STAGE III NONSTRUCTURAL APPENDIX

CENTRAL ARIZONA WATER CONTROL STUDY

Los Angeles District
U.S. Army Corps of Engineers
November 1981

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CHAPTER I

INTRODUCTION AND SUMMARY OF FINDINGS

Purpose and Scope

Nonstructural flood mitigation measures are defined herein as measures which directly modify the damage potential (as opposed to managing the flood event). They are generally implemented on a localized or small scale and typically are less disruptive environmentally than structural measures (reservoirs, levees, and channels). Principal consideration was given to performing a comprehensive and balanced nonstructural investigation. This was accomplished by emphasizing the analysis and reporting on three classes of nonstructural measures: (a) measures which modify the damage susceptibility of existing structures (flood proofing, raising, relocation); (b) measures to enable management of future development (regulatory actions); and (c) preparedness planning components (flood threat recognition, warning, emergency response actions).

The study area includes a major portion pf the Salt River Valley which lies almost entirely within Maricopa County in Central Arizona. The investigation is limited to areas potentially impacted by direct flooding from the Salt and Gila Rivers in the metropolitan Phoenix area. Specifically, the area under investigation is bounded by: The Salt River flood plain from Gilbert Road in Mesa to the confluence with the Gila River; and the Gila River from its confluence with the Salt River to the Highway 80 crossing just west of Buckeye. Study boundaries shown in Figure I-1.

Analytical evaluation aspects of the investigation were performed using spatial analysis (gridded) data storage, retrieval and processing procedures (Hydrologic Engineering Center 1976, 1977, and 1979). The methodology automates conventional information processing and analysis to provide expedient and consistent assessments of nonstructural alternatives.

Nonstructural Measures Considered

Chronology of Nonstructural Measures Considered. Nonstructural flood mitigation measures selected for investigation have been suggested primarily by Federal, State and local planners, and have been refined by local interest groups in public participation workshops. Also, a few refinements to the nonstructural measures came about as the result of recent flood events and implementation of some small scale measures outside the perview of the CAWCS.
Specific nonstructural measures identified include:

1. Flood proofing alternatives to modify the potential damages to existing structures resulting from a wide range of flows;
2. Flood plain regulations (legislative actions) to manage future flood plain activities;
3. Relocation or land acquisition in flood prone areas to remove the flood damage potential and encourage alternative compatible use of flood plain areas;
4. Flood preparedness plans to mitigate flood impacts by use of emergency response actions based on enhanced flood threat recognition, warning dissimination procedures and public awareness programs;

5. Flood insurance, a federally subsidized program designed to idemnify flood plain occupants against catastrophic property losses and provide a means to regulate future flood plain development;

6. Gravel mining regulations to minimize the potential of increased damage due to the nature of operations.

7. Floodplain excavation along the Salt River to improve the channel conveyance while providing marketable sand and gravel.

In addition, two limited structural measures have been evaluated:

1. Construction of limited levees to protect groups of structures at specific locations or to protect areas from major breakouts;

2. Determination if the Central Avenue, I-10, and Mill Avenue bridges are capable of passing safely the Standard Project Flood (SPF), and if none of the structures have that capability, construction of at least one bridge designed to withstand the SPF.

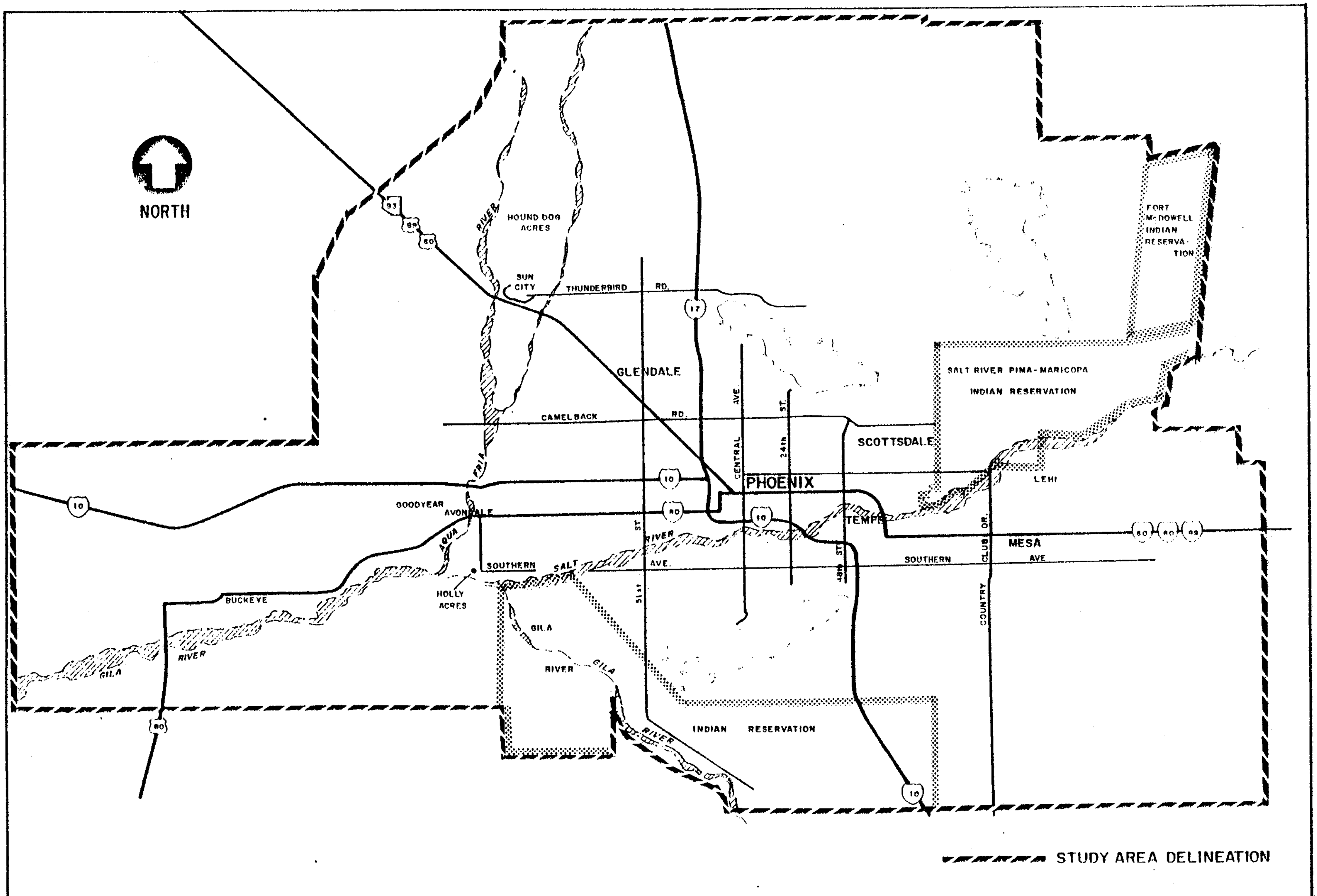

Figure I-1. Study Area Delineation

CHAPTER II

DEFINITION OF FLOOD PROBLEM

Description of Area

Topography of metropolitan Phoenix ranges from flat desert in the valley to mountains in and near the study area. The flood plain of the Salt River is relatively flat and alluvial in nature. The channel is braided and poorly defined through much of the area under investigation.

Residential, commerical and industrial structures have potential for inundation damage from a large flood (defined herein as the 500-year flood). Residential structures susceptible to flooding are concentrated primarily in Mesa, western Tempe, south Phoenix and the Holly Acres subdivision in the Gila River flood plain between the confluences of the Salt and Agua Fria Rivers. Industrial and commercial structures in the 500-year flood plain are principally located in Tempe and Phoenix.

Nature of Floods

Flooding from the Salt and Gila Rivers in the study area is seasonally related to large regional storms and associated snowmelt that occur primarily in winter and early spring. Major floods result from spills from upstream water storage reservoirs. The reservoirs are designed and authorized to operate specifically for water supply and hydroelectric power needs, although in the past they have been operated to attenuate flood hydrographs within the constraints mentioned.

The alluvial flood plain downstream of the reservoir through the metropolitan Phoenix area undergoes continuous aggregation and degradation during and between flood events. Channel alinements may also be altered. The results are often different flood elevations and inundated areas for events of similar magnitudes causing difficulties in predicting flood related consequences.

Historic Flood Events

Flooding along the Salt and Gila Rivers in the metropolitan Phoenix area occurs periodically, with substantial periods of time often elapsing between major flood events. During the 58-year period from 1920 to 1978, only one significant event (greater than a 10-year flood) occurred, but three major events and two lesser events have occurred in the past three years. The three major events, March of 1978, December 1978 and February 1980 have significantly damaged portions of the study area and resulted in particularly heavy losses to public facilities (bridges, roads, etc.) private and personal property and disruption of social services. Inundation damage totals to residential, commercial and industrial structures and contents were estimated to be $5.1 2.2 and 1.4 million dollars for the March 1978, December 1978 and February 1980 floods, respectively (Los Angeles District 1979 a, b, and c).

Flood Hazard Analysis-Present Conditions

A flood hazard analysis was performed to provide additional information pertinent to evaluation of nonstructural flood mitigation measures. The information increased knowledge of flood characteristics, provided input for flood damage evaluations at damage reach index locations, and assisted in determining potential flood impacts to important social and community services. Analysis included development of discharge-frequency relationships and rating functions (discharge-elevation functions).

Discharge-frequency relationships at selected locations were developed by period-of-record analysis (1889-1979) for the Salt River system. Table II-1, shows the discharge-freqency functions at specific control points throughout the study area. Differences in peak discharges reflect attenuation of flood peaks due to storage and natural percolation into the Salt River Bed.

TABLE II-1

DISCHARGE-FREQUENCY RELATIONSHIPS
(LOS ANGELES DISTRICT 1979d)
cfs

Salt River Location	5-Year	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year
Below Granite Reed Dam	45,000	102,000	141,000	175,000	245,000	290,000	360,000
Gilbert Road	44,000	100,000	139,000	170,000	230,000	285,000	345,000
Tempe Bridge	40,000	93,000	135,000	160,000	215,000	275,000	330,000
Central Avenue	39,000	91,000	130,000	155,000	200,000	265,000	325,000
67th Avenue	38,000	90,000	126,000	150,000	190,000	255,000	315,000
115th Avenue (above confluence with Gila River)	36,000	85,000	125,000	145,000	185,000	250,000	310,000

Water surface profile analyses for the Salt and Gila Rivers were also performed, and the results used primarily to develop rating functions at damage reach index locations and to delineate flood inundation boundaries for selected events and conditions. Because of the alluvial nature of the rivers, it should be stressed that these analyses represent only one point in time corresponding to conditions existing when the stream geometric data were gathered (1977) and calibrated to the December 1978 flood. The profiles, and therefore rating curves, are expected to change both during flood events and over the long-term. Water surface profiles and specific flood inundation boundary maps of the rivers under investigation are provided in subsequent reports of the Central Arizona Water Control Study. Table II-2, shows rating functions at damage the reach index locations used in the nonstructural analyses.

Flood Damage Analysis-Present Conditions

Overview. Flood damage analyses of existing conditions identified potential damage locations, the type of damage, and estimated the number of structures inundated at various flood elevations. Geographic information (spatial gridded data) processing and anlysis procedures formed the basis of the damage evaluation methods. Geographic information sets, in the form of grid cell data bank, were developed. Flood damage assessments and associated information presented in this report are limited to those considered essential for this investigation.

Reach Delineations. The Salt-Gila study area (Mesa to Buckeye) was delineated into 20 damage reaches for the investigation. Reach delineations were predicated upon jurisdictional boundaries, water surface profile sets, and definition necessary for nonstructural measure assessments. Table II-3, defines the damage reaches used in the evaluations of nonstructural measures for the metropolitan Phoenix area.

Assessment Procedures and Results. Flood damage evaluations of present conditions were performed for damage categories (structure types) and damage reaches. Damage evaluations were limited to those categories considered pertinent to performing nonstructural assessments. They include structure and content assessments for single family residential, multifamily residential, mobile homes, and commercial and industrial structures.

Verification of computation methods and calibration of data sets were based primarily on flood damage survey data of the recent floods, field reconnaissance in which the type and damage potential by reaches were examined, review of flood inundation boundary maps and aerial photographs, and extensive interviews with government personnel (federal, state and local), businesspersons and local residents. Each type of information assisted in developing the flood damage potential of the damage categories. Because of the continuously changing river bed and alignment of the Salt and Gila Rivers in the study area, emphasis was placed on calibration of the damage results to the December 1978 flood event which corresponded to available hydrologic/hydraulic data.

Results included estimates of damage and number of structures inundated for selected flood events (50-, 100-, and 500-year exceedance frequency events) and the calculation of expected annual damage. Table II-4, shows present conditions expected annual damage values for the study area by category and reach. The data indicate areas with the greatest damage potential and possible locations warranting the most consideration in implementing nonstructural flood mitigation measures. Estimated number of structures inundated (by category and reach) for the 50-, 100-, and 500-year events are shown in Table II-5, II-6 and II-7, respectively.. The estimated number of residential structures (single family, multifamily and mobile homes) at specific flood elevations were developed automatically by procedures described in Appendix B. Industrial and commercial evaluations of present conditions were developed from typical percentage structure, vacant land, parking lots, etc., values per grid cell, Consequently, the number of structures inundated were not directly obtainable. Industrial structures were estimated from field reconnaissance, aerial photography and number of industrial acres inundated at specific elevations.

Flood Hazard Analysis-Present Conditions

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Below Granite Reed Dam	45,000	102,000	141,000	175,000	245,000	290,000	360,000
Gilbert Road	44,000	100,000	139,000	170,000	230,000	285,000	345,000
Tempe Bridge	40,000	93,000	135,000	160,000	215,000	275,000	330,000
Central Avenue	39,000	91,000	130,000	155,000	200,000	265,000	325,000
67th Avenue	38,000	90,000	126,000	150,000	190,000	255,000	315,000
115th Avenue (above confluence with Gila River)	36,000	85,000	125,000	145,000	185,000	250,000	310,000

Water surface profile analyses for the Salt and Gila Rivers were also performed, and the results used primarily to develop rating functions at damage reach index locations and to delineate flood inundation boundaries for selected events and conditions. Because of the alluvial nature of the rivers, it should be stressed that these analyses represent only one point in time corresponding to conditions existing when the stream geometric data

TABLE II-2

FREQUENCY - WATER SURFACE

ELEVATIONS AT DAMAGE REACH
INDEX LOCATIONS (1)

DAMAGE REACH INFORMATION			WATER SURFACE ELEVATIONS FT. (MSL)					
POLITICAL BOUNDARY	NO.	LOCATION	DEC. 78	20-YR.	50-YR.	100-YR.	200-YR.	500-YR.
MESA	1.0	Gilbert Rd.-Country Club Rd.	1241.0	1244.8	1245.5	1246.5	1247.4	1248.1
	2.0	Country Club Rd. - Pima Rd.	1188.0	1192.5	1193.4	1194.8	1195.9	1196.7
		MESA TOTALS						
TEMPE	3.1	Pima Rd. - McClintock Rd.	1174.0	1174.9	1176.0	1177.8	1179.4	1180.4
	3.2	McClintock Rd.-Scottsdale Rd.	1161.0	1167.3	1168.0	1169.7	1170.6	1171.8
	3.3	Scottsdale Rd. - Mill Ave.	1153.0	1157.3	1158.4	1160.2	1163.1	1166.0
	3.4	Mill Ave. - 48th St.	1143.0	1144.4	1144.9	1146.1	1147.2	1148.1
		TEMPE TOTALS						
PHOENIX	4.1	48th St. - 44th St.	1129.4	1131.2	1131.8	1132.7	1133.9	1134.9
	4.2	44th St. - 40th St.	1123.2	1126.6	1127.4	1128.8	1130.4	1131.6
	4.3	40th St. - Mid Airport	1119.5	1119.6	1120.5	1121.9	1123.6	1125.2
	4.4	Mid Airport - 36th St.	1114.0	1111.0	1112.1	1113.6	1115.5	1117.0
	4.5	36th St. - 30th St.	1110.0	1110.2	1111.0	1112.4	1114.3	1116.4
	4.6	30th St. - I-10 Highway	1107.9	1108.8	1109.6	1111.0	1113.0	1115.2
		SUBTOTAL ECONOMIC REACH 4						
	5.1	I-10 Hwy. - 16th St.	1094.0	1096.6	1097.3	1098.5	1100.0	1101.2
	5.2	16th St. - 7th St.	1072.0	1079.6	1081.2	1083.1	1084.8	1087.8
	5.3	7th St. - 7th Ave.	1065.0	1062.8	1064.1	1066.2	1069.0	1071.8
	5.4	7th Ave. - 19th Ave.	1053.0	1055.8	1057.1	1058.8	1060.8	1062.2
	5.5	19th Ave. - 35th Ave.	1040.0	1039.6	1040.5	1041.7	1043.1	1044.2
		SUBTOTAL ECONOMIC REACH 5						
		PHOENIX TOTAL						
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	992.0	993.0	993.5	994.4	995.9	996.2
	7.0	Gila R.Confl.-Agua Fria Confl.	928.0	928.4	928.9	929.8	931.0	932.0
	8.0	Agua Fria Confl.- Hwy 80	873.0	873.5	874.3	875.6	877.1	878.2
		PHOENIX TO BUCKEYE TOTALS						
		STUDY TOTALS						

(1) Water Surface Elevations obtained from water surface profile analysis using HEC-2 computer program and provided by the Los Angeles District.

TABLE II-3
DAMAGE REACH INFORMATION

POLITICAL BOUNDARY	DAMAGE REACH NO.	DAMAGE & REACH DESCRIPTION	REACH RIVER MILES	DAMAGE REACH INDEX LOCATION	INDEX LOCATION RIVER MILE
MESA	1.0	Gilbort Rd. - County Club Rd.	32.8 - 29.0	Copper Rd.	31.6
	2.0	Country Club Rd. - Pima Rd.	29.0 - 26.3	Copper Rd.	31.6
	3.1	Pima Rd. - McCintock Ave.	26.3 - 25.4	Smith Rd.	25.8
	3.2	McClintock Rd. - Scottsdale Rd.	25.4 - 24.8	Scottsdale Rd.	24.8
TEMPE	3.3	Scottsdale Rd. - Mill Rd.	24.8 - 23.4		24.0
	3.4	Mill Ave. - 48th St.	23.4 - 21.0	56th Street	22.3
	4.1	48th St. - 44th St.	21.0 - 20.7		20.8
	4.2	44th St. - 40th St.	20.7 - 20.0		20.3
	4.3	40th St. - Mid Airport	20.0 - 19.7	Airport	19.7
	4.4	Mid Airport - 36th St.	19.7 - 19.1		19.1
	4.5	36th St. - 30th St.	19.1 - 18.7		18.7
	4.6	30th St. - I-10 Hwy	18.7 - 18.2		18.4
PHOENIX	5.1	I-10 Hwy - 16th St.	18.2 - 16.4		17.4
	5.2	16th St. - 7th St.	16.4 - 15.4	12th St.	15.8
	5.3	7th St. - 7th Ave.	15.4 - 14.3	Central Ave.	14.9
	5.4	7th Ave. - 19th Ave.	14.3 - 13.1	15th Ave.	13.9
	5.5	19th Ave. - 35th Ave.	13.1 - 11.0	27th Avenue	12.4
	5.6	Isolated area above I-10 Hwy			
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	11.0 - 0.0	67th Ave.	6.3
	7.0	Gila R. Confl. - Agua Fria R.	100.0 - 96.2	Dysart Rd.	97.9
	8.0	Agua Fria River - Hwy 80	92.0 - 79.0	Jackrabbit Trail	88.2

TABLE II-4

PRESENT CONDITIONS EXPECTED

ANNUAL DAMAGE SUMMARY
(Los Angeles District 1979d)

DAMAGE REACH INFORMATION			EXPECTED ANNUAL DAMAGE ($1000's)					
POLITICAL BOUNDARY	NO.	LOCATION	S.F. RES.	MULTI-RES.	MOBILE HOMES	COM.	INDUS.	
MESA	1.0	Gilbert Rd.-Country Club Rd.	6.0	0	0	0	4.5	
	2.0	Country Club Rd. - Pima Rd.	25.5	5.1	74.9	4.1	4.4	
		MESA TOTALS	31.5	5.1	74.9	4.1	8.9	
TEMPE	3.1	Pima Rd. - McClintock Rd.	0	5.7	0	50.1	191.7	
	3.2	McClintock Rd.-Scottsdale Rd.	0	11.4	0	23.1	87.5	
	3.3	Scottsdale Rd. - Mill Ave.	3.6	.1	0	5.0	42.3	
	3.4	Mill Ave. - 48th St.	55.5	17.9	4.8	6.2	161.3	
		TEMPE TOTALS	59.1	35.1	4.8	84.4	482.8	
PHOENIX	4.1	48th St. - 44th St.	0	0	0	.1	9.4	
	4.2	44th St. - 40th St.	.1	0	0	1.8	65.3	
	4.3	40th St. - Mid Airport	.1	0	0	0	78.6	
	4.4	Mid Airport - 36th St.	0	0	0	0	4.1	
	4.5	36th St. - 30th St.	0	0	0	0	41.5	
	4.6	30th St. - I-10 Highway	.1	0	0	.2	10.7	
		SUBTOTAL ECONOMIC REACH 4	.3	0	0	2.1	209.6	
	5.1	I-10 Hwy. - 16th St.	24.7	0	0	15.1	111.4	
	5.2	16th St. - 7th St.	73.5	57.7	0	168.8	254.5	
	5.3	7th St. - 7th Ave.	8.0	5.4	0	39.6	52.1	
	5.4	7th Ave. - 19th Ave.	5.8	.3	0	7.9	13.4	
	5.5	19th Ave. - 35th Ave.	0	0	.2	0	29.4	
		SUBTOTAL ECONOMIC REACH 5	112.0	63.4	.2	231.4	460.8	
		PHOENIX TOTAL	112.3	63.4	.2	233.5	670.4	
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	222.9	0	14.8	29.8	23.7	
	7.0	Gila R.Confl.-Agua Fria Confl.	82.2	0	0	0	0	
	8.0	Agua Fria Confl.- Hwy 80	.4	0	0	0	2.1	
		PHOENIX TO BUCKEYE TOTALS	305.5	0	14.8	29.8	25.8	
		STUDY TOTALS	508.4	103.6	94.7	351.8	1187.9	

TABLE II-5

ESTIMATED NUMBER OF STRUCTURES

INUNDATED - 50-YEAR EVENT (1)

DAMAGE REACH INFORMATION			NUMBER OF STRUCTURES					
POLITICAL BOUNDARY	NO.	LOCATION	S.F. RES.	MULTI-RES.	MOBILE HOMES	COM.	INDUS.	
MESA	1.0	Gilbert Rd.-Country Club Rd.	12	0	0		4	
	2.0	Country Club Rd. - Pima Rd.	7	0	0		0	
		MESA TOTALS	19	0	0		4	
TEMPE	3.1	Pima Rd. - McClintock Rd.	0	0	0		40	
	3.2	McClintock Rd.-Scottsdale Rd.	0	10	0		40	
	3.3	Scottsdale Rd. - Mill Ave.	0	0	0		0	
	3.4	Mill Ave. - 48th St.	39	15	0		0	
		TEMPE TOTALS	39	25	0		80	
PHOENIX	4.1	48th St. - 44th St.	0	0	0		0	
	4.2	44th St. - 40th St.	0	0	0		10	
	4.3	40th St. - Mid Airport	0	0	0		0	
	4.4	Mid Airport - 36th St.	0	0	0		0	
	4.5	36th St. - 30th St.	0	0	0		0	
	4.6	30th St. - I-10 Highway	0	0	0		0	
		SUBTOTAL ECONOMIC REACH 4	0	0	0		10	
	5.1	I-10 Hwy. - 16th St.	18	0	0		0	
	5.2	16th St. - 7th St.	29	0	0		30	
	5.3	7th St. - 7th Ave.	0	0	0		45	
	5.4	7th Ave. - 19th Ave.	0	0	0		15	
	5.5	19th Ave. - 35th Ave.	0	0	0		19	
		SUBTOTAL ECONOMIC REACH 5	47	0	0		109	
		PHOENIX TOTAL	47	0	0		119	
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	290	0	60		12	
	7.0	Gila R.Confl.-Agua Fria Confl.	114	0	0		0	
	8.0	Agua Fria Confl.- Hwy 80	0	0	0		0	
		PHOENIX TO BUCKEYE TOTALS	404	0	60		12	
		STUDY TOTALS	509	25	60		215	

(1) Based on 1978 hydraulic conditions.

TABLE II-6

ESTIMATED NUMBER OF STRUCTURES

INUNDATED: 100-YEAR EVENT (1)

DAMAGE REACH INFORMATION			NUMBER OF STRUCTURES					
POLITICAL BOUNDARY	NO.	LOCATION	S.F. RES.	MULTI-RES.	MOBILE HOMES	COM.	INDUS.	
MESA	1.0	Gilbert Rd.-Country Club Rd.	27	0	0		4	
	2.0	Country Club Rd. - Pima Rd.	13	0	210		12	
		MESA TOTALS	40	0	210		16	
TEMPE	3.1	Pima Rd. - McClintock Rd.	0	15	0		90	
	3.2	McClintock Rd.-Scottsdale Rd.	0	10	0		65	
	3.3	Scottsdale Rd. - Mill Ave.	0	0	0		11	
	3.4	Mill Ave. - 48th St.	219	41	45		65	
		TEMPE TOTALS	219	56	45		231	
PHOENIX	4.1	48th St. - 44th St.	0	0	0		0	
	4.2	44th St. - 40th St.	0	0	0		28	
	4.3	40th St. - Mid Airport	0	0	0		25	
	4.4	Mid Airport - 36th St.	0	0	0		0	
	4.5	36th St. - 30th St.	0	0	0		32	
	4.6	30th St. - I-10 Highway	0	0	0		2	
		SUBTOTAL ECONOMIC REACH 4	0	0	0		87	
	5.1	I-10 Hwy. - 16th St.	99	0	0		35	
	5.2	16th St. - 7th St.	112	0	0		156	
	5.3	7th St. - 7th Ave.	0	0	0		30	
	5.4	7th Ave. - 19th Ave.	0	0	0		7	
	5.5	19th Ave. - 35th Ave.	0	0	0		16	
		SUBTOTAL ECONOMIC REACH 5	211	0	0		244	
		PHOENIX TOTAL	211	0	0		331	
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	434	0	60		23	
	7.0	Gila R.Confl.-Agua Fria Confl.	134	0	0		0	
	8.0	Agua Fria Confl.- Hwy 80	0	0	0		3	
		PHOENIX TO BUCKEYE TOTALS	568	0	60		26	
		STUDY TOTALS	1038	56	315		604	

(1) Based on 1978 hydraulic conditions.

TABLE II-7

ESTIMATED NUMBER OF STRUCTURES

INUNDATED: 500-YEAR EVENT (1)

DAMAGE REACH INFORMATION			NUMBER OF STRUCTURES					
POLITICAL BOUNDARY	NO.	LOCATION	S.F. RES.	MULTI-RES.	MOBILE HOMES	COM.	INDUS.	
MESA	1.0	Gilbert Rd.-Country Club Rd.	51	0	0		6	
	2.0	Country Club Rd. - Pima Rd.	325	62	250		20	
		MESA TOTALS	376	62	250		26	
TEMPE	3.1	Pima Rd. - McClintock Rd.	0	47	0		140	
	3.2	McClintock Rd.-Scottsdale Rd.	0	15	0		100	
	3.3	Scottsdale Rd. - Mill Ave.	78	0	0		35	
	3.4	Mill Ave. - 48th St.	603	129	98		115	
		TEMPE TOTALS	681	191	98		390	
PHOENIX	4.1	48th St. - 44th St.	0	0	0		35	
	4.2	44th St. - 40th St.	0	0	0		127	
	4.3	40th St. - Mid Airport	5	0	0		96	
	4.4	Mid Airport - 36th St.	0	0	0		8	
	4.5	36th St. - 30th St.	0	0	0		48	
	4.6	30th St. - I-10 Highway	1	0	0		30	
		SUBTOTAL ECONOMIC REACH 4	6	0	0		344	
	5.1	I-10 Hwy. - 16th St.	250	0	0		100	
	5.2	16th St. - 7th St.	1140	945	0		430	
	5.3	7th St. - 7th Ave.	290	83	0		187	
	5.4	7th Ave. - 19th Ave.	95	0	0		64	
	5.5	19th Ave. - 35th Ave.	0	0	0		70	
		SUBTOTAL ECONOMIC REACH 5	1775	1028	0		851	
		PHOENIX TOTAL	1781	1028	0		1195	
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	787	0	60		101	
	7.0	Gila R.Confl.-Agua Fria Confl.	160	0	0		0	
	8.0	Agua Fria Confl.- Hwy 80	16	0	0		11	
		PHOENIX TO BUCKEYE TOTALS	963	0	60		112	
		STUDY TOTALS	3801	1281	408		1723	

(1) Based on 1978 hydraulic conditions.

CHAPTER III

FLOOD PROOFING

General Background

Damage surveys of historic events, field inspections and interviews reported in Chapter II indicated relatively few residential, commercial and industrial structures inundated by recent flood events. One exception was in the Holly Acres development near the confluence of the Agua Fria and Gila Rivers. Flood frequency estimates (based on discharge) associated with the March 1978, December 1978 and February 1980 events were estimated to have recurrence intervals of 14-year, 18-year and 70-year, respectively, However, because of the alluvial nature of the rivers under study (discharge-frequency relationships in this instance are poor indicators of when a structure will be flooded) and suspected inaccuracies of topographic data, it is difficult to determine precisely the flood hazard of the lowest structures in the study area. In several locations, structures inundated by the March 1978 flood (122,000 cfs) were not flooded by the February 1980 (180,000 cfs) event. This was the result of degradation of the riverbed by major floods of the past three years. As previously described, hydraulic analyses were based on calibration of water surface profiles using fixed bed channel geometry of the December 1978 conditions. This condition was considered representative of the average time history of the riverbed.

Overview of Methodology

The complexity of the CAWCS, scale of the study area, federal planning regulations and guidelines, and the interest in nonstructural alternatives made the development of a clear and comprehensive assessment strategy essential. This is especially true of assessments involving nonstructural measures implemented for existing buildings. Such assessments have been the focus of most nonstructural interest and evaluation both in the study area and nationally. The strategy developed is comprised of three fundamental phases: (a) development of a comprehensive set of nonstructural measures and plans for evaluation; (b) preliminary screening to eliminate from further consideration those measures obviously (economically or physically) not feasible for implementation; and (c) more complete assessments to determine those warranting implementation.

Initial consideration was given to nonstructural measures identified during Stage II of the CAWCS. From this list an assessment was made to determine if additional measures warranted evaluation. The review indicated a need to consider raising of structures and plans providing lower uniform level of protection than the 100-yr., SPF, and 500-yr. Provision of a lower uniform level of protection was considered, because nonstructural studies and research of nonstructural measures (Hydrologic Engineering Center 1977b and 1980c) suggested that measures are unlikely to be economically feasible for structures located above the 15 to 20-year recurrence interval. Since relatively few structures are located below the 50-year frequency level, relocation and flood proofing analyses were performed beginning at the 50-year uniform level of protection.

Once the comprehensive list of nonstructural measures for investigation was determined, a preliminary screening identified those measures meriting more complete analyses. This screening used flood damage reduction analyses for each measure, interviews with local residents and government agency personnel, and field reconnaissance. Field inspections were used to verify, to the extent possible, number of structures inundated at specific flood levels, the attributes of structures and the physical feasibility of implementing the various measures. Only measures obviously (economically or physically) unfeasible were eliminated from further consideration.

The final phase was to perform a more complete economic evaluation, including costs, of the remaining measures. Evaluations were performed for each structural type (single family residential, multi-family residential and industrial) by damage reach. Flood damage reduction analyses were performed for commercial structures and mobile homes although information was not available to perform cost assessments. The results for each damage reach were used to formulate 50-, 100-, and 500-year uniform protection plans for the study area.

Initial Assessment

Flood damage reduction analyses were performed by structure type and reach for each non-structural measure. Aggregate damage reduction results were divided by the number of structures to obtain the average damage reduction per structure for each measure. These values then were used, along with other information sources (primarily field inspection), to assist in estimating the physical and economic feasibility of implementing the various measures.

An example of the preliminary screening assessment methodology can be demonstrated by using the estimated 18 structures in south Phoenix located below the 50-year reoccurrence interval flood in damage reach 5.1 (Interstate 10 to 16th Street). Average annual damage reduced per structure was determined to be $300 for an earthen dike 2 feet high, $650 for permanent relocation of the structure from the flood plain and $570 for raising of the structure 2 feet. Field reconnaissance of the area indicated that the structures were probably substandard housing over 30 years old, wood frame, and with a market value of under $20,000. Based on these initial assessments and the relative low cost of implementing 2 feet high earthen dikes around individual structures it was determined that more complete assessments were required for earthen dikes. Relocation alternatives also warranted more complete assessments due to the nature and complexities of the associated benefit calculations and substandard housing. Raising existing structures on site was eliminated due to the physical condition of the structures and the relative high capital cost estimate of $6,000 to $9,000 per structure.

Similar procedures were performed by reach and structure type, throughout the study area for each measure and plan. Based on the results of the initial assessments of the nonstructural measures only flood proofing and relocation alternatives for the 50-, 100-, and 500-year uniform protection plans were considered potentially implementable and warranting more complete evaluations. Relocation was considered potentially feasible only for single family residential structures.

Detailed Assessment

Detailed assessments included flood damage reduction (actually performed during the initial screening process for each measure evaluations) and preparation of cost estimates associated with the remaining nonstructural measures. Because of insufficient information and the nature of the investigation, complete economic benefit assessments were not performed.

Flood Damage Reduction Analysis. Flood damage reduction analyses used automatic retrieval and processing of geographic information sets (spatial gridded data) from a grid cell data bank to develop elevation-damage relationships by category (structure type) and reach. The analyses were performed for existing conditions (see Chapter II) and for each of the potential 18 nonstructural measures and protection levels evaluated. Adjustments in the elevation-damage functions were based on user input specifications. Figure III-1, shows typical adjustments to the elevation-damage relationships for the analysis of existing structures. Detailed descriptions of the flood damage procedures and methodology are presented in Appendix B. Numeric values and flood damage reduction calculations resulting from these evaluations for the 50-, 100- and 500-year uniform level of protection plans for flood proofing and relocation alternatives are presented in Appendix C. The calculations are for single family and multi-family residential and commercial and industrial structures. Values associated with nonstructural measures eliminated from consideration in the initial screening phase of the investigation are not shown.

Cost Analysis. Cost analyses were performed for those measures determined to have potential for implementation (flood proofing and relocation) for each structure type after the initial screening process. Designs for the structure types used in the cost analysis are shown in Figures III-2-4. Flood proofing costs for single family, multi-family and industrial structures were obtained from flood proofing height of protection versus annual cost curves developed specifically for this investigation (Los Angeles District 1980b). To assure consistent interpretation of the values from the cost curves they were placed in a table format. Table III-1, shows the annual cost values for various heights of protection for single family residential, multi-family residential, commercial and industrial structures. Only earthen dikes (least cost) were considered in the analysis. These annual costs were developed using 7 1/8% interest rate. Using 7 3/8% interest rate, the annual costs would be 3% higher.

Relocations of single family residential structures, were the only relocation measures determined to warrant further investigations. Relocation cost estimates were adapted from previous studies for Allenville and Holly Acres (Los Angeles District 1980c and 1980d, respectively). Costs to remove a structure and contents to a flood free site include: purchase of land at the flood hazard site; purchase of land at new flood free site; preparation of new site (grading, utilities, etc.); moving structure to new site; conversion of vacant land to new use; moving expenses; and costs to transfer title of the old land to the government. Annual costs were estimated to total about $5,400 per structure for structures similar to those in Holly Acres and $4,000 per year for structures such as those in south Phoenix. Table III-2 shows itemized cost values used for single family residential structures similar to those in Holly Acres.

Costs to remove contents to a flood free site and to demolish the existing structure include: Acquisition of existing structure and site; demolition of existing structure; related moving expenses, conveyance of land to the government; and conversion of vacated land to new acceptable flood plain usage. Annual costs per structure were determined to be 6,700 and 5,000 single family structures similar to those in Holly Acres and south Phoenix, respectively. Since demolition of structures in place is more costly than physical structural relocation this alternative was not actually used in the nonstructural evaluation of relocation measures. Table III-2, however, depicts the itemized cost values associated with single family residential structures similar to Holly Acres.

Development of Plans

Overview. The nonstructural investigation determined the most cost effective plan for the 50-, 100- and 500-year uniform protection levels. Flood damage reduction and cost analyses were performed for flood proofing and relocation alternatives as previously described. The evaluations were performed for residential and industrial structures for each target level by damage reach. Appendix C shows the tabulated results of the economic evaluations. The results of each reach were used to determine the most economically feasible measure by structure type for each protection level. The summation of the economic results of each structural type (excluding commercial due to lack of data) for each protection level produced the "best" plan. In each case flood proofing measures have better benefit-cost ratios (BCR) than relocation alternatives. The summary at the bottom of the tabulation tables in Appendix C for the 50-, 100- and 500-year uniform protection levels represents the "best" economic results for each reach.

The following subsections describe the 50-year, 100-year and 500-year plans determined to have the highest benefit to cost ratio for the entire study area.

50-Year Uniform Protection Plan. Summary results for 50-year uniform protection levels by damage reach, jurisdictional boundaries, and for the entire study area are shown in Table III-3. The results indicate expected annual damage values to existing residential (single family and multi-family) and industrial structures to be about $1.8 million per year. Implementation of earthen dikes (measure with the highest BCR) around individual structures providing 50-year uniform level of protection would reduce annual damages for the study area by about $317,000 per year at an estimated annual cost of $391,000 per year for a benefit cost ratio of .81.

