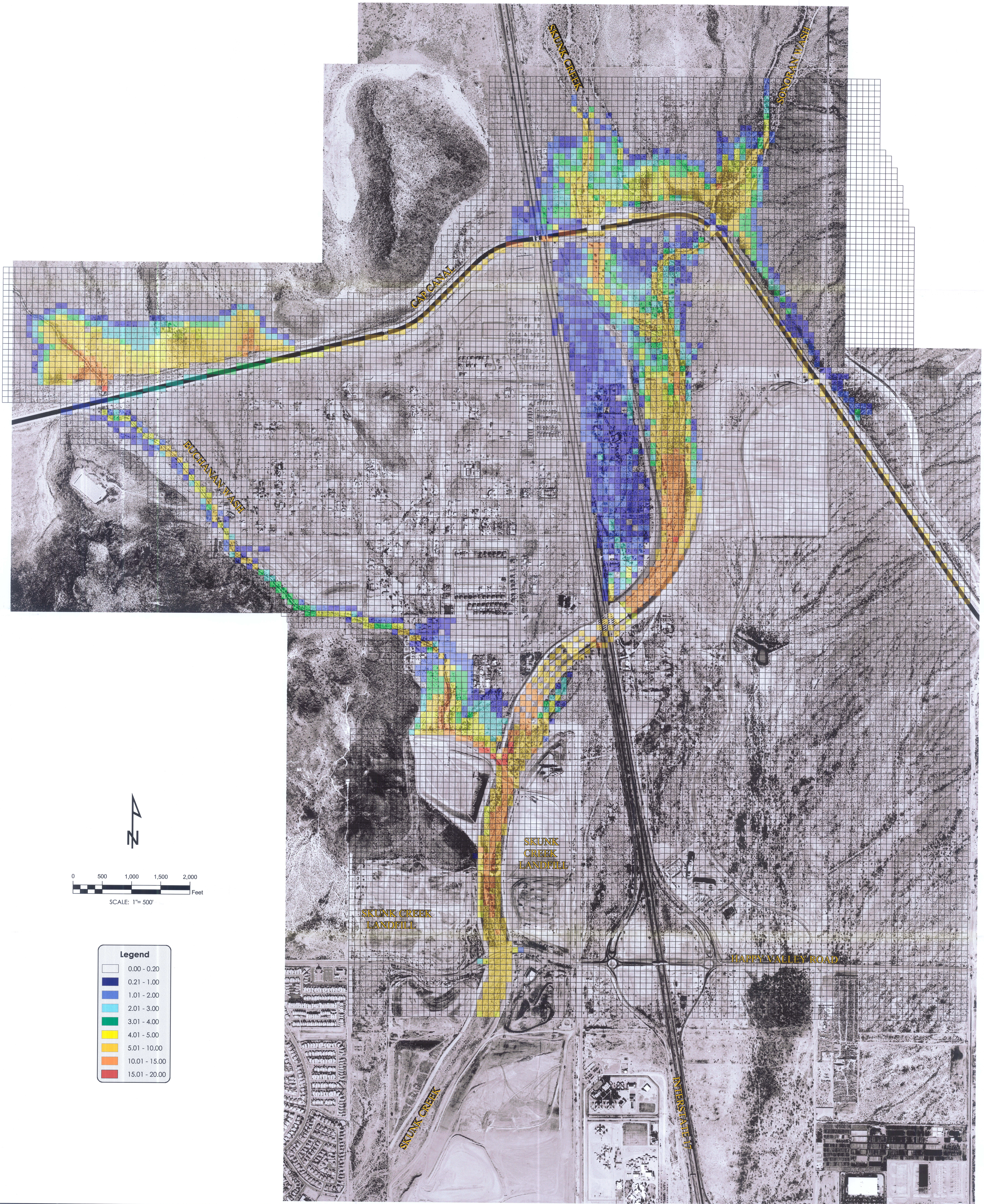
DES: LML	DWN: CBC	SCALE: HORIZ: 1"= 200'	DRAWING FILE: P:\4501\GRID-PROPERTIES.DWG	SHEET NO. 5	TOTAL SHEETS 5
JOB NO: PFCMC4501	DATE: 4/22/02				

EXHIBIT A
SKUNK CREEK TWO-DIMENSIONAL MODEL WORK MAP

Exhibit B

Existing Conditions
100-Year Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