The plan would be applicable to an estimated 519 single family residential structures, 25 multi-family structures and 215 industrial structures. Table II-5, illustrates general locations of the structures by damage reaches. For the most part the structures are grouped in clusters.

Single family residential structures identified as having potential for flood proofing by earthen dikes include several structures in Mesa, West Tempe, South Phoenix, along the lower reaches of the Salt River and on the Gila River between its confluences with the Salt and Agua Fria Rivers. There are an estimated 12 structures in Mesa located east of Country Club Road and about seven structures located in a subdivision just north of McKellips Road west of Country Club Road. The 39 estimated structures in West Tempe are located north of the

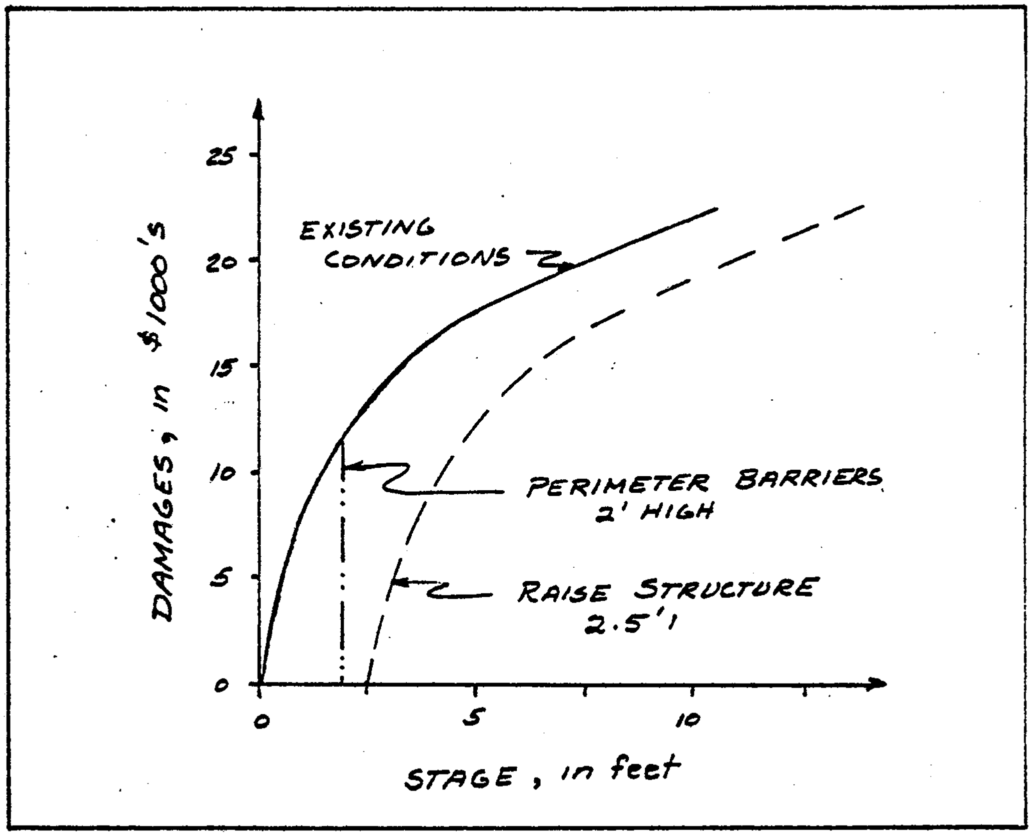


FIGURE III-1, Modification to Stage Damage Functions

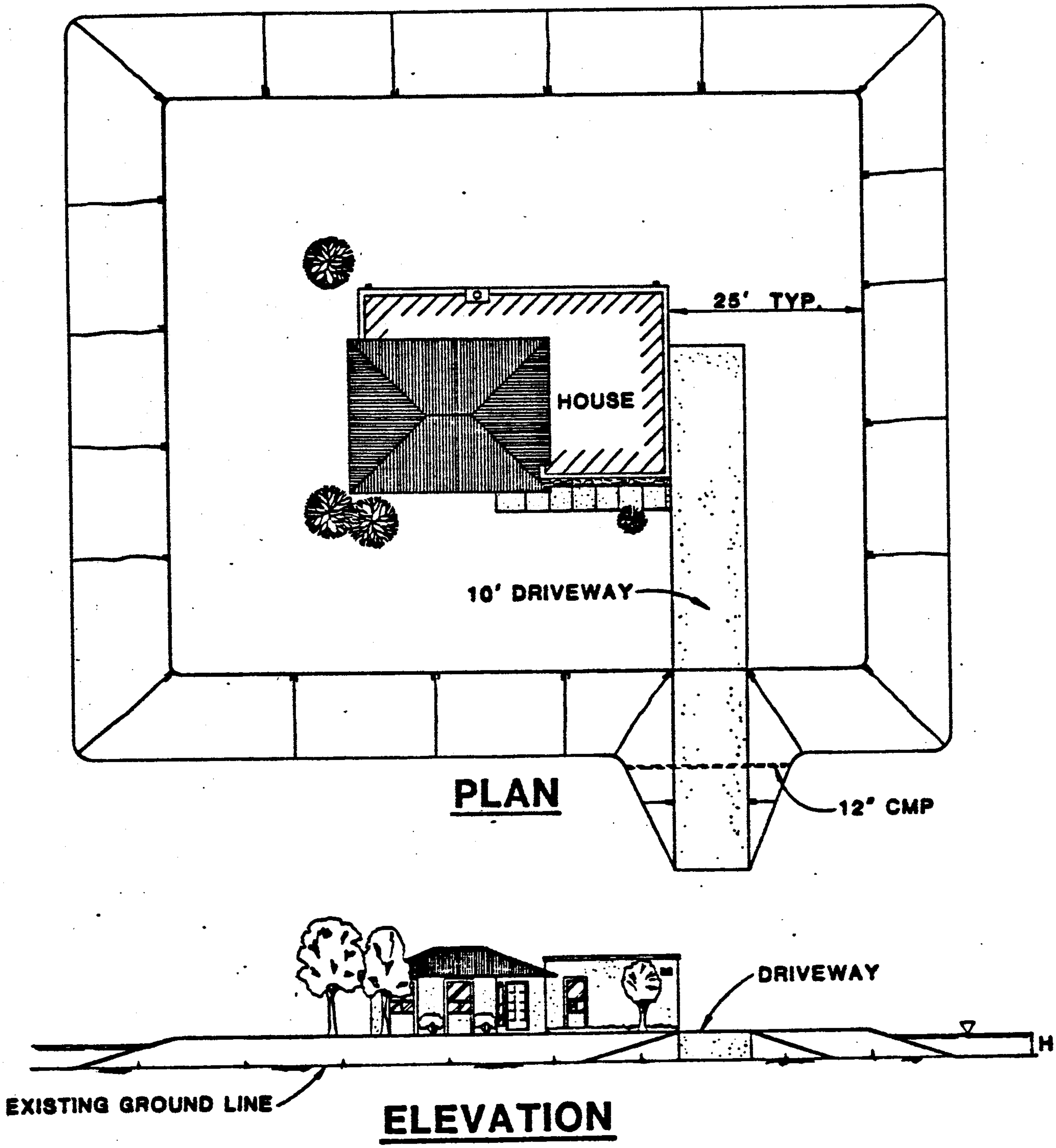
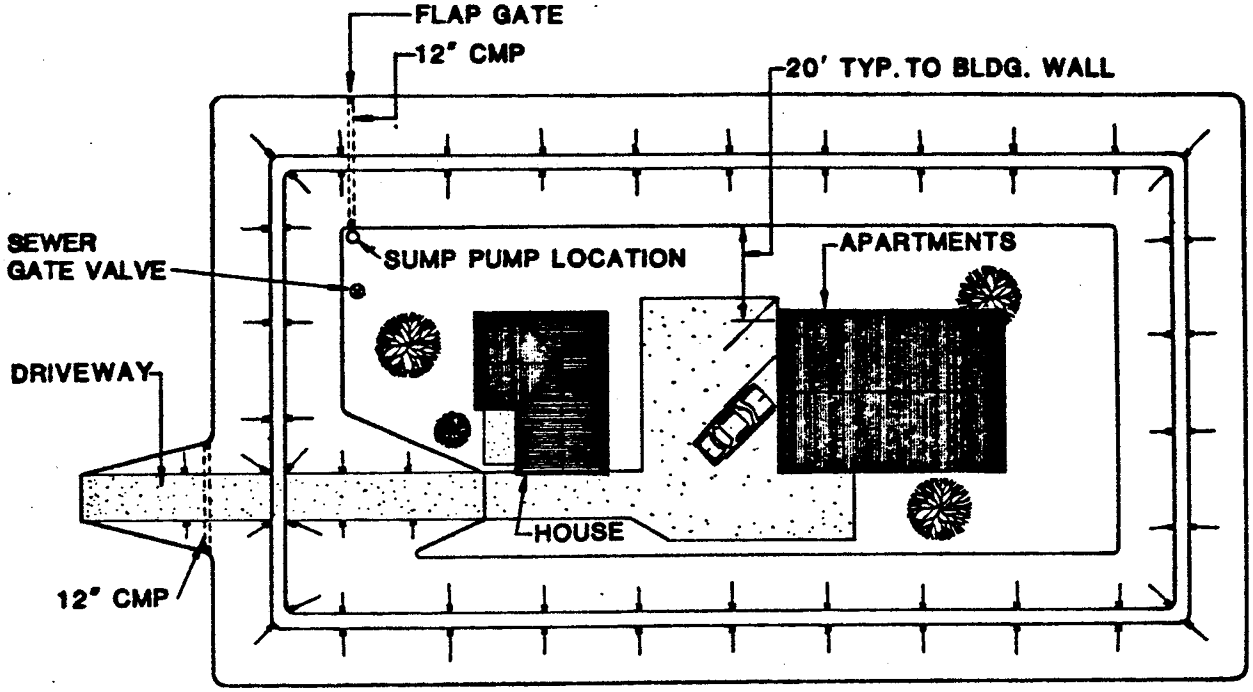


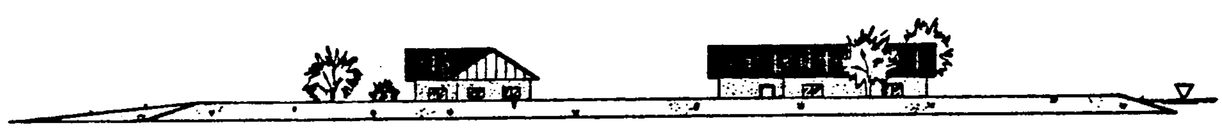
FIGURE III-2

Sample Raising of Single Family Home

▽ FLOODWATER SURFACE



PLAN



ELEVATION

▽ FLOODWATER SURFACE

FIGURE III-3

Sample Earthen Dike for Multi-family Residential Structure

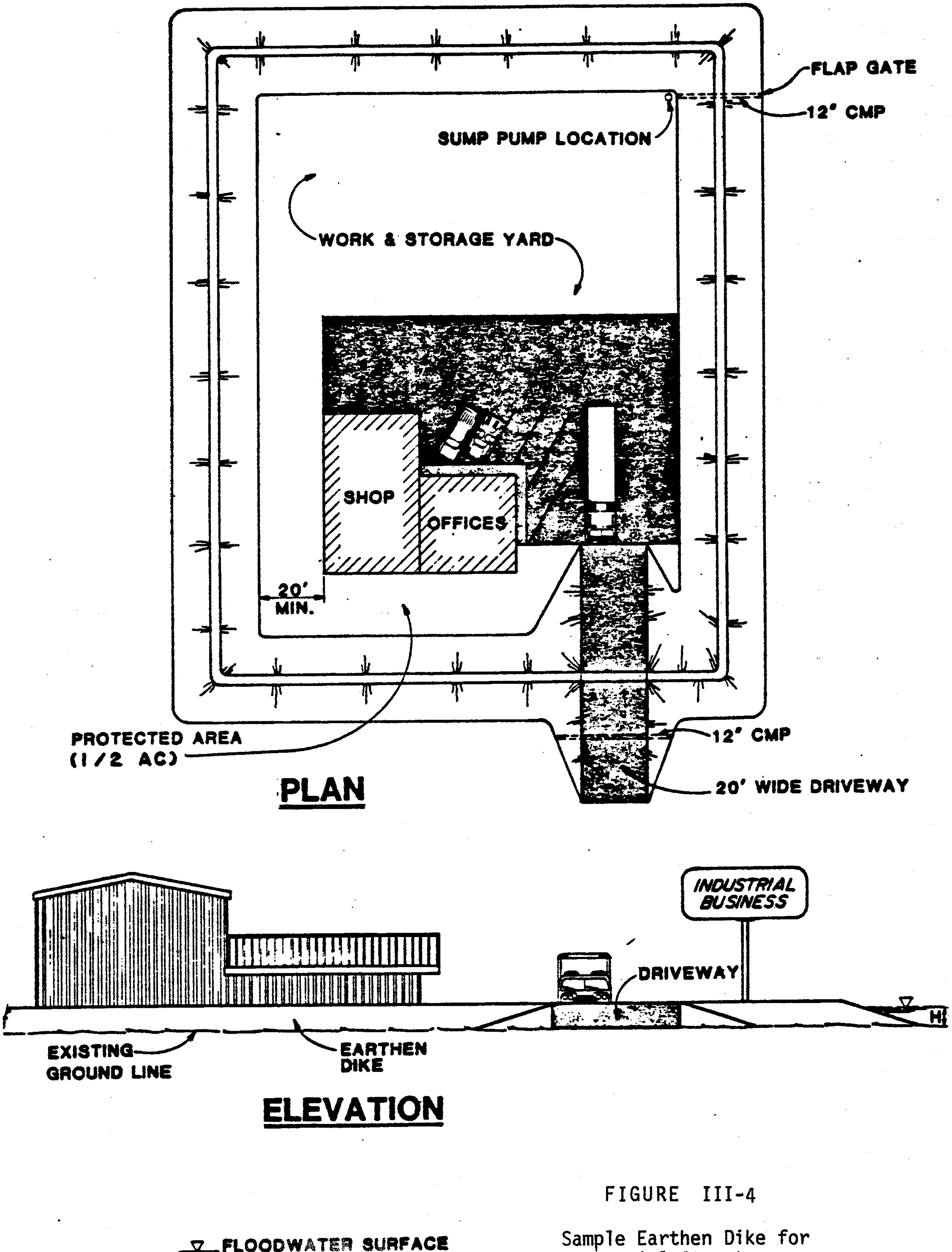


FIGURE III-4

Sample Earthen Dike for Commercial Structure

TABLE III-1

ANNUAL COST OF CONSTRUCTING EARTHEN DIKES*

[In Dollars] (1)

TYPE OF STRUCTURE	HEIGHT OF EARTHEN DIKE IN FEET								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Single-Family Residential (1500 Sq. Ft. House)	370	420	550	700	900	1100	1400	1800	2250
Multi-Family Residential (3000 Sq. Ft. Building Area)	450	550	750	975	1200	1500	1850	2300	2900
Commercial Buildings (20,000 Sq. Ft. Protected Area)	450	550	750	975	1200	1500	1850	2300	2900
Industrial Buildings (½ - 1-Acre Protected Area)	550	750	1000	1250	1600	2000	2500	3000	3900

*Annual costs developed at 7 1/8%. Using 7 3/8%, the annual costs would be 3% higher.

(1) Los Angeles District 1980 b

TABLE III-2

RELOCATION COST ESTIMATES
(Los Angeles District 1980c and d)

1. Remove Structure and Contents to Flood Free Site:
(1,600 square feet residential structure, block construction, slab-on-grade)

a.	Purchase land in flood hazard site	$ 5,000
b.	Purchase land in flood free site	10,000
c.	Prepare new site (grade, foundation, utilities, etc.)	15,000
d.	Move structure to new site (maximum of 15 miles)	11,000
e.	Conversion of vacated land to new use	4,400
f.	Moving and related expenses	800
g.	Conversion of vacated land to Government	500
	Subtotal	$46,700
	Contingencies 25%	11,675
	Supervision & Administration 25%	11,675
	Total	$70,050
	Say $70,050 per structure	
	Annual cost @ 7-3/8%, 50-year life	$5,400

2. Remove Contents and Demolish Existing Structure:
(1,600 square feet residential structure, block construction, slab-on-grade)

a.	Acquisition of existing structure and site	$50,000
b.	Demolition of existing structure	2,700
c.	Moving and related expenses	800
d.	Conversion of title to Government	500
e.	Conversion of vacated land	4,400
	Subtotal	$58,400
	Contingencies 25%	14,600
	Supervision & Administration 25%	14,600
	Total	$87,600
	Annual cost % @ 7-3/8%, 50-year life	$6,700

TABLE III-3

50-YEAR PLAN ECONOMIC SUMMARY

DAMAGE REACH INFORMATION			ECONOMIC ANALYSIS ($1000's)					
POLITICAL BOUNDARY	NO.	LOCATION	EXIST. EAD	W/MEA EAD	ANN. DAM. RED.	ANN. COSTS	ANN. NET	ANN. DAM. RED. / COSTS
MESA	1.0	Gilbert Rd.-Country Club Rd.	10.50	7.33	3.17	6.64	- 3.47	.48
	2.0	Country Club Rd. - Pima Rd.	35.00	33.20	1.80	2.59	- .79	.69
		MESA TOTALS	45.50	40.53	4.97	9.23	- 4.26	.54
TEMPE	3.1	Pima Rd. - McClintock Rd.	197.40	178.97	18.43	22.00	- 3.57	.83
	3.2	McClintock Rd.-Scottsdale Rd.	98.90	73.56	25.34	37.50	-12.16	.68
	3.3	Scottsdale Rd. - Mill Ave.	46.00	46.00	0	0	0	---
	3.4	Mill Ave. - 48th St.	234.70	225.57	9.13	21.80	-12.67	.42
		TEMPE TOTALS	577.00	524.10	52.90	81.30	-28.40	.65
PHOENIX	4.1	48th St. - 44th St.	9.40	9.40	0	0	0	---
	4.2	44th St. - 40th St.	65.40	63.20	2.20	5.50	- 3.30	.40
	4.3	40th St. - Mid Airport	78.70	78.70	0	0	0	---
	4.4	Mid Airport - 36th St.	4.10	4.10	0	0	0	---
	4.5	36th St. - 30th St.	41.50	41.50	0	0	0	---
	4.6	30th St. - I-10 Highway	10.80	10.80	0	0	0	---
		SUBTOTAL ECONOMIC REACH 4	209.90	207.70	2.20	5.50	- 3.30	.40
	5.1	I-10 Hwy. - 16th St.	136.10	130.74	5.36	6.66	- 1.30	.80
	5.2	16th St. - 7th St.	385.70	315.76	69.94	75.95	- 6.01	.92
	5.3	7th St. - 7th Ave.	65.50	53.93	11.57	12.10	- .53	.96
	5.4	7th Ave. - 19th Ave.	19.50	16.90	2.60	2.75	- .15	.95
	5.5	19th Ave. - 35th Ave.	29.40	28.30	1.10	3.85	- 2.75	.29
		SUBTOTAL ECONOMIC REACH 5	636.20	545.63	90.57	101.31	-10.74	.89
		PHOENIX TOTAL	846.10	753.33	92.77	106.81	-14.04	.87
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	246.66	135.67	110.99	130.80	-19.81	.84
	7.0	Gila R.Confl.-Agua Fria Confl.	82.20	27.00	55.20	62.70	- 7.50	.88
	8.0	Agua Fria Confl.- Hwy 80	2.50	2.50	0	0	0	---
		PHOENIX TO BUCKEYE TOTALS	331.36	165.17	166.19	193.50	-27.31	.86
		STUDY TOTALS	1799.96	1483.13	316.83	390.84	-74.01	.81

intersection of Priest Road and University Avenue along the south side of the Salt River. In South Phoenix and estimated 47 structures between Interstate 10 and 7th Street warrant consideration. The largest group of single family residences, 290 structures, is located in a subdivision southwest of the intersection of 35th Avenue and Broadway. Depending on the condition of the river, some of the above structures may not be inundated. For purposes of this analysis, however, it is assumed that they all are subject to flooding.

Approximately 114 structures are located in the north portion of the Gila River flood plain between the confluences with the Salt and Agua Fria Rivers.

An estimated 25 multi-family residential structures in Tempe were identified as having potential for flood proofing in the uniform 50-year protection plan. These include an estimated 10 structures located along University Avenue between Scottsdale and McClintock Roads and 15 structures located north of the intersection of University Avenue and Priest Road in west Tempe.

Industrial structures of various types were determined to merit consideration for flood proofing by construction of earthen dikes around the structures. Industrial structures are scattered through out the study area, however, a River. An estimated 80 buildings are located between Pima and Scottsdale Road in Tempe. Many of these buildings are small and range from older metal sheds to newer stucco structures. Those located between Pima and McClintock Roads in the south of the Salt River channel were among those warranting the most consideration. Approximately 109 structures in Phoenix, both north and south of the river from 16th Street to 25th Avenue, were identified as having potential for the 50-year uniform protection plan. Some of these buildings are found in groups, while others exist as individual structures somewhat remote from other structures.

The plan would protect an estimated 2,100 people living in single family residential structures and an unknown number in multi-family structures and industrial workers. During flood events temporary evacuation of the areas protected would be required. Gas, electrical and water sewage systems would need to be managed appropriately. Surveillance of the protected areas would be required. Any openings in the perimeter barriers would have to be closed. In essence, almost all emergency activities that are presently required with the exception of flood mitigation, would still be needed. The plan by itself would not reduce the social impact resulting from floods in the area.

The analysis of the 50-year uniform protection plan was performed using only flood proofing data on construction of perimeter barriers around individual structures. When structures are grouped together it appears that small earthen barriers around several structures to provide the 50-year level of protection would be easier to implement and more socially acceptable.

<u>100-Year Uniform Protection Plan</u>. The 100-year uniform protection plan is similar to those presented for the 50-year plan. Table III-4, shows the economic summary results by damage reach, jurisdiction boundaries and for the study area. The investigation results indicate that construction of earthen dikes around individual single family, multi-family or industrial structures are the most feasible measure for each type of structure. The plan would reduce the existing $1,000,000 annual damages by $593,000 per year for the study area. The estimated annual cost of implementation would be about $1,787,000, yielding a benefit/cost ratio of .33.

Economic analyses associated with providing uniform protection for commercial structures to the 100-year flood event are not included in the economic summary of Table III-4 because of insufficient data. Field inspection of the mobile home parks showed that implementation of earthen dikes around individual mobile homes was physically impossible. However, flood damage assessments were performed for permanent relocation and construction of a perimeter barrier around the mobile home complexes. Table III-5, shows the results of the analyses for each of the mobile home parks. For the trailer park located in Mesa (Reach 2.0) flood proofing to the 100-year level would reduce the estimated existing annual damages from about $75,000 per year to $36,000 or about $170 per mobile unit per year. Permanent relocation would result in an annual damage reduction of about $64,000 per year or an average of about $3000 per mobile home per year.

TABLE III-5

FLOOD DAMAGE REDUCTION
ANALYSIS OF MOBILE HOMES

Location	Description of Measure	No. of Structures	Height of Protection-	FLOOD DAMAGE ASSESSMENT Existing EAD	With Measure EAD	Annual Damage Reduced
2.0 Country Club - Pima Rd.	1. 50-Yr Flood Proof	0	N.A.	74.86	74.86	0
	2. 100-Yr Flood Proof	210	4.0	74.86	39.13	35.73
	3. 500-Yr Flood Proof	250	6.0	74.86	10.38	64.48
	4. 50-Yr Relocation	0	N.A.	74.86	74.86	0
	5. 100-Yr Relocation	210	Remove	74.86	11.03	63.88
	6. 500-Yr Relocation	250	Remove	74.86	2.80	72.06
3.4 Mill Ave. - 48th Street	1. 50-Yr Flood Proof	0	N.A.	4.78	4.78	0
	2. 100-Yr Flood Proof	45	4.0	4.78	3.12	1.66
	3. 500-Yr Flood Proof	98	6.0	4.78	1.15	3.36
	4. 50-Yr Relocation	0	N.A.	4.78	4.78	0
	5. 100-Yr Relocation	45	Remove	4.78	.92	3.86
	6. 500-Yr Relocation	98	Remove	4.78	.10	4.68
6.0 35th Ave. - Gila R. Conflu.	1. 50-Yr Flood Proof	60	4.0	14.77	10.20	4.57
	2. 100-Yr Flood Proof	60	5.0	14.77	5.16	9.61
	3. 500-Yr Flood Proof	60	7.0	14.77	1.20	13.57
	4. 50-Yr Relocation	60	Removed	14.77	0	14.77
	5. 100-Yr Relocation	60	Removed	14.77	0	14.77
	6. 500-Yr Relocation	60	Removed	14.77	0	14.77

TABLE III-4

100-YEAR PLAN ECONOMIC SUMMARY

DAMAGE REACH INFORMATION			ECONOMIC ANALYSIS ($1000's)					
POLITICAL BOUNDARY	NO.	LOCATION	EXIST. EAD	W/MEA EAD	ANN. DAM. RED.	ANN. COSTS	ANN. NET	ANN. DAM. RED./COSTS
MESA	1.0	Gilbert Rd.-Country Club Rd.	10.50	5.44	5.06	18.85	- 13.79	.27
	2.0	Country Club Rd. - Pima Rd.	35.00	31.34	3.66	12.06	- 8.40	.30
		MESA TOTALS	45.50	36.78	8.72	30.91	- 22.19	.28
TEMPE	3.1	Pima Rd. - McClintock Rd.	197.40	155.46	41.94	98.25	- 56.31	.43
	3.2	McClintock Rd.-Scottsdale Rd.	98.90	48.46	50.44	116.00	- 65.56	.43
	3.3	Scottsdale Rd. - Mill Ave.	46.00	44.82	1.18	6.05	- 4.87	.20
	3.4	Mill Ave. - 48th St.	234.70	181.61	53.09	210.90	- 157.81	.25
		TEMPE TOTALS	577.00	430.35	146.65	431.20	- 284.55	.34
PHOENIX	4.1	48th St. - 44th St.	9.40	9.40	0	0	0	---
	4.2	44th St. - 40th St.	65.40	57.43	7.97	28.00	- 20.03	.28
	4.3	40th St. - Mid Airport	78.70	74.53	4.17	18.75	- 14.58	.23
	4.4	Mid Airport - 36th St.	4.10	4.10	0	0	0	---
	4.5	36th St. - 30th St.	41.50	32.06	9.44	17.60	- 8.16	.54
	4.6	30th St. - I-10 Highway	10.80	10.56	.24	1.10	- .86	.22
		SUBTOTAL ECONOMIC REACH 4	209.90	188.08	21.82	65.45	- 43.63	.33
	5.1	I-10 Hwy. - 16th St.	136.10	112.40	23.70	73.70	- 50.00	.32
	5.2	16th St. - 7th St.	385.70	255.62	130.08	546.80	- 416.72	.24
	5.3	7th St. - 7th Ave.	65.50	45.34	20.16	48.00	- 27.84	.42
	5.4	7th Ave. - 19th Ave.	19.50	15.25	4.25	7.00	- 2.75	.61
	5.5	19th Ave. - 35th Ave.	29.40	5.27	24.13	140.00	- 115.87	.17
		SUBTOTAL ECONOMIC REACH 5	636.20	433.88	202.32	815.50	- 613.18	.25
		PHOENIX TOTAL	846.10	621.96	224.14	880.95	- 656.81	.26
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	246.66	99.06	147.60	322.55	- 184.95	.44
	7.0	Gila R.Confl.-Agua Fria Confl.	82.20	16.70	65.50	120.60	- 55.10	.54
	8.0	Agua Fria Confl.- Hwy 80	2.50	2.22	.28	1.15	- .87	.24
		PHOENIX TO BUCKEYE TOTALS	331.36	117.98	213.38	444.30	- 240.92	.48
		STUDY TOTALS	1799.96	1207.07	592.89	1787.36	-1204.47	.33

The 100-year plan would protect an estimated 1,038 single family residential, 56 multi-family residential, 315 mobile homes and 604 industrial buildings (various compositions). Table III-6, summarizes the location of the structures. The specific location of the structures are the same as those described for the 50-year uniform plan. Mobile home locations, not inundated by the 50-year event are located just north of 8th Street in Mesa (about 250 structures), north of University Avenue in West Tempe (about 100 structures) and near 67th Avenue in the south Salt River flood plain (about 60 structures).

Approximately 4,500-5,000 residents would be directly affected by the plan. In general, the height of the dikes would be about 1.2 feet higher than the average 2-3 feet required to provide 50-year protection. Present emergency services (i.e., temporary evacuation, management of vital services, and surveillance) would still be required during flood events. Temporary closures of openings would have to be performed, and interior drainage outlets for local storms runoff would have to be provided. The plan would not reduce the social disruption of the study area resulting from flood events.

The investigation results of the 100-year uniform protection plan clearly indicates that the overall plan is not economically feasible. The possible exception is protection or relocation of the mobile home complexes.

<u>500-Year Uniform Protection Plan</u>. The 500-year uniform protection plan has similar features as the 50- and 100-year uniform protection plan. Earthen dikes around individual structures were determined to be more feasible for each reach than permanent relocation, raising or other nonstructural measures applicable to existing structures. Table III-6, summarizes the results of the economic analysis of each damage reach (see Appendix C).

The economic analysis results indicate that construction of earthen dikes around individual structures to provide 500-year uniform protection for the study area would reduce existing annual damages by about $1,500,000 at an estimated cost of $12,418,000 per year. This yields an annual net of a minus $10,920,000 and a benefit/cost ratio of .12.

The plan would provide protection for an estimated 3,800 single family residential structures, 1,280 multi-family structures, 408 mobile homes and 1,723 industrial buildings. An estimated 15,000-20,000 residents would be protected by the plan.

Implementation of a 500-year uniform nonstructural protection plan for existing structures is obviously neither economically justified, nor socially or politically acceptable. Present development in the 500-year flood plain in the study area constitutes a major portion of the metropolitan study area. Current flood plain regulations permit future development to the 100-year flood levels. Earthen dikes around groups of structures would constitute most of the length of the study area, would be between 4-7 feet in height, and come under the purview of levee design criteria. Any measure of this magnitude should be considered a structural alternative.

Summary of Findings

Analysis of nonstructural flood proofing measures indicates that such measures are not economically feasible for 100- and 500-year uniform protection levels. However, the findings of the investigations provided some insights as to the nature of nonstructural measures having the best potential for implementation. For the most part they represent relatively small scale projects implemented on a local or neighborhood basis. These measures are briefly discussed in subsequent paragraphs.

Earthen Dikes. The investigation was performed for flood proofing individual structures only, due to resource availability. Since this measure cannot be implemented by CAWCS because the BCR is less than 1, the local agency or residents might try to implement them with technical assistance from the Corps of Engineers. Level of protection would probably be upwards to a 50-year event with complete evacuation of people during flood events. Detailed investigations would be required to determine specific spot elevations of selected structures, dike materials, effects on river hydraulics, the effect velocities against the dikes, interior drainage, etc. Primary locations for consideration include the mobile home parks in Mesa and Tempe, grouped industrial structures in Tempe and Phoenix and residential areas in West Tempe and South Phoenix, and in the vicinity of the subdivision Holly Acres.

Relocation of Existing Structures. Relocation alternatives are less economically feasible than flood proofing alternatives. Nevertheless, relocation warrants further consideration for the most flood threatened single family residential structures in West Tempe and South Phoenix because of the apparently substandard housing conditions. Although the CAWCS cannot implement relocation because the BCR is less than 1, other federal programs, may be able to provide assistance in relocation of the inhabitants to standard housing conditions. More detailed assessments would include spot elevations and appraisals of the structures and better definition of the flood hazard.

Flood Insurance. The Federal Insurance Program does not directly reduce damage to existing structures but does indemnify participating flood plain occupants for financial losses resulting from flood events. For most residents and business establishments in the study area flood insurance appears to offer the best protection against possible catastrophic financial losses. The program offers the advantage of being federally subsidized and is available to flood plain occupants in the metropolitan Phoenix area.

TABLE III-6

500-YEAR PLAN ECONOMIC SUMMARY

DAMAGE REACH INFORMATION			ECONOMIC ANALYSIS ($1000's)					
POLITICAL BOUNDARY	NO.	LOCATION	EXIST. EAD	W/MEA EAD	ANN. DAM. RED.	ANN. COSTS	ANN. NET	ANN. DAM. RED. / COSTS
MESA	1.0	Gilbert Rd.-Country Club Rd.	10.50	.10	10.40	264.60	- 254.20	.04
	2.0	Country Club Rd. - Pima Rd.	35.00	8.08	26.92	244.85	- 217.93	.11
		MESA TOTALS	45.50	8.18	37.32	509.45	- 472.13	.08
TEMPE	3.1	Pima Rd. - McClintock Rd.	197.40	37.00	160.40	490.50	- 330.10	.33
	3.2	McClintock Rd.-Scottsdale Rd.	98.90	2.23	96.67	333.50	- 236.83	.29
	3.3	Scottsdale Rd. - Mill Ave.	46.00	11.40	34.60	561.00	- 526.40	.06
	3.4	Mill Ave. - 48th St.	234.70	58.75	175.95	892.68	- 716.73	.20
		TEMPE TOTALS	577.00	109.38	467.62	2277.68	-1810.06	.21
PHOENIX	4.1	48th St. - 44th St.	9.40	4.13	5.27	19.25	- 13.98	.27
	4.2	44th St. - 40th St.	65.40	13.33	52.07	381.00	- 328.93	.14
	4.3	40th St. - Mid Airport	78.70	24.17	54.53	289.85	- 235.32	.19
	4.4	Mid Airport - 36th St.	4.10	2.04	2.06	6.00	- 3.94	.34
	4.5	36th St. - 30th St.	41.50	4.22	37.33	180.00	- 142.67	.21
	4.6	30th St. - I-10 Highway	10.80	6.58	4.22	60.37	- 56.15	.07
		SUBTOTAL ECONOMIC REACH 4	209.90	54.47	155.48	936.47	- 780.99	.17
	5.1	I-10 Hwy. - 16th St.	136.10	17.68	118.42	650.00	- 531.58	.18
	5.2	16th St. - 7th St.	385.70	72.33	313.37	4998.00	-4684.63	.06
	5.3	7th St. - 7th Ave.	65.50	12.89	52.61	689.25	- 636.64	.08
	5.4	7th Ave. - 19th Ave.	19.50	6.32	13.18	115.15	- 101.97	.11
	5.5	19th Ave. - 35th Ave.	29.40	5.27	24.13	140.00	- 115.87	.17
		SUBTOTAL ECONOMIC REACH 5	636.20	114.49	521.71	6592.40	-6070.69	.08
		PHOENIX TOTAL	846.10	168.96	677.19	7528.87	-6851.68	.10
PHOENIX TO BUCKEYE	6.0	35th Ave. - Gila River Confl.	246.66	9.09	237.57	1719.60	-1482.03	.14
	7.0	Gila R.Confl.-Agua Fria Confl.	82.20	5.11	77.09	360.00	- 282.91	.21
	8.0	Agua Fria Confl.- Hwy 80	2.50	.22	2.28	23.52	- 21.24	.10
		PHOENIX TO BUCKEYE TOTALS	331.36	14.42	316.94	2103.12	-1786.18	.15
		STUDY TOTALS	1799.96	300.94	1499.07	12419.12	- 10920.05	.12

CHAPTER IV

EVALUATION OF NONSTRUCTURAL MEASURES THAT MANAGE FUTURE DEVELOPMENT

Overview

Flood plain regulations designed to manage future flood plain activities are an intergral aspect of reducing future flood related losses. Maricopa County and most incorporated communities along the Salt and Gila Rivers have flood plain regulations based on requirements established by federal flood insurance program. Due to the number of jurisdictional responsibilities and private ownership of the riverbed in some locations, implementation of flood plain regulations on a comprehensive scale has occurred only recently in several of the study reaches. Enforcement of the regulations has varied, but is significantly improved since the past major flood events. For the most part the regulations center about meeting requirements of the Federal Emergency Management Agency (FEMA) which call for structures to be located at or above the 100-year flood level and for the establishment of floodways and floodway fringe area. According to interviews with governmental agency personnel (Hydrologic Engineering Center 1980a) flood related problems also presently exist with land fills and gravel mining operations scattered throughout the study area flood plains. Gravel mining operations in the flood plain areas have increased significantly in the past decade. Major concerns also were expressed by local government agency personnel regarding potential increases in flood damages resulting from gravel mining operations in the main channel of the Salt River.

The purpose of this aspect of the nonstructural flood mitigation investigation is to determine the relative value of existing flood plain regulations (based on a projected future land use pattern) and to discuss possible impacts of land fills and gravel mining in order to ascertain the need for more stringent flood plain management actions. Analyses of the value of existing regulatory policies on future development were performed using present regulations as well as possible future policy conditions. Assessments of land fills were developed primarily from interviews of local and federal government agency personnel (Hydrologic Engineering Center 1980d). Assessments of gravel mining operations were developed from field inspections, interviews and other documentation prepared for the CAWCS (Los Angeles District 1980e) describing associated problems and potential sand and gravel mining guidelines.

Evaluation of Present Regulations on Future Development

Evaluations of the effect of present flood plain regulations on future development were formulated from a land use pattern for year 2000 adopted from Maricopa County and encoded into the grid cell data bank. The plan projected little future development in Mesa, Phoenix and the Phoenix to Buckeye reaches within the 100 year floodway fringe.. Most of the future development was projected to occur in the Tempe area within the 100 year floodway fringe. Evaluations of regulatory policies performed for this investigation include:

- Future conditions without any regulatory policies;
- All future development placed on fill to the 20-year flood level; 100-year flood level (present regulations); and 500-year flood level;
- No future development in the 20-year flood plain; 100-year flood plain; and 500-year flood plain;
- Future residential development on fill to the 100-year flood level and commercial and industrial structures flood proofed (perimeter barriers) to the 100-year levels (also possible under present flood insurance regulations).

Policies for the 20- and 500-year flood levels are not considered viable but were evaluated to show the sensitivity of various regulatory assumptions as compared to the present regulations.

The results of these analyses are shown in Table IV-1. The table shows, that for the projected future land use pattern if regulations were not enforced, the difference in expected annual damage between existing and future conditions (plan 1 and plan 2, respectively) is estimated to be an increase of about 68% between now and the year 2000. Analysis also shows that even with present regulations (Plan 4) in place, the increase in expected annual damage to structures and contents will be about 27% over present conditions.* If future commercial and industrial structures were flood proofed (Plan 9) instead of placed on fill (Plan 4) the percentage increase (difference in the plans) is estimated to be about 7%. The anticipated damage increase to structures placed on fill to the 100-year levels is relatively minor as indicated by only a slight decrease in damages as a result of complete elimination of future development within the 100-year flood plain (Plan 7). Plans 3, 5, 6 and 8 are provided to simply show the sensitivity of flood plain regulations.

The analysis indicates that enforcement of present flood plain regulations will result in significantly less damage than would no regulation of future development. The results also indicate that some damage will continue to increase in the future even with the regulatory policies in effect.

Land Fills

Interviews with local governmental personnel indicated that sanitary and other land fills containing toxic chemicals and other assorted matter have been indiscriminantly placed in the Salt and Gila Rivers flood plains. The fill materials have presented numerous problems during the recent floods. Flood waters eroded the fills, dispersed chemicals and debris, and generally increased the decaying process, forming methane gas, which resulted in fires and a high risk of explosions. Eroded fill materials presented several downstream problems with debris both around bridges and overbank areas. The debris and chemicals presented potential health problems both during and after the flood events.

The effect of the fills on the hydraulics of the rivers has not been estimated. The potential exists for improperly placed fills in the future to reduce the conveyance capacity of the river through the fill area resulting in higher elevations and increased damage.

*At the time this analysis the City of Phoenix utilized the regulations in Plan 4. Since that time, the city has adopted regulations contained in Plan 9.

TABLE IV-1
ANALYSIS OF MANAGEMENT
OF FUTURE DEVELOPMENT ALTERNATIVES
[STRUCTURE AND CONTENT INUNDATION DAMAGE] (1)

LOCATION	EXPECTED ANNUAL DAMAGE ($1000s)								
	PLAN 1	PLAN 2	PLAN 3	PLAN 4	PLAN 5	PLAN 6	PLAN 7	PLAN 8	PLAN 9
MESA	113.9	849.0	382.4	178.9	146.1	184.8	144.9	136.1	315.4
TEMPE	687.5	1392.2	1183.8	1101.1	1042.3	1125.0	1057.9	1053.0	1145.4
PHOENIX	1218.5	1285.3	1280.4	1279.2	1179.5	1295.7	1287.6	1274.2	1279.9
PHOENIX-BUCKEYE	254.8	304.4	304.2	302.8	297.1	336.2	324.1	316.3	302.8
TOTALS	2274.7	3830.8	3150.8	2882.0	2665.0	2941.7	2816.5	2779.6	3043.5
% CHANGE EAD	---	+68	+39	+27	+17	+29	+24	+22	+34

DESCRIPTION OF PLANS

PLAN 1 - Existing w/o conditions.
PLAN 2 - Future w/o any regulatory policies.
PLAN 3 - All future development on fill to 20-year level.
PLAN 4 - All future development on fill to 100-year level.
PLAN 5 - All future development on fill to 500-year level.
PLAN 6 - No future development in 20-year flood plain.
PLAN 7 - No future development in 100-year flood plain.
PLAN 8 - No future development in 500-year flood plain.
PLAN 9 - Future residential development on 100-year fill; future commercial and industrial structures flood-proofed to 100-year level.

(1) Values do not reflect: (a) any hydrologic/hydraulic affects resulting from reduction in natural storage or channel conveyance;
(b) damage reaches 1 and 6 values (small affect).

Uniform regulations of sanitary and other fills are an important aspect of managing future damages. Placement and material of fills should be strictly regulated under existing statutes, where possible, and under uniform comprehensive flood plain regulations where not.

Gravel Mining Operations

Gravel mining operations are extensive throughout the entire study area. The operations have increased significantly in the past several years. Most present mining operations are not subject to the flood plain regulations because a state law exempts flood plain users existing prior to enactment, however any additions or changes in operation are subject to regulation. Operations damaging others are prohibited. Multi-jurisdictional responsibilities also hinder the enforcement of such ordinances (Los Angeles District 1980e).

An investigation of gravel mining impacts of flood events was performed by Boyle Engineering Corporation (Los Angeles District 1980e). The report describes proposed minimum guidelines for regulating gravel mining operations including operation, reclamation, and administrative guidelines. According to the report the guidelines should acknowledge the economic importance of sand and gravel mining while protecting other values and activities in the flood plain. The guidelines should be implemented through a permit process which should apply to existing, as well as, new operations. Sand and gravel operations should be liable for damages resulting from failure to adhere to permit requirements. The following material is excerpted largely from the Boyle Engineering Corporation report, with other insights obtained from interviews and field inspections of gravel mining operations.

Definition of Problem. Sand and gravel extraction has followed the patterns of urbanization in the study area. Extensive mining operations near central Phoenix and Tempe have expanded upstream and downstream with development. There are presently no major extraction operations downstream of the Salt River's confluence with the Gila River. The streambeds of rivers in the study are in both public and private ownership. Jurisdictional authority is fragmented. Tribal regulations apply on the Indian reservations. Federal laws and regulations of sand gravel operations are not applicable to Indian lands, although some restrictions may accompany the use of Federal grant funds for such operations. Municipalities have control over the areas within their corporate boundaries and Maricopa County has jurisdiction in all non-Federal, unicorporated areas.

Historically, sand and gravel operations have experienced the greatest industrial losses in the study area from flooding due to their location in or near the riverbed. Damages experienced have been primarily to conveyors, flooded materials, water-filled pits and interrupted business. Losses from the March 1978 and December 1978 floods were estimated as $2.5 and $5.2 million, respectively (Los Angeles District 1979b and c).

Although the industry has incurred significant damage in recent years, sand and gravel operations have also been accused of causing damage to adjacent property and transportation crossings of the river. In the February 1980 flood a main pier footing of the 1,500 foot Interstate 10 freeway bridge over the Salt River was undercut as a result of riverbed shifting and scouring. It is alleged that both downstream and upstream gravel extraction pits caused the shifting of the main channel, creating souring at the piers. The problem is also alleged to have been aggravated by the headcutting of the downstream excavation. Erosion problems also were noted in other locations (Bishop 1980).

Another problem related to in-channel sand and gravel operations has been the obstruction of the floodway by stockpiles, or dikes constructed to protect equipment and pits. These obstructions and constrictions can redirect flood flows and alter the main conveyance channel resulting in damage to nearby properties. Velocities, and therefore erosion capacities, may also be increased resulting in problems with the streambed and river banks (Los Angeles District 1980e).

Potential Guidelines. The following guidelines summarize those recommended by Boyle Engineering Corporation in its analysis of sand and gravel mining operations in the study area:

- Extraction operations should be conducted only on approval of regulatory agencies;
- Environmental impacts from the operations should be addressed;
- No stockpiling of any kind should be permitted in the floodway during the winter and spring flood season;
- Pit excavation grades should not exceed a grade of one percent ending no closer than 200 feet downstream of a structure or river crossing;
- Extraction operations should be performed on a continuous pit basis within the property confines of any operation;
- Regulatory agencies should monitor operation activities, be able to suspend operations if necessary while acting with diligence in reviewing and ruling on applications.

Summary. Gravel mining operations allegedly have induced damage to adjacent properties, river crossing structures and other facilities and altered the river channel. Regulation of their activities is needed to mitigate future damage. This regulation should be part of a uniform comprehensive flood plain regulatory policy including future land development and land fills. Because of the importance and magnitude of the gravel mining industry in the metropolitan Phoenix area, formulation and implementation of regulations will require careful study. Impact assessments, as to the history and potential hydraulic and damage effects must be formulated. Proposed operation guidelines likewise must be developed.

Floodplain Excavation Through Gravel Mining

In addition to evaluating regulations for gravel mining operations in the study area, the CAWCS examined the feasibility of floodplain excavation along the Salt River to improve channel conveyance while providing marketable sand and gravel.

Natural materials present within the boundaries of the Salt River bed in the Phoenix area that are suitable for aggregate use consist of sand and gravel. In recent years the rapid growth of Phoenix and vicinity has caused a high demand for aggregate. As a result, sand and gravel extraction along Salt River has been extensive. The pits are excavated mostly in a "leap-frogging" fashion resulting in large sand and gravel pits at random locations.

An economic feasibility study of sand and gravel extraction along the Salt River floodplain identifying costs and benefits is beyond the scope of this study. Prior to selection and execution of any excavation plan, a number of issues and impacts as well as costs and benefits must be considered.

The scope of this part of the study includes:

- For a typical study reach, formulation of a preliminary sand and gravel excavation plan along the Salt River floodplain.
- Estimation of the quantity of material that can be removed from this preliminary excavation plan.
- Estimation of the present extraction rates of sand and gravel along the Salt River in the vicinity of Phoenix.
- Analysis of the hydraulic performance of the study reach with the preliminary excavation plan in place.

The preliminary excavation plan along the main channel and floodplain of the Salt River in the study reach is shown on Plate IV-1. This plan is formulated so that the limits of excavtion do not encroach upon physical features such as buildings, roads and railroads. Side slopes of 3:1 (H:V) and a bottom slope of 0.01 percent have been selected for the plan. This bottom slope will maintain a positive grade for low flow conditions. Selection of this bottom slope and invert elevations were made to limit the maximum depth of channel excavation at about 30 feet. As will be discussed later, a maximum excavation depth of 30 feet in the channel (or about 40 feet in the floodplain) is recommended because this surface layer contains the optimum quality of aggregate material. Nevertheless, sand and gravel operators may wish to excavate deeper. Figure IV-1, shows representative cross-sections for the preliminary excavation plan.

The differential between the natural river bottom slope (about 0.002) and the selected slope (0.0001) requires a number of control structures to maintain the integrity of the bridges and to match the bottom elevations upstream and downstream from the study reach. Locations and the corresponding drop heights of these control structures are tabulated in Table IV-2.

TABLE IV-2

LOCATION AND MAGNITUDE OF DROPS FOR CONTROL STRUCTURES
PRELIMINARY FLOODPLAIN EXCAVATION PLAN

Location of Control Structure	Magnitude of Drop in Feet
D/S of Central Avenue	17
D/S of 16th Avenue	12
D/S of 24th Street	27
D/S of Scottsdale Road	26

The preliminary excavation plan extends from Scottsdale Road downstream to the Sky Harbor Airport channel, and from the existing drop structure at the I-10 Freeway downstream to 43rd Avenue. The reach along the Sky Harbor Airport channel has been excluded from the preliminary excavation plan since there is a relatively small amount of material available, and sand and gravel extraction in this reach does not appear to be cost-effective. Also, the reach upstream of Scottsdale road has been excluded from the preliminary excavation plan because of problems at the confluence of Indian Bend Wash and the relatively small amount of excavation material available in this portion of the study reach.

Aggregate Resources

At present, most of the sand and gravel extraction for the aggregate materials occurs in the active channels and floodplain of the Salt River. Extraction of sand and gravel is generally limited to the upper 30 to 40 feet of alluvium by the presence of significantly greater concentrations of caliche below that approximate depth. This factor was considered in the formulation of the preliminary excavation plan, and therefore no deep sand and gravel mining pits have been proposed.

Based on the preliminary excavation plan, the quantity of material available for extraction is estimated to be 120 million cubic yards. Considering the length of the excavation plan (approximately 56,300 feet) this averages out to about 2,131 cubic yards per foot. In a survey of the available aggregate material along the Salt River in the Phoenix area, it has been estimated that about 368 million cubic yards of sand and gravel is available between Granite Reef Dam and 67th Avenue. This quantity is based on an assumed average channel width of 1/2 mile and a minimum depth of 30 feet. Using 368 million cubic yards and a distance of 33 miles, the quantity per unit length is 2,112 cubic yards per foot which is remarkably close to the preliminary excavation plan quantity per linear foot of channel length.

Because of the very mild slope (0.01%) which has been selected for the preliminary excavation plan, the Salt River flowing through this type of a river geometry will have the tendency to deposit material. In general, the sand transported and deposited by the river under these conditions is too fine and too difficult to separate to be usable for ready mixed concrete. The result is that any renewed resources in a pit are usually of a limited value for sand and gravel extraction.

As shown in Figure IV-2, the price of sand and gravel in Maricopa County and the United States increased sharply since 1970. Using this trend for Maricopa County, it can be show that

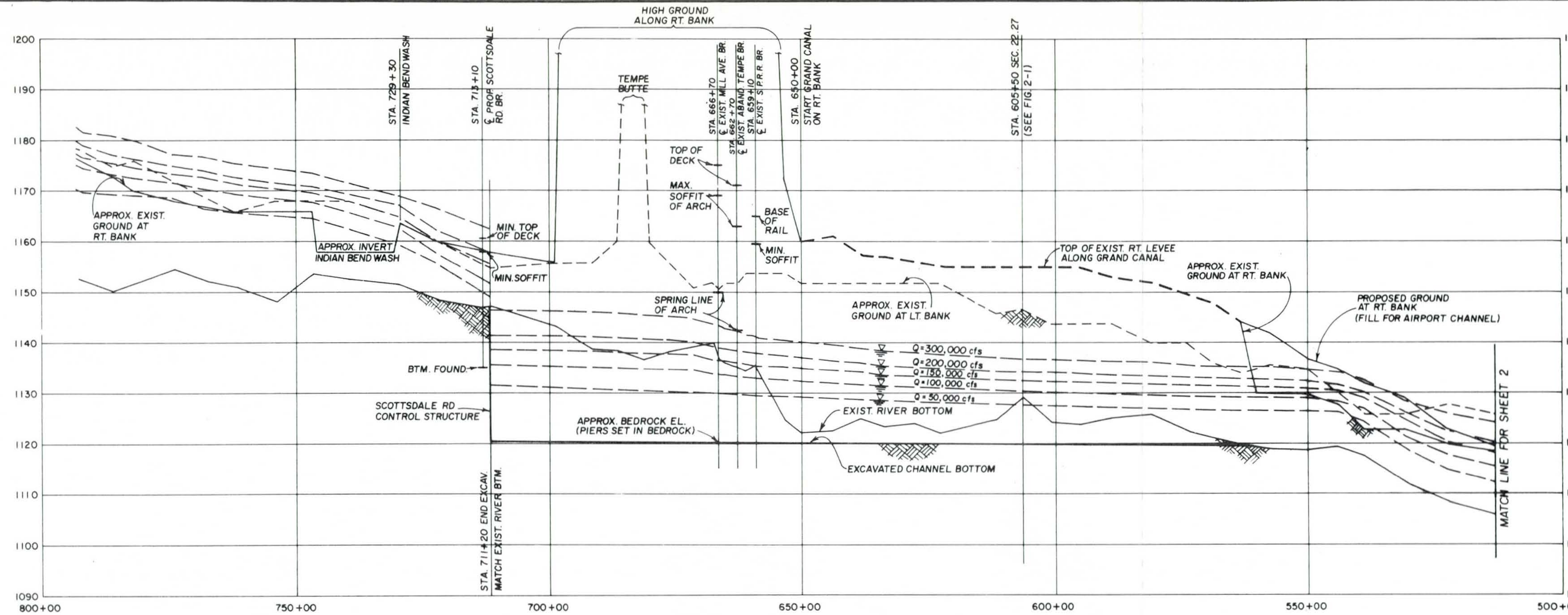
$$P_t = 1.03 + 0.065t - 0.027t^2 + .0029t^3$$

where

P_t = estimated price of an average ton of sand and gravel in dollars
t = number of years after 1965.

Based on the above equation the price of the sand and gravel in 1981 ($t=16$) is about $7.00 per ton. This conforms to the August 1981 market value of sand and gravel in the Phoenix area of about $6.80 per ton.

The 1981 value of the available aggregate material in the study reach, estimated at 120 million cubic yards, is computed to be $1.3 billion. This assumes a unit price of $6.80 per ton and a conversion factor of 1.6 tons per cubic yard.



PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

VERT. SCALE 10 0 10 20 FEET

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

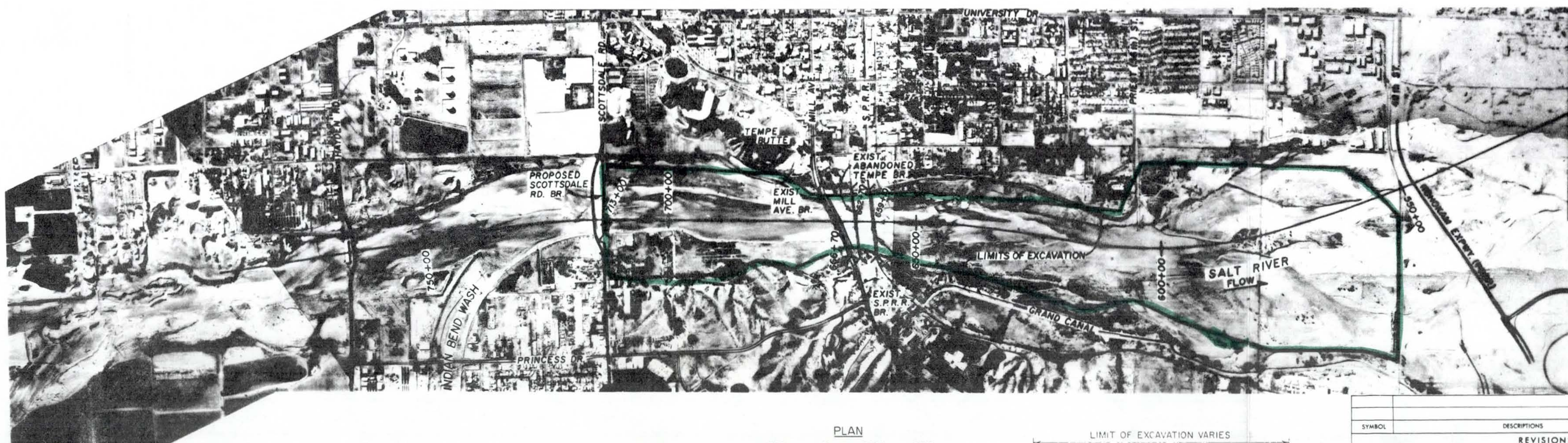
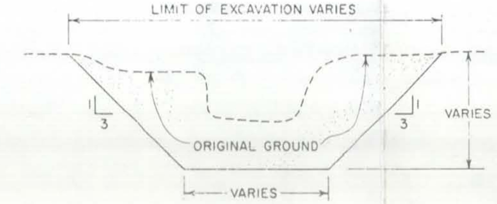


PLATE IV-1

PLAN

SCALE 1000 0 1000 2000 FEET



TYPICAL PROPOSED EXCAVATION SECTION

N. T. S.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

CAMP DRESSER & McKEE INC.
710 South Broadway
Walnut Creek, California 94596

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: M.J.W.
DRAWN BY: D.A.P.
CHECKED BY: H.M.N.

CENTRAL ARIZONA WATER CONTROL STUDY
STRUCTURAL FLOOD CONTROL ALTERNATIVES

SALT RIVER CONCEPTUAL EXCAVATION PLAN

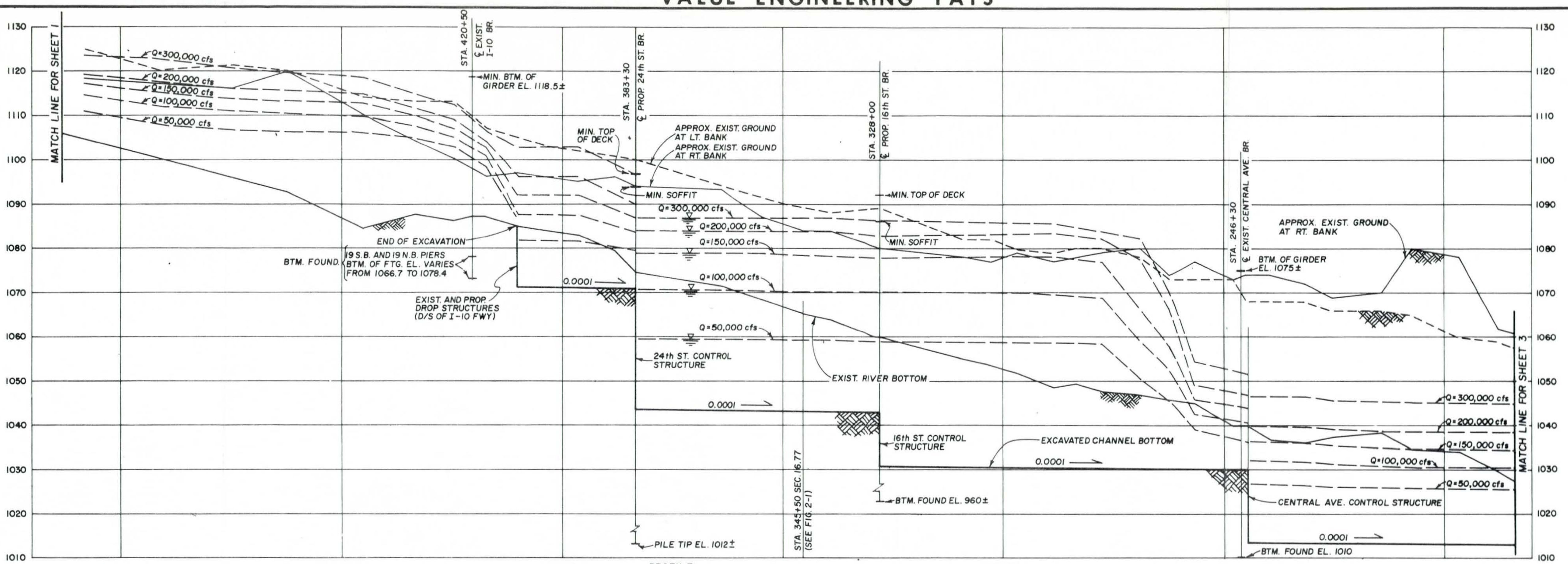
SUBMITTED BY: DATE APPROVED: SPEC. NO. DACW09-____ B-____ DISTRICT FILE NO.

CHIEF, BRANCH

SHEET 1 OF 3

VALUE ENGINEERING PAYS

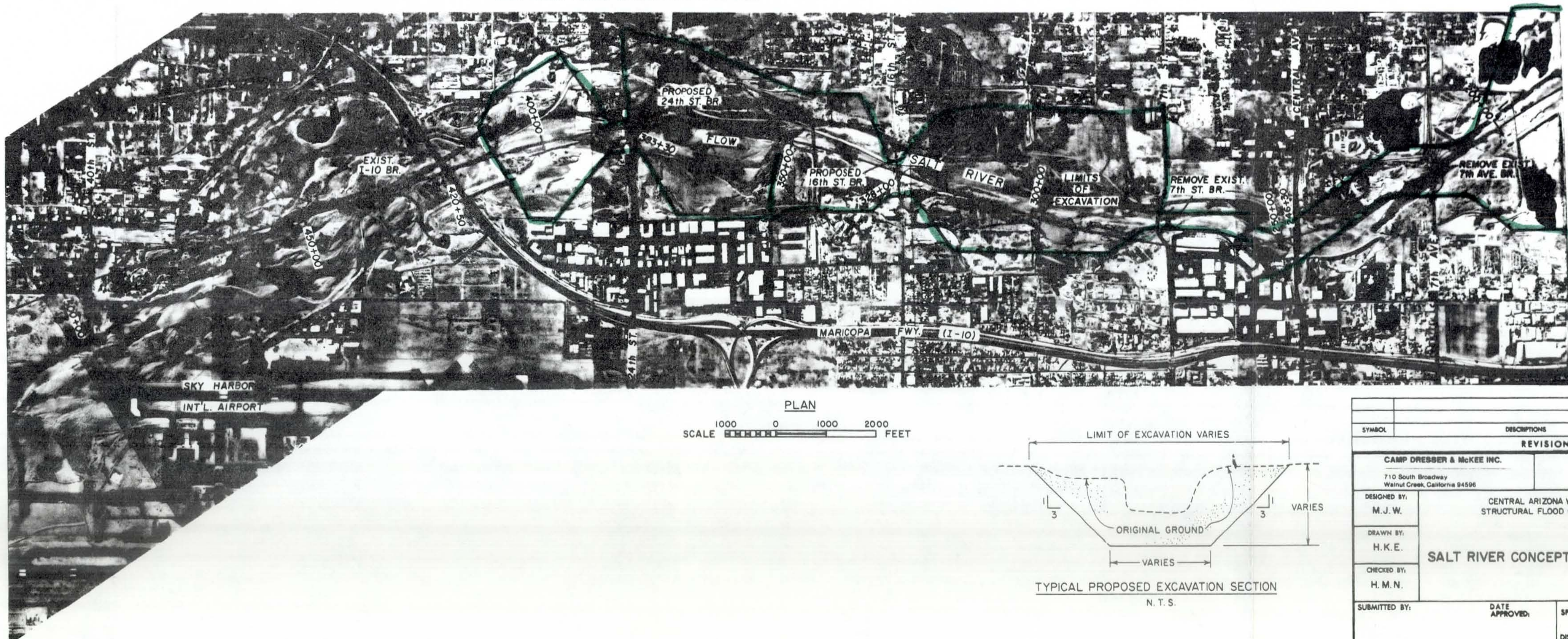
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

VERT. SCALE 10 0 10 20 FEET



PLAN

SCALE 1000 0 1000 2000 FEET

LIMIT OF EXCAVATION VARIES

ORIGINAL GROUND

VARIES

VARIES

TYPICAL PROPOSED EXCAVATION SECTION

N. T. S.

PLATE IV-1

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
REVISIONS			

CAMP DRESSER & McKEE INC.
710 South Broadway
Walnut Creek, California 94596

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: M.J.W.
DRAWN BY: H.K.E.
CHECKED BY: H.M.N.

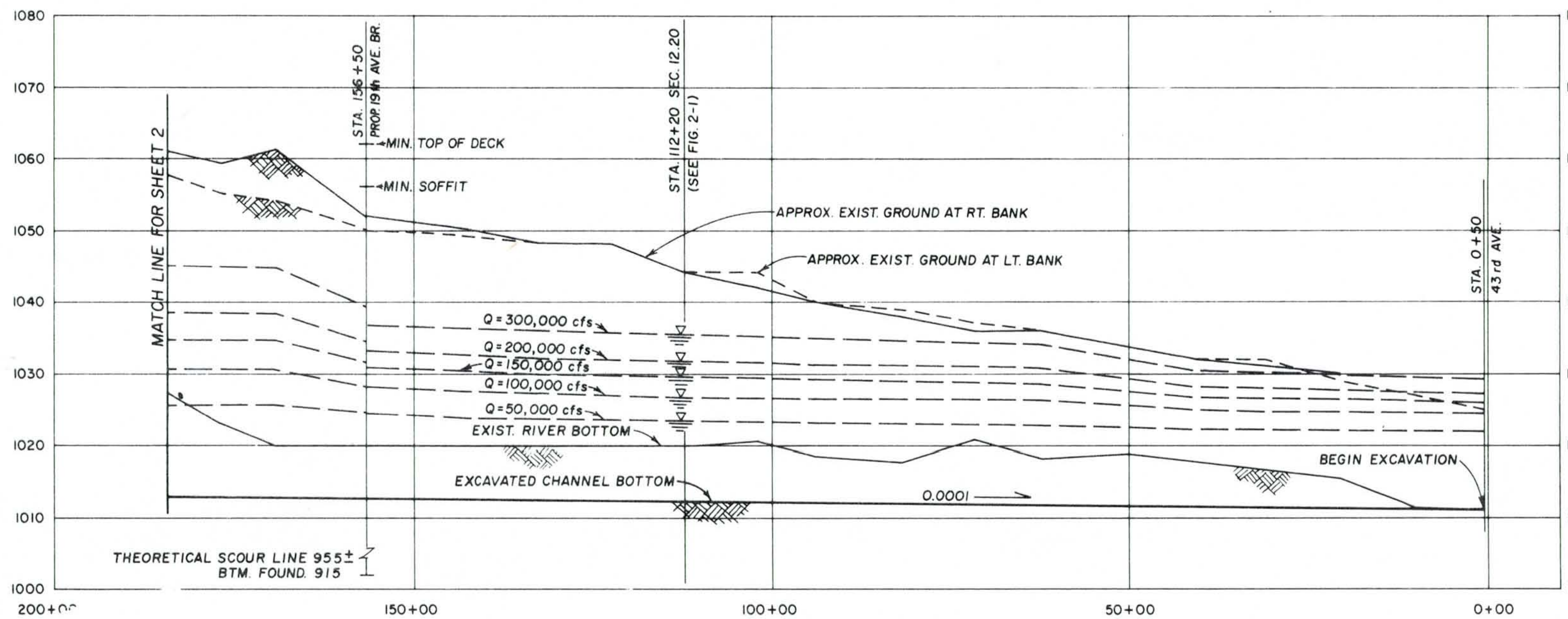
CENTRAL ARIZONA WATER CONTROL STUDY
STRUCTURAL FLOOD CONTROL ALTERNATIVES

SALT RIVER CONCEPTUAL EXCAVATION PLAN

SUBMITTED BY: CHIEF, BRANCH
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET 2 OF 3

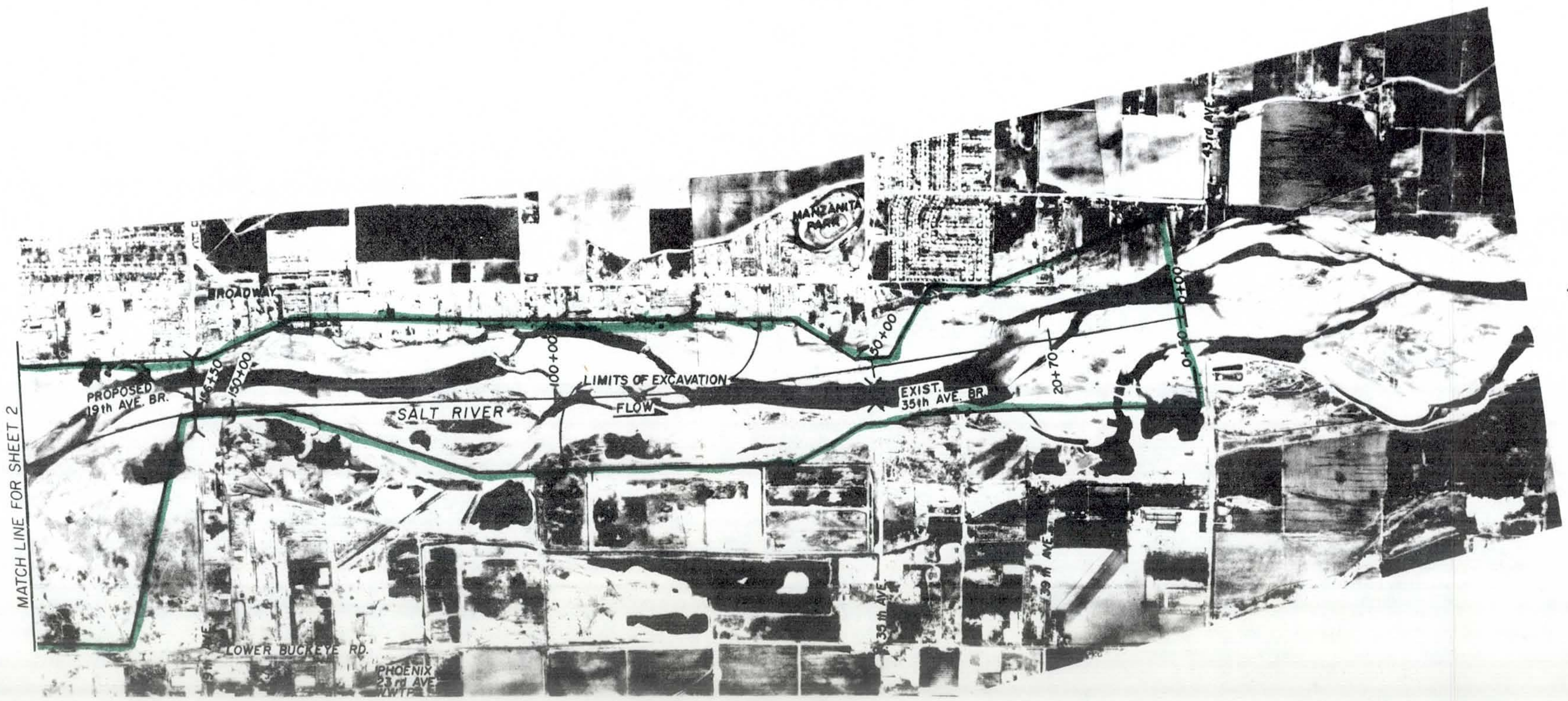
SAFETY PAYS

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET
VERT. SCALE 10 0 10 20 FEET

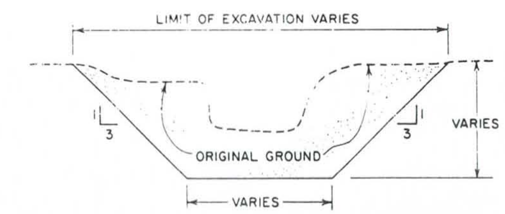


NORTH

PLAN

SCALE 1000 0 1000 2000 FEET

PLATE IV-1



TYPICAL PROPOSED EXCAVATION SECTION

N.T.S.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

CAMP DRESSER & McKEE INC. 710 South Broadway Walnut Creek, California 94596	U. S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS
DESIGNED BY: M.J.W.	CENTRAL ARIZONA WATER CONTROL STUDY STRUCTURAL FLOOD CONTROL ALTERNATIVES
DRAWN BY: H.K.E.	SALT RIVER CONCEPTUAL EXCAVATION PLAN
CHECKED BY: H.M.N.	
SUBMITTED BY: CHIEF, BRANCH	DATE APPROVED: SPEC. NO. DACW 09-____ B-____ DISTRICT FILE NO. SHEET 3 OF 3

CROSS SECTION 22.27
(Station 605+50)

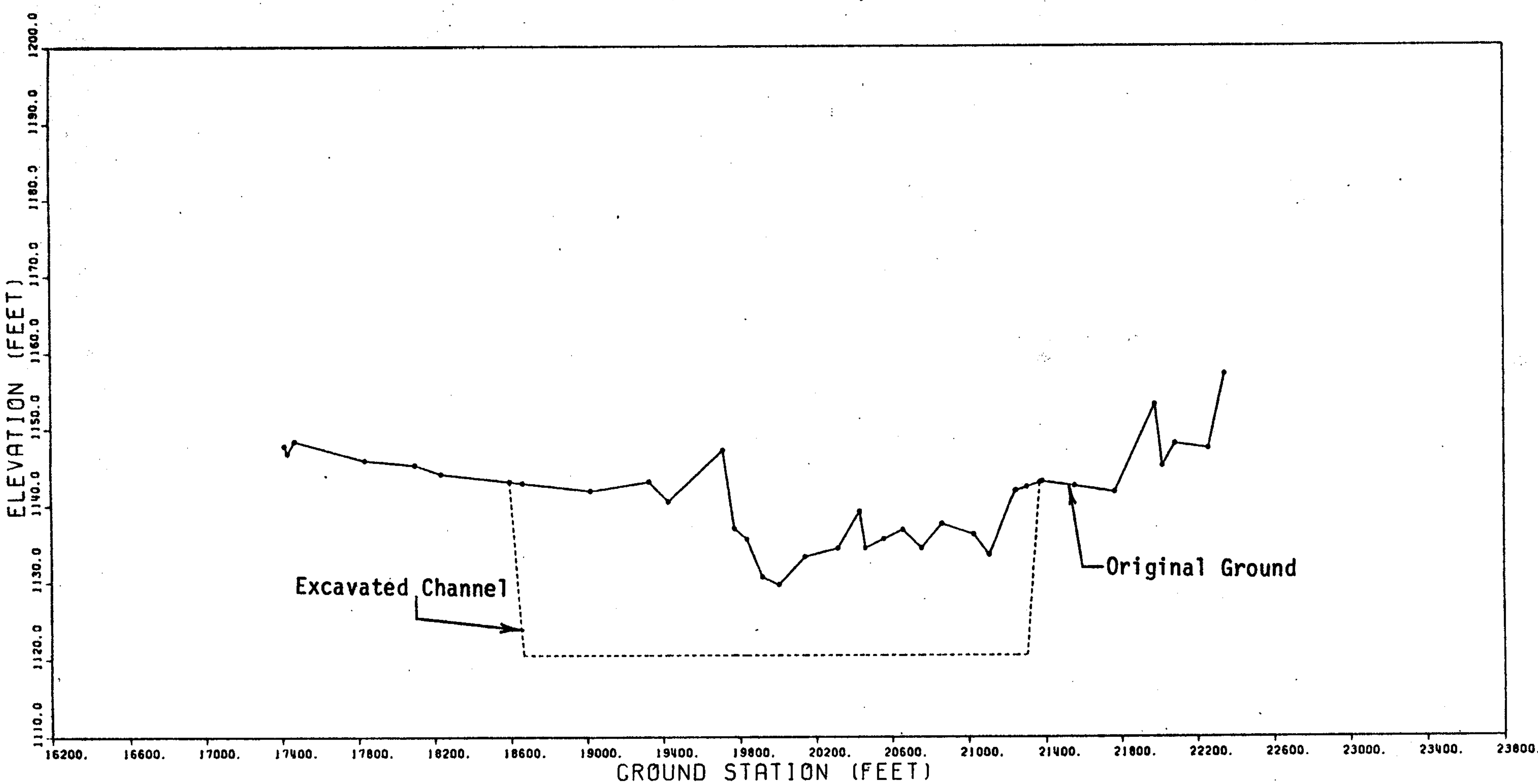


FIGURE IV-1

TYPICAL SECTION FOR PRELIMINARY EXCAVATION PLAN

CROSS SECTION 16.77
(Station 345+50)