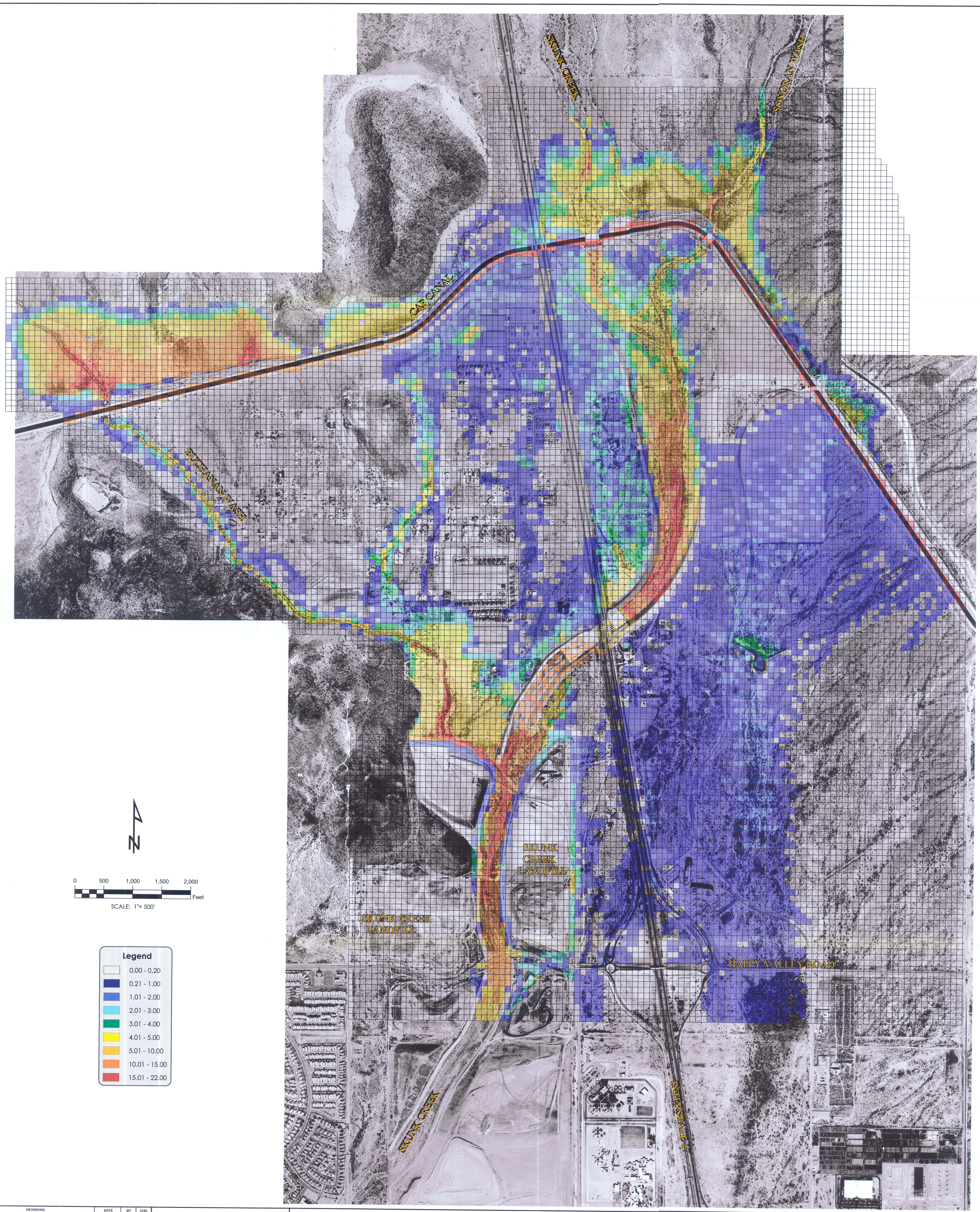
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