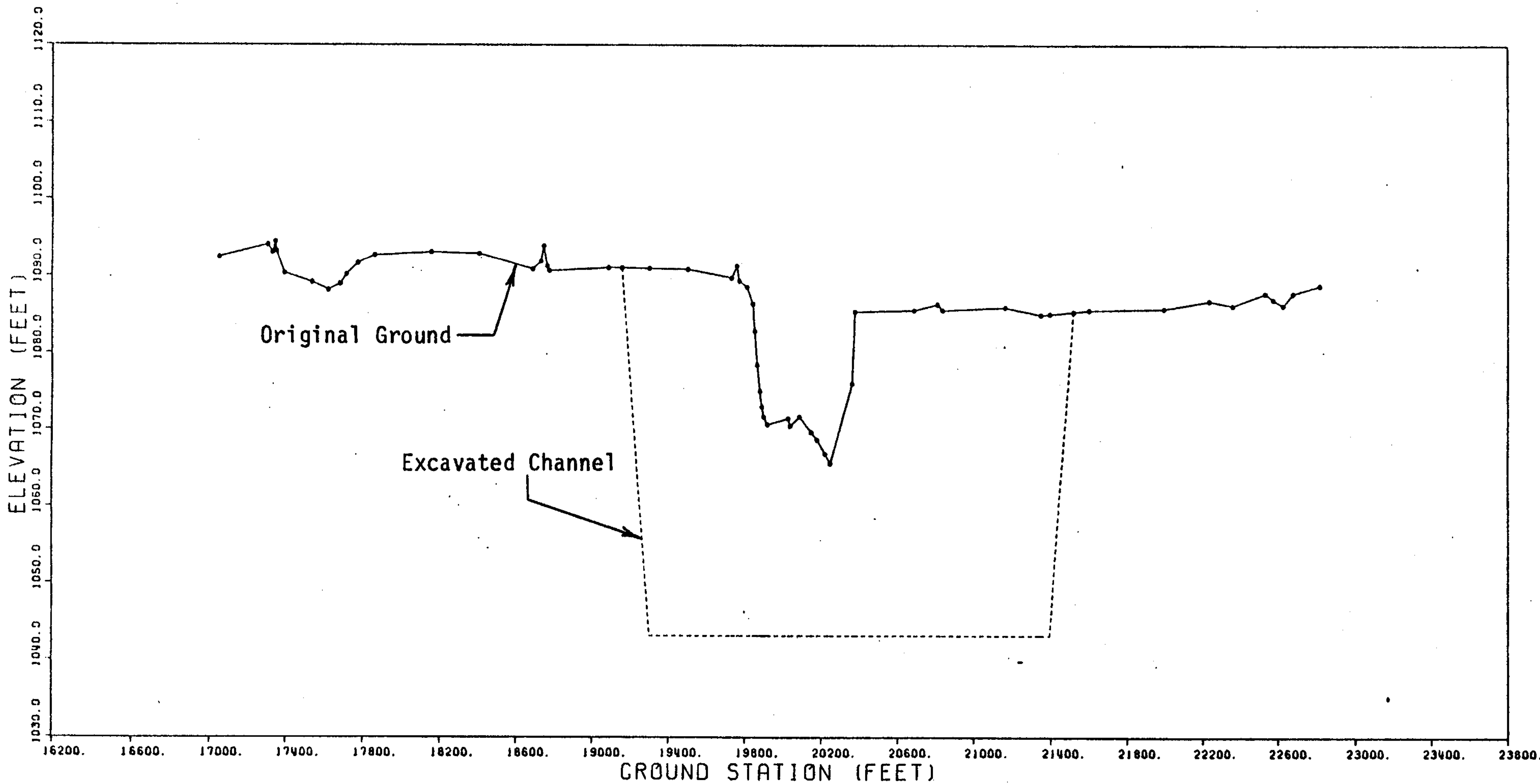


FIGURE IV-1
(Continued)

TYPICAL SECTION FOR PRELIMINARY EXCAVATION PLAN

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(Station 112+20)

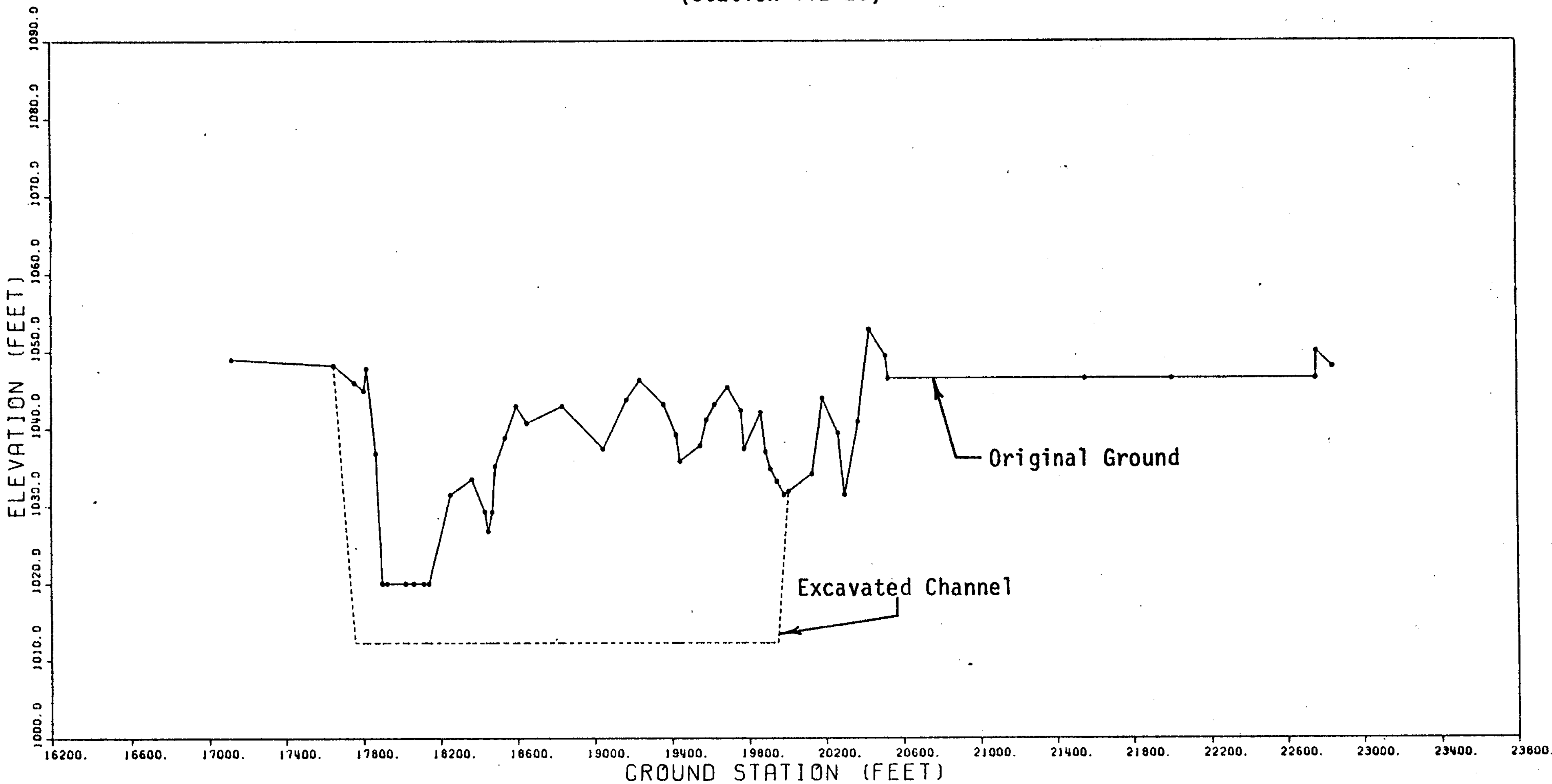


FIGURE IV-1
(Continued)

TYPICAL SECTION FOR PRELIMINARY EXCAVATION PLAN

Figure IV-3 shows the trend in annual demand for aggregate in Maricopa County, Arizona, and the total U.S. Market. Based on this data, the 10-year average in Maricopa County is approximately 10 million tons per year. Using this average, the proposed preliminary excavation plan can meet Maricopa County's demand for about 19 years. The actual demand for sand and gravel depends on many variables. For Maricopa County it has been shown that

$$D = -10.3 + 0.59M + 3.11C + 0.38E$$

where

- D = estimated annual demand for sand and gravel in Maricopa County
- M = annual miles of road construction in Maricopa County
- C = annual number of commercial building permits issued in Maricopa County
- E = annual number of workers employed in construction in Maricopa County

Figures IV-2 and IV-3 reveal that both demand and price for sand and gravel have increasing trends with the price rising sharply since 1977. Rises in energy costs for processing and transportation and higher property value as well as inflation are probably the main reasons for this increase in cost of sand and gravel. Due in part to the future demand that will be imposed by the Central Arizona Project, it is anticipated that this increasing trend in price of sand and gravel will continue.

Hydraulic Analysis

The hydraulic analysis for the Salt River with the preliminary excavation plan was carried out using the same floodplain geometry as was used in the CAWCS "Stage II, Channelization Elements Study". The encroachments used to simulate the levees in "Stage II" were removed or replaced as necessary to develop a HEC-2 geometric model for a pre-project condition. This pre-project model embodied the same assumptions and design criteria as the "Stage II" model with respect to bridges, Sky Harbor Airport channel and the remainder of the study reach. Finally, the model for the excavated Salt River was developed by modifying the cross-sections of the pre-project model to have the same geometric representation as the preliminary excavation plan.

Results of the analysis for discharges of 50,000 cfs, 100,000 cfs, 150,000 cfs, 200,000 cfs and 300,000 cfs are shown in Plate IV-1.

River Mechanics

From the aspect of river mechanics, the proposed preliminary excavation plan can be implemented without any adverse impacts only if additional protection measures are provided. This is because the bottom slope has been reduced by a factor of 20 (from 0.002 to 0.0001) and the variable width channel is widened substantially. The design of these protection measures would require an in-depth study of sediment transportation and river mechanics in the Salt River. The two major protection measures are described in the following paragraphs.

Control structures will be required to prevent headcutting in the river and to maintain the integrity of the bridges. As shown in Plate IV-1, these structures are located downstream of the bridges to minimize the depth of excavation at bridge foundations. A typical structure will require revetment at bridges for a considerable distance upstream and downstream. Because of the extremely mild bottom slope, river flow will have the tendency to cause extensive lateral erosion. If side slopes are unprotected, even minor floods could be quite damaging.

Reducing side slopes from the proposed 3:1 to a less steep slope will not prevent side cutting since the river through the preliminary excavated reach will continue to have a meandering pattern. This process is presented schematically in Figure IV-4.

Summary of Findings

1. Comprehensive uniform regulations are needed for flood plain development and other activities. The regulations should cover development in the flood plain, land fills (location and contents), and gravel mining operations. Current regulations are based on State Law, and only to that extent are they uniform.

2. Existing flood plain regulations, basically limited to flood insurance criteria, are effective in managing future flood damage. Damage will continue to increase in the future although the increase will be significantly less than without the regulations.

3. Regulation of the location, height and materials of land fills in the flood plain fills is needed. If properly enforced the regulations should minimize health hazards, downstream debris, and fire and explosions in the fill areas. Toxic chemicals and other similar matter should be prohibited.

4. Gravel mining operations should be regulated to minimize the potential of these activities to induce damage to nearby river crossing structures and facilities as well as nearby properties. Regulatory guidelines should be developed based on sound engineering analyses and criteria. Mitigation for future business losses may be required.

5. From a technical standpoint, extraction of sand and gravel from the Salt River floodplain is a viable option and will improve the channel conveyance. The excavated facility will require protection measures to maintain the integrity of the bridges and other structures located in the vicinity of the Salt River. An economic feasibility of the facility must be made prior to the design and implementation of the concept. This economic feasibility study will require a sediment transport and river mechanics investigation.

6. Enforcement of flood plain regulations has been limited and loosely enforced in the past. A major problem is the multi-jurisdictioned responsibilities for enforcing the regulations. Additional staff, with appropriate expertise for each jurisdiction, will be required to monitor, assess and enforce the regulations.

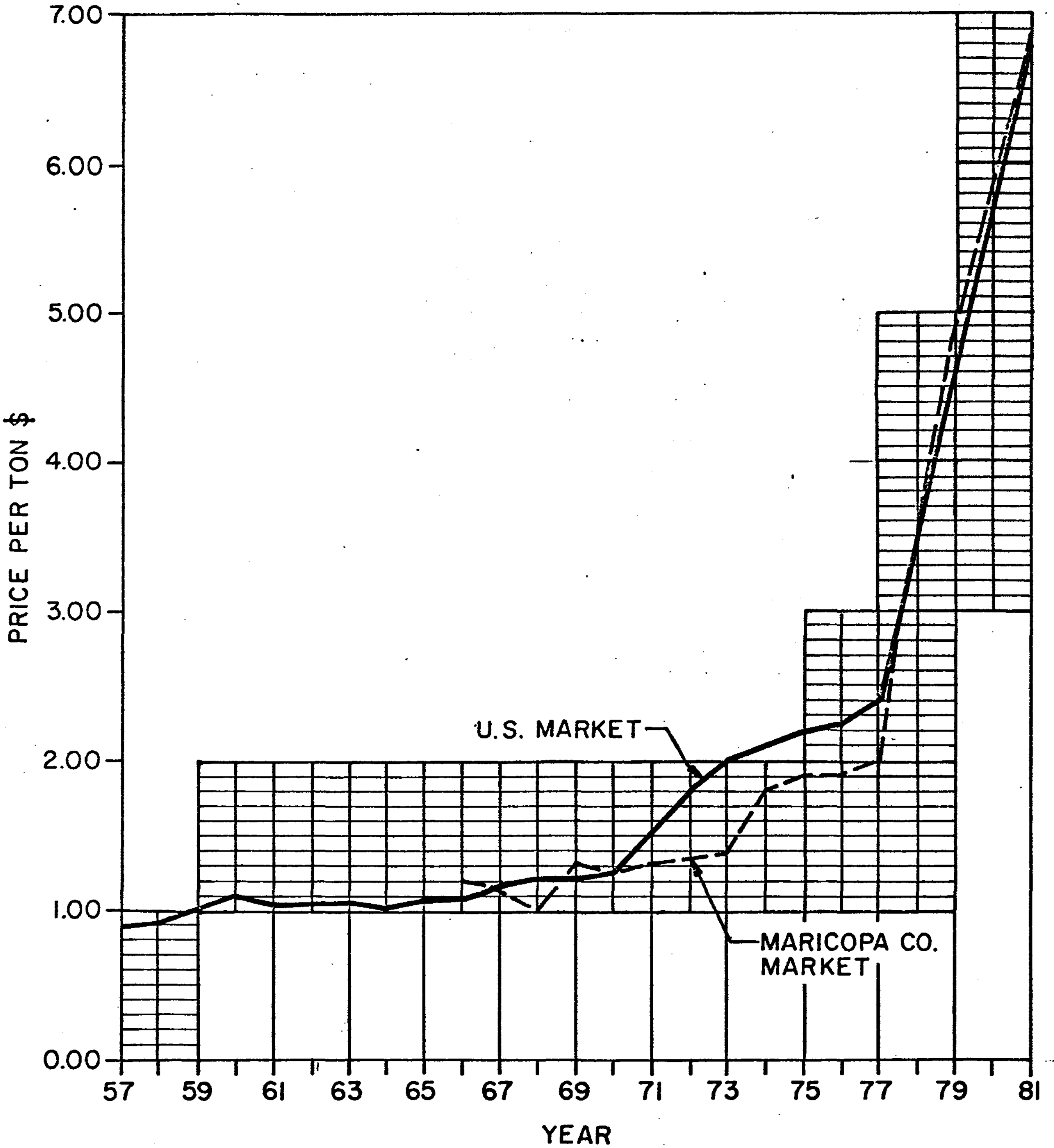


FIGURE IV-2
HISTORICAL PRICE PER TON OF SAND AND GRAVEL

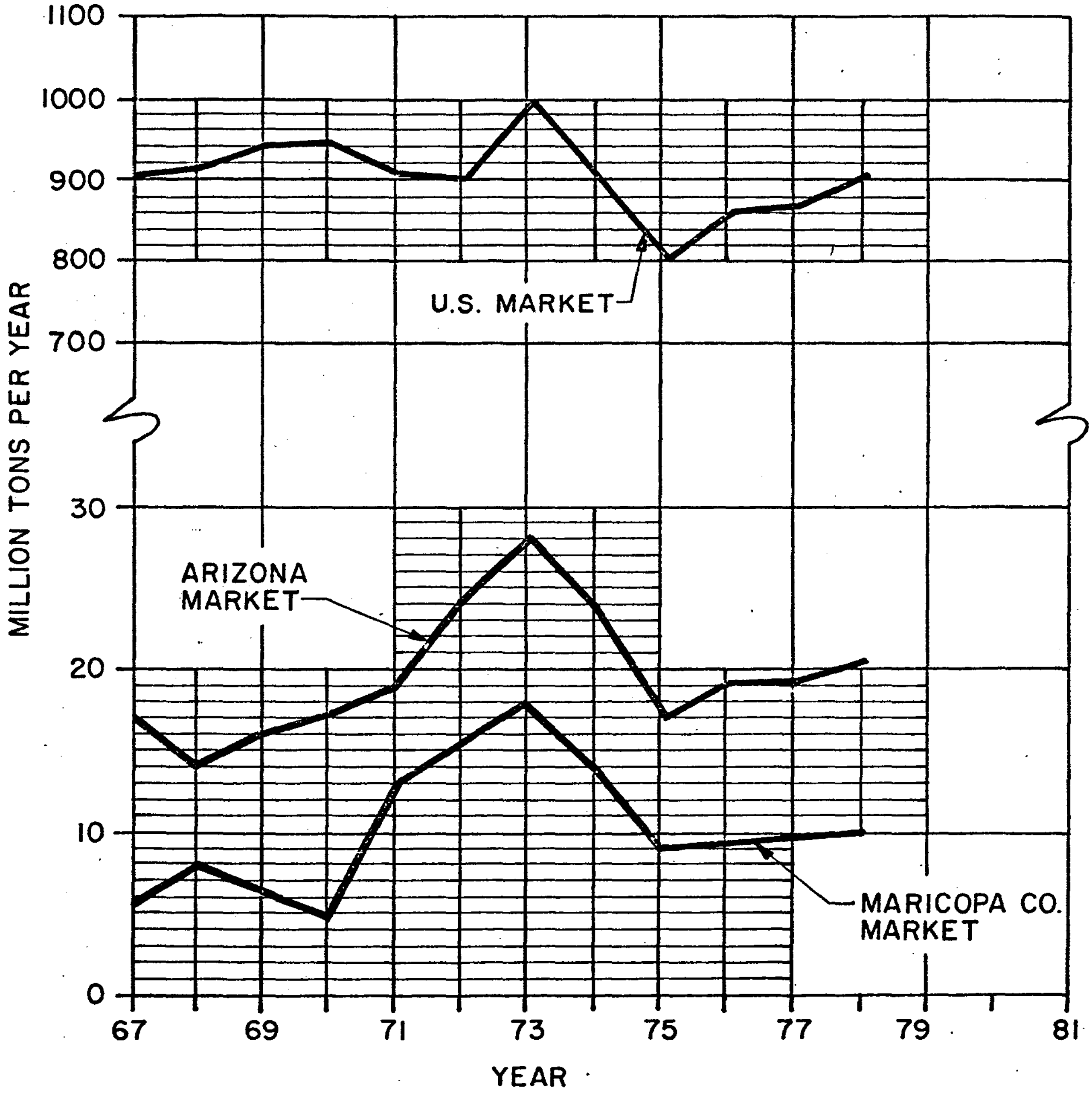


FIGURE IV-3

HISTORICAL SAND AND GRAVEL DEMAND

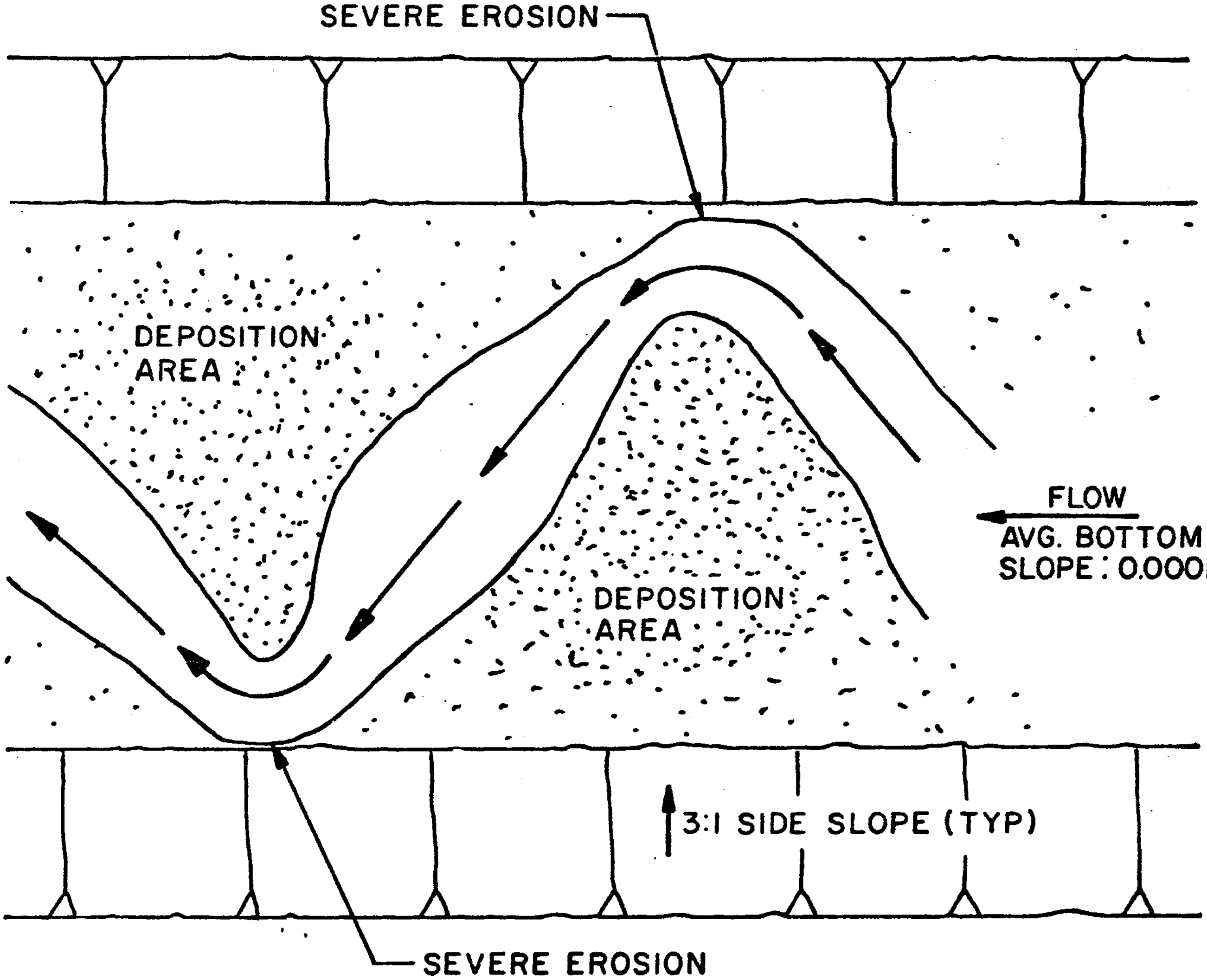


FIGURE IV-4

PROCESS OF SIDE CUTTING IN THE EXCAVATED CHANNEL

CHAPTER V

PREPAREDNESS PLANNING EVALUATIONS

General Background

Preparedness planning procedures and recommendation presented in this paper are excerpted from a report prepared for the Los Angeles District by the Hydrologic Engineering Center entitled, "Flood Preparedness Planning, Metropolitan Phoenix Area." The primary purpose of the investigation was to formulate and assess the value of enhancements to existing flood preparedness planning arrangements in the metropolitan Phoenix area. The investigation consisted of three primary phases: (1) extensive interviews and discussions with agency personnel; (2) development of flood scenarios and descriptions of events with and without proposed enhancements; and, (3) analytical data processing and evaluations. Each was considered necessary to develop potential enhancements to present preparedness planning arrangements. Because of the complexity of the subject and need for brevity the scenarios have been omitted. However, their value in the investigation should not be overlooked.

Overview

Preparedness plans and procedures consist largely of inter- and intra-organizational arrangements and commitments in which the human element is and essential ingredient. As such, plans and procedures cannot be guaranteed to work in the same sense that a guarantee might be made for a well tested piece of equipment or a structure of concrete and steel. Preparedness plans also are vulnerable to decreasing effectiveness over time as the result of disuse, changes in circumstance such as community growth, and turnover of experienced participants. A primary consideration in the design of preparedness plans and procedures, therefore, is incorporation of provisions aimed at reliability and longevity include clear lines of communications, detailed description of actions to be taken, clear assignments of responsibility, provisions for continuous plan maintenance, and formal implementation of the plan which makes it a part of the community's administrative and institutional structure.

Implementation of the proposed enhancements will help minimize the potential for loss of life, reduce social congestion and general disruption and reduce flood damage associated with a large event, even through social disruption and damages related to such an occurence will still be significant. Specific preparedness planning actions taken must be determined based on the flood event, considering all factors and ramifications of the actions.

Evaluation of existing preparedness planning arrangements and procedures for the metropolitan Phoenix area indicate that their reliability, comprehensiveness and longevity could be enhanced by the following:

1. Modification of existing preparedness plans to base flood response actions on predicted water surface elevations rather than flood frequencies or discharge rates;

2. Increased emphasis within the present organizational structure of County's Emergency Operating Center on management of important services, temporary flood loss reduction activities, post flood recovery, and continued plan management;

3. Streamlining and updating the collection process hydrometeorological data and information;

4. Modification and extension of arrangements for warning disemination;

5. Development of detailed plans and procedures for:

   A. Evacuation of endangered areas

   B. Flood fighting

   C. Management of vital services

   D. Recovery/reoccupation actions in the immediate post-flood period

   E. Continuous plan maintenance

Flood Preparedness Defined

Flood preparedness activities consist of complex organizational arrangements, agency interactions and documented emergency contingency actions which are implemented during flood events and are kept viable between flood episodes by proper plan management. The essential elements of flood preparedness plans are: flood threat recognition, warning dissemination, emergency response actions, post-flood recovery/reoccupation, and continued plan management. These elements are described in the following paragraphs.

Flood Threat Recognition. Flood threat recognition consists of the means and procedures for identifying an impending flood and, includes such activities as weather forecasting, precipitation and/or streamflow measurements, transmission of collected data, and processing and interpretation of collected data. These activities must be designed to provide accurate and timely warnings appropriate to the area to be protected. Principal features of the flood threat recognition system include: computerized systems featuring telemetric querying or signaling capability between gages and a mini-computer equipped with a rainfall-runoff model for prediction of flood information, various water level sensing devices which signal when stream levels reach some predetermined stage, and networks of observers who take direct readings of precipitation and river stages, forwarding the information to some central location for processing and interpretation.

Flood Warning Dissemination. Flood warning dissemination provides the critical link between recognition of an impending flood and execution of the emergency response actions. It consists of three main parts: a decision on whether or not a warning should be issued, as well as a determination of its intended audience, procedures for formulation of the warning message, and procedures and means for actual distribution of the message to affected parties by such means as radio, television, sirens, bullhorns, and door-to-door notification. For maximum effectiveness, the warning should reach each individual who could be directly affected by the impending flood with a message stating the time available for flooding occurs, its expected severity, and the appropriate response actions (evacuation routes, safe destinations, protection measures, etc.).

Emergency Response Actions. Emergency response actions consist of planned activities that take place immediately prior to and during a flood event. The actions are designed to reduce the threat to life, and lessen the social and economic impact of the flood.

Emergency response actions normally deal with: search and rescue of endangered people, temporary evacuation of threatened areas, temporary removal or raising of movable public and private property, flood fighting efforts, and management of important services and facilities such as those related to electric power, gas, water supply, sewage collection and disposal, fire fighting, law enforcement, and emergency medical service.

Post-Flood Recovery and Reoccupation. Post-flood recovery/reoccupation component of preparedness plans deals with steps and resources necessary to return the community to normal status as rapidly as possible after a flood episode and to mitigate secondary problems occurring in the post-flood period. Specific matters usually addressed include: the return to normal operation of important services and facilities, steps to prevent unsafe reoccupation of endangered structures, and identification and provision of assistance to the general public and local governments.

Continued Plan Management. The successful implementation of a community level flood preparedness plan requires a high degree of communication, cooperation and coordination between a broad range of public and private organizations as well as the general public. Interjurisdictional efforts between cities and counties are frequently required in implementation of successful preparedness plans during flood conditions.

Without periodic use, such arrangements are likely to become obsolete and/or unworkable. Continued plan management provides for actions needed to maintain the viability of the plan during the period between flood episodes. Continued plan management involves: updating those portions of the plan subject to obsolescence such as telephone numbers, assignments of responsibility, etc., provisions for maintenance and testing of equipment, and educational and informational activities including training of participants in plan execution, conduct of exercises and drills, conduct of public awareness program, and education of the public with respect to actions to be taken during the floods.

Overview of Existing Arrangements.

Recent floods have caused preparedness actions of various types to be formulated and implemented in the study area. The purposes of this section are to describe in general terms the presently accepted elements of preparedness plans, and to catalogue the specific components that have recently evolved in the study area.

Information was derived primarily through extensive interviews with local government officials involved in disaster management, private businesses, and flood plain residents. Other sources of information included newspaper and magazine clippings, and post-flood documents prepared by several agencies.

A significant amount of flood preparedness planning already has been done in the study area. In addition to the State's emergency plan, (Arizona Division of Emergency Services no date), there are formal written plans for Maricopa County (Maricopa County Board of Supervisors 1980) and for most of the municipalities in the County. The assignment of responsibility to the Maricopa County Department of Civil Defense and Emergency Services (MCCD) for deveopment of both County and municipal emergency plans has assured the compatibility and coordination of those plans. The MCCD has also prepared an extensive listing of resources which are available in the area.

Existing plans developed for the Phoenix metro area deal mostly with temporary evacuation, rescue and other matters related to safety from the direct flood threat. Implementation of temporary flood mitigation measures, safety from secondary problems related to flooding, emergency management of important services and facilities, and post-flood recovery and reoccupation constitute lesser portion of the existing plans. Although present plans lack certain aspects of these elements, most people interviewed expressed satisfaction with the performance of emergency agencies during the February 1980 flood. Deaths directly due to past floods have been limited, and adequate warnings have enabled residents in the area to reduce damage through relocation or protection of property on an individual basis.

Existing plans also contain provisions concerning periodic updating of practice, public awareness programs or other activities to maintain the plan over the period between floods. The Maricopa County Civil Defense updates it preparedness plans every two years.

Proposed Plan Enhancements.

Proposed enhancements to existing preparedness plans were formulated using extensive interviews with federal, state, and local government agencies, scenario assessments of moderate and severe flood events, and evaluation of the present damage potential of the study area (Hydrologic Engineering Center 1980). Based on this information, this section presents potential enhancements to present preparedness arrangements and procedures.

Response Based on Water Surface Elevation. The study area has available state-of-the-art techniques for forecasting floodflows through the combined efforts of the National Weather Service (NWS) River Forecast Center, in Salt Lake City, NWS-State Flood Forecasting Center in Phoenix and the Salt River Project (SRP). The relationships between flows and water surface leveles for the streams in the area, however, are unstable due to natural aggregation and degradation which takes place between and during flood episodes and due to gravel mining in river channels. Consequently, the nature and extent of response actions necessary for a particular predicted flow may vary from time to time. In order to avoid overreaction or underreaction to the actual threat, preparedness plans could be keyed to water surface elevations rather than to flows.

Accurate prediction of water surface elevations requires knowledge of the configuration and roughness of river channels and areas of overbank flow. This information should be determined immediately after every significant flood and periodically thereafter (e.g., every 3 - 5 years) in order to assure availability of an updated information base. These profiles and rating curves would enable the NWS-State Flood Forecast Center to convert predictions of flow into predictions of water surface elevations at selected downstream points.

Automatic reporting stream level gages should also be placed at selected index locations. Four index locations including three on the Salt River, and one on the Gila River downstream of its confluence with the Salt River, would be sufficient. These gages would enable checking and confirmation of predicted water surface elevations during a flood and collection of data valuable for future flood forecasting.

The Flood Control District of Maricopa County has prepared evacuation maps for floods of 50,000 cfs, 100,000 cfs, 150,000 cfs, 250,000 cfs and 350,000 cfs. An analysis also could be made for selected water surface elevations to determine in greater detail the needs for flood fighting, traffic control, management of important services and other emergency activities. Plans and assignments of responsibility could be organized so that all of the actions to be taken at each successively higher predicted water surface elevation are clearly apparent and described in specific terms.

Establishment of Functional Coordinators at EOC. Numerous jurisdictions and agencies from throughout Maricopa County have been invited to send representatives to the County's Emergency Operations Center during past flood episodes, although no formal agreements exist to assure such participation and no formal organization exists with the EOC's operational procedures to allocate responsibilities to those representatives who attend. Nevertheless, participation responsibilities are defined (in limited scope) in disaster plans of the county and local communities.

Maricopa County Civil Defense has a peacetime disaster plan which operates during periods of flooding. This plan has operated satisfactorily during the recent floods. The organization of the Plan is depicted in Figure V-1.

Through interviews and analyses possible enhancements to the existing plans were developed. These possible enhancements to the existing plans could include a more formal arrangement with six positions reporting directly to the director of the MCCD staff. The position and their basic functions are shown in Figure V-2. The functions of these positions would vary over the period of a flood. During the preflood period and during a flood, each position could have an established set of responsibilities for warning dissemination. During the flood, each position could also have responsibility for internal coordination (e.g., the law enforcement position providing coordination among law enforcement agencies) and external coordination (e.g., the law enforcement position providing coordination between law enforcement and health agencies). Responsibilities of each position would be documented, with each position staffed by a designated coordinator and alternates as needed to provide for 24 hour operations during flood periods. Each coordinator would supervise whatever staff was necessary to assist in performing the assigned responsibilities of their position.

Update Arrangements for Data Collection. Hydrometeorological data and information useful for flood prediction in the study area is available from a variety of sources. The MCCD has played a key role in the collection of local data and its forwarding to the Phoenix Weather Service Forecast Office (WSFO), during past flood events.

The Arizona Legislature funded a Flood Warning Office in early 1979. It appropriated $100,000 for data collection equipment in FY 80. Similar amounts were appropriated for FY 81 and FY 82, and a similar amount is in Arizona Department of Water Resources FY 83 budget request, for a total of $400,000. Congress authorized the U.S. Geological Survey to spend $300,000 for a flood warning system in Arizona, and Maricopa County has budgeted about $500,000 for FY 80, FY 81 and FY 82.

FIGURE V-1

Maricopa County Peacetime Disaster Plan Emergency Staff Organization and Personnel

FUNCTION	1st Shift	2nd Shift	(3d Shift)	Anticip Emerg	Minor Emerg	Major Emerg
THE EMERGENCY STAFF -- Emergency Operations Center						
EMERGENCY STAFF HEADQUARTERS						
DIRECTOR	CD&ES	CD&ES		X	X	X
PUBLIC INFORMATION	Info Office	Info Office	Info Office	(X)	(X)	X
TYPIST	Parks & Rec	Parks & Rec	Parks & Rec		(X)	X
RECORDER	CD&ES	CD&ES	CD&ES	X	X	X
INTELLIGENCE SECTION						
INTEL OFFICER	CD&ES	CD&ES	CD&ES	X	X	X
FLOOD ANALYSIS	Flood Control	Flood Control	Flood Control	(X)	(X)	X
FLOOD ANALYSIS	Flood Control	Flood Control	Flood Control	(X)	(X)	(X)
WATER RELEASE INFO	SRP	SRP	SRP		(X)	(X)
CALL DIRECTOR OPR	Personnel	Personnel	Personnel	(X)	X	X
TEL-OPERATOR	Personnel	Personnel	Personnel		(X)	(X)
OPERATIONS SECTION						
OPERATIONS OFFICER	CD&ES	CD&ES	CD&ES	X	X	X
ASS'T TO OPNX OFF	Highway	Bldg Safety	Bldg Safety	(X)	(X)	(X)
LAW ENFORCEMENT	Sheriff	Sheriff	Sheriff		X	X
LAW ENFORCEMENT	Sheriff	Sheriff	Sheriff		(X)	X
HEALTH-MED	Health Svcs	Health Svcs	Health Svcs		(X)	X
HEALTH-MED	Health Svcs	Health Svcs	Health Svcs			(X)
MASS CARE	State DES	State DES	State DES		(X)	(X)
MASS CARE	Red Cross	Red Cross	Red Cross		(X)	X
MASS CARE	Human Res.	Human Res.	Human Res.		(X)	X
ENGR/PUB WKS	Highway	Highway	Highway		(X)	X
ENGR/PUB WKS	Highway	Highway	Highway		(X)	X
TRANSPORTATION	Mech Equip	Mech Equip	Mech Equip		(X)	(X)

( ) - Conditional, to be requested if required by the situation.

NOTE: Other departments may be asked to provide additional personnel, if needed.

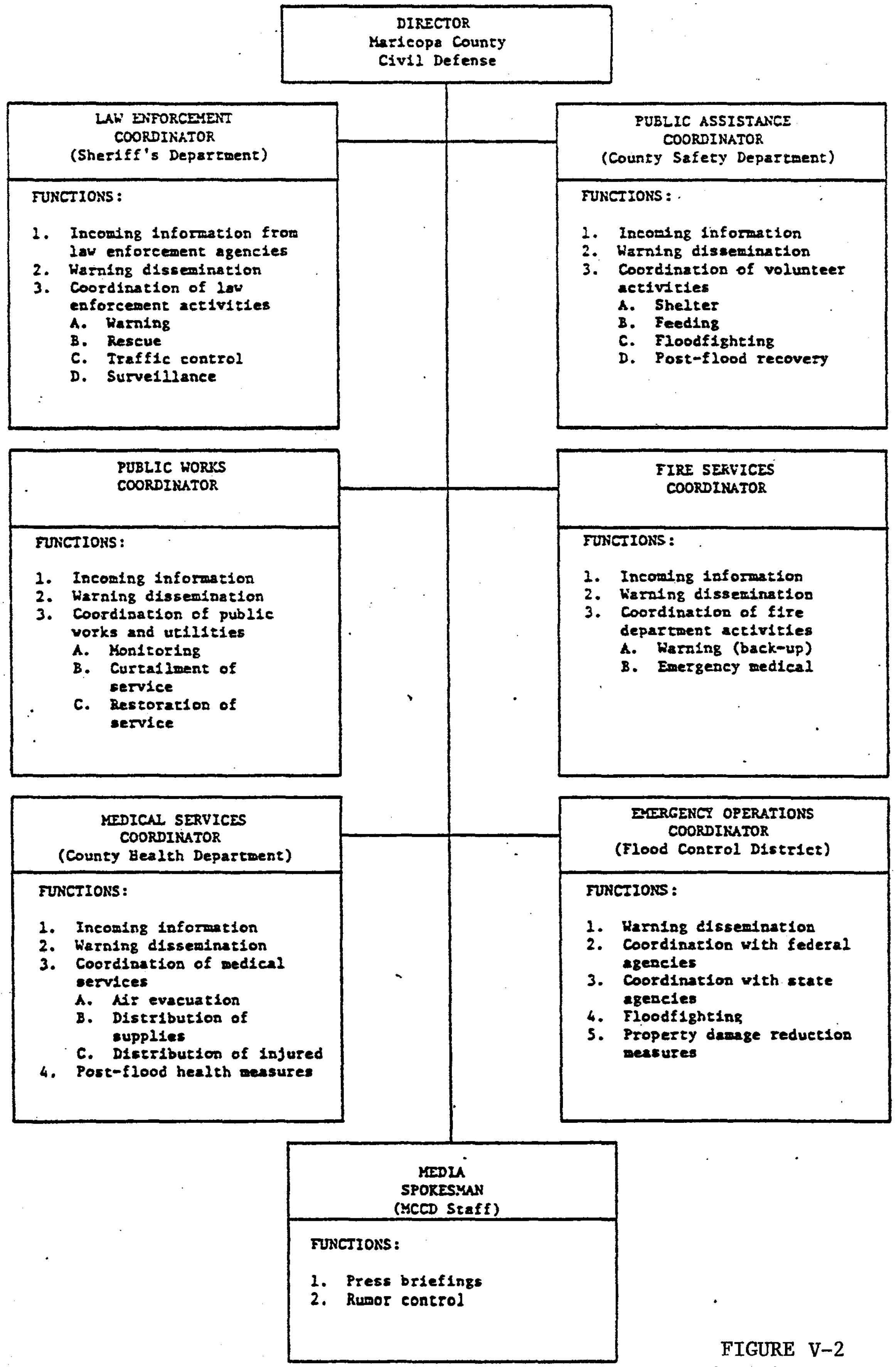


FIGURE V-2
Possible Enhancements to Emergency Operations

The $400,000 of State funds, something more than $300,000 of Federal funds, and about $100,000 of Maricopa County funds will have been used by June 30, 1983, to establish a data collection and analysis system for streamflow and precipitation data on all of the major rivers in Arizona for which warning is needed. Through this system, data is collected at streamgauge sites, transmitted via satellite to a ground receiving station, and analyzed to provide flood forecasts. Data is normally collected at the site every 15 minutes and transmitted every 3 hours. However, thresholds are set at each site so that at a specified flood level or precipitation intensity, the station will transmit every 15 minutes.

The data collection and anlysis system will be fully operational by about July 1982. This system will collect data from 65 streamgauges and 40 or 42 precipitation gauges at intervals of 15 minutes to three hours. This data will be available to Arizona users through their computer terminals within a few seconds after the data is collected. The Flood Warning Office will be notified automatically of any flood threat sensed by these gauges, and will take appropriate steps to inform affected parties throughout the State.

<u>Development of Formal Plans for Evacaution</u>. Significant portions of the study area are subject to inundation and therefore require evacuation during floods in the interest of safety. Other portions of the study area are subject to total or near isolation by flooding so far as land routes are concerned. Isolation from law enforcement, fire protection, medical treatment and other emergency services poses additional hazards. People in isolated areas also risk being trapped the event of subsequent higher floods due to lack of an escape route. Some areas subject to a significant degree of isolation also require timely evacuation in the interest of safety.

Past decisions to recommend evacaution of areas have been based on problems experienced in prior floods and the present predications of flow and inundated areas. Present plans have selected evacuation levels based on relations of predicted discharge values to respective flood inundation boundaries delineated on aerial photographs. Modification to present procedures should base evacuation boundaries on predicted water surface elevations instead of discharge. The reason for this is the continuous change in the riverbed due to the alluvial nature of the river and the intense gravel mining operations in the channel. More specific plans are needed to identify evacuation routes, shelters, etc.

Much of the information necessary to develop a detailed evacuation plan is readily available. Considerable information on the number and type of structures to be evacuated is presented in Chapter II. The principal remaining needs are for:

1. Identification of areas expected to require evacuation at each of several water surface elevations;

2. Detailed arrangements for feeding and sheltering evacuees;

3. Development and stockpiling of brochures describing evacuation plan arrangements and actions to be taken by property owners prior to evacuation;

4. Arrangement of safe storage areas for property removal from evacuated areas; and

5. Development of implementing arrangements including those required to enable mandatory evacuation of threatened areas.

Development of Formal Plans for Direct Damage Reduction. Organized efforts at flood damage reduction through temporary flood mitigation measures either to individual strucutres or on a larger scale have not been undertaken on any widespread basis during past floods. The MCCD, Maricopa County Flood Control District, and other agencies, however, have recently identified potential areas for future flood fighting efforts. Analyses of Chapter II and interviews (Hydrologic Engineering Center 1980) support these and other comprehensive efforts. The findings indicate that because of topography, available warning time and nature and extent of development in the study area, significant damage can be prevented through relatively small efforts. Flood mitigation efforts can be implemented for individual structures or, on a larger scale to blocks or neighborhoods.

The study indicated that implementation of effective perimeter barriers and raising or removal of contents present a means of significantly reducing damages to residential, commerical, and industrial structures on an individual strucutre basis. Locations identified (Hydrologic Engineering Center 1980) as having potential for larger scaled flood fight efforts are: Lehi area in Mesa; Indian School Road at the Agua Fria River; and the I-17 crossing of Skunk Creek. Public and quasi-public structures and facilities which warrant priority consideration for application of such measures are law enforcement facilities, sanitary facilities, fire stations, and electrical substations and switchyards.

The principal matters to be accomplished in the development of plans and procedures for flood fighting must begin with specific identification of areas where organized public flood fighting efforts would be productive at various water surface elevations. Analysis of public flood fighting opportunities should be performed with respect to available warning time, techniques to be employed, requirements for equipment and personnel, relative priority, impact or traffic and other factors. Sources of equipment and personnel needed for public flood fighting efforts need identification. Development of implementing arrangements for public flood fighting efforts including provisions for stockpiling or obtaining necessary equipment and obtaining needed personnel is required. The types and quantities of materials to be stockpiled for distribution to private property owners for flood fighting efforts also need to be identified and arrangements formulated for safe storage during flood periods.

Development of Plan for Management of Important Services. Floods disrupt the provision of vital services by damaging facilities and equipment. Inundation of normal access routes also makes delivery of some services either difficult or impracticable for some areas. In some cases, the continuation of utility service to inundated areas also poses risks.

Police and fire agencies in the study area a linked by mutual aid arrangements and maintain a high degree of coordination. Difficulties with access to regular service areas during past floods often have been overcome by requesting an adjacent jurisdiction to temporarily take responsibility for such areas. Police and fire agencies also have informal plans for dispersal of equipment during floods both to avoid damage to the equipment and to improve service to areas expected to become isolated.

Public and private utilities crossing the Salt River sustained extensive damages during past floods. Water supply, gas and electric, and sewage collection facilities have been especially vulnerable to damage. Losses have been reduced in some cases by monitoring to identify the damage locations, quick action to curtail operation of damaged facilities, and provisions for alternate routes of service (Hydrologic Engineering Center 1980).

Inundation of structures and some other facilities poses the risk of fire and explosion in the event electric and gas supplies are not curtailed. Continuation of electric service in flooded areas also poses a risk of electrocution during the flood and during the reentry period.

All major problems pertinent to management of important services could be reduced through development and implementation of a series of emergency plans and procedures. Principal objectives to be accomplished are:

1. Development of a formal inter-jurisdictional plan for dispersal of fire and police equipment and personnel at each of several water surface elevations, based on past experience and on analysis of needs in the case of floods greater than those experienced in the past.

2. Development of specific plans for management of utilities crossing the Salt, Agua Fria and Gila Rivers including provisions for detailed monitoring of performance during floods, revised operations to reduce losses in the event of damage, prompt cutoff of damaged services, rerouting of services and use of substitution services.

3. Development of plans for curtailment of gas and electric service as inundation occurs.

Development of Plan for Recovery/Reoccupation. Prompt action in the immediate post-flood period can reduce secondary losses stemming from flooding, improve safety, and speed return to normal conditions. Among types of post-flood actions likely to be required are financial assistance, emergency cleanup, inspections of structural building safety, vector control, and chlorination of contaminated wells. Existing plans, as previously described, include assistance to individuals, financial relief for governments and preparation of post-flood reports and summaries. Development of more specific aspects of post-flood recovery and reoccupation is needed.

Land fills present a potentially serious problem during floods. If not regulated properly, placement of fills may significantly increase flood heights, deposit debris downstream, and present a direct risk to life. Some existing flood plain fills contain toxic chemicals which have been dispersed into the river during recent floods. Also, rapid decomposition of fill material occurs when the fills are saturated, and results in a sufficient production of methane gas to pose a risk of fire and explosion. Several sanitary fill fires were reported during past floods (Hydrologic Engineering Center 1980). Restriction of access to such areas in the post-flood period is needed so long as sanitary land fills exists on the flood plain. The need also exists in the post-flood period for safety inspection inundated structures, restoration of public services, and provision of information to property owners on dealing with flood damage.

A specific plan needs to be developed to guide post-flood recovery/reoccupation. Past flood experiences should be reviewed and analyzed to determine the impact of potentially greater floods to identify the full range of post-flood problems and needs likely to be encountered. Procedures for conduct of post-flood actions and assignment of responsibility for their accomplishment need development. Preparation for distribution to the public of a brochure describing means of repairing flood damages also would be very useful. In addition development of implementation arrangements including identification of any equipment or materials to be stockpiled for post-flood use should be carried out.

Development of Enhancements for Continuous Plan Management. Continuous plan management is essential for maintaining the reliability and effectiveness of preparedness plans. This is especially true in the study area because long periods of time are likely to elapse between floods. The passage of time, coupled with the normally dry stream channels and poorly defined flood plains, erodes public awareness of the flood hazard. The effectiveness of preparedness plans also are reduced over time by turnover of personnel, changes in the area at risk and changes in the flood hazard.

Present flood preparedness plans for the study area have elements for continued plan management as described in Chapter III. Possible enhancements are designed to maintain the present level of agency and public awareness. The following are identified as possible enhancements:

1. Explicit procedures and documentation for updating agency personnel telephone numbers, addresses, and responsibilities. These are presently being performed to a large extent, but additional steps to assure periodic updating of plan procedures and responsibilities over time should be performed.

2. Location of equipment and materials for flood fighting efforts, both on a large scale and for private individuals. This also should include means of making public aware as to best locations.

3. Preprinted brochures describing appropriate actions to be taken by the general public during flood situations. The brochures would be distributed each flood season ,or during the early flood threat recognition phase. The brochures should include explicit descriptions, materials, and illustrations for:

   a. Means of obtaining flood information;

   b. Procedures for temporary evacuation: possible items to take, content adjustments (raising or removal), shut off of water, gas, and electricity, and security precautions;

   c. Flood fighting procedures for individual structures: placement of earth fill, sand bags, flashboard, and polyethylene and;

   d. Recovery and reoccupation procedures: general assistance; financial assistance and safety considerations prior to reoccupation.

4. Other means of distributing information to the public which might include preprinted newspaper inserts and, seminars and workshops for specific areas.

5. Periodic coordinated drills (say every 2-4 years) among involved agencies.

6. Periodic evaluation and modification of the plan to adapt to community growth and other long-term changes.

7. Negotiation and renewal of contracts, inter-jurisdictional agreements, memoranda of understanding, and other implementation arrangements as necessary.

Evaluation of Proposed Plan Enhancements.

Purpose and Overview. Preparedness plans are unique among flood loss reduction measures due to the potential for implementation of measures on an event basis. This enables flexibility in preparing a broad range of mitigation procedures not possible in permanent measures. However, the event oriented temporary nature of the measures, variability of actions, the relationship of the effectiveness of the actions to the nature of event, community status, and other factors result in considerable uncertainty in the reliability of the measures. The measures function differently than do permanent alternatives which are designed to operate in a specific manner for a range of hydrologic occurrences. Consequently, evaluations of the proposed enhancements to present plans center around two distinct aspects. The first is the determination of the value of possible enhancements to present plans and arrangements, and the second is the actual feasibility (decision process) of implementing those measures for specific flood event. Understanding of these two aspects of feasibility assessments is important in differentiating the functions of preparedness plans. Possible enhancements to existing plans and arrangements are particularly difficult to evaluate because of different levels of implementation for a range of flood events.

Preparedness Plan Cost Items. Costs required to implement the plan enhancements consist of (1) the first costs of formally investigating and adopting the plan elements themselves and acquiring, developing, and preparing those items needed for the general plan implementation; (2) annual costs of maintaining plan elements in a state-of-readiness; and (3) costs associated with implementing specific actions during flood events. Table V-1 itemizes and summarizes general cost items associated with the proposed preparedness plan.

TABLE V-1

PREPAREDNESS PLAN COST ITEMS

First Cost

- Development of formal plans
- Outfitting/equipping administrative facilities
- Purchase and installation of equipment and hardware
- Development/printing brochures, instructions, etc.
- Stockpiling equipment and materials

Annual Periodic Cost

- Updating formal plans
- Updating/printing brochures, instructions, etc.
- Operations drills
- Supplement/replace stockpiled materials
- Periodic river section surveys

Event Cost

- Personnel overtime and emergency hires
- Equipment purchase and rental

Transport/storage of personal property
Materials/supplies consumed
Mass care operations
(And several fold more general items)

It is immediately recognized that there are difficulties in distinguishing between cost items that may already fall within the purview of an existing agency's operations, and those that are not presently accounted for. In general, the approach has been to assign most administrative costs to existing ongoing programs and to designate specifically identifiable products as bona fide cost increments. The intent also has been to attempt to separate out those items that could be specifically assigned to the enhancements proposed in this report.

The development of formal plans, e.g., written documents of procedural actions and administrative arrangements, must of necessity be prepared by the local agencies involved. It is envisioned that the "plan" might consist of a set of instructions for the director and/or staff of the emergency operations center and the several coordinators. Each agency or group with a specific role to play in the emergency operations could well have its own procedures documented for their own use. The responsibility for the development of the plan at the emergency operations center level would be the existing MCCD director. Overall coordination, plan documentation and arrangements preparation are estimated to cost at one time increment over and above the existing responsibilities of MCCD for $100,000. The preparation of action plans on the part of participating agencies are assumed to be part of the functional role of these agencies and have no direct cost.

The existing MCCD offices and facilities are adequate and no more than temporary rearrangements of space and phones for coordinated use during flood emergencies are necessary.

The purchase and installation of equipment and hardware is specifically related to the recommendation of adopting index stations along the main streams from stage forecasts. Plans for the normal implementation actions of the flood forecast center may include such equipment. The initial cost of installing hardware for continuous monitoring of flood elevations at selected index locations on the Salt, Gila and Agua Fria Rivers is $80,000-100,000. This cost would include the installation of six stream gages with automatic data transmission capabilities and a receiver/printer located with the NWS-State of Arizona Flood Forecast Center.

The development and printing of public awareness brochures, pamphlets, preprinted newspaper inserts, etc., are estimated to cost $75-125,000. Distribution of these informational materials would be made early in the flood season on a general scale, or immediately prior to a predicted event or threatening situation on a mass scale. The brochures would include general information for temporary evacuation, temporary flood proofing procedures, content adjustments and post-flood recovery/reoccupation considerations. More specific information on technical guidance for significant self help type temporary measures may be warranted and would cost an additional increment. The specific scope and number of public information needs would be determined as part of the formal plan preparation. The need for stockpiling of equipment and materials should be investigated in some detail. Emergency equipment for preparedness agency use includes such items as portable pumps and generators, shovels, sandbags, etc. An inventory of the resources available for such emergency use is needed to define new purchase needs. Since no flood fight activities have been attempted in the past, the availability of such items as shovels, sandbags, polyethylene plastic etc., has not been determined. It is conceivable that the formation of a central storage area for regional distribution might be reasonable and economical. A one-time purchase of equipment and materials for public agency use might be $75,000 to $100,000.

Stockpiling or arranging by some contingency contract for materials and small equipment for use by private citizens in a self help mode is a specific endeavor that warrants serious study. Materials costing $200 per structure would prevent upwards of 1 foot of water from entering certain types of structures. As an outside estimate a contingency contract for short call delivery of materials for 1,500 homes might cost 25% of full cost of $75,000. The expected use rate is a function of flooding frequency. The expected annual number of structures that would be flooded computed from data in Tables II-5 6 and 7, is 65. Increasing this number by 50% to allow for conservative estimates of material consumption for temporary flood damage mitigation results in 100 structures per year.

Annual costs associated with the proposed enhancements include general maintenance of equipment and programs described earlier, costs for periodic drills, and cost of material consumed for temporary flood mitigation measures. Maintenance of the automatic stream gage system, periodic updating of cross-section information, and subsequent rating functions are estimated to be $10-20,000. Annual rent and contingency lease for materials requisition and storage of flood fight equipment are estimated at $5-10,000. Public awareness programs and printing/distribution of brochures drills, etc., are estimated to cost $15-25,000 per year. The annual cost of materials used for temporary flood damage flood mitigation is $200 per structure of $20,000. Table V-2, lists cost ranges for proposed enhancements to existing preparedness plans and arrangements.

TABLE V-2

PREPAREDNESS PLAN COST SUMMARY

First Cost

Item	Cost Range ($1,000)		
Formal Plan	$75.	-	$100.
Office/Administrative Outfilling	0.	-	0.
Equipment/Hardware (Stream Gage)	80.	-	100.

Information/Brochures	75.	-	125.
Equipment/Materials (Agency Use)	75.	-	100.
Equipment/Materials (Temporary Flood Mitigation)	75.	-	75.
Totals	$380.		$500.
Amortized (50 Yr.@ 7-3/8%)	29.		38.

Annual Cost

Item	Cost Range ($1,000)		
Equipment/Hardware (Stream Gage)	$10.	-	$20.
Storage/Rent	5.	-	10.
Public Information/Brochures, Drills	15.	-	25.
Flood Mitigation Materials	20.	-	20.
Totals	$50.		$75.
Total Annual Cost Range	$79.		$113.

Cost in Perspective. Costs incurred during the occurance of a significant but not major flood event are expected to be about the same as without the proposed plan enhancements. It is expected that the more effective management and communication is proposed would, in fact, result in not only increased effectiveness but would likely result in lower overall costs. Costs incurred during a major flood in which significant attempts are made to assist in private/individual temporary flood mitigation actions could be significant. On an annual basis this cost may increase the annual cost by 10%, given the rare occurence of major floods.

The investment cost range of $380,000 to $500,000 is judged to be a conservative estimate. It may well be that several of the items included can be absorbed by the normal activities of the existing agencies. This is even truer for the annual recurring cost items total ranging from $79-$113,000. For discussion purposes, the total investment cost can be adopted as $450,000 and total annual cost, including amortized investment and levelized event costs as $110,000.

Benefits. The benefits of flood emergency preparedness are primarily the reduction of the threat to life, and to a lesser extent, the mitigation of the negative impacts of flood disasters on society in terms of reduced social disruption, business losses and damage to private and public building and facilities. Table V-3 summarizes the general categories of benefits from the proposed preparedness plan.

While significant monetary benefits are in all likelihood generated by these contributions, an estimate of their numerical value has been found to be impossible. Debates as to placing a monetary value on saving lives and reducing threats to lives and property have occurred for many years and are continuing. The growing activities in the field of emergency preparedness provides general evidence that society places sufficient value on these endeavors to support use of scarce financial and manpower resources to increase their responsiveness and utility.

TABLE V-3

GENERAL BENEFIT CATEGORIES - PREPAREDNESS PLANS

Category	Contributing Action
Reduced threat to life	Barricading, evacuations, rescues, public awareness
Reduced social disruption	Traffic management, emergency services, public awareness
Reduced health hazards	Evacuation, public information, emergency services
Reduced disruption services	Utility shutoffs, emergency supplies, inspection, public information
Reduced clean-up costs	Flood fighting, self-help mitigation, efficient resource use
Reduction in inundation damage	Flood fighting, temporary measures, technical assistance

Some measure of the flood damage reduction value, mostly due to private citizen implementation of temporary flood mitigation measures, can be inferred from flood proofing data presented in Table V-4 (Hydrologic Engineering Center 1980a). Once again, however, the values presented are preliminary, and at best are only indicators of the true damage that might occur. It is assumed that on the average, 30% of the flooded properties would attempt to implement perimeter barriers, that most would make some attempt to adjust contents to a less vulnerable position either through partial removal or elevation. Further, it is assumed that the perimeter barrier attempts would be 50% successful and that content adjustment actions would be 40% removal of half the contents and raising of 80% of the remaining contents. Table V-4 summarizes the results of these actions.

Based on damage reduction from temporary measures alone (no credit for flood fighting, effectiveness of emergency services etc.) a minimum estimate of the annual benefit would be $390,000.

TABLE V-4

DAMAGE REDUCTION ESTIMATE

Measure	Annual Damage ($1,000) 1/	Annual Damage Reduced ($1,000)	Adjusted * Reduction ($1,000)
Existing	$2,454	$ 0	$ 0
1 Foot Barrier	2,142	312	47
40% Content Removal	1,676	778	156
85% Content Raise	2,071	383	184
		TOTAL	$387

1/ Data from Table V-5, also note cautions.

*Perimeter barrier - 30% attempt, 50% effective
Contents removal - 40% removed 50% of contents
Contents raise - 80% raised 85% 3-feet

Cost-Benefit Summary. Cost items have been identified and initial and annual cost ranges estimated for the major items. Total investment cost range is estimated at $360,000 to $480,000 with reasonable value of $450,000 adopted for analysis purposes. The total annual cost including amortized investment, recurring annual cost, and event costs levelized is estimated at $110,000. It is judged that these costs are conservative and it is likely several items would fall within the normal activities of existing agencies. The benefits are primarily contribution to reduction to the threat to life and increased effectiveness of emergency services and recovery. A monetary estimate of these benefits is not presented. The benefits from implementation of temporary flood damage reduction measures made possible by the collective capabilities of the preparedness plan enhancements are roughly estimated as a lower bound of $390,000. Based on these estimates, the possible preparedness plan enhancements are economically justified.

CHAPTER VI

NONSTRUCTURAL PLANS

Overview

Previous chapters have described investigation procedures and findings related to the feasibility of nonstructural measures and plans consisting of: (a)permanent measures designed to modify the damage susceptability of existing structures; (b) measures designed to manage future flood plain development and activities; and (c) preparedness planning enhancements. Emphasis has been placed on performing comprehensive and consistent assessments of nonstructural measures in each category. In addition to the measures and plans analyzed and presented for each category of nonstructural measures, the need exists to formulate other and more comprehensive plans (composites of various nonstructural measures or mixes of nonstructural and structural measures). These plans may be formulated to maximize the return on the Federal investment (National Economic Development Benefits) or to determine the most cost effective plans to meet specified uniform protection levels.

Nonstructural plans may consist of a single type of measure at specific locations or may represent a composition of different types of nonstructural measures. An example of the former would be a plan consisting of earthen dikes around specific groups of single family residential structures in south Phoenix between 16th Street and 7th Street to provide uniform 50-year protection. An example of the latter plan would be one consisting of flood proofing measures to 50-year uniform protection levels, enforcement of comprehensive flood plain regulations and implementations of preparedness plans.

The following sections briefly describe the composite nonstructural plan, discuss the inter-relationships of the measures and describe the relationships of that plan with potential structural measures.

Description of the Composite Nonstructural Plan

The nonstructural candidate plan consists of elements of the three nonstructural categories described previously. Following paragraphs describe possible elements of such a plan.

Existing Structures Measures. Economic results described in Chapter IV indicate that individual flood proofing involving the use of earthen dikes, up to the 50-year uniform level of protection, was the measure that had the highest benefit/cost ratio (.8-.9). Possible exceptions were relocation of earthen dikes for the 100-year protection level for mobile homes, and a combined Federal agency effort for relocation of residents living in substandard housing. Of the three uniform level of protection plans evaluated, earthen dikes constructed around existing structures to the 100-year to 500-year uniform protection levels were not even marginally feasible, and based on economic considerations alone did not warrant additional investigation.

Economic results for the 50-year uniform protection plan, shown in Table IV-3, and reach computation results provided in Appendix C, indicate the economic value of flood proofing is significantly less in some areas and reaches than others. Therefore, uniform level of protection by flood proofing to the 50-year flood levels was determined to be not practical for the entire study area, and only those locations determined to be the most feasible were considered in this composite nonstructural plan. Flood proofing measures at locations identified as having annual damage reduction values to annual cost ratios greater than .80 were included in the plan. The following paragraphs summarize flood proofing (earthen dikes) measures and locations for the plan:

- Single Family Residential. For purposes of this analysis the areas of single family residential structures meeting the criteria are located: in south Phoenix between Interstate Highway 10 and 7th Street (about 47 structures); the subdivision southwest of 35th Avenue and Broadway (about 290 structures); and on the north side of the Gila River between the confluences of the Salt and Agua Fria Rivers (estimated 114 structures in and surrounding the Holly Acres subdivision).

- Multi-Family Residential. The estimated 10 multi-family residential structures located between McClintock and Scottsdale Roads near University Drive were the multi-family residences identified as meeting the criteria of the plan.

- Industrial Structures. An estimated 139 industrial structures met the plan criteria as having the best potential for implementation to the 50-year flood level. Locations most applicable for construction of earthen dikes were determined to be a group of about 40 structures bounded by Pima and McClintock Roads and University Drive and the River; estimated 87 structures scattered and grouped between 16th Street and 19th Avenue; and about 12 structures scattered between 35 and the Gila River.

A summary of the economic results of the flood proofing elements of the composite nonstructural plan is shown in Table VI-1. The results indicate that an estimated $280,590 annual flood damage would be reduced at an annual cost of $320,460. Flood proofing just the most feasible locations instead of the entire study area yielded flood damage reduction to cost ratios of .88 compared to .81, respectively.

TABLE VI-1

ECONOMIC SUMMARY OF COMPOSITE

NONSTRUCTURAL PLAN - FLOOD PROOFING ELEMENT

Damage Reach	Estimated No. of Structures	Existing Conditions EAD	With Measure EAD	Annual Damage Reduced	Annual Cost	Annual Net	Annual Damage Reduced Annual Costs
			(SINGLE FAMILY RESIDENTIAL)				
5.1	18	24.70	19.34	5.36	6.66	-1.30	.80
5.2	29	73.50	60.30	13.20	15.95	-2.75	.83
6.0	290	222.93	119.22	103.71	121.80	-18.09	.85
7.0	114	82.20	27.00	55.20	62.70	- 7.50	.88
Subtotal	451	403.33	225.86	177.47	207.11	-27.64	.86
			(MULTI-FAMILY RESIDENTIAL)				
3.2	10	11.40	4.90	6.50	7.50	-1.00	.87
			(INDUSTRIAL STRUCTURES)				
3.1	40	191.70	173.27	18.43	22.00	-3.57	.83
5.2	60	254.50	197.76	56.74	60.00	-3.26	.95
5.3	22	65.50	53.93	11.74	12.10	-.53	.96
5.4	5	19.50	16.90	2.60	2.75	-.15	.95
6.0	12	23.73	16.45	7.28	9.00	-1.72	.81
Subtotal	139	554.93	458.31	96.62	105.85	-9.23	.91
TOTAL	600	969.66	689.07	280.59	320.46	-39.87	.88

Future Development Management Measures. This aspect of the composite nonstructural plan designed to manage future development is important to controlling future flood damage and social disruption. Regulatory policies should be comprehensive and uniform throughout the study area. The regulations proposed as part of composite plan are regulations based on FEMA standards which manage future development to the 100-year frequency flood levels, management of placement and materials of sanitary land fills, and regulation of sand and gravel mining operations to minimize the activities with potential to increase damage during flood events. Firm enforcement of the regulations is required. Costs associated with potential regulatory plans include development of the comprehensive regulatory statues, continuous enforcement, and perhaps mitigation costs to sand and gravel operators for business revenue impact of the regulations.

Preparedness Plans. Preparedness planning functions are included in a composite plan to enable implementation of emergency activities during flood events. Emergency actions are those which minimize the potential for loss of life, mitigate flood losses by temporary measures, and reduce social disruption. The proposed enhancements, over present arrangements and plans, are designed to enable these functions to be conducted in a more comprehensive and effective manner. Considerations also are given to post-flood recovery and reoccupation and continuous plan management to ensure the viability of the plan over time.

Specific possible preparedness plan enhancements include basing emergency actions on water surface elevations instead of discharge, increased emphasis on implementing temporary flood loss reduction measures and development of more detailed plans for various preparedness planning components. The estimated implementation costs from Chapter V are about $450,000 first cost, which is amortized to be $110,000 per year. Annual benefits associated with the plans are estimated to be $390,000 as a lower bound (Hydrologic Engineering Center 1980a). The costs and benefits associated with implementing temporary flood proofing and content adjustments overlap (double count) to some extent for existing structures permanently flood proofed as recommended in the composite plan. Since the temporary flood proofing measures were assumed to be only partially effective and implemented for the full range of probability occurences (not limited to the 50-year protection level) calculation of benefits and costs would require additional assessments to determine benefit and cost estimates to the composite plan. The aspects of raising or evacuating personal contents would be valid whether or not temporary or permanent flood proofing actions were implemented.

Relationship Between Nonstructural Measures

The purpose of this section is to describe the general interrelationships of the measures of the potential composit nonstructural plan with respect to each other. The relationships are general and applicable to almost any composition of nonstructural measures implemented. The nonstructural measures are designed to modify the damage susceptibility of the threatened areas as opposed to modifying the flood event. The intent is to emphasize the need of each measure in order to minimize existing and future flood damage, social disruption and potential for loss of life. Implementation of one category of nonstructural measures, or determination that one aspect of the plan is not feasible, will have little impact on the need or feasibility of the other types of measures.

Flood proofing is designed to mitigate inundation damage to single family residential, multi-family residential and industrial structures. This aspect of the composite potential plan would uniformly protect selected groups of structures up to the 50-year flood levels, thereby effecting only a relatively small portion of the flood plain. The measure, by itself, would have no impact on future flood plain development or activities. It alone would not reduce the necessity of flood preparedness planning activities i.e., flood warning, temporary evacuation of flood plain occupants or social disruption of the communities in the study area. Sufficient warning would be required to implement closure of openings in the dikes. The measures applied to existing structures do not impact on the necessity to manage vital services (gas, electric, water, surveillance, etc.) during flood episodes. The measures would reduce the need for implementation of temporary flood mitigation measures (evacuation, removal or raising of personal property) for events up to the 50-year recurrence interval. The measures also would have little impact on the loss of life potential (if people are evacuated) in the study area.

Management of future flood plain development and activities does not impact on present conditions, damage potential, or social disruption. In addition, the events exceeding the preview of the regulations (100-year in the proposed plan), damage and social disruption to existing and future structures in place at the time of the event, may be catastrophic. If future development is raised to regulatory required elevations the associated damage would be less than if constructed at lower elevations. Regulation of sand and gravel mining activities, may significantly reduce damage to existing structures. These measures would have little direct impact on the potential to loss of life. The elimination of construction of structures in areas having a high flood hazard also would reduce the potential for loss of life.

Preparedness plans are specifically designed to reduce the potential for loss of life, mitigate flood losses via implementation of temporary measures, and manage and reduce social disruption. The effectiveness of preparedness plans is dependent upon several factors, primarily, the magnitude of the event and public and involved agency awareness (usually a function of the time since the last event) at the the time of the flood. As opposed to other measures, preparedness planning actions taken are event specific. Flood fighting efforts for areas that would be permanently flood proofed would be minimized for events up to the 50-year recurrence interval. Temporary evacuation and management of vital services are still required. Periodic updating of preparedness plans to incorporate emergency activities based on future development, also is required.

Permanent relocation negates the need for preparedness planning. Relocation would probably be limited to substandard housing which comprised only a small segment of flood threatened areas. Consequently relocation would have little effect on overall preparedness planning of the study area.

All aspects of preparedness plans are applicable to structures having flood insurance. Regulatory aspects concerning future development above existing 100-year flood levels will have little effect on preparedness plans. The long-term FEMA authorized flood plain regulatory objective of purchase of property subjected to repetitive damage or damage beyond repair (Federal Flood Insurance Act 1968) may eventually reduce significantly the damage potential and necessary emergency actions in the 100-year flood plain. If the implementation costs of these actions are borne by the subscriber, as is usually the case, the incentive for taking preventive actions may be significantly reduced.

Relationship With Structural Measures

Construction of flood control structures could eliminate the need for implementation of many nonstructural measures. Upstream flood control reservoirs would regulate flood flows throughout the study area, whereas channels and levees would control events for specific reaches.

A potential exception to the above is the use of nonstructural measures to provide an additional increment of protection over that provided by a structural project. The increment would have to be more cost effective and overall feasible that the increment associated with increasing the size of the physical works project. For example, it may be more cost effective to relocate or flood proof several structures to provide a 100-year uniform protection than to increase the size of a reservoir another 300,000 acre-feet to provide the same protection.

Preparedness plans for emergency operations associated with potential structural failure to existing or proposed upstream dams above a metropolitan area are mandated for projects constructed by the federal government (Hydrologic Engineerng Center 1980b). The probability of such occurrence is rare, but the possibility does exist and local concern has surfaced as, evidenced by media reporting of possible failure to Stewart Mountain Dam during the February 1980 flood. Formal plans should be developed for these contingencies for non-Corps dams.

Flood plain regulations are applicable with structural projects in order to minimize encroachment into flood plain area after a project is in place. If not enforced, encroachment may result in greater flood hazards risks and damage potential than preproject conditions. This condition may also result in altered operation of reservoirs to minimize the potential risk and damage, resulting in less efficiencies in other project purposes such as water supply or hydroelectric power. Flood plain regulations involving gravel mining operations and land fills would still be required to assure damage would not occur to existing bridges and to local protection physical works measures (levees and channels).

CHAPTER VII

ASSESSMENT OF NONSTRUCTURAL INVESTIGATION

Analyses of the implementation feasibility of a comprehensive set of nonstructural measures have been performed and documented herein. The evaluations included: measures designed to modify the damage susceptability of existing structures; measures designed to manage future flood plain development and other activities; and enhancement components to present flood preparedness arrangements and plans.

The investigation determined the need for a composite nonstructural plan consisting of elements of the three categories of nonstructural measure. No single measure provides potential protection to existing structures, regulates flood plain activities and performs emergency actions and services during flood events. Regulatory and preparedness planning activities are most viable in concert with implementation of structural flood control projects.

Recommended nonstructural measures include: earthen dikes around selected groups of structures to the 50-year or less protection level; comprehensive flood plain regulations for future development, sanitary land fills, and gravel mining operatons; and enhanced preparedness planning arrangements and documented detailed plans of flood related actions. Implementation of the measures described will not significantly reduce the damage to existing structures and the social disruption associated with large flood events. The plan will, however, reduce damage related to smaller events (less than 50-year), minimize the risk to loss of life, and control the social disruption in the area.

CHAPTER VIII

LIMITED STRUCTURAL MEASURES

Up to this point, the CAWCS Stage III nonstructural study involved the examination of standard nonstructural measures for protection of individual buildings. In order to determine the feasibility of protecting groups of structures without the construction of large-scale levees or other works, the Stage III nonstrucutral analysis investigated limited structural measures. This investigation consisted of a hydraulic analysis of limited levees to protect groups of buildings along the Salt River through metropolitan Phoenix where the potential exists for significant damage.

Since the inundation of bridges across the Salt River accounts for substantial transportation losses, as well as severe social dislocation, an evaluation also was made of the capability of the Central Avenue, I-10 Freeway, and Mill Avenue bridges to pass the Standard Project Flood.

Limited Levees

Locations, alignments, and sizes for limited levees were identified along the Salt River from about 3000 feet upstream from Hayden Road downstream to 43rd Avenue.

The first alternative plan (A levees) is designed as a substitute for floodproofing individual structures and small groups of structures. The A levees are designed to provide protection against a flood of 150,000 cfs.

The second plan (B levees) is designed to protect areas that have the greatest potential for flooding or where major breakouts of flow occur. The B levees are designed to provide protection against 150,000 cfs (65-year flood) and 200,000 cfs (100-year flood) flows.