EXISTING CONDITIONS
100 - YEAR EVENT

SCALE:	1"= 500'
DRAWING NO.	
SHEET NO. 1	OF: 1

Exhibit C

Existing Conditions
SPF Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

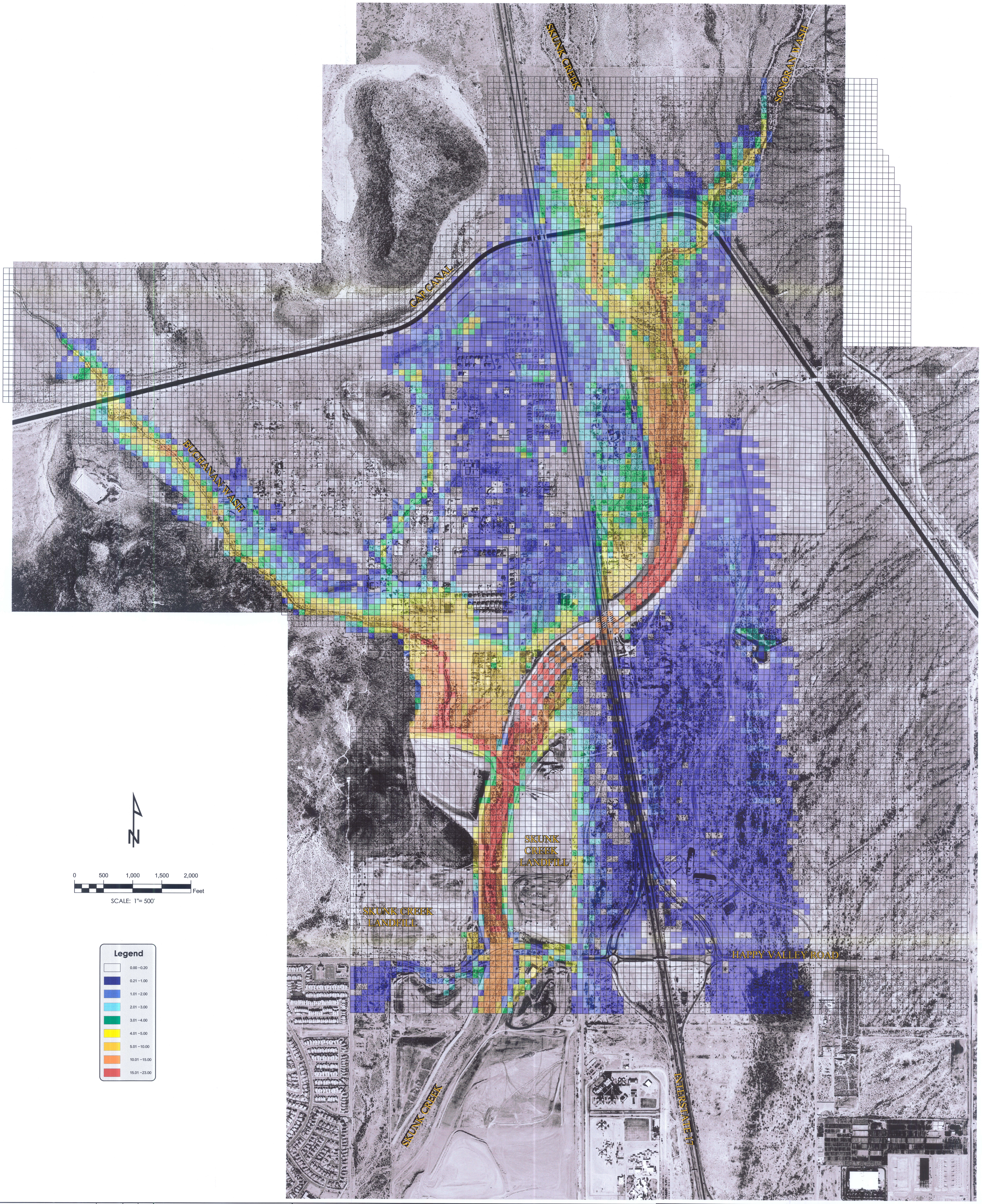
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

EXISTING CONDITIONS
SPF EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit D

Pre-Development of CAP Canal
100-Year Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.
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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

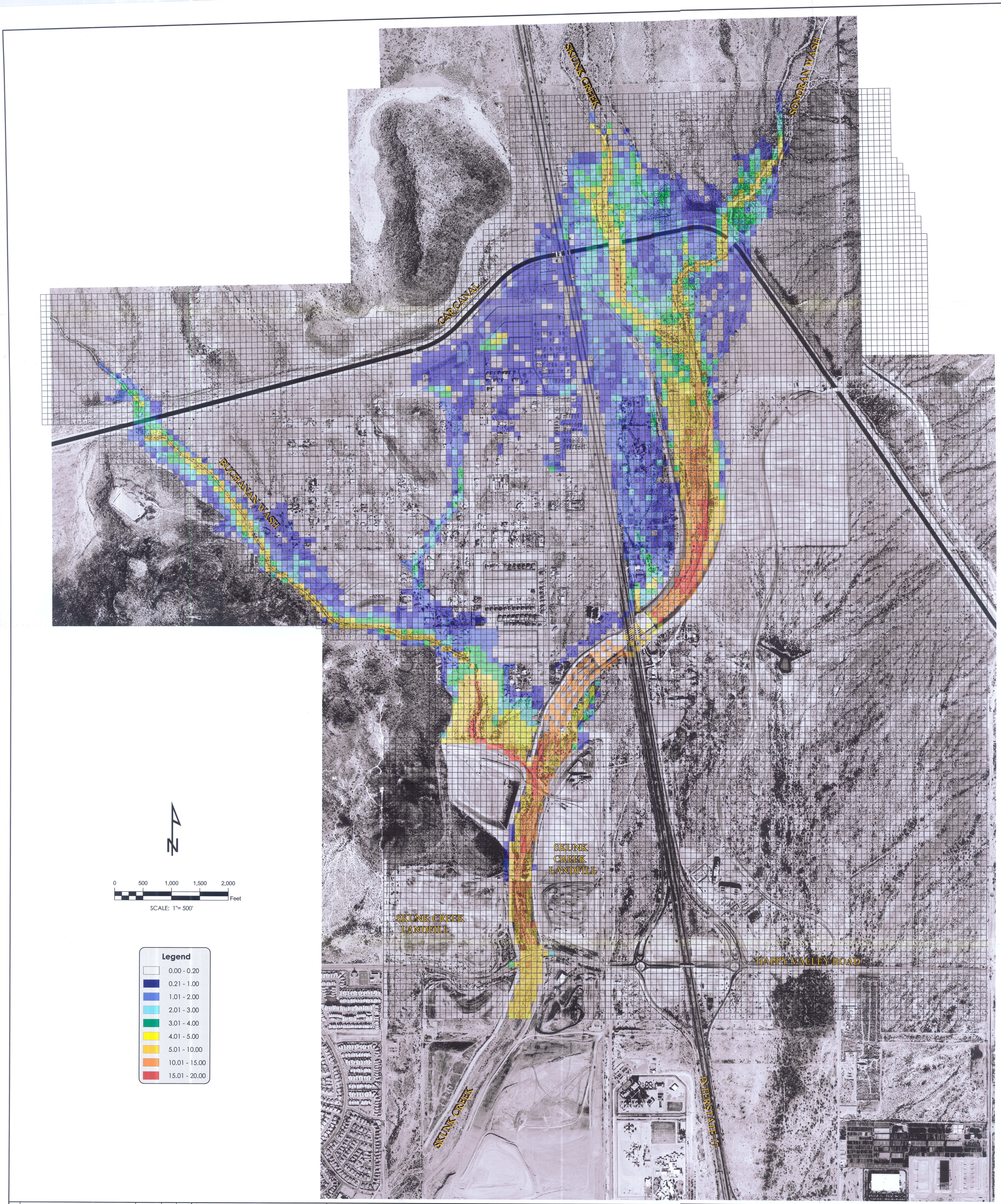
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