Hydraulic Analysis

All water surface profiles were computed using the HEC-2 computer program. Results of the hydraulic analysis are presented in Plate VIII-1 for A levees and in Plate VIII-2 for B levees. The design discharge for A levees was limited to only one discharge, 150,000 cfs. Water surface profiles corresponding to this discharge for A levees are shown in Plate VIII-1. The analysis for B levees included design discharges of 50,000, 100,000, 150,000 and 200,000 cfs. Because the Salt River through the study reach can pass up to 100,000 cfs with only minor flood damges, only profiles corresponding to 150,000 and 200,000 cfs were computed for B. levees. These are shown in Plate VIII-2.

Results of the study showed that four A levees and four B levees are required to protect the areas under consideraton. In the analysis it was assumed that the proposed levees for the Sky Harbor Airport

Channelization Project will be completed by the City of Phoenix prior to the construction of the limited levees, and that levees A and B can be tied into the proposed airport levees.

The floodplain geometry and ground topography used in this study are consistent with the 1977 topographic maps. It is believed that the bottom of the Salt River has degraded considerably since that time. This is the result of several factors including the extraction of riverbed material by sand and gravel operators, the occurrence of large floods in 1978 to 1980, the reduction in sediment supply by upstream reservoirs, and the constriction of flow by bridges and levees. Because the available information on existing topography is insufficient, the extent of this bottom degradation cannot be estimated at this time. Since the actual riverbed is assumed to be lower than the one used in this study, the water surface profiles and hence the levee heights are computed conservatively. This means that the actual conveyance of the Salt River in the Phoenix area is probably more than that which was estimated using the 1977 topographic information.

Design and Cost

Plates VIII-1 and VIII-2 show the preliminary typical sections for both of the two alternative limited levee plans. The A levee conforms to the typical section except for a portion of the tie-in levee which is a simple earth dike without revetment and is keyed into the ground by a foot-deep excavation. In addition, only a two-foot freeboard is assumed for this tie-in portion of the A levees. Although FEMA mandates a height of at least 3 feet, this criterion was not adhered to because this portion of the tie-in levee is not subject to critical shear stresses or water surface fluctuations which normally exist along the river channel.

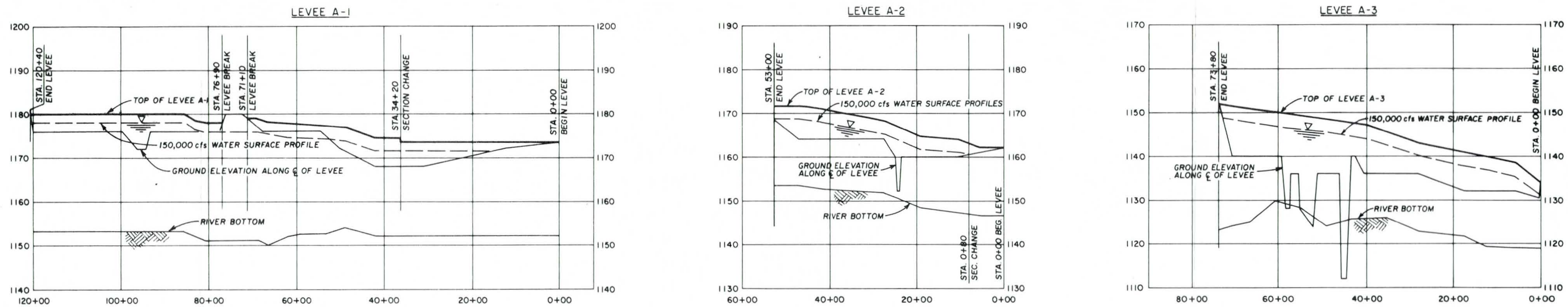
Additional cost criteria and design assumptions are:

1. An interior drainage system is provided to allow a 100-year flow across the B levees and a 50-year flow across the A levees to enter the dry river. When the river is flowing at design capacity, the local 10-year event is accomodated. This will require the local flows be pumped over the levees, with the exception of flow from major tributaries to which tie-in levees will be built.

2. A compaction and loss factor of 1.15 is used to compute fill quantities.

3. To maintain the integrity of the levees, restrictions would be placed on gravel mining immediately adjacent to the back (land) side of the levees.

Table VIII-1 summarizes the costs and benefits for each A and B levee. As can be seen in this table, none of the limited levee alternatives are economically justified because none have benefit/ cost ratio equal to or greater than 1.0.



PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

VERT. SCALE 10 0 10 20 FEET

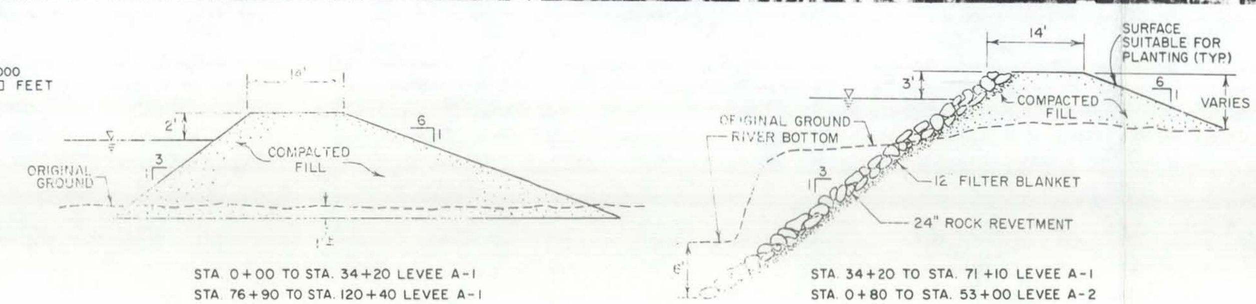
NOTE: SUBSTITUTE LIMITED LEVEES A-1, A-2 AND A-3 ARE DESIGNED TO PROTECT SMALL AREAS.

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

PLAN

SCALE 1000 0 1000 2000 FEET

PLATE VIII-1



STA. 0+00 TO STA. 34+20 LEVEE A-1
STA. 76+90 TO STA. 120+40 LEVEE A-1
STA. 0+00 TO STA. 0+80 LEVEE A-2

STA. 34+20 TO STA. 71+10 LEVEE A-1
STA. 0+80 TO STA. 53+00 LEVEE A-2
STA. 0+00 TO STA. 73+80 LEVEE A-3

TYPICAL LEVEE SECTIONS

N.T.S.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

CAMP DRESSER & McKEE INC.
710 South Broadway
Walnut Creek, California 94596

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: M. J. W.
DRAWN BY: H. K. E.
CHECKED BY: H. M. N.

CENTRAL ARIZONA WATER CONTROL STUDY
STRUCTURAL FLOOD CONTROL ALTERNATIVES

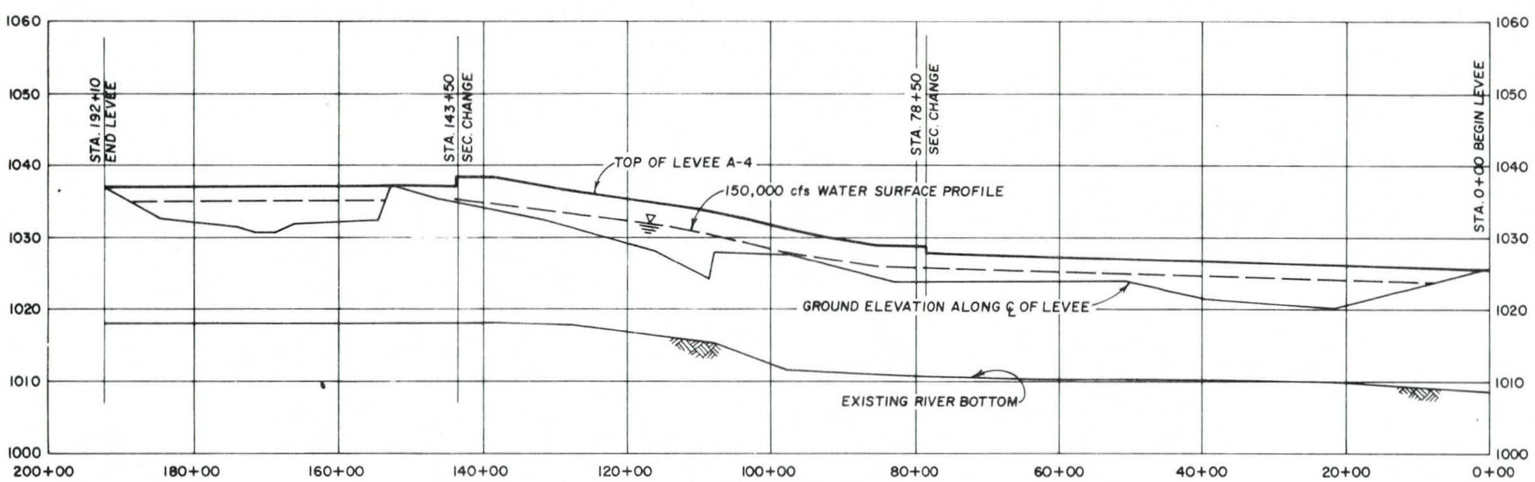
SUBSTITUTE LIMITED LEVEES ALONG SALT RIVER

LEVEES A-1, A-2 AND A-3
PLAN, PROFILE AND SECTION DETAILS
DESIGN Q = 150,000 cfs

SUBMITTED BY: DATE APPROVED: SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET 1 OF 2

CHIEF, BRANCH

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

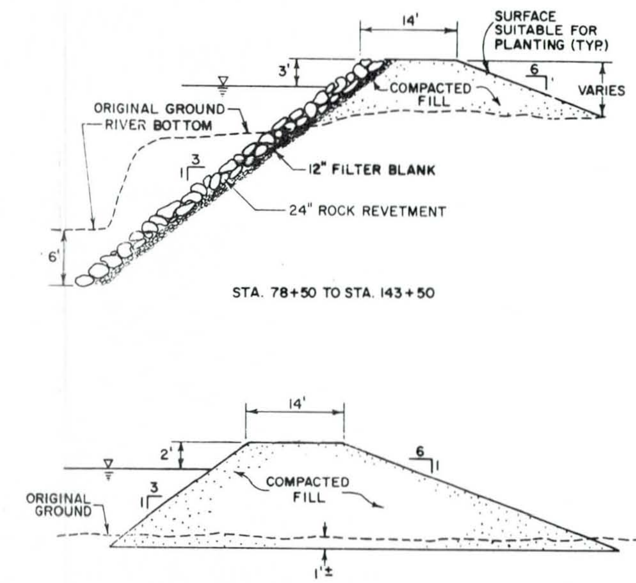


PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

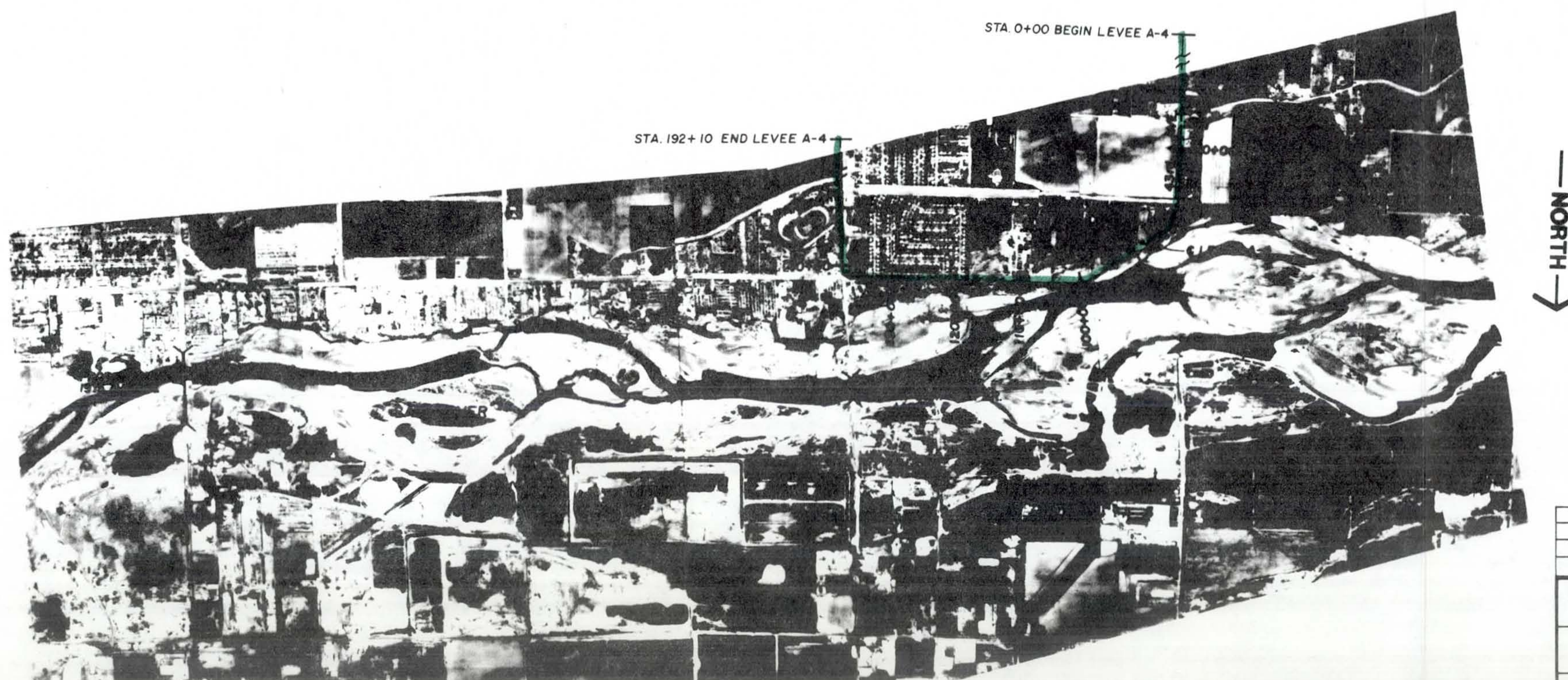
VERT. SCALE 10 0 10 20 FEET

NOTE: SUBSTITUTE LIMITED LEVEE A-4 IS DESIGNED TO PROTECT A SMALL AREA



TYPICAL LEVEE SECTIONS

N.T.S.



PLAN

SCALE 1000 0 1000 2000 FEET

PLATE VIII-1

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

CAMP DRESSER & McKEE INC.
710 South Broadway
Walnut Creek, California 94596

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: M. J. W.

DRAWN BY: D. A. P.

CHECKED BY: H. M. N.

CENTRAL ARIZONA WATER CONTROL STUDY
STRUCTURAL FLOOD CONTROL ALTERNATIVES

SUBSTITUTE LIMITED LEVEES ALONG SALT RIVER

LEVEE A-4
PLAN, PROFILE AND SECTION DETAILS
DESIGN Q = 150,000 cfs

SUBMITTED BY:
CHIEF, BRANCH

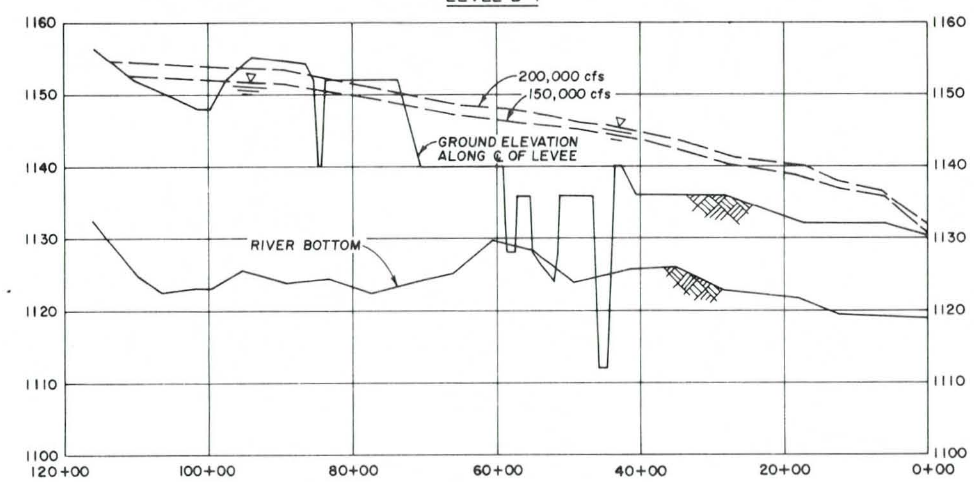
DATE APPROVED:

SPEC. NO. DACW 09-____ B-____

DISTRICT FILE NO.

SHEET 2 OF 2

LEVEE B-1



PROFILE

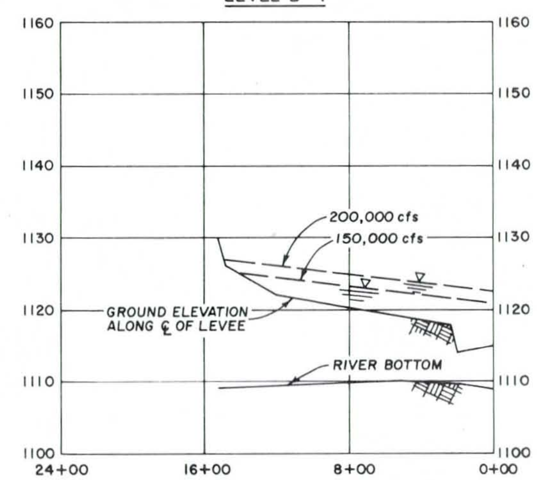
HORIZ. SCALE 1000 0 1000 2000 FEET

VERT. SCALE 10 0 10 20 FEET

NOTES: 1. FOR BOTH B-1 AND B-4 LEVEES TOP OF LEVEE SHALL BE 3 FT. ABOVE THE INDICATED WATER SURFACE PROFILE.

2. LIMITED LEVEES B-1 AND B-4 ARE DESIGNED TO PROTECT LARGE AREAS FROM MAJOR BREAKOUTS.

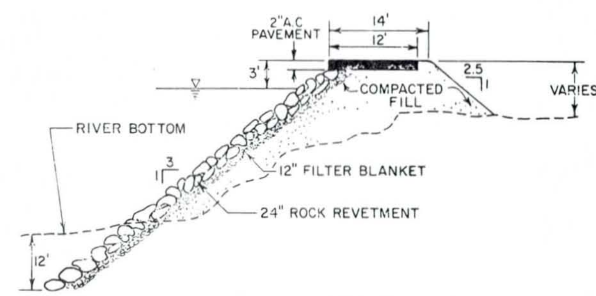
LEVEE B-4



PROFILE

HORIZ. SCALE 400 0 400 800 FEET

VERT. SCALE 10 0 10 20 FEET



TYPICAL LEVEE SECTION

N.T.S.

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

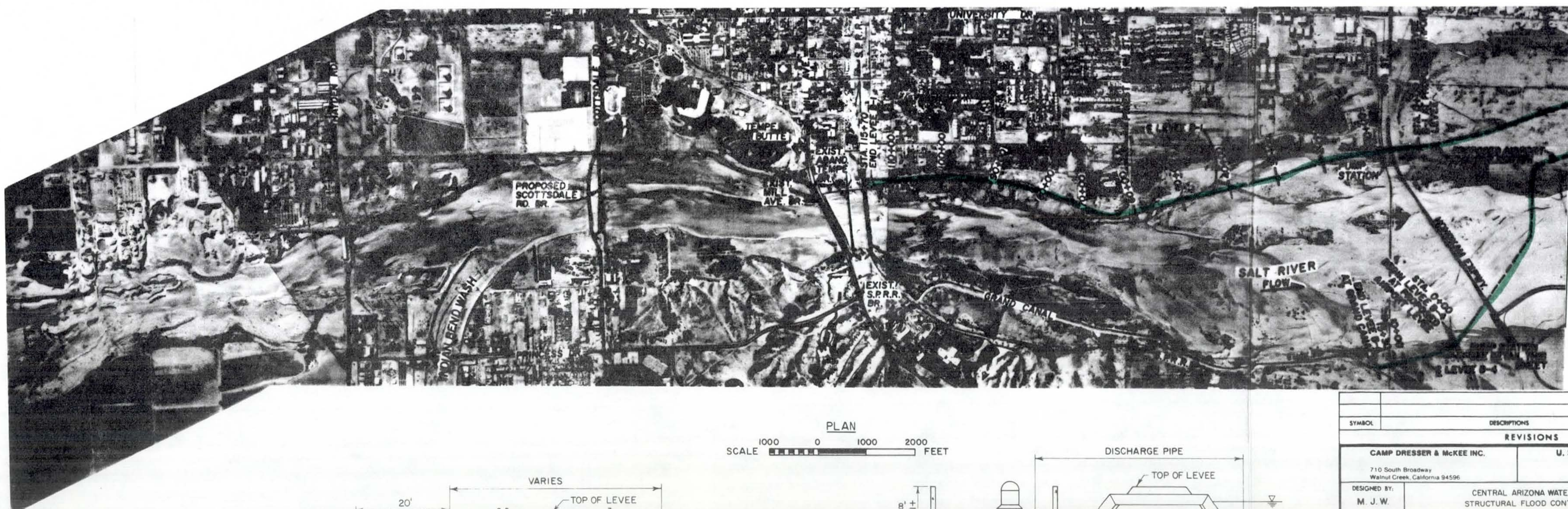
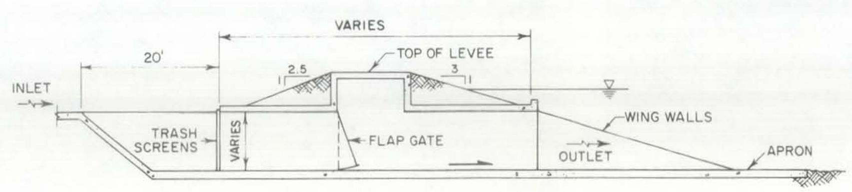


PLATE VIII-2

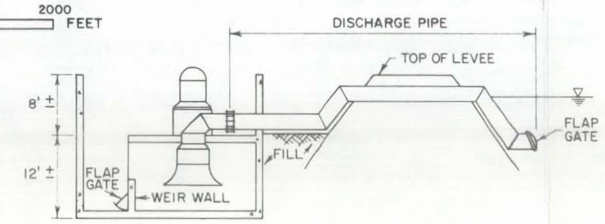
PLAN

SCALE 1000 0 1000 2000 FEET



TYPICAL SECTION FLOOD GATE

N.T.S.



TYPICAL SECTION PUMP STATION

N.T.S.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

CAMP DRESSER & McKEE INC.
710 South Broadway
Walnut Creek, California 94596

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: M. J. W.

DRAWN BY: D. A. P.

CHECKED BY: H. M. N.

CENTRAL ARIZONA WATER CONTROL STUDY
STRUCTURAL FLOOD CONTROL ALTERNATIVES

LIMITED LEVEES ALONG SALT RIVER

LEVEES B-1 AND B-4
PLAN, PROFILE AND SECTION DETAILS
DESIGN Q = 150,000 AND 200,000 cfs

SUBMITTED BY:

DATE APPROVED:

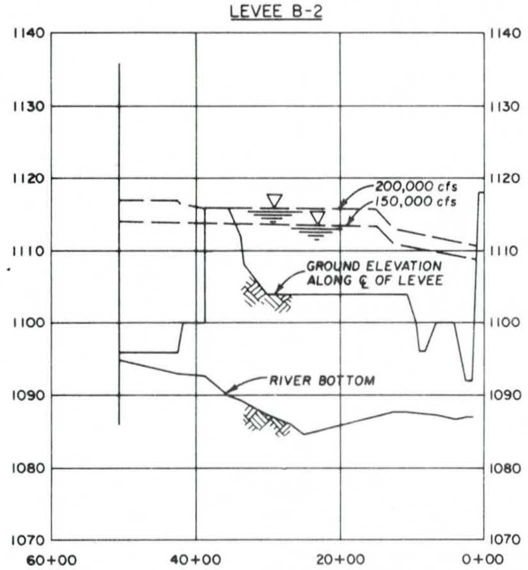
SPEC. NO. DACW 09- ____ B- ____

DISTRICT FILE NO.

SHEET 1 OF 2

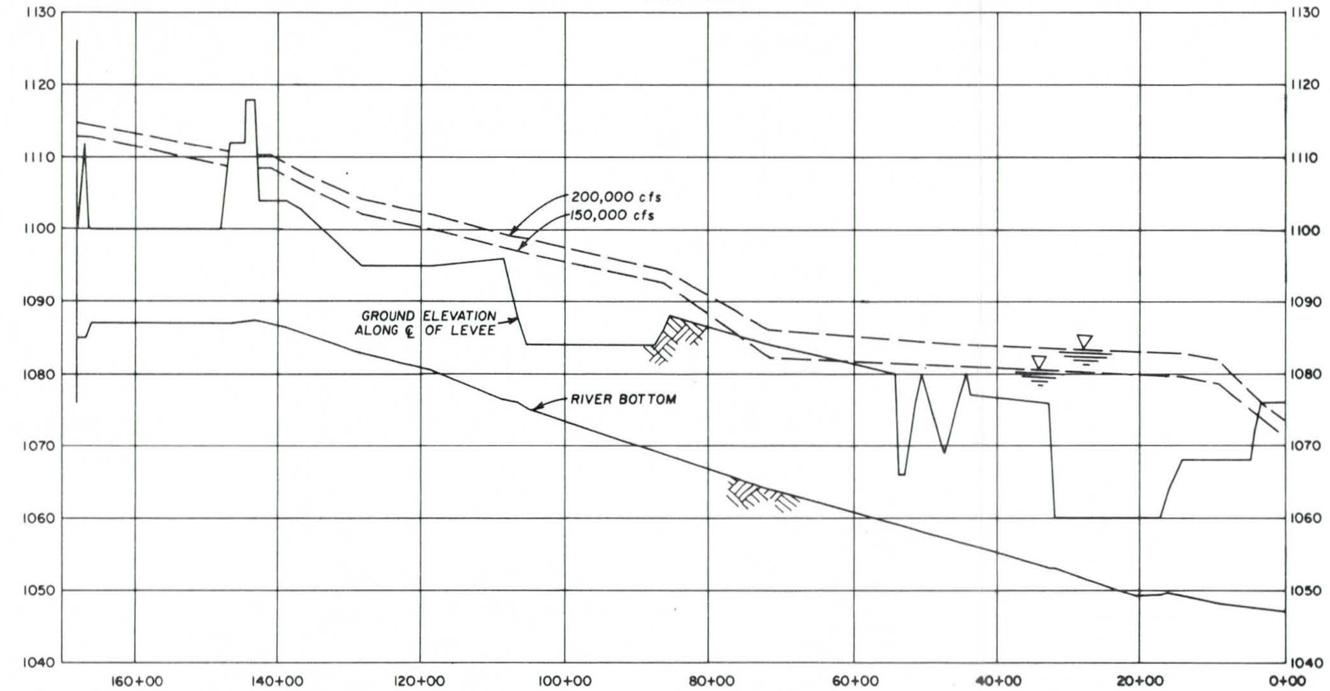
CHIEF, BRANCH

LEVEE B-2



PROFILE

LEVEE B-3

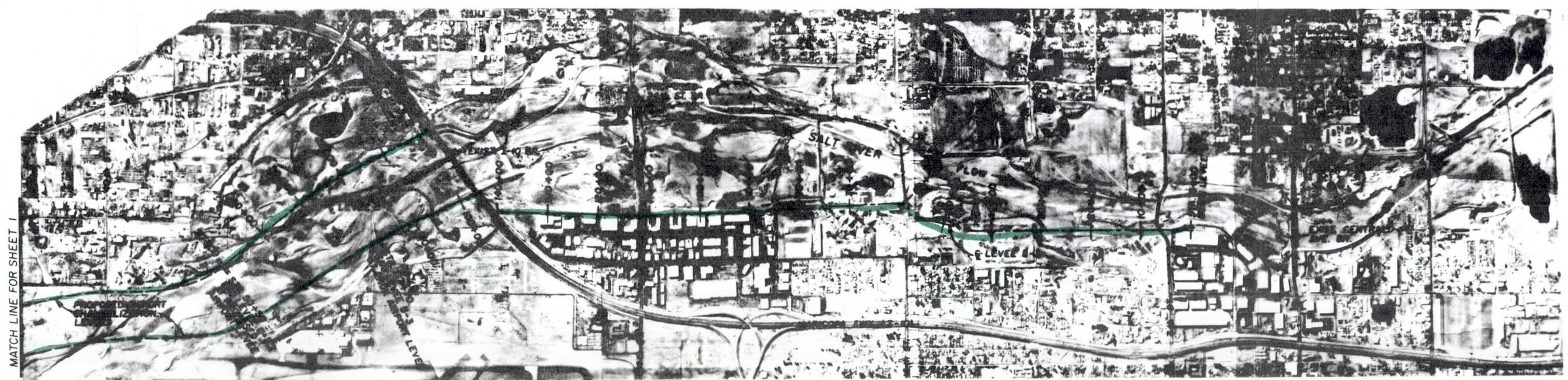


PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

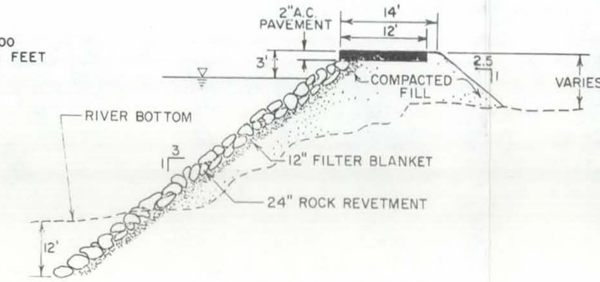
VERT. SCALE 10 0 10 20 FEET

NOTES:
1. FOR BOTH B-2 AND B-3 LEVEES TOP OF LEVEE SHALL BE 3 FT. ABOVE THE INDICATED WATER SURFACE PROFILE
2. LIMITED LEVEES B-2 AND B-3 ARE DESIGNED TO PROTECT LARGE AREAS FROM MAJOR BREAKOUTS



PLAN

SCALE 1000 0 1000 2000 FEET



TYPICAL LEVEE SECTION

N. T. S.

PLATE VIII-2

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

CAMP DRESSER & McKEE INC. 710 South Broadway Walnut Creek, California 94596	U. S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS
DESIGNED BY: M. J. W. DRAWN BY: H. K. E. CHECKED BY: H. M. N.	CENTRAL ARIZONA WATER CONTROL STUDY STRUCTURAL FLOOD CONTROL ALTERNATIVES **LIMITED LEVEES ALONG SALT RIVER** LEVEES B-2 AND B-3 PLAN, PROFILE AND SECTION DETAILS DESIGN Q = 150,000 AND 200,000 cfs
SUBMITTED BY: CHIEF, BRANCH DATE APPROVED:	SPEC. NO. DACW09-____ B-____ DISTRICT FILE NO. SHEET 2 OF 2

TABLE VIII - 1

LIMITED LEVEES BENEFITS AND COSTS

Levee A1 - South bank of the Salt River between Pima and Hayden Roads - Design 150,000 cfs

a.	Average annual damages without levee	- $71,000
b.	Average annual damages prevented	- $17,800
c.	Total cost for levee	- $4,000,000
d.	Annual cost @7 3/8% and 50 years	- $303,600
	Annual maintenance cost	- $22,000
e.	Total annual cost	- $325,600
f.	Benefit/cost ratio	- .05

Levee A2 - Vicinity of Indian Bend Wash and the Salt River - Design 150,000 cfs

a.	Average annual damages without levee	- $71,000
b.	Average annual damages prevented	- $17,800
c.	Total cost for levee	- $3,000,000
d.	Annual cost @7 3/8% and 50 years	- $227,700
	Annual maintenance cost	- $18,000
e.	Total annual cost	- $245,700
f.	Benefit/cost ratio	- .07

Levee A3 - South bank of the Salt River between Priest Road and 48th Street - Design 150,000 cfs

a.	Average annual damages without levee	- $426,300
b.	Average annual damages prevented	- $138,900
c.	Total cost for levee	- $6,900,000
d.	Annual cost @7 3/8% and 50 years	- $523,800
	Annual maintenance cost	- $49,000
e.	Total annual cost	- $572,800
f.	Benefit/cost ratio	- .24

Levee A4 - South bank of the Salt River between 35th and 43rd Avenues - Design 150,000 cfs

a.	Average annual damages without levee	- $103,500
b.	Average annual damages prevented	- $46,000
c.	Total cost for levee	- $8,300,000
d.	Annual cost @7 3/8% and 50 years	- $630,000
	Annual maintenance cost	- $60,000
e.	Total annual cost	- $691,000
f.	Benefit/cost ratio	- .07

BREAKOUT LEVEES - 150,000 cfs and 200,000 cfs

Levees B-1 & B-2 - South bank of the Salt River from Mill Avenue to I-10 - Design 150,000 cfs

a. Average annual damages without levee - $426,300
b. Average annual damages prevented - $138,000
c. Total cost for levee - $19,600,000
d. Annual cost @7 3/8% and 100 years - $1,450,000
   Annual maintenance cost - $135,000
e. Total annual cost - $1,585,000
f. Benefit/cost ratio - .09

Levees B-3 & B-4 - North bank of the Salt River from 48th to 7th Streets - Design 150,000 cfs

a. Average annual damages without levee - $1,082,500
b. Average annual damages prevented - $78,900
c. Total cost for levee - $27,700,000
d. Annual cost @7 3/8% and 100 years - $2,044,500
   Annual maintenance cost - $212,000
e. Total annual cost - $2,256,500
f. Benefit/cost ratio - .03

Levees B-1 & B-2 - South bank of the Salt River from Mill Avenue to I-10 - Design 200,000 cfs

a. Average annual damages without levee - $426,000
b. Average annual damages prevented - $195,000
c. Total cost for levee - $21,400,000
d. Annual cost @7 3/8% and 100 years - $1,580,000
   Annual maintenance cost - $145,000
e. Total annual cost - $1,725,000
f. Benefit/cost ratio - .11

Levees B-3 & B-4 - North bank of the Salt River from 48th to 7th Streets - Design 200,000 cfs

a. Average annual damages without levee - $1,082,500
b. Average annual damages prevented - $170,800
c. Total cost for levee - $28,600,000
d. Annual cost @7 3/8% and 100 years - $2,111,000
   Annual maintenance cost - $217,000
e. Total annual cost - $2,328,000
f. Benefit/cost ratio - .07

TABLE VIII - 1 (cont.)

SPF LEVEE - North bank of the Salt River from 48th Street to I-10 - Design 290,000 cfs

a.	Average annual damages without levee	- $570,200
b.	Average annual damages prevented	- $152,500
c.	Total cost for levee	- $17,000,000
d.	Annual cost @7 3/8% and 100 years	- $1,255,000
	Annual maintenance cost	- $111,000
e.	Total annual cost	- $1,366,000
f.	Benefit/cost ratio	- .11

Standard Project Flood Bridges

The hydraulic performance of the Central Avenue, I-10 Freeway, and Mill Avenue bridges was examined under Standard Project Flood (SPF) conditions. The SPF is assumed to be 290,000 cfs.

The ability of one or more of the above-mentioned bridges to withstand the SPF could reduce substantially the social, health, and safety impacts of such a flood.

Hydraulic Analysis

The hydraulic analysis of the Salt River at Central Avenue and Mill Avenue used the same bridge representation and upstream/downstream floodplain geometry as were used in the CAWCS report "Stage II, Channelization Elements Study" prepared by the firm of Camp Dresser & McKee. The encroachments used to simulate the levees upstream and downstream of the bridges in this report were removed or replaced as necessary to develop a HEC-2 geometric model for a pre-project condition. This pre-project model embodied the same assumptions and design criteria as did the model in the Stage II channelization report. Water surface profiles through the Central Avenue and Mill Avenue bridges were developed as illustrated in Plate VIII-3. The analysis shows that both bridges are capable of passing the Standard Project Flood and remaining open to traffic.

The I-10 Freeway bridge and its adjacent reach recently underwent modifications and have therefore the most current geometry, drop structure plans and bridge plans available. These plans are dated June 1980 by the Arizona Department of Transportation. The water surface profile through the I-10 bridge is shown in Plate VIII-3. The hydraulic analysis revealed that the I-10 bridge is capable of passing the SPF.

The results of the hydraulic analysis, however, also indicated that during the SPF, a breakout occurs upstream of I-10 along the north bank of the river in the vicinity of 32nd Street. A small portion of this off stream flow re-enters the river through freeway underpasses, while most of it (94%) continues to flow westward along the north side of the freeway. After crossing the I-17 freeway and a number of major traffic arteries, this off-stream flow re-enters the Salt River in the vicinity of 27th Avenue. This breakout would effectively prevent the use of the I-10 Freeway bridge and Central Avenue bridge during the SPF, even though the bridge itself would not be inundated.

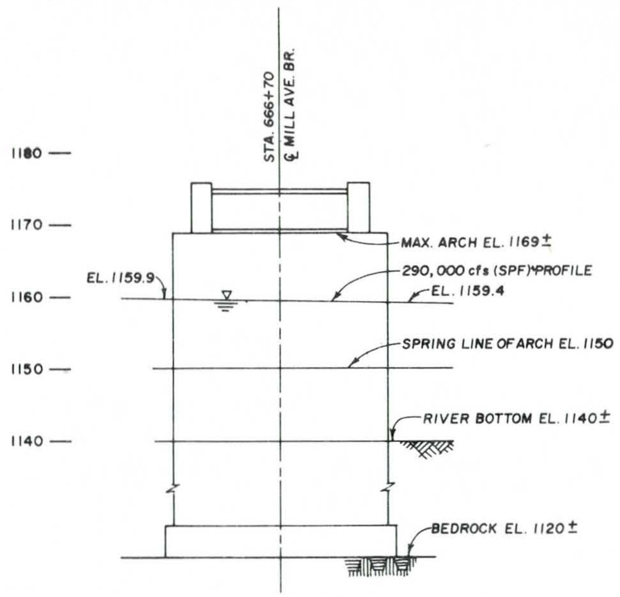
In order to maintain the flow of traffic over the freeway and major surface streets during the occurrence of a SPF, two viable solutions are available. The first solution is to modify the City of Phoenix Sky Harbor Airport Channelization Project to contain the SPF at 32nd Street. The second solution is to construct a new levee on the north side of the Sky Harbor Airport Channel for the prevention of SPF breakout at this location. Because the design of the Airport Channel does not conform to the design criteria established by the Corps of Engineers, the second solution is preferred. The plan and profile of this levee is shown in Plate VIII-3, and is designated levee C. The cost of the levee is estimated at $17 million. The benefit/cost summary for this feature is presented in Table VIII-1.

Conclusions

1. The Central Avenue, I-10 Freeway, and Mill Avenue bridges are capable of passing the Standard Project Flood of 290,000 cfs without being inundated.

2. A major breakout occurs upstream of the I-10 Freeway bridge on the north side of the river during the SPF event. To maintain the flow of traffic on the freeway and major surface streets during the SPF event, a levee on the north side of the river is required. The estimated cost for this levee is $17 million.

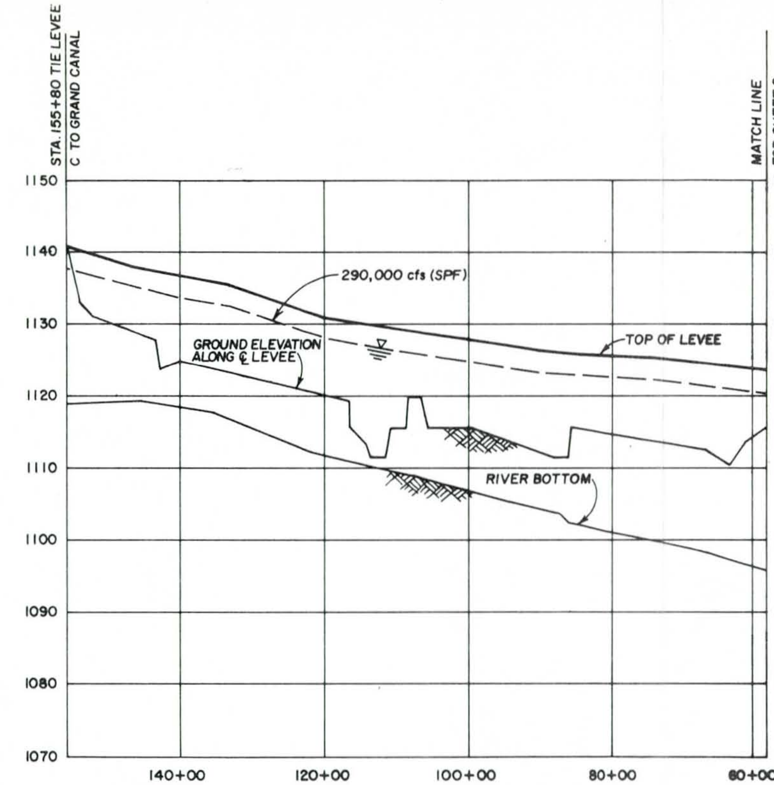
3. Further studies would be required to determine scour and structural integrity of the bridges during and following the occurence of a SPF.



PROFILE THROUGH MILL AVE. BRIDGE

HORIZ. SCALE 20 0 20 40 FEET

VERT. SCALE 10 0 10 20 FEET

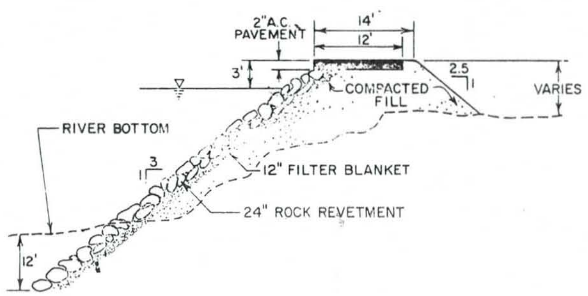


PROFILE

HORIZ. SCALE 1000 0 1000 2000 FEET

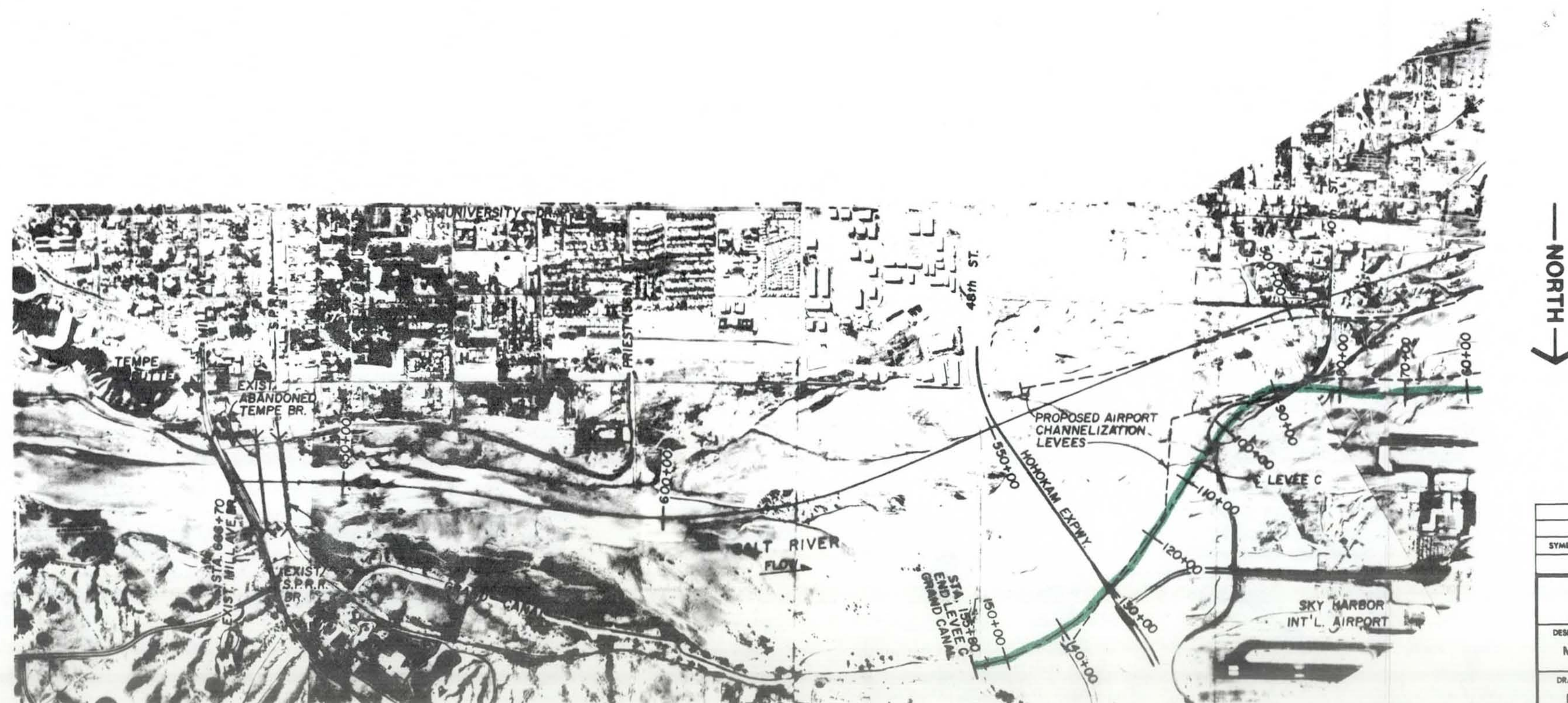
VERT. SCALE 10 0 10 20 FEET

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



TYPICAL LEVEE SECTION
N. T. S.

NOTE: LEVEE C IS DESIGNED TO PREVENT INUNDATION OF I-10 FWY., CENTRAL AVE. AND OTHER MAJOR ARTERIES LOCATED IN THE NORTHERN FLOOD-PLAIN FROM SPF.



PLAN

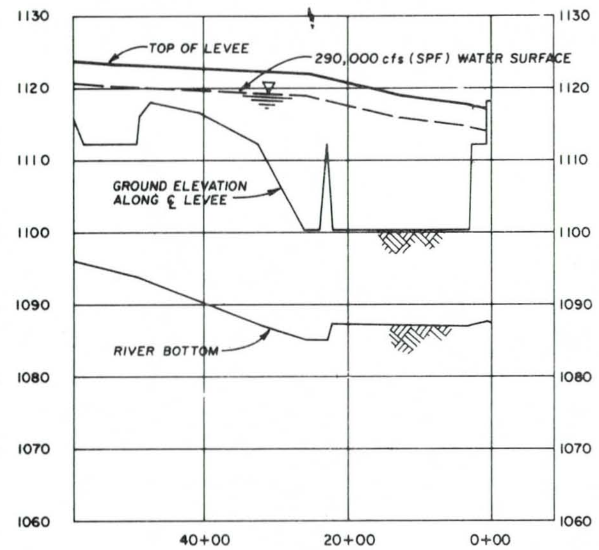
SCALE 1000 0 1000 2000 FEET

PLATE VIII-3

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
REVISIONS			

CAMP DRESSER & McKEE INC. 710 South Broadway Walnut Creek, California 94596	U. S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS
DESIGNED BY: M. J. W.	CENTRAL ARIZONA WATER CONTROL STUDY STRUCTURAL FLOOD CONTROL ALTERNATIVES
DRAWN BY: D. A. P.	SPF BRIDGES OVER SALT RIVER
CHECKED BY: H. M. N.	MILL AVE. BRIDGE AND LEVEE C PLAN AND PROFILE - HYDRAULIC DESIGN - 290,000 cfs
SUBMITTED BY: CHIEF, BRANCH — DATE APPROVED:	SPEC. NO. DACW 09-___ B-___ DISTRICT FILE NO. — SHEET 1 OF 2

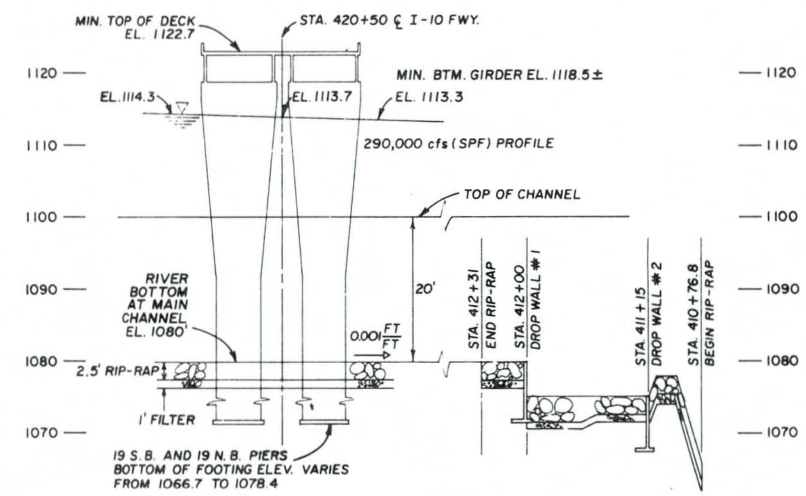
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



PROFILE LEVEE C

HORIZ. SCALE 1000 0 1000 2000 FEET

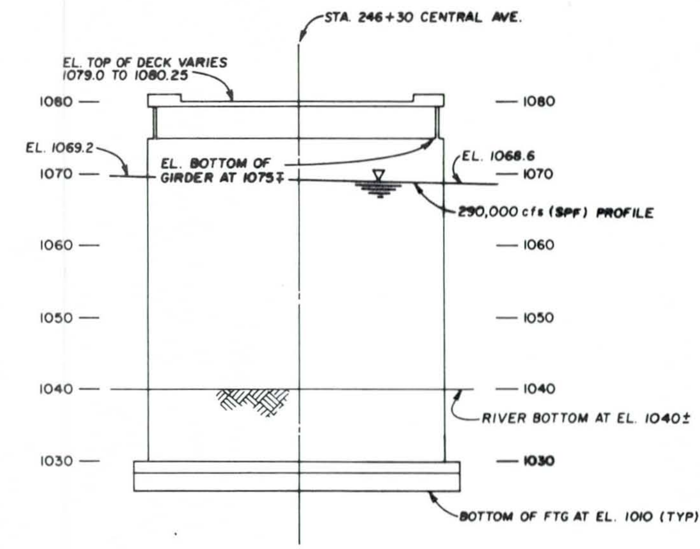
VERT. SCALE 10 0 10 20 FEET



PROFILE THROUGH I-10 FWY. BRIDGE AND DROP STRUCTURE

HORIZ. SCALE 50 0 50 100 FEET

VERT. SCALE 10 0 10 20 FEET

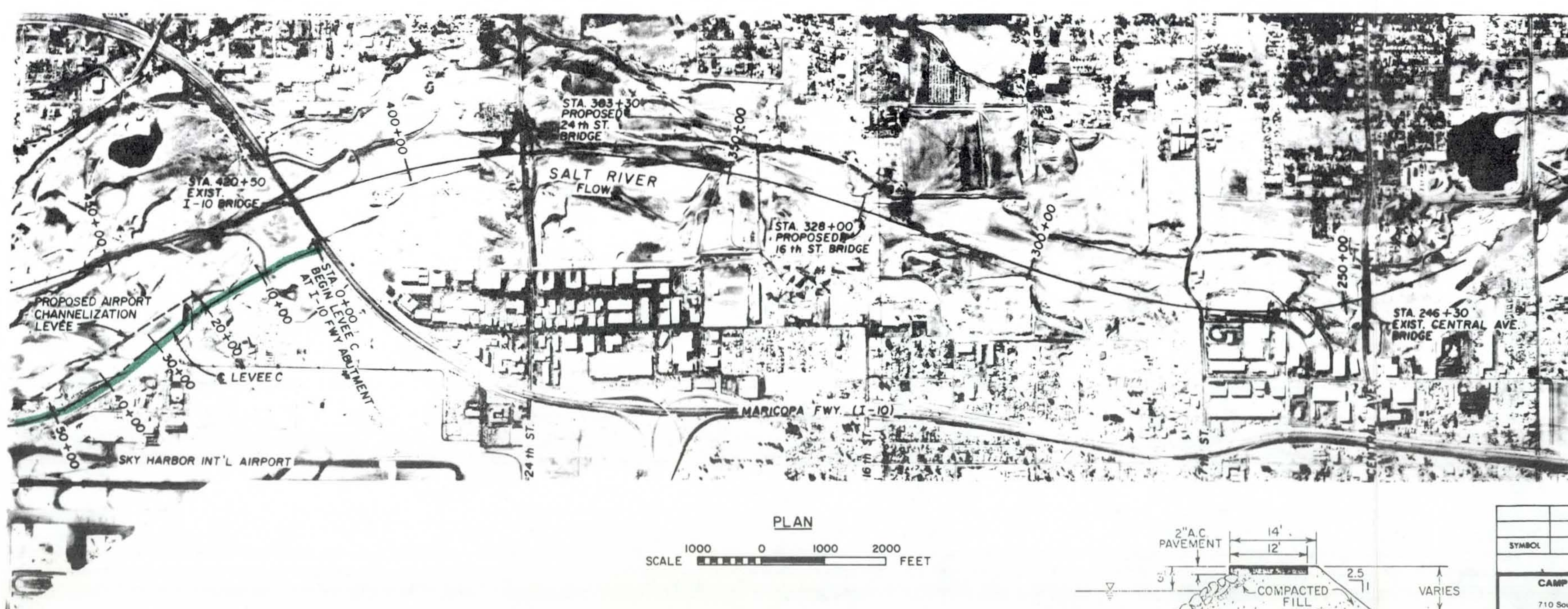


PROFILE THROUGH CENTRAL AVE. BRIDGE

HORIZ. SCALE 20 0 20 40 FEET

VERT. SCALE 10 0 10 20 FEET

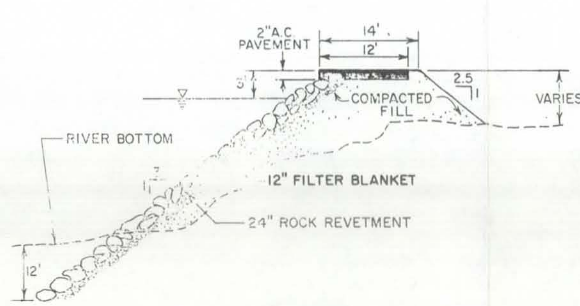
NOTE: LEVEE C IS DESIGNED TO PREVENT INUNDATION OF I-10 FWY., CENTRAL AVE. AND OTHER MAJOR ARTERIES LOCATED IN THE NORTHERN FLOOD-PLAIN FROM SPF.



PLAN

SCALE 1000 0 1000 2000 FEET

PLATE VIII-3



TYPICAL LEVEE SECTION

N. T. S.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

CAMP DRESSER & McKEE INC. 710 South Broadway Walnut Creek, California 94596	U. S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS
DESIGNED BY: M. J. W.	CENTRAL ARIZONA WATER CONTROL STUDY STRUCTURAL FLOOD CONTROL ALTERNATIVES
DRAWN BY: H. K. E.	SPF BRIDGES OVER SALT RIVER
CHECKED BY: H. M. N.	I-10 FWY. AND CENTRAL AVE. BRIDGES AND LEVEE C PLAN AND PROFILE - HYDRAULIC DESIGN-290,000 cfs
SUBMITTED BY: DATE APPROVED:	SPEC. NO. DACW 09-____ B-____ DISTRICT FILE NO. — SHEET 2 OF 2
CHIEF, BRANCH	

CHAPTER IX

SALT RIVER PROJECT REREGULATION

During Stage II of the CAWCS, reregulation of the operation of Salt River Project (SRP) dams was considered for flood control. By the beginning of Stage III, however, the issue of the safety of the SRP structures became a primary concern of the CAWCS as the result of revisions in the Bureau's Inflow Design Flood (IDF) and maximum credible earthquake value. Because of the dam safety concerns, it was necessary to reanalyze SRP reregulation in Stage III based on the most likely Safety of Dams solution. This dam safety solution was determined to be construction of Cliff Dam and a New Roosevelt Dam to suppress the IDF.

The first approach in this Stage III planning effort was to determine the greatest reduction of the Standard Project Flood (SPF) that could be obtained assuming Cliff and New Roosevelt to be constructed for dam safety and using only the SRP replacement conservation space at Cliff, Bartlett, and New Roosevelt for flood control (encroachment into space alotted for dam safety was not allowed). Larger outlets at these structures would be added if required. The analysis resulted in the control of the SPF to 90,000 cfs at the confluence of the Salt and Verde Rivers. Storage required at Cliff was determined to be 126,000 acre-feet with outlets at Cliff of 95,000 cfs. Storage required at Bartlett was determined to be 178,500 acre-feet with outlets of 70,000 cfs. Storage required at New Roosevelt was determined to be 494,000 acre-feet with outlets of 30,000 cfs. The following table illustrates the reduction in frequency flow values using the first approach to Stage III SRP reregulation:

Approach I

Frequency Values	Existing (cfs)	SPF to 90,000 cfs (cfs)
500 year	360,000	180,000
200 year	290,000	138,000
100 year	245,000	90,000
50 year	175,000	90,000
20 year	141,000	90,000
10 year	102,000	90,000 (8*)
5 year	44,500	44,500

* Actual frequency value

The second approach to SRP reregulation taken during Stage III was to determine the storage and outlet requirements for reduction of the SPF to 150,000 cfs at the confluence. This analysis indicated that the storage required at Cliff would be 126,000 acre-feet, with outlets of 95,000 cfs. Storage required at Bartlett would be 43,000 acre-feet, with outlets of 75,000 cfs, and storage at New Roosevelt would be 125,000 acre-feet with outlets of 50,000 cfs. The following table presents the reduction in frequency flow values through the second approach to Stage III SRP re-regulation:

Approach II

Frequency Values	Existing (cfs)	SPF to 150,000 cfs (cfs)
500 year	360,000	250,000
200 year	290,000	220,000
100 year	245,000	150,000 (111*)
50 year	175,000	150,000
20 year	141,000	150,000 (25*)
10 year	102,000	102,000
5 year	44,500	44,500

* Actual frequency value

The final approach taken during Stage III was to calculate the amount of reduction to all flows achieved by Cliff and New Roosevelt operating only in a dam safety mode, that is the suppression of the entire range of inflows including the IDF. For dam safety purposes, Cliff would have an SRP replacement storage of 144,000 acre-feet and storage for suppression of the IDF of 1,022,000 acre-feet, with outlets of 37,500 cfs and a spillway capacity of 148,500 cfs. The SRP replacement and sediment storage at New Roosevelt would be 1,622,00 acre-feet and storage for suppression of the IDF of 944,000 acre-feet. The spillway capacity at New Roosevelt would be 92,000 cfs. It should be noted that in this analysis, the storage space is not dedicated for flood control. The reduction in flows is provided by operating for dam safety only. The following table presents the resultant reduction in frequency flows measured at the confluence:

Approach III

Frequency Values	Existing (cfs)	SOD Only (cfs)
500 year	360,000	175,000
200 year	290,000	165,000
100 year	245,000	160,000
50 year	175,000	150,000
20 year	141,000	130,000
10 year	102,000	90,000
5 year	44,500	40,000

CONCLUSION

It was determined that operating for dam safety only met the objectives of providing an intermediate level of flood control with limited construction and without the institutional problems and water loss associated with dedicating flood control space in existing Salt River Project dams.

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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APPENDIX B

NONSTRUCTURAL FLOOD DAMAGE EVALUATION PROCEDURES

APPENDIX B

NONSTRUCTURAL FLOOD DAMAGE EVALUATION PROCEDURES

General Approach

Objectives of the flood damage analyses were to develop damage potential information and perform systematic assessments of nonstructural flood mitigation measures. Analyses focused on flood mitigation measures associated with reducing damage of residential, commercial and industrial structures. Also, information sets depicting the number of structures at or below specified elevations which may be used to estimate the potential number of structures inundated by specific events, number of people evacuated, etc.

Damage evaluation procedures made use of automatic information retrieval and processing of geographic information sets (spatial gridded data) from a grid cell bank to develop elevation-damage relationships by category and reaches (Davis 1978). Land use definition, topography, damage reach delineations and reference flood elevations were obtained for the Salt and Gila River flood plains of the study area from cartographic sources. These data were encoded into a gridded format, maintaining proper legending, using procedures previously developed (Hydrologic Engineering Center, 1976 and 1978). Three grid cell data banks were constructed by the Los Angeles District for the investigation because of an identified need for different topographic and land use specificity throughout the study area. Two data banks, Mesa and 35th Avenue to Buckeye comprised of grid cell sizes of 4.60 acres while the data bank from Mesa to 35th Avenue (including Tempe and Phoenix) was based on a 1.15 acre cell size.

Damage functions were developed automatically by the DAMCAL computer program (Hydrologic Engineering Center 1979) by constructing unique elevation-damage relationships for each grid cell based on ground elevation, land use classification and specified damage potential associated with land use. Table B-1 is a tabulation of the land use categories developed by the District for use in the study. Functions for each cell were aggregated to designated damage reach index locations, adjusting for slope in profiles by use of reference flood elevations. These data were the results of DAMCAL

TABLE B-1

DEFINITION OF LAND USE CLASSIFICATIONS

1. LOW DENSITY RESIDENTIAL. - Single Family: Average 1 unit per acre. Areal Breakdown: 5% structure; 10% pavement; 25% lawns, 60% barren or vegetation. Proportion developed = 85%.

2. MEDIUM AND HIGH DENSITY RESIDENTIAL. - Single Family: Average 1 unit per 1/4-1/6 acre. Areal Breakdown: 15% structure; 15% pavement, 40% lawns; 30% vegetation or barren. Proportion developed = 95%.

3. MOBILE HOMES. - Single Family: Average 1 unit per 1/7 acre. Areal Breakdown: 15% structure; 25% pavement; 30% lawns, 30% vegetation or barren. Proportion developed = 95%.

4. MULTI-FAMILY RESIDENTIAL. - Multi-Family: Apartments, townhouses, etc.: Average 1 unit per 1/6 acre. Areal Breakdown: 25% structure; 20% pavement, 25% lawns; 30% vegetation or barren. Proportion developed = 75%.

5. COMMERCIAL. - Shopping centers and "strip" commercial areas. Average 25 businesses per acre. Areal Breakdown: Structures 30%; pavement 55%; lawns 5%; vegetation 10%. Proportion developed = 30%.

6. INDUSTRIAL. - Industrial centers and parks, light and heavy industry. Average 1 plant per 1/5 acres. Areal Breakdown: 20% pavement; 50% structure; 30% open space. Proportion developed = 35%.

output elevation-damage relationships for each damage category and damage index location. The data may be used in conjunction with hydrologic data (flood frequency and rating functions) to obtain single event damage values (direct from DAMCAL) or expected annual damages using the expected Annual Damage Computation Program (Hydrologic Engineering Center 1977). Adjustments to the elevation-damage relationships of each damage category associated with implementing nonstructural flood mitigation measures is performed in DAMCAL based on user specifications. The evaluation procedure is repeated for modified conditions. Figure B-1, schematically depicts the process.

Damage Function Development Criteria

The assessment of existing damage potential was limited to residential, commercial and industrial structures. Damage reaches were delineated, based on desired information displays for jurisdictional community boundaries and consistent sets of water surface profiles for a range of discharges. Twenty damage reaches were delineated from Mesa to Buckeye.

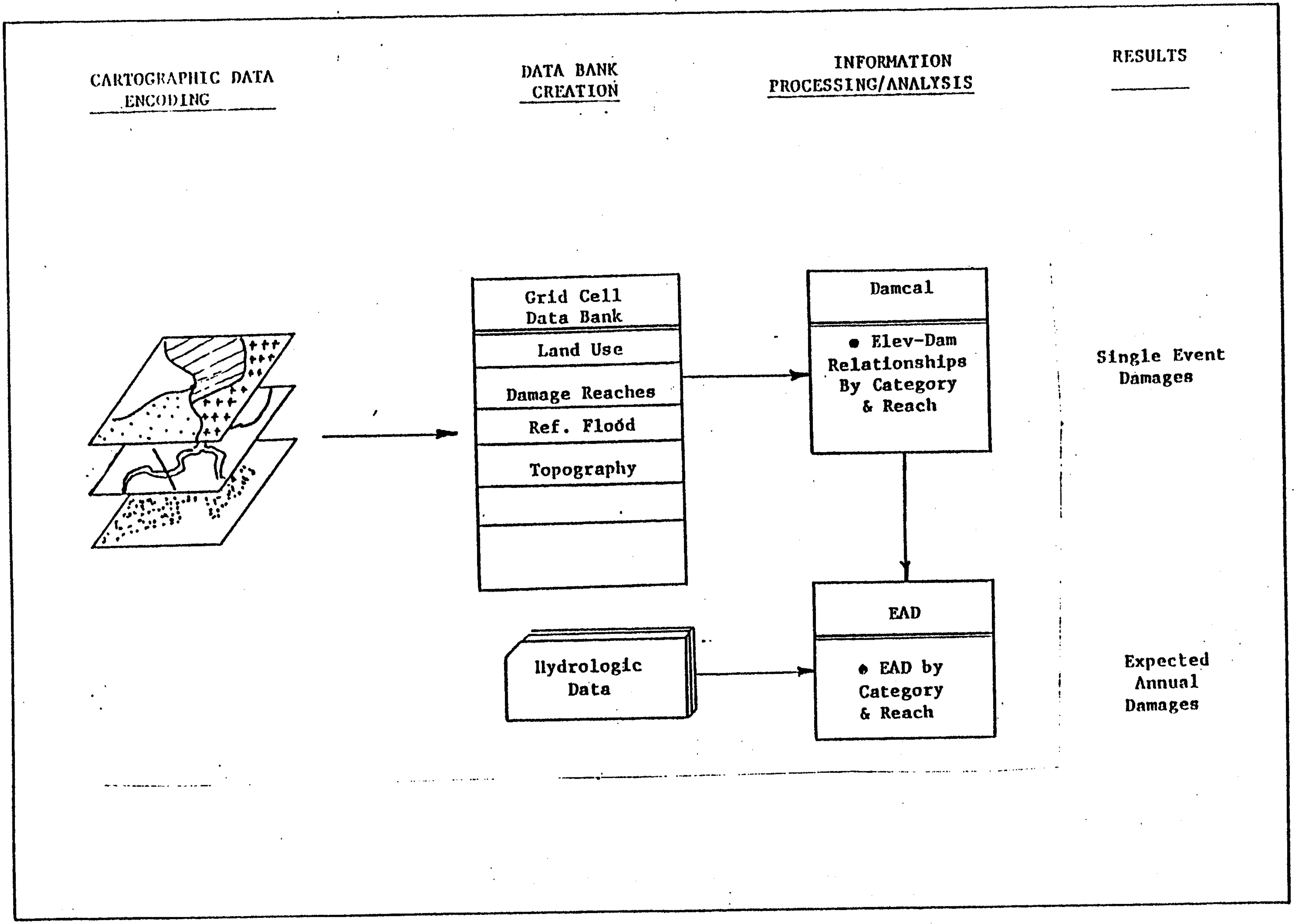

Figure 6-1. Flood Damage Evaluation Procedures

The December 1978 flood was designated as the reference flood based on inspection of several historic and hypothetical flood profiles through the study area. Reference flood elevation assignments to each grid cell enabled adjustments for water surface slopes during the damage aggregation process to reach index locations. Composite damage functions for each damage category were developed, based on user input specifications to the DAMCAL program. The functions (land use associated) for each grid cell were matched with the topographic elevation of the cell to generate elevation-damage relationships for the cell. These functions were than aggregated to index locations to yield aggregated elevation-damage functions by damage category for each damage reach.

Calibration of the damage results was performed by review of damage survey data of recent historic events (primarily the December 1978 flood), field inspection of the area, interviews of government officials, businesspersons and residents and the use of aerial photographs and flood inundation maps. The composite damage functions were adjusted (normally raised .5-2.0 feet) to calibrate the model and more accurately reflect topographic elevations of structures in various reaches.

Flood Damage Evaluations

Flood damage evaluations of present conditions and implementation of nonstructural flood loss reduction measures were performed using spatial data processing and analysis procedures previously described in this appendix and in Chapter II. Following paragraphs summarize the damage analysis procedures for nonstructural measures designed to (a) permanently modify the damage susceptability to existing structures; (b) manage future flood plain development and activities and (c) flood preparedness actions which temporary modify the damage potential of existing structures.

Permanent Measures For Existing Structures. The spatial data analysis process enables evaluations of several types of nonstructural measures which permanently modify the damage potential of existing buildings (Webb 1976). The evaluations may be performed expediently and consistently using input user specifications to the DAMCAL computer program. The evaluations are performed by adjustments to the stage (or elevation) damage functions in a manner reflecting implementation of a specific nonstructural measure.

Uniform flood proofing measures are analyzed by trucation of the aggregated elevation-damage function at the index location (for a particular structure type) to the user specified protection level. Flood proofing assessments of measures implemented at a non-uniform protection level, say each structure flood proofed 2 feet, are performed by tuncating the stage-damage functions of the individual grid cells prior to aggregation of the relationships to the damage reach index locations. Raising structures assessments are evaluated by adjusting upwards in elevation (user specified amount) the entire elevation-damage function. This is performed at individual cells (prior to aggregation) if the raise amount is constant for each structure or at the damage reach index location (after aggregation) if uniform level of protection is desired for the reach. Relocation alternatives are evaluated by removing the damage potential below the user specified elevations (level of protection) from the analysis process.

Development of modified elevation-damage functions were performed for each specified structural type and damage reach. The results were used in conjunction with hydrologic/hydraulic data to calculate expected annual damage values by structure type and reach, for each measure investigated, using the procedures illustrated in Figure B-1.

Measures Managing Future Development. This aspect of the investigation determined future damage reductions associated with implementing various flood plain regulations. The assessments were performed using the DAMCAL computer program and adjustments to future development (future land use patterns) to capture the affect of the regulatory policy being investigated. Future land use classifications were compared with existing classifications at each grid cell. For cells denoting changes, i.e., from say agricultural to single family residential, modifications in the stage-damage relationships to reflect policy criteria specified by the user.

An example would be the Federal Insurance Administration's criteria of all future development raised to the 100-year exceedance frequency levels (present policy conditions for the study area). Damage categories (land use) changed to single family residential, multi-family residential, commercial and industrial were assumed to be anticipated future development with stage-damage functions for these identified cells raised to 100-year flood levels specified by reach. The results were combined with existing damage values (no change between existing and future land use patterns) to obtained the total elevation-damage functions for each reach.

The procedure is performed automatically by the DAMCAL program for each policy criteria specified by the user. Expected annual damage for each policy condition was performed using procedures illustrated in Figure B-1.

Temporary Flood Mitigation Measures. One aspect of preparedness plans is the implementation of temporary emergency actions to mitigate damage to structures and property during flood events. Evaluation of temporary measures included removal of contents (50 and 100 percent), raising of contents (85 percent 3 feet) and installation of temporary perimeter barriers (1, 2, and 3 feet).

Analysis of temporary installation of perimeter barriers (earthen dikes, seals, sandbags, etc.) were performed by DAMCAL user specifications of desired height of protection for each designated damage category.

Analysis of temporary removal of contents was performed by adjusting the base value of the contents factor of the DAMCAL composite damage function. The value would be zero for 100 percent removal and 50 percent of the present conditions value for analysis of removal of half of the contents.

The evaluation of raising contents were conducted by modifying the stage-percent content damage relationship of the composite damage functions. Fifteen percent of the present conditions content values remained the same while 85 percent were adjusted upward three feet. The 15 percent was assumed reasonable for placement of personal goods on tables, chairs, etc., which would retain that current portion of the content damage potential.

As with each of the modifications evaluated, the results were compared with existing conditions values to obtain the flood damage reduced for each measure. These values were calculated for each structure type for each reach in the study area.

APPENDIX C

NONSTRUCTURAL ECONOMIC FEASIBILITY ANALYSIS FOR EXISTING STRUCTURES

APPENDIX C

NONSTRUCTURAL ECONOMIC FEASIBILITY ANALYSIS FOR EXISTING STRUCTURES

The following tables comprise the economic calculations performed by damage reach to determine the feasibility of implementing flood proofing and relocation measures for 50-, 100-, and 500-year uniform levels of protection. The results of the calculations were used to determine the most feasible alternative for each protection level implemented to single family residential, multi-family residential and industrial structures. Assessments for commercial structures were limited to flood damage reduction values since estimates of number of commercial structures were not available (unable to determine costs). Flood damage reduction values were determined based on procedures described in Appendix B. Cost data was obtained from procedures described in Chapter IV and based on data developed and shown in Table IV-1 and IV-2.

Emphasis was placed on consistent assessments between measures and damage reaches. Least cost flood proofing (earthen dikes instead of small flood walls) and relocation (moving instead of demolition of structures) measures were evaluated in each assessment.

MESA
(SALT RIVER)

DAMAGE REACH 1.0
GILBERT ROAD - COUNTRY CLUB ROAD (1)

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	12	2.00	6.03	4.54	1.46	.37	4.44	- 2.98	.33
	2. 100-Yr. Flood Proof	27	3.00	6.03	3.52	2.51	.55	14.85	- 12.34	.17
	3. 500-Yr. Flood Proof	51	4.00	6.03	.01	6.02	.90	45.90	- 39.88	.13
	4. 50-Yr. Relocation	12	Removed	6.03	2.09	3.94	5.00	60.00	- 56.06	.07
	5. 100-Yr. Relocation	27	Removed	6.03	.58	5.45	5.00	135.00	-129.55	.04
	6. 500-Yr. Relocation	51	Removed	6.03	.01	6.02	5.00	255.00	-248.98	.02
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0		0	0	0	0	0	0	
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0	N.A.	0	0	0	Relocation considered not feasible			---
	5. 100-Yr. Relocation	0		0	0	0				
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof	Unknown	N.A.	0	0	0	Information to calculate costs not available			---
	2. 100-Yr. Flood Proof			0	0	0				
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation	Unknown	N.A.	0	0	0	Relocation considered not feasible			---
	5. 100-Yr. Relocation			0	0	0				
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	4	2.00	4.47	2.76	1.71	.55	2.20	- .49	.78
	2. 100-Yr. Flood Proof	4	3.00	4.47	1.92	2.55	1.00	4.00	- 1.45	.64
	3. 500-Yr. Flood Proof	6	4.00	4.47	.52	3.95	1.60	9.60	- 5.65	.41
	4. 50-Yr. Relocation	4	Removed	4.47	.27	4.20	Relocation considered not feasible			---
	5. 100-Yr. Relocation	4	Removed	4.47	.26	4.21				
	6. 500-Yr. Relocation	6	Removed	4.47	.09	4.38				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		16	N.A.	10.50	7.33	3.17	N.A.	6.64	- 3.47	.48
Total "Best" Measures 100-Yr. Protection (1)		31	N.A.	10.50	5.44	5.06	N.A.	18.85	- 13.79	.27
Total "Best" Measures 500-Yr. Protection (1)		57	N.A.	10.50	.10	10.40	N.A.	264.60	-254.20	.04

(1) Does not include commercial data.