PRE - CAP CANAL
SPF EVENT

SCALE:	1"= 500'
DRAWING NO.	
SHEET NO. 1	OF: 1

Exhibit E

Pre-Development of CAP Canal
SPF Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

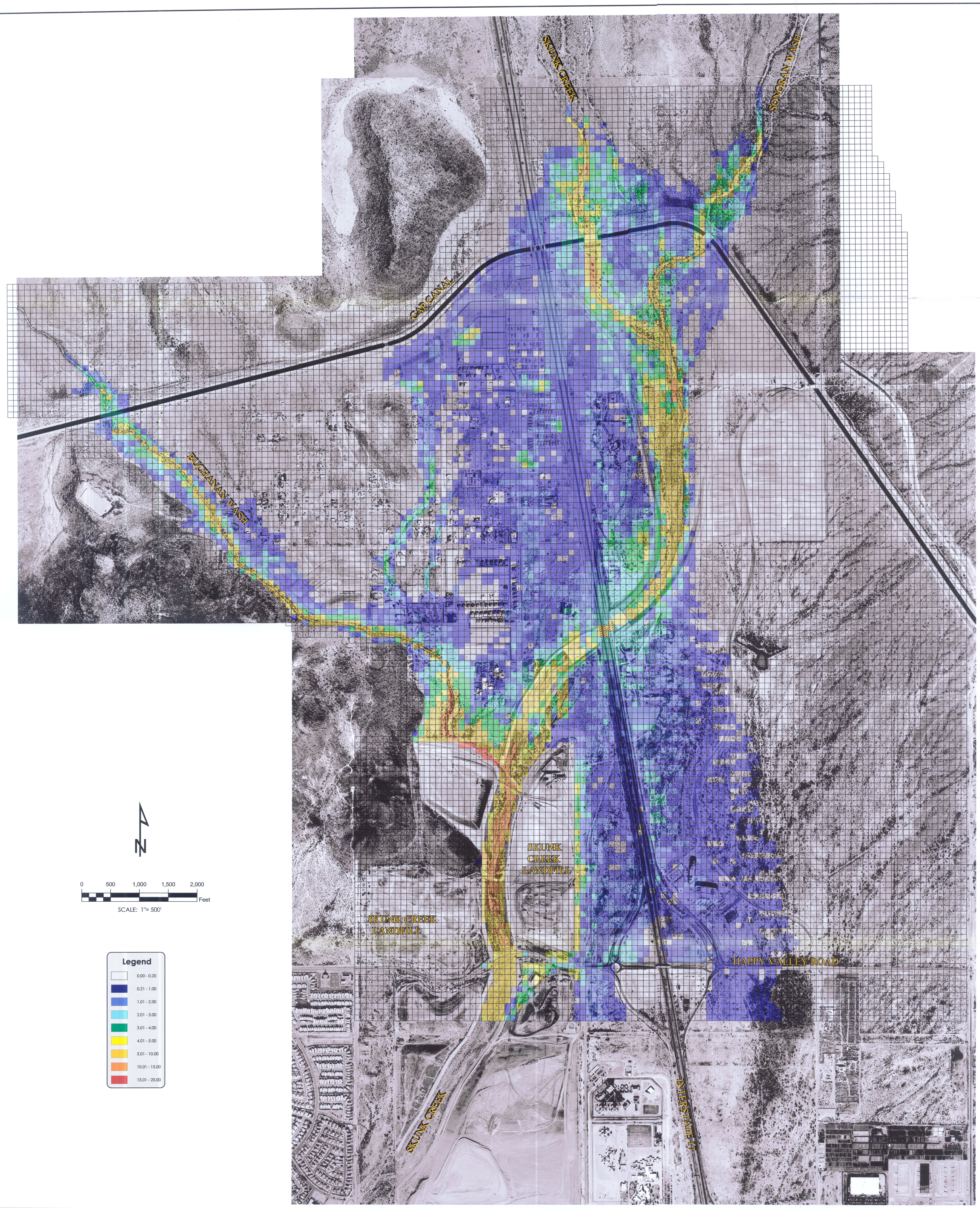
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

PRE - CAP CANAL
100 - YEAR EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit F

Pre-Development of I-17 & CAP Canal
100-Year Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY

TWO - DIMENSIONAL HYDRAULIC MODEL

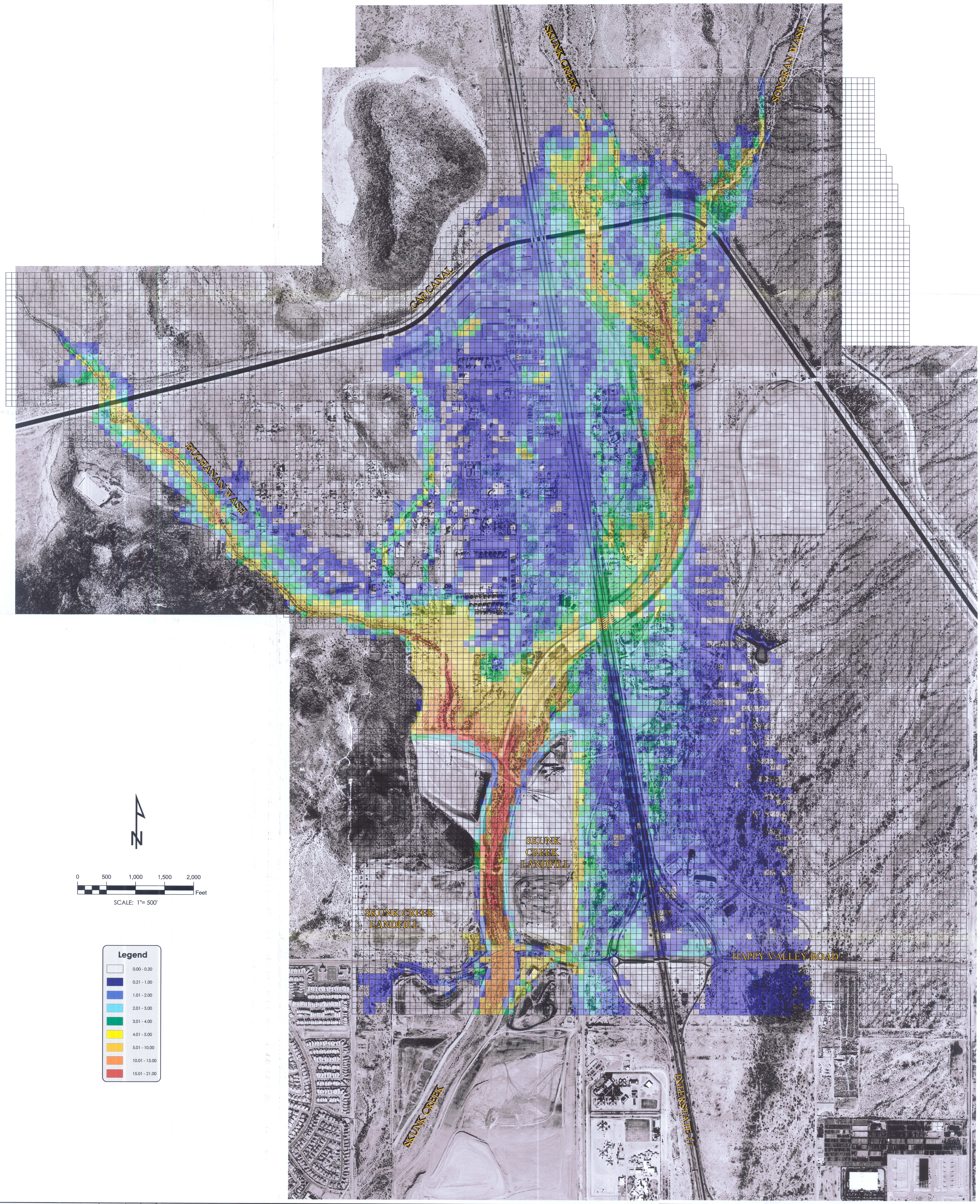
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

PRE - CAP CANAL & I - 17
100 - YEAR EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit G

Pre-Development of I-17 & CAP Canal
SPF Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