MESA
(SALT RIVER)

DAMAGE REACH 2.0
COUNTRY CLUB ROAD - PIMA ROAD

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	7	2.0	25.50	23.70	1.80	.37	2.59	- .79	.69
	2. 100-Yr. Flood Proof	13	2.5	25.50	22.70	2.80	.42	5.46	- 2.66	.51
	3. 500-Yr. Flood Proof	325	3.0(2)	25.50	7.87	17.63	.55	178.75	- 161.12	.11
	4. 50-Yr. Relocation	7	Removed	25.50	21.40	4.10	4.50	31.50	- 27.40	.13
	5. 100-Yr. Relocation	13	Removed	25.50	20.60	4.90	4.50	58.50	- 53.60	.08
	6. 500-Yr. Relocation	325	Removed	25.50	7.87	17.63	4.50	1462.00	-1444.37	.01
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	0	5.10	5.10	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	0	5.10	5.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	62	2.5	5.10	.01	5.09	.55	34.10	- 29.01	.15
	4. 50-Yr. Relocation	0	Removed	5.10	5.10	0	Relocation considered			
	5. 100-Yr. Relocation	0	Removed	5.10	5.10	0	not feasible			
	6. 500-Yr. Relocation	62	Removed	5.10	.01	5.09				---
COMMERCIAL	1. 50-Yr. Flood Proof			4.10	3.80	.30	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	4.10	3.20	.90	costs not available			---
	3. 500-Yr. Flood Proof			4.10	.40	3.70				
	4. 50-Yr. Relocation			4.10	2.61	1.49	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	4.10	1.00	3.10	not feasible			---
	6. 500-Yr. Relocation			4.10	.40	3.70				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	0	4.40	4.40	0	0	0	0	---
	2. 100-Yr. Flood Proof	12	2.0	4.40	3.54	.86	.55	6.60	- 5.74	.13
	3. 500-Yr. Flood Proof	20	4.0	4.40	.20	4.20	1.60	32.00	- 27.80	.12
	4. 50-Yr. Relocation	0	Removed	4.40	4.40	0	Relocation considered			
	5. 100-Yr. Relocation	12	Removed	4.40	.36	4.04	not feasible			---
	6. 500-Yr. Relocation	20	Removed	4.40	.20	4.40				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		7	N.A.	35.00	33.20	1.80	N.A.	2.59	- .79	.69
Total "Best" Measures 100-Yr. Protection (1)		25	N.A.	35.00	31.34	3.66	N.A.	12.06	- 8.40	.30
Total "Best" Measures 500-Yr. Protection (1)		407	N.A.	35.00	8.08	26.92	N.A.	244.85	- 217.93	.11

(1) Does not include commercial data. (No. of structures data not available.)

(2) Assumed average ht., ignoring few lowest structures.

TEMPE
(SALT RIVER)

DAMAGE REACH 3.1
PIMA ROAD - McCLINTOCK ROAD

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	5.70	5.70	0	0	0	0	---
	2. 100-Yr. Flood Proof	15	2.5	5.70	5.26	.44	.55	8.25	- 7.81	.06
	3. 500-Yr. Flood Proof	47	4.5	5.70	1.67	4.03	1.50	70.50	- 66.47	.06
	4. 50-Yr. Relocation	0	N.A.	5.70	5.70	0	Relocation considered			
	5. 100-Yr. Relocation	15	Removed	5.70	2.15	3.55	not feasible			---
	6. 500-Yr. Relocation	47	Removed	5.70	1.67	4.03				
COMMERCIAL	1. 50-Yr. Flood Proof			50.10	22.91	27.19	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	50.10	15.13	34.97	costs not available			---
	3. 500-Yr. Flood Proof			50.10	.31	49.79				
	4. 50-Yr. Relocation			50.10	.80	49.30	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	50.10	.75	49.35	not feasible			---
	6. 500-Yr. Relocation			50.10	.31	49.79				
INDUSTRIAL	1. 50-Yr. Flood Proof	40	2.0	191.70	173.27	18.43	.55	22.00	- 3.57	.83
	2. 100-Yr. Flood Proof	90	3.0	191.70	150.20	41.50	1.00	90.00	- 48.50	.46
	3. 500-Yr. Flood Proof	140	5.5	191.70	35.33	156.37	3.00	420.00	-263.63	.37
	4. 50-Yr. Relocation	40	Removed	191.70	110.10	81.60	Relocation considered			
	5. 100-Yr. Relocation	90	Removed	191.70	46.20	145.50	not feasible			---
	6. 500-Yr. Relocation	140	Removed	191.70	35.33	156.37				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		40	N.A.	197.40	178.97	18.43	N.A.	22.00	- 3.57	.83
Total "Best" Measures 100-Yr. Protection (1)		105	N.A.	197.40	155.46	41.94	N.A.	98.25	- 56.31	.43
Total "Best" Measures 500-Yr. Protection (1)		187	N.A.	197.40	37.00	160.40	N.A.	490.50	-330.10	.33

(1) Does not include commercial data. No. of structures not available.

TEMPE
(SALT RIVER)

DAMAGE REACH 3.2
McCLINTOCK ROAD - SCOTTSDALE ROAD

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	10	3.0(2)	11.40	4.90	6.50	.75	7.50	- 1.00	.87
	2. 100-Yr. Flood Proof	10	4.0	11.40	2.81	8.59	1.20	12.00	- 3.41	.72
	3. 500-Yr. Flood Proof	15	6.0	11.40	.21	11.19	2.90	43.50	- 32.31	.26
	4. 50-Yr. Relocation	10	Removed	11.40	.40	11.00	Relocation	considered		
	5. 100-Yr. Relocation	10	Removed	11.40	.40	11.00	not	feasible		---
	6. 500-Yr. Relocation	15	Removed	11.40	.21	11.19				
COMMERCIAL	1. 50-Yr. Flood Proof			23.10	17.06	6.04	Information	to calculate		
	2. 100-Yr. Flood Proof	Unknown	N.A.	23.10	12.00	11.10	costs not	available		---
	3. 500-Yr. Flood Proof			23.10	.04	22.70				
	4. 50-Yr. Relocation			23.10	9.25	13.85	Relocation	considered		
	5. 100-Yr. Relocation	Unknown	N.A.	23.10	2.04	21.06	not	feasible		---
	6. 500-Yr. Relocation			23.10	.04	22.70				
INDUSTRIAL	1. 50-Yr. Flood Proof	40	2.5	87.50	68.66	18.84	.75	30.00	- 11.16	.63
	2. 100-Yr. Flood Proof	65	4.0	87.50	45.65	41.85	1.60	104.00	- 62.15	.40
	3. 500-Yr. Flood Proof	100	6.0	87.50	2.02	85.48	3.90	390.00	-304.52	.22
	4. 50-Yr. Relocation	40	Removed	87.50	15.68	71.82	Relocation	considered		
	5. 100-Yr. Relocation	65	Removed	87.50	4.37	83.13	not	feasible		---
	6. 500-Yr. Relocation	100	Removed	87.50	2.02	85.48				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		50	N.A.	98.90	73.56	25.34	N.A.	37.50	- 12.16	.68
Total "Best" Measures 100-Yr. Protection (1)		75	N.A.	98.90	48.46	50.44	N.A.	116.00	- 65.56	.43
Total "Best" Measures 500-Yr. Protection (1)		115	N.A.	98.90	2.23	96.67	N.A.	333.50	-236.83	.29

(1) Does not include commercial data. No. of structures not available.

(2) Ht. reflects structures located below 50 yr. elev.

TEMPE
(SALT RIVER)

DAMAGE REACH 3.3
SCOTTSDALE ROAD - MILL AVENUE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	3.60	3.60	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	3.60	3.60	0	0	0	0	---
	3. 500-Yr. Flood Proof	78	3.0(2)	3.60	2.01	1.59	.55	42.90	- 41.31	.04
	4. 50-Yr. Relocation	0	Removed	3.60	3.60	0	0	0	0	---
	5. 100-Yr. Relocation	0	Removed	3.60	3.60	0	0	0	0	---
	6. 500-Yr. Relocation	78	Removed	3.60	2.01	1.59	4.50	351.00	-349.41	.03
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	
	4. 50-Yr. Relocation	0	Removed	.10	.10	0	Relocation considered			---
	5. 100-Yr. Relocation	0	Removed	.10	.10	0	not feasible			
	6. 500-Yr. Relocation	0	Removed	.10	.10	0				
COMMERCIAL	1. 50-Yr. Flood Proof			5.00	5.00	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	5.00	5.00	0	costs not available			---
	3. 500-Yr. Flood Proof			5.00	.01	4.99				
	4. 50-Yr. Relocation			5.00	5.00	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	5.00	5.00	0	not feasible			
	6. 500-Yr. Relocation			5.00	.01	4.99				---
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	42.30	42.30	0	0	0	0	---
	2. 100-Yr. Flood Proof	11	2.0(2)	42.30	41.12	1.18	.55	6.05	- 4.87	.20
	3. 500-Yr. Flood Proof	35	7.5	42.30	9.29	33.01	6.00	210.00	-176.99	.16
	4. 50-Yr. Relocation	0	Removed	42.30	42.30	0	Relocation considered			
	5. 100-Yr. Relocation	11	Removed	42.30	22.45	17.85	not feasible			---
	6. 500-Yr. Relocation	35	Removed	42.30	9.29	33.01				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	46.00	46.00	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		11	N.A.	46.00	44.82	1.18	N.A.	6.05	- 4.87	.20
Total "Best" Measures 500-Yr. Protection (1)		113	N.A.	46.00	11.40	34.60	N.A.	561.00	-526.40	.06

(1) Does not include commercial data. No. of structures not available.
(2) Ht. reflects river construction through this reach and differences between 50-, 100-, 500-yr. elevations.

TEMPE
(SALT RIVER)

DAMAGE REACH 3.4
MILL AVENUE - 48TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s: EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	39	2.0	55.50	48.40	7.10	.37	14.43	- 7.33	.49
	2. 100-Yr. Flood Proof	219	3.0	55.50	37.70	17.80	.55	120.45	- 102.65	.15
	3. 500-Yr. Flood Proof	603	4.0	55.50	6.98	48.52	.90	542.70	- 494.18	.09
	4. 50-Yr. Relocation	39	Removed	55.50	41.31	14.19	4.00	156.00	- 141.81	.09
	5. 100-Yr. Relocation	219	Removed	55.50	18.87	36.63	4.00	876.00	- 839.40	.04
	6. 500-Yr. Relocation	603	Removed	55.50	6.98	48.52	4.00	2412.00	-2363.48	.02
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	15	2.0	17.90	15.87	2.03	.45	6.75	- 4.72	.30
	2. 100-Yr. Flood Proof	41	3.0	17.90	12.39	4.70	.75	30.75	- 26.05	.15
	3. 500-Yr. Flood Proof	129	4.0	17.90	2.61	15.29	1.20	154.48	- 139.19	.10
	4. 50-Yr. Relocation	15	Removed	17.90	11.28	6.62	Relocation considered			
	5. 100-Yr. Relocation	41	Removed	17.90	6.20	11.70	not feasible			---
	6. 500-Yr. Relocation	129	Removed	17.90	2.61	15.29				
COMMERCIAL	1. 50-Yr. Flood Proof			6.20	5.80	.40	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	6.20	5.10	1.10	costs not available			---
	3. 500-Yr. Flood Proof			6.20	.50	5.70				
	4. 50-Yr. Relocation			6.20	4.70	1.50	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	6.20	2.66	3.54	not feasible			---
	6. 500-Yr. Relocation			6.20	.50	5.70				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	161.30	161.30	0	0	0	0	---
	2. 100-Yr. Flood Proof	65	2.5	161.30	131.52	29.78	.75	48.75	- 18.97	.59
	3. 500-Yr. Flood Proof	115	4.0	161.30	49.16	112.14	1.60	195.50	- 83.36	.57
	4. 50-Yr. Relocation	0	Removed	161.30	161.30	0	Relocation considered			
	5. 100-Yr. Relocation	65	Removed	161.30	75.18	86.12	not feasible			---
	6. 500-Yr. Relocation	115	Removed	161.30	49.16	112.14				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		54	N.A.	234.70	225.57	9.13	N.A.	21.80	- 12.67	.42
Total "Best" Measures 100-Yr. Protection (1)		325	N.A.	234.70	181.61	53.09	N.A.	210.90	- 157.81	.25
Total "Best" Measures 500-Yr. Protection (1)		847	N.A.	234.70	58.75	175.95	N.A.	892.68	- 716.73	.20

(1) Does not include commercial data. No. of structures not available.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.1
48TH STREET - 44TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered not feasible			
	5. 100-Yr. Relocation	0	N.A.	0	0	0				---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			.10	.10					
	2. 100-Yr. Flood Proof	Unknown	N.A.	.10	.10		Information to calculate costs not available			
	3. 500-Yr. Flood Proof			.10	.10					---
	4. 50-Yr. Relocation			.10	.10		Relocation considered not feasible			
	5. 100-Yr. Relocation	Unknown	N.A.	.10	.10					---
	6. 500-Yr. Relocation			.10	.10					
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	9.40	9.40	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	9.40	9.40	0	0	0	0	---
	3. 500-Yr. Flood Proof	35	2.0	9.40	4.13	5.27	.55	19.25	13.98	.27
	4. 50-Yr. Relocation	0	Removed	9.40	9.40	0	Relocation considered not feasible			
	5. 100-Yr. Relocation	0	Removed	9.40	9.40	0				---
	6. 500-Yr. Relocation	35	Removed	9.40	4.13					
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	9.40	9.40	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		0	N.A.	9.40	9.40	0	N.A.	0	0	---
Total "Best" Measures 500-Yr. Protection (1)		35	N.A.	9.40	4.13	5.27	N.A.	19.25	-13.98	.27

(1) Does not include commercial data. No. of structures not available.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.2
44TH STREET - 40TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		.10	.10	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		.10	.10	0	0	0	0	
	4. 50-Yr. Relocation	0		.10	.10	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	.10	.10	0	0	0	0	---
	6. 500-Yr. Relocation	0		.10	.10	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	---
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			1.80	1.80	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	1.80	1.80	0	costs not available			---
	3. 500-Yr. Flood Proof			1.80	0	1.80				
	4. 50-Yr. Relocation			1.80	1.80	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	1.80	1.80	0	not feasible			---
	6. 500-Yr. Relocation			1.80	0	1.80				
INDUSTRIAL	1. 50-Yr. Flood Proof	10	2.0	65.30	63.10	2.20	.55	5.50	- 3.30	.40
	2. 100-Yr. Flood Proof	28	3.0	65.30	57.33	7.97	1.00	28.00	- 20.03	.28
	3. 500-Yr. Flood Proof	127	5.5	65.30	13.23	52.07	3.00	381.00	-328.93	.14
	4. 50-Yr. Relocation	10	Removed	65.30	52.51	12.79	Relocation considered			
	5. 100-Yr. Relocation	28	Removed	65.30	30.28	35.02	not feasible			---
	6. 500-Yr. Relocation	127	Removed	65.30	13.23	52.07				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		10	N.A.	65.40	63.20	2.20	N.A.	5.50	- 3.30	.40
Total "Best" Measures 100-Yr. Protection (1)		28	N.A.	65.40	57.43	7.97	N.A.	28.00	- 20.03	.28
Total "Best" Measures 500-Yr. Protection (1)		127	N.A.	65.40	13.33	52.07	N.A.	381.00	-328.93	.14

(1) Does not include commercial data. No. of structures not available.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.3
40TH STREET - MID AIRPORT

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	5	2.0	.10	0	.10	.37	1.85	- 1.75	.05
	4. 50-Yr. Relocation	0	Removed	.10	.10	0	0	0	0	---
	5. 100-Yr. Relocation	0	Removed	.10	.10	0	0	0	0	---
	6. 500-Yr. Relocation	5	Removed	.10	0	.10	4.00	20.00	- 19.90	.01
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	4. 50-Yr. Relocation	0	Removed	0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	Removed	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0	Removed	0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0	costs not available			---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	78.60	78.60	0	0	0	0	---
	2. 100-Yr. Flood Proof	25	2.5	78.60	74.43	4.17	.75	18.75	- 14.58	.23
	3. 500-Yr. Flood Proof	96	5.5	78.60	24.17	54.43	3.00	288.00	-233.57	.19
	4. 50-Yr. Relocation	0	Removed	78.60	78.60	0	Relocation considered			
	5. 100-Yr. Relocation	25	Removed	78.60	49.39	27.21	not feasible			---
	6. 500-Yr. Relocation	96	Removed	78.60	24.17	54.43				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	78.70	78.70	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		25	N.A.	78.70	74.53	4.17	N.A.	18.75	- 14.58	.23
Total "Best" Measures 500-Yr. Protection (1)		101	N.A.	78.70	24.17	54.53	N.A.	289.85	-235.32	.19

(1) Does not include commercial data. No. of structures not available.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.4
MID AIRPORT - 36TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	---
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	---
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	---
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	---
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0	costs not available			---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	4.10	4.10	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	4.10	4.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	8	2.5	4.10	2.04	2.06	.75	6.00	-3.94	.34
	4. 50-Yr. Relocation	0	Removed	4.10	4.10	0	Relocation considered			
	5. 100-Yr. Relocation	0	Removed	4.10	4.10	0	not feasible			---
	6. 500-Yr. Relocation	8	Removed	4.10	2.04					
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	4.10	4.10	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		0	N.A.	4.10	4.10	0	N.A.	0	0	---
Total "Best" Measures 500-Yr. Protection (1)		8	N.A.	4.10	2.04	2.06	N.A.	6.00	-3.94	.34

(1) Does not include commercial data. No. of structures not available.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.5
36TH STREET - 30TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0	costs not available			---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	41.50	41.50	0	0	0	0	---
	2. 100-Yr. Flood Proof	32	2.0	41.50	32.06	9.44	.55	17.60	- 8.16	.53
	3. 500-Yr. Flood Proof	48	6.0(2)	41.50	4.22	37.33	3.90	187.20	-149.87	.20
	4. 50-Yr. Relocation	0	N.A.	41.50	41.50	0	Relocation considered			
	5. 100-Yr. Relocation	32	Removed	41.50	7.53	33.97	not feasible			---
	6. 500-Yr. Relocation	48	Removed	41.50	4.22	37.28				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	41.50	41.50	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		32	N.A.	41.50	32.06	9.44	N.A.	17.60	- 8.16	.53
Total "Best" Measures 500-Yr. Protection (1)		48	N.A.	41.50	4.22	37.33	N.A.	180.00	-142.67	.21

(1) Does not include commercial data.

(2) 4.0 ft. difference equals difference in W.S. profiles between 100- and 500-yr. events for this reach.

PHOENIX
(SALT RIVER)

DAMAGE REACH 4.6
30TH STREET - I-10 HIGHWAY

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	.10	.10	0	0	0	0	---
	3. 500-Yr. Flood Proof	1	2.0	.10	0	.10	.37	.37	- .27	.27
	4. 50-Yr. Relocation	0	Removed	.10	.10	0	0	0	0	---
	5. 100-Yr. Relocation	0	Removed	.10	.10	0	0	0	0	---
	6. 500-Yr. Relocation	1	Removed	.10	0	.10	4.00	4.00	- 3.90	0
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			.20	.20	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	.20	.20	0	costs not available			---
	3. 500-Yr. Flood Proof			.20	.20	0				
	4. 50-Yr. Relocation			.20	.20	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	.20	.20	0	not feasible			---
	6. 500-Yr. Relocation			.20	.20	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	10.70	10.70	0	0	0	0	---
	2. 100-Yr. Flood Proof	2	2.0	10.70	10.46	.24	.55	1.10	- .86	.22
	3. 500-Yr. Flood Proof	30	4.5	10.70	6.58	4.12	2.00	60.00	-55.88	.07
	4. 50-Yr. Relocation	0		10.70	10.70	0	Relocation considered			
	5. 100-Yr. Relocation	2	N.A.	10.70	7.98	2.72	not feasible			---
	6. 500-Yr. Relocation	30		10.70	6.58	4.12				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	10.80	10.80	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		2	N.A.	10.80	10.56	.24	N.A.	1.10	- .86	.22
Total "Best" Measures 500-Yr. Protection (1)		31	N.A.	10.80	6.58	4.22	N.A.	60.37	-56.15	.07

(1) Does not include commercial data.

PHOENIX
(SALT RIVER)

DAMAGE REACH 5.1
I-10 HIGHWAY - 16TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	18	2.0	24.70	19.34	5.36	.37	6.66	- 1.30	.80
	2. 100-Yr. Flood Proof	99	3.0	24.70	15.87	8.83	.55	54.45	- 45.62	.16
	3. 500-Yr. Flood Proof	250	5.5(2)	24.70	3.09	21.61	1.80	450.00	-428.39	.05
	4. 50-Yr. Relocation	18	Removed	24.70	13.10	11.64	4.00	72.00	- 60.36	.16
	5. 100-Yr. Relocation	99	Removed	24.70	7.78	16.92	4.00	396.00	-379.08	.04
	6. 500-Yr. Relocation	250	Removed	24.70	3.09	21.61	4.00	1000.00	-978.39	.02
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			15.10	15.10	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	15.10	15.10	0	costs not available			---
	3. 500-Yr. Flood Proof			15.10	8.29	6.81				
	4. 50-Yr. Relocation			15.10	15.10	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	15.10	15.10	0	not feasible			---
	6. 500-Yr. Relocation			15.10	8.29	6.81				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	111.40	111.40	0	0	0	0	---
	2. 100-Yr. Flood Proof	35	2.0	111.40	96.51	14.89	.55	19.25	- 4.36	.77
	3. 500-Yr. Flood Proof	100	4.5(2)	111.40	14.59	96.81	2.00	200.00	-103.19	.48
	4. 50-Yr. Relocation	0	N.A.	111.40	111.40	0	Relocation considered			
	5. 100-Yr. Relocation	35	Removed	111.40	33.06	78.34	not feasible			---
	6. 500-Yr. Relocation	100	Removed	111.40	14.59	96.81				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		18	N.A.	136.10	130.74	5.36	N.A.	6.66	- 1.30	.80
Total "Best" Measures 100-Yr. Protection (1)		134	N.A.	136.10	112.40	23.70	N.A.	73.70	- 50.00	.32
Total "Best" Measures 500-Yr. Protection (1)		350	N.A.	136.10	17.68	118.42	N.A.	650.00	-531.58	.18

(1) Does not include commercial data.

(2) Reflects differences between 100-yr. and 500-yr. profiles.

PHOENIX
(SALT RIVER)

DAMAGE REACH 5.2
16TH STREET - 7TH STREET

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	29	3.0	73.50	60.30	13.20	.55	15.95	- 2.75	.83
	2. 100-Yr. Flood Proof	112	5.0	73.50	53.83	19.67	1.40	156.80	- 137.13	.13
	3. 500-Yr. Flood Proof	1140	6.0(2)	73.50	8.09	65.41	2.75	2565.00	-2499.59	.03
	4. 50-Yr. Relocation	29	Removed	73.50	53.40	20.10	4.00	116.00	- 95.90	.17
	5. 100-Yr. Relocation	112	Removed	73.50	41.33	32.17	4.00	448.00	- 415.83	.07
	6. 500-Yr. Relocation	1140	Removed	73.50	8.09	65.41	4.00	4560.00	-4494.59	.01
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	57.70	57.70	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	57.70	57.70	0	0	0	0	---
	3. 500-Yr. Flood Proof	945	3.0	57.70	41.86	15.84	.80	756.00	- 740.16	.02
	4. 50-Yr. Relocation	0	N.A.	57.70	57.70	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	57.70	57.70	0	not feasible			---
	6. 500-Yr. Relocation	945	Removed	57.70	41.86	15.84				
COMMERCIAL	1. 50-Yr. Flood Proof			168.80	132.27	36.53	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	168.80	104.98	63.82	costs not available			---
	3. 500-Yr. Flood Proof			168.80	33.43	135.37				
	4. 50-Yr. Relocation			168.80	83.16	85.64	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	168.80	55.45	113.35	not feasible			---
	6. 500-Yr. Relocation			168.80	33.43	135.37				
INDUSTRIAL	1. 50-Yr. Flood Proof	60	3.0	254.50	197.76	56.76	1.00	60.00	- 3.31	.95
	2. 100-Yr. Flood Proof	156	5.0	254.50	144.09	110.41	2.50	390.00	- 279.59	.28
	3. 500-Yr. Flood Proof	430	6.0(2)	254.50	22.38	223.12	3.90	1677.00	-1453.88	.13
	4. 50-Yr. Relocation	60	Removed	254.50	104.40	150.10	Relocation considered			
	5. 100-Yr. Relocation	156	Removed	254.50	39.69	214.81	not feasible			---
	6. 500-Yr. Relocation	430	Removed	254.50	22.38	232.12				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		89	N.A.	385.70	315.76	69.94	N.A.	75.95	- 6.01	.92
Total "Best" Measures 100-Yr. Protection (1)		268	N.A.	385.70	255.62	130.08	N.A.	546.80	- 416.72	.24
Total "Best" Measures 500-Yr. Protection (1)		2515	N.A.	385.70	72.33	313.37	N.A.	4998.00	-4684.63	.06

(1) Does not include commercial data.
(2) Assumed average ht.

PHOENIX
(SALT RIVER)

DAMAGE REACH 5.3
7TH STREET - 7TH AVENUE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	8.00	8.00	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	8.00	8.00	0	0	0	0	---
	3. 500-Yr. Flood Proof	290	3.0	8.00	4.99	3.01	.55	159.50	- 156.49	.02
	4. 50-Yr. Relocation	0	N.A.	8.00	8.00	0	0	0	0	---
	5. 100-Yr. Relocation	0	N.A.	8.00	8.00	0	0	0	0	---
	6. 500-Yr. Relocation	290	Removed	8.00	4.99	3.01	4.00	1160.00	-1156.99	.01
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	5.40	5.40	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	5.40	5.40	0	0	0	0	---
	3. 500-Yr. Flood Proof	83	3.0	5.40	3.36	2.04	.75	62.25	- 60.01	.03
	4. 50-Yr. Relocation	0	N.A.	5.40	5.40	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	5.40	5.40	0	not feasible			---
	6. 500-Yr. Relocation	83	Removed	5.40	3.36	2.04				
COMMERCIAL	1. 50-Yr. Flood Proof			39.60	35.84	3.76	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	39.60	34.03	5.57	costs not available			---
	3. 500-Yr. Flood Proof			39.60	18.96	20.64				
	4. 50-Yr. Relocation			39.60	29.69	9.91	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	39.60	29.69	9.91	not feasible			---
	6. 500-Yr. Relocation			39.60	18.96	20.64				
INDUSTRIAL	1. 50-Yr. Flood Proof	22	2.0	52.10	40.53	11.57	.55	12.10	- .53	.96
	2. 100-Yr. Flood Proof	30	4.0	52.10	31.94	20.16	1.60	48.00	- 27.84	.42
	3. 500-Yr. Flood Proof	187	5.0(2)	52.10	4.54	47.56	2.50	467.50	- 419.94	.10
	4. 50-Yr. Relocation	22	Removed	52.10	10.78	41.32	Relocation considered			
	5. 100-Yr. Relocation	30	Removed	52.10	6.44	45.66	not feasible			---
	6. 500-Yr. Relocation	187	Removed	52.10	4.54	47.56				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		22	N.A.	65.50	53.93	11.57	N.A.	12.10	- .53	.96
Total "Best" Measures 100-Yr. Protection (1)		30	N.A.	65.50	45.34	20.16	N.A.	48.00	- 27.84	.42
Total "Best" Measures 500-Yr. Protection (1)		560	N.A.	65.50	12.89	52.61	N.A.	689.25	- 636.64	.08

(1) Does not include commercial data.

(2) Assumed average ht.

PHOENIX
(SALT RIVER)

DAMAGE REACH 5.4
7TH AVENUE - 19TH AVENUE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
	1. 50-Yr. Flood Proof	0	N.A.	5.80	5.80	0	0	0	0	---
SINGLE	2. 100-Yr. Flood Proof	0	N.A.	5.80	5.80	0	0	0	0	---
FAMILY	3. 500-Yr. Flood Proof	95	2.0	5.80	3.38	2.42	.37	35.15	- 32.73	.07
RESIDENTIAL	4. 50-Yr. Relocation	0	N.A.	5.80	5.80	0	0	0	0	---
	5. 100-Yr. Relocation	0	N.A.	5.80	5.80	0	0	0	0	---
	6. 500-Yr. Relocation	95	Removed	5.80	3.38	2.42	4.00	380.00	-377.58	.01
	1. 50-Yr. Flood Proof	0		.30	.30	0	0	0	0	---
MULTI-	2. 100-Yr. Flood Proof	0	N.A.	.30	.30	0	0	0	0	---
FAMILY	3. 500-Yr. Flood Proof	0		.30	.30	0	0	0	0	---
RESIDENTIAL	4. 50-Yr. Relocation	0		.30	.30	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	.30	.30	0	not feasible			---
	6. 500-Yr. Relocation	0		.30	.30	0				
	1. 50-Yr. Flood Proof			7.90	7.20	.70	Information to calculate			
COMMERCIAL	2. 100-Yr. Flood Proof	Unknown	N.A.	7.90	6.40	1.50	costs not available			---
	3. 500-Yr. Flood Proof			7.90	1.67	6.23				
	4. 50-Yr. Relocation			7.90	5.30	2.60	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	7.90	3.00	4.90	not feasible			---
	6. 500-Yr. Relocation			7.90	1.67	6.23				
	1. 50-Yr. Flood Proof	5	2.0	13.40	10.80	2.60	.55	2.75	- .15	.95
INDUSTRIAL	2. 100-Yr. Flood Proof	7	3.0	13.40	9.15	4.25	1.00	7.00	- 2.75	.61
	3. 500-Yr. Flood Proof	64	3.5(2)	13.40	2.64	10.76	1.25	80.00	- 69.24	.13
	4. 50-Yr. Relocation	5	Removed	13.40	5.61	7.79	Relocation considered			
	5. 100-Yr. Relocation	7		13.40	4.54	8.86	not feasible			---
	6. 500-Yr. Relocation	64		13.40	2.64	10.76				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		5	N.A.	19.50	16.90	2.60	N.A.	2.75	- .15	.95
Total "Best" Measures 100-Yr. Protection (1)		7	N.A.	19.50	15.25	4.25	N.A.	7.00	- 2.75	.61
Total "Best" Measures 500-Yr. Protection (1)		159	N.A.	19.50	6.32	13.18	N.A.	115.15	-101.97	.11

(1) Does not include commercial data.
(2) Assumed average ht.

PHOENIX
(SALT RIVER)

DAMAGE REACH 5.5
19TH AVENUE - 35TH AVENUE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	0	0	0	
	5. 100-Yr. Relocation	0	N.A.	0	0	0	0	0	0	---
	6. 500-Yr. Relocation	0		0	0	0	0	0	0	
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered not feasible			
	5. 100-Yr. Relocation	0	N.A.	0	0	0				---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate costs not available			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0				---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocation considered not feasible			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0				---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	7	2.0	29.40	28.30	1.10	.55	3.85	- 2.75	.29
	2. 100-Yr. Flood Proof	16	3.0	29.40	25.55	3.85	1.00	16.00	- 12.15	.24
	3. 500-Yr. Flood Proof	70	4.5	29.40	5.27	24.13	2.00	140.00	-115.87	.17
	4. 50-Yr. Relocation	7	Removed	29.40	16.20	13.20	Relocation considered not feasible			
	5. 100-Yr. Relocation	16	Removed	29.40	11.36	18.04				---
	6. 500-Yr. Relocation	70	Removed	29.40	5.27	24.13				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		9	N.A.	29.40	28.30	1.10	N.A.	3.85	- 2.75	.29
Total "Best" Measures 100-Yr. Protection (1)		16	N.A.	29.40	25.55	3.85	N.A.	16.00	- 12.15	.24
Total "Best" Measures 500-Yr. Protection (1)		70	N.A.	29.40	5.27	24.13	N.A.	140.00	-115.87	.17

(1) Does not include commercial data.

BUCKEYE TO PHOENIX
(SALT RIVER)

DAMAGE REACH 6.0
35TH AVENUE - GILA RIVER CONFLUENCE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	290	2.5	222.93	119.22	103.71	.42	121.80	- 18.09	.85
	2. 100-Yr. Flood Proof	434	3.5	222.93	86.29	136.64	.70	303.80	- 167.16	.45
	3. 500-Yr. Flood Proof	787	5.5	222.93	7.74	215.19	1.80	1416.60	-1202.00	.15
	4. 50-Yr. Relocation	290	Removed	222.93	43.53	179.40	4.50	1305.00	-1125.60	.16
	5. 100-Yr. Relocation	434	Removed	222.93	20.26	202.67	4.50	1953.00	-1750.33	.10
	6. 500-Yr. Relocation	787	Removed	222.93	7.74	215.19	4.50	3541.50	-3326.31	.06
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			29.75	13.65	16.10	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	29.75	10.16	19.59	costs not available			---
	3. 500-Yr. Flood Proof			29.75	.26	29.49				
	4. 50-Yr. Relocation			29.75	.60	29.15	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	29.75	.60	29.15	not feasible			---
	6. 500-Yr. Relocation			29.75	.26	29.49				
INDUSTRIAL	1. 50-Yr. Flood Proof	12	2.5	23.73	16.45	7.28	.75	9.00	- 1.72	.81
	2. 100-Yr. Flood Proof	23	3.5	23.73	12.77	10.96	1.25	28.75	- 17.79	.38
	3. 500-Yr. Flood Proof	101	5.5	23.73	1.35	22.38	3.00	303.00	- 280.62	.07
	4. 50-Yr. Relocation	12	Removed	23.73	11.14	12.59	Relocation considered			
	5. 100-Yr. Relocation	23	Removed	23.73	3.46	20.27	not feasible			---
	6. 500-Yr. Relocation	101	Removed	23.73	1.35	22.38				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		302	N.A.	246.66	135.67	110.99	N.A.	130.80	- 19.81	.84
Total "Best" Measures 100-Yr. Protection (1)		457	N.A.	246.66	99.06	147.60	N.A.	332.55	- 184.95	.44
Total "Best" Measures 500-Yr. Protection (1)		888	N.A.	246.66	9.09	237.57	N.A.	1719.60	-1482.03	.14

(1) Does not include commercial data.

BUCKEYE TO PHOENIX
(GILA RIVER)

DAMAGE REACH 7.0
SALT RIVER CONFLUENCE - AQUA FRIA CONFLUENCE

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s: EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	114	3.0	82.20	27.00	55.20	.55	62.70	- 7.50	.88
	2. 100-Yr. Flood Proof	134	4.0	82.20	16.70	65.50	.90	120.60	- 55.10	.54
	3. 500-Yr. Flood Proof	160	6.0	82.20	5.12	77.09	2.25	360.00	-282.91	.21
	4. 50-Yr. Relocation	114	Removed	82.20	4.00	78.20	5.40	615.60	-537.40	.13
	5. 100-Yr. Relocation	134	Removed	82.20	1.33	80.87	5.40	723.60	-642.73	.11
	6. 500-Yr. Relocation	160	Removed	82.20	.67	81.53	5.40	864.00	-782.47	.09
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocations considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0	costs not available			---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocations considered			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	
	4. 50-Yr. Relocation	0		0	0	0	Relocations considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		114	N.A.	82.20	27.00	55.20	N.A.	62.70	- 7.50	.88
Total "Best" Measures 100-Yr. Protection (1)		134	N.A.	82.20	16.70	65.50	N.A.	120.60	- 55.10	.54
Total "Best" Measures 500-Yr. Protection (1)		160	N.A.	82.20	5.11	77.09	N.A.	360.00	-282.91	.21

(1) Does not include commercial data.

PHOENIX TO BUCKEYE
(GILA RIVER)

DAMAGE REACH 8.0
AGUA FRIA RIVER CONFLUENCE - HIGHWAY 80

STRUCTURE TYPE	DESCRIPTION OF MEASURE	NO. OF STRUCTURES	HEIGHT OF PROTECTION	ECONOMIC ANALYSIS IN $1000s						
				EXISTING EAD	WITH MEASURE EAD	ANNUAL DAMAGE REDUCED	ANNUAL COST PER STRUCTURE	TOTAL ANNUAL COST	ANNUAL NET	ANNUAL DAM REDUCED / ANNUAL COST
SINGLE FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0	N.A.	.40	.40	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	.40	.40	0	0	0	0	---
	3. 500-Yr. Flood Proof	16	2.0	.40	.12	.28	.37	5.92	- 5.64	.05
	4. 50-Yr. Relocation	0	N.A.	.40	.40	0	0	0	0	---
	5. 100-Yr. Relocation	0	N.A.	.40	.40	0	0	0	0	---
	6. 500-Yr. Relocation	16	Removed	.40	.05	.35	5.40			
MULTI-FAMILY RESIDENTIAL	1. 50-Yr. Flood Proof	0		0	0	0	0	0	0	---
	2. 100-Yr. Flood Proof	0	N.A.	0	0	0	0	0	0	---
	3. 500-Yr. Flood Proof	0		0	0	0	0	0	0	---
	4. 50-Yr. Relocation	0		0	0	0	Relocation considered			
	5. 100-Yr. Relocation	0	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation	0		0	0	0				
COMMERCIAL	1. 50-Yr. Flood Proof			0	0	0	Information to calculate			
	2. 100-Yr. Flood Proof	Unknown	N.A.	0	0	0	costs not available			---
	3. 500-Yr. Flood Proof			0	0	0				
	4. 50-Yr. Relocation			0	0	0	Relocation considered			
	5. 100-Yr. Relocation	Unknown	N.A.	0	0	0	not feasible			---
	6. 500-Yr. Relocation			0	0	0				
INDUSTRIAL	1. 50-Yr. Flood Proof	0	N.A.	2.10	2.10	0	0	0	0	---
	2. 100-Yr. Flood Proof	3	2.0	2.10	1.82	.28	.55	1.15	- .87	.24
	3. 500-Yr. Flood Proof	11	4.0	2.10	.10	2.00	1.60	17.60	-15.60	.11
	4. 50-Yr. Relocation	0	N.A.	2.10	2.10	0	Relocation considered			
	5. 100-Yr. Relocation	3	Removed	2.10	.50	1.60	not feasible			---
	6. 500-Yr. Relocation	11	Removed	2.10	.02	2.08				
REACH SUMMARIES										
Total "Best" Measures 50-Yr. Protection (1)		0	N.A.	2.50	2.50	0	N.A.	0	0	---
Total "Best" Measures 100-Yr. Protection (1)		3	N.A	2.50	2.22	.28	N.A.	1.15	- .87	.24
Total "Best" Measures 500-Yr. Protection (1)		11	N.A.	2.50	.22	2.28	N.A.	23.52	-21.24	.10

(1) Does not include commercial data.