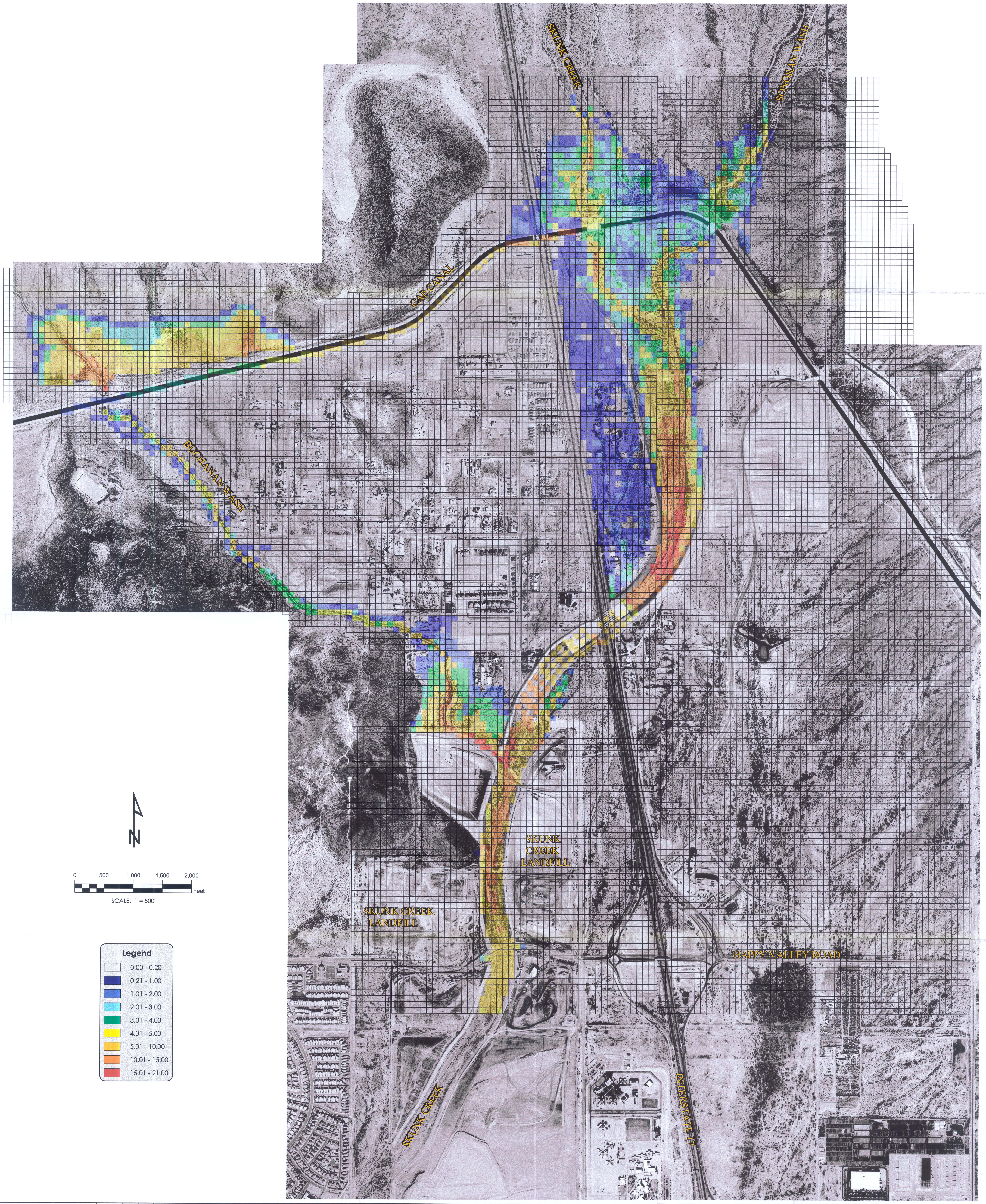
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

PRE - CAP CANAL & I - 17
SPF EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit H

Widened Overchutes Alternative
100-Year Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY

TWO - DIMENSIONAL HYDRAULIC MODEL

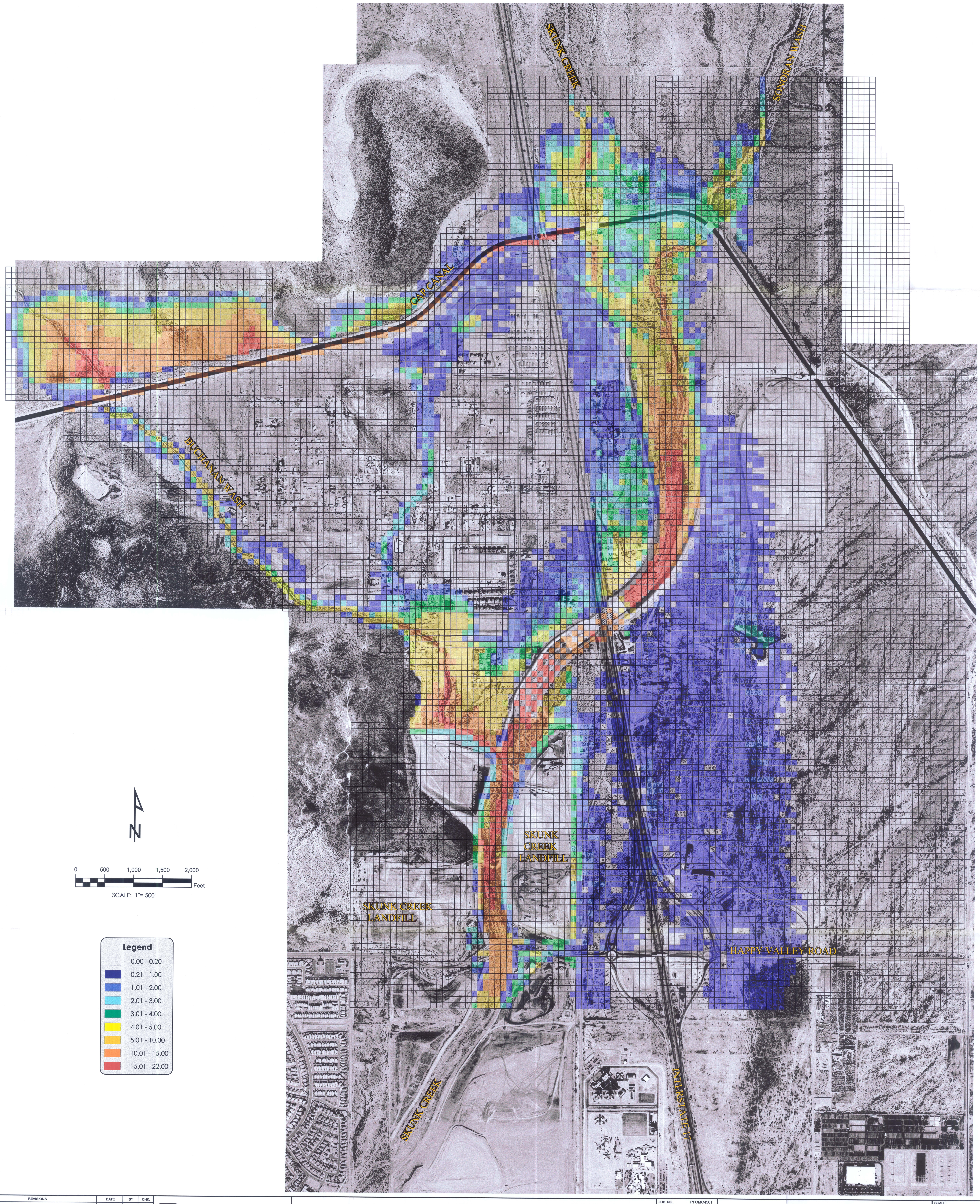
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

WIDENED OVERCHUTES
100 - YEAR EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit I

Widened Overchutes Alternative
SPF Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

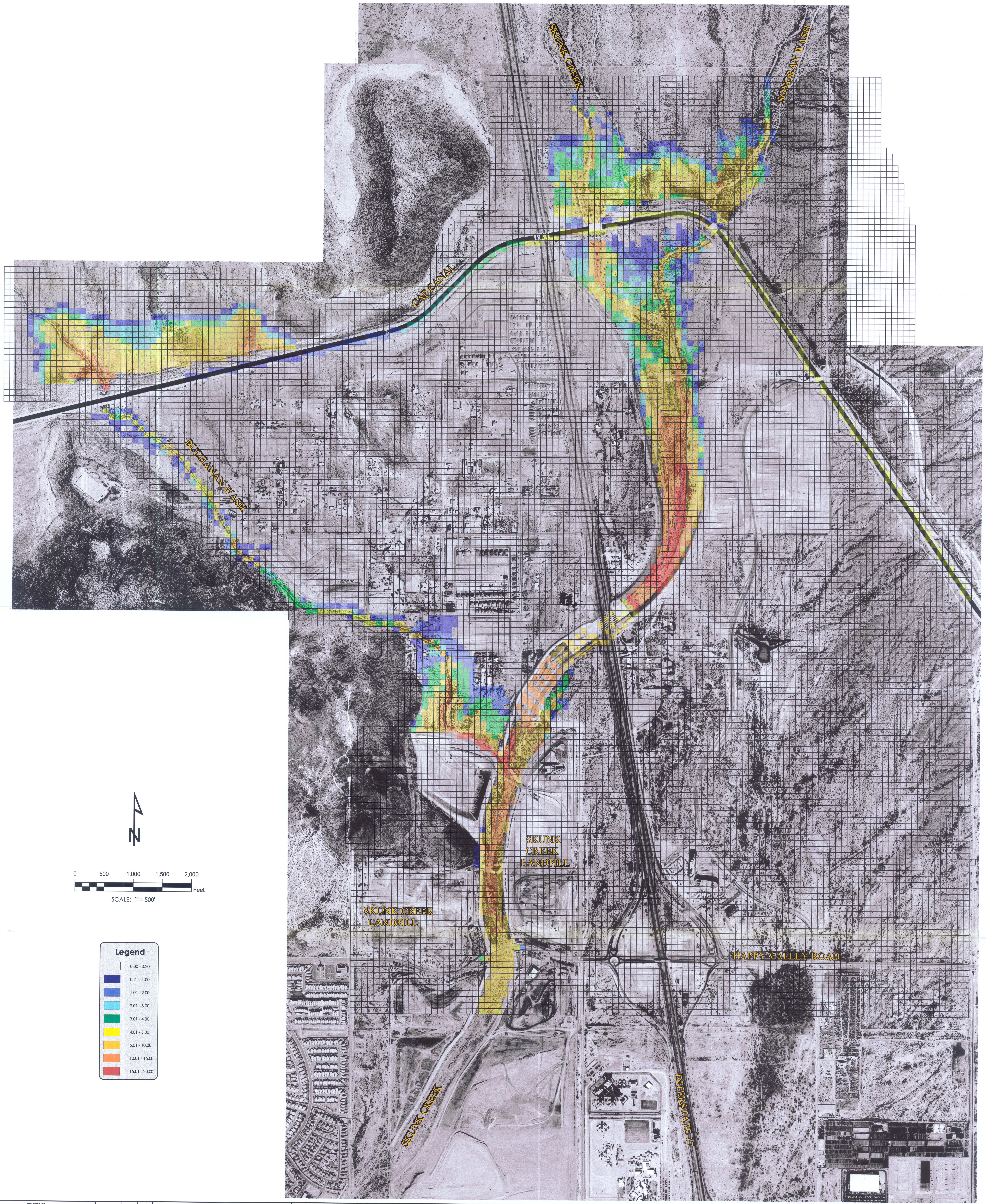
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

WIDENED OVERCHUTES
SPF EVENT

SCALE:	1"= 500'
DRAWING NO.	
SHEET NO. 1	OF: 1

Exhibit J

Extended Levees Alternative
100-Year Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

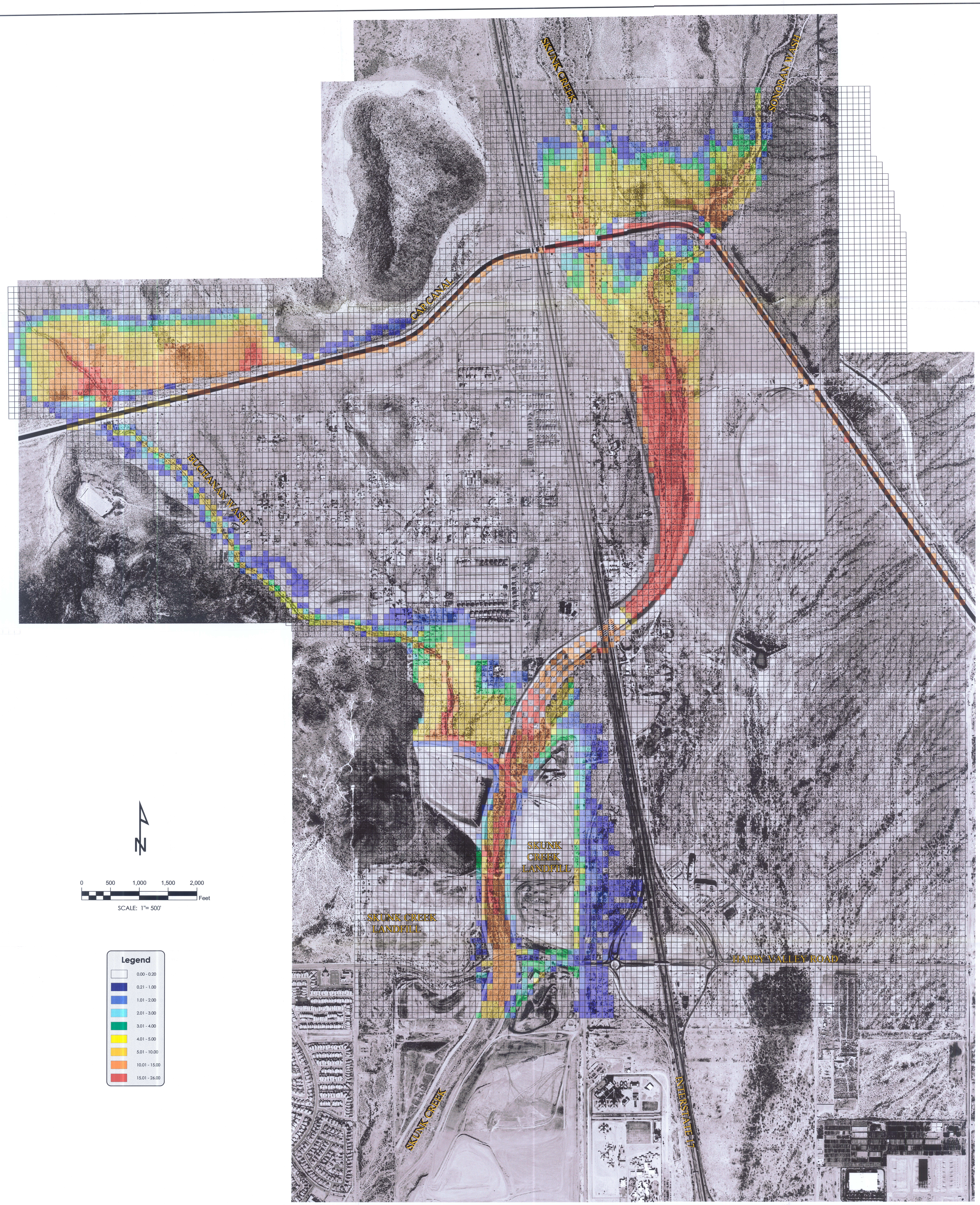
JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
CHECKED BY:	JAD
APPROVED BY:	JAD
DATE:	04/16/02

EXTENDED LEVEES
100 - YEAR EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1

Exhibit K

Extended Levees Alternative
SPF Event
Maximum Flow Depths



NO.	REVISIONS	DATE	BY	CHK.

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SKUNK CREEK FLOODPLAIN DELINEATION STUDY
TWO - DIMENSIONAL HYDRAULIC MODEL

JOB NO.	PFCMC4501
DESIGNED BY:	LML
DRAWN BY:	ARF
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APPROVED BY:	JAD
DATE:	04/16/02

EXTENDED LEVEES
SPF EVENT

SCALE: 1"= 500'
DRAWING NO.
SHEET NO. 1 OF: 